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MPx-18
Functions

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1 System Overview

1.1 General Information

1.1.1 About This Documentation

Means of Representation in This Documentation

To make the reading of this documentation easier for you, the table below contains the means of representation and notations of recurring terms.

What?	How?	For example...
Important facts which are to be highlighted in the body text	Boldface	Transmission of freely configurable external **process data** (command values and actual values of the external control unit)
Parameter names, diagnostic message names, function designations	Quotation marks	...the function "set/shift coordinate system" for the firmware MPx18...

Tab. 1-1: Conventions of Notation

All important notes are highlighted. A symbol tells you what kind of note is used in the text. The symbols have the following significances:

⚠ DANGER ...

In case of non-compliance with this safety instruction, death or serious injury will occur.

⚠ WARNING ...

In case of non-compliance with this safety instruction, death or serious injury could occur.

⚠ CAUTION ...

In case of non-compliance with this safety instruction, minor or moderate injury could occur.

NOTICE ...

In case of non-compliance with this safety instruction, property damage could occur.

Signal words in accordance with ANSI Z535.6-2006 draw the reader's attention to hazards (see "Explanation of Signal Words and the Safety Alert Symbol").

☞ This box contains important information that should be taken into consideration.

This symbol highlights useful tips and tricks.

Your Feedback

Your experience is important for our improvement processes of products and documentations.

If you discover mistakes in this documentation or suggest changes, you can send your feedback to the following e-mail address:

Dokusupport@boschrexroth.de

We need the following information to handle your feedback:

- The number indicated under "Internal File Reference".
- The page number.

1.1.2 How to Use This Documentation

Structure of the Functional Description

The functional descriptions of the IndraDrive firmware are divided into fixed chapters. The individual subjects of the firmware description are assigned to these chapters according to their content.

The description of the respective firmware functionality is basically divided into the following sections:

- Brief Description
- Functional Description
- Notes on Commissioning
- Diagnostic and Status Messages, Monitoring Functions

Within one subject, these sections are always contained in the mentioned order, but for practical and formal reasons they do not always exist or may have a different title.

Brief Description

The brief description contains an overview of the firmware function or the subject of the section. The Brief Description can contain, for example, general basics, the most important features of the function, overviews and examples of application. At the end of the brief description you can find, where possible and useful, a list of the parameters and diagnostic messages that are associated with this function.

Functional Description

The section "Functional Description" explains the operating principle of the respective drive function in an application-oriented way. The relevant parameters of this function are described with regard to their settings and effects. The parameter configuration is only explained in detail where this is necessary for the description of the function. As a basic principle, the functional description contains references to the separate documentations for parameters and diagnostic messages.

The detailed description of the parameters, their function and structure is contained in the separate documentation "Rexroth IndraDrive, Parameters".

The detailed description of the diagnostic messages, their causes and remedies is contained in the separate documentation "Rexroth IndraDrive, Diagnostic Messages".

Notes on Commissioning

The section "Notes on Commissioning" or "Notes on Parameterization" provides the user with the steps required for commissioning the function, similar to a checklist. The necessary parameter settings are described in compact form and, if necessary, instructions are given for activating the function and the diagnostic messages of the immediate functional sequence are mentioned.

Diagnostic and Status Messages, Monitoring Functions

The section "Diagnostic and Status Messages" (also "Monitoring Functions", if necessary) summarizes the diagnostic messages and possible status displays available for the respective function and describes them briefly. If there are function-specific monitoring functions, they are also described in this section.

The detailed description of the diagnostic messages, their causes and remedies is contained in the separate documentation "Rexroth IndraDrive, Diagnostic Messages".

Markers and Terms

The complete functionality of the IndraDrive firmware is divided into functional packages (base packages and optional expansion packages). The scope of the available functions does not only depend on the hardware design, but in the majority of cases also on the variant and characteristic of the firmware.

The descriptions of the master communication, the drive functions and the operation modes have a marker containing information on the availability of this functionality in the respective functional package of the firmware, e.g.:

Assignment to the functional firmware package, see the section "Supported Operation Modes"

Terms

The application-specific scalability of the hardware and firmware provides a multitude of possibilities. For detailed information, the following terms are used in the Functional Description:

- Firmware **range**, e.g. IndraDrive
- Firmware **version** e.g. single-axis, double/multiple-axis
- Firmware **variant** e.g. MPB, MPE
- Firmware **version** e.g. MPM-18VRS
- Firmware **characteristic**, e.g. open-loop/closed-loop
- Firmware **performance** e.g. Basic/Economy/Advanced
- Firmware **type**, complete firmware type designation

Cross References

Many basic subfunctions of the firmware, as well as necessary settings and definitions, are of multiple use within the overall functionality or have an effect on neighboring areas of the drive functionality. Such subfunctions normally are described only once. Descriptions that are part of other IndraDrive documentations (Parameter Description, Troubleshooting Guide, Project Planning Manuals ...) are only repeated in detail in exceptional cases. Cross references indicate the source of more detailed information.

For cross references to other sections or documentations, we make the following distinction:

- References to sections within this documentation are specified by indicating the title of the respective section and the designation of the superordinate topic, if necessary (both can be easily found via the index).
- References to other documentation are also signaled by the "info icon" if they are not contained in a note, in a table or in parentheses.

Documentations

For a list of the reference documentations, see chapter 1.9 "Documentations" on page 44

1.1.3 Terms, Basic Principles

Parameters

Communication between master and drive takes place, with a few exceptions, by means of parameters.

Parameters are used for:

- Determining the configuration
- Parameterizing the control loop
- Triggering and controlling drive functions and commands
- Transmitting command values and actual values (according to requirements, cyclically or acyclically)

All operating data are mapped to parameters!

The operating data stored in parameters can be identified by means of the IDN. They can be read and transferred, if required. The user write access to parameters depends on the properties of the respective parameter and the current communication phase. The drive firmware checks specific parameter values (operating data) for validity.

Data Storage and Parameter Handling

Data Memory

Several non-volatile data memories are available in an IndraDrive device:

- In the controller
- In the motor encoder (depending on motor type)
- In the programming module / control panel

In addition, a volatile data memory (working memory) is available in the controller.

Condition as Supplied

Condition as supplied of the Rexroth drive components:

- The controller memory contains controller-specific parameter values.
- The programming module / control panel contains the firmware.
- The motor encoder memory contains the encoder-specific and, depending on the motor type, the motor-specific parameter values.

Storing the Application-Specific Parameter Values

- The application-specific parameter values are stored in the programming module / control panel. Due to the limited number of writing cycles of non-volatile storage media, application-specific parameter values can also be stored in the working memory (volatile memory) of the controller.
- With the "IMST" or "IDST" service tool (as of MPx18V10), parameter values can be saved on an external data carrier.

Saving Parameter Values

Saving application-specific parameter values is required in the following cases:

- After initial commissioning of the machine axis or the motor
- Before replacing the controller for servicing (if possible)

Application-specific parameter values can be saved via:

- "IndraWorks Ds/D/MLD" commissioning tool

  → Saving parameter values on external data carrier
- Control master

  → Saving parameter values on master-side data carrier

Parameter IDN Lists

The drive supports master-side saving of parameter values by listing parameter identification numbers (IDNs). Using these lists guarantees complete storage of the application-specific parameter values. It is also possible to determine IDN lists defined by the customer.

Loading Parameter Values

Loading parameter values is required in the following cases:

- Initial commissioning of the motor

  → Loading default values (factory settings) and the motor-specific parameter values
- Serial commissioning of machine axes on series machines

  → Loading the parameter values saved after initial commissioning
- Reestablishing a defined initial state

  → Reloading the parameter values saved after initial commissioning
- Replacing the controller for servicing

  → Loading the parameter values currently saved before servicing

Possibilities of loading parameter values to the controller:

- Motor encoder data memory

  → Loading the parameter values by command or via the control panel during initial motor commissioning
- "IndraWorks Ds/D/MLD" commissioning tool

  → Loading the parameter values from an external data carrier
- "IMST" or "IDST" service tool as of MPx18V10

  → Loading the parameter values from an external data carrier
- Control master

  → Loading the parameter values from a master-side data carrier

Checksum of Parameter Values

By means of checksum comparison, the control master can determine whether the values of the application-specific parameter values currently active in the drive correspond to the values saved on the master side.

Password

IndraDrive controllers provide the possibility to protect parameter values against accidental or unauthorized change by means of a password. With regard to write protection, there are 3 groups of writable parameters:

- Parameters that are generally write-protected, such as motor parameters, hardware code parameters, encoder parameters, error memories, etc. ("administration parameters"). The values of these parameters ensure correct function and performance of the drive.
- Parameters the customer can combine in groups and protect them with a so-called customer password. This allows protecting parameter values, that are used for adjusting the drive to the axis, after having determined them.
- All other writable parameters and are not contained in the above-mentioned groups. They are not write-protected.

Types of Passwords

The drive firmware allows activating and deactivating the write protection for parameter values by means of three hierarchically different passwords:

- **Customer password**

  The parameter values of a parameter group combined by the customer can be protected.
- **Control password**

  Parameters protected by a customer password are writable; "administration parameters" remain read-only.

- **Master password**

  All writable parameters, including "administration parameters" and parameters protected by a customer password, can be changed.

Commands

Commands are used to activate and control complex functions or monitoring features in the drive. The higher-level master can start, interrupt and clear commands.

Each command is assigned to a parameter by means of which the execution of the command can be controlled. While the command is executed, the display of the control panel reads "Cx", "C" representing the diagnostic command message and "x" representing the number of the command.

☞ Each command that was started must be actively cleared again.

All commands available in the drive are stored in parameter "S-0-0025, IDN-list of all procedure commands".

Types of Commands

There are 3 different types of commands:

- **Drive control commands**
  - can cause automatic drive motion,
  - can be started only when drive enable has been set,
  - deactivate the active operation mode while they are executed.
- **Monitor commands**
  - activate or deactivate monitoring features or functions in the drive.
- **Administration commands**
  - carry out administration tasks,
  - cannot be interrupted.

See also section "Command Processing"

Operation Modes

The selection of operation modes defines which command values will be processed in which way, in order to lead to the desired drive motion. The operation mode does not determine how these command values are transmitted from the master to the slave.

One of the eight operation modes that are defined in parameters is always active if the conditions below are fulfilled:

- Control section and power section are ready for operation
- Drive enable signal sees a positive edge
- Drive follows command value input
- "Drive Halt" function has not been activated
- No drive control command is active
- No error reaction is carried out

The display of the control panel reads "AF" when an operation mode was activated.

☞ All implemented operation modes are stored in parameter "S-0-0292, List of supported operation modes".

See also chapter "Operation Modes"

Warnings

Depending on the active operation mode and the parameter settings, many monitoring functions are carried out. If a state is detected that permits correct operation, but if continued results in the occurrence of an error and the automatic shutdown of the drive, the drive firmware generates an error message.

☞ Warnings do not cause automatic shutdown (exception: fatal warning).

Warning Classes

Warnings are classified in different warning classes which determine whether or not the drive carries out an automatic reaction when the warning is generated.

☞ The warning class can be recognized by the diagnostic message.

We distinguish the following warning classes:

- **Without** drive reaction → diagnostic message number **E2**xxx, **E3**xxx, **E4**xxx
- **With** drive reaction → diagnostic message number **E8**xxx

☞ Warnings cannot be cleared. They persist until the condition that activated the warning is no longer fulfilled.

Errors

Depending on the active operation mode and the parameter settings, many monitoring functions are carried out. If a state is detected that affects or prevents correct operation, the drive firmware generates an error message.

Error Classes

Errors are assigned to various error classes that differ based on the different error reactions of the drive.

☞ The error class can be recognized by the diagnostic message number.

Diagnostic message number	Error class
F2xxx	Non-fatal error
F3xxx	Non-fatal safety technology error
F4xxx	Interface error
F6xxx	Travel range error
F7xxx	Safety technology error
F8xxx	Fatal error
F83xx	Fatal error of safety technology
F9xxx	Fatal system error

Tab. 1-2: Overview of Error Classes

☞ Apart from the mentioned error classes that can occur during operation, errors can occur when the devices are booted and during firmware download. These errors are displayed on the control panel with a short diagnostic text rather than with a diagnostic message number of the "Fxxxx" pattern. Boot and firmware download errors are described in the separate "Troubleshooting Guide" documentation (description of diagnostic messages).

Error Reactions of the Drive

If the drive controller is in control and an error state is detected, the execution of a drive error reaction is automatically started. The diagnostic message number "Fxxxx" flashes on the display of the control panel.

The drive reaction in the case of F2xxx, F3xxx, F4xxx, F6xxx, F7xxx and F8xxx errors is defined in parameter "P-0-0119, Best possible deceleration". At the end of each error reaction, the drive goes torque-free.

See also "Error Reactions"

Clearing an Error Message

Error messages are not automatically cleared; instead, there is a procedure for this depending on the severity of the error; see the separate "Troubleshooting Guide" documentation (description of diagnostic messages).

For example, if the error state persists, the error message is immediately generated again.

Clearing Error Messages when Drive Enable Was Set

If a drive error occurs while operating with drive enable having been set, the drive carries out an error reaction. The drive automatically deactivates itself at the end of each error reaction; in other words, the output stage is switched off and the drive switches from an energized to a de-energized state.

To reactivate the drive,

- clear the error message and
- set a positive edge for drive enable again.

Error Memory

The diagnostic message numbers of occurring errors are written to an error memory. This memory contains the diagnostic message numbers of the last 50 errors that occurred and the time when they occurred. Errors caused by a shutdown of the control voltage (e.g. "F8070 Control voltage failure") are not stored in the error memory.

The diagnostic message numbers in the error memory are mapped to parameter "P-0-0192, Error memory of diagnostic numbers" and can be displayed by means of the control panel. The "IndraWorks Ds/D/MLD" commissioning tool allows displaying the diagnostic message numbers and the respective times at which the errors occurred.

Reconfigure an Error as a Warning

In some cases, the user can reconfigure an error as a warning. After an error has been reconfigured, it is not an error reaction that takes place when such an error occurs, but only a warning is output. The list of axis errors that can be reconfigured can be found in "P-0-0173, List of configurable axis-specific monitoring functions"; the reconfiguration takes place in this parameter, too.

☞ When an error has been reconfigured, only a warning is output instead of the error message; the warning shows the control master that there is a problem. It then is the user's responsibility to react to the diagnostic warning messages in an appropriate way. If this is not the case, the machine or installation can be damaged.

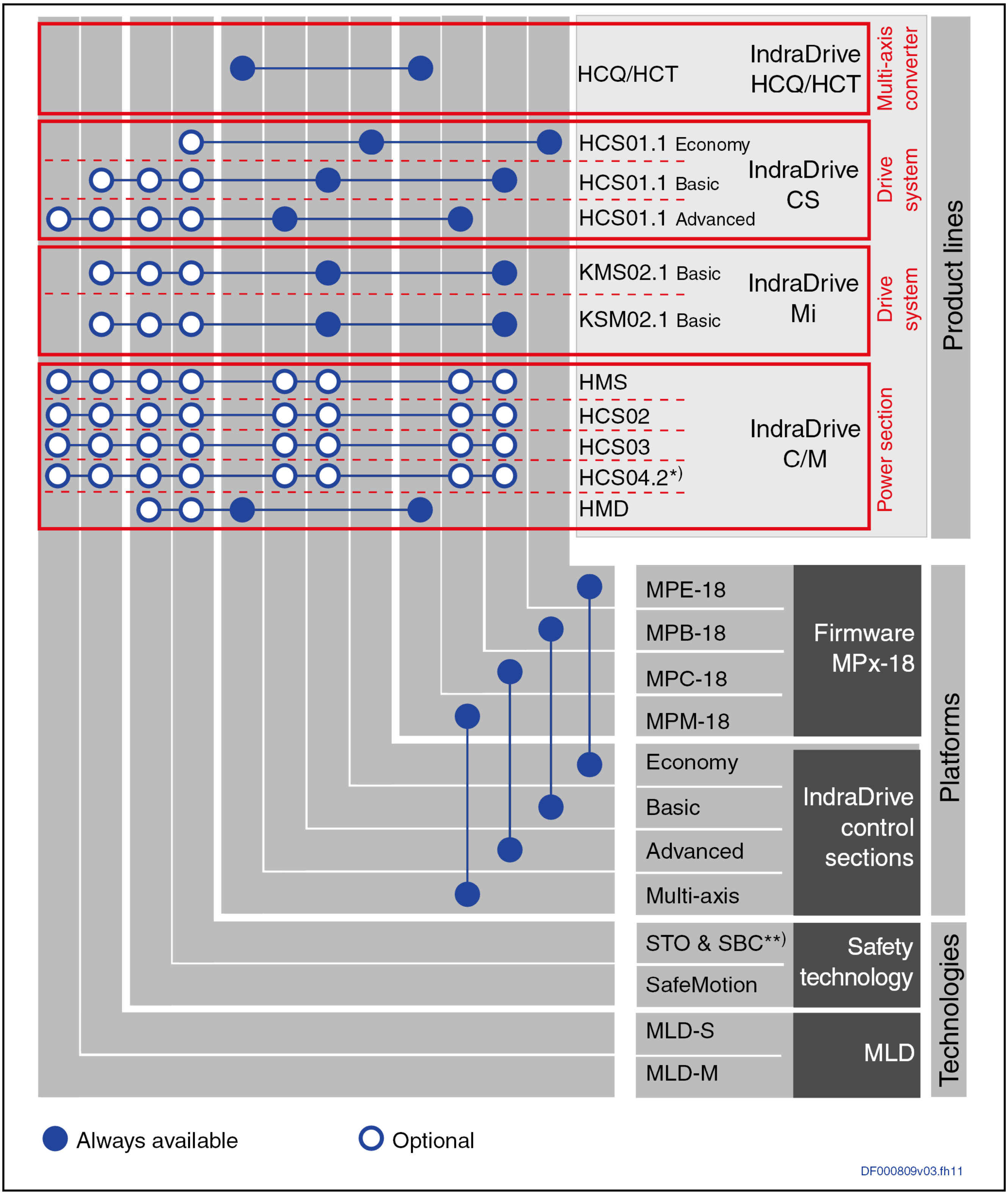
The reconfiguration of errors as warnings can be used in application-related form in the following cases:

- Use of an external encoder as a redundant motor encoder, see chapter "Redundant Motor Encoder"
- Use of a measuring encoder, see "Measuring Encoder"
- Position control with cyclic command value input, see chapter of the same name, "Position Control with Cyclic Command Value Input" under "Operation Modes"

1.2 IndraDrive Product Range

The figure below shows the relations between control sections and power sections, firmware derivatives and possible technology modules.

System Overview



*) As of MPx18V12
**) Hardware-dependent, see type code

Fig. 1-1: IndraDrive Product Range - Version 18

1.3 Overview of Drive Firmware

1.3.1 Firmware Variants

For the IndraDrive range, there are different application-related firmware types available that are characterized by their scope of functions and their performance:

- **MPx**: Drives for general automation (including machine tool applications) with a MultiEthernet interface (sercos, EtherCAT®, PROFINET®, EtherNet/IP™), field bus interface (e.g. PROFIBUS-DP) and analog interface (design versions include **MPB**, **MPC**, **MPE** and **MPM**; see below)

☞ The **first two letters** of the firmware designation identify the application and profile of the firmware:

- **MP:** "Multi Purpose" → Drives for general automation (including machine tool applications) with a MultiEthernet interface (sercos, EtherCAT®, PROFINET®, EtherNet/IP™), field bus interface (e.g. PROFIBUS-DP, CANopen) and analog interface.

The **third letter** of the firmware designation identifies the hardware, as well as the performance and functionality of the firmware (**x** contains **B, C, E and M**):

- **B**: **Single-axis** firmware with **BASIC** performance and functionality plus MLD-S functions
- **C**: **Single-axis** firmware with **ADVANCED** performance and functionality plus CCD + MLD-M functions
- **E**: **Single-axis** firmware with **ECONOMY** performance and functionality
- **M**: **Double-axis/multi-axis** firmware with **BASIC** performance and functionality

---

This documentation describes the functionality of the following firmware types:

- FWA-INDRV*-MPB-18VRS-D5
- FWA-INDRV*-MPC-18VRS-D5
- FWA-INDRV*-MPE-18VRS-D5
- FWA-INDRV*-MPM-18VRS-D5

The "IndraWorks Ds/D/MLD" commissioning tool is available for commissioning these firmware variants.

1.3.2 Organization of the Firmware

For the application-specific definition of the drive functionality, the firmware functions are divided into different "functional packages". There are a **generally available base package** and various **additional functional packages** (e.g. main spindle, IndraMotion MLD) that can be optionally activated.

☞ The scope of functions of the functional packages and their possible combinations are described in the section "Overview of Functions/Functional Packages".

1.4 Overview of Master Communication

The **MPx-18VRS** firmware supports the following interfaces for master communication:

	Firmware variant			
Master Communication	MPB	MPC	MPE	MPM
sercos	■	■	■	■
PROFIBUS-DP	■	■	-	■
EtherNet/IP interface	■	■	-	-
PROFINET	■	■	-	-
Analog interface	■	■	■	■
EtherCAT®	■	■	-	■
CANopen	■	■	-	-

Tab. 1-3: Supported Interfaces for Master Communication

1.5 Overview of Functions/Functional Packages

1.5.1 Overview

General Information

The application-specific scope of usable functions of the **FWA-INDRV*-MP*-18VRS** drive firmware depends on

- the existing device configuration

- and -

- the licensed functional firmware packages.

☞ Depending on the hardware design, the scope of firmware functionality can be determined according to the respective application (scalability of the firmware functionality). The scope of corresponding parameters depends on the available functions.

Scaling the Drive Functionality

Firmware Scaling by Control Section Configuration

IndraDrive drive controllers have slots for optional cards. Depending on the available optional cards, it is possible to activate certain functions (incl. corresponding parameters), e.g.:

- Master Communication
- Safety technology
- Encoder emulation
- Optional encoders
- I/O extension

Controller or control section	Number of Optional Card Slots
KMS02.1, KSM02.1	1
HCS01, HCQ02.1, HCT02.1, CSB02.1A	2

Controller or control section	Number of Optional Card Slots
CSB02.1B, CSH02.1	3
CDB02.1	4

Tab. 1-4: Number of Optional Card Slots

☞ The functions and parameters for the evaluation of the measuring systems as control encoders do not depend on the device configuration, since their functions can be freely assigned to the various optional encoder modules.

See also the section "Drive Controllers"

Firmware Scaling by Functional Packages

The firmware functionality is divided into the following package groups:

- **Base packages** (open-loop or closed-loop)
- Optional **expansion packages**:
  - Alternative functional packages (expansion packages for servo function, main spindle function, synchronization)
  - Additive functional package "IndraMotion MLD" (drive-integrated PLC and technology functions)

Depending on the hardware configuration, the base packages are available without any access enable. Using the optional expansion packages, however, requires licensing.

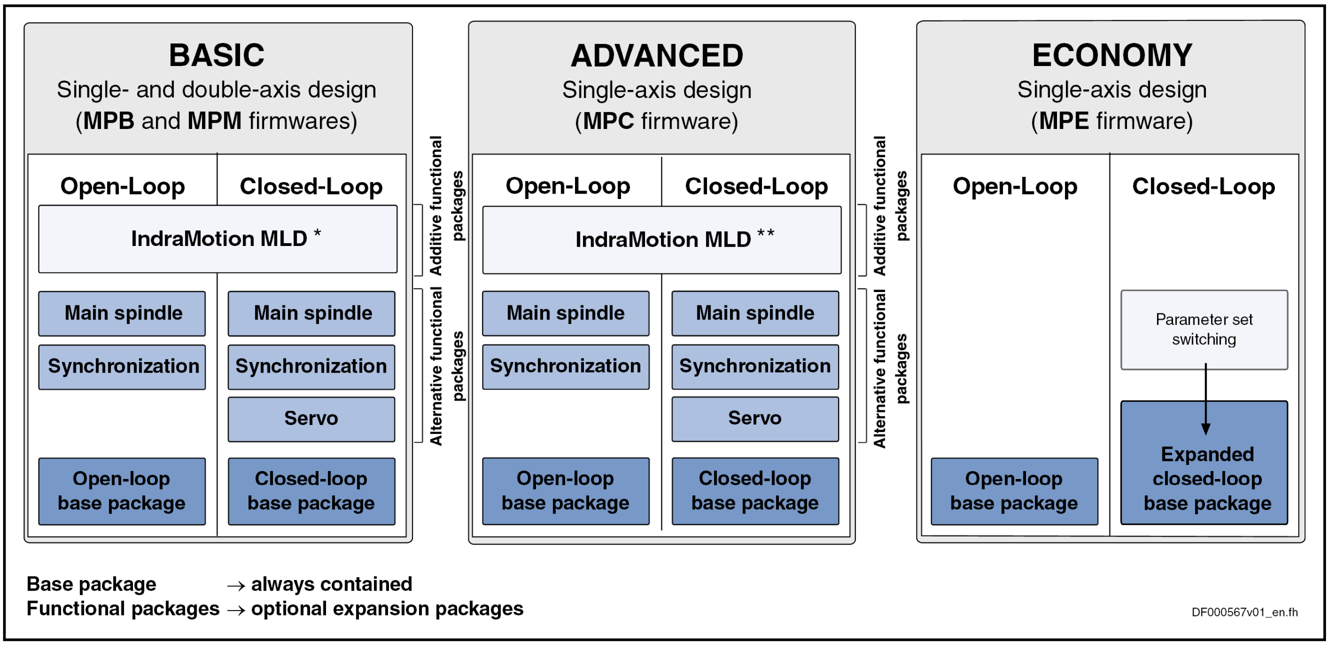
☞ The desired scope of firmware functions should preferably be defined when the firmware is ordered. This guarantees that the required functional packages have been enabled when the firmware is delivered. In individual cases, it is possible to provide access enable subsequently (additional licensing) or to reduce the activated scope of functions.

This procedure is described in the section "Enabling of Functional Packages".

☞ The **drive-integrated safety technology** is a functionality only scalable by means of the hardware and does not require any additional enabling of functions!

The figure below contains an overview of the possibilities of firmware scaling by functional packages:

System Overview



*	IndraMotion MLD only MLD-S functionality, single-axis motion, not with MPM firmware
**	IndraMotion MLD-M functionality, multi-axis motion

Fig. 1-2: Functional Packages of IndraDrive Firmware MPx18 Depending on Control Performance

Brief Description of the Functional Packages

The overall functionality of an IndraDrive device is divided into groups of functions, the so-called "functional packages". The **FWA-INDRV*-MP*-18VRS** firmware supports the functional packages listed below.

☞ Each of the listed packages is available in **Basic, Economy** or **Advanced** characteristic which differ with regard to their performance and functionality.

Base Packages

The following base packages are available:

- **Base package "open-loop"** (open-loop motor control)

  → No position evaluation and functions depending thereof and no position control modes are possible

- **Base package "closed-loop"** (closed-loop motor control)

  → Position evaluation and functions and operation modes depending thereof are possible

Alternative Functional Packages

The following alternative functional packages are available:

- **Servo functions**[1)]

  This package makes available all specific expansions for servo applications, such as compensations and correction functions (e.g. axis error correction, quadrant error correction).

- **Synchronization**[1)]

  With this package, the possibilities of synchronization of the drive can be used (support of synchronization modes, measuring encoder function, probe function, …).

- **Main spindle functions**[1)]

This package contains the specific functions for the use of main spindles (e.g. spindle positioning, parameter set switching).

☞ [1)]...These functional packages cannot be activated simultaneously (only individually)!

Additive Functional Packages

There is also an additional functional package available:

- IndraMotion MLD

☞ For single-axis devices (ADVANCED and BASIC) the expansion package "IndraMotion MLD" can be activated in addition to a possibly available alternative package.

Firmware Types

Structure of the Firmware Type Designation

The type designation of the IndraDrive firmware consists of the following type code elements:

	IndraDrive firmware	Base package of variant (depending on control section)	Version	Release	Language	OL/CL	Alternative expansion packages	Additive expansion packages
Basic single-axis	FWA-INDRV*	-MPB-	18	VRS-	D5-	x-	xxx-	xx
Advanced single-axis	FWA-INDRV*	-MPC-	18	VRS-	D5-	x-	xxx-	xx
Economy single-axis	FWA-INDRV*	-MPE-	18	VRS-	D5-	x-	xxx-	xx
Basic multi-axis	FWA-INDRV*	-MPM-	18	VRS-	D5-	x-	xxx-	xx

OL Open-loop characteristic
CL Closed-loop characteristic

Tab. 1-5: Basic Structure of the Firmware Type Designation

Function-Specific Abbreviations in Type Designation of IndraDrive Firmware

Base package (application and performance):

- MPB → Single-axis firmware with Basic performance
- MPC → Single-axis firmware with Advanced performance
- MPE → Single-axis firmware with Economy performance
- MPM → Multi-axis firmware with Basic performance

Firmware characteristic:

- 0 → Open-loop
- 1 → Closed-loop

Alternative expansion packages:

- NNN → Without alternative expansion package
- SRV → Functional package "Servo function"
- SNC → Functional package "Synchronization"
- MSP → Functional package "Main spindle"
- ALL → All alternative expansion packages

Additive expansion packages:

- **NN** → Without additive expansion package
- **ML** → IndraMotion MLD for free programming; incl. use of technology functions (for MPB, MPC firmware)
- **MA** → IndraMotion MLD Advanced (only for MPB, MPC firmware)

☞ The sales representative in charge will help you with the current status of available firmware types.

1.5.2 Base Packages

General Information

In the base packages of the firmware, the minimum scope of functionalities is available depending on the respective firmware characteristic ("open-loop" or "closed-loop"). They contain the basic functions of a drive firmware and a number of other fundamental functions.

Basic Functions

The following basic functions are available for every drive and contain the fundamental basic functions of a digital drive (available in the firmware characteristics "open-loop" and "closed-loop"):

- Extensive diagnostic functions:
  - Drive-internal generation of diagnostic messages
  - Monitoring function
  - Patch Function
  - Status displays, status classes
  - Oscilloscope function
  - Code of optional card
  - Parameter value check
  - Operating hours counter, logbook function, error memory
- Undervoltage monitor
- Output of control signals
- Limitations that can be parameterized

Scope of Functions

Motor Control Modes

	MPB	MPC	MPE*	MPM
V/Hz (U/f)	CL/OL	CL/OL	CL/OL	CL/OL
FXC	CL/OL	CL/OL	-	CL/OL

	MPB	MPC	MPE*	MPM
FOC	CL	CL	CL	CL
FOCsl	CL	CL	CL	CL

V/Hz (U/f) Frequency-controlled operation of sensorless asynchronous three-phase a.c. motors
FXC Flux-controlled, sensorless operation of three-phase a.c. motors
FOC Current-controlled operation of three-phase a.c. motors (with motor encoder)
FOCsl Current-controlled operation of sensorless three-phase a.c. motors
OL Open-loop characteristic
CL Closed-loop characteristic
***** MPE has an expanded closed-loop base package (CL). It includes the parameter set switching.

Tab. 1-6: Motor Control Mode Depending on Firmware Variant

Supported operation modes

☞ The operation modes supported by the firmware depend on the hardware and firmware and are contained in parameter "S-0-0292, List of supported operation modes".

The following overview illustrates with which base or functional package the respective operation mode is supported and it applies to all firmware variants.

Operation mode	In base package (characteristic)	In functional package ... (on the basis of a base package with the following characteristic)		
		Servo function	Synchronization	Main spindle
Standard operation modes:				
- Torque/force control	CL	+	+	+
- Velocity control	OL/CL	+	+	+
- Position control	CL	+	+	+
- Drive-internal interpolation	CL	+	+	+
- Drive-controlled positioning	CL	+	+	+
- Positioning block mode	CL	+	+	+
Synchronization modes:				
- Velocity synchronization	–	–	OL/CL	–
- Phase synchronization	–	–	CL	–

Operation mode	In base package (characteristic)	In functional package ... (on the basis of a base package with the following characteristic)		
		Servo function	Synchronization	Main spindle
- Electronic cam	–	–	CL	–
- Electronic motion profile	–	–	CL	–

+ Operation mode already contained in base package (for characteristic see base package)
- Operation mode not possible
OL Open-loop characteristic
CL Closed-loop characteristic

Tab. 1-7: Supported Operation Modes

To use a functional package, it must have been activated (enabled). The currently enabled functional packages are displayed in parameter "P-0-2004, Active functional packages".

See also "Enabling of Functional Packages"

Availability of the Extended Axis Functions

The following overview illustrates in which base or functional packages the respective extended axis function is available (if not stated otherwise, this applies to all firmware versions MPB, MPC, MPE and MPM).

Extended axis function	In base package (characteristic)	In functional package … (on the basis of a base package with the following characteristic)		
		Servo function	Synchronization	Main spindle
Drive Halt	OL/CL	+	+	+
v_{cmd} reset (emergency stop)	OL/CL	+	+	+
v_{cmd} reset with ramp and filter (quick stop)	OL/CL	+	+	+
v_{cmd} reset with ramp and filter (emergency stop)	OL/CL	+	+	+
Torque disable	OL/CL	+	+	+
Return motion	-	CL	–	–
Package reaction on error	OL/CL	+	+	+
NC reaction on error	OL/CL	+	+	+
MLD reaction on error	OL/CL 1) 2)	+ 1) 2)	+ 1) 2)	+ 1) 2)
E-Stop function	OL/CL	+	+	+
Friction torque compensation	CL	+	+	+
Encoder error correction	CL	+	+	+
Backlash on reversal correction	CL 1)	+ 1)	+ 1)	+ 1)
Precision axis error correction	–	CL 1)	–	–
Control-side axis error correction	–	CL 1)	–	–

Extended axis function	In base package (characteristic)	In functional package … (on the basis of a base package with the following characteristic)		
		Servo function	Synchronization	Main spindle
Temperature error correction	–	CL 1)	–	–
Quadrant error correction	–	CL 1)	–	–
Cogging torque compensation	–	CL 1)	CL 1)	–
Measuring wheel mode	–	–	CL 1)	–
Positive stop drive procedure	OL/CL	+	+	+
Redundant motor encoder	CL 1)	+ 1)	+ 1)	+ 1)
Spindle positioning	–	–	–	CL 1)
Parameter set switching	CL 3)	–	–	OL/CL
Drive-controlled oscillation	–	–	–	OL/CL 1)
Parking axis	OL/CL	+	+	+
Programmable position switch	–	CL 1)2)	CL 1)2)	–
Set/shift coordinate system	–	CL 1)	CL 1)	CL 1)
Integrated safety technology (STO/SBC)	Only available with the corresponding hardware configuration			

+	Extended axis function already contained in base package (for characteristic see base package)
-	Extended axis function not possible
OL	Open-loop characteristic
CL	Closed-loop characteristic
1)	Not for the MPE firmware variant
2)	Not for the MPM firmware variant
3)	Only the MPE firmware variant has an expanded closed-loop base package (CL). It includes the parameter set switching.

Tab. 1-8: Availability of the Extended Axis Functions

To use a functional package, it must have been activated (enabled). The currently enabled functional packages are displayed in parameter "P-0-2004, Active functional packages".

See also "Enabling of Functional Packages"

Availability of the Optional Device Functions

The following overview illustrates in which base or functional packages the respective optional device function is available (if not stated otherwise, this applies to all firmware versions MPB, MPE, MPC and MPM).

Optional device function	In base package (characteristic)	In functional package …		
		Servo function	Synchronization	Main spindle
Cross communication (CCD)	Only possible with HCS01 in conjunction with MPC-17VRS or MPC-18VRS, or with CSH02.1 in conjunction with MPC-18VRS			
IndraMotion MLD	Independent expansion packages (ML, MA) 2) 3)			
Digital inputs/outputs 1)	OL/CL	+	+	+
Analog inputs 1)	OL/CL	+	+	+

System Overview

Optional device function	In base package (characteristic)	In functional package ...		
		Servo function	Synchronization	Main spindle
Virtual master axis generator	OL/CL	-	+	-
Command value generator	OL/CL	+	+	+
Command value box	CL	+	+	+
Encoder emulation	OL/CL	+	+	+
Programmable position switch	–	CL[2)]	CL[2)]	–
Probe	CL	+	+	+
Measuring encoder[1)]	–	OL/CL[2)]	OL/CL[2)]	–

+ Optional device function already contained in base package (for characteristic see base package)
- Optional device function not possible
OL Can be used in open-loop operation
CL Can be used in closed-loop operation
1) Depending on hardware configuration
2) Not for the firmware version MPE
3) Not for the firmware version MPM

Tab. 1-9: Availability of the Optional Device Functions

To use a functional package, it must have been activated (enabled). The currently enabled functional packages are displayed in parameter "P-0-2004, Active functional packages".

See also "Enabling of Functional Packages"

1.5.3 Alternative Functional Packages

General Information

In addition to the base packages that are always available, the alternative functional packages are provided as optional expansion packages. When these functional packages are used, only one package can be activated (alternative activation).

The following expansion packages are available:

- Expanded Servo Function
- Synchronization
- Main spindle function

Servo function

Depending on the firmware variant and characteristic, the "servo function" expansion package has the following scope of functions:

	MPB	MPC	MPE	MPM
Relative return motion	CL	CL	–	–
Precision axis error correction	CL	CL	–	–
Temperature error correction	CL	CL	–	CL
Quadrant error correction	CL	CL	–	CL
Cogging torque compensation	CL	CL	–	CL
Programmable position switch	CL	CL	–	–

	MPB	MPC	MPE	MPM
Set/shift coordinate system	CL	CL	–	–
Parameter set switching (without motor / gearbox switching)	CL/OL	CL/OL	Contained in base package	–

OL Open-loop characteristic (not with "servo function" expansion package)
CL Closed-loop characteristic

Tab. 1-10: Overview of the "Servo Function" Expansion Package

Synchronization

Depending on the firmware variant and characteristic, the "synchronization" expansion package has the following scope of functions:

	MPB	MPC	MPE	MPM
Velocity synchronization	OL, CL	OL, CL	–	OL, CL
Phase synchronization	CL	CL	–	CL
Electronic cam	CL	CL	–	CL
Electronic motion profile	CL	CL	–	CL
Cogging torque compensation	CL	CL	–	CL
Measuring wheel mode	CL	CL	–	CL
Programmable position switch	CL	CL	–	–
Measuring encoder	OL, CL	OL, CL	–	CL

OL Open-loop characteristic
CL Closed-loop characteristic

Tab. 1-11: Overview of the "Synchronization" Expansion Package

Main spindle function

Depending on the firmware variant and characteristic, the "main spindle" expansion package has the following scope of functions:

	MPB	MPC	MPE	MPM
Spindle positioning	CL	CL	–	CL
Parameter set switching	OL, CL	OL, CL	CL 1)	OL, CL
Drive-controlled oscillation	OL, CL	OL, CL	–	OL, CL

OL Open-loop characteristic
CL Closed-loop characteristic
1) Contained in the expanded base package for MPE

Tab. 1-12: Overview of the "Main Spindle" Expansion Package

1.5.4 Additive Functional Packages

General Information

So-called additive functional packages are part of the optional expansion packages. Additive functional packages can be used in addition to the basic function and one of the alternative functional packages (additive activation).

At present, IndraMotion MLD (drive-integrated PLC and technology functions) is available as an additive functional package (in different designs).

IndraMotion MLD (drive-integrated PLC)

☞ As of the MPB-18V08 firmware, using the performance level "Advanced performance" (P-0-0556, bit 2) is impossible when "IndraMotion MLD" is active (expansion packages "ML" or "MA").

Optional Expansion Package "IndraMotion MLD"

The following designs of the optional expansion package "IndraMotion MLD" are available:

- The **"ML"** design allows:
  - Loading and using self-contained PLC programs (technology functions) by Rexroth (see "Technology Functions")
  - Freely programming Rexroth IndraMotion MLD-S / MLD-M using the function block libraries made available by Rexroth and supported by "IndraMotion MLD" (see "Library Description IndraMotion MLD (2G)")
- The **"MA"** design allows using a freely programmable "Advanced" PLC for complex tasks.

☞ The technology functions can be loaded via IndraWorks (see also MLD Application Manual: "Using Technology Functions").

Examples of technology functions: Following-on cutting devices, pick&place, process controller (register controller, winding computation, …), preventive maintenance, …

ℹ See documentation "Rexroth IndraDrive, Rexroth IndraMotion MLD (2G) as of MPx-18, Application Manual" (DOK-INDRV*-MLD3-**VRS*-AP; mat. no.: R911338914) and "Rexroth IndraMotion MLD (2G) Libraries as of MPx18, Reference Book" (DOK-INDRV*-MLD-SYSLIB3-RE; mat. no.: R911338915).

Integrated Safety Technology

☞ The **drive-integrated safety technology** is a functionality only scalable by means of the hardware and does not require any additional enabling of functions! The requirement for using this function is the availability of the optional safety technology modules "L3"/"L4" or "S3"/"S4".

In conjunction with the optional safety technology modules **L3** and **L4**, the safety function "Safe torque off" (STO) is supported.

When the safety function "Safe torque off" (STO) is selected, the safe brake control (SBC) is automatically activated with **L4.**

ℹ See separate documentation "Rexroth IndraDrive integrated safety technology "Safe Torque Off" (as of MPx-16), Application Manual " (DOK-INDRV*-SI3- **VRS**-AP; Mat. No.: R911332634).

The following safety functions can be implemented by using the optional safety technology modules "Safe Motion" (S3/S4):

IndraDrive Mi

The IndraDrive Mi drive systems with the motor-integrated servo drive KSM02 and the near motor servo drive KMS02 can be equipped with the optional safety technology module "S3". In this configuration, the systems provide universally programmable safe motion and standstill monitoring. The following safety technology functions are supported:

SDI	Safe direction	SIL2
SLI	Safely-limited increment	SIL2
SLS	Safely-limited speed	SIL2
SLS-LT	Safely-monitored transient oscillation	SIL2
SMD	Safely-monitored deceleration	SIL2
SMS	Safe maximum speed	SIL2
SOS	Safe operating stop	SIL2
SS1	Safe stop 1 (time-monitored)	SIL3
SS1	Safe stop 1 (monitored deceleration)	SIL2
SS2	Safe stop 2	SIL2
STO	Safe torque off	SIL3

Tab. 1-13: Safety Functions of the Optional Safety Technology Module "S3"

IndraDrive Cs and IndraDrive M / IndraDrive C

The control sections of the IndraDrive Cs drive system, as well as the Cxx02 control sections of the IndraDrive M / IndraDrive C drive systems, can be equipped with the optional safety technology module "S4". In this configuration, the systems provide universally programmable safe motion and standstill monitoring. The following safety technology functions are supported:

SBC	Safe brake control[1)]	SIL3
SDI	Safe direction	SIL2
SDL	Safe door locking[2)]	SIL3
SLI	Safely-limited increment	SIL2
SLS	Safely-limited speed	SIL2
SLS-LT	Safely-monitored transient oscillation	SIL2
SMD	Safely-monitored deceleration	SIL2
SMS	Safe maximum speed	SIL2
SOS	Safe operating stop	SIL2
SS1	Safe stop 1 (time-monitored)	SIL3
SS1	Safe stop 1 (monitored deceleration)	SIL2
SS2	Safe stop 2	SIL2
STO	Safe torque off	SIL3
SZA	Safety zone acknowledge[2)]	SIL3
SZE	Safe zone error[2)]	SIL3

1) Function presently only available with Indradrive Cs (in preparation for Cxx02)
2) Only in conjunction with safety zone module (HSZ01)

Tab. 1-14: Safety Functions of the Optional Safety Technology Module "S4"

See separate documentation "Rexroth IndraDrive Integrated Safety Technology "Safe Motion" (as of MPx-18), Application Manual " (DOK-INDRV*-SI3*SMO-VRS**-AP; Mat. No.: R911338920).

1.6 Performance Data

1.6.1 Overview

Levels of Control Performance

For the control performance of the IndraDrive range, we basically distinguish three levels with regard to the clock rates (cycle times):

- **Advanced** performance

  → High control performance by shorter clock rates for the control loops and the signal processing of inputs and outputs or drive-integrated PLC (IndraMotion MLD).
- **Basic** performance

  → Standard control performance by medium internal clock rates for the control loops and the signal processing of inputs/outputs or drive-integrated PLC (IndraMotion MLD)
- **Economy** performance

  → Low control performance due to reduced clock rates (cycle times) for the control loops and signal processing of inputs/outputs.

☞ Basic control section and "Advanced performance" setting are not possible when functional package "MLD" is active.

Performance and Clock Rates

In this documentation, the clock rate data refer to the following characteristic values:

- Current controller clock $T_{A\_current}$
- Velocity controller clock $T_{A\_velocity}$
- Position controller clock $T_{A\_position}$
- Cycle time of PLC (IndraMotion MLD) T_{MLD}
- Cycle time of master communication $T_{MastCom}$

The table below contains an overview of the clock rates depending on the respective control performance. The detailed assignment of clock rate to control section design, performance level and parameter setting is contained in the table "Performance Depending on the Control Section Design" in the section "Control Section Design and Performance" (see below).

☞ The control performance is not synonymous with the control section design, because it is determined by several factors.

The available performance depends on the following requirements and parameter settings:

- **Device configuration** and the associated drive **firmware** (MPB, MPC, MPM and MPE)
- **Activation of functional packages** (cf. P-0-2004)
- Performance level in "P-0-0556, Config word of axis controller"
- Switching frequency in "P-0-0001, Switching frequency of the power output stage"

See also "Overview of Drive Control"

1.6.2 Control Section Design and Performance

The control section design differs with regard to the performance levels that can be reached (cycle times or switching frequencies).

The table below contains an overview of the performance levels and clock rates that can be reached depending on the control section design.

<table>
<tr><th>Drive system
or
Control section/Firmware</th><th>Functional packages</th><th>Perform. level</th><th>f_{PWM} [1)]</th><th>PWM switching [2)]</th><th>$T_{A\_current}$</th><th>$T_{A\_velocity}$</th><th>$T_{A\_position}$</th><th>T_{MLD}</th><th>$T_{MastCom}$</th></tr>
<tr><td rowspan="8">HCS01.1 / MPB
CSB02.1 / MPB
KSM02.1 / MPB
KMS02.1 / MPB
CDB02.1 / MPM</td><td rowspan="5">All[7)]</td><td rowspan="5">Basic</td><td>2 kHz</td><td>No</td><td>250 µs</td><td rowspan="5">250 µs</td><td rowspan="5">500 µs</td><td rowspan="5">1000 µs
(not available with MPM)</td><td rowspan="16">As for
($T_{A\_position}$[3)])
1000 µs[4)]
2000 µs[5)]
500 µs[6)]</td></tr>
<tr><td>4 kHz</td><td>Yes</td><td>125 µs</td></tr>
<tr><td>8 kHz</td><td>Yes</td><td>125 µs</td></tr>
<tr><td>12 kHz</td><td>Yes</td><td>83.3 µs</td></tr>
<tr><td>16 kHz</td><td>Yes</td><td>62.5 µs</td></tr>
<tr><td rowspan="3">All[7)], except MLD</td><td rowspan="3">Advanced</td><td>4 kHz</td><td>No</td><td>125 µs</td><td rowspan="3">125 µs</td><td rowspan="3">250 µs</td><td rowspan="3">Not available</td></tr>
<tr><td>8 kHz</td><td>Yes</td><td>62.5 µs</td></tr>
<tr><td>16 kHz</td><td>Yes</td><td>62.5 µs</td></tr>
<tr><td rowspan="8">HCS01.1 / MPC
CSH02.1 / MPC</td><td rowspan="8">All[7)]</td><td rowspan="5">Basic</td><td>2 kHz</td><td>No</td><td>250 µs</td><td rowspan="5">250 µs</td><td rowspan="5">500 µs</td><td rowspan="8">1000 µs</td></tr>
<tr><td>4 kHz</td><td>Yes</td><td>125 µs</td></tr>
<tr><td>8 kHz</td><td>Yes</td><td>125 µs</td></tr>
<tr><td>12 kHz</td><td>Yes</td><td>83.3 µs</td></tr>
<tr><td>16 kHz</td><td>Yes</td><td>62.5 µs</td></tr>
<tr><td rowspan="3">Advanced</td><td>4 kHz</td><td>No</td><td>125 µs</td><td rowspan="3">125 µs</td><td rowspan="3">250 µs</td></tr>
<tr><td>8 kHz</td><td>Yes</td><td>62.5 µs</td></tr>
<tr><td>16 kHz</td><td>Yes</td><td>62.5 µs</td></tr>
<tr><td rowspan="2">HCS01.1 / MPE</td><td rowspan="2">All[7)]</td><td rowspan="2">Economy</td><td>4 kHz</td><td>No</td><td>125 µs</td><td rowspan="2">500 µs</td><td rowspan="2">1000 µs</td><td rowspan="2">Not available</td><td rowspan="2">2000 µs</td></tr>
<tr><td>8 kHz</td><td>No</td><td>125 µs</td></tr>
</table>

System Overview

Drive system or Control section/Firmware	Functional packages	Perform. level	f_{PWM} 1)	PWM switching 2)	$T_{A\_current}$	$T_{A\_velocity}$	$T_{A\_position}$	T_{MLD}	$T_{MastCom}$
HCQ02.1 / MPM HCT02.1 / MPM	All7)	Basic	4 kHz	No	125 µs	250 µs	500 µs	Not availa-ble	500 µs
			8 kHz	No	125 µs				

1) Switching frequency of the power output stage, device-dependent (can be set via P-0-0001)
2) Reduction of the PWM frequency depending on velocity or load (can be set via P-0-0045)
3) With sercos
4) With PROFIBUS®
5) With PROFINET® and EtherNet/IP™
6) With EtherCAT®
7) The selection of functional packages depends on the drive system and on the control section/firmware

Tab. 1-15: Performance Depending on the Control Section Design

1.6.3 Performance at Reduced Switching Frequency

At switching frequencies of 4 kHz, 8 kHz, 12 kHz or 16 kHz and the corresponding setting in parameter "P-0-0045, Control word of current controller" (type of PWM clocking), the switching frequency is automatically reduced by half in order to increase the ability of the controller to withstand thermal loads:

- Depending on the thermal load of the controller
- Depending on the velocity

When the reduction of the PWM frequency is used, the switching frequency of the power output stage is changed, but not the cycle times! The performance is not reduced!

See "Current Limitation: Principles of Current Limitation"

For the automatic PWM adjustment, see chapter "Dynamic Current Limitation", section "Continuous Current of Controller Depending on Work Load at PWM of 12 kHz or 16 kHz"

1.7 Drive Controllers

1.7.1 Standard Design of the IndraDrive Controller

Design of the IndraDrive Controllers

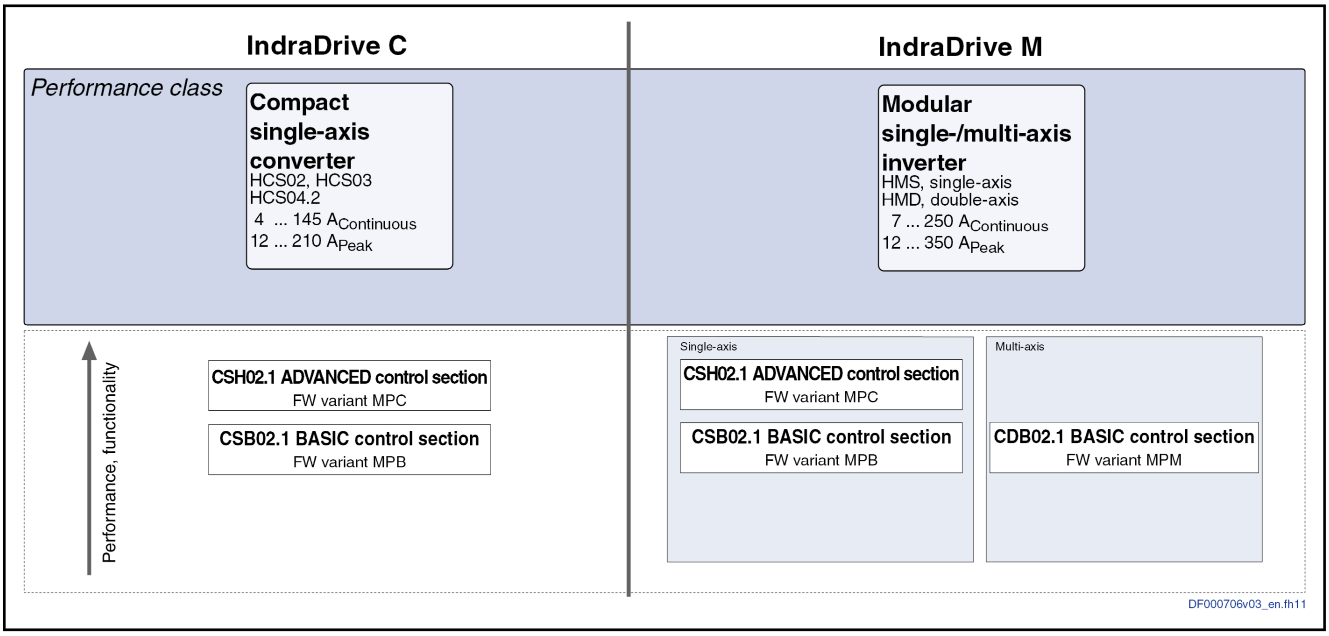


Fig. 1-3: Standard Design of the IndraDrive Controllers

Power section

The following are connected to the power section:

- Mains or DC bus voltage
- 24 V control voltage
- Motor

> ☞ The design versions of the power sections are described, respectively, in separate documentations (see "Reference Documentations").

Control section

The control section additionally makes available connections for:

- Encoder
- Master Communication
- Optional Ethernet engineering
- Safety technology
- Optional memories for user data
- Digital / analog inputs / outputs

The control section is a separate part of the IndraDrive controller and is plugged in the power section. The drive controller is supplied ex works complete with the control section. The control section may only be replaced by a qualified service engineer.

> ☞ The available control sections are described in the separate documentation "Control Sections for Drive Controllers, Project Planning Manual" (DOK-INDRV*-CSH********-PR**-EN-P; mat. no.: R911295012).

1.7.2 Special Design of the IndraDrive Controllers

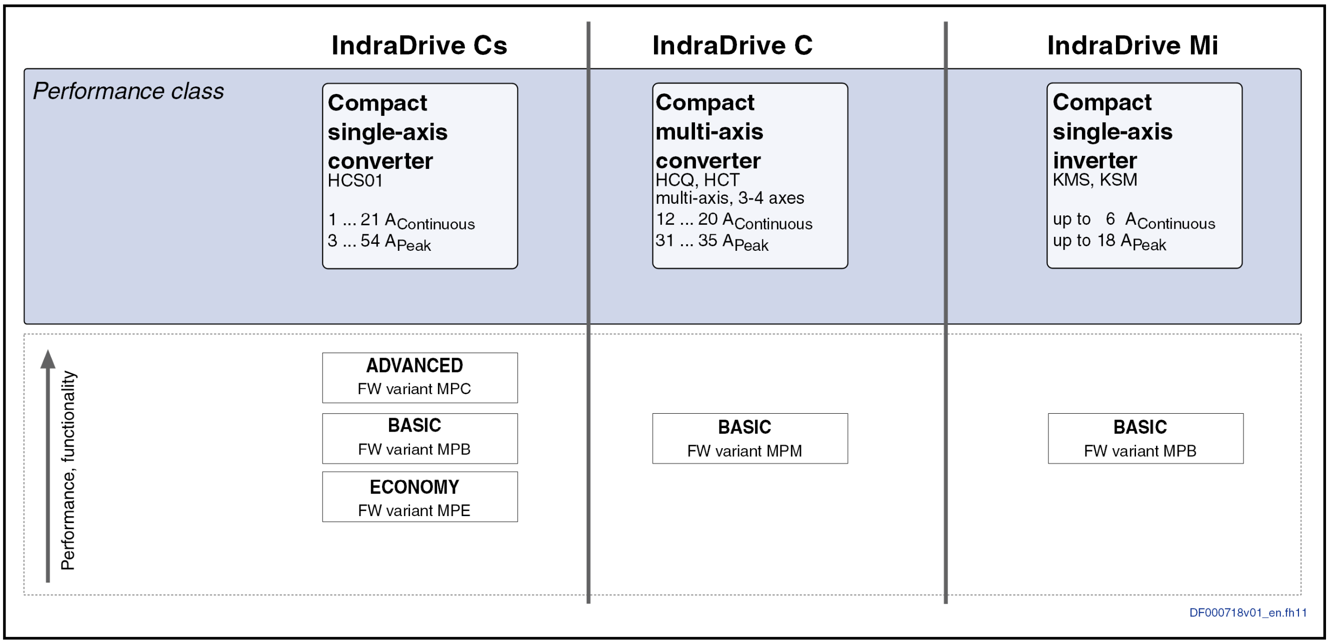


Fig. 1-4: Special Design of the IndraDrive Controllers

Compact Converters, Special Design

- IndraDrive Cs (HCS01), compact single-axis converter

  In contrast to the usual device design with power sections and control sections that can be explicitly ordered, the control section and power section of the HCS01 controller (IndraDrive Cs) are inseparably integrated in one device.

  For information on the functional and performance features of HCS01 controllers, see "Rexroth IndraDrive Cs, Drive Systems with HCS01", Project Planning Manual, mat. no. R911322210, DOK-INDRV*-HCS01******-PR02-EN-P.

- IndraDrive C (HCQ, HCT), compact multi-axis converter

  Also in contrast to the usual device design, each of the compact HCT and HCQ controllers can operate 3 - 4 axes. The control section and power section are inseparably integrated in one device.

  For information on the functional and performance features, see "Rexroth IndraDrive, Drive Controllers HCQ02, HCT02", Project Planning Manual, mat. no. R911324185, DOK-INDRV*-HCQ-T+HMQ-TPRxx-EN-P.

Inverters for Cabinet-Free Drive Technology

- IndraDrive Mi (KSM01.2-B, motor-integrated servo drive)

  ⇒ Synchronous servo motors with integrated inverter

  In KSM (distributed servo drive), the control section and the power section are integrated in the motor (synchronous servo motor), it is not possible to configure the control section. KSM can be operated with the IndraDrive firmware of version **FWA-INDRV*-MPB-17VRS and above.**

  See also separate documentations:

  – "Rexroth IndraDrive Mi, Drive Systems with KCU01, KSM01, KMS01" (DOK-INDRV*-KCU+KSM****-PR04-EN-P; mat. no.: R911320924)

  – "Rexroth IndraDrive Mi, Distributed Servo Drive KSM01" (DOK-INDRV*-KSM01******-IT01-EN-P; mat. no.: R911339087).

- IndraDrive Mi (KMS01.2-B, near motor servo drive)

  ⇒ Compact inverter with control section

  In KMS (distributed drive controller), the control section and the power section are integrated and separated from the motor, and due to the high degree of protection can be mounted as near as possible to the motor. It is not possible to configure the control section. This variant of IndraDrive Mi does not have a HIPERFACE® encoder interface. The converter can be operated with the IndraDrive firmware of version **FWA-INDRV*-MPB-17VRS and above**.

  See also separate documentations:

  – "Rexroth IndraDrive Mi, Distributed Drive Controller KMS01" (DOK-INDRV*-KMS01******-IT01-EN-P; mat. no.: R911339094).

  – "Rexroth IndraDrive Mi, Drive Systems with KCU01, KSM01, KMS01" (DOK-INDRV*-KCU+KSM****-PR04-EN-P; mat. no.: R911320924)

1.7.3 Power Sections, Drive Systems

All HMS01, HMD01, HCS02, HCS03 and HCS04.2 power sections from the table below with the production date **FD: 07W01** and above are supported (07W01 means production year 2007, week 01).

Power Sections

Power Sections
HMS01.1N-W0020-A-07-NNNN
HMS01.1N-W0036-A-07-NNNN
HMS01.1N-W0054-A-07-NNNN
HMS01.1N-W0070-A-07-NNNN
HMS01.1N-W0110-A-07-NNNN
HMS01.1N-W0150-A-07-NNNN
HMS01.1N-W0210-A-07-NNNN
HMS01.1N-W0350-A-07-NNNN
HMD01.1N-W0012-A-07-NNNN
HMD01.1N-W0020-A-07-NNNN
HMD01.1N-W0036-A-07-NNNN
HMS02.1N-W0028-A-07-NNNN
HMS02.1N-W0054-A-07-NNNN
HCS02.1E-W0012-A-03-xNNx
HCS02.1E-W0028-A-03-xNNx
HCS02.1E-W0054-A-03-xNNx[1)]
HCS02.1E-W0070-A-03-xNNx[1)]

System Overview

Power Sections
HCS03.1E-W0070-A-05-xNxx
HCS03.1E-W0100-A-05-xNxx
HCS03.1E-W0150-A-05-xNxx
HCS03.1E-W0210-A-05-xNxx
HCS04.2E-W0290-N-0x-xNxN[2)]
HCS04.2E-W0350-N-0x-xNxN[2)]
HCS04.2E-W0520-N-0x-xNxN[2)]
HCS04.2E-W0640-N-0x-xNxN[2)]
HCS04.2E-W0790-N-0x-xNxN[2)]
HCS04.2E-W1010-N-0x-xNxN[2)]
HCS04.2E-W1240-N-0x-xNxN[2)]
HCS04.2E-W1540-N-0x-xNxN[2)]

1) As of week 30/2007
2) As of MPx18V12

Tab. 1-16: Power Sections

☞ For devices of an older production date, the message "F8118 Invalid power section/firmware combination" is output.

Drive Systems

For HCS01, HCQ, HCT, KMS and KSM, there are no restrictions as regards the production period.

Drive Systems
HCS01.1E-W00xx-A-0x-x-xx-EC-xx-xx-NN-FW
KMS02.1B-A0xx-P-D7-ET-xxx-xx-xx-FW
KSM02.1B-0xxC-xxN-xx-Hxx-ET-xx-D7-xx-FW
HCQ02.1E-W-00xx-A-03-B-L8-1S-xx-xx-NN-xx
HCT02.1E-W00xx-A-03-B-xx-xx-xx-xx-NN-xx

Tab. 1-17: Drive Systems

1.7.4 Control Sections and Optional Modules

Control sections supported by the MPx18VRS firmware, as well as the possible combinations of optional modules.

☞ Our sales representative will help you with the current status of available control section card types.

Control section types →	CSE02.1	CSB02.1	CDB02.1	CSH02.1
	ECONOMY "Single-axis"	BASIC "Single-axis"	BASIC "Multi-axis"	ADVANCED "Single-axis"
Firmware variant →	MPE-18VRS	MPB-18VRS	MPM-18VRS	MPC-18VRS
Optional modules for master communication				

Control section types →		CSE02.1	CSB02.1	CDB02.1	CSH02.1
ET	MultiEthernet	-	■	-	■
PB	PROFIBUS-DP	-	■	■	■
CN	CANopen	-	■	-	■
Optional modules for encoder evaluation					
EC	Encoder interface for EnDat2.1, 1Vpp sine and TTL signals, HIPER-FACE®	-	■	■	■
EM	Encoder emulation	-	■	■	■
Optional modules for safety technology					
L3	Safe Torque Off	-	■	■	■
L4	Safe Torque Off / Safe Brake Control	-	-	-	-
S3	Safe Motion SIL 2 (without SBC)	-	-	-	-
S4	Safe Motion SIL 2	-	■	■	■
Optional modules for I/O extension					
DA*)	I/O extension digital/analog	-	■	■	■
Optional module MultiEthernet					
ET	MultiEthernet option	-	-	-	■

*) As of MPx18V10

Tab. 1-18: Supported Control Section Configurations

Device		HCS01.1		
		ECONOMY "Single-axis"	BASIC "Single-axis"	ADVANCED "Single-axis"
Firmware variant →		MPE-18VRS	MPB-18VRS	MPC-18VRS
Optional modules for master communication				
ET	MultiEthernet	-	■	■
PB	PROFIBUS-DP	-	■	■
CN	CANopen	-	■	■
Optional modules for encoder evaluation				
EC	Encoder interface for EnDat2.1, 1Vpp sine and TTL signals, HIPER-FACE®	-	■	■
EM	Encoder emulation	-	■	■
Optional modules for safety technology				
L3	Safe Torque Off	■	■	■
L4	Safe Torque Off / Safe Brake Control	■	■	■
S3	Safe Motion SIL 2 (without SBC)	-	-	-

System Overview

Device		HCS01.1		
S4	Safe Motion SIL 2	-	■	■
Optional modules for I/O extension				
DA*)	I/O extension digital/analog	-	■	■
Optional module MultiEthernet				
ET	MultiEthernet option	-	-	■

*) As of MPx18V10

Tab. 1-19: Supported Control Section Configurations

Device		KSM02.1	KMS02.1
		BASIC "Single-axis"	BASIC "Single-axis"
Firmware variant →		MPB-18VRS	MPB-18VRS
Optional modules for master communication			
ET	MultiEthernet	■	■
PB	PROFIBUS-DP	-	-
CN	CANopen	-	-
Optional modules for encoder evaluation			
ENH	HIPERFACE®	-	■
Optional modules for safety technology			
L3	Safe Torque Off	■	■
L4	Safe Torque Off / Safe Brake Control	-	-
S3	Safe Motion SIL 2 (without SBC)	■	■
S4	Safe Motion SIL 2	-	-
Optional module MultiEthernet			
TO	MultiEthernet output coupling	■	■

Tab. 1-20: Supported Control Section Configurations

Device		HCT02.1	HCQ02.1
		BASIC "Single-axis"	BASIC "Single-axis"
Firmware variant →		MPB-18VRS	MPB-18VRS
Optional modules for master communication			
ET	MultiEthernet	■	-
PB	PROFIBUS-DP	■	-
CN	CANopen	-	-
L8	Embedded PC, LX 800	■	■
Optional modules for encoder evaluation			
Number of encoder evaluations in basic device		4	5

Device		HCT02.1	HCQ02.1
Optional modules for I/O extension			
D1	Digital I/O extension (DEA40.1)	■	■

Tab. 1-21: Supported Control Section Configurations

1.8 Supported Motors and Measuring Systems

1.8.1 Supported Motors

The following table provides an overview of the Rexroth motors that are supported by this firmware:

Rexroth housing motors		Rexroth kit motors	
Synchronous	Asynchronous	Synchronous	Asynchronous
MSK (IndraDyn S) MSM	MAD (IndraDyn A) MAF (IndraDyn A) MAL	MLF (IndraDyn L) MBS (IndraDyn H) MCL MBT (IndraDyn T)	1MB

Tab. 1-22: Appropriate Rexroth Motors for IndraDrive

In addition to the Rexroth motors, it is basically possible to operate three-phase third-party motors (synchronous and asynchronous motors) at IndraDrive controllers. However, it is necessary to check whether the specific motor type can be controlled (see chapter "Third-Party Motors" in "Rexroth IndraDrive, Drive System, R911309636, DOK-INDRV*-SYSTEM*****-PR0x-…..").

☞ The operation of SBC motors of the manufacturer Parker is directly supported by motor-type-specific parameters made available in the encoder data memory!

1.8.2 Supported Measuring Systems

Supported Encoder Systems

Encoder systems with a supply voltage of **5 and 12 volt**:

- MSM motor encoder (with HCS01 only)
- MSK motor encoder
- Sin-cos encoder 1 V_{pp}; HIPERFACE®
- Sin-cos encoder 1 V_{pp}; EnDat2.1
- Sin-cos encoder 1 V_{pp}; with reference track
- 5V-TTL square-wave encoder; with reference track
- Sin-cos encoder 1 V_{pp} and SSI encoder (combined encoder for SSI)
- SSI encoder
- Resolver
- Sin-cos encoder 1 Vpp; with Hall sensor box SHL02.1
- EnDat 2.2 (as of MPx18V10)

1.9 Documentations

1.9.1 Drive Systems, System Components

Drive Systems with Single-Axis or Double-Axis Drive Controllers

Title Rexroth IndraDrive …	Kind of documentation	Document typecode[1)] DOK-INDRV*-…	Material number R911…
Cs Drive Systems with HCS01	Project Planning Manual	HCS01******-PRxx-EN-P	322210
Mi Drive Systems with KCU02, KSM02, KMS02	Project Planning Manual	KCU02+KSM02-PRxx-EN-P	335703
Drive Systems with HMV01/02 HMS01/02, HMD01, HCS02/03	Project Planning Manual	SYSTEM*****-PRxx-EN-P	309636
Supply Units, Power Sections HMV, HMS, HMD, HCS02, HCS03	Project Planning Manual	HMV-S-D+HCS-PRxx-EN-P	318790
Control Sections CSE02, CSB02, CDB02, CSH02	Project Planning Manual	Cxx02******-PRxx-EN-P	338962
Additional Components and Accesso-ries	Project Planning Manual	ADDCOMP****-PRxx-EN-P	306140

1) In the document typecodes, "xx" is a wild card for the current edition of the documentation (example: PR01 is the first edition of a Project Planning Manual)

Tab. 1-23: Documentations – Drive Systems, System Components

Drive Systems with Multi-Axis Drive Controllers

Title	Kind of documentation	Document typecode[1)]	Material number R911…
Rexroth IndraDrive Drive Controllers HCQ02, HCT02	Project Planning Manual	DOK-INDRV*-HCQ-T+HMQ-T-PRxx-EN-P	324185
Rexroth IndraDrive Additional Components and Accesso-ries	Project Planning Manual	DOK-INDRV*-ADDCOMP****-PRxx-EN-P	306140
Rexroth IndraControl VDP 80.1 Machine Operator Panel Operator Display	Project Planning Manual	DOK-SUPPL*-VDP*80.1***-PRxx-EN-P	329156

1) In the document typecodes, "xx" is a wild card for the current edition of the documentation (example: PR01 is the first edition of a Project Planning Manual)

Tab. 1-24: Documentations – Drive Systems, System Components

1.9.2 Motors

Title Rexroth IndraDyn …	Kind of documentation	Document typecode[1)] DOK-MOTOR*-…	Material number R911…
A Asynchronous Motors MAD / MAF	Project Planning Manual	MAD/MAF****-PRxx-EN-P	295781
H Synchronous Kit Spindle Motors	Project Planning Manual	MBS-H******-PRxx-EN-P	297895
L Synchronous Linear Motors	Project Planning Manual	MLF********-PRxx-EN-P	293635
L Ironless Linear Motors MCL	Project Planning Manual	MCL********-PRxx-EN-P	330592
S Synchronous Motors MKE	Project Planning Manual	MKE*GEN2***-PRxx-EN-P	297663
S Synchronous Motors MSK	Project Planning Manual	MSK********-PRxx-EN-P	296289
S Synchronous Motors MSM	Data Sheet	MSM********-DAxx-EN-P	329338
S Synchronous Motors QSK	Project Planning Manual	QSK********-PRxx-EN-P	330321
T Synchronous Torque Motors	Project Planning Manual	MBT********-PRxx-EN-P	298798

1) In the document typecodes, "xx" is a wild card for the current edition of the documentation (example: PR01 is the first edition of a Project Planning Manual)

Tab. 1-25: Documentations – Motors

1.9.3 Cables

Title	Kind of documentation	Document typecode[1)] DOK-CONNEC-…	Material number R911…
Rexroth Connection Cables IndraDrive and IndraDyn	Selection Data	CABLE*INDRV-CAxx-EN-P	322949

1) In the document typecodes, "xx" is a wild card for the current edition of the documentation (example: CA02 is the second edition of the documentation "Selection Data")

Tab. 1-26: Documentations – Cables

1.9.4 Firmware

Title	Kind of documentation	Document typecode[1)]	Material number
Rexroth IndraDrive MPx-18 Functions	Application Manual	DOK-INDRV*-MP*-18VRS**-APxx-EN-P	R911338673
Rexroth IndraDrive MPx-18 Version Notes	Release Notes	DOK-INDRV*-MP*-18VRS**-RNxx-EN-P	R911338658
Rexroth IndraDrive MPx-16 to MPx-18 Parameters	Reference Book	DOK-INDRV*-GEN1-PARA**-RExx-EN-P	R911328651
Rexroth IndraDrive MPx-16 to MPx-18 Diagnostic Messages	Reference Book	DOK-INDRV*-GEN1-DIAG**-RExx-EN-P	R911326738
Integrated Safety Technology "Safe Torque Off" (as of MPx-16)	Application Manual	DOK-INDRV*-SI3-**VRS**-APxx-EN-P	R911332634
Integrated Safety Technology "Safe Motion" (as of MPx-18)	Application Manual	DOK-INDRV*-SI3*SMO-VRS-APxx-EN-P	R911338920

System Overview

Title	Kind of documentation	Document typecode[1)]	Material number
Rexroth IndraDrive Rexroth IndraMotion MLD (2G) Libraries as of MPx-18	Reference Book	DOK-INDRV*-MLD-SYSLIB3-RExx-EN-P	R911338916
Rexroth IndraDrive Rexroth IndraMotion MLD (2G) as of MPx-18	Application Manual	DOK-INDRV*-MLD3-**VRS*-APxx-EN-P	R911338914
Rexroth IndraDrive Rexroth IndraMotion MLD (2G) as of MPx-18	Commissioning Manual	DOK-INDRV*-MLD3-F*STEP-COxx-EN-P	R911341708
Rexroth IndraMotion MLD 13VRS Service Tool	Reference Book	DOK-IM*MLD-IMST****V13-RExx-EN-P	R911341347

1) In the document typecodes, "xx" is a wild card for the current edition of the documentation (example: RE02 is the second edition of a Reference Book)

Tab. 1-27: Documentations – Firmware

1.9.5 Control Unit

Title Rexroth IndraMotion MTX micro	Kind of documentation	Document typecode[1)] DOK-MTXMIC-…	Material number R911…
Easy setup for Standard Turning and Milling Machines	Commissioning Manual	EASY*******-COxx-EN-P	332281
12VRS System Description	Manual	SYS*DES*V12-RExx-EN-P	334369
12VRS Functional Description	Manual	NC*FUNC*V12-APxx-EN-P	334357
12VRS Machine Parameters	Reference Book	MA*PAR**V12-RExx-EN-P	334365
12VRS Programming Manual	Manual	NC**PRO*V12-RExx-EN-P	334361

1) In the document typecodes, "xx" is a wild card for the current edition of the documentation (example: RE02 is the second edition of a reference documentation)

Tab. 1-28: Documentations – Control Unit

2 Important Directions for Use

2.1 Appropriate Use

2.1.1 Introduction

Rexroth products reflect the state-of-the-art in their development and their manufacture. They are tested prior to delivery to ensure operating safety and reliability.

⚠ WARNING **Personal injury and property damage caused by incorrect use of the products!**

The products have been designed for use in industrial environments and may only be used in the appropriate way. If they are not used in the appropriate way, situations resulting in property damage and personal injury can occur.

☞ Rexroth as manufacturer is not liable for any damages resulting from inappropriate use. In such cases, the guarantee and the right to payment of damages resulting from inappropriate use are forfeited. The user alone carries all responsibility of the risks.

Before using Rexroth products, the following pre-requisites must be met to ensure appropriate use of the products:

- Personnel that in any way, shape or form uses our products must first read and understand the relevant safety instructions and be familiar with their appropriate use.
- If the products take the form of hardware, then they must remain in their original state, in other words, no structural changes are permitted. It is not permitted to decompile software products or alter source codes.
- Damaged or faulty products may not be installed or put into operation.
- Make sure that the products have been installed in the manner described in the relevant documentation.

2.1.2 Areas of Use and Application

Drive controllers made by Rexroth are designed to control electrical motors and monitor their operation.

Control and monitoring of the Drive controllers may require additional sensors and actors.

☞ The drive controllers may only be used with the accessories and parts specified in this documentation. If a component has not been specifically named, then it may neither be mounted nor connected. The same applies to cables and lines.

Operation is only permitted in the specified configurations and combinations of components using the software and firmware as specified in the relevant Functional Descriptions.

Drive controllers have to be programmed before commissioning to ensure that the motor executes the specific functions of an application.

Drive controllers of the Rexroth IndraDrive line have been developed for use in single- and multi-axis drive and control tasks.

To ensure application-specific use of Drive controllers, device types of different drive power and different interfaces are available.

Typical applications include, for example:

- Handling and mounting systems,
- Packaging and food machines,
- Printing and paper processing machines and
- Machine tools.

Drive controllers may only be operated under the assembly and installation conditions described in this documentation, in the specified position of normal use and under the ambient conditions as described (temperature, degree of protection, humidity, EMC, etc.).

2.2 Inappropriate Use

Using the Drive controllers outside of the operating conditions described in this documentation and outside of the technical data and specifications given is defined as "inappropriate use".

Drive controllers may not be used, if ...

- they are subject to operating conditions that do not meet the specified ambient conditions. This includes, for example, operation under water, under extreme temperature fluctuations or extremely high maximum temperatures.
- Furthermore, Drive controllers may not be used in applications which have not been expressly authorized by Rexroth. Please carefully follow the specifications outlined in the general Safety Instructions!

☞ Components of the Rexroth IndraDrive system are **products of category C3** (with limited availability) according to IEC 61800-3. To ensure that this category (limit values) is maintained, suitable line filters must be used in the drive system.

These components are not provided for use in a public low-voltage network supplying residential areas with power. If these components are used in such a public network, high-frequency interference is to be expected. This can require additional measures of radio interference suppression.

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3 Safety Instructions for Electric Drives and Controls

3.1 Definitions of Terms

Application Documentation Application documentation comprises the entire documentation used to inform the user of the product about the use and safety-relevant features for configuring, integrating, installing, mounting, commissioning, operating, maintaining, repairing and decommissioning the product. The following terms are also used for this kind of documentation: Operating Instructions, Commissioning Manual, Instruction Manual, Project Planning Manual, Application Description, etc.

Component A component is a combination of elements with a specified function, which are part of a piece of equipment, device or system. Components of the electric drive and control system are, for example, supply units, drive controllers, mains choke, mains filter, motors, cables, etc.

Control System A control system comprises several interconnected control components placed on the market as a single functional unit.

Device A device is a finished product with a defined function, intended for users and placed on the market as an individual piece of merchandise.

Electrical Equipment Electrical equipment encompasses all devices used to generate, convert, transmit, distribute or apply electrical energy, such as electric motors, transformers, switching devices, cables, lines, power-consuming devices, circuit board assemblies, plug-in units, control cabinets, etc.

Electric Drive System An electric drive system comprises all components from mains supply to motor shaft; this includes, for example, electric motor(s), motor encoder(s), supply units and drive controllers, as well as auxiliary and additional components, such as mains filter, mains choke and the corresponding lines and cables.

Installation An installation consists of several devices or systems interconnected for a defined purpose and on a defined site which, however, are not intended to be placed on the market as a single functional unit.

Machine A machine is the entirety of interconnected parts or units at least one of which is movable. Thus, a machine consists of the appropriate machine drive elements, as well as control and power circuits, which have been assembled for a specific application. A machine is, for example, intended for processing, treatment, movement or packaging of a material. The term "machine" also covers a combination of machines which are arranged and controlled in such a way that they function as a unified whole.

Manufacturer The manufacturer is an individual or legal entity bearing responsibility for the design and manufacture of a product which is placed on the market in the individual's or legal entity's name. The manufacturer can use finished products, finished parts or finished elements, or contract out work to subcontractors. However, the manufacturer must always have overall control and possess the required authority to take responsibility for the product.

Product Examples of a product: Device, component, part, system, software, firmware, among other things.

Project Planning Manual A project planning manual is part of the application documentation used to support the sizing and planning of systems, machines or installations.

Qualified Persons In terms of this application documentation, qualified persons are those persons who are familiar with the installation, mounting, commissioning and operation of the components of the electric drive and control system, as well as with the hazards this implies, and who possess the qualifications their work requires. To comply with these qualifications, it is necessary, among other things,

1) to be trained, instructed or authorized to switch electric circuits and devices safely on and off, to ground them and to mark them

2) to be trained or instructed to maintain and use adequate safety equipment

3) to attend a course of instruction in first aid

User

A user is a person installing, commissioning or using a product which has been placed on the market.

3.2 General Information

3.2.1 Using the Safety Instructions and Passing Them on to Others

Do not attempt to install and operate the components of the electric drive and control system without first reading all documentation provided with the product. Read and understand these safety instructions and all user documentation prior to working with these components. If you do not have the user documentation for the components, contact your responsible Rexroth sales partner. Ask for these documents to be sent immediately to the person or persons responsible for the safe operation of the components.

If the component is resold, rented and/or passed on to others in any other form, these safety instructions must be delivered with the component in the official language of the user's country.

Improper use of these components, failure to follow the safety instructions in this document or tampering with the product, including disabling of safety devices, could result in property damage, injury, electric shock or even death.

3.2.2 Requirements for Safe Use

Read the following instructions before initial commissioning of the components of the electric drive and control system in order to eliminate the risk of injury and/or property damage. You must follow these safety instructions.

- Rexroth is not liable for damages resulting from failure to observe the safety instructions.
- Read the operating, maintenance and safety instructions in your language before commissioning. If you find that you cannot completely understand the application documentation in the available language, please ask your supplier to clarify.
- Proper and correct transport, storage, mounting and installation, as well as care in operation and maintenance, are prerequisites for optimal and safe operation of the component.
- Only qualified persons may work with components of the electric drive and control system or within its proximity.
- Only use accessories and spare parts approved by Rexroth.
- Follow the safety regulations and requirements of the country in which the components of the electric drive and control system are operated.
- Only use the components of the electric drive and control system in the manner that is defined as appropriate. See chapter "Appropriate Use".
- The ambient and operating conditions given in the available application documentation must be observed.
- Applications for functional safety are only allowed if clearly and explicitly specified in the application documentation "Integrated Safety Technolo-

gy". If this is not the case, they are excluded. Functional safety is a safety concept in which measures of risk reduction for personal safety depend on electrical, electronic or programmable control systems.

- The information given in the application documentation with regard to the use of the delivered components contains only examples of applications and suggestions.

  The machine and installation manufacturers must

  – make sure that the delivered components are suited for their individual application and check the information given in this application documentation with regard to the use of the components,
  – make sure that their individual application complies with the applicable safety regulations and standards and carry out the required measures, modifications and complements.
- Commissioning of the delivered components is only allowed once it is sure that the machine or installation in which the components are installed complies with the national regulations, safety specifications and standards of the application.
- Operation is only allowed if the national EMC regulations for the application are met.
- The instructions for installation in accordance with EMC requirements can be found in the section on EMC in the respective application documentation.

  The machine or installation manufacturer is responsible for compliance with the limit values as prescribed in the national regulations.
- The technical data, connection and installation conditions of the components are specified in the respective application documentations and must be followed at all times.

National regulations which the user must take into account

- European countries: In accordance with European EN standards
- United States of America (USA):
  – National Electrical Code (NEC)
  – National Electrical Manufacturers Association (NEMA), as well as local engineering regulations
  – Regulations of the National Fire Protection Association (NFPA)
- Canada: Canadian Standards Association (CSA)
- Other countries:
  – International Organization for Standardization (ISO)
  – International Electrotechnical Commission (IEC)

3.2.3 Hazards by Improper Use

- High electrical voltage and high working current! Danger to life or serious injury by electric shock!
- High electrical voltage by incorrect connection! Danger to life or injury by electric shock!
- Dangerous movements! Danger to life, serious injury or property damage by unintended motor movements!
- Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electric drive systems!

- Risk of burns by hot housing surfaces!
- Risk of injury by improper handling! Injury by crushing, shearing, cutting, hitting!
- Risk of injury by improper handling of batteries!
- Risk of injury by improper handling of pressurized lines!

3.3 Instructions with Regard to Specific Dangers

3.3.1 Protection Against Contact with Electrical Parts and Housings

☞ This section concerns components of the electric drive and control system with voltages of **more than 50 volts**.

Contact with parts conducting voltages above 50 volts can cause personal danger and electric shock. When operating components of the electric drive and control system, it is unavoidable that some parts of these components conduct dangerous voltage.

High electrical voltage! Danger to life, risk of injury by electric shock or serious injury!

- Only qualified persons are allowed to operate, maintain and/or repair the components of the electric drive and control system.
- Follow the general installation and safety regulations when working on power installations.
- Before switching on, the equipment grounding conductor must have been permanently connected to all electric components in accordance with the connection diagram.
- Even for brief measurements or tests, operation is only allowed if the equipment grounding conductor has been permanently connected to the points of the components provided for this purpose.
- Before accessing electrical parts with voltage potentials higher than 50 V, you must disconnect electric components from the mains or from the power supply unit. Secure the electric component from reconnection.
- With electric components, observe the following aspects:

  Always wait **30 minutes** after switching off power to allow live capacitors to discharge before accessing an electric component. Measure the electrical voltage of live parts before beginning to work to make sure that the equipment is safe to touch.
- Install the covers and guards provided for this purpose before switching on.
- Never touch electrical connection points of the components while power is turned on.
- Do not remove or plug in connectors when the component has been powered.
- Under specific conditions, electric drive systems can be operated at mains protected by residual-current-operated circuit-breakers sensitive to universal current (RCDs/RCMs).

- Secure built-in devices from penetrating foreign objects and water, as well as from direct contact, by providing an external housing, for example a control cabinet.

High housing voltage and high leakage current! Danger to life, risk of injury by electric shock!

- Before switching on and before commissioning, ground or connect the components of the electric drive and control system to the equipment grounding conductor at the grounding points.
- Connect the equipment grounding conductor of the components of the electric drive and control system permanently to the main power supply at all times. The leakage current is greater than 3.5 mA.
- Establish an equipment grounding connection with a minimum cross section according to the table below. With an outer conductor cross section smaller than 10 mm^2 (8 AWG), the alternative connection of two equipment grounding conductors is allowed, each having the same cross section as the outer conductors.

Cross section outer conductor	Minimum cross section equipment grounding conductor Leakage current ≥ 3.5 mA	
	1 equipment grounding conductor	2 equipment grounding conductors
1.5 mm^2 (16 AWG)	10 mm^2 (8 AWG)	2 × 1.5 mm^2 (16 AWG)
2.5 mm^2 (14 AWG)		2 × 2.5 mm^2 (14 AWG)
4 mm^2 (12 AWG)		2 × 4 mm^2 (12 AWG)
6 mm^2 (10 AWG)		2 × 6 mm^2 (10 AWG)
10 mm^2 (8 AWG)		-
16 mm^2 (6 AWG)	16 mm^2 (6 AWG)	-
25 mm^2 (4 AWG)		-
35 mm^2 (2 AWG)		-
50 mm^2 (1/0 AWG)	25 mm^2 (4 AWG)	-
70 mm^2 (2/0 AWG)	35 mm^2 (2 AWG)	-
...	...	...

Tab. 3-1: Minimum Cross Section of the Equipment Grounding Connection

3.3.2 Protective Extra-Low Voltage as Protection Against Electric Shock

Protective extra-low voltage is used to allow connecting devices with basic insulation to extra-low voltage circuits.

On components of an electric drive and control system provided by Rexroth, all connections and terminals with voltages up to 50 volts are PELV ("Protective Extra-Low Voltage") systems. It is allowed to connect devices equipped with basic insulation (such as programming devices, PCs, notebooks, display units) to these connections.

Danger to life, risk of injury by electric shock! High electrical voltage by incorrect connection!

If extra-low voltage circuits of devices containing voltages and circuits of more than 50 volts (e.g., the mains connection) are connected to Rexroth products, the connected extra-low voltage circuits must comply with the requirements for PELV ("Protective Extra-Low Voltage").

3.3.3 Protection Against Dangerous Movements

Dangerous movements can be caused by faulty control of connected motors. Some common examples are:

- Improper or wrong wiring or cable connection
- Operator errors
- Wrong input of parameters before commissioning
- Malfunction of sensors and encoders
- Defective components
- Software or firmware errors

These errors can occur immediately after equipment is switched on or even after an unspecified time of trouble-free operation.

The monitoring functions in the components of the electric drive and control system will normally be sufficient to avoid malfunction in the connected drives. Regarding personal safety, especially the danger of injury and/or property damage, this alone cannot be relied upon to ensure complete safety. Until the integrated monitoring functions become effective, it must be assumed in any case that faulty drive movements will occur. The extent of faulty drive movements depends upon the type of control and the state of operation.

Dangerous movements! Danger to life, risk of injury, serious injury or property damage!

A **risk assessment** must be prepared for the installation or machine, with its specific conditions, in which the components of the electric drive and control system are installed.

As a result of the risk assessment, the user must provide for monitoring functions and higher-level measures on the installation side for personal safety. The safety regulations applicable to the installation or machine must be taken into consideration. Unintended machine movements or other malfunctions are possible if safety devices are disabled, bypassed or not activated.

To avoid accidents, injury and/or property damage:

- Keep free and clear of the machine’s range of motion and moving machine parts. Prevent personnel from accidentally entering the machine’s range of motion by using, for example:
  - Safety fences
  - Safety guards
  - Protective coverings
  - Light barriers
- Make sure the safety fences and protective coverings are strong enough to resist maximum possible kinetic energy.
- Mount emergency stopping switches in the immediate reach of the operator. Before commissioning, verify that the emergency stopping equip-

ment works. Do not operate the machine if the emergency stopping switch is not working.

- Prevent unintended start-up. Isolate the drive power connection by means of OFF switches/OFF buttons or use a safe starting lockout.
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- Additionally secure vertical axes against falling or dropping after switching off the motor power by, for example,
  - mechanically securing the vertical axes,
  - adding an external braking/arrester/clamping mechanism or
  - ensuring sufficient counterbalancing of the vertical axes.
- The standard equipment **motor holding brake** or an external holding brake controlled by the drive controller is **not sufficient to guarantee personal safety**!
- Disconnect electrical power to the components of the electric drive and control system using the master switch and secure them from reconnection ("lock out") for:
  - Maintenance and repair work
  - Cleaning of equipment
  - Long periods of discontinued equipment use
- Prevent the operation of high-frequency, remote control and radio equipment near components of the electric drive and control system and their supply leads. If the use of these devices cannot be avoided, check the machine or installation, at initial commissioning of the electric drive and control system, for possible malfunctions when operating such high-frequency, remote control and radio equipment in its possible positions of normal use. It might possibly be necessary to perform a special electromagnetic compatibility (EMC) test.

3.3.4 Protection Against Magnetic and Electromagnetic Fields During Operation and Mounting

Magnetic and electromagnetic fields generated by current-carrying conductors or permanent magnets of electric motors represent a serious danger to persons with heart pacemakers, metal implants and hearing aids.

Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electric components!

- Persons with heart pacemakers and metal implants are not allowed to enter the following areas:
  - Areas in which components of the electric drive and control systems are mounted, commissioned and operated.
  - Areas in which parts of motors with permanent magnets are stored, repaired or mounted.
- If it is necessary for somebody with a heart pacemaker to enter such an area, a doctor must be consulted prior to doing so. The noise immunity of implanted heart pacemakers differs so greatly that no general rules can be given.
- Those with metal implants or metal pieces, as well as with hearing aids, must consult a doctor before they enter the areas described above.

3.3.5 Protection Against Contact with Hot Parts

Hot surfaces of components of the electric drive and control system. Risk of burns!

- Do not touch hot surfaces of, for example, braking resistors, heat sinks, supply units and drive controllers, motors, windings and laminated cores!
- According to the operating conditions, temperatures of the surfaces can be **higher than 60 °C** (140 °F) during or after operation.
- Before touching motors after having switched them off, let them cool down for a sufficient period of time. Cooling down can require **up to 140 minutes**! The time required for cooling down is approximately five times the thermal time constant specified in the technical data.
- After switching chokes, supply units and drive controllers off, wait **15 minutes** to allow them to cool down before touching them.
- Wear safety gloves or do not work at hot surfaces.
- For certain applications, and in accordance with the respective safety regulations, the manufacturer of the machine or installation must take measures to avoid injuries caused by burns in the final application. These measures can be, for example: Warnings at the machine or installation, guards (shieldings or barriers) or safety instructions in the application documentation.

3.3.6 Protection During Handling and Mounting

Risk of injury by improper handling! Injury by crushing, shearing, cutting, hitting!

- Observe the relevant statutory regulations of accident prevention.
- Use suitable equipment for mounting and transport.
- Avoid jamming and crushing by appropriate measures.
- Always use suitable tools. Use special tools if specified.
- Use lifting equipment and tools in the correct manner.
- Use suitable protective equipment (hard hat, safety goggles, safety shoes, safety gloves, for example).
- Do not stand under hanging loads.
- Immediately clean up any spilled liquids from the floor due to the risk of falling!

3.3.7 Battery Safety

Batteries consist of active chemicals in a solid housing. Therefore, improper handling can cause injury or property damage.

Risk of injury by improper handling!

- Do not attempt to reactivate low batteries by heating or other methods (risk of explosion and cauterization).
- Do not attempt to recharge the batteries as this may cause leakage or explosion.
- Do not throw batteries into open flames.
- Do not dismantle batteries.

- When replacing the battery/batteries, do not damage the electrical parts installed in the devices.
- Only use the battery types specified for the product.

☞ Environmental protection and disposal! The batteries contained in the product are considered dangerous goods during land, air, and sea transport (risk of explosion) in the sense of the legal regulations. Dispose of used batteries separately from other waste. Observe the national regulations of your country.

3.3.8 Protection Against Pressurized Systems

According to the information given in the Project Planning Manuals, motors and components cooled with liquids and compressed air can be partially supplied with externally fed, pressurized media, such as compressed air, hydraulics oil, cooling liquids and cooling lubricants. Improper handling of the connected supply systems, supply lines or connections can cause injuries or property damage.

Risk of injury by improper handling of pressurized lines!

- Do not attempt to disconnect, open or cut pressurized lines (risk of explosion).
- Observe the respective manufacturer's operating instructions.
- Before dismounting lines, relieve pressure and empty medium.
- Use suitable protective equipment (safety goggles, safety shoes, safety gloves, for example).
- Immediately clean up any spilled liquids from the floor due to the risk of falling!

☞ Environmental protection and disposal! The agents (e.g., fluids) used to operate the product might not be environmentally friendly. Dispose of agents harmful to the environment separately from other waste. Observe the national regulations of your country.

3.4 Explanation of Signal Words and the Safety Alert Symbol

The Safety Instructions in the available application documentation contain specific signal words (DANGER, WARNING, CAUTION or NOTICE) and, where required, a safety alert symbol (in accordance with ANSI Z535.6-2011).

The signal word is meant to draw the reader's attention to the safety instruction and identifies the hazard severity.

The safety alert symbol (a triangle with an exclamation point), which precedes the signal words DANGER, WARNING and CAUTION, is used to alert the reader to personal injury hazards.

⚠ DANGER

In case of non-compliance with this safety instruction, death or serious injury **will** occur.

⚠ WARNING

In case of non-compliance with this safety instruction, death or serious injury could occur.

⚠ CAUTION

In case of non-compliance with this safety instruction, minor or moderate injury could occur.

NOTICE

In case of non-compliance with this safety instruction, property damage could occur.

4 Master Communication

4.1 Safety Instructions

⚠ WARNING **Dangerous movements! Danger to life, risk of injury, serious injury or property damage!**

- Keep free and clear of the ranges of motion of machines and moving machine parts.
- Prevent personnel from accidentally entering the machine’s range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

4.2 Basic Functions of Master Communication

4.2.1 Brief Description

General Information

The same basic functions of master communication for IndraDrive devices apply to:

- MultiEthernet interface with
  - sercos
  - EtherCAT®
  - PROFINET®
  - EtherNet/IP™
- Field bus interface
- Analog interface

The protocol is selected and deactivated via "P-0-4089.0.1, Master communication: Protocol".

IP engineering can also be carried out via the MultiEthernet interface. This function is maintained after the master communication has been switched off. When the EtherCAT® protocol has been activated, IP engineering cannot be carried out, because it is not supported by EtherCAT®; EoE (Ethernet over EtherCAT) can be used for EtherCAT® instead.

Notes on Parameter Access

The following mechanisms are available for control units that cannot access 4-byte EIDN parameters:

- 4-byte EIDNs with sercos element and sercos instance = 0, which are available in the drive, can be accessed as 2-byte IDNs. Example: Parameter P-0-4006.0.0 via P-0-4006
- The below-mentioned 4-byte EIDNs with sercos element or sercos instance unequal 0 are mapped to the assigned 2-byte IDN parameters

Master Communication

4-byte EIDN parameter	2-byte IDN parameter
P-0-4089.0.1, Master communication: Protocol	P-0-2310, Master communication: Protocol
P-0-4089.0.2, Master communication: Device name	P-0-2311, Master communication: Device name
P-0-4089.0.3, Device Address	P-0-2303, Device Address
P-0-4089.0.4, Active Device Address	P-0-2304, Active Device Address
P-0-4089.0.10, Master communication: MAC address device	P-0-2312, Master communication: MAC address device
P-0-4089.0.11, Master communication: MAC address Port1	P-0-2313, Master communication: MAC address Port1
P-0-4089.0.12, Master communication: MAC address Port2	P-0-2314, Master communication: MAC address Port2
P-0-4089.0.13, Master communication: IP address	P-0-2315, Master communication: IP address
P-0-4089.0.14, Master communication: Network mask	P-0-2316, Master communication: Network mask
P-0-4089.0.15, Master communication: Gateway address	P-0-2317, Master communication: Gateway address

Tab. 4-1: Parameters for Configuring the Master Communication

By means of the above-mentioned mechanisms, all parameters can thus be accessed via 2-byte IDNs. The CCD configuration parameters represent the only exception.

Features

When the field bus card (PROFIBUS® and CANopen) has been plugged in, it is only possible to change between inactive master communication and PROFIBUS® or CANopen master communication. Switching to sercos®, EtherCAT®, EtherNet/IP™ or PROFINET® is impossible.

Without the field bus card, only sercos is possible as the master communication for IndraDrive Cs with the MPE-18VRS (Economy) firmware.

- Protocol selection via the control panel or "P-0-4089.0.1, Master communication: Protocol"
- IP engineering is supported depending on the protocol
- Master communication engineering is supported depending on the protocol
- Command processing

  → Drive commands to be externally activated (via master communication, "Engineering over IP" or control panel)
- Device control (state machine)

  → Individual state machines for master communication and device
  - According to the variant of master communication, the master communication state machine has different functionality and complexity. The communication-specific states are distinguished and mapped to the status words of the corresponding master communication (e.g. for sercos: "S-0-0135, Drive status word"; "S-0-1045, ".
  - The device state machine is independent of the variant of master communication and maps the device-specific states to parameter "S-0-0424, Status parameterization level". We always distinguish between the operating mode (OM) and the parameter mode (PM).
- Extended control options

– Signal control word (S-0-0145) and signal status word (S-0-0144)
– Multiplex channel

See chapter "Control Options / Additional Functions".

☞ The state machine of the master communications is briefly outlined in this section; it will be described in detail, i.e. including the individual status transitions, in the main chapter of the respective master communication.

Pertinent Parameters

The following parameters are used independent of the variant of master communication:

Parameters for State Machine and Phase Switch

- S-0-0011, Class 1 diagnostics
- S-0-0012, Class 2 diagnostics
- S-0-0013, Class 3 diagnostics
- S-0-0014, Interface status
- S-0-0420, C0400 Activate parameterization level procedure command
- S-0-0422, C0200 Exit parameterization level procedure command
- S-0-0423, IDN-list of invalid data for parameterization levels
- S-0-0424, Status parameterization level
- P-0-4086, Master communication status
- P-0-4088, Master communication: Drive configuration

Operation Mode Parameters

- S-0-0032, Primary operation mode
- S-0-0033, Secondary operation mode 1
- S-0-0034, Secondary operation mode 2
- S-0-0035, Secondary operation mode 3
- S-0-0284, Secondary operation mode 4
- S-0-0285, Secondary operation mode 5
- S-0-0286, Secondary operation mode 6
- S-0-0287, Secondary operation mode 7

Control and Status Words Specific to sercos

For the "sercos" interface, the following **additional** parameters are used:

- S-0-0134, Master control word
- S-0-0135, Drive status word
- S-0-1044, sercos: Device Control (C-Dev)
- S-0-1045,

Field-Bus-Specific Parameters

The following **additional** parameters are used for field buses:

- P-0-4068, Field bus: Control word IO
- P-0-4077, Field bus: Control word
- P-0-4078, Field bus: Status word

Specific Parameters for Analog Interface

For the analog interface, the following **additional** parameters are used:

- P-0-4028, Device control word
- P-0-0115, Device control: Status word

Pertinent Diagnostic Messages

- C0100 Communication phase 3 transition check
- C5200 Communication phase 4 transition check
- C0200 Exit parameterization level procedure command
- C0400 Activate parameterization level 1 procedure command

4.2.2 Protocol Selection

Protocol Selection

The protocol is selected via parameter P-0-4089.0.1. The setting is either made in a menu-controlled way via the "display" or via the "IndraWorks" commissioning tool.

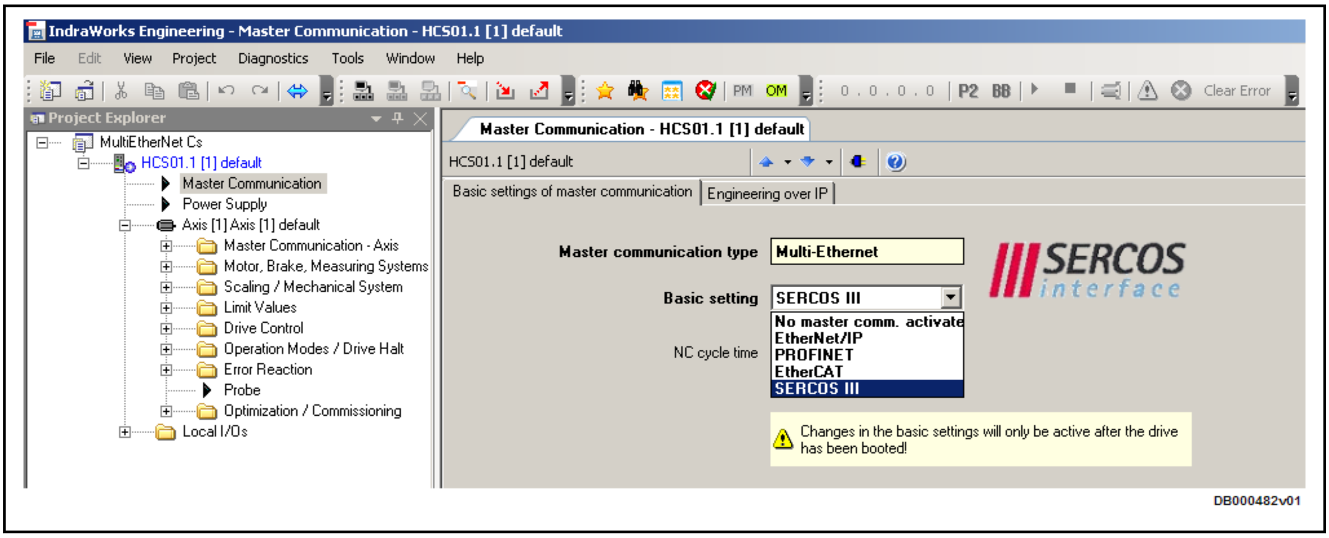


Fig. 4-1: MultiEthernet, Protocol Selection

After the parameter "P-0-4089.0.1, Master communication: Protocol" was changed, the drive must be rebooted. If no reboot is carried out and one tries to switch to the operating mode (OM), the drive signals "C0299 Configuration changed. Restart".

4.2.3 Command processing

Overview

Commands are used to control complex functions in the drive. For example, the functions "drive-controlled homing procedure" or "transition check for communication phase 4" are defined as commands.

☞ All commands available in the drive are stored in parameter "S-0-0025, IDN-list of all procedure commands".

Types of Commands

We distinguish 3 types of commands:

- **Drive control commands**
  - Can cause automatic drive motion
  - Can only be started when drive enable has been set
  - Deactivate the active operation mode during its execution
- **Administration commands**
  - carry out administration tasks,
  - Cannot be interrupted

Command execution

General Information

Observe the following aspects for command execution:

- Belonging to each command there is a parameter with which the command execution can be controlled.
- The higher-level master can start, interrupt and clear commands.
- While a command is being executed, the diagnostic message "Cx" appears on the display, "x" representing the number of the command.
- Each command that was started by the master must be actively cleared again.

NOTICE **Damage to the internal memory (flash) caused by cyclic command execution (write accesses to the flash)!**

⇒ During the execution of some commands (see description of the respective diagnostic command message; e.g. "C0500 Reset class 1 diagnostics, error reset"), data are also written to the internal memory (flash), which, however, only allows a limited number of write accesses. For this reason, you should make sure that such write accesses are not carried out too often (a maximum of approx. 100,000 writing cycles).

Controlling the Command Execution

The command execution is controlled and monitored by command input and command acknowledgment. In the input the drive is informed on whether the command execution is to be started, interrupted or completed. The input takes place via the operating data of the respective parameter.

Commands are started or terminated by:

- Directly writing data to the respective command parameter (e.g. "S-0-0099, C0500 Reset class 1 diagnostics" in the case of command "C0500 Reset class 1 diagnostics, error reset") via master communication

- or -

- A positive edge when the command was assigned to a digital input

  See also chapter:

  – "Configurable Signal Control Word"
  – "Digital Inputs/Outputs"

Possible Command Inputs

For command execution, we distinguish the following inputs (= content of command parameter):

- 0: Not set and not enabled
- 1: Interrupted
- 3: Set and enabled

Command Acknowledgment

In the command acknowledgment, the drive informs about the current state of the command execution. The current state is contained in the data status of the command parameter.

☞ The command status can be obtained by executing a command to write data to the parameter element 1 (data status) of the command parameter.

Command Status

The command status can be:

- 0x0: Not set and not enabled

- 0x7: In process
- 0xF: Error, command execution impossible
- 0x5: Command execution interrupted
- 0x3: Command correctly executed

Command change bit

For master-side detection of a change of the command acknowledgment by the drive, the "command change bit" (KA Bit) is available for sercos in parameter "S-0-0135, Drive status word".

- The drive sets this bit when the command acknowledgment changes from the "in process (0x7)" state to one of the following states:
  - Error, command execution impossible (0xF)

  - or -
  - Command correctly executed (0x3)
- The bit is cleared when the master clears the input (0x0), i.e. writes "0" to the parameter belonging to the command.

☞ The command change bit is only set if the command is activated via the master communication.

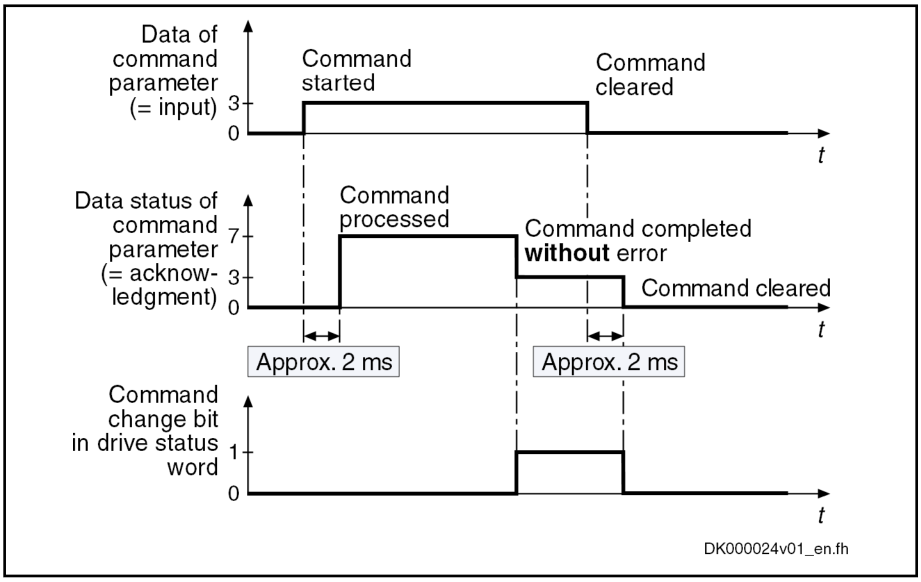


Fig. 4-2: Input, Acknowledgment and Command Change Bit in the Case of Correct Execution

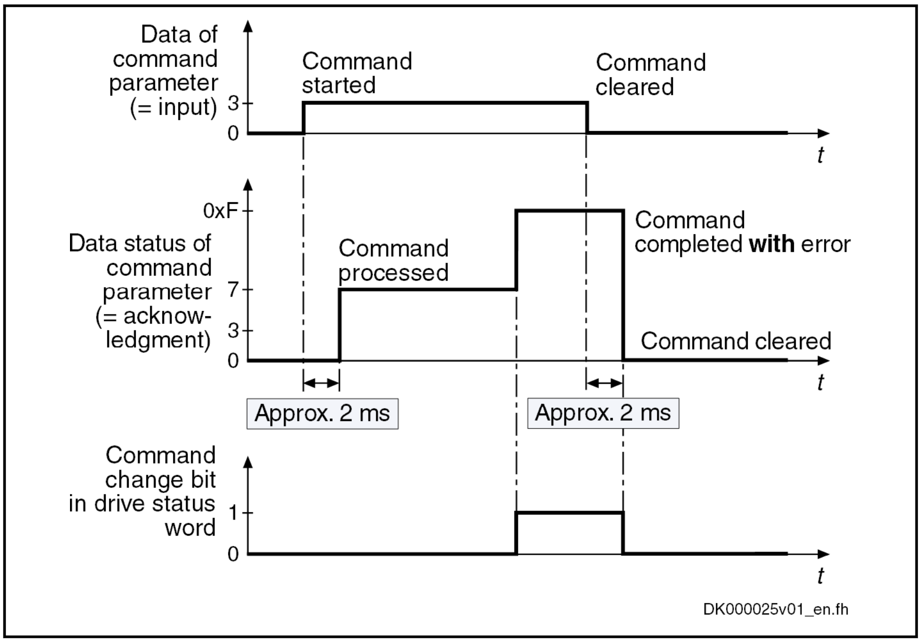


Fig. 4-3: Input, Acknowledgment and Command Change Bit in the Case of Incorrect Execution

4.2.4 Device Control and State Machines

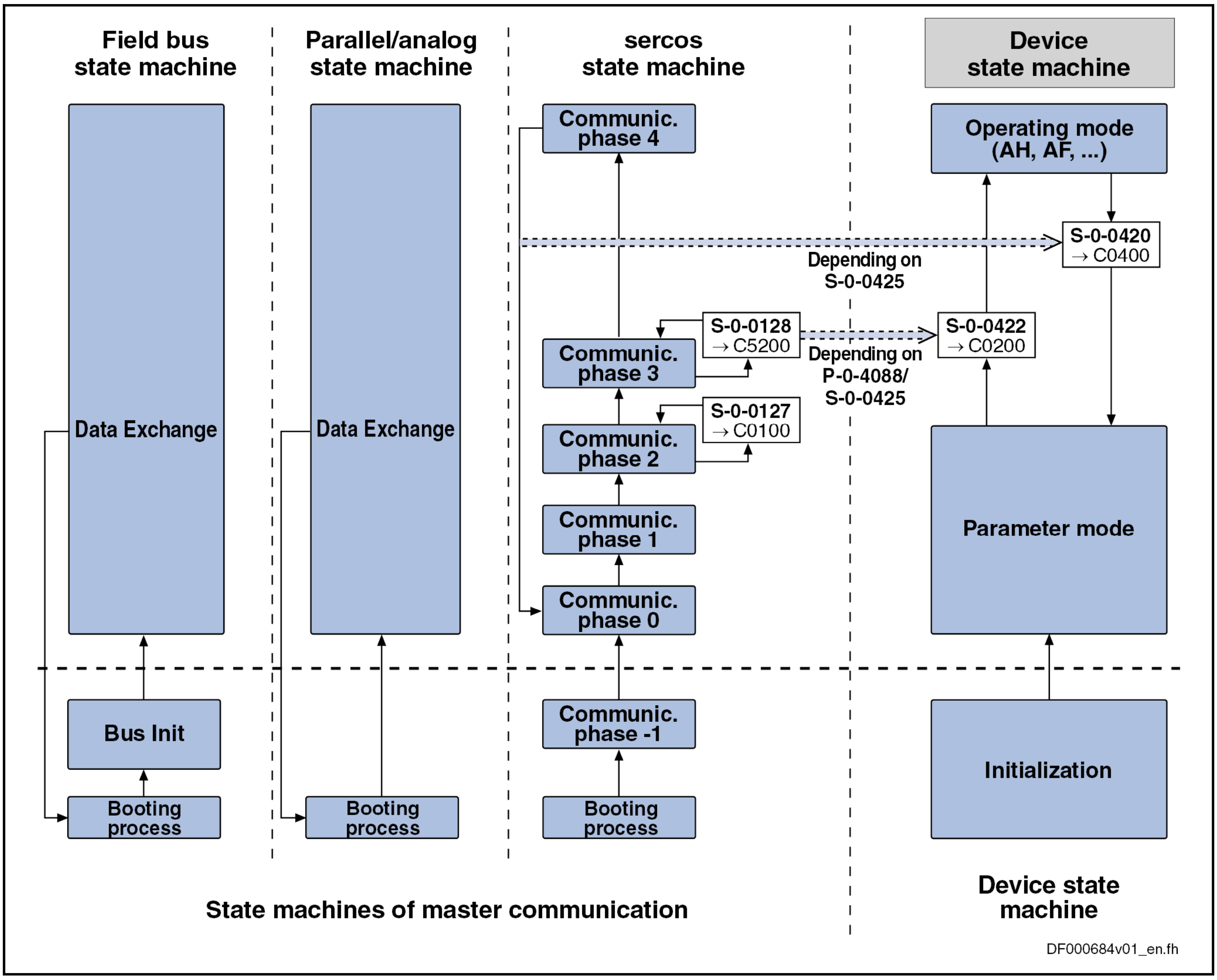
Overview

The drive state (e.g. Drive Halt, drive error) represents a specific internal and external drive behavior of the drive. It can be exited by defined events (e.g. drive commands, switching of operation modes). Corresponding state transitions are assigned to the events. The state transitions or the interaction of control and status bits are called state machine.

We distinguish between:

- Device-internal state machine (defines the device-specific states which determine the behavior of the device)
- State machine of master communication

Master Communication



S-0-0127, C0100 Communication phase 3 transition check
S-0-0128, C5200 Communication phase 4 transition check
S-0-0420, C0400 Activate parameterization level 1 procedure command
S-0-0422, C0200 Exit parameterization level procedure command
S-0-0425, C0200 Exit parameterization level procedure command
P-0-4088, Master communication: Drive configuration

Fig. 4-4: Overview: State Machines of Master Communications and Device

Device-Internal State Machine

Parameter Mode/Operating Mode

For the device-internal state machine we distinguish the following states:

- Parameter mode (PM)

  → Allows write access to all drive parameters which are not password-protected

- Operating mode (OM)

  → Only allows write access to all drive parameters which can be changed in operation and preferably can be cyclically transmitted

Switching

You can change between these two states via the following commands:

- S-0-0420, C0400 Activate parameterization level procedure command
- S-0-0422, C0200 Exit parameterization level procedure command

Observe the following aspects for switching:

- Switching is generally possible by directly executing the transition commands S-0-0420 or S-0-0422.
- For field bus devices, switching can additionally take place in the freely configurable operating mode (P-0-4084 = 0xFFFE or 0xFFFD) by presetting the desired mode via bit 1 in "P-0-4077, Field bus: Control word".
- In the case of the MultiEthernet interface, the state machine of the master communication is connected to the device-internal state machine. This means that when master communication is switched (communication phase 2 → communication phase 4 or back), the device-internal state machine is switched, too. Via the parameter "P-0-4088, Master communication: Drive configuration", this dependence can be deactivated.

Control Word and Status Word

The device-specific states are mapped to the following parameters:

- S-0-0424, Status parameterization level
- P-0-0115, Device control: Status word
- P-0-0116, Device control: Control word

Master Communication

State Machine of the Device

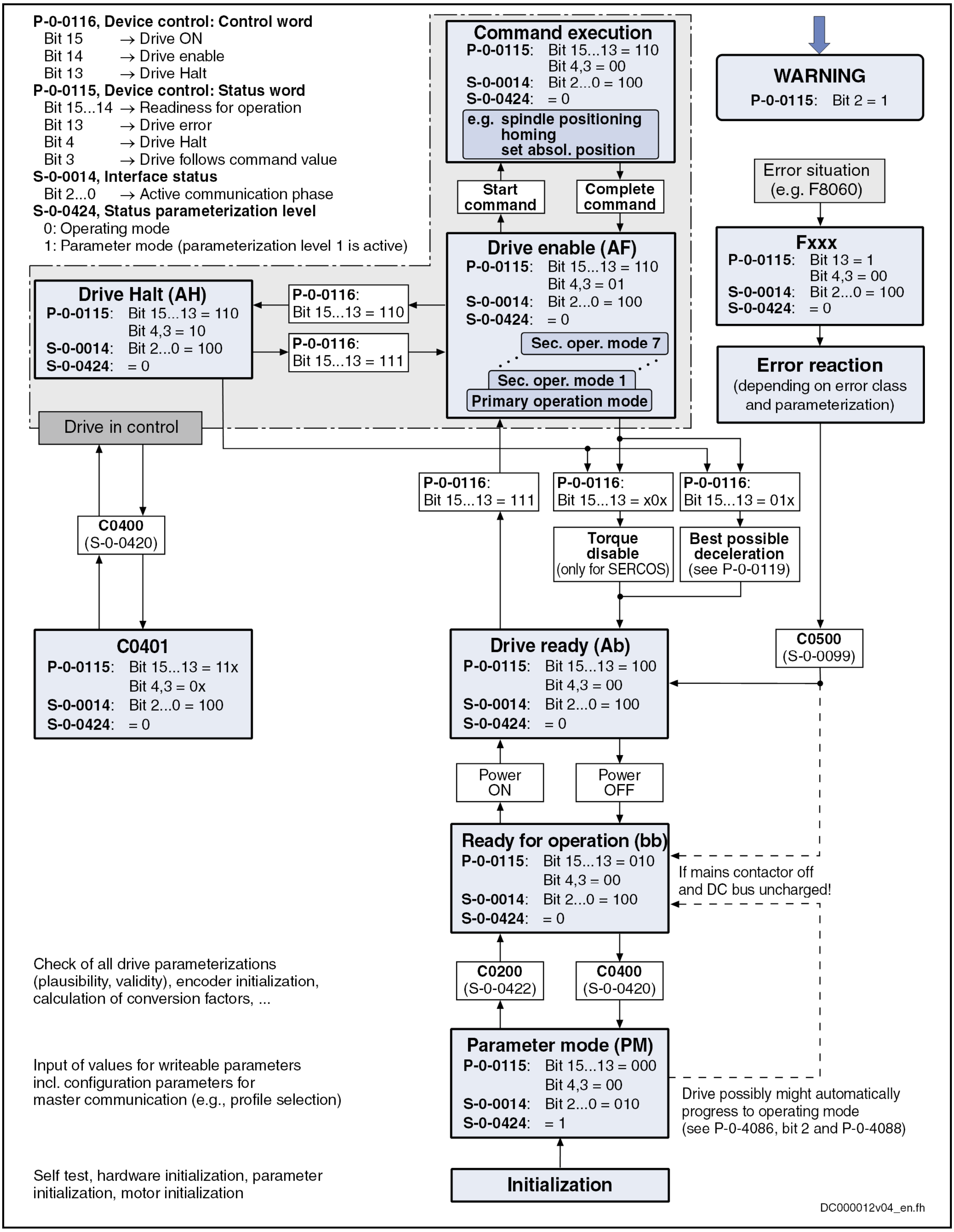


Fig. 4-5: Device Control (General State Machine)

See also "Timing diagrams for device control".

For the state machine of master communication, we distinguish 3 characteristics which differ with regard to their functionality and complexity:

- sercos state machine
- Field Bus State Machine

The following sections only describe the most important states which are described in detail in the section of the respective master communication.

sercos State Machine

For the master communication "sercos" interface, we distinguish the following states specific to this kind of communication:

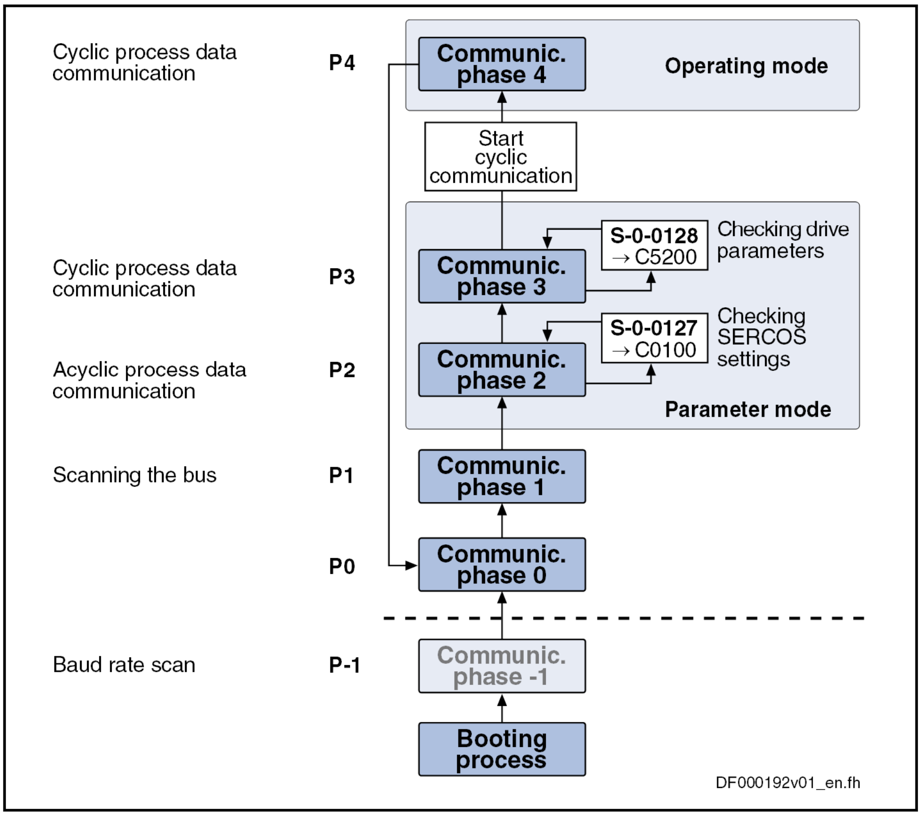


Fig. 4-6: State Machine of the Communication Phases of the Drive According to sercos specification

See also chapter "sercos" in the function description.

The currently valid communication phase is contained in parameter "S-0-0014, Interface status" (bit 0...2).

Field Bus State Machine

For the field bus master communication, we distinguish the following states specific to this type of communication:

Master Communication

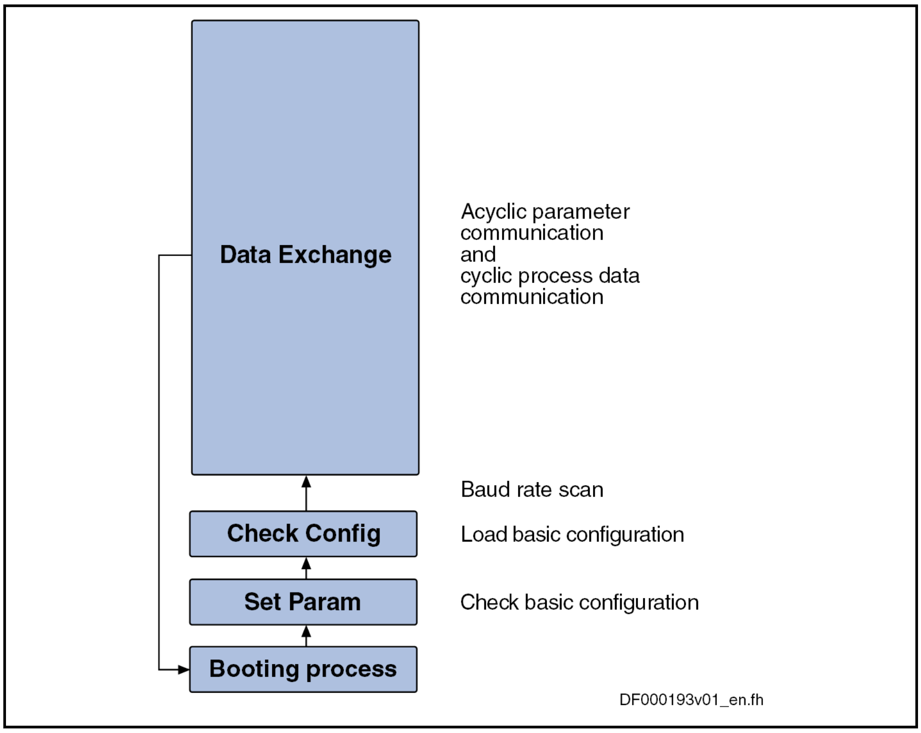


Fig. 4-7: State Machine for Field Bus Interfaces

See also sections on the respective variants of the field bus master communication.

Communication Phases of Master Communication

The supported communication phases, as well as the handling of the switching between the communication phases (e.g. parameter and operation mode), depend on the master communication that is used.

> ☞ The currently valid communication phase is contained in parameter "S-0-0014, Interface status" (bit 0...2) and for field bus drives additionally in parameter "P-0-4078, Field bus: Status word" (bit 0,1).

Communication Phases According to sercos Specification

According to **sercos specification**, the individual communication phases (states) have the following significance:

- **P-1**: In this phase, the drive can communicate via standard Ethernet mechanisms.
- **P0**: In P0, the master determines the topology (ring/line). The slaves determine their topology addresses and transmit them to the master, together with the respective sercos address that has been set. At the end of P0, the master knows the sercos addresses that are used and their positions in the topology.
- **P1**: In P1, the service channels of the connected slaves are initialized by the master.
- **P2**: In phase 2, the drive can be completely parameterized.

  The following types of parameters **can only be changed in phase 2**:

  – Communication parameters (according to sercos)

  – Configuration of axis control (sampling times)

  – All factory-specific settings (can only be changed via master password)

- **P3**: When changing from P2 → P3, only the parameters that can be changed in phase 2 (see above) are checked.

  In phase 3, the following parameters can be changed:

  – Parameters for operation mode configuration
  – Error reaction settings
  – Motor configuration parameters, holding brake parameters
  – Encoder configuration parameters
  – Mechanical transmission elements (gear, feed constant)
  – Scaling and polarity parameters, position data format, modulo value
  – Configuration of analog and digital inputs/outputs
  – Configuration of switch-on / switch-off sequence of drive enable (waiting times, …)

☞ The parameter mode is divided according to the sercos specification into phases 2 and 3. In phase 3, the limit values for all scaling-dependent parameters are not yet known. When these parameters are written in phase 3, the extreme value check is only carried out during the phase switch to phase 4.

- **P4**: In Phase 4, the so-called "operating mode", only the cyclical data can be changed, not the configuration parameters. Switching to the operating mode always causes a new initialization of all functions available in the drive.

The following aspects have to be observed for **phase switch**:

- After the controller has been switched on, it does not automatically go to the operating mode, but must be switched to this mode by the master.
- This switching of the drive controller to the operating mode is closely connected to establishing the readiness for operation.
- The procedure comprises several steps and is controlled by the master by presetting communication phases -1 to 4 and starting/completing the following commands:

  – S-0-0127, C0100 Communication phase 3 transition check
  – S-0-0128, C5200 Communication phase 4 transition check

☞ sercos devices support **all 5 communication phases** (as well as phase -1 → baud rate scan). According to sercos specification, switching takes place by the master setting the communication phase.

Communication Phases for Field Bus Interface

For devices with **field bus interface**, there only is the "Data Exchange" state, apart from the basic initialization. In the "Data Exchange" state, we distinguish the following device states:

- Parameter mode
- Operating mode

Communication Phases for Analog Interface

Basically, the same communication phases as for devices with field bus interface apply to devices with **analog interface**.

Switching always takes place when the transition check commands are executed.

☞ After the drive controller has been switched on, it automatically changes to the operating mode!

Control Words and Status Words of Master Communication

The control word and status word of the respective master communication are an essential part of the communication between the master communication master and the drive.

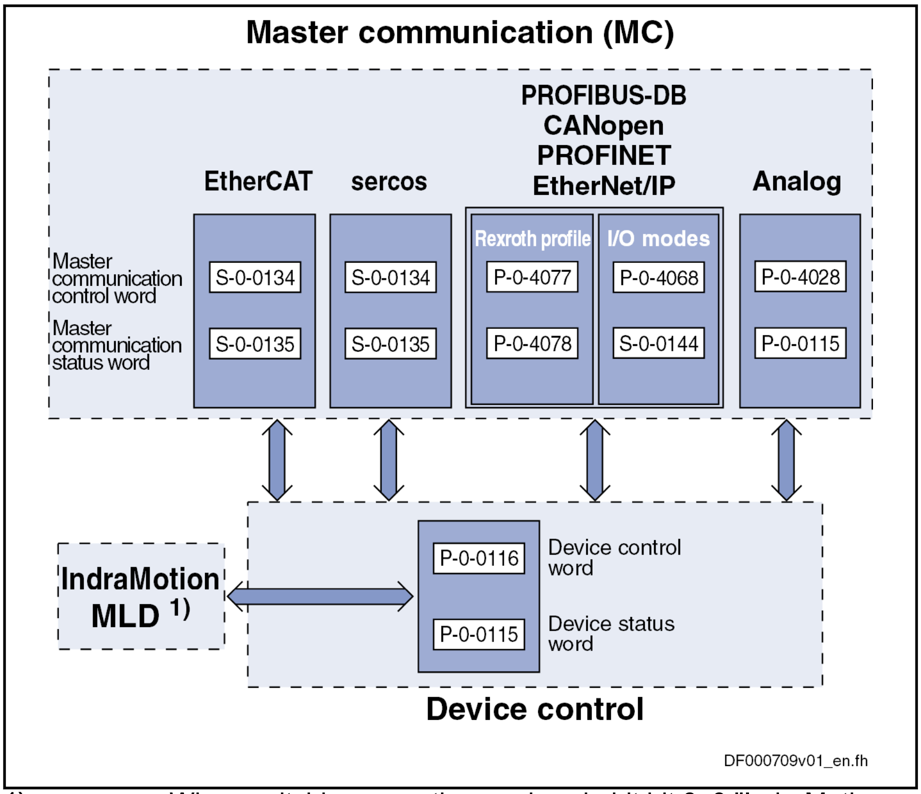
Depending on the master communication, different parameters are used:

- EtherCAT®
  - S-0-0134, Master control word
  - S-0-0135, Drive status word
- Field bus interface (e.g. PROFIBUS®, PROFINET®, EtherNet/IP™)
  - P-0-4077, Field bus: Control word
    - or -
    P-0-4068, Field bus: Control word IO
  - P-0-4078, Field bus: Status word
    - or -
    S-0-0144, Signal status word
- Analog interface (analog mode)
  - P-0-4028, Device control word
  - P-0-0115, Device control: Status word

The following device-specific parameters are used drive-internally:

- P-0-0115, Device control: Status word
- P-0-0116, Device control: Control word

The figure below illustrates the interaction of the above control and status words:



1) When switching operation modes via bit bit 8, 9 "IndraMotion MLD" has the highest priority. An AND-link is effective with bits 13...15 in P-0-0116 between the external bits in the master communication control word and the internal control bits 13...15 of "IndraMotion MLD".

Fig. 4-8: Interaction of the Available Control and Status Words

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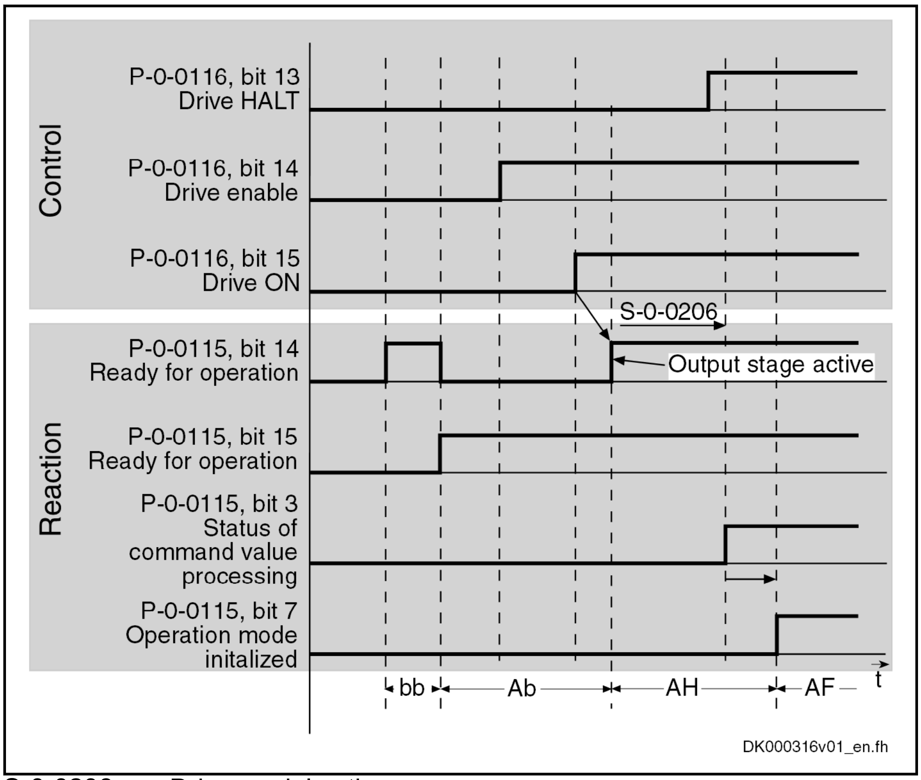
It is impossible to write data to the field bus control word via acyclic services. To allow axis control, the cyclic data channel must be used in the higher-level control unit or the corresponding logic must be programmed with permanent control in MLD. If the control unit does not have a cyclic data channel, axis control cannot take place without MLD.

See also separate documentation "IndraMotion MLD".

Timing Diagrams for Device Control

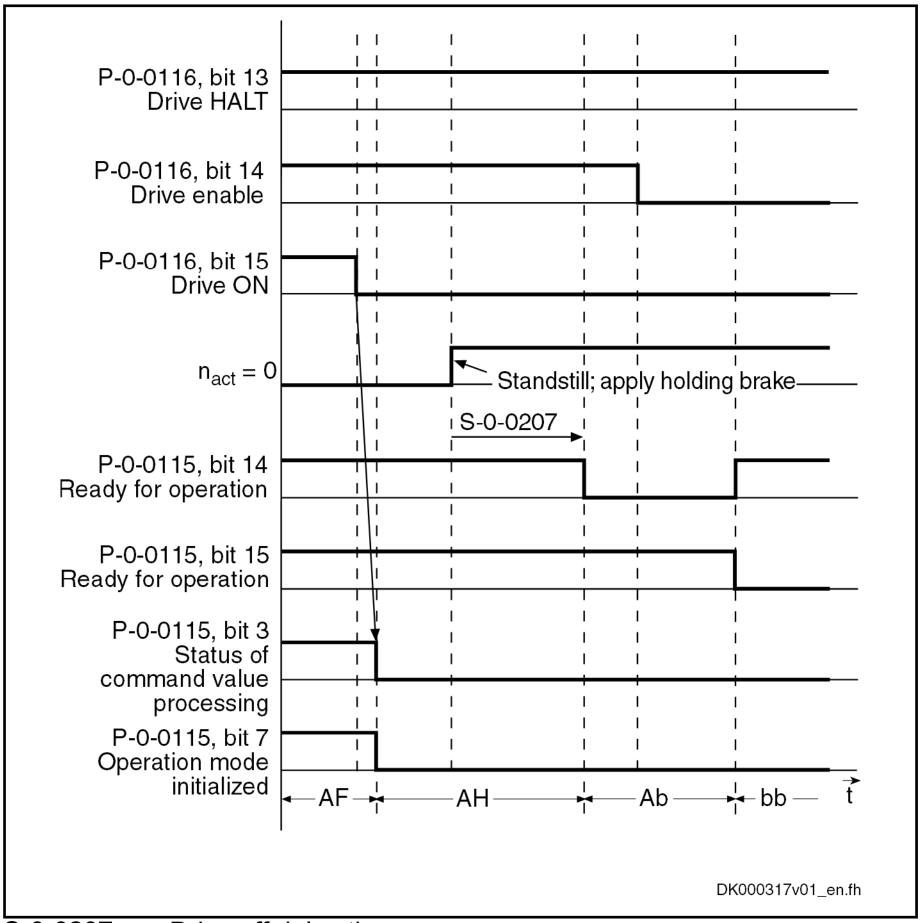
Bit Sequence During Switch-On Process



S-0-0206 Drive on delay time

Fig. 4-9: Bit Sequence During Switch-On Process

Bit Sequence During Switch-Off Process

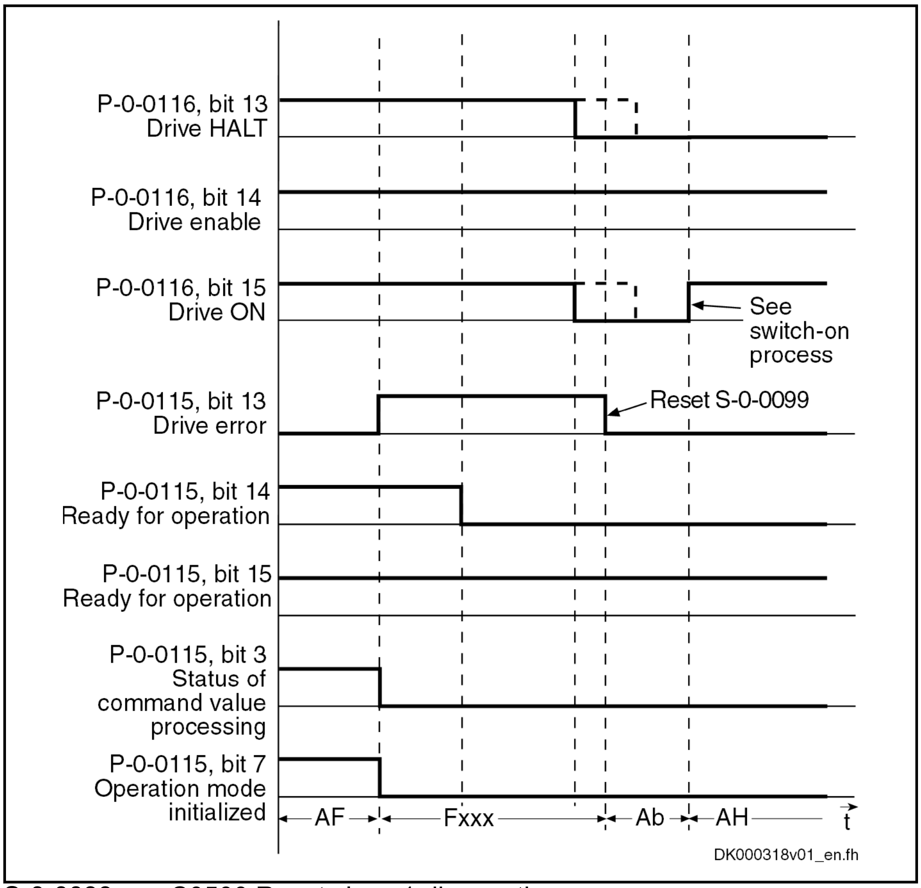


S-0-0207 Drive off delay time

Fig. 4-10: Bit Sequence During Switch-Off Process

Master Communication

Bit Sequence During Error Reaction



S-0-0099 C0500 Reset class 1 diagnostics

Fig. 4-11: Bit Sequence During Error Reaction

Bit Sequence During Change of Operation Modes

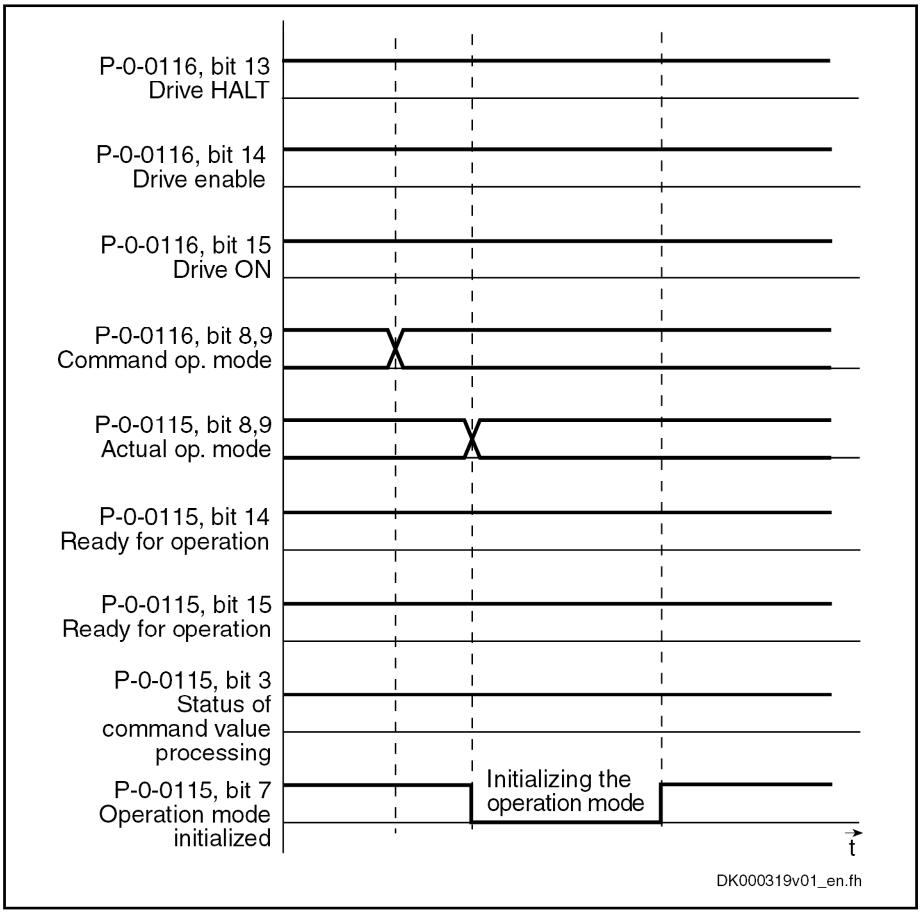


Fig. 4-12: Bit Sequence During Change of Operation Modes

Commands and Diagnostic Messages for Mode Change and Phase Switch

Distinguishing the Commands

According to the desired action, the commands are related to the following groups:

- Commands for changing between parameter mode and operating mode:
  – S-0-0420, C0400 Activate parameterization level procedure command
  – S-0-0422, C0200 Exit parameterization level procedure command
- Commands for transition check to communication phases 3 and 4 (only with sercos):
  – S-0-0127, C0100 Communication phase 3 transition check
  – S-0-0128, C5200 Communication phase 4 transition check

☞ With sercos, the command C0200 (S-0-0128) is automatically called during the execution of command C5200 (S-0-0422). This is why the diagnostic command message C02xx can be displayed after the command C5200 has been started.

Communication Phase 3 Transition Check

By executing the command "S-0-0127, C0100 Communication phase 3 transition check", a number of checks and parameter conversions are carried out that can possibly cause the listed diagnostic command messages:

- Checking validity of parameters required for switching to phase 3

If one of these parameters has never been written or the backup was carried out incorrectly, the error message "C0101 Invalid parameters (-> S-0-0021)" is generated. The ID numbers of the faulty parameters are listed in the parameter "S-0-0021, IDN-list of invalid operation data for CP2". These parameters must be set valid by writing correct values to them.

- Checking device configuration
- Checking telegram configuration, especially in the case of configured telegrams

  In this case a check is run to find out whether the parameters selected for the configurable data block in the cyclic command value channel (MDT) or actual value channel (AT) may be configured and whether the allowed length of the configurable data blocks is complied with.
- If necessary, checking timing parameters for sercos communication in phases 3 and 4 for validity and compliance with requirements
- Limit value check of communication parameters and system

Communication Phase 4 Transition Check or Command "Exit Parameterization Level Procedure"

With the command "S-0-0128, C5200 Communication phase 4 transition check" or "S-0-0422, C0200 Exit parameterization level procedure command", the following checks and initializations are carried out that can possibly cause the listed command errors:

- Checking whether functional package selection was changed
  - C0299 Configuration changed. Restart

    → Drive must be rebooted before it is possible to switch to the operating mode (OM)
- Checking validity of parameters required for subsequent initializations
  - C0201 Invalid parameters (->S-0-0423)
  - C0212 Invalid control section data (->S-0-0423)
- Checking device configuration
  - C0223 Invalid settings for controller cycle times
- If necessary, checking parameters for field bus communication for validity and compliance with requirements
  - C0229 Field bus: IDN for cycl. command val. not configurable
  - C0230 Field bus: Max. length for cycl. command val. exceeded
  - C0231 Field bus: IDN for cycl. actual val. not configurable
  - C0232 Field bus: Length for cycl. actual values exceeded
  - C0233 Field bus: Tcyc (P-0-4076) incorrect
  - C0234 Field bus: P-0-4077 missing for cycl. command values
- Checking configuration of multiplex channel
  - C0238 Order of cyclic command value configuration incorrect
  - C0239 IDN for command value data container not allowed
  - C0240 IDN for actual value data container not allowed
- Checking motor and encoder configuration
  - C0210 Feedback 2 required (->S-0-0423)
  - C0219 Max. travel range too large
  - C0270 Error when reading encoder data => motor encoder
  - C0271 Incorrect parameterization of motor encoder (hardware)

- C0272 Incorr. parameteriz. of motor enc. (mechanical system)
- C0273 Modulo value for motor encoder cannot be displayed
- C0274 Motor encoder unknown
- C0275 Error when reading encoder data => optional encoder
- C0276 Incorrect parameterization of optional enc. (hardware)
- C0277 Incorr. parameteriz. of opt. enc. (mechanical system)
- C0278 Modulo value for optional encoder cannot be displayed
- C0279 Optional encoder unknown
- C0280 Maximum travel range cannot be displayed internally
- C0284 Invalid motor data in encoder memory (->S-0-0423)
- C0285 Type of construction of motor P-0-4014 incorrect
- C0286 Several motor encoders connected
- C0287 Error during initialization of motor data (->S-0-0423)
- C0288 Rotary scaling not allowed
- C0289 Error at init. of synchr. motor with reluctance torque
- C0290 Error when reading encoder data => measuring encoder
- C0291 Incorr. parameterization of measuring enc. (hardware)
- C0292 Measuring encoder unknown
- C0293 Modulo value for measuring encoder cannot be displayed
- C0294 Incorrect measuring encoder configuration

- Checking modulo range
  - C0244 Act. modulo value cycle greater than max. travel range
- Checks during encoder initialization
  - C0220 Error when initializing position of encoder 1
  - C0221 Initialization velocity encoder 1 too high
  - C0224 Error when initializing position of encoder 2
  - C0225 Initialization velocity encoder 2 too high
  - C0227 Error when initializing position of measuring encoder
  - C0228 Initialization velocity measuring encoder too high
- Initializing optional additional functions (digital I/Os)
  - C0243 Brake check function not possible
  - C0250 Probe inputs incorrectly configured
- Initializing integrated safety technology
  - C0256 Safety technology configuration error
- Limit value check
  - C0202 Parameter limit error (->S-0-0423)
  - C0203 Parameter conversion error (->S-0-0423)
- General system checks
  - C0245 Operation mode configuration (->S-0-0423) not allowed
- Initializing fine interpolator
  - C0258 Error in relation TNcyc (S-0-0001) to fine interpol.
- Checking interface configuration

  - C0242 Multiple configuration of a parameter (->S-0-0423)
- Checking master communication
  - C0251 Error during synchronization to master communication
- Checking whether boot error is present or firmware download has been carried out
  - C0298 Impossible to exit parameterization level

Checking whether it was possible to switch CCD group without error:

C0265 Incorrect CCD address configuration

C0266 Incorrect CCD phase switch

C0267 CCD timeout phase switch

"Error-Free" Message

When the drive has reached communication phase 4 without error, the display reads "bb". The corresponding diagnostic message is:

- A0013 Ready for power on

4.3 Control Options / Additional Functions

4.3.1 Configurable Signal Control Word

Brief Description

The signal control word allows writing individual control bits, that are available in different parameters, by a freely configurable collective parameter. The configurable signal control word is used to accept a maximum of 16 copies of bits from other drive parameters.

Examples of Use

This functionality can be used, for example,

- for setting bits in drive parameters and for starting commands via the cyclic channel (master communication)
- for defining an application-specific combination of 16-bit wide control and status words which can then be transmitted in the cyclic data channel.

☞ For sercos and field bus interfaces the parameter "S-0-0145, Signal control word" must be accordingly configured in the cyclic data so that the configured control bits are evaluated.

Pertinent Parameters

- S-0-0027, Configuration list for signal control word
- S-0-0145, Signal control word
- S-0-0329, Assign list signal control word
- S-0-0399, IDN-list of configurable data in signal control word

Notes on Commissioning for the Signal Control Word

Selection List

Only parameters contained in "S-0-0399, IDN-list of configurable data in signal control word" can be assigned to parameter "S-0-0027, Configuration list for signal control word".

Configuring the IDNs

In parameter "S-0-0027, Configuration list for signal control word", the IDNs of those parameters are indicated that are to be configured by means of the signal control word (= targets).

The position of an IDN in this list defines which bit is assigned to which IDN (targets) in the signal control word. For example, the 1st list element determines the parameter to which bit 0 of the signal control word is assigned.

Configuring the Bit Numbers

Which bit of the selected parameters (= targets in parameter S-0-0027) is set (or cleared) by the signal control word, has to be defined in parameter "S-0-0329, Assign list signal control word".

☞ Only so many entries from S-0-0027 are processed as there are entries in S-0-0329. You must make sure that the lists in S-0-0027 and S-0-0329 have the same length.

Bit numbers from "0" (LSB) to "31" (MSB) can be entered.

☞ A maximum of 16 bits can be configured. Configuration must always be carried out from the least significant to the most significant bit; in other words, the position of the bit copy in the signal control word results from the continuous configuration in parameter "S-0-0027, Configuration list for signal control word".

Exceptions

- If the assigned parameter is a command, the bit number in parameter "S-0-0329, Assign list signal control word" is irrelevant.

☞ When cross communication is used in the "CCD system mode", the parameter "S-0-0145, Signal control word" is used to map the control bits which are not contained in parameter "S-0-0134, Master control word". That is why this parameter, in the CCD system mode, has already been configured by default in the cyclic master data telegram (MDT → S-0-0024)! In addition, other bits have been permanently configured so that in this case the user can only define the bits 12 to 15!

Diagnostic Messages and Error Messages

When entering data in the parameters "S-0-0027, Configuration list for signal control word" and "S-0-0329, Assign list signal control word", the following checks are run:

- If an IDN specified in parameter S-0-0027 is not contained in parameter "S-0-0399, IDN-list of configurable data in signal control word", the error message "0x7008 Invalid data" is generated.

☞ In this case, only those inputs up to the faulty element are accepted!

4.3.2 Configurable Signal Status Word

Brief Description

The configurable signal status word is used to accept a maximum of 16 copies of bits from other drive parameters. The user can thereby freely configure a bit list with status bits. This allows defining a bit list which contains all the important pieces of status information of the drive for the control unit.

Pertinent Parameters

- S-0-0026, Configuration list for signal status word
- S-0-0144, Signal status word
- S-0-0328, Assign list signal status word
- S-0-0398, IDN-list of configurable data in signal status word

Notes on Commissioning for the Signal Status Word

Configuring the IDNs

In parameter "S-0-0026, Configuration list for signal status word", the IDNs of those parameters are indicated that contain the original bits (sources). The parameters that can be entered into the configuration list are contained in parameter "S-0-0398, IDN-list of configurable data in signal status word". The position of an IDN in the list determines the bit in the signal status word to which the IDN applies. For example, the 1st list element determines from which parameter bit 0 of the signal status word is taken.

Configuring the Bit Numbers

Which bit of the parameters selected in "S-0-0026, Configuration list for signal status word" is copied to the signal status word has to be determined in "S-0-0328, Assign list signal status word".

☞ Only so many entries from S-0-0026 are processed as there are entries in S-0-0328. You must make sure that the lists in S-0-0026 and S-0-0328 have the same length.

Bit numbers from "0" (LSB) to "31" (MSB) can be entered.

The signal status word can have the following configuration, for example:

Bit no. in signal status word (S-0-0144)	IDN of original parameter in S-0-0026	Bit no. of original parameter in S-0-0328	Significance
0	S-0-0403	0	Position status

Tab. 4-2: Example of Configuration of the Signal Status Word

☞ A maximum of 16 bits can be configured. Configuration must always be carried out from the least significant to the most significant bit; in other words, the position of the bit copy in the signal status word results from the continuous configuration in parameter "S-0-0026, Configuration list for signal status word".

☞ When cross communication is used in the "CCD system mode", the parameter "S-0-0144, Signal status word" is used to map the status bits which are not contained in parameter "S-0-0135, Drive status word". That is why this parameter, in the CCD system mode, has already been configured by default in the cyclic drive telegram (AT → S-0-0016)! In addition, other bits have been permanently configured so that in this case the user can only define the bits 12 to 15!

Diagnostic Messages and Error Messages

When entering data in the parameters "S-0-0328, Assign list signal status word" and "S-0-0026, Configuration list for signal status word", the following checks are run:

- Check whether the IDN specified in S-0-0026 has variable data length (list parameter) or a so-called online read function. If yes, the service channel error message "0x7008 Invalid data" is generated.

  Parameters with online read functions generally are parameters with physical units (position, velocities, accelerations and currents), as well as the parameters "S-0-0135, Drive status word" and "S-0-0011, Class 1 diagnostics".

In this case, only those inputs up to the faulty element are accepted!

4.3.3 Multiplex Channel

Brief Description

The multiplex channel is an expansion of the cyclic data channel. By means of index assignment and switching, cyclic access to list elements is possible for the multiplex channel, too.

The "multiplex channel" mechanism cannot be used with the analog interface.

Features

- 8 multiplex containers with 4 bytes each are available for cyclic command value data (MDT) and cyclic actual value data (AT)
- Multiplex data to be transmitted is addressed via parameter "S-0-0368, Data container A: Addressing" (L-byte for MDT; H-byte for AT)
- Individual elements from list parameters can be addressed via parameters S-0-0362 and S-0-0366
- Multiplex data are transmitted in communication cycle

Possible Applications

By means of the multiplex channel it is possible:

- To increase the number of transmittable bytes in the cyclic real-time channel (command and actual values) by multiplexing data
- To transmit the multiplex data in every cycle with a cycle time of "T_{scyc} x quantity of multiplex data" by incrementing the addressing index (S-0-0368)
- To achieve operation mode dependent configuration of the cyclic data by index switching in case the operation mode is changed

When IndraMotion MLC and IndraDrive MLD-M are used, the multiplex channel is used for communication between MLC and MLD-M and drive and can therefore no longer be used freely.

Pertinent Parameters

Parameters for command value channel:

- S-0-0362, Data container A: List index command values
- S-0-0368, Data container A: Addressing
- S-0-0360, Data container A: Command value 1
- S-0-0450, Data container A: Command value 2

  - to -

  S-0-0456, Data container A: Command value 8

Parameters for actual value channel:

- S-0-0366, Data container A: List index feedback values
- S-0-0364, Data container A: Feedback value 1
- S-0-0480, Data container A: Feedback value 2

  - to -

  S-0-0486, Data container A: Feedback value 8

Configuration lists of the command value data containers:

- S-0-0370, Data container A: Configuration list command value-1

- S-0-0490, Data container A: Configuration list command value 2
  - to -
  S-0-0496, Data container A: Configuration list command value 8

Configuration lists of the actual value data containers:

- S-0-0371, Data container A: Configuration list feedback value-1
- S-0-0500, Data container A: Configuration list feedback value 2
  - to -
  S-0-0506, Data container A: Configuration list feedback value 8

Pertinent Diagnostic Messages

- C0151 IDN for command value data container not allowed
- C0152 IDN for actual value data container not allowed
- C0238 Order of cyclic command value configuration incorrect
- E4008 Invalid addressing command value data container A
- E4009 Invalid addressing actual value data container A

Functional Description

General Information

Possible Multiplex Data

In the multiplex channel it is possible to configure all parameters that can be transmitted in the cyclic real-time channel. The possible multiplex data are contained in the list parameters for the command value and actual value channel:

- S-0-0187, List of configurable data in the AT
- S-0-0188, List of configurable data in the MDT

Data Containers

For data exchange between master and drive there is a total of 8 data containers available. For each container the following distinction is made according to its content or direction of data transfer:

- Master → drive: Data Container A: Command Value-x
- Drive → master: Data Container A: Feedback Value-x

☞ "x" represents a command/feedback value from 1 to 8.

Configuration Lists

The 8 multiplex channels are configured via 2 configuration lists (command value and actual value) per channel:

- In the "configuration list command value-x" lists (S-0-0370, …), the IDNs of those parameters are entered, the data of which are to be transmitted, depending on the setting in parameter "S-0-0368, Data container A: Addressing" (L-byte), to the "Data container A: Command value-x" (S-0-0360, …).
- In the "configuration list feedback value-x" lists (S-0-0371, …), the IDNs of those parameters are entered, the data of which are to be transmitted, depending on the setting in parameter "S-0-0368, Data container A: Addressing" (H-byte), to the "Data container A: Feedback value-x" (S-0-0364, …).

☞ It is possible to define a maximum of 32 parameter IDNs in the configuration lists; but these lists can only be changed in communication phase 2 (parameter mode).

Addressing the Data Containers

Addressing the Parameters to be Transmitted

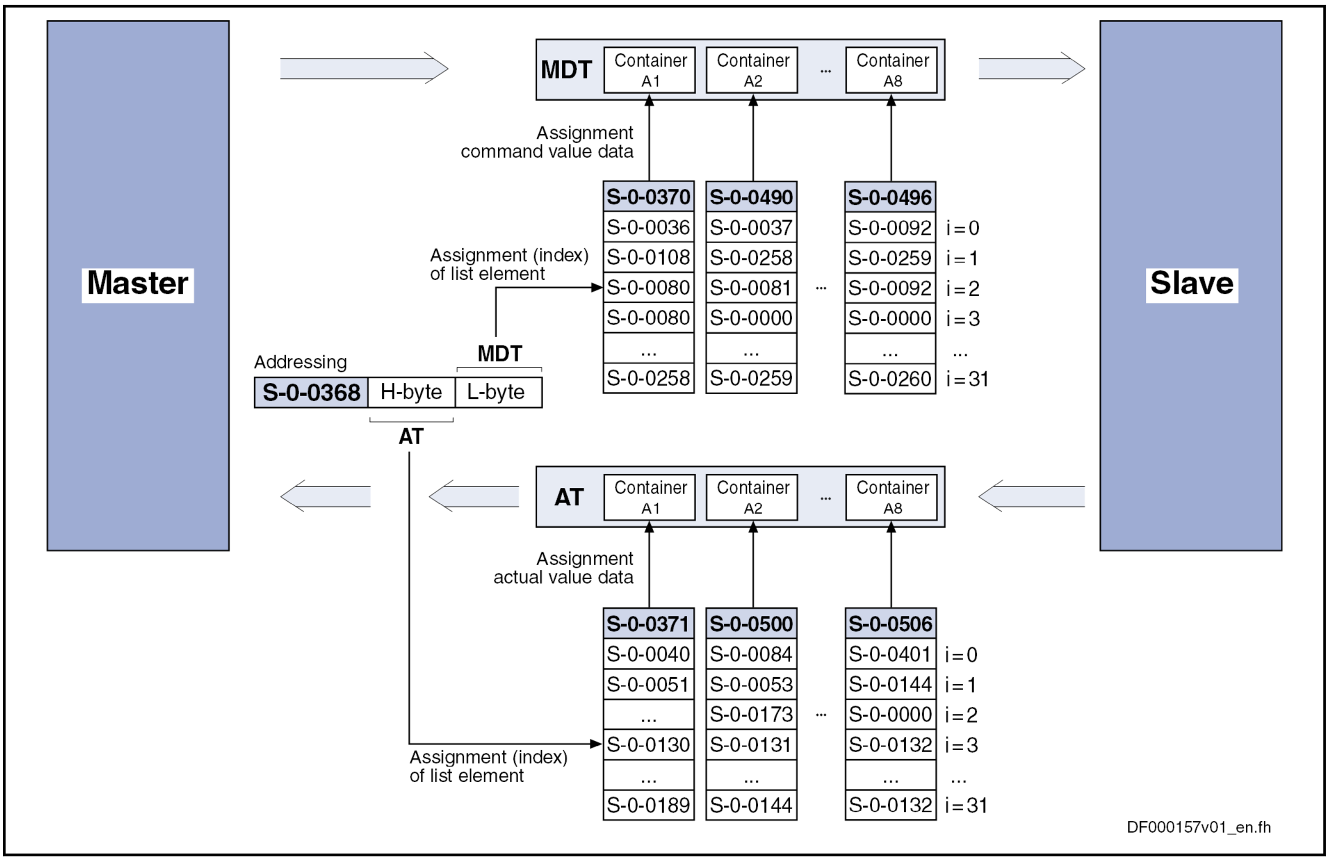
The parameter "S-0-0368, Data container A: Addressing" contains the indices for selecting the parameters from the configuration lists the values of which are to be transmitted to the data containers (command values and feedback values).

The following assignment applies to S-0-0368:

- Bit 0…4 → Addressing for all data containers configured in the cyclic command value telegram (MDT)
- Bit 8…12 → Addressing for all data containers configured in the cyclic actual value telegram (AT)

> ☞ Only the bits 0…4 (for MDT) and the bits 8…12 (for AT) are used for addressing via the parameter S-0-0368. The other bits are ignored. This is why no value greater than 31 can be set for addressing!

The figure below illustrates the relationship between addressing and assignment of parameter values to the data containers of the multiplex channel.



i	Index (= list element no.)
S-0-0368	Data Container A: Addressing
S-0-0370	Data Container A: configuration list command value -1
S-0-0490	Data Container A: configuration list command value 2
S-0-0496	Data Container A: configuration list command value 8
S-0-0371	Data Container A: Feedback value 1 configuration list
S-0-0500	Data Container A: Configuration list feedback value2
S-0-0506	Data Container A: Configuration list feedback value8

Fig. 4-13: Addressing and Assignment for Multiplex Channel

☞ The parameter "S-0-0368, Data container A: Addressing" can, depending on the requirements, be configured in the cyclic command value telegram or write accessed via the non-cyclical data channel or some other interface.

Assigning Single List Elements

The value (data) transmitted in the data container is written to the determined target parameter; in this case we distinguish between single and list parameters.

In order to allow cyclic transmission or change of single elements in the case of list parameters, there are two more addressing parameters available:

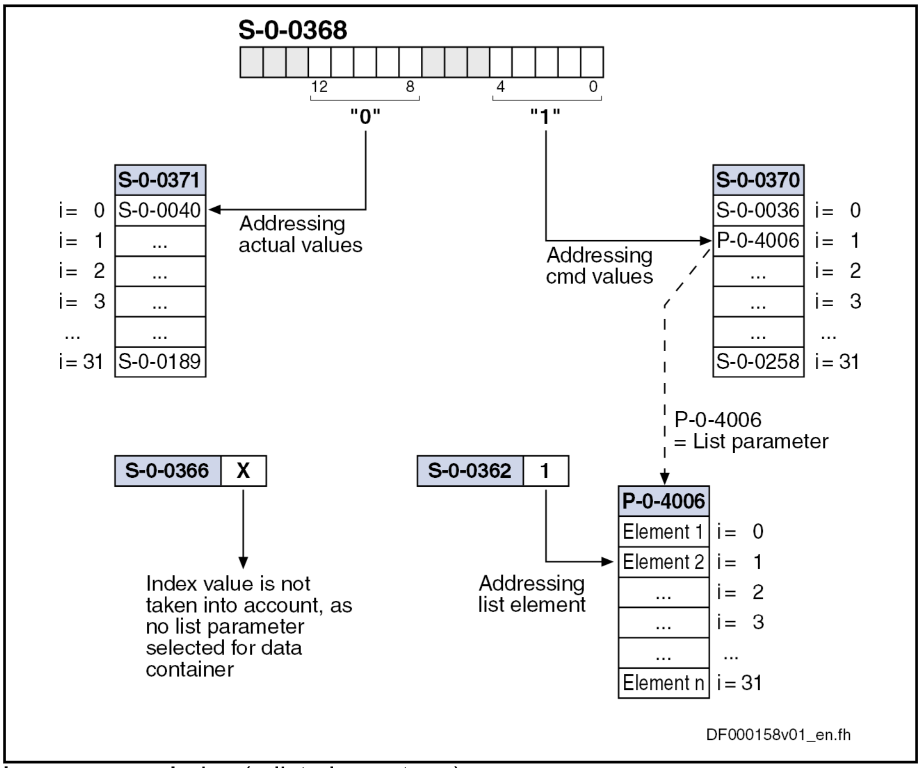
- S-0-0362, Data container A: List index command values

  → Addressing elements of list parameters that have been entered as target for the content of command value data containers (for **write access**)
- S-0-0366, Data container A: List index feedback values

  → Addressing elements of list parameters that have been entered as source for the content of actual value data containers (for **read access**)

☞ The parameters S-0-0362 and S-0-0366 only take effect when a list parameter is addressed as target/source for the content of the data container.

The figure below illustrates the access to an element of a list parameter for the multiplex channel.



i	Index (= list element no.)
S-0-0368	Data Container A: Addressing
S-0-0362	Data Container A: List index command values
S-0-0366	Data Container A: List index feedback values
S-0-0370	Data Container A: configuration list command value -1
S-0-0371	Data Container A: Feedback value 1 configuration list
P-0-4006	Positioning block target position

Fig. 4-14: Access to Elements of a List Parameter via Multiplex Channel (Example of Command Values → MDT Data Container)

Notes on Commissioning

Activation

To use the function of the multiplex channel, it is not necessary to take any measures for activation.

Data Container A: Command Value-x

For determining the target parameter to which the content (data) of "Data container A: Command value-x" (S-0-0360, …) is to be written, we distinguish between single and list parameters:

- Single parameters

  → The target parameter is determined by means of addressing (S-0-0368) in the respective configuration list (S-0-0370, S-0-0490 to S-0-0496).

- List Parameters

  → The element of the target parameter is determined by means of addressing (S-0-0368) in the respective configuration list (S-0-0370, S-0-0490 to S-0-0496) and the parameter "S-0-0362, Data container A: List index command values".

☞ The display format is hexadecimal without decimal places.

If the configuration list contains 16-bit parameters, only the lower 16 bits from the data container are used when a 16-bit parameter is addressed.

Data Container A: Feedback Value-x

For determining the source parameter the content (data) of which is to be copied to the "Data container A: Feedback value-x" (S-0-0364, …), we also distinguish between single and list parameters:

- **Single parameters**

  → The source parameter is determined by means of addressing (S-0-0368) in the respective configuration list (S-0-0371, S-0-0500 to S-0-0506).

- **List Parameters**

  → The element of the source parameter is determined by means of addressing (S-0-0368) in the respective configuration list (S-0-0371, S-0-0500 to S-0-0506) and the parameter "S-0-0366, Data container A: List index feedback values".

☞ The display format is hexadecimal without decimal places.

If the configuration list contains 16-bit parameters, only the lower 16 bits are copied to the data container when a 16-bit parameter is addressed (the H-byte does not contain any useful data).

Diagnostic and Status Messages

In conjunction with the multiplex channel, various checks are carried out.

Checking the Configured IDN Order

The chronology of the processing of cyclic command value data in the drive has the order in which the parameter IDNs of the configured list have been entered in parameter "S-0-0024, Configuration list of MDT".

If the parameters "data container A, command value-x" (S-0-0360, S-0-0450 to S-0-0456) and the parameter "S-0-0368, Data container A: Addressing" were configured in the cyclic command value telegram, the MDT data container is only processed correctly when the addressing had been processed before.

To make sure the correct order is followed when configuring the cyclic command values, the drive during the execution of "S-0-0127, C0100 Communication phase 3 transition check" checks whether IDN S-0-0368 was configured before the IDNs S-0-0360 or S-0-0450 to S-0-0456. If this was not the case, the drive generates the error message "C0118 Order of cyclic command value configuration incorrect".

Checking the Configuration Lists

You have to make sure that the IDNs contained in the configuration lists exist and the corresponding parameters can be cyclically configured.

Therefore, a check is run by executing "S-0-0127, C0100 Communication phase 3 transition check" to find out whether the entered IDNs are contained in the lists "S-0-0187, List of configurable data in the AT" or "S-0-0188, List of configurable data in the MDT".

There are the following possible error messages:

- If a **command value configuration list** contains one or several IDNs that do not exist or are not contained in "S-0-0188, List of configurable data in the MDT", the following error message is generated:
  - C0151 IDN for command value data container not allowed
- If an **actual value configuration list** contains one or several IDNs that do not exist or are not contained in "S-0-0187, List of configurable data in the AT", the following error message is generated:
  - C0152 IDN for actual value data container not allowed

Checking the Index

During the runtime, the drive monitors whether the index in parameter "S-0-0368, Data container A: Addressing" points to a non-initialized point in the MDT data containers or AT data containers.

According to the case that occurred, one of the following warning messages is generated:

- E4008 Invalid addressing command value data container A
- E4009 Invalid addressing actual value data container A

> These warning messages can only occur if less IDNs than possible at maximum are entered in the configuration lists.

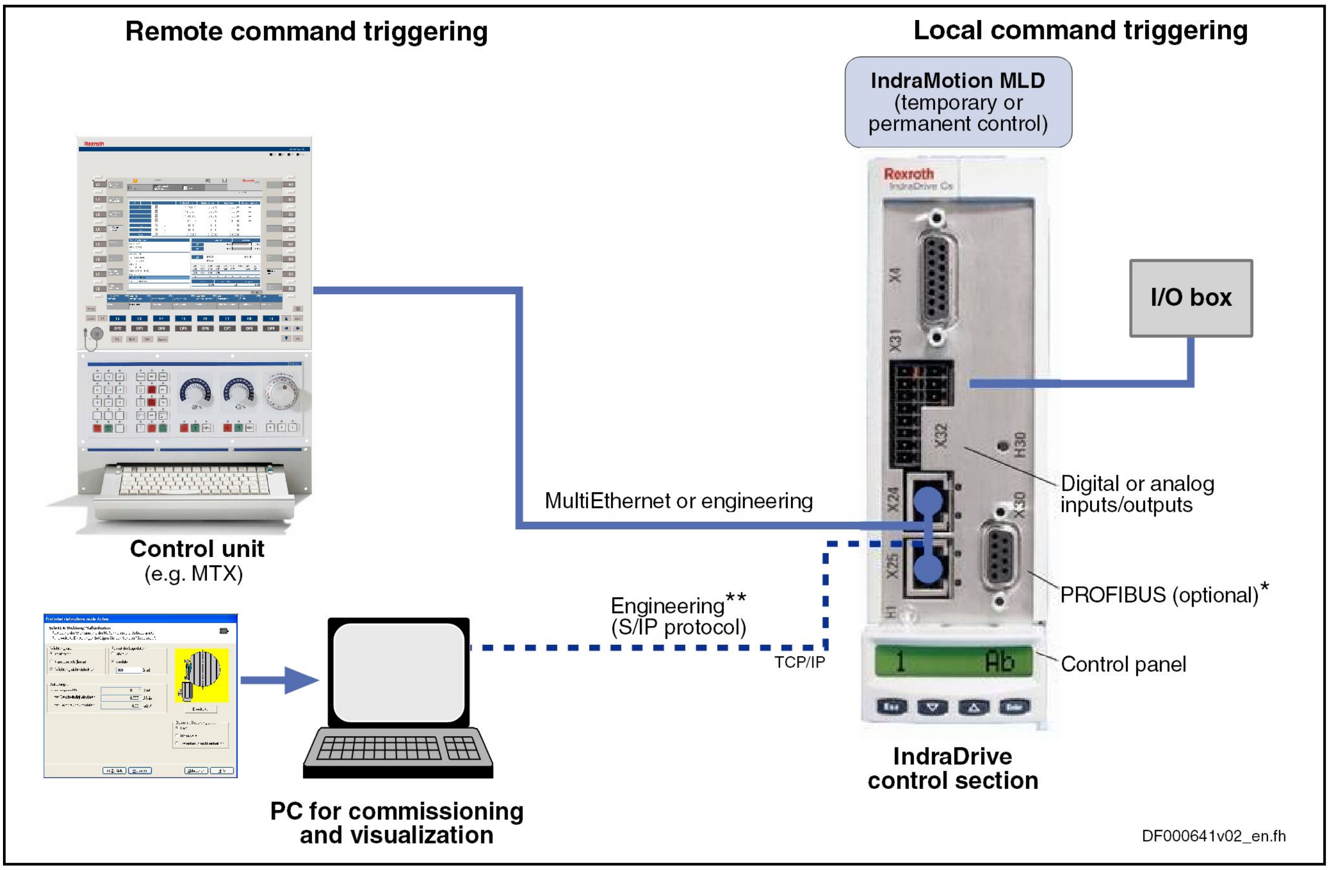
4.4 Operating Modes of Master Communication

4.4.1 Introduction and Overview

Overview of Operating Modes and Possibilities of Command Triggering

Command triggering for the drive can take place by an external control master (remote mode) or internally via IndraMotion MLD or the inputs/outputs which are available (local mode).

The figure below contains an overview of the possibilities of drive command triggering.



*	MultiEthernet is not available for PROFIBUS, interfaces can be used for engineering
**	Only as of MPx17 and not possible for EtherCAT

Fig. 4-15: Overview of Possibilities of Command Triggering for an IndraDrive Device

Operating Modes and Changes of States

The overview below shows the basically possible operating states and the actions required for change/transition from one operating mode to the other.

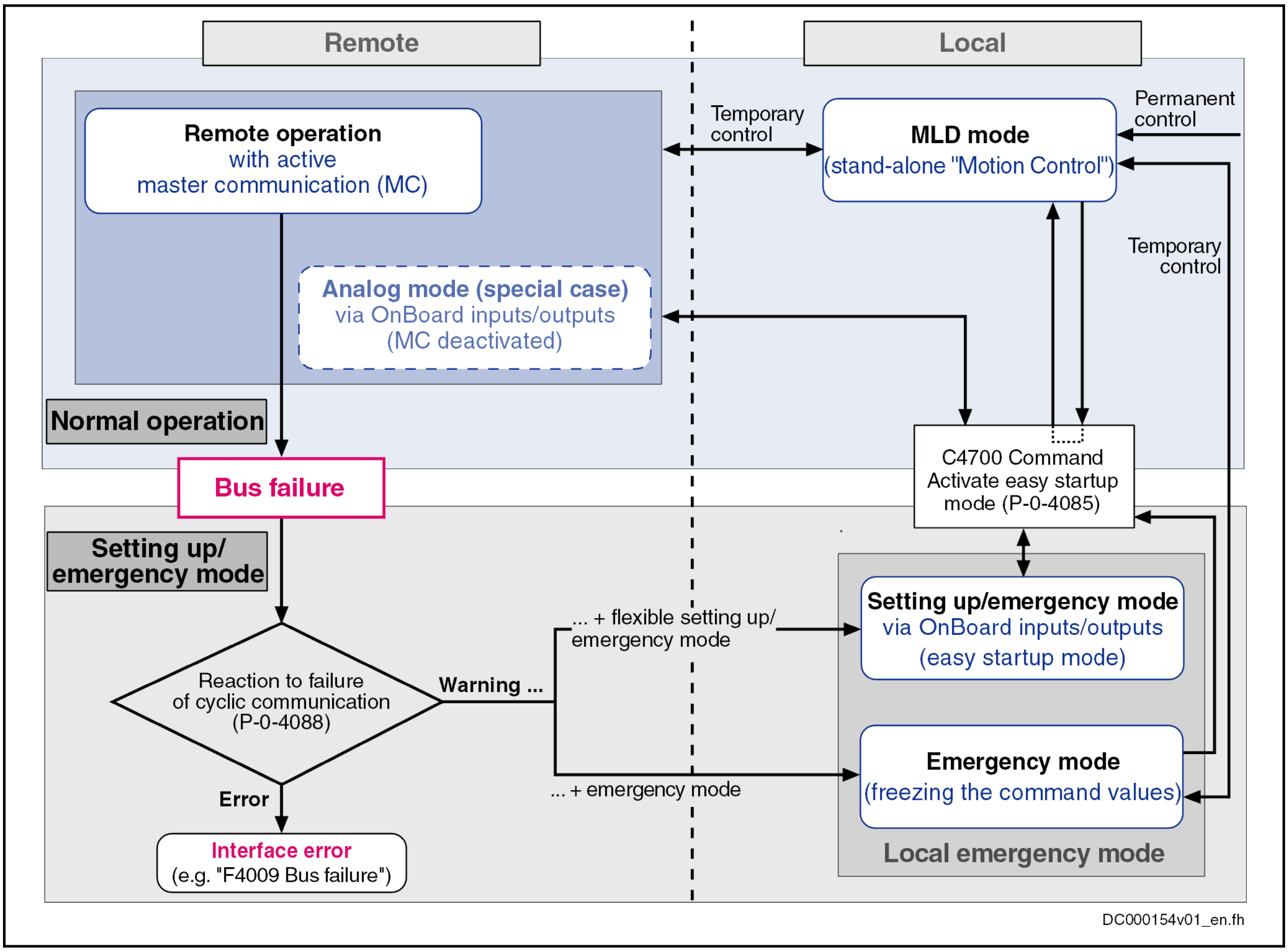


Fig. 4-16: Operating States and Operating Modes of Master Communication

Device Control and State Machine

According to the type of master communication or setting of the device control, different control words take effect. Internally, however, all relevant control bits are always displayed in parameter "P-0-0116, Device control: Control word".

☞ The actual state machines of master communication are described in the section "Device Control and State Machines"!

Normal Operation (via Internal or External Control Unit)

In the so-called normal operation, the command triggering for the drive takes place via an internal (IndraMotion MLD) or external control unit (e.g. IndraMotion MTX or MLC); we distinguish the following cases:

- **Remote mode** with active master communication (standard case)

  Command triggering for the axis takes place via the master communication (sercos, field bus, analog interface).

  Special case (respective configuration via "P-0-4089.0.1, Master communication: Protocol"):

  – **Analog mode** for sercos or field bus devices (master communication has been deactivated and a device with sercos or field bus interface is permanently operated via the digital/analog inputs/ outputs)

See also "Special Cases of Operation with External Control Unit"

- **MLD mode** (stand-alone "Motion Control")

  → The PLC integrated in the drive (IndraMotion MLD) takes over command triggering of the axis or, in conjunction with cross communication (CCD), of an entire axis group.

  → Configuration via parameter P-0-1367 (see also "Stand-alone motion control" in the separate documentation "IndraMotion MLD, Application Manual")

Local Setting-Up Mode/Emergency Mode (Easy Startup Mode)

During operation, the drive can, **due to the situation**, change to a local mode for setting-up or to remedy an emergency (e.g. bus failure). We distinguish the following operating modes:

- **Setting-up mode** (easy startup mode)

  For commissioning or the setting-up procedure, the drive can temporarily be moved via the inputs/outputs (digital and analog), independently of the external master (e.g. field bus interfaced PLC or NC) or the the internal control (IndraMotion MLD).

- **Emergency mode** in the case of bus failure (freezing the last command values)

  Even if the master communication fails, it is possible to continue operating the drive in an emergency mode via the (local) inputs/outputs at the device.

> ☞ Using the emergency mode requires the corresponding configuration in the parameter "P-0-4088, Master communication: Drive configuration"; the automatic activation of the easy startup mode can be set in this parameter.

4.4.2 Normal Operation (Remote or Local)

Remote Mode with External Control Unit and Active Master Communication

In the standard case, the command triggering for the axis takes place externally via the master communication ("remote"). In this case, command values and actual values are exchanged with the external control unit via the master communication interface (incl. control word and status word).

See description of the respective master communication:

- sercos
- PROFIBUS-DP
- MultiEthernet
- Analog interface

When using field bus interfaces, also take the profile types for this type of master communication into account [see "Profile Types (with Field Bus Interfaces)"].

> ☞ The analog operation with optional module available for these master communications requires specific configuration and handling (see "Notes on Commissioning and Utilization: Special Cases of Operation with External Control Unit").

MLD Mode with Permanent Control (Stand-Alone Motion Control)

> ☞ Using IndraMotion MLD requires the functional firmware package "ML" or "MA" and the corresponding MLD software!

With small, stand-alone subsystems, command triggering often takes place directly in the drive with an integrated PLC (IndraMotion MLD). In this case, IndraMotion MLD can independently communicate with external devices via all interfaces available in the drive (master communication, digital/analog inputs/outputs, engineering port, etc.).

Observe the following aspects for **commissioning and utilization**:

- You have to configure the MLD mode with permanent control in parameter "P-0-1367, ".
- The configuration can only be changed in the parameter mode (PM) and only takes effect after repeated run-up to the operating mode (OM).
- Command value input by an external control unit is interrupted and has to be freely programmed with IndraMotion MLD.

4.4.3 Setting-Up Mode (Easy Startup Mode)

Brief Description of Easy Startup Mode

The setting-up mode as so-called "easy startup mode" allows moving the drive without a connected or active control unit (or master communication master), or an external command value box. When using a Rexroth motor with encoder data memory, this is possible without using a commissioning PC, because all motor and controller parameters are stored in the encoder data memory.

Fields of Application

The easy startup mode is particularly suited for

- **initial commissioning** of individual axes without active master communication
- maintaining a configurable **emergency mode** (local mode) when the internal or external control unit (or master communication) has failed

  See also section "Introduction and Overview: Local Setting-Up Mode / Emergency Mode ("Easy Startup Mode")"

Features

The easy startup mode has the following features:

- **Activation/deactivation** of the easy startup mode:
  - By writing parameter "P-0-4085, C4700 Command Activate easy startup mode"
  - Via control panel of controller (incl. switch-off)
- **Command triggering** (axis control) via digital inputs/outputs by
  - Predefined digital I/O configuration in operation mode "**velocity control**" with a velocity command value (default) that can be parameterized
  - Freely configurable I/O configuration and operation mode with active easy startup mode
  - Selecting the **travel direction** (positive/negative) via digital input signals
  - Activating and changing the fixed velocity command values via standard control panel

- **Switching off command triggering** by master communication interface (see "P-0-4077, Field bus: Control word", "S-0-0134, Master control word") and possibly available drive-integrated PLC (IndraMotion MLD)

Pertinent Parameters

- S-0-0014, Interface status
- P-0-0120, Control word easy startup
- P-0-0300, Digital inputs, assignment list
- P-0-0301, Digital inputs, bit numbers
- P-0-1200, Control word 1 velocity control
- P-0-1206, Memory of velocity command values
- P-0-4085, C4700 Command Activate easy startup mode
- P-0-4086, Master communication status
- P-0-4088, Master communication: Drive configuration
- P-0-4089.0.1, Master communication: Protocol

Pertinent Diagnostic Messages

When the easy startup mode is used, simple diagnostic texts appear on the display of the control panel in "light writing":

- When the easy startup mode has been activated, the display changes between the drive address and the message "CM" (Commissioning Mode).
- During commissioning, the relevant messages appear on the display (see fig. "Activating the Easy Startup Mode via the Control Panel").

Functional Description of Easy Startup Mode

In the setting-up mode ("easy startup mode"), the drive can be controlled either via the digital and analog inputs or via the commissioning interface.

Control via Digital or Analog Inputs

If the drive is to be controlled via the digital or analog inputs, the inputs must have been configured accordingly. The form and point of time of the configuration are set in parameter "P-0-4088, Master communication: Drive configuration":

- Automatically by activating the easy startup mode

- or -

- Manually before or after the easy startup mode has been activated

Automatic Configuration of the Inputs

For automatic configuration of the inputs, the following actions are performed:

- Deactivation of master communication interface and activation of drive enable in parameter "P-0-0120, Control word easy startup"
- Setting of operation mode "velocity control" with values from memory of fixed command values (P-0-1206, Memory of velocity command values)
- Assignment of the command velocity selected via the control panel (in percent) of "S-0-0091, Bipolar velocity limit value" to element 1 or 2 of parameter "P-0-1206, Memory of velocity command values" (with positive sign to element 1, with negative sign to element 2).
- Assignment of allocation of inputs

☞ The automatic configuration of the inputs/outputs depends on the available digital inputs of the control section (see tables below).

☞ The automatic configuration of the inputs/outputs for the easy startup mode takes place **in volatile form**, i.e. any I/O configuration existing before is reestablished when the command is completed. This is not the case, if the I/O configuration was specifically (manually) changed with the command being active.

IndraDrive Cs			
Connection	Signal	Function	I/O assignment
X31_1	I_1	Drive enable	P-0-0120, Control word easy startup (bit 15)
X31_6	I_6	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 0)
X31_6	I_7	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 1)

Tab. 4-3: Automatic I/O Configuration for Easy Startup Mode with IndraDrive Cs

IndraDrive Mi (KSM)			
Connection	Signal	Function	I/O assignment
X37.4	I/O_3	Drive enable	P-0-0120, Control word easy startup (bit 15)
X37.2	I/O_1	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 0)
X38.4	I/O_2	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 1)

Tab. 4-4: Automatic I/O Configuration for Easy Startup Mode with IndraDrive Mi

☞ IndraDrive Mi (motor-integrated inverter drive) only has a limited number of digital inputs/outputs (4 inputs/outputs), it has no analog input and no control panel!

Operating the Drive via Ethernet

The drive can be controlled via Ethernet via which it is possible to write the control word and the command values.

☞ Exception: EtherCAT

Connection via Ethernet is not possible when EtherCAT is used as the master communication.

Take the following aspects into account:

- The digital inputs mustn't have been assigned to "P-0-1200, Control word 1 velocity control".
- Drive enable mustn't have been assigned to any digital input ("P-0-0120, Control word easy startup").

NOTICE **Property damage caused by errors when controlling motors and moving parts!**

It is necessary to wire the E-Stop input at the drive so that the drive can be shut down when the commissioning interface fails.

Notes on Commissioning for Easy Startup Mode

Requirements

The following requirements and conditions must have been fulfilled for using the easy startup mode:

- For Rexroth motors with encoder data memory, there is no commissioning PC required; for motors without encoder data memory, the motor parameters have to be manually written during commissioning.
- Master communication should not be active, as the easy startup mode switches off any possibly active command triggering via master communication or IndraMotion MLD!
- There mustn't be any error message present in the drive, not even a transition command error (C01xx, C02xx).
- The drive must be ready for operation ("bb").
  - With conventional field bus interfaces (e.g. PROFIBUS®), the drive is automatically ready for operation ("bb") after run-up, even if master communication is not active. In this way, the requirements for manual mode basically are always fulfilled!
  - With sercos, EtherNet^{TM} interface and EtherCAT, the drive after run-up is **not ready for operation** (e.g. communication phase "NRT" with sercos master communication is not active.

☞ Depends on the setting of bit 0 or bit 1 in parameter "P-0-4088, Master communication: Drive configuration"

Possibilities of Activation

The easy startup mode is activated by starting "P-0-4085, C4700 Command Activate easy startup mode" in one of the following ways:

- Activate the corresponding menu item on **standard control panel**
- **Set a digital input** on which the command parameter "P-0-4085, C4700 Command Activate easy startup mode" has been configured
- **Write the parameter "P-0-4085, C4700 Command Activate easy startup mode"** via master communication or via engineering
- **Automatically by internal command start** in the case of bus failure, if configured accordingly (see "P-0-4088, Master communication: Drive configuration")

☞ If the drive already is in the easy startup mode and this mode is activated again, the display reads "easymode active"!

Activation via Control Panel

The command "P-0-4085, C4700 Command Activate easy startup mode" can be activated and deactivated via the standard control panel of the IndraDrive controllers.

The figure below shows the sequence for activating the easy startup mode via the control panel:

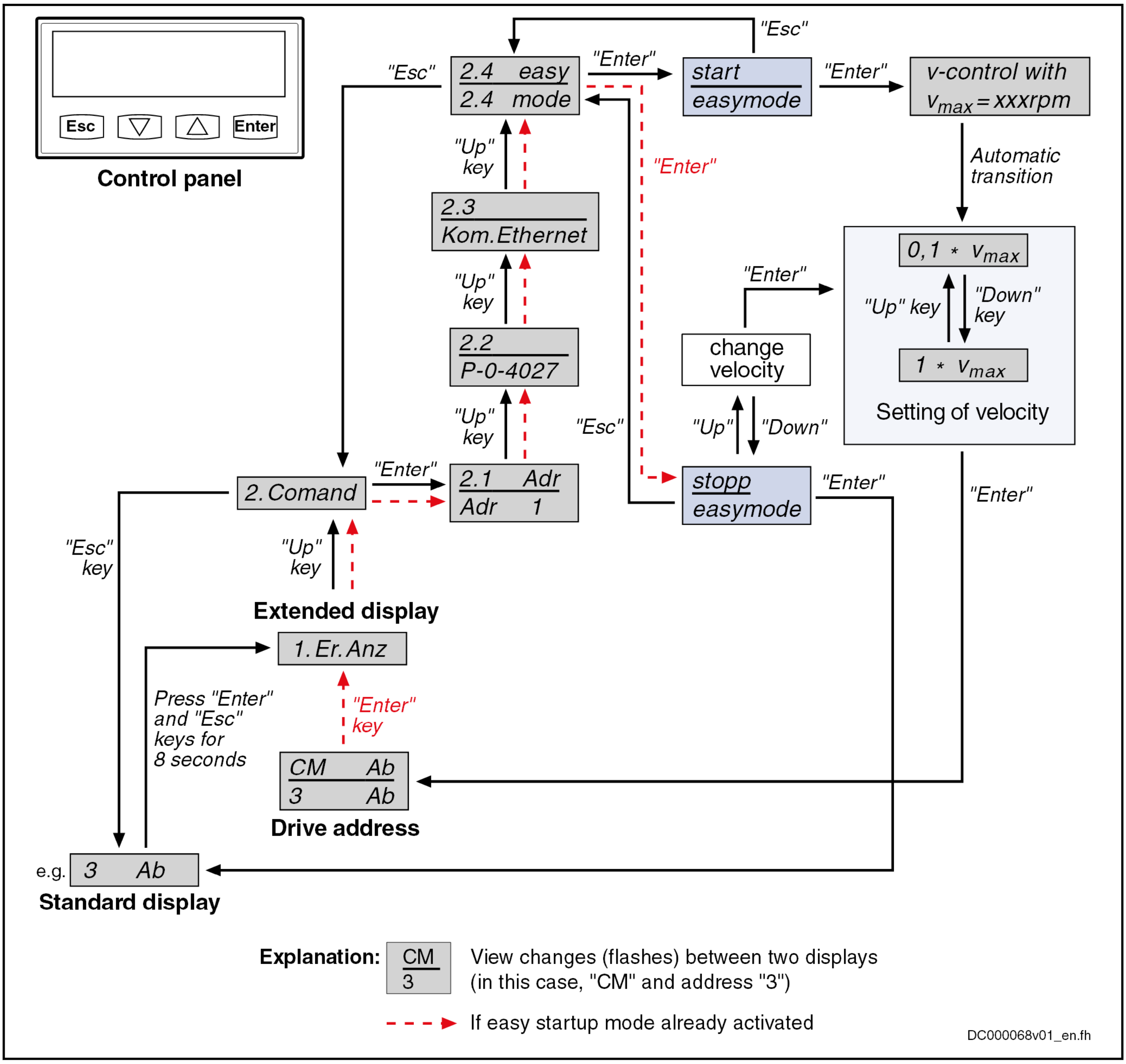


Fig. 4-17: Activating the Easy Startup Mode via the Control Panel

See also "Control Panels of the IndraDrive Controllers"

Activation via Digital Input

To activate the easy startup mode via a digital input, bit 0 of parameter P-0-4085 has to be assigned to a digital input.

See "Digital Inputs/Outputs"

Activation via Engineering Interface

To activate the easy startup mode via the engineering interface, the parameter "P-0-4085, C4700 Command Activate easy startup mode" must be written.

See "TCP/IP Communication"

☞ Parameter P-0-4085 can also be directly written via the master communication (e.g. sercos or field bus), but the master would thereby deactivate itself!

Acknowledging the Activation

The activation of the easy startup mode is acknowledged by:

- Setting bit 8 in parameter "P-0-4086, Master communication status"
- Changing the display on the control panel between "CM" (Commissioning Mode) and the drive address
- Clearing the bit "Drive follows (ext.) command value input" in parameter P-0-0115, bit 3

☞ With active easy startup mode, the active operating mode is not acknowledged in the status word (see P-0-0115)!

Deactivating/Exiting the Easy Startup Mode

The easy startup mode is deactivated by completing the command execution. The command can be deactivated by writing parameter P-0-4085 or by confirming the corresponding menu item with the standard control panel.

☞ After you have exited the easy startup mode, the previously active state becomes active again. The command triggering of the drive again takes place via the master communication (see P-0-4077, S-0-0134, …) or IndraMotion MLD and the originally active operation modes are carried out.

Control Parameter P-0-0120

The control parameter "P-0-0120, Control word easy startup" active in the easy startup mode can be changed or influenced in the following ways:

- Via digital inputs, if they were accordingly configured before
- Via the engineering interface via the parameter P-0-0120

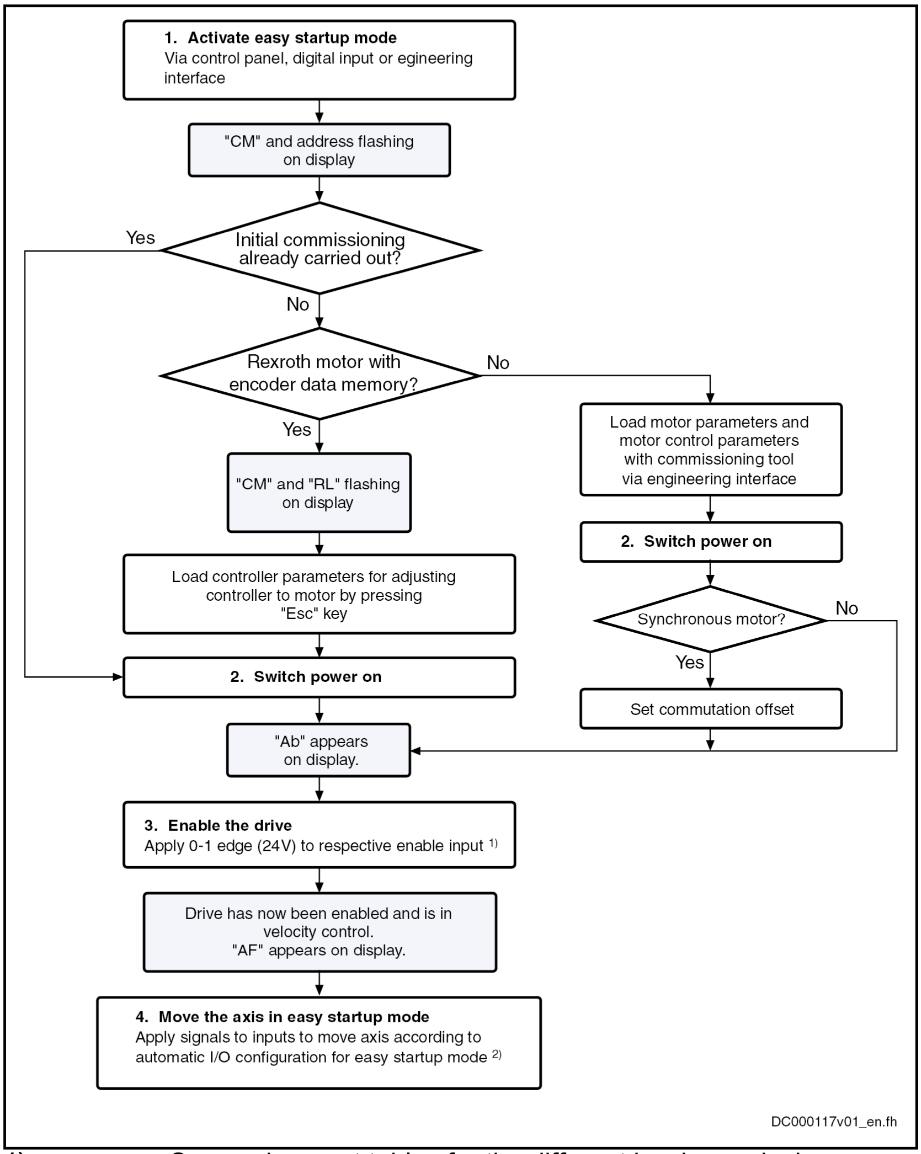
Invalid Commands

The commands for the backup of the working memory ("C2200 Backup working memory procedure command" and "C2400 Selectively backup working memory procedure command") should not be triggered in the easy startup mode, because otherwise the settings of the easy startup mode will be stored in the non-volatile memory and will be active again after the drive is switched on the next time!

Commissioning with Easy Startup Mode

The figure below summarizes the commissioning sequence with the easy startup mode:

Master Communication



1) See assignment tables for the different hardware designs under "Automatic Configuration of the Inputs"

Fig. 4-18: Commissioning Sequence with the Easy Startup Mode

For loading the default values, see "Default Settings in the Motor Encoder Data Memory" under "Overview of Drive Control".

Special Case: Commissioning Motors without Encoder Data Memory

Initial commissioning of Rexroth motors without encoder data memory or of third-party motors is only possible in the manual mode in conjunction with the "IndraWorks Ds/D/MLD" commissioning tool, in order to load or enter the values for motor control parameters and motor encoder parameters. For synchronous motors with absolute measuring system, the commutation offset only has to be determined at initial commissioning. For synchronous motors with relative measuring system, the commutation offset is automatically determined every time drive enable is set for the first time after transition "PM → OM".

If for synchronous motors the commutation offset can only be determined by supplying current, this is only possible in the operating status "Ab" with active easy startup mode!

See "Commissioning Motors: Initial Start with the Commissioning Tool"

NOTICE	**Danger of property damage during initial start in the easy startup mode caused by incorrect parameter values!**

For motors without encoder data memory, the required motor and controller parameters have to be checked before initial start in the easy startup mode!

Recommissioning

In the easy startup mode, recommissioning (after initial commissioning having been carried out) of drives is possible without any problem, because the correct values of motor control parameters and motor encoder parameters are already available in the drive.

Only the commutation setting of synchronous motors with relative measuring system is automatically determined again every time drive enable is set for the first time after the "PM → OM" transition!

4.4.4 Local Mode

Overview

During operation it is possible, **depending on the situation**, to go to a setting-up or emergency mode, **on digital and analog inputs/outputs of the controller or to the control panel**:

- MLD mode with temporary control by IndraMotion MLD (intelligent servo axis) to carry out, for example, an intelligent error reaction.
- **Operation under emergency conditions (local mode)** for bus failure → With the corresponding configuration, you can continue using the drive in an emergency mode, even if master communication (field bus, sercos, etc.) has failed.

MLD Mode with Temporary Control (Intelligent Servo Axis)

Starting from any state (except for setting-up mode), you can get temporary control (see parameter "P-0-1367, " and function block "MX_SetControl") over the axis with IndraMotion MLD and thereby interrupt the command value input of an external control unit. As IndraMotion MLD can be freely programmed, this provides high flexibility for drive control which can be used, for example, for realizing an intelligent error reaction.

☞ Using the MLD mode with temporary control requires the functional firmware package "ML" and the corresponding MLD software!

Emergency Mode (When Master Communication has Failed)

Behavior in the Case of Bus Failure

For bus failure (line interruption), bus stop or PLC stop, the reaction of the drive can be set in the parameter "P-0-4088, Master communication: Drive configuration":

- **Bus failure as error**

  → The drive normally switches off, generates the message of an interface error (e.g. "F4009 Bus failure") and carries out the defined **error reaction** ("best possible deceleration").
- **Bus failure as warning**

  → In the case of bus failure, the drive does **not** react by switching off and generating an error message, but the state of the last command triggering is maintained (command value and control word are "frozen") or the easy startup mode is automatically activated and the warning "E4005 No command value input via master communication" is output.

See also section "Setting-Up Mode ("Easy Startup Mode")"

See also Parameter Description "P-0-4088, Master communication: Drive configuration"

NOTICE **Property damage caused by errors when controlling motors and moving parts!**

If bus failure has been configured as a warning, the E-Stop input should be wired at the drive. It is no longer possible to switch the drive off via the master communication.

Status Display

The parameter "S-0-0014, Interface status" displays the current status of the master communication interface.

4.4.5 Notes on Commissioning and Utilization

Using the Operating Modes

The table below summarizes the different operating modes of master communication, their operation criteria and activation.

Place of command triggering	Mode	Use	Execution of command triggering	Activation	Operation modes	Notes
Control unit (remote)	Master comm. mode (remote)	Field bus or sercos device is operated as usual via existing interface of master communication	Via external control unit (bus or inputs/ outputs)	Not required	Standard operation modes 0…7 take effect and can be selected	Standard Case
	Special case: Analog mode	Field bus device can be permanently operated as analog drive, if master comm. option deactivated (for mounting spare parts or emergency mode without master)	Only via digital onboard inputs/ outputs and analog inputs	Configuration of parameter P-0-4089.0.1 **Note:** Activation requires complete booting process	Standard operation modes 0…7 take effect and can be defined according to application, if required	Special case in which master comm. option existing, but not active
Control unit (internal)	MLD mode (permanent control)	For motion solutions with permanent control by MLD over the axis/axes	Internal via MLD with motion function blocks	Configuration of parameter P-0-1367	Standard operation modes 0…6 are automatically configured, operation mode 7 can be freely defined	No access by master communication (only E-Stop is possible)

Place of command triggering	Mode	Use	Execution of command triggering	Activation	Operation modes	Notes
Local	**Setting-up mode**	Setting-up and commissioning of axes, even without running master	Via digital inputs/outputs or acyclic channel with "IndraWorks Ds /D/MLD"	Control panel and "easy startup mode" command	Internal operation modes 8…12 take effect **Note:** Operation modes 8…12 have been permanently configured	
	Emergency mode	Moving the axes when master communication or MLD fails	Via MLD, digital inputs/outputs or acyclic channel with "IndraWorks Ds /D/MLD"	"Easy startup mode" command, can be manually started in the case of bus failure	The operation modes last active take effect (0...7)	Control via MLD or activation of easy startup mode is possible
	Special Case: Temporary control for intelligent error reaction	Preferably for use as intelligent servo axis (MLD has control only temporarily, e.g. for carrying out an intelligent error reaction)	Internal via MLD with motion function blocks	With function block "MX_SetControl"	Internal operation modes 8…12 take effect **Note:** Operation modes 8…12 have been permanently configured	Access by master communication with sercos **Note:** With field bus, bit 14 in the control word does not take effect.

Master comm. option Hardware option for master communication
MLD IndraMotion MLD (drive-integrated PLC)

Tab. 4-5: Operation Criteria of the Operating Modes

Control Words of the Operating Modes and Master Communications

According to the operating mode or master communication used, different control words take effect; they are shown in the figure below.

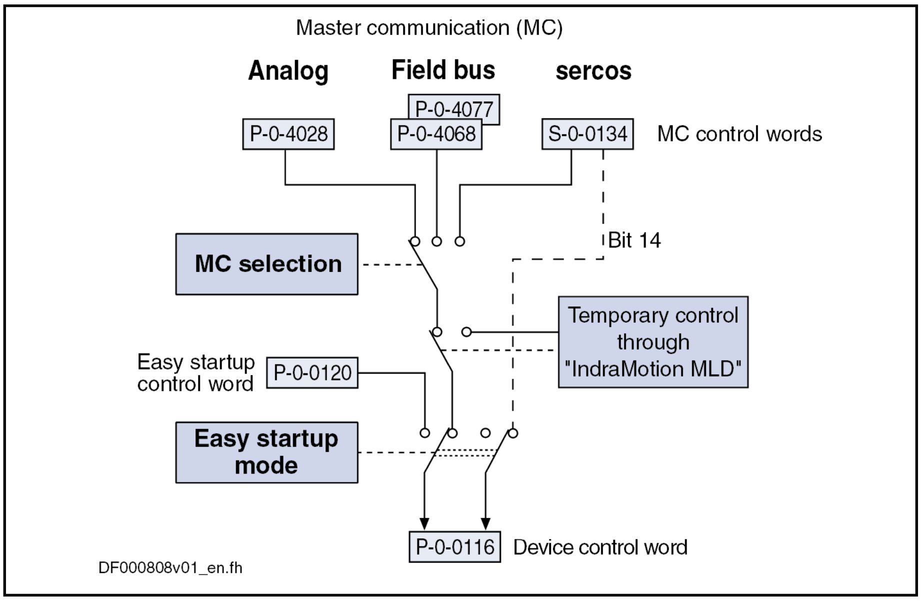


Fig. 4-19: Overview of Control Words of Operating Modes and Master Communication

Special Cases of Operation with External Control Unit

There is the following special case of operation via an external master communication:

Analog Mode with Existing Analog Optional Module

You canpermanently switch off a master communication interface (e.g. sercos or field bus) available in the control section and thereby use a sercos or field bus device like an analog device. The axis is then controlled via the digital inputs or the engineering connection of the control section.

☞ In this operating mode, there aren't any command values and actual values transmitted between the drive and an external control unit!

Observe the following aspects for **commissioning and utilization**:

- Deactivation of master communication and activation of the analog mode take place in the parameter "P-0-4089.0.1 Master communication: Protocol".
- The configuration only takes effect after repeated booting process, i.e. it is necessary to switch the control voltage of the drive controller off and on again.
- In order to control the device via the digital inputs, you have to assign the drive enable signal (see Parameter Description "P-0-0120, Control word easy startup") to a digital input of the control section.

  See "Digital Inputs/Outputs"
- The operation mode of the axis can be freely selected, but in the analog mode it is only the operation modes "velocity control" and "positioning block mode" which can be practically used.

  See "Velocity Control" and "Positioning Block Mode"

4.5 Profile Types (with Field Bus Interfaces)

4.5.1 Brief Description

Supported Profile Types, Overview

When a field bus interface is used for master communication, IndraDrive controllers support the following profile types (modes):

- "No profile"
- I/O mode positioning
- I/O mode preset velocity
- Freely configurable mode (IndraDrive profile type)

The tables below contain an overview of the most important properties and features of these 4 profile types:

Profile type: "No profile"			
Content of "P-0-4084, Field bus: Profile type"	Master Communication	Field bus or drive operation mode	Features
0x0000	PROFIBUS® CANopen PROFINET® EtherNet/IP™	- With the profile type "No profile", all settings relevant to the profile type are deactivated - The profile type "No profile" is intended for MLD applications with "permanent control"	- Field bus control word and field bus status word are not available in the cyclic data - Field bus control word and field bus status word are deactivated and cannot be written via acyclic services - Real-time data can be freely configured - Drive is controlled via MLD

Tab. 4-6: Profile Type "No Profile"

I/O mode positioning			
Content of "P-0-4084, Field bus: Profile type"	Master Communication	Field bus or drive operation mode	Features
0xFF82	PROFIBUS® CANopen PROFINET® EtherNet/IP™	I/O mode positioning (positioning block mode, encoder 1, lagless)	- Up to 64 positioning blocks can be controlled via field bus - Apart from control word and status word, other real-time data can be configured (in P-0-4080 and P-0-4081) - Bits can be freely defined in signal status word via "configurable signal status word" function

Tab. 4-7: Profile Type "I/O Mode Positioning"

I/O mode preset velocity			
Content of "P-0-4084, Field bus: Profile type"	Master Communication	Field bus or drive operation mode	Features
0xFF92	PROFIBUS® CANopen PROFINET® EtherNet/IP™	I/O mode preset velocity	- Fixed velocity command values can be controlled and ramp-function generator can be operated via field bus - Apart from control word and status word, other real-time data can be configured (in P-0-4080 and P-0-4081) - Bits can be freely defined in signal status word via "configurable signal status word" function

Tab. 4-8: Profile Type "I/O Mode Preset Velocity"

Freely configurable mode			
Content of "P-0-4084, Field bus: Profile type"	Master Communication	Field bus or drive operation mode	Features
0xFFFE	PROFIBUS® CANopen PROFINET® EtherNet/IP™	Freely configurable mode (Default assignment is "drive-controlled positioning" with corresponding required cyclic data)	- Possible use of complete drive functionality by free configuration of real-time data and operation mode selection - Control word and status word have a Rexroth-specific structure - Selection suited for operation with analog command values in commissioning phase
0xFFFD	As for profile 0xFFFE, but reduced field bus control word		

Tab. 4-9: Profile Type "Freely Configurable Mode"

Pertinent Parameters

- S-0-0026, Configuration list for signal status word
- S-0-0144, Signal status word
- S-0-0328, Assign list signal status word
- P-0-4068, Field bus: Control word IO
- P-0-4071, Field bus: Length of cyclic command value data channel
- P-0-4074, Field bus: Data format
- P-0-4077, Field bus: Control word
- P-0-4078, Field bus: Status word
- P-0-4080, Field bus: Config. list of cyclic actual value data ch.
- P-0-4081, Field bus: Config. list of cyclic command value data ch.
- P-0-4082, Field bus: Length of cyclic actual value data channel
- P-0-4083, Parameter channel: Length
- P-0-4084, Field bus: Profile type

Supported Profile Types, Basic Principles and Terms

Drive Profile

The drive profile defines

- the structure of the field bus control word (P-0-4077) and of the field bus status word (P-0-4078),

- the structure and content of real-time channel (P-0-4080, P-0-4081),
- the active operation mode (S-0-0032, S-0-0033, S-0-0034, S-0-0035),
- the drive states and their transitions (state machine of IndraDrive profile type or I/O mode).

By selecting a profile type, the commissioning of field bus drives becomes very easy for the user. The advantage of the profile selection is that all important basic settings for the desired drive function are thereby made automatically in the drive. As the profile types are defined independently of the bus, the transfer of applications from one field bus to the other is also facilitated.

State Machine

A state (e.g. Drive Halt, drive error, …) represents a specific internal and external behavior. The state can be exited by defined events (e.g. drive commands, switching of operation modes, …). Corresponding state transitions are assigned to the events. The interaction of control and status bits and the state transitions are called state machine.

Abbreviations

- **i16**: Signed 16-bit variable (1 word) in Intel format
- **i32**: Signed 32-bit variable (2 words) in Intel format
- **u16**: Unsigned 16-bit variable (1 word) in Intel format
- **u32**: Unsigned 32-bit variable (2 words) in Intel format
- **ZKL1**: Class 1 diagnostics
- **ZKL2**: Class 2 diagnostics

4.5.2 Profile Type "No Profile"

Brief Description

There are applications in which the field bus control word parameters "P-0-4077, Field bus: Control word" or "P-0-4068, Field bus: Control word IO" and "P-0-4078, Field bus: Status word" are not desired, because the axis is to be controlled by the drive-integrated PLC. The profile type "No profile" is available for this purpose.

Activating the profile for the first time causes the following actions:

- The content of the real-time data channel (configuration parameters "P-0-4080, Field bus: Config. list of cyclic actual value data ch." and "P-0-4081, Field bus: Config. list of cyclic command value data ch.") is cleared.
- The operation modes are set to their default values.

Features

- The structure (content) of the real-time data channel must be defined via the configuration parameters P-0-4080 and P-0-4081. No profile-dependent settings and checks are carried out.
- In this profile type, the field bus control word and the field bus status word are not expected in the configuration and are not evaluated either.
- This profile type allows using the entire drive functionality (e.g. velocity synchronization, drive-controlled positioning, …) from MLD.
- The primary operation mode and the secondary operation modes can be freely determined in the parameters S-0-0032, S-0-0033 etc.

Real-Time Channel

In the real-time channel of the field bus, the data configured in the parameters "P-0-4081, Field bus: Config. list of cyclic command value data ch." and "P-0-4080, Field bus: Config. list of cyclic actual value data ch." are transmitted between master and drive (slave).

Data direction	24 words	Format
Master → slave	Complete command value data channel can be freely defined	-
Slave → master	Complete actual value data channel can be freely defined	-

Tab. 4-10: Structure of the Real-Time Channel for the Profile "No Profile"

☞ The IDNs of the parameters of the cyclic configurable command and actual values are contained in "S-0-0188, List of configurable data in the MDT" and "S-0-0187, List of configurable data in the AT".

Data direction	(Double) word1	(Double) word2	...	(Double) word_n
Master → slave	Command value 1	Command value 2	...	
Slave → master	Actual value 1	Actual value 2	...	

Tab. 4-11: Example of the Data in the Real-Time Channel with the Profile "No Profile"

4.5.3 I/O mode (positioning and preset velocity)

Brief Description

We distinguish the following variants of the "I/O mode" profile type:

- I/O mode positioning
- I/O mode preset velocity (e.g. for open-loop applications)

General Features

The I/O mode has the following features:

- Optional parameter channel can be activated, if required, via "P-0-4083, Parameter channel: Length" (max. 8 words)

  Default: P-0-4083 = 0 → without parameter channel
- Real-time channel consists of at least one word (16 bits), the field bus control word (P-0-4068) and the signal status word (S-0-0144)
- Freely expandable real-time channel by configuration of real-time data:
  - **Master → slave** (drive)

    → Configuration of "P-0-4081, Field bus: Config. list of cyclic command value data ch."
  - **Slave → master** (drive)

    → Configuration of "P-0-4080, Field bus: Config. list of cyclic actual value data ch."
- Freely configurable field bus status word (cf. S-0-0144)
- Relationship between profile type selection and operation mode which takes effect
  - In the **I/O modes**, there is a determined relationship between the profile type (P-0-4084) and the predefined primary operation mode (S-0-0032).
  - The **freely configurable mode** allows free selection of the operation modes (S-0-0032, S-0-0033, …).

☞ The respective default settings are activated by selecting the profile type and subsequent action "load default communication parameters" (see also P-0-4090 and S-0-0262).

Structure of the Real-Time Channel

Data direction	Word1	Format
Master → slave	P-0-4068, Field bus: Control word IO	u16 (1 word)
Slave → master	S-0-0144, Signal status word	u16 (1 word)

Tab. 4-12: Structure of the Real-Time Channel for the I/O Modes

Features "I/O Mode Positioning"

Specific features of "I/O mode positioning":

- The drive is operated in the "positioning block mode, lagless, encoder 1" (see also description of the operation mode "Positioning Block Mode").
- In this operation mode, 64 programmable positioning blocks can be selected and started via 6 bits (in the 16 bit wide control word).
- The jog function can be activated in "P-0-4068, Field bus: Control word IO". "Drive-controlled positioning" was set as the 1st secondary operation mode (see also description of the operation mode "Drive-Controlled Positioning").

Features "I/O Mode Preset Velocity"

Specific features of "I/O mode preset velocity":

- The drive is operated in the "velocity control" mode (see also description of the operation mode "Velocity Control").
- In this operating mode you can, for example, select and start 5 programmable fixed velocity command values (in the 16 bit wide control word) and operate the function of the ramp-function generator.

State Machine in I/O Mode

Interaction of control and status bits (state machine):

Master Communication

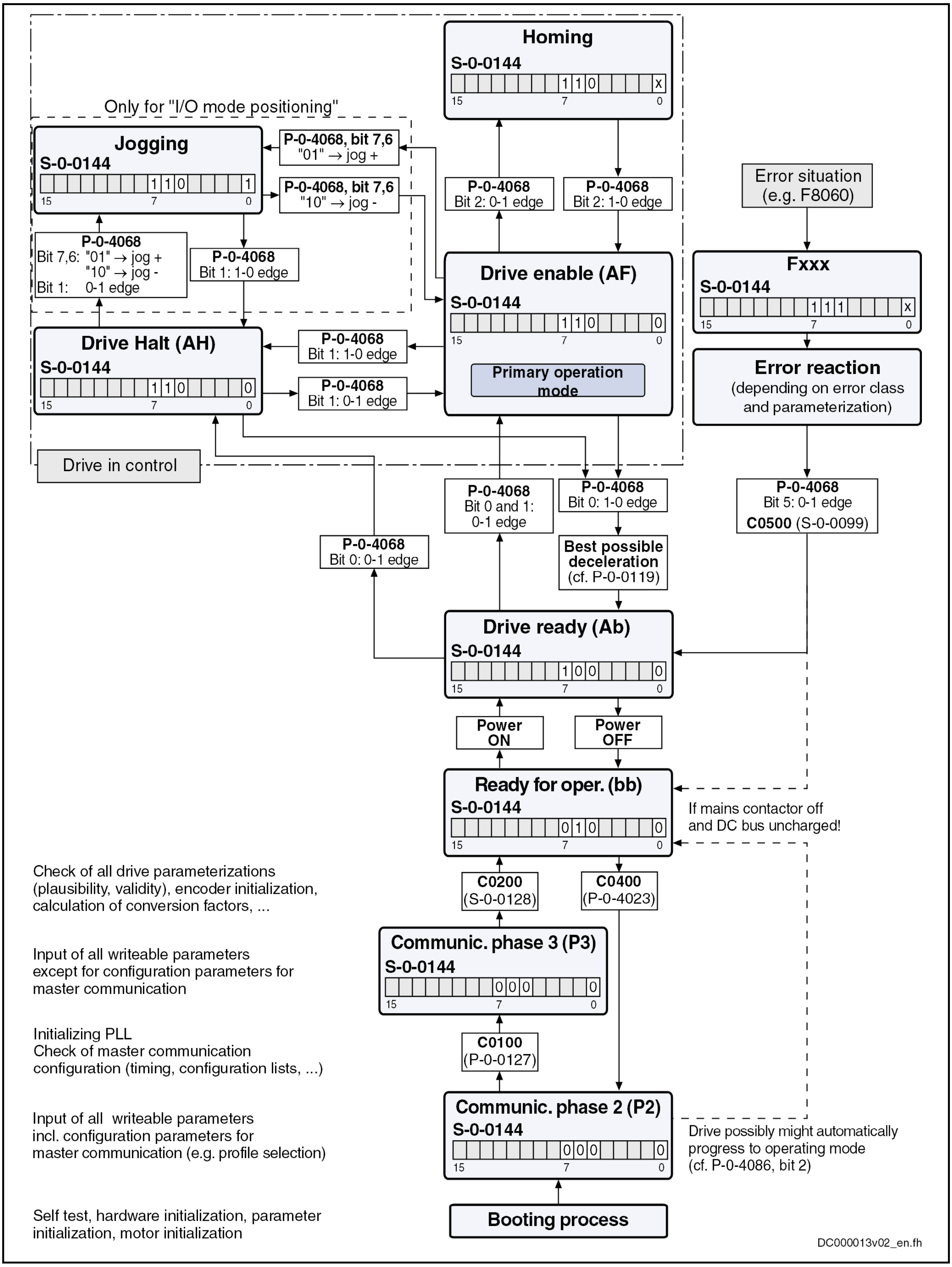


Fig. 4-20: Device Control of Variants of I/O Mode (State Machine)

☞ The figure illustrates the status word (S-0-0144) in its default configuration. If required, it can be given any configuration.

NOTICE **Automatic restart after bus failure!**

In case the bus fails (message "F4009" or "E4005"), an error reaction must be carried out in the control unit, too, to avoid automatic restart after the bus has been reestablished. This means that in the case of bus failure, the bits "Drive Halt", "Drive enable" and "Drive ON" (e.g. bits 13, 14 and 15 in parameter "P-0-4077, Field bus: Control word") or bits 0 and 1 in parameter "P-0-4068, Field bus: Control word IO" should be reset in the control unit.

Field Bus Control Word in I/O Mode

The bits in the parameter "P-0-4068, Field bus: Control word IO" are fixed by Rexroth and the user cannot change them. If additional control bits should be required, the parameter "S-0-0145, Signal control word" has to be configured accordingly and transmitted to the real-time channel of the field bus.

See Parameter Description "P-0-4068, Field bus: Control word IO"

See Parameter Description "S-0-0145, Signal control word"

Signal Status Word in I/O Mode

- In the I/O modes (P-0-4084 = 0xFF82 or 0xFF92), the parameter "S-0-0144, Signal status word" is transmitted instead of the field bus status word (P-0-4078). The configuration of S-0-0144 is given by default setting (see below).
- According to the selected I/O profile type, there is a different default configuration for S-0-0144 (see below).

The tables below show the two default configurations for S-0-0144 which depend on the profile type:

Bit	Pin assignment	Significance
0	Active Operation Mode	**1:** Jogging (S-0-0437) **0:** Positioning
1	Position switch point (PSP)	**1:** To the right of PSP **0:** To the left of PSP (S-0-0060)
2	In reference	**1:** Drive has been homed (S-0-0403)
3	In motion	**0:** In motion (S-0-0331)
4	In position	**1:** Drive is in positioning window & no sequential block (P-0-4061)
5	Drive error (error flag)	**1:** Error (P-0-0115) **0:** No error
6	Readiness for operation; display "bb"	**1:** Ready for operation (P-0-0115)
7	Power switched on; display "Ab"	**1:** Power has been switched on (P-0-0115)
13…8	Positioning block acknowledgment	P-0-4051, Positioning block acknowledgment
15…14	Not assigned	

Tab. 4-13: Default assignment of parameter "S_0_0144, Signal status word" for "I/O mode positioning" (P_0_4084 = 0xFF82)

Bit	Pin assignment	Significance
0	State of ramp-function generator	**1:** Run-up stop active (P-0-1210, bit 1)
1	State of ramp-function generator	**1:** Acceleration active (P-0-1210, bit 2)
2	State of ramp-function generator	**1:** Deceleration active (P-0-1210, bit 3)
3	In motion	**1:** Message n_feedback = 0 (S-0-0331, bit 0)
4	State of ramp-function generator	**1:** Cmd value reached (P-0-1210, bit 0)
5	Drive error (error flag)	**1:** Error (P-0-0115) **0:** No error
6	Readiness for operation; display "bb"	**1:** Ready for operation (P-0-0115)
7	Power switched on; display "Ab"	**1:** Power has been switched on (P-0-0115)
8	State of ramp-function generator	**1:** Cmd value within masking window (P-0-1210, bit 4)
9	State of ramp-function generator	**1:** V-ramp within masking window (P-0-1210, bit 5)
15…10	Not assigned	

Tab. 4-14: Default assignment of parameter "S_0_0144, Signal status word" for "I/O mode velocity" (P-0-4084 = 0xFF92)

☞ As the parameter "S-0-0144, Signal status word" is already used as field bus status word in the I/O mode, it cannot be configured again in the cyclic channel.

ⓘ See also Parameter Description "S-0-0144, Signal status word"

Notes on Parameterization/Commissioning

Features with Default Configuration

The following definitions apply to the default setting in the I/O modes:

- Fixed real-time channel length of 2 bytes. Thus the length of the real-time channel corresponds to the length of the cyclic data channel (P-0-4082 = P-0-4071 = 2)!
- "P-0-4068, Field bus: Control word IO" and "S-0-0144, Signal status word" have been set to the above-mentioned default configuration.
- In the real-time channel, only "P-0-4068, Field bus: Control word IO" and "S-0-0144, Signal status word" are transmitted.

Features/Settings with Free Configuration or Expansion

There are the following options for free configuration/expansion:

- The user can freely expand the length of cyclic data channel P-0-4082 or P-0-4071 up to a maximum of 23 words. In addition to control word and status word, other real-time data can be configured via the parameters "P-0-4080, Field bus: Config. list of cyclic actual value data ch." and "P-0-4081, Field bus: Config. list of cyclic command value data ch.".
- The content of

  "S-0-0144, Signal status word" can be freely parameterized via "S-0-0026, Configuration list for signal status word" and "S-0-0328, Assign list signal status word".
- The content of "S-0-0145, Signal control word" can be freely parameterized via "S-0-0027, Configuration list for signal control word" and "S-0-0329, Assign list signal control word".

4.5.4 Freely configurable mode (IndraDrive profile type)

Brief Description

To use the extensive and numerous functions of a Rexroth drive with field bus interface, it is necessary, in addition to the I/O modes, to define another profile, the freely configurable mode. This implies the use of a specific control word and status word ("P-0-4077, Field bus: Control word" and "P-0-4078, Field bus: Status word").

Features

- The structure (content) of the real-time data channel must be defined via the configuration parameters P-0-4080 and P-0-4081. No profile-dependent settings and checks are carried out!
- In this profile type, it is the Rexroth-specific definitions for the field bus control and status words which apply. Some bits in the parameters "P-0-4077, Field bus: Control word" and "P-0-4078, Field bus: Status word" can only be used in conjunction with certain operation modes.
- This profile type allows using the entire drive functionality (e.g. velocity synchronization, drive-controlled positioning, …).
- The primary operation mode and the secondary operation modes can be freely determined in the parameters S-0-0032, S-0-0033 etc.
- The operation mode "drive-controlled positioning" is set as default with the command values S-0-0282, S-0-0259 and twice S-0-0000 and the actual values S-0-0386, S-0-0040, S-0-0390 (see also below "Exemplary Configurations: Drive-Controlled Positioning").

☞ The parameters "P-0-4077, Field bus: Control word" and "P-0-4078, Field bus: Status word" should always be contained in the 1st place in the configuration parameters P-0-4080 and P-0-4081.

Real-Time Channel

In the real-time channel of the field bus, the data configured in the parameters "P-0-4081, Field bus: Config. list of cyclic command value data ch." and "P-0-4080, Field bus: Config. list of cyclic actual value data ch." are transmitted between master and drive (slave).

Data direction	Word1	Format
Master → slave	P-0-4077, Field bus: Control word	u16 (1 word)
	Optional command values	According to selection
Slave → master	P-0-4078, Field bus: Status word	u16 (1 word)
	Optional command values	According to selection

Tab. 4-15: Structure of the Real-Time Channel in the Freely Configurable Mode

☞ The IDNs of the parameters of the cyclic configurable command and actual values are contained in "S-0-0188, List of configurable data in the MDT" and "S-0-0187, List of configurable data in the AT".

Data direction	Word1	Word2	...	Word_n
Master → slave	P-0-4077	Command value 1	...	
Slave → master	P-0-4078	Actual value 1	...	

Tab. 4-16: Content and Order of Data in Real-Time Channel in the Freely Configurable Mode

State Machine in Freely Configurable Mode (IndraDrive Profile Type)

Each field bus drive of Rexroth, independent of the master communication interface, is equipped with a uniform "state machine". This includes a continuous structure of the parameters "P-0-4077, Field bus: Control word" and "P-0-4078, Field bus: Status word".

See Parameter Description "P-0-4077, Field bus: Control word"

See Parameter Description "P-0-4078, Field bus: Status word"

Interaction of control and status bits (state machine):

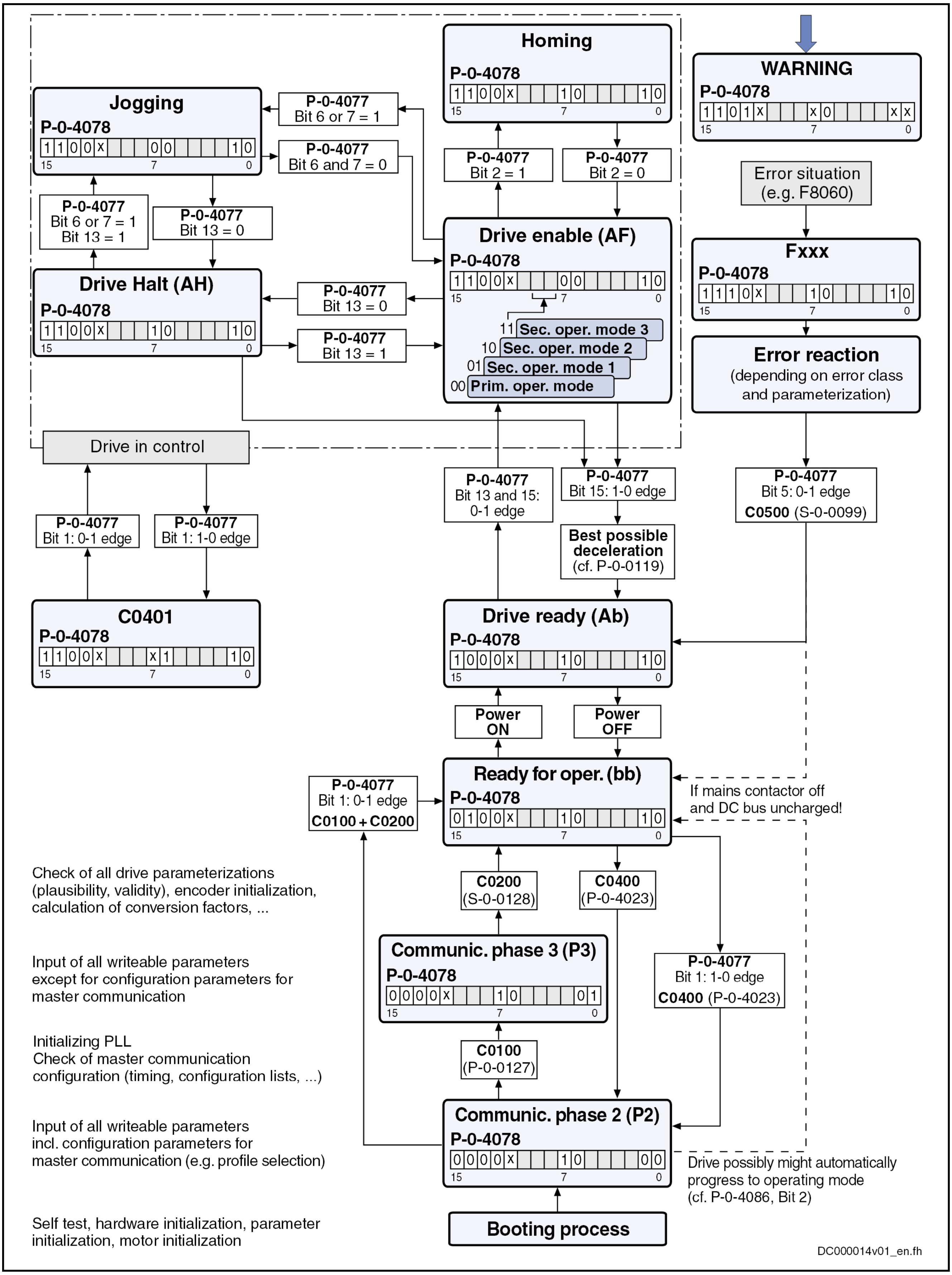


Fig. 4-21: Device Control in the Freely Configurable Mode (State Machine)

NOTICE **Automatic restart after bus failure!**

In case the bus fails (message "F4009" or "E4005"), an error reaction must be carried out in the control unit, too, to avoid automatic restart after the bus has been reestablished. This means that in the case of bus failure, the bits "Drive Halt", "Drive enable" and "Drive ON" (e.g. bits 13, 14 and 15 in parameter "P-0-4077, Field bus: Control word") or bits 0 and 1 in parameter "P-0-4068, Field bus: Control word IO" should be reset in the control unit.

Field Bus Control Word and Field Bus Status Word

For this profile type, the field bus control word and status word are preset by Rexroth and the user cannot change them. If freely configurable control and status bits are required, the signal control word or signal status word has to be configured in the cyclic channel in addition to the available field bus status word or field bus control word.

See Parameter Description "S-0-0144, Signal status word"

See Parameter Description "S-0-0145, Signal control word"

With field bus drives, the parameters "P-0-0116, Device control: Control word" and "P-0-0115, Device control: Status word" are only used for diagnostic purposes. The actual control and status information is contained in the parameters "P-0-4077, Field bus: Control word" and "P-0-4078, Field bus: Status word". These parameters are always an inherent part of the real-time channel.

See also "Device Control and State Machine"

Exemplary Configurations

General Information

All of the following examples of configuration refer to the freely configurable mode (P-0-4084 = 0xFFFE). This mode provides the highest degree of flexibility and the highest number of possibilities to use the available drive functions of the field bus master communication.

Velocity Control

Features/Settings

- "Velocity control" must have been set as the primary operation mode in parameter S-0-0032 (see also description of the operation mode "velocity control").
- Via the field bus, the contents of parameter "S-0-0036, Velocity command value" are cyclically transmitted in the command value data channel and the contents of "S-0-0040, Velocity feedback value", "S-0-0051, Position feedback value 1" and "S-0-0390, Diagnostic message number" are cyclically transmitted in the actual value data channel.
- The Rexroth-specific definitions for the field bus control and status words are applying (see also section "Freely Configurable Mode (IndraDrive Profile Type)"). Some bits in the parameters "P-0-4077, Field bus: Control word" and "P-0-4078, Field bus: Status word" are irrelevant for this configuration (or operation mode).
- The length of the cyclic data channel has been defined with:
  - P-0-4082 = 14 bytes

– P-0-4071 = 6 bytes

Structure of the Real-Time Channel

In the real-time channel of the field bus, the velocity data configured in parameter "P-0-4081, Field bus: Config. list of cyclic command value data ch." are transmitted from master to drive; the data configured in parameter "P-0-4080, Field bus: Config. list of cyclic actual value data ch." are transmitted from drive to master.

Data direction	Parameters	Format
Master → slave	P-0-4077, Field bus: Control word	u16 (1 word)
	S-0-0036, Velocity command value	i32 (2 words)
Slave → master	P-0-4078, Field bus: Status word	u16 (1 word)
	S-0-0040, Velocity feedback value	i32 (2 words)
	S-0-0051, Position feedback value 1	i32 (2 words)
	S-0-0390, Diagnostic message number	u32 (2 words)

Tab. 4-17: Structure of the Real-Time Channel in Velocity Control (and Freely Configurable Mode)

Data direction	Word1	Word2	Word3	Word4	Word5	Word6	Word7
Master → slave	P-0-4077	S-0-0036 (H)	S-0-0036 (L)				
Slave → master	P-0-4078	S-0-0040 (H)	S-0-0040 (L)	S-0-0051 (H)	S-0-0051 (L)	S-0-0390 (H)	S-0-0390 (L)

Tab. 4-18: Content and Order of Data in Real-Time Channel in Velocity Control (and Freely Configurable Mode)

Drive-internal interpolation

Features/Settings

- "Drive-internal interpolation, encoder 1, lagless" must have been set as the primary operation mode in parameter "S-0-0032, Primary operation mode" (see also description of the operation mode "drive-internal interpolation").
- Via the field bus, the contents of parameters "S-0-0258, Target position" and "S-0-0259, Positioning velocity", as well as "S-0-0051, Position feedback value 1" and "S-0-0040, Velocity feedback value", are cyclically transmitted.

  → The configuration of P-0-4081 or P-0-4080 has to be adjusted accordingly!
- The Rexroth-specific definitions for the field bus control and status words are applying (see also section "Freely Configurable Mode (IndraDrive Profile Type)"). Some bits in the parameters "P-0-4077, Field bus: Control word" and "P-0-4078, Field bus: Status word" are irrelevant for this configuration (or operation mode).
- The length of the cyclic data channel has been defined with:
  - P-0-4082 = 14 bytes
  - P-0-4071 = 10 bytes

☞ To use the functional expansion (switching absolute/relative) of the "drive-internal interpolation" mode, it is necessary to configure "S-0-0282, Positioning command value" instead of "S-0-0258, Target position" in the list parameter P-0-4081!

Structure of the Real-Time Channel

In the real-time channel of the field bus, the positioning data configured in parameter "P-0-4081, Field bus: Config. list of cyclic command value data ch." are transmitted from master to drive; the positioning data configured in parameter "P-0-4080, Field bus: Config. list of cyclic actual value data ch." are transmitted from drive to master.

Data direction	Parameters	Format
Master → slave	P-0-4077, Field bus: Control word	u16 (1 word)
	S-0-0258, Target position	i32 (2 words)
	S-0-0259, Positioning velocity	i32 (2 words)
Slave → master	P-0-4078, Field bus: Status word	u16 (1 word)
	S-0-0051, Position feedback value 1	i32 (2 words)
	S-0-0040, Velocity feedback value	i32 (2 words)
	S-0-0390, Diagnostic message number	u32 (2 words)

Tab. 4-19: Structure of the Real-Time Channel in Drive-Internal Interpolation (and Freely Configurable Mode)

Data direction	Word1	Word2	Word3	Word4	Word5	Word6	Word7
Master → slave	P-0-4077	S-0-0258 (H)	S-0-0258 (L)	S-0-0259 (H)	S-0-0259 (L)		
Slave → master	P-0-4078	S-0-0051 (H)	S-0-0051 (L)	S-0-0040 (H)	S-0-0040 (L)	S-0-0390 (H)	S-0-0390 (L)

Tab. 4-20: Content and Order of Data in Real-Time Channel in Drive-Internal Interpolation (and Freely Configurable Mode)

Drive-controlled positioning

Features/Settings

- "Drive-controlled positioning, encoder 1, lagless" must have been set as the primary operation mode in parameter "S-0-0032, Primary operation mode" (see also description of the operation mode "drive-controlled positioning").
- The Rexroth-specific definitions for the field bus control and status words are applying (see also section "Freely Configurable Mode (IndraDrive Profile Type)").
- By configuring the content of "S-0-0282, Positioning command value" as a cyclic command value, the bits 0, 3, 4 in "P-0-4077, Field bus: Control word" can be used to directly switch between relative to absolute positioning (functionally compatible with position target setting).
- In this configuration, a drive functionality is achieved which corresponds to the position target setting of DRIVECOM (functionally compatible).

Structure of the Real-Time Channel

In the real-time channel of the field bus, the positioning data configured in parameter "P-0-4081, Field bus: Config. list of cyclic command value data ch." are transmitted from master to drive; the positioning data configured in parameter "P-0-4080, Field bus: Config. list of cyclic actual value data ch." are transmitted from drive to master.

Data direction	Parameters	Format
Master → slave	P-0-4077, Field bus: Control word	u16 (1 word)
	S-0-0282, Positioning command value	i32 (2 words)
	S-0-0259, Positioning velocity	i32 (2 words)

Data direction	Parameters	Format
Slave → master	P-0-4078, Field bus: Status word	u16 (1 word)
	S-0-0051, Position feedback value 1	i32 (2 words)
	S-0-0040, Velocity feedback value	i32 (2 words)
	S-0-0390, Diagnostic message number	u32 (2 words)

Tab. 4-21: Structure of the Real-Time Channel in Drive-Controlled Positioning (and Freely Configurable Mode)

Data direction	Word1	Word2	Word3	Word4	Word5	Word6	Word7
Master → slave	P-0-4077	S-0-0282 (H)	S-0-0282 (L)	S-0-0259 (H)	S-0-0259 (L)		
Slave → master	P-0-4078	S-0-0051 (H)	S-0-0051 (L)	S-0-0040 (H)	S-0-0040 (L)	S-0-0390 (H)	S-0-0390 (L)

Tab. 4-22: Content and Order of Data in Real-Time Channel in Drive-Controlled Positioning (and Freely Configurable Mode)

Using the Signal Control Word and the Signal Status Word

By using the parameters "S-0-0145, Signal control word" and "S-0-0144, Signal status word", the user has the option to freely configure control and status bits in the drive which are also transmitted along with the field bus control word and field bus status word in real time via the field bus.

See also "Configurable Signal Control Word" and "Configurable Signal Status Word"

Features

- By using the parameters S-0-0144 and S-0-0145, there are 16 more freely configurable control and status bits available.
- Thus, you can, for example, start commands that are contained in parameter "S-0-0399, IDN-list of configurable data in signal control word" (see "Configurable Signal Control Word").
- It is possible to read any bit in any parameter (see "Configurable Signal Status Word").

Settings

The following settings are required:

- To configure the bit lists, the list parameters S-0-0026 (for "S-0-0144, Signal status word") and S-0-0027, S-0-0329 (for "S-0-0145, Signal control word") can be used.
- To use the function, select profile type "freely configurable mode" (P-0-4084 = 0xFFFE).
- Set "drive-controlled positioning, encoder 1, lagless", for example, in parameter "S-0-0032, Primary operation mode".
- Parameterize the configuration lists P-0-4080 and P-0-4081 as follows:

Structure of the Real-Time Channel

In the real-time channel of the field bus, the positioning data configured in parameter "P-0-4081, Field bus: Config. list of cyclic command value data ch." are transmitted from master to drive; the positioning data configured in parameter "P-0-4080, Field bus: Config. list of cyclic actual value data ch." are transmitted from drive to master.

Data direction	Parameters	Format
Master → slave	P-0-4077, Field bus: Control word	u16 (1 word)
	S-0-0282, Positioning command value	i32 (2 words)
	S-0-0259, Positioning velocity	i32 (2 words)
	S-0-0145, Signal control word	u16 (1 word)

Data direction	Parameters	Format
Slave → master	P-0-4078, Field bus: Status word	u16 (1 word)
	S-0-0051, Position feedback value 1	i32 (2 words)
	S-0-0040, Velocity feedback value	i32 (2 words)
	S-0-0390, Diagnostic message number	u32 (2 words)
	S-0-0144, Signal status word	u16 (1 word)

Tab. 4-23: Structure of the Real-Time Channel when Using Signal Control Word and Signal Status Word (and Freely Configurable Mode)

Data direction	Word1	Word2	Word3	Word4	Word5	Word6	Word7	Word8
Master → slave	P-0-4077	S-0-0282 (H)	S-0-0282 (L)	S-0-0259 (H)	S-0-0259 (L)	S-0-0145		
Slave → master	P-0-4078	S-0-0051 (H)	S-0-0051 (L)	S-0-0040 (H)	S-0-0040 (L)	S-0-0390 (H)	S-0-0390 (L)	S-0-0144

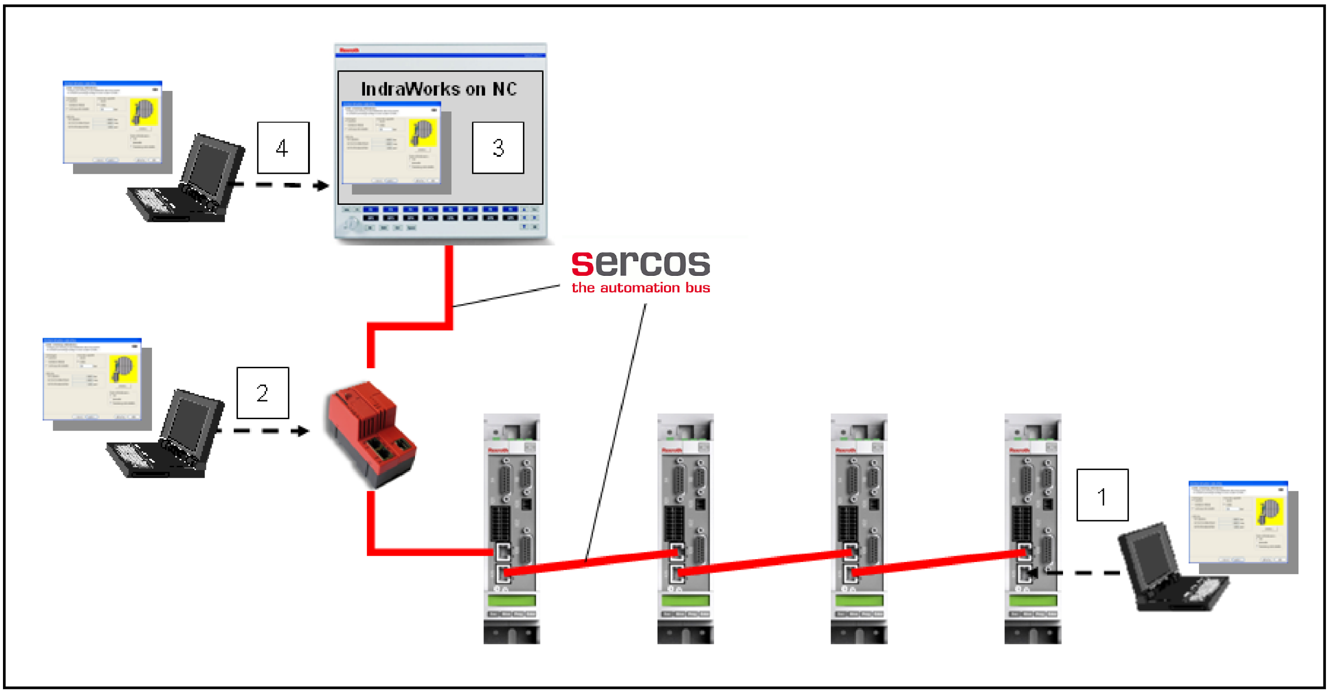
Tab. 4-24: Content and Order of Data in Real-Time Channel when Using Signal Control Word and Signal Status Word (and Freely Configurable Mode)

See also Parameter Description "P-0-4074, Field bus: Data format"

4.6 sercos

4.6.1 Brief Description

Topology



1	Engineering via inactive sercos port of a node at the bus
2	Engineering via optional sercos netSWITCH
3	Engineering via IndraWorks on sercos control
4	Engineering via routing using control unit (if routing control is available)

Fig. 4-22: Engineering Options via sercos

It is possible to operate IndraDrive controllers with a MultiEthernet interface (ET) or the optional module "sercos" as sercos master communication. Via these modules it is possible to exchange real-time data with a sercos master.

We distinguish the following communication channels:

- **Cyclic data channel**

  → Channel for cyclic transmission of useful data (**process data**) in real time

- **Acyclic data channel** (service channel)

  → Channel for acyclic transmission of useful data (**service data**)

- **Non-real time channel (NRT channel)**

  → Defined time slot within the cycle time for transmission of standard Ethernet telegrams

General Features

- Transmission rate 100 Mbit/s
- Cyclical data exchange of command values and actual values in equal time intervals
- Data transmission via Ethernet cable (CAT5e-copper)
- Service channel for parameterization and diagnostics
- Free configuration of telegram contents
- Synchronization between time command value takes effect and measurement starting time of the actual values for all devices on a ring
- Overall synchronization of all connected devices

Firmware-Specific Features

Master Communication

			BASIC MPB-18VRS	ECONOMY MPE-18VRS	ADVANCED MPC-18VRS	MULTIAXIS MPM-18VRS
Position controller cycle	$T_{Position}$	µs	**250/500**	**1000**	**250**	**500**
Master communication cycle time	min	µs	**250/500**	**2000**	**250**	**500**
	max	ms	65	65	65	65
Motion data for MDT/AT respectively [excl. 2 byte connection control word (C_Con)]	$T_{sercos}=T_{position}$	Byte	**26**	**26**	**26**	**26**
		IDN	12	12	12	12
	$T_{sercos}>T_{position}$	Byte	50	50	50	50
		IDN	16	16	16	16
CC connections [excl. 2 byte connection control word (C_Con)]		Byte	12	12	12	12
		IDN	2	2	2	2
Safety connections		Byte	10	10	10	10
		IDN	SMP container	SMP container	SMP container	SMP container

Tab. 4-25: sercos Key Data

- IndraDrive supports 6 connections, 2 between control unit and drive and 4 CC connections for direct communication with one or several other nodes

☞ In this firmware version, CC connections or connections for exchanging safety data have been implemented according to the status of the sercos specification (SCP V1.1.2). Regarding use and configuration, see Technical Note "TN_332_CC-Verbindungen_SERCOS3_EIDN.pdf"

☞ The number of configurable bytes in consumer/producer connections depends on the relation of the position cycle time (P-0-0556, bit 2) to the sercos cycle time:

- sercos cycle time = position cycle time → max. length 26 bytes / 12 IDNs
- sercos cycle time > position cycle time → max. length 50 bytes / 16 IDNs

The NRT channel is only possible, if a time slot of more than 125 µs is available.

Hardware Requirements

Optional Module with sercos Communication

IndraDrive Cs	
ECONOMY	HCS01.1E-W00xx-A-0x-E-S3-EC-NN-xx-NN-FW

Tab. 4-26: Control Section Design for "sercos interface"

Optional Module with MultiEthernet Communication

IndraDrive Cs	
ADVANCED	HCS01.1E-W00xx-A-0x-A-CC-EC-xx-xx-NN-FW
IndraDrive Mi	
Distributed servo drive	KSM02.1B-xxxC-xxN-xx-Hxx-ET-NN-D7-xx-FW

Distributed drive controller	KMS02.1B-Axxx-P-D7-ET-xxx-xx-xx-FW
Drive connection box	KCU02.1N-ET-ET*-025-NN-N-NN-NN
IndraDrive control sections	
BASIC single-axis	CSB02.1x-ET-EC-xx-xx-xx-NN-FW
BASIC double-axis	CDB02.1B-ET-EC-EC-xx-xx-xx-xx-NN-FW
ADVANCED single-axis	CSH02.1B-CC-EC-xx-xx-xx-NN-FW

* See central standard ZN 41001-021

Tab. 4-27: Control Section Design for MultiEthernet

Axis Addressing

The axis address can be set directly using the control panel of the drive. This can be done using the so-called Easy Menu (see also "Standard Control Panel").

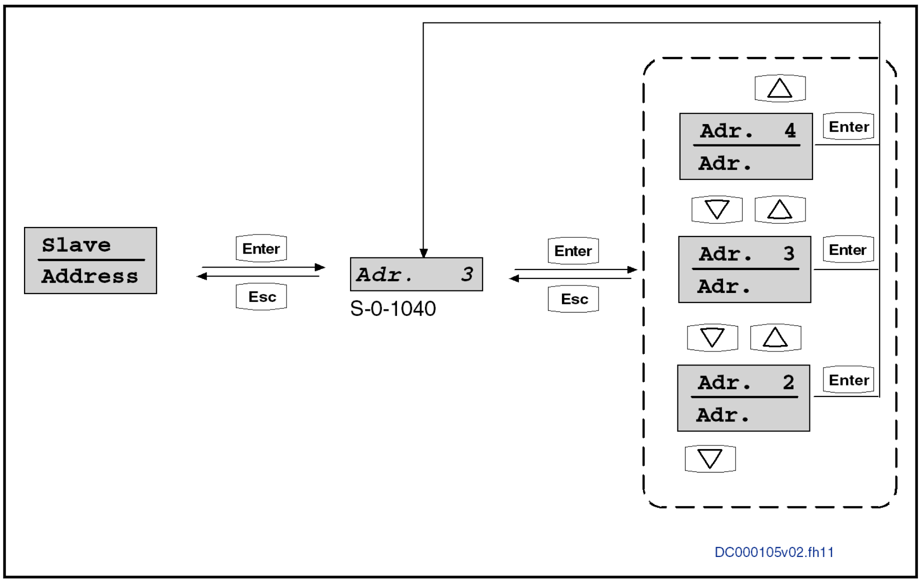


Fig. 4-23: Submenu for "Slave___" "_Addresss"

Alternatively, the address can be directly changed or displayed using the parameter "S-0-1040, Drive address of master communication". With sercos the address can be set remotely and automatically via the master using remote address assignment. This function must be supported by the master, the CCD master, for example. On this topic, see chapter "Cross Communication (CCD)". The topology address of the drive determined in communication phase 0 (CP0) is displayed in parameter "S-0-1042, sercos: Topology index".

The axis address is always displayed in the left side of the standard display of the control panel.

Pertinent Parameters

Specific parameters for sercos communication:

- S-0-1000, sercos: SCP Type & Version
- S-0-1002, sercos: Communication Cycle time (tScyc)
- S-0-1003, sercos: Allowed MST losses
- S-0-1005, sercos: Minimum feedback processing time (t5)
- S-0-1006, sercos: AT0 transmission starting time (t1)
- S-0-1007, sercos: Feedback acquisition capture point (t4)
- S-0-1008, sercos: Command value valid time (t3)
- S-0-1009, sercos: Device Control (C-Dev) offset in MDT

- S-0-1010, sercos: Lengths of MDTs
- S-0-1011, sercos: Device Status (S-Dev) offset in AT
- S-0-1012, sercos: Length of ATs
- S-0-1013, sercos: SVC offset in MDT
- S-0-1014, sercos: SVC offset in AT
- S-0-1015, sercos: Ring delay
- S-0-1016, sercos: Slave delay (P/S)
- S-0-1017, sercos: NRT transmission time
- S-0-1019, Master comm. engineering over IP: MAC address
- S-0-1020, Master comm. engineering over IP: IP address
- S-0-1021, Master comm. engineering over IP: Network mask
- S-0-1022, Master comm. engineering over IP: Gateway address
- S-0-1023, sercos: SYNC jitter
- S-0-1024, C5300 sercos: SYNC delay measuring procedure command
- S-0-1026, sercos: Version of communication hardware
- S-0-1027.0.1, sercos: Requested MTU
- S-0-1027.0.2, sercos: Effective MTU
- S-0-1028, sercos: Error counter MST-P/S
- S-0-1031, sercos: Signal assignment TSx
- S-0-1034, sercos: PHY error counter Port1 and Port2
- S-0-1035, sercos: Error counter Port1 & Port2
- S-0-1035.0.1, sercos: Error counter P&S
- S-0-1036, sercos: Inter Frame Gap
- S-0-1037, sercos: Slave Jitter
- S-0-1040, Drive address of master communication
- S-0-1041, sercos: AT Command value valid time (t9)
- S-0-1042, sercos: Topology index
- S-0-1044, sercos: Device Control (C-Dev)
- S-0-1045,
- S-0-1046, sercos: Slave addresses of the device
- S-0-1047, sercos: Maximum Consumer Activation Time
- S-0-1050.x.1, sercos Connection: Connection setup
- S-0-1050.x.2, sercos Connection: Connection number
- S-0-1050.x.3, sercos Connection: Telegram assignment
- S-0-1050.x.4, sercos Connection: Max. length of connection
- S-0-1050.x.5, sercos Connection: Current length of connection
- S-0-1050.x.6, sercos Connection: Configuration list
- S-0-1050.x.7, sercos Connection: Connection class
- S-0-1050.x.8, sercos Connection: Connection control (C-Con)
- S-0-1050.x.9, sercos Connection: State
- S-0-1050.x.10, sercos Connection: Producer cycle time
- S-0-1050.x.11, sercos Connection: Allowed data losses

- S-0-1050.x.12, sercos Connection: Error counter data losses
- S-0-1050.x.20, sercos Connection: IDN allocation of real-time bit
- S-0-1050.x.21, sercos Connection: Bit allocation of real-time bit
- S-0-1051, sercos Connection: Image of connection setups
- S-0-1060.x.1, sercos Connectiontype: Default configuration
- S-0-1060.x.2, sercos Connectiontype: Configuration mask
- S-0-1060.x.3, sercos Connectiontype: Max. quantity of conn. Capability
- S-0-1060.x.4, sercos Connectiontype: Max. Length of Connection
- S-0-1060.x.6, sercos Connectiontype: Configurable IDNs
- S-0-1060.x.7, sercos Connectiontype: Min. processing time
- S-0-1060.x.10, sercos Connectiontype: Minimum producer cycle time

Pertinent Diagnostic Messages

- A0000 Communication phase 0
- A0001 Communication phase 1
- A0002 Communication phase 2
- A0003 Communication phase 3
- A0008 sercos: NRT-Mode
- E4020 sercos: Ring interruption (FF to LF)
- F4001 Sync telegram failure
- F4002 RTD telegram failure
- F4003 Invalid communication phase shutdown
- F4004 Error during phase progression
- F4005 Error during phase regression
- F4006 Phase switching without ready signal
- F4017 sercos: Incorrect sequence during phase switch
- F4020 sercos: Cable break (L+F to NRT)

4.6.2 Functional Description

sercos Diagnostics LED

In IndraDrive a diagnostics LED is realized according to the sercos specification, see also section "Diagnostic and Status Messages".

Blinking code												Function	P
												No sercos Telegrams (NRT mode)	6
Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	CP0	6
Orange	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	CP1	6
Orange	Green	Orange	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	CP2	6
Orange	Green	Orange	Green	Orange	Green	Orange	Orange	Orange	Orange	Orange	Orange	CP3	6
Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	CP4	6

Master Communication

Blinking code												Function	P
Green		Green		Green		Green		Green		Green		CPx →Loop-back	5
Red	Orange	Red	Orange	Red	Orange	Red	Orange	Red	Orange	Red	Orange	Application-related C1D	4
Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	S-Dev.Bit15 (MST warning)	3
Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	C1D of Communication	2
Orange		Orange		Orange		Orange		Orange		Orange		C-Dev.Bit15 (Identification)	1
Red		Red		Red		Red		Red		Red		Internal watchdog has triggered	0

P Display priority (1 = highest)
Black LED is off
CP Communication phase

Tab. 4-28: Supported Blinking Codes and Their Significance to the Diagnostic LED Correspond to the sercos Specification

4.6.3 sercos Timing

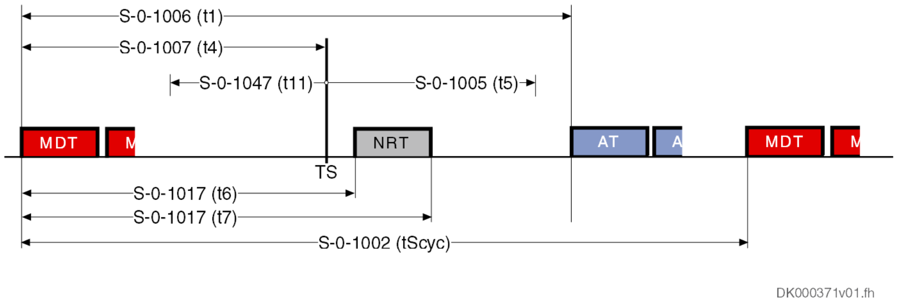
In IndraDrive, the process data are processed in a synchronous way. The characteristic of synchronous processing is that a master, via timing parameters, can exactly define the time of actual value determination (and command value acceptance). For the calculation, IndraDrive via parameters makes available its time conditions. The master sets the point of time of processing as TS (S-0-1007, sercos: Feedback acquisition capture point (t4)).

In the parameter "S-0-1005, sercos: Minimum feedback processing time (t5)", a slave specifies its maximum processing time (tmp-P) as a producer.

Rule: Process data (actual values) are transmitted in the AT block for which the maximum processing time is **completely** within the beginning of the AT block and the synchronization time TS.

In the parameter "S-0-1047, sercos: Maximum Consumer Activation Time", a slave specifies its maximum activation time (tmp-C) as a consumer.

Rule: Process data (command values) are taken from the telegram block (MDT and/or AT) for which the maximum activation time is **completely** within its telegram block end and the synchronization time TS.



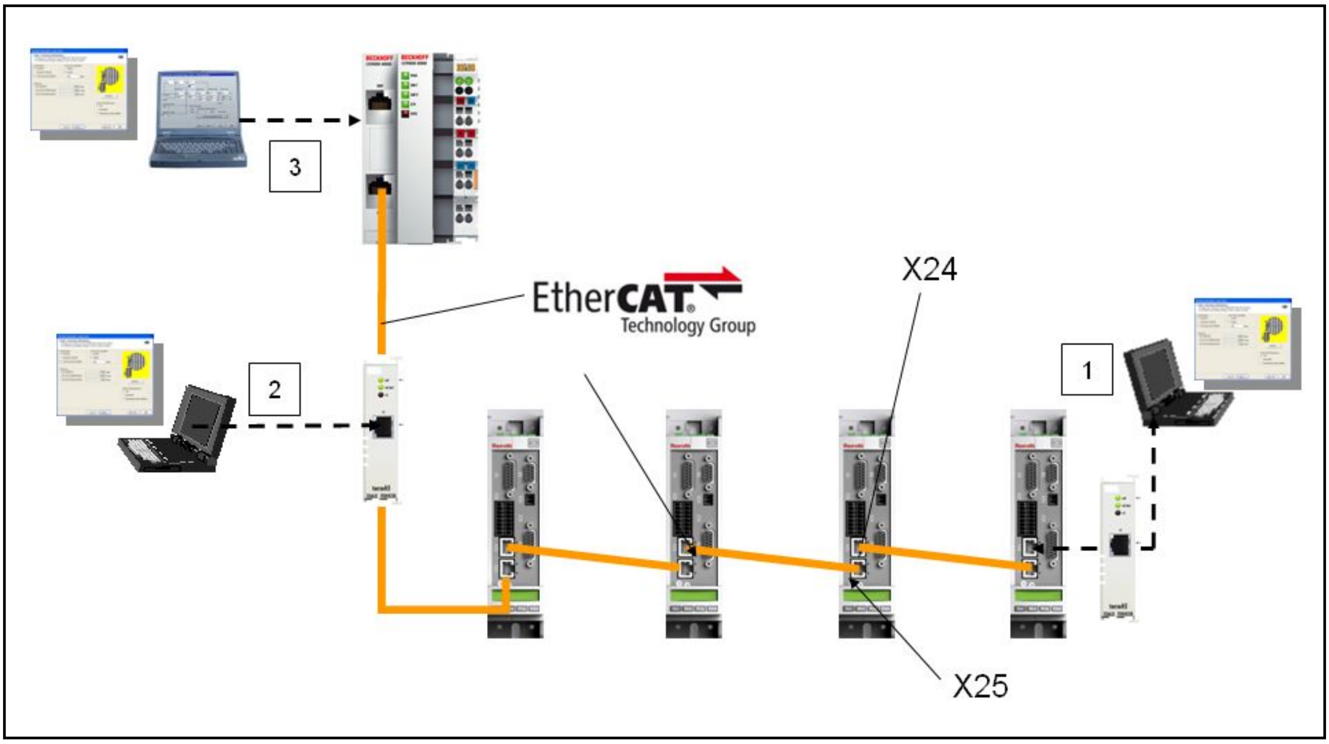
MDT	Master Data Telegram
AT	Response Telegram
NRT	Non Real Time
TS	Synchronization time
S-0-1002	sercos: sercos cycle time (tScyc)
S-0-1005	sercos: Minimum time between t4 and t1 (t5)
S-0-1006	sercos: AT0 transmission starting time (t1)
S-0-1007	sercos: Feedback acquisition starting time (t4)
S-0-1047	sercos: Maximum consumer processing time
S-0-1017	sercos: NRT transmission starting time; Start (t6)
S-0-1017	sercos: NRT transmission starting time; End (t7)

Fig. 4-24: Telegrams

4.7 EtherCAT®

4.7.1 Brief Description

Topology



1 Engineering using EoE via optional Ethernet switch port
2 Engineering using EoE via optional Ethernet switch port
3 Engineering using ADS interface via third-party control or Engineering using EoE (control includes switch port)

Fig. 4-25: Engineering Options with EtherCAT®

IndraDrive controllers with MultiEthernet interface (ET) can be operated as EtherCAT® master communication. Via these modules it is possible to exchange real-time data with an EtherCAT® master. The "Servo Drive Profile over EtherCAT® (SoE)", which is based on the drive profile from the SERCOS II specification, is supported.

The following communication channels are distinguished:

- **Cyclic data channel** (process data)

  → Data container for cyclic transmission of useful data (**process data**) in real time
- **Acyclic data channel** (service channel)

  → EtherCAT® mailbox method for acyclic transmission of useful data (**service data**)
- **Non-real time channel** [Ethernet over EtherCAT® (EoE)]

  → Transmission of Ethernet telegrams via an EtherCAT® mailbox method [Ethernet over EtherCAT® (EoE)]

General Features

- Transmission rate 100 Mbit/s
- Data transmission via Ethernet cable (CAT5e-copper)
- Topology: "Line"
- Access to 16 bit sercos parameters of the drive via "SoE" protocol ("Servo Drive Profile over EtherCAT®" protocol)
- EtherCAT® mailbox method for parameterization and diagnostics
- Cyclic data exchange of command values and actual values

- Free configuration of telegram contents
- Max. length of the configurable MDT/AT data, 15 IDNs with max. 48 bytes; if bus clock = position clock, the max. length is reduced by half to 24 bytes
- Cycle time: Min. 500 µs (multiples of the position clock can be set)
- Optional synchronization via "distributed clock synchronization" (exact adjustment of distributed clocks)
- Synchronization between time command value takes effect and measurement starting time of the actual values for all drives on a ring when using Distributed Clocks
- Overall synchronization of all connected drives to the master when using Distributed Clocks
- Non-synchronous operation without synchronization via "Distributed Clock" is possible
- "CAN over EtherCAT®" (CoE) is not supported
- Only released in conjunction with "Beckhoff-TwinCAT"

Hardware Requirements

The master communication "EtherCAT®" requires the following control section design:

IndraDrive Cs	
BASIC	HCS01.1E-W00xx-A-0x-B-ET-EC-xx-xx-NN-FW
ADVANCED	HCS01.1E-W00xx-A-0x-A-CC-EC-ET-xx-NN-FW
IndraDrive Mi	
Distributed servo drive	KSM02.1B-xxxC-xxN-xx-Hxx-ET-NN-D7-xx-FW
Distributed drive controller	KMS02.1B-Axxx-P-D7-ET-xxx-xx-xx-FW
Electronic control system	KCU02.1N-ET-ET*-025-NN-N-NN-NN
IndraDrive control sections	
Basic control section - single-axis	CSB02.1x-ET-EC-xx-xx-xx-NN-FW
Basic control section - double-axis	CDB02.1B-ET-EC-EC-xx-xx-xx-xx-NN-FW
Advanced control section - single-axis	CSH02.1B-CC-ET-xx-xx-NN-FW

* See central standard ZN 41001-021

Tab. 4-29: Control Section Design for MultiEthernet

Axis Addressing

The axis address can be set directly using the control panel of the drive. This can be done using the so-called Easy Menu, see also "Standard Control Panel". Alternatively, the address can be directly changed or displayed using the parameter "P-0-4089.0.3, Device Address". The topology address of the drive is assigned by the master and displayed in parameter "P-0-4089.0.4, Active Device Address", and cannot be changed. With EtherCAT®, this address is used as the "Device Identification Value / 2nd Address".

Pertinent Parameters

- P-0-4089.0.3, Device Address
- P-0-4089.0.4, Active Device Address
- S-0-0001, NC cycle time (TNcyc)

- S-0-0002, sercos cycle time (TScyc)
- S-0-0005, Minimum feedback acquisition time (T4min)
- S-0-0007, Feedback acquisition starting time (T4)
- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0016, Configuration list of AT
- S-0-0024, Configuration list of MDT
- S-0-0029, MDT error counter
- S-0-0097, Mask class 2 diagnostics
- S-0-0098, Mask class 3 diagnostics
- S-0-0134, Master control word
- S-0-0135, Drive status word
- S-0-0185, Length of the configurable data record in the AT
- S-0-0186, Length of the configurable data record in the MDT
- S-0-0187, List of configurable data in the AT
- S-0-0188, List of configurable data in the MDT
- S-0-0301, Allocation of real-time control bit 1
- S-0-0303, Allocation of real-time control bit 2
- S-0-0305, Allocation of real-time status bit 1
- S-0-0307, Allocation of real-time status bit 2
- S-0-0413, Bit number allocation of real-time control bit 1
- S-0-0414, Bit number allocation of real-time control bit 2
- S-0-0415, Bit number allocation of real-time status bit 1
- S-0-0416, Bit number allocation of real-time status bit 2

Pertinent Diagnostic Messages

- C0101 Invalid parameters (-> S-0-0021)
- C0104 Config. IDN for MDT not configurable
- C0105 Maximum length for MDT exceeded
- C0106 Config. IDNs for AT not configurable
- C0107 Maximum length for AT exceeded
- C0108 Time slot parameter > sercos cycle time
- C0112 TNcyc (S-0-0001) or TScyc (S-0-0002) error
- C0113 Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error
- C0114 T4 > TScyc (S-0-0002) - T4min (S-0-0005)
- C0201 Invalid parameters (->S-0-0423)
- C0299 Configuration changed. Restart
- E4005 No command value input via master communication
- F4002 RTD telegram failure
- F4009 Bus failure

4.7.2 Notes on Commissioning

Rexroth provides a commissioning manual which explains the essential steps for commissioning an IndraDrive with EtherCAT® at BECKHOFF TwinCAT (IndraDrive with EtherCAT®, example of TwinCAT.pdf).

When setting up an EtherCAT® network with IndraDrive Cs controllers, observe the following points:

- Use slot X25_IN as an input
- Use slot X24_OUT as an output

Diagnostic LEDs

- The LED H24 at the drive controller is used to diagnose the EtherCAT® communication.
- The PHY-LEDs on the RJ45 connectors of the master communication module are used to diagnose the physical EtherCAT® connection.

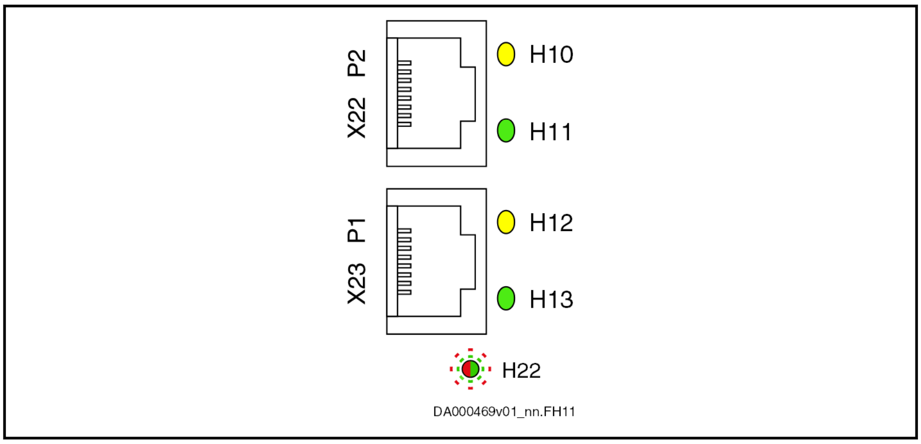


Fig. 4-26: ET, Display Elements

Display elements of optional module ET:

- Two LEDs (H10, H11 and H12, H13) at each connection point
- One bicolor LED (H24)

The significance of the LED displays depends on the field bus system.

LED	Significance	Color / flashing pattern	Description
H10, H12	None	-	With EtherCAT, these LEDs have no function
H11, H13	Link	Off	No connection to the network
		Permanently lit green	Connection to network available, but no telegram exchange (EtherCAT bus inactive)
		Flickering green	Connection to network available with telegram exchange (EtherCAT bus active)

Master Communication

LED	Significance	Color / flashing pattern	Description
H24	Status INIT	Off	• Cyclic process data and acyclic data channel are not transmitted • No error
	Status PRE-OPERATIONAL	GN -- 1) Flashing green	Acyclic data channel is transmitted
	Status SAFE-OPERATIONAL	GN -- -- -- -- -- 1) Green, one LED lighting up	Acyclic data channel is transmitted
	Status OPERATIONAL	Permanently lit green	Cyclic process data and acyclic data channel are transmitted
	Configuration error	RD -- 1) Flashing red	General EtherCAT configuration error
	Synchronization error	RD -- -- -- -- -- 1) Red, one LED lighting up	• The drive controller has not been synchronized to the EtherCAT master • Communication error of the drive controller
	Timeout - watchdog	RD -- RD -- -- -- -- -- 1) Red, two LEDs lighting up	• Timeout during monitoring of the cyclic process data • Watchdog of the EtherCAT master

1) Flashing pattern: One square corresponds to a duration of 200 ms; the arrow marks the end of a cycle; abbreviations on the squares: GN = LED permanently lit green, RD = LED permanently lit red, -- = LED is off

Tab. 4-30: EtherCAT® Display Elements

☞ The yellow PHY LED is not used with EtherCAT®

Pulse-Pause Relation of the Diagnostic LEDs

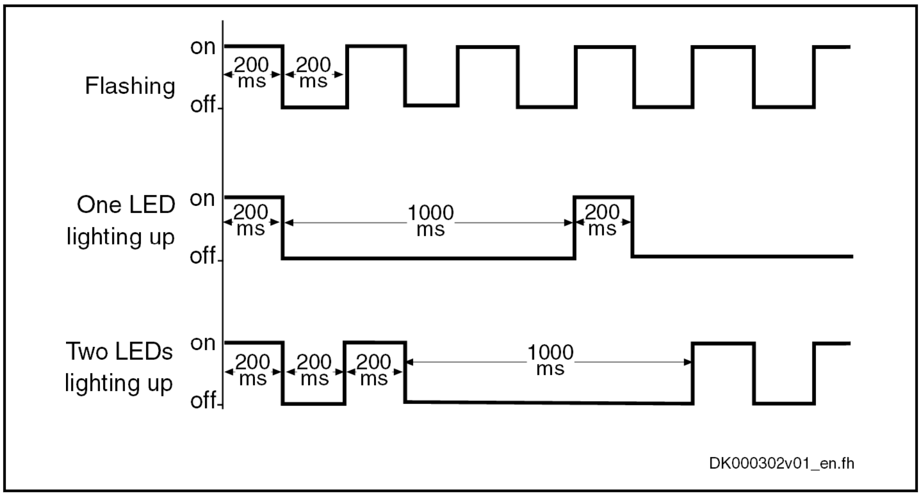
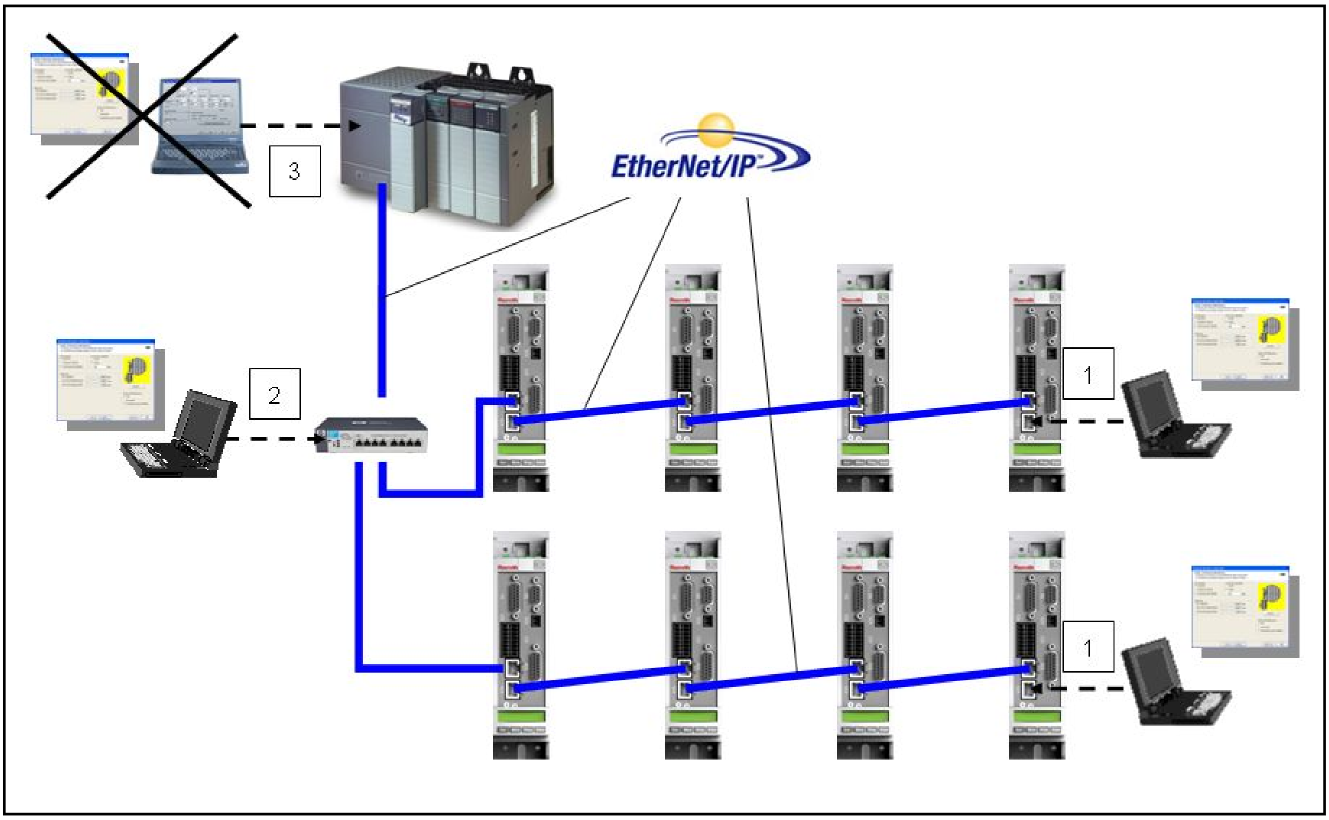


Fig. 4-27: Pulse-Pause Relation

4.8 EtherNet/IP(TM) interface

4.8.1 Brief Description

Topology



1	Engineering via inactive EtherNet/IP™ port of a node at the bus
2	Engineering using optional industrial Ethernet switch
3	Engineering using third-party control is not possible

Fig. 4-28: EtherNet/IP(TM) Topology

IndraDrive controllers with MultiEthernet interface can be operated as EtherNet/IP™ master communication. This module can be used to exchange real-time data with an EtherNet/IP™ scanner.

Real-time data can be transmitted via this interface using an I/O connection (Class 1 connection).

To achieve high system flexibility, all data are accessible via objects. With Ethernet/IP™ interfaces, these objects can be addressed via class, instance and attribute. Some of these objects can be assigned to the I/O connection as real-time data and thus be cyclically transmitted. There is also the option of transmitting via "Explicit Message", but no objects defined in the real-time channel (P-0-4081) may be written by the master via "Explicit Message".

Features

- Transmission rate 100 Mbit/s (full duplex)
- Data transmission via Ethernet cable (CAT5e-copper)
- Topologies: "Star", "line" (with integrated cut through switch)
- Autonegotiation is supported; the transmission rate listed above is required
- Profile type is "Generic Device", specified in ODVA 2.0 (**O**pen **D**eviceNet **V**endors **A**ssociation)
- EtherNet/IP™ Level 2 server
- Cyclic exchange via "Ethernet/IP™ I/O messaging" (Class 1)
- Acyclic data exchange via "Ethernet/IP™ Unconnected Explicit Messaging" and "Explicit Messaging" (Class 3)
- The smallest supported cycle time (API → Actual Packet Interval) is 2 ms.
- Configurable cyclic data up to 15 parameters (incl. field bus control word and field bus status word) in both data directions (max. 48 bytes or 24 words)

☞

- It is recommended that the industrial Ethernet network not be coupled with a company network (office communications). (Alternatively, a Level 3 router can be used to connect the industrial Ethernet network to a company network.)
- It is recommended that only switches with cut through method be used for industrial Ethernet communication.
- It is recommended that a star topology with cable type AWG22 or shielded cables be used, particularly for cables that exit the control cabinet and for cables longer than 10 meters.

- Supported field bus profiles:
  - 0x0000: "No profile"
  - 0xFF82: I/O mode "positioning" with configurable real-time data
  - 0xFF92: I/O mode "preset velocity" with configurable real-time data
  - 0xFFFD: Freely configurable mode "Neutral operation modes"
  - 0xFFFE: Freely configurable mode

Hardware Requirements

The master communication "EtherNet/IP™" requires the following control section design:

IndraDrive Cs	
BASIC	HCS01.1E-W00xx-A-0x-B-ET-EC-xx-xx-NN-FW
ADVANCED	HCS01.1E-W00xx-A-0x-A-CC-EC-ET-xx-NN-FW
IndraDrive Mi	
Distributed servo drive	KSM02.1B-xxxC-xxN-xx-Hxx-ET-NN-D7-xx-FW
Distributed drive controller	KMS02.1B-Axxx-P-D7-ET-xxx-xx-xx-FW
Electronic control system	KCU02.1N-ET-ET*-025-NN-N-NN-NN
IndraDrive control sections	
Basic control section - single-axis	CSB02.1x-ET-EC-xx-xx-xx-NN-FW
Basic control section - double-axis	CDB02.1B-ET-EC-EC-xx-xx-xx-xx-NN-FW
Advanced control section - single-axis	CSH02.1B-CC-ET-xx-xx-NN-FW

* See central standard ZN 41001-021

Tab. 4-31: Control Section Design for MultiEthernet

Axis Addressing

With EtherNet/IP the master communication address is an IP address. It is set in "P-0-4089.0.13, Master communication: IP address".

☞ The device address set in "P-0-4089.0.3, Device Address" is applied to the parameter "P-0-4089.0.4, Active Device Address" after the device has been restarted. This address is shown on the display and is irrelevant for the EtherNet/IP communication!

Pertinent Parameters

- P-0-4073, Field bus: Diagnostic message
- P-0-4074, Field bus: Data format
- P-0-4075, Field bus: Watchdog
- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: Baud rate
- P-0-4088, Master communication: Drive configuration
- P-0-4089.0.2, Master communication: Device name
- P-0-4089.0.10, Master communication: MAC address device
- P-0-4089.0.13, Master communication: IP address
- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

Profile type parameters

Apart from mere communication parameters, we use parameters in conjunction with the profile types.

In this regard, see "Profile Types (with Field Bus Interfaces)"

Parameters for extended communication

We use additional parameters for extended communication.

See the following sections:

- "Configurable Signal Control Word"
- "Configurable Signal Status Word"

- "Multiplex channel"

Pertinent Diagnostic Messages

- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable
- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- C0299 Configuration changed. Restart
- E4005 No command value input via master communication
- E4006 Communication module overload
- E4011 Communication watchdog: Overload of cyclic communication
- F4009 Bus failure
- F4011 Communication watchdog: Overload of cyclic communication

4.8.2 Configuring the EtherNet/IP(TM) Slave

EDS File

For each EtherNet/IP™ device, it is necessary to have an EDS file (*.EDS) which contains the data required for operating the device on the field bus. When configuring bus masters which support the EDS file, this file is required for each node.

The EDS file for IndraDrive is an ASCII file with the name "IndraDrive_EIP_MPx18.EDS".

Setting the IP Address of the Slave

Setting is either made manually, in a menu-controlled way via the display or by means of the "IndraWorks" commissioning tool.

The IP address for the EtherNet/IP™ adapter is saved in parameter "P-0-4089.0.13, Master communication: IP address", the subnet mask in parameter "P-0-4089.0.14, Master communication: Network mask", and the gateway address in parameter "P-0-4089.0.15, Master communication: Gateway address".

> ☞ After the device has been restarted, the device address set in "P-0-4089.0.3 Device Address" is applied to the parameter "P-0-4089.0.4 Active Device Address". This address is shown on the display and is irrelevant for the EtherNet/IP communication!

> ☞ This IP address is only relevant to the communication with the scanner! For engineering (e.g. IndraWorks), the engineering address (S-0-1020, Master comm. engineering over IP: IP address) must be used.

Configuring the Cyclic Data

The parameters for configuring the cyclic data (P-0-4080 and P-0-4081) can contain a maximum of 15 elements each. The maximum length is limited to 24 words.

Setting options via "P-0-4076, Field bus: Process data - updating clock", min. 2 ms, max. 65 ms (can be set in steps of 1 ms).

Via the parameter "P-0-4076, Field bus: Process data - updating clock", you can set in which updating clock the data are applied from the MultiEthernet interface to the drive and vice versa.

For the configuration of cyclic data of a possible subordinate CCD system see also "Cross Communication (CCD)"

These parameters are set via the "IndraWorks" commissioning tool.

4.8.3 Specification of the EtherNet/IP(TM) Interface

With the EtherNet/IP^{TM} interface switched on, the drive works as a level 2 device. This means that the drive makes available one server each for implicit messages (Class 1) and explicit messages (Class 3). The explicit messages are limited to the standard objects.

The implemented EtherNet/IP^{TM} object directory contains the objects specified for a "Generic Device":

- Identity object (0x01)
- Message router object (0x02)
- Ethernet link object (0xF6)
- TCP/IP object (0xF5)
- Port object (0xF4)
- Connection manager object (0x06)
- Assembly object (0x04)

4.8.4 Cyclic Communication via the Process Data Channel (Class 1)

EtherNet/IP(TM) Connection Types

With an IndraDrive device as EtherNet/IP^{TM} slave, parameters can be cyclically transmitted via an I/O container. This can be done via an "Exclusive Owner Connection" (Transport-Class-1) or a "Listen Only Connection" (Transport-Class-1).

With the "Exclusive Owner Connection", the EtherNet/IP^{TM} input image is transmitted to the drive by means of "point-to-point connection". The output image can be transmitted by means of "point-to-point" or "multicast" connection.

With an already existing "Multicast-Exclusive Owner Connection", a second master can, with a "Listen Only Connection", read the EtherNet/IP^{TM} output image of the IndraDrive device. In this case, a "Heartbeat Connection Point" is used as Consuming Connection Point, and the same Connection Point as with the "Exclusive Owner Connection" is used as Producing Connection Point.

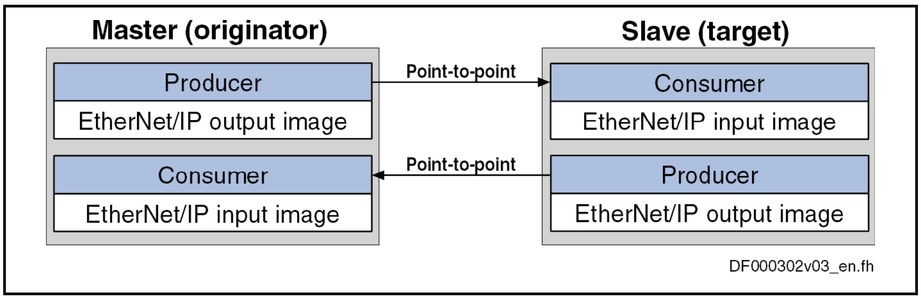


Fig. 4-29: EtherNet/IP(TM) Connection Type "Point-to-Point"

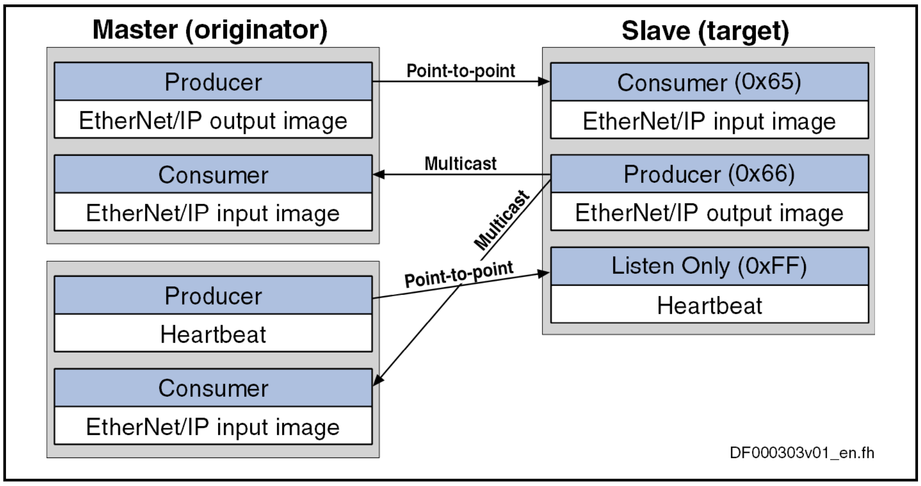


Fig. 4-30: EtherNet/IP(TM) Connection Type "Multicast"

For the cyclic I/O data channel ("implicit Message"), the drive makes available a consumer and producer, i.e. it consumes the command values from the master and produces the actual values for the master.

Communication in this case runs via a UDP protocol; the direction from master to slave is transmitted with unicast telegrams, the opposite direction is transmitted with multicast telegrams.

Characteristic of the Cyclic Data Transmission

Features

- The smallest cycle time IndraDrive supports (API → Actual Packet Interval) is 2 ms.
- The "Idle/Run Header" of the EtherNet/IP^{TM} interface is supported (32 bits). The header is not visible in the cyclic I/O image of the IndraDrive device. The reaction of the IndraDrive device to the Idle/Run Header is defined via the settings of the setting-up mode (easy startup mode).
- The consumer instance of the IndraDrive device monitors the cyclic transmission of the master output image via a so-called "TimeOut" time which the master determines when the connection is established.

The monitoring time is calculated according to the formula below:

$$t = TM \times API$$
$$TM = 2^{(TMV + 2)}$$

t Monitoring time (in ms)
TM TimeOut Multiplier
API Actual Packet Interval
TMV TimeOut Multiplier value

Fig. 4-31: Calculating the Monitoring Time in two Steps

Examples

TMV	TM	API (in ms)	t (in ms)
0	4	2	8
0	4	5	20
1	8	2	16
1	8	5	40
2	16	2	32

TMV	TM	API (in ms)	t (in ms)
3	32	2	64
4	64	5	320
2	16	10	160

Tab. 4-32: Exemplary Values for the Monitoring Time

In most of the configuration user interfaces it is possible to directly enter the "TimeOut Multiplier", the user then does not have to take the first formula into account.

Configuring the Cyclic Process Data

The cyclic channel is configured by parameterizing "P-0-4080, Field bus: Config. list of cyclic actual value data ch." and "P-0-4081, Field bus: Config. list of cyclic command value data ch.".

On the level of EtherNet/IP^{TM} communication, a static Output Assembly Instance (Class 4, instance 101) and a static Input Assembly Instance (Class 4, instance 102) are created in the cyclic channel. The data direction in this case is written from the master's point of view. If the parameter setting of P-0-4080 and P-0-4081 or the data length of a CCD slave is changed, new assembly instances are created during the transition from parameter mode (PM) to operating mode (OM). This results in a short interruption of communication.

Specific Features of Cross Communication (CCD) in System Mode

For communication via EtherNet/IP^{TM} with a CCD system, the configurable I/O data of the individual axes are copied one after the other to the data container of the assembly or removed. This means that the length of the assembly results from the sum of the individual lengths of the local axis and the CCD slave axes (see also "Cross Communication (CCD)").

4.8.5 Acyclic Parameter Access via "Explicit Message" (Class 3 / UCM)

General Information on Parameter Setting

To allow parameter setting via EtherNet/IP^{TM} interface, all IDN parameters can be reached via a manufacturer-specific class object with the corresponding instances for each IDN parameter. The IDN parameters can be addressed either via an "Unconnected Explicit Message" (UCM) or via a "Connected Explicit Message" (Class 3).

> The acyclic parameter access via "Explicit Message" (Class 3/UCM) only allows accessing IDN parameters, e.g. "P-0-4006 Positioning block target position". EIDN see also "Note on Parameter Access"

> It is not possible to parameterize the field bus control word via "Explicit Message". To allow axis control, the cyclic data channel must be used in the higher-level control unit in accordance with the specification "Class 1 Connection", or the corresponding logic must be programmed with permanent control in MLD. If the control unit does not have a "Class 1 Connection", axis control cannot take place without MLD.

Addressing

For EtherNet/IP communication, the objects are addressed according to the following scheme:

Class → instance → attribute

Class

All parameters of a sub-device (e.g. drive) are mapped to the manufacturer-specific classes 100 (0x64) + sub-device index, i.e. sub-device 0 --> class 100, sub-device 1 --> class 101,…, sub-device 98 --> class 198.

Instance

The instance number is identical to the IDN of the drive parameter.

Bit	Significance
15	**0**: Standard data (standardized) **1**: Product data (specified by the manufacturer)
14 … 12	Parameter sets from 0 to 7
11 … 0	Data block number from 0 to 4095

Tab. 4-33: Structure of the IDN

The instance number can be calculated with the following formula:

$$\text{Inst} = (32768 \times \text{type}) + (4096 \times \text{set}) + \text{block}$$

Inst Instance number
type Parameter type (0 for S-parameters and 1 for P-parameters)
set Set number
block Data block number

Fig. 4-32: Calculating the Instance Number

Attribute

The format of the parameter depends on the attribute number.

The operating data can have four different formats:

- Data length 2 bytes → **W**
- Data length 4 bytes → **L**
- ASCII text with max. length of 64 bytes → **T**

There are three types of parameters:

- Single parameters
- Command parameters
- List Parameters

Independent of its type, each parameter has these attributes (read-only):

No.	Name	Function	Format
0	Number of elements	Number of supported elements	W
1	IDN	sercos ID number (IDN)	T[8]
2	Name	Parameter name	T[60]
3	Attribute	Display mode of the parameter	L
4	Unit	Parameter unit	T[12]

No.	Name	Function	Format
5	Min. input value	Min. possible value of the data	W/L/T
6	Max. input value	Max. possible value of the data	W/L/T

Tab. 4-34: Basic Attributes of a Drive Parameter

Depending on its type, each parameter has other attributes of different significance:

No.	Name/function	Format
7	Operating data	W/L/T
8	Max. number of list elements / length of text	L
9	Actual number of list elements / length of text	L
10	Pointer to the element from which access takes place to element 11 – 20 at the next access	L
11	Action for 1 list element (pointer to the list element is transferred)	W/L/T
12	Action for 2 list elements (pointer to the list element is transferred)	W/L/T
13	Action for 3 list elements (pointer to the list element is transferred)	W/L/T
14	Action for 4 list elements (pointer to the list element is transferred)	W/L/T
15	Action for 5 list elements (pointer to the list element is transferred)	W/L/T
16	Action for 6 list elements (pointer to the list element is transferred)	W/L/T
17	Action for 7 list elements (pointer to the list element is transferred)	W/L/T
18	Action for 8 list elements (pointer to the list element is transferred)	W/L/T
19	Action for 9 list elements (pointer to the list element is transferred)	W/L/T
20	Action for 10 list elements (pointer to the list element is transferred)	W/L/T

Tab. 4-35: Type-Dependent Attributes of a Drive Parameter

Accessing Single Parameters

The value can be accessed by writing and reading the operating data of the parameter. For single parameters, the number of attributes is the value "7".

Accessing Texts

The value can be accessed by writing and reading the operating data of the parameter. The maximum length of the text and the actual length of the text can be read with attributes 8 and 9. In addition, a text can be handled like a 1-byte list. With access to parameter texts, the number of attributes is the value "20".

Accessing Command Parameters

A command can be started by writing "3" to the operating data, the command status is obtained by read-accessing the operating data. With access to command parameters, the number of attributes is the value "7".

Accessing List Parameters

The maximum list size can be determined by reading the maximum quantity of data of the parameter (attribute 8). The real size is stored in the actual quantity of data of the parameter (attribute 9) and can be modified unless the list is write-protected. All data refer to the parameter format. The pointer to the data (attribute 10) determines which data in the list is processed. If the value of the data is zero, the pointer is automatically modified in the following situations:

- Zero is loaded when changing from another parameter to this parameter.
- After each access to the operating data, the pointer is incremented by the number of elements which were read.

By access to attribute 11 one element is processed, to attribute 12 two elements are processed etc. up to attribute 20 for processing 10 elements. The pointer is increased by the processed elements. With access to list parameters, the number of attributes is the value "20".

☞ For successful access to the operating data, the pointer must be smaller than the actual length.

Example

The parameter "P-0-0072, Cam table 1" has 18 list elements and is to be read:

- Calculate instance with formula

  Input:

  – P-parameter → type = 1
  – Parameter set 0 → set = 0
  – Data block number 72 → block = 72

  → Instance = 32840
- Read: Class 100, instance 32840, attribute 9 = 18 (actual length)
- Write: Class 100, instance 32840, attribute 10 = 0 (list pointer)
- Read: Class 100, instance 32840, attribute 11 = element 0

  → List pointer now automatically pointing to 1
- Read: Class 100, instance 32840, attribute 20 = elements 1 to 10

  → List pointer now automatically pointing to 11
- Read: Class 100, instance 32840, attribute 12 = element 11, 12

  → List pointer now automatically pointing to 13
- Read: Class 100, instance 32840, attribute 15 = elements 13 to 17

  → List pointer now automatically pointing to 18
- Read: Class 100, instance 32840, attribute 10 = 18 (pointer)

Another access to the operating data would not supply any data without loading the list pointer again (list pointer = actual length). The number of attributes supplies the value "20".

Storing List Elements

List elements are not directly stored in permanent form. Storage takes place by one of the following actions:

- Writing the last element of the list
- Read-accessing the list
- Accessing a different parameter
- Abortion of connection

When the control voltage fails, all changes which were not stored are cleared!

Error Codes at Parameter Access

When a vendor-specific error occurs during parameter access, the additional error code provides hints at the cause of the error.

The following table lists the most important error codes.

Error No. (hex)	Significance
0x03	Invalid parameter value • Value is smaller than minimum input value • Value is greater than maximum input value • Incorrect value • Invalid indirect addressing • Procedure command not executable (invalid or false parameters)
0x0E	Parameter cannot be changed
0x0F	Parameter is password-protected
0x10	Parameter write-protected • Parameter is write-protected at this time • Parameter write-protected, as cyclically configured in MDT • Parameter is write protected at this time, due to other settings (parameter, operation mode, drive enable…) • Procedure command at this time not executable (e.g., in this phase procedure command cannot be activated)
0x13	Parameter transmitted too short
0x15	Parameter transmitted too long
0x1F	• Procedure command already active • Procedure command not interruptible

Tab. 4-36: Error Codes and Their Significances at Parameter Access

4.8.6 Diagnostic and Status Messages

Diagnostic Messages via Display

The diagnostic displays via LED (module status, network status), required according to EtherNet/IP™ specification, have been realized by the corresponding display messages and the network status LED.

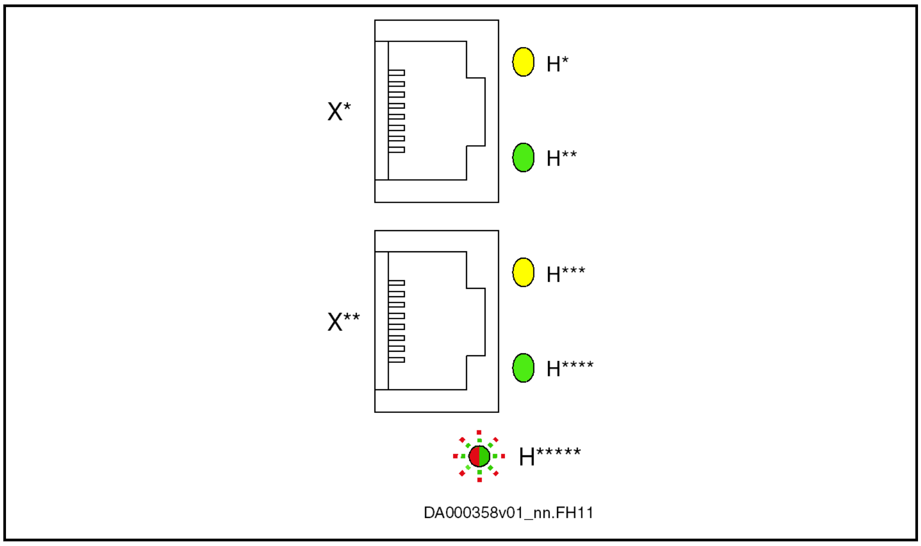


Fig. 4-33: ET, Display Elements

Display elements of optional module ET:

- Two LEDs (H10, H11 and H12, H13) at each connection point
- One bicolor LED (H24)

The significance of the LED displays depends on the field bus system.

Module Status As the EtherNet/IP™ functionality is not an individual module, the module status is covered by the error messages of the drive.

Network Status The network status of the EtherNet/IP™ unit is displayed via the corresponding "network status LED".

LED	Significance	Color	Description
H10, H12	Status	Permanently lit yellow	Data transmission running
H11, H13	Link	Permanently lit green	Connection to the network available

LED	Significance	Color	Description
H24	Not active	Off	Interface has been switched off (24V supply) or has no IP address
	Not connected	Flashing green	Interface has received an IP address, but no connection
	Connected	Permanently lit green	Connection to the network available, data transmission running
	Timeout	Flashing red	Existing connection was aborted
	Invalid IP address	Permanently lit red	Assigned IP address is already used by another device
	Self test	Flashing red-green	After the device has been switched on, the interface performs a self test

Tab. 4-37: EtherNet/IP™ Display Elements

Diagnostic Messages of IndraDrive

Diagnostic messages of IndraDrive and their significances in conjunction with EtherNet/IP™ master communication:

- E4005 No command value input via master communication

  → The master is in the stop mode and the EtherNet/IP™ stack thereby is in the status "IDLE" or the master has specifically aborted the I/O connection and the EtherNet/IP™ stack thereby is in the status "CLOSED".

- F4009 Bus failure

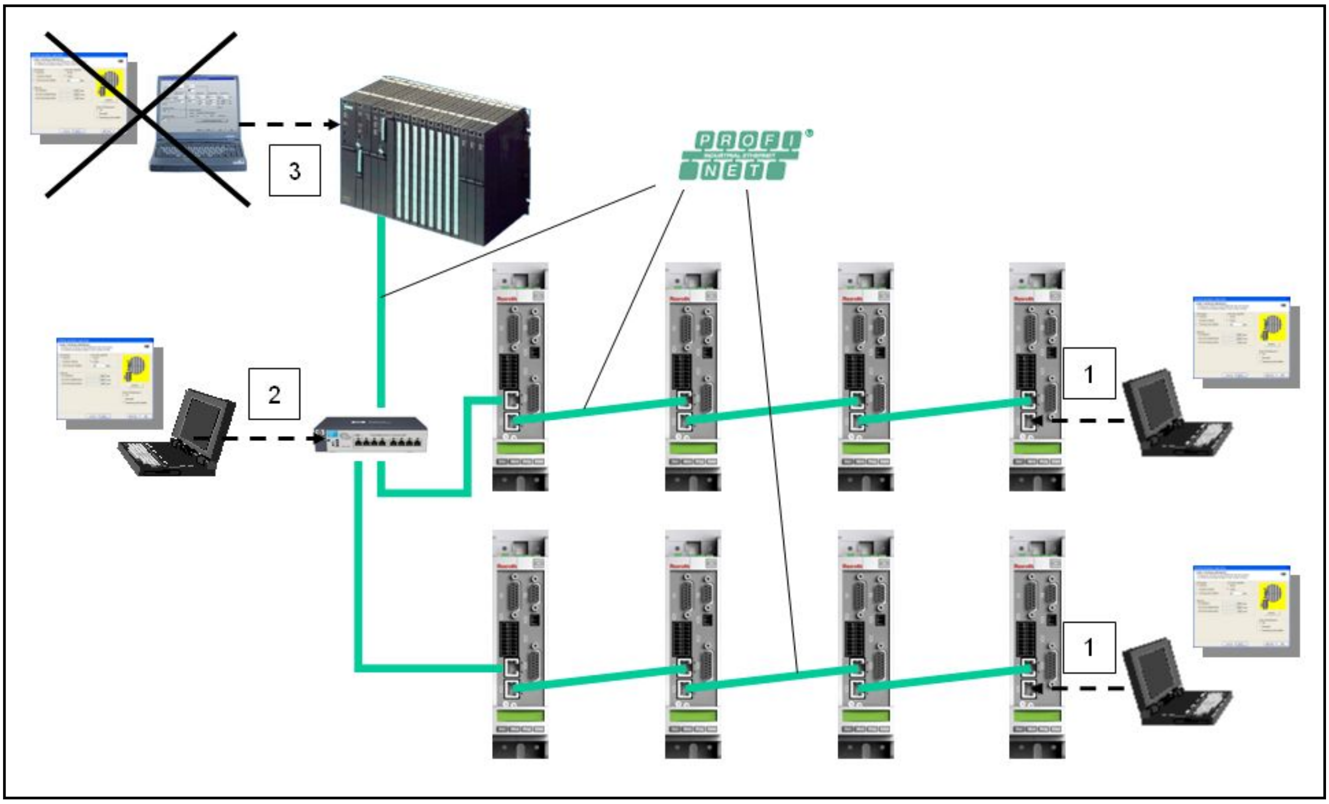
  → The master hasn't received any telegram within the watchdog time. The watchdog time is calculated by the formula for the "timeout" time explained under 1.4.2.

4.9 PROFINET®

4.9.1 Brief Description

Topology

Master Communication



1	Engineering via inactive PROFINET® port of a node at the bus
2	Engineering using optional industrial Ethernet switch
3	Engineering using third-party control via TCI is not possible

Fig. 4-34: Engineering Options with PROFINET®

IndraDrive controllers with MultiEthernet interface (ET) can be operated as PROFINET® master communication. Via this module it is possible to exchange real-time data with a PROFINET® controller.

The field bus provides data containers in which useful data can be cyclically transmitted. This section is referred to as **cyclic data channel** (PROFINET®).

The cyclic data channel is divided as follows:

- One (optional) **device-specific parameter channel** for reading and writing of all parameters via PROFINET®.

> ☞ The **device-specific parameter channel** does not fulfill any "real-time properties"!

- One (optional) **safe, axis-specific process data channel** (PROFIsafe).

> ☞ The **safe, axis-specific process data channel** is not available in MPx18VRS. For configuration, however, the module "F-Module not used" must be integrated!

- One **axis-specific process data channel** (real-time channel) which contains specified information that can be directly interpreted by the receiver.

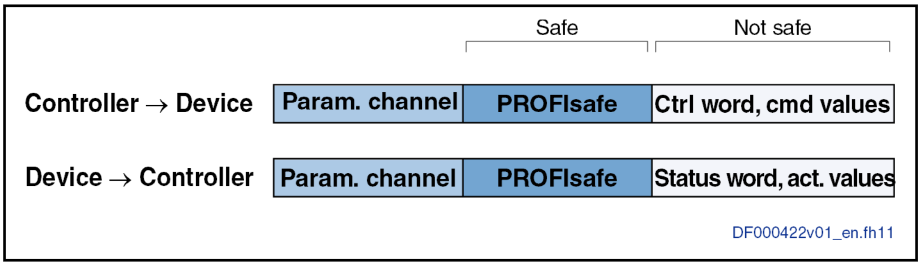


Fig. 4-35: Overview of Cyclic Data Channel

To simplify field bus communication, PLC function blocks are available for different programmable logic controllers (PLCs). The function blocks support the basic functionalities of the axis-specific process data channel and device-specific parameter channel. The principles applied can be easily used for other PROFINET® controllers.

Features

The PROFINET® device circuit with MultiEthernet interface has the following features:

- Ethernet in accordance with IEEE 802.3 and prioritization in accordance with IEEE 802.1Q
- Transmission rate 100 Mbit/s
- Data transmission via Ethernet cable (CAT5e-copper)
- Topologies: "Star", "line" (with integrated cut through switch)
- Assignment of the IP addresses via DCP protocol (Discovery and Basic Configuration)
- The lowest supported cycle time (IO cycle update time) is 2 ms.

The IO cycle update time is written by the control unit and is the time cycle in which the process data from the PROFINET network are applied to the MultiEthernet interface and written in the other direction.

- Configurable cyclic data up to 15 parameters (incl. field bus control word and field bus status word) in both data directions (max. 48 bytes or 24 words)
- Setting options via "P-0-4076, Field bus: Process data - updating clock", min. 2 ms, max. 65 ms (can be set in steps of 1 ms).

The parameter "P-0-4076, Field bus: Process data - updating clock" is used to set the update cycle with which the process data from the MultiEthernet interface are applied to the drive and vice versa.

In the planning, assembly and commissioning of an installation, the following guidelines are referred to (designation: PROFINET trilogy):

- Planning guideline
- Assembly guideline
- Commissioning guideline

The guidelines are made available by the administrative office of the PNO (PROFIBUS Nutzerorganisation e. V.).

It is recommended that

- the industrial Ethernet network not be coupled with a company network (office communications). (Alternatively, a Level 3 router can be used to connect the industrial Ethernet network to a company network.)
- only switches with cut through method be used for industrial Ethernet communication
- a star topology with cable type AWG22 or shielded cables be used, particularly for cables that exit the control cabinet and for cables longer than 10 meters

- Additional optional parameter channel in the cyclic channel with up to 16 bytes (8 words)
- LED for diagnosing PROFINET® status (network status)
- LEDs for displaying link/activity status
- Support for CCA and RT_CLASS_1
- Diagnostic messages and alarms are not used due to reasons of compatibility with IndraDrive controllers with the PROFIBUS® master communication module.
- PROFINET® IRT is not supported.
- Operation in PROFINET® IRT networks is not possible.
- Supported field bus profiles:
  - 0x0000: "No profile" selected
  - 0xFF82: I/O mode "positioning" with configurable real-time data
  - 0xFF92: I/O mode "preset velocity" with configurable real-time data
  - 0xFFFD: Freely configurable mode "Neutral operation modes"
  - 0xFFFE: Freely configurable mode

Hardware Requirements

The master communication "PROFINET®" requires the following control section design:

IndraDrive Cs	
BASIC	HCS01.1E-W00xx-A-0x-B-ET-EC-xx-xx-NN-FW
ADVANCED	HCS01.1E-W00xx-A-0x-A-CC-EC-ET-xx-NN-FW
IndraDrive Mi	
Distributed servo drive	KSM02.1B-xxxC-xxN-xx-Hxx-ET-NN-D7-xx-FW
Distributed drive controller	KMS02.1B-Axxx-P-D7-ET-xxx-xx-xx-FW
Electronic control system	KCU02.1N-ET-ET*-025-NN-N-NN-NN

IndraDrive control sections	
Basic control section - single-axis	CSB02.1x-ET-EC-xx-xx-xx-NN-FW
Basic control section - double-axis	CDB02.1B-ET-EC-EC-xx-xx-xx-xx-NN-FW
Advanced control section - single-axis	CSH02.1B-CC-ET-xx-xx-NN-FW

* See central standard ZN 41001-021

Tab. 4-38: Control Section Design for MultiEthernet

Axis Addressing

A node in PROFINET is addressed using the so-called device name. This name is saved in P-0-4089.0.2 and can be changed there.

☞ The device address set in "P-0-4089.0.3, Device Address" is applied to the parameter "P-0-4089.0.4, Active Device Address" after the device has been restarted. This address is shown on the display and is irrelevant for the PROFINET communication!

Pertinent Parameters

Communication parameters

Specific parameters for communication via PROFINET®:

- P-0-4089.0.11, Master communication: MAC address Port1
- P-0-4089.0.12, Master communication: MAC address Port2

Parameters for general communication via field bus interfaces:

- P-0-4073, Field bus: Diagnostic message
- P-0-4074, Field bus: Data format
- P-0-4075, Field bus: Watchdog
- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: Baud rate
- P-0-4083, Parameter channel: Length
- P-0-4083.0.1, Parameter channel: Configuration
- P-0-4088, Master communication: Drive configuration
- P-0-4089.0.2, Master communication: Device name
- P-0-4089.0.10, Master communication: MAC address device
- P-0-4089.0.13, Master communication: IP address
- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

Profile type parameters

Apart from mere communication parameters, we use parameters in conjunction with the profile types.

In this regard, see "Profile Types (with Field Bus Interfaces)"

In this regard, see "Engineering/Diagnostic Interfaces"

Parameters for extended communication

We use additional parameters for extended communication.

See the following sections:

- "Configurable Signal Control Word"
- "Configurable Signal Status Word"

- "Multiplex channel"

Pertinent Diagnostic Messages

- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable
- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- C0299 Configuration changed. Restart
- E4005 No command value input via master communication
- E4006 Communication module overload
- E4011 Communication watchdog: Overload of cyclic communication
- F4009 Bus failure
- F4011 Communication watchdog: Overload of cyclic communication
- F4012 Incorrect I/O length

4.9.2 Configuring the PROFINET® Slave

Device Master File for IndraDrive

Like every other PROFINET® device, IndraDrive controllers must be configured in the field bus controller. This requires the corresponding device data sheet (DDS) "GSDML-V2.1-Bosch Rexroth AG-011F-Indradrive_xxVxx-xxxxxxxx.xml" that has to be included in the project ("YYYYMMDD" represents the creation date of the DDS file). This DDS file, when configuring the bus controller, is required for each node.

> The device data sheet for IndraDrive controllers supports all hardware types and enabling of functional packages.

IndraDrive controllers assign their data to four slots (for single-axis devices) or up to 31 slots for devices operated via CCD group (1 CCD master + 9 CCD slaves), which might possibly have to be configured. Each drive in the CCD group has an F module, one input module and one output module: A slot is used for plugging in modules.

Each slot has a certain module assignment which must be complied with for correct configuration.

- Slot 1: Parameter Channel
- Slot 2: F module axis 0 (optional for PROFIsafe)
- Slot 3: Inputs axis 0
- Slot 4: Outputs axis 0
- Slot 5: F-module axis 1 (only with devices operated at the CCD group)
- Slot 6: Inputs axis 1 (only with devices operated at the CCD group)
- Slot 7: Outputs axis 1 (only with devices operated at the CCD group)
- Slot X: F-module axis X (according to number of CCD drives)
- Slot Y: Inputs axis X (according to number of CCD drives)
- Slot Z: Outputs axis X (according to number of CCD drives)

The default configuration stored in the device data sheet is "Input 1 Word" and "Output 1 Word" (single-axis device) without safety technology and without parameter channel. For IndraDrive, this setting is active after the default values have been loaded.

> During the installation of "IndraWorks Ds/D/MLD", the device data sheet is stored by default in the directory "C:\Program Files \REXROTH\IndraWorks\DeviceDataSheets\IndraDrive\Profinet".

Module 1: Parameter Channel

These modules are of the input/output module type and marked with "ParamCh". If no parameter channel is required, the module "ParamCh not used" has to be selected.

When IDN parameters or EIDN parameters are to be written via the parameter channel, observe the following aspects:

- IDN parameters

  To write a 2-byte IDN parameter (e.g. P-0-4006), include the "ParamCh 5 Words" module and configure it accordingly in the parameter "P-0-4083.0.1, Parameter channel: Configuration".
- EIDN parameters

  To write a 4-byte EIDN parameter (e.g. P-0-4006.0.0), include the "ParamCh 6 Words" module and configure it accordingly in the parameter "P-0-4083.0.1, Parameter channel: Configuration".

> The parameter channel length is displayed in parameter "P-0-4083, Parameter channel: Length" in bytes.
>
> With the wrong configuration of the command values / actual values, the error "F4012 Incorrect I/O length" is displayed.

F Module

The blank module "F module not used" is assigned to slot 2.

Inputs Module

With these modules, the length of the input data is set in words. The module identifier is "Input". For the successful data exchange of the axis-specific process data channel, the length that has been set must correspond to the value in parameter "P-0-4082, Field bus: Length of cyclic actual value data channel", specifying the length in bytes.

> Even if the input data length is wrong, it is possible to communicate via the device-specific parameter channel.

> If the configuration of the controller does not correspond to the one of the IndraDrive controller, the IndraDrive device will generate the error message "F4012 Incorrect I/O length".

Outputs Module

With these modules, the length of the output data is set in words. The module identifier is "Output". The length of the output data that has been set must correspond to the value of parameter "P-0-4071, Field bus: Length of cyclic command value data channel".

> If the configuration of the controller does not correspond to the one of the IndraDrive controller, the IndraDrive device will generate the error message "F4012 Incorrect I/O length".

Modules 5 to 31

The modules 5 to 31 are provided for devices operated at the CCD group.

Displaying the Device Name/IP Address of the IndraDrive Device

The device name of the IndraDrive device assigned when naming the device is displayed in "P-0-4089.0.2, Master communication: Device name". When exchanging a device, the device name can be set manually via this parameter using IndraWorks (see "Notes on How to Replace the Devices"). The IP settings permanently assigned to the device during project planning are displayed in the following parameters:

- P-0-4089.0.13, Master communication: IP address
- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

With the configuration "temporary assignment" (assignment by the controller during run-up), the IP address "0.0.0.0" is displayed in the parameters.

☞ After the device has been restarted, the device address set in "P-0-4089.0.3 Device Address" is applied to the parameter "P-0-4089.0.4 Active Device Address". This address is shown on the display and is irrelevant for the PROFINET communication!

☞ The IP address is only relevant to communication with the controller! For engineering (e.g. IndraWorks), the engineering address (S-0-1020, Master comm. engineering over IP: IP address) must be used.

Configuration of the Process Data Channel

Standard Process Data Channel (Non-Safe)

The user can freely configure the cyclic data in the standard process data channel according to the process requirements.

☞ For the profile types "freely configurable mode" (P-0-4084 = 0xFFFE), "I/O mode positioning" (P-0-4084 = 0xFF82) or "I/O mode" (P-0-4084 = 0xFF92 preset velocity), there is a default configuration that the user can change at any time.

See also "Profile Types (with Field Bus Interfaces)"

Configuration List Cyclic Actual Value Data Channel

In parameter "P-0-4080, Field bus: Config. list of cyclic actual value data ch.", the structure and thereby the number of words and their assigned objects (indices) are mapped for the process input data (device → controller). The controller can use this configuration in order to locate the individual real-time data in the field bus.

Cyclic Command Value Data Channel Configuration List

The structure of the process output data (controller → device) is mapped to parameter "P-0-4081, Field bus: Config. list of cyclic command value data ch.". This allows reading the current structure and thus the assignment in the field bus via the parameter channel.

☞ It is possible to configure up to 15 real-time parameters (incl. control word or status word) at the bus in each data direction (max. 48 bytes or 24 words).

PROFIsafe Process Data Channel (Safe)

☞ The **safe, axis-specific process data channel** is not available in MPx18VRS. For configuration, however, the module "F-Module not used" must be integrated!

Length of the Process Data Channel (Real-Time Data Channel)

Standard Process Data Channel (Non-Safe)

Within the cyclic channel, the parameter channel (optional) and the process data channel, in which the real-time data of the drive controller are transmitted, are arranged.

The PROFINET® device interface allows flexible configuration of the process data channel, the length of the process data channel thereby changes accordingly.

> The currently valid length can be seen from parameters "P-0-4082, Field bus: Length of cyclic actual value data channel" and "P-0-4071, Field bus: Length of cyclic command value data channel".

The process data channel (real-time data channel) can only have words or double words, but not bytes, as data types. Length, however, is specified in bytes for the sake of compatibility with other bus systems.

The length of the process data channel results from the content of the configuration lists "P-0-4080, Field bus: Config. list of cyclic actual value data ch." or "P-0-4081, Field bus: Config. list of cyclic command value data ch." and can be taken from the following parameters:

- P-0-4071, Field bus: Length of cyclic command value data channel
- P-0-4082, Field bus: Length of cyclic actual value data channel

The setting is calculated from the contents of the parameters P-0-4080 and P-0-4081 and takes effect as the drive controller runs up to the operating mode.

> Please note that a change in the length of the process data channel also requires a change in the controller configuration. The length of the process data channel that was set must comply with the projected length in the controller. Otherwise the error message "F4012 Incorrect I/O length" is generated.

4.9.3 Cyclic Communication via Process Data Channel

Communication Cycle Time

The smallest supported cycle time (I/O cycle updating time) is 2 ms and preset by the control unit. This is the frequency in which the data are read from and written to the PROFINET network by the MultiEthernet interface.

Setting options via "P-0-4076, Field bus: Process data - updating clock", min. 2 ms, max. 65 ms (can be set in steps of 1 ms).

> Via the parameter "P-0-4076, Field bus: Process data - updating clock", you can set in which updating clock the data are applied from the MultiEthernet interface to the drive and vice versa.

Axis-Specific Process Data Channel

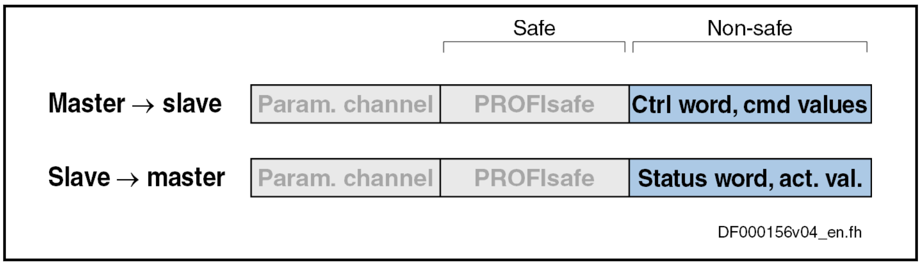


Fig. 4-36: Position of the Non-Safe Process Data Channel in the Cyclic Data Channel

Processing the Cyclic Data

The internal processing of the command values and actual values is carried out synchronously with the control clock. As the communication via PROFINET® RT is not carried out in a synchronous way, this type of master communication is not suited for synchronous operation modes such as "position control with cyclic command value input", but only for positioning modes and the "velocity control" mode.

> ☞ There is no limit value check for the cyclically transmitted command values and they are stored in volatile form.

Configuring the Cyclic Data

The cyclic data must be configured in the parameter mode. This configuration is described in the section "Configuring the PROFINET® Slave".

Safe, Axis-Specific Process Data Channel (PROFIsafe)

General Information

> ☞ The **safe, axis-specific process data channel** is not available in MPx18VRS.

Parameter Channel in Cyclic Channel (Device-Specific)

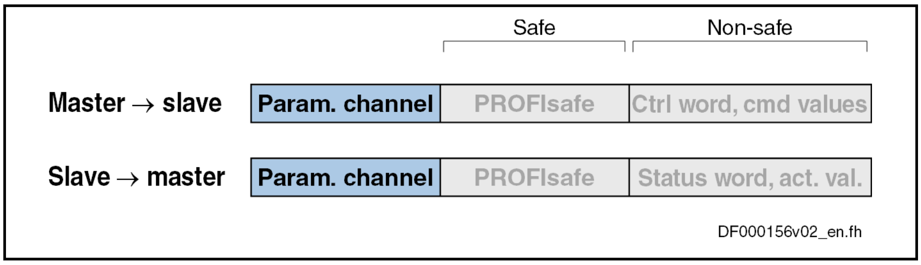


Fig. 4-37: Position of the Parameter Channel in the Cyclic Data Channel

Via the parameter channel, the drive can be parameterized via the field bus. The parameter channel is part of the cyclic data.

For IndraLogic and Siemens S7, function blocks are available which implement the parameter channel protocol. This allows the user to ignore the parameter channel details.

The parameter channel is described in the Technical Note "TN_40_Bosch_Rexroth PROFIBUS_PROFINET_Parameterkanal_V1.x".

> ☞ The parameter channel is always at the beginning of the cyclic data channel. The length of the parameter channel is configured in the controller and in the drive. Use parameter "P-0-4083.0.1, Parameter channel: Configuration" for this purpose.

> ☞ It is not possible to parameterize the field bus control word via the optional parameter channel. To allow axis control, the cyclic data channel must be used in the higher-level control unit or the corresponding logic must be programmed with permanent control in MLD. If the control unit does not have a cyclic data channel, axis control cannot take place without MLD.

4.9.4 Monitoring Functions and Diagnostic Functions

Diagnostic Possibilities

A network status LED is provided for simple diagnosis of the network status.

The following table shows the possible states:

Message on display	Significance
Permanently off	The device does not have any valid IP address or has been switched off.
Flashing green	The device has run up with a valid IP address, but has no cyclic connection.
Permanently green	The I/O connection has been established without error.
Flashing red	The existing I/O connection was unexpectedly interrupted (e.g. watchdog).
Permanently red	During "Duplicate IP Address Check", the IP address which was set was detected to already exist in the network.
Flashing green/red	The device is currently initializing and performs a self test.

Tab. 4-39: Overview of Diagnostic Messages for PROFINET® Communication

Error Codes of PROFINET® Communication

Parameter Channel Errors

The table below contains an overview of the possible parameter channel error messages and their significances:

Error code	Significance
0x0082	Quantity of all transmitted data is too small, i.e. less than 4 bytes
0x0083	Quantity of data still to be transmitted is greater than the internal buffer
0x0088	The length of the valid data indicated in the control word is longer than the parameter channel
0x008C	Status conflict, a new request was transmitted although there are still data to be retrieved
0x008D	The length of data still to be transmitted that is indicated in the control word is incorrect
0x008E	The type of EIDN/IDN access specified in the control word bit 15 does not match the type of access configured in P-0-4083.0.1

Tab. 4-40: Overview Parameter Channel Errors

Parameter Access Errors

The table below contains an overview of the possible parameter access errors and their significances; the error values are transmitted in word format:

Error No. (hex)	Significance
0x1001	No IDN
0x1009	Invalid access to element 1
0x2001	No name
0x2004	Name cannot be changed (read only)
0x3004	Attribute cannot be changed (read only)
0x4001	No units
0x4004	Unit cannot be changed (read only)

Error No. (hex)	Significance
0x5001	No minimum input value
0x5004	Minimum input value cannot be changed (read only)
0x6001	No maximum input value
0x6004	Maximum input value cannot be changed (read only)
0x7002	Operation data transmission too short
0x7003	Operation data transmission too long
0x7004	Operation data cannot be changed (read only)
0x7005	Operation data is write-protected at this time (e.g. communication phase)
0x7006	Operation data is smaller than minimum input value
0x7007	Operation data is greater than maximum input value
0x7008	Invalid operation data: Configured IDN will not be supported, invalid bit number or bit combination
0x7009	Operation data write protected by a password
0x700A	Operation data is write protected, it is configured cyclically
0x700B	Invalid indirect addressing (e.g. data container, list handling)
0x700C	Data currently write-protected due to other settings (e.g., parameter, operation mode, drive enable, ...)
0x7010	Procedure command already active
0x7011	Procedure command not interruptible
0x7012	Procedure command at this time not executable (e.g., in this phase the procedure command cannot be activated)
0x7013	Procedure command not executable (invalid or false parameters)
0x9001	Input cannot be identified as application
0x9002	Parameter type error
0x9003	Invalid data record number
0x9004	Invalid data block number
0x9005	Data element number invalid
0x9006	Error in R/W flag
0x9007	Invalid character in the data

Tab. 4-41: Overview Parameter Access Errors

4.10 PROFIBUS-DP

4.10.1 Brief Description

IndraDrive controllers with PROFIBUS interface (PB) can be operated as PROFIBUS slaves in a PROFIBUS installation. Via these PROFIBUS components, it is possible to exchange real-time data with a PROFIBUS-DP master.

Cyclic data channel (PROFIBUS-DP)

The field bus provides data containers in which useful data can be cyclically transmitted. This section is referred to as cyclic data channel.

The cyclic data channel is divided as follows:

- One (optional) **device-specific parameter channel** for reading and writing of all IndraDrive parameters via PROFIBUS-DP.

> The **device-specific parameter channel** does not fulfill any "real-time properties"!

- One (optional) **safe, axis-specific process data channel** (PROFIsafe).

> The **safe, axis-specific process data channel** is not available in MPx18VRS. For configuration, however, the module "F-Module not used" must be integrated!

- One **axis-specific process data channel** (real-time channel) which contains specified information that can be directly interpreted by the receiver.

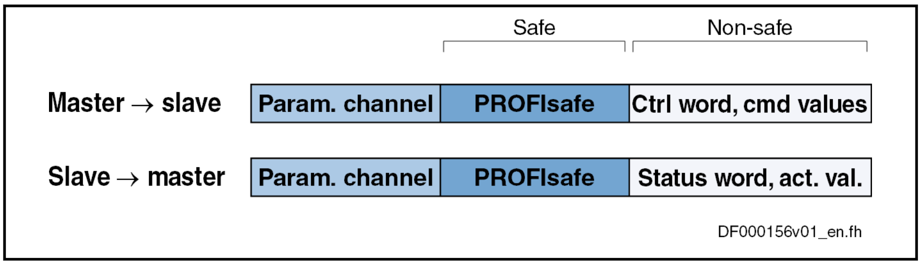


Fig. 4-38: Overview of Cyclic Data Channel

> To simplify field bus communication, Rexroth PLC function blocks are available for different programmable logic controllers (PLCs). The function blocks support the basic functionalities of the axis-specific process data channel and device-specific parameter channel. The principles applied can be easily used for other field bus masters.

Features

The slave PROFIBUS-DP circuit with master communication module PROFIBUS interface (PB) has the following functional features:

- Support of **RS485 interfaces according to IEC 61158-2**
- Support of all **data rates according to IEC 61158-2**, with exclusive use of PROFIBUS-DP (9.6 kBaud, 19.2 kBaud, 45.45 kBaud, 93.75 kBaud, 187.5 kBaud, 500 kBaud,1.5 MBaud, 3 MBaud, 6 MBaud, 12 Mbaud)
- Automatic baud rate detection
- Configurable cyclic data up to 15 parameters (incl. field bus control word and field bus status word) in both data directions (max. 48 bytes or 24 words)
- Setting options for P-0-4076: Min. 2 ms, max. 65 ms (can be set in steps of 1 ms)

☞ The parameter "P-0-4076, Field bus: Process data - updating clock" is used to set the update cycle with which the process data from the PROFIBUS interface are applied to the drive and from the drive.

- Additional optional parameter channel in the cyclic channel with up to 16 bytes (8 words)
- Monitoring of the cyclic data exchange (watchdog function)
- LED for diagnosing the PROFIBUS interface
- Supported DPV0 services:
  - Slave_Diag (read diagnostic data)
  - Get_Cfg (read configuration data)
  - Set_Prm (send parameterization data)
  - Chk_Cfg (check configuration data)
  - Data Exchange (transfer I/O data)
  - Global Control (synchronization)
  - RD_Outp (read output data)
  - RD_Inp (read input data)
- Supported DPV1 Class 1 services
  - DDLM_Initiate (establishment of connection)
  - DDLM_Read (acyclic read access)
  - DDLM_Write (acyclic write access)
  - DDLM_Abort (abortion of connection)
  - DDLM_Idle (connection monitoring)
- Support of up to two DPV1 Class 2 connections
- TCI (Tool Calling Interface) support
- Supported field bus profiles:
  - 0x0000: "No profile selected"
  - 0xFF82: I/O mode "positioning" with configurable real-time data
  - 0xFF92: I/O mode "preset velocity" with configurable real-time data
  - 0xFFFD: Freely configurable mode "Neutral operation modes"
  - 0xFFFE: Freely configurable mode

Hardware Requirements

The master communication "PROFIBUS-DP" requires the following device design:

IndraDrive Cs	
BASIC	HCS01.1E-W00xx-A-0x-B-ET-EC-PB-xx-NN-FW
ADVANCED	HCS01.1E-W00xx-A-0x-A-CC-EC-PB-xx-NN-FW
IndraDrive control sections	
Basic control section - single-axis	CSB02.1x-ET-EC-PB-xx-xx-NN-FW

Basic control section - double-axis	CDB02.1B-ET-EC-EC-PB-xx-xx-xx-NN-FW
Advanced control section - single-axis	CSH02.1B-CC-EC-PB-xx-xx-NN-FW

Tab. 4-42: Control Section Design for PROFIBUS

In the case of devices with PROFIBUS option, it is only possible to change between inactive master communication and PROFIBUS master communication. Switching to sercos, EtherCAT, EtherNet/IP or PROFINET is impossible.

Axis Addressing

The axis address can be set directly using the display of the drive. This can be done using the so-called Easy menu.

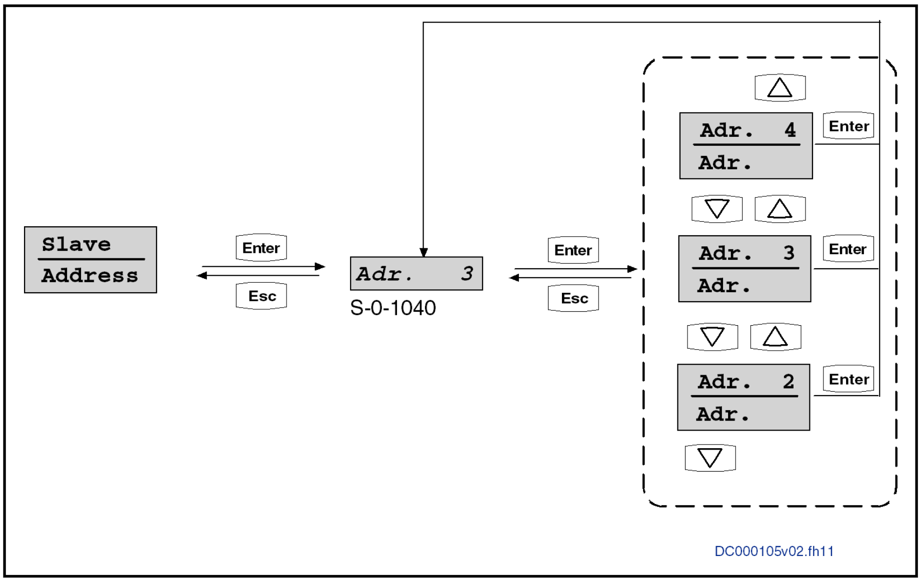


Fig. 4-39: Submenu for "Slave___" "_Addresss"

Alternatively, the address can be directly changed or displayed using the parameter "S-0-1040, Drive address of master communication".

The axis address is always displayed in the left side of the standard display of the control panel.

Pertinent Parameters

Communication parameters

Specific parameters for communication via PROFIBUS-DP:

- P-0-4069, Field bus: Module diagnosis

Parameters for general communication via field bus interfaces:

- P-0-4073, Field bus: Diagnostic message
- P-0-4074, Field bus: Data format
- P-0-4075, Field bus: Watchdog
- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: Baud rate
- P-0-4083, Parameter channel: Length
- P-0-4083.0.1, Parameter channel: Configuration

Profile type parameters

Apart from mere communication parameters, we use parameters in conjunction with the profile types.

In this regard, see "Profile Types (with Field Bus Interfaces)"

Parameters for extended communication

We use additional parameters for extended communication.

See the following sections:

- "Configurable Signal Control Word"
- "Configurable Signal Status Word"
- "Multiplex channel"

Pertinent Diagnostic Messages

- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable
- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- E4005 No command value input via master communication
- F4009 Bus failure
- F4012 Incorrect I/O length

4.10.2 Configuring the PROFIBUS-DP Slave

Device Master File for IndraDrive

Like every other PROFIBUS slave, IndraDrive controllers must be configured in the field bus master. This requires the corresponding device data sheet (GSD) "**RX**0107.GSD**" that has to be included in the project ("**" represents the version number of the GSD file). This GSD file, when configuring the bus master, is required for each node.

☞ The device data sheet for IndraDrive controllers supports all hardware types and enabling of functional packages.

IndraDrive controllers assign their data to four slots (for single-axis devices) or up to 25 slots for devices operated via CCD group (1 CCD master + 7 CCD slaves), which have to be configured, if necessary. Each drive in the CCD group has an F module, one input module and one output module: A slot is used for plugging in modules. In the example: A parameter channel module is plugged in slot 1. As described above, the parameter channel module may have different lengths.

With single-axis devices, IndraDrive controllers assign their data to four slots into which certain modules must be plugged.

- Slot 1: Parameter Channel
- Slot 2: F module axis 0 (optional for PROFIsafe)
- Slot 3: Inputs axis 0
- Slot 4: Outputs axis 0
- Slot 5: F-module axis 1 (only with devices operated at the CCD group)
- Slot 6: Inputs axis 1 (only with devices operated at the CCD group)
- Slot 7: Outputs axis 1 (only with devices operated at the CCD group)
- Slot X: F-module axis X (according to number of CCD drives)

- Slot Y: Inputs axis X (according to number of CCD drives)
- Slot Z: Outputs axis X (according to number of CCD drives)

The default configuration stored in the device data sheet is "Input 1 Word" and "Output 1 Word" (single-axis device) without safety technology and without parameter channel. For configurators supporting the GSD version 03 or higher, this default configuration is automatically set. For IndraDrive, this setting is active after the default values have been loaded.

The device data sheet also contains the IDN assigned to the IndraDrive controller by the PROFIBUS User Organization (PNO):

- Ident. no. 107 hex

> ☞ During the installation of "IndraWorks MLD", the device data sheet is stored by default in the directory "C:\Program Files\REXROTH\IndraWorks\DeviceDataSheets\IndraDrive\Profibus".

Module 1: Parameter Channel

These modules are of the input/output module type and marked with "ParamCh". If no parameter channel is required, the module "ParamCh not used" has to be selected.

When IDN parameters or EIDN parameters are to be written via the parameter channel, observe the following aspects:

- IDN parameters

  To write a 2-byte IDN parameter (e.g. P-0-4006), the "ParamCh 5 Words" module must be included and configured accordingly in parameter "P-0-4083.0.1, Parameter channel: Configuration".
- EIDN parameters

  To write a 4-byte EIDN parameter (e.g. P-0-4006.0.0), the "ParamCh 6 Words" module must be included and configured accordingly in parameter "P-0-4083.0.1, Parameter channel: Configuration".

> ☞ The parameter channel length is displayed in parameter "P-0-4083, Parameter channel: Length" in bytes.
>
> With the wrong configuration of the command values / actual values, the error "F4012 Incorrect I/O length" is displayed.

The drive automatically recognizes the configuration of the master and adjusts accordingly. Parameterization by the master is therefore always possible, even in the case of incorrect configuration of the command values/actual values. This allows parameter download from the master after a device was replaced.

F Module

The blank module "F module not used" is assigned to slot 2.

Inputs Module

With these modules, the length of the input data is set in words. The module identifier is "Input". For the successful data exchange of the axis-specific process data channel, the length that has been set must correspond to the value in parameter "P-0-4082, Field bus: Length of cyclic actual value data channel", specifying the length in bytes.

> ☞ Even if the input data length is wrong, it is possible to communicate via the device-specific parameter channel.

> ☞ If the configuration of the master does not comply with the one of the IndraDrive controller, the IndraDrive device will generate the error message "F4012 Incorrect I/O length".

Outputs Module

With these modules, the length of the output data is set in words. The module identifier is "Output". The length of the output data that has been set must correspond to the value of parameter "P-0-4071, Field bus: Length of cyclic command value data channel".

☞ If the configuration of the master does not comply with the one of the IndraDrive controller, the IndraDrive device will generate the error message "F4012 Incorrect I/O length".

Modules 5 to 31

The modules 5 to 31 are provided for devices operated at the CCD group. In the case of single-axis devices, the blank modules "F-Modul not used", "Input not used" or "Output not used" should be assigned to these modules.

Configuration of the Process Data Channel

Standard Process Data Channel (Non-Safe)

The user can freely configure the cyclic data in the standard process data channel according to the process requirements.

☞ With profile types "Freely configurable mode" (P-0-4084 = 0xFFFE), "Operation mode neutral" (P-0-4084 = 0xFFFD), "I/O mode" (P-0-4084 = 0xFF82), "I/O mode" (P-0-4084 = 0xFF92 preset velocity) or "No profile" (P-0-4084 = 0x0000), a default configuration is provided that the user can change at any time.

See also "Profile Types (with Field Bus Interfaces)"

Configuration List Cyclic Actual Value Data Channel

The structure and thereby the number of words and their assigned objects (indices) for the process input data (slave → master) are mapped to parameter "P-0-4080, Field bus: Config. list of cyclic actual value data ch.". The master can use this configuration in order to localize the individual real-time data in the field bus.

Cyclic Command Value Data Channel Configuration List

The structure of the process output data (master → slave) is mapped to parameter "P-0-4081, Field bus: Config. list of cyclic command value data ch.". This allows reading the current structure and thus the assignment in the field bus via the parameter channel.

☞ It is possible to configure up to 15 real-time parameters (incl. control word or status word) at the bus in each data direction (max. 48 bytes or 24 words).

PROFIsafe Process Data Channel (Safe)

☞ The **safe, axis-specific process data channel** is not available in MPx18VRS. For configuration, however, the module "F-Module not used" must be integrated!

Length of the Process Data Channel (Real-Time Data Channel)

Standard Process Data Channel (Non-Safe)

Within the cyclic channel, the parameter channel (optional) and the process data channel, in which the real-time data of the drive controller are transmitted, are arranged.

The PROFIBUS slave interface allows flexible configuration of the process data channel, the length of the process data channel thereby changes accordingly.

☞ The currently valid length can be seen from parameters "P-0-4082, Field bus: Length of cyclic actual value data channel" and "P-0-4071, Field bus: Length of cyclic command value data channel".

The process data channel (real-time data channel) can only have words or double words, but not bytes, as data types. Length, however, is specified in bytes for the sake of compatibility with other bus systems.

The length of the process data channel can range between 1…24 words or 2…48 bytes in either direction.

The length of the process data channel results from the content of the configuration lists "P-0-4080, Field bus: Config. list of cyclic actual value data ch." or "P-0-4081, Field bus: Config. list of cyclic command value data ch." and can be taken from the following parameters:

- P-0-4071, Field bus: Length of cyclic command value data channel
- P-0-4082, Field bus: Length of cyclic actual value data channel

The setting is calculated from the contents of the parameters P-0-4080 and P-0-4081 and takes effect as the drive controller runs up to the operating mode.

☞ Please note that a change in the length of the process data channel also requires a change in the master configuration. The length of the process data channel that was set must comply with the projected length in the master. If not, the error message "F4012 Incorrect I/O length" is generated.

4.10.3 Cyclic Communication via Process Data Channel

Communication Cycle Time

The communication cycle time results from the baud rate set in the master. This baud rate is transmitted to the slave and displayed in the parameter"P-0-4079, Field bus: Baud rate".

Via the parameter "P-0-4076, Field bus: Process data - updating clock", you can set in which updating clock the data are applied from the PROFIBUS® interface to the drive and vice versa. For reasons of performance, the default setting should be maintained.

Valid values for "P-0-4076, Field bus: Process data - updating clock": Min. 2 ms, max. 65 ms (can be set in steps of 1 ms)

Axis-Specific Process Data Channel

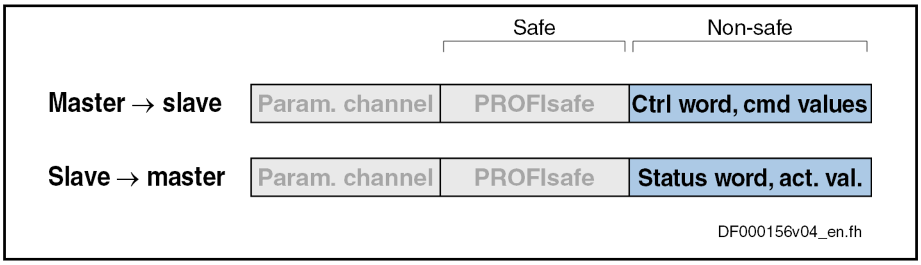


Fig. 4-40: Position of the Non-Safe Process Data Channel in the Cyclic Data Channel

Processing the Cyclic Data

The internal processing of the command values and actual values is carried out synchronously with the control clock. As the communication via PROFIBUS-DP is not carried out in a synchronous way, this type of master communication is not suited for synchronous operation modes such as "position control with cyclic command value input", but only for positioning modes and the "velocity control" mode.

> There is no limit value check for the cyclically transmitted command values and they are stored in volatile form.

Configuring the Cyclic Data

The cyclic data must be configured in the parameter mode. The configuration of the cyclic data is described in the section "Configuring the PROFIBUS-DP Slave".

Safe, Axis-Specific Process Data Channel (PROFIsafe)

General Information

> The **safe, axis-specific process data channel** is not available in MPx18VRS.

PROFIsafe Configuration

Configuring the Control Unit

In MPx18VRS, the **safe, axis-specific process data channel** is not available; it is therefore necessary to include the following PROFIsafe module (blank module) in the control unit configuration:

- F module not used

  This axis does not exchange any data via PROFIsafe.

Parameter Channel in Cyclic Channel (Device-Specific)

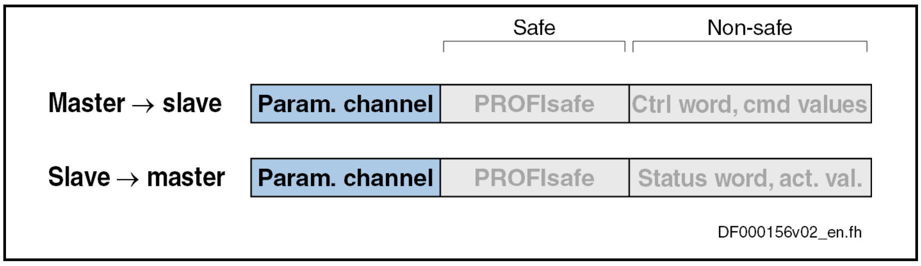


Fig. 4-41: Position of the Parameter Channel in the Cyclic Data Channel

Via the parameter channel, the drive or the drives can be parameterized via the field bus. The parameter channel is part of the cyclic data.

For IndraLogic and Siemens S7, function blocks are available which implement the parameter channel protocol. This allows the user to ignore the parameter channel details.

The parameter channel is described in the Technical Note "TN_40_Bosch_Rexroth PROFIBUS_PROFINET_Parameterkanal_V1.x".

> The parameter channel is always at the beginning of the cyclic data channel. The length of the parameter channel is configured in the master and taken over by the drive to parameter "P-0-4083, Parameter channel: Length".

> It is not possible to parameterize the field bus control word via the optional parameter channel. To allow axis control, the cyclic data channel must be used in the higher-level control unit or the corresponding logic must be programmed with permanent control in MLD. If the control unit does not have a cyclic data channel, axis control cannot take place without MLD.

4.10.4 Acyclic Data Exchange (DPV1)

Overview of Acyclic Communication

DP Master Class 1

An acyclic communication relationship of the "MSAC_C1" type to a DP master class 1 (MSAC_C1) is supported. The following DP services are available for this communication relationship:

- DDLM_Read (MSAC1_Read)
- DDLM_Write (MSAC1_Write)

DP Master Class 2

A maximum of two acyclic communication relationships of the "MSAC_C2" type to a DP master class 2 (MSAC_C2) are supported. The following DP services are available for this communication relationship:

- DDLM_Initiate (MSAC2_Initiate)
- DDLM_Abort (MSAC2_Abort)
- DDLM_Read (MSAC2_Read)
- DDLM_Write (MSAC2_Write)

4.10.5 Monitoring Functions and Diagnostic Functions

Monitoring Functions

Watchdog for Cyclic Communication

As a standard, the time required for the watchdog monitoring function is automatically calculated and configured by the configuration program of the master. It is displayed in parameter "P-0-4075, Field bus: Watchdog" (in ms).

☞ Inputting "0" in parameter "P-0-4075, Field bus: Watchdog" means that the watchdog monitoring function is deactivated.

F4012 Incorrect I/O Length

When the error message "F4012 Incorrect I/O length" is generated, the drive is in the PROFIBUS status "Data_Exchange"; the LED display "H30" is active. The parameter channel is working, but the data of the input and output module are not processed internally.

Diagnostic Possibilities

The state of the field bus master communication of an IndraDrive device is diagnosed via

- LED display "H30" at the front panel of the controller

  - and -
- Diagnostic parameter "P-0-4073, Field bus: Diagnostic message".

Diagnostic LED "H30"

The LED display "H30" is active when the drive is in the PROFIBUS state "Data_Exchange". This means that real-time data are exchanged between IndraDrive device and master.

Parameter for Diagnostic Field Bus Message

In parameter "P-0-4073, Field bus: Diagnostic message", the status of the field bus master communication is stored in plain text. The contents of parameter P-0-4073 have the following significances:

Text	Significance
"OFFLINE"	Initialization value of the diagnostic message
"Power-On"	PROFIBUS-DP has been recognized as master communication and the hardware is checked.
"Baud-Search"	The hardware is okay; the PROFIBUS interface is monitored in order to recognize the baud rate used.

Text	Significance
"Wait-Prm"	The baud rate has been found, the drive waits for a parameterization telegram of the master that contains its IDN (contained in the device data sheet).
"Wait-Cfg"	The IndraDrive device has received a valid parameterization telegram and now waits for the configuration telegram in which the master tells the drive which modules it is expecting for input/output configuration.
"Data-Exch WD+"	The drive has received a valid configuration, it exchanges real-time data with the master. The communication is monitored by a watchdog.
"Data-Exch WD-"	The drive has received a valid configuration. It exchanges real-time data with the master without the communication being monitored by a watchdog.

Tab. 4-43: Significances of the Entries in Parameter P-0-4073

Error Codes of PROFIBUS Communication

Parameter Channel Errors

The table below contains an overview of the possible parameter channel error messages and their significances:

Error code	Significance
0x0082	Quantity of all transmitted data is too small, i.e. less than 4 bytes
0x0083	Quantity of data still to be transmitted is greater than the internal buffer
0x0088	The length of the valid data indicated in the control word is longer than the parameter channel
0x008C	Status conflict, a new request was transmitted although there are still data to be retrieved
0x008D	The length of data still to be transmitted that is indicated in the control word is incorrect
0x008E	The type of EIDN/IDN access specified in the control word bit 15 does not match the type of access configured in P-0-4083.0.1

Tab. 4-44: Overview Parameter Channel Errors

DPV1 Errors

The table below contains an overview of the possible DPV1 error messages and their significances:

Error code	Significance	Designation acc. to DPV1 standard
0x80 0xA0 0x00	The read request has a length of more than 10 bytes.	DPV1, access, read error
0x80 0xA1 0x00	The write request has a length of less than 11 bytes.	DPV1, access, write error
0x80 0xA9 0x00	DPV1 service not supported	DPV1, application, feature not supported
0x80 0xB0 0x00	No access to index 47.	DPV1, access, invalid index

Error code	Significance	Designation acc. to DPV1 standard
0x80 0xB1 0x00	There isn't any DPV1 header available.	DPV1, access, write length error
0x80 0xB2 0x00	No access to slot 0.	DPV1, access, invalid slot
0x80 0xB3 0x00	Access is only allowed to the value of the object.	DPV1, access, type conflict
0x80 0xB5 0x00	Parameter request not yet received, therefore response not yet available.	DPV1, access, state conflict
0x80 0xB6 0x00	The parameter cannot be written.	DPV1, access, access denied
0x80 0xB8 0x00	It is only allowed to process one parameter in one access.	DPV1, access, invalid parameter
0x80 0xC0 0x00	The request is still processed, the read request has to be repeated.	DPV1, resource, read constrain conflict

Tab. 4-45: Overview DPV1 Errors

Parameter Access Errors

The table below contains an overview of the possible parameter access errors and their significances; the error values are transmitted in word format:

Error No. (hex)	Significance
0x1001	No IDN
0x1009	Invalid access to element 1
0x2001	No name
0x2004	Name cannot be changed (read only)
0x3004	Attribute cannot be changed (read only)
0x4001	No units
0x4004	Unit cannot be changed (read only)
0x5001	No minimum input value
0x5004	Minimum input value cannot be changed (read only)
0x6001	No maximum input value
0x6004	Maximum input value cannot be changed (read only)
0x7002	Operation data transmission too short
0x7003	Operation data transmission too long
0x7004	Operation data cannot be changed (read only)
0x7005	Operation data is write-protected at this time (e.g. communication phase)
0x7006	Operation data is smaller than minimum input value
0x7007	Operation data is greater than maximum input value
0x7008	Invalid operation data: Configured IDN will not be supported, invalid bit number or bit combination

Error No. (hex)	Significance
0x7009	Operation data write protected by a password
0x700A	Operation data is write protected, it is configured cyclically
0x700B	Invalid indirect addressing (e.g. data container, list handling)
0x700C	Operation data is write protected, due to other settings (e.g., parameter, operation mode, drive enable, drive on etc.)
0x7010	Procedure command already active
0x7011	Procedure command not interruptible
0x7012	Procedure command at this time not executable (e.g., in this phase the procedure command cannot be activated)
0x7013	Procedure command not executable (invalid or false parameters)
0x9001	Input cannot be identified as application
0x9002	Parameter type error
0x9003	Invalid data record number
0x9004	Invalid data block number
0x9005	Data element number invalid
0x9006	Error in R/W flag
0x9007	Invalid character in the data

Tab. 4-46: Overview Parameter Access Errors

4.11 CANopen interface

4.11.1 Brief Description

It is possible to operate IndraDrive controllers with a CANopen interface as master communication module. This requires the control section design with the optional module "CANopen" (CN). Via this optional module, it is possible to exchange real-time data with a CANopen master. The "CANopen" protocol (according to Draft Standard DS301, version 4.0.2) has been implemented in the drive controller.

Communication Channels

We distinguish the following communication channels:

- Cyclic data channel (process data objects → PDO)

  The field bus provides data containers in which useful data can be cyclically transmitted in real time (process data objects).
- Acyclic data channel (service data objects → SDO)

  The field bus provides data containers in which useful data (service data objects) can be acyclically transmitted.

☞ The process data are always transmitted via PDOs.

Features

- Simple configuration through use of "Predefined Connection Set" and "Minimal Boot-Up" according to DS301

- Baud rates of 20, 50, 125, 250, 500, 800 and 1000 kbit/s specified by CANopen according to DS301 are supported
- Configurable cyclic data up to 15 parameters (incl. field bus control word and field bus status word) in both data directions (max. 32 bytes or 16 words)
- Functional compatibility with EcoDrive functions through profile selection (I/O mode)
- Node monitoring (heartbeat function and node guard function)
- LED displays at the front panel of the master communication module for simple diagnosis of bus functions and most important communication relationships between drive and field bus (2 LEDs: "Run" status and "Error" status)
- All parameters of the drive can be directly read via SDO and, if permitted, can be written
- Upload/download function for all parameters of the drive possible with SDO services
- Event-controlled or synchronous transmission of process data
- CANopen Device profile DSP402 is not supported; field bus profiles according to DSP402 are partly supported (see "Profile Types (with Field Bus Interfaces)")

Hardware Requirements

The optional module with CANopen interface is available for the following configurable control sections:

IndraDrive Cs	
BASIC	HCS01.1E-W00xx-A-0x-B-ET-EC-CN-xx-NN-FW
ADVANCED	HCS01.1E-W00xx-A-0x-A-CC-EC-EN-xx-NN-FW
IndraDrive control sections	
Basic control section - single-axis	CSB02.1x-ET-EC-CN-xx-xx-NN-FW
Advanced control section - single-axis	CSH02.1B-CC-EC-CN-xx-xx-NN-FW

Tab. 4-47: Control Section Design for CANopen Communication

Pertinent Parameters

Communication parameters

Specific parameters for CANopen communication:

- P-0-3610, CANopen: Heartbeat/NodeGuard Configuration
- P-0-3611, CANopen: COB-IDs
- P-0-3612, CANopen: Transmission Types
- P-0-3613, CANopen: List of the Event Parameters

Parameters for general field bus communication:

- P-0-4025, Drive address of master communication
- P-0-4073, Field bus: Diagnostic message
- P-0-4074, Field bus: Data format
- P-0-4075, Field bus: Watchdog
- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: Baud rate

Profile type parameters

Apart from mere communication parameters, we use parameters in conjunction with the profile types.

In this regard, see "Profile Types (with Field Bus Interfaces)"

Parameters for extended communication

We use additional parameters for extended communication.

See the following sections:

- "Configurable Signal Control Word"
- "Configurable Signal Status Word"

Pertinent Diagnostic Messages

- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable
- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- F4001 Sync telegram failure
- F4002 RTD telegram failure
- F4009 Bus failure
- F4012 Incorrect I/O length

4.11.2 Configuration CANopen Slave

EDS File

Due to the object directory, there is an individual EDS file for each firmware. These files comply with the specifications according to DSP306 and are checked according to versions V3.01, V3.02 and V4.01. Their names consist of the firmware designation and "…_Co.EDS":

- MPB18_Co.EDS
- MPC18_Co.EDS

Setting the Node Address of the Slave

The bus address can be set within the range of 1 to 127. This range is smaller than the range allowed for CANopen, as only 2 digits can be displayed.

- Setting is either made via the display or by means of the "IndraWorks Ds/D/MLD" commissioning tool.
- The node address is set in the parameter "P-0-4089.0.3, Device Address" and displayed in the parameter "P-0-4089.0.4, Active Device Address".
- A new node address can only be set during baud rate search and in the CANopen states "Initialised" (with CAN warning present) and "Stopped". The corresponding diagnostic messages in parameter "P-0-4073, Field bus: Diagnostic message" are:
  - "CANopen: Auto Baud rate detection"
  - "CANopen: Initialised CAN-Warning"
  - "CANopen: Stopped"
  - "CANopen: Stopped CAN-Warning"

See also section "Setting the Axis Address"

Baud Rate Search/Baud Rate Input

Supported Transmission Rates

All transmission rates specified by CANopen are supported. The bit timing corresponds to DS301 (version 4.0.2) and must have been implemented accordingly in the master.

Baud rate	Max. network dimension	Description
10 kBaud	5,468.07 yd	
20 kBaud	2,734.03 yd	Supported by baud rate search
50 kBaud	1,093.61 yd	
125 kBaud	546.81 yd	Supported by baud rate search
250 kBaud	273.40 yd	Supported by baud rate search
500 kBaud	109.36 yd	Supported by baud rate search
800 kBaud	54.68 yd	
1000 kBaud	27.34 yd	Supported by baud rate search

Tab. 4-48: CANopen Transmission Rates

Baud Rate Search

The automatic baud rate search is activated by writing the value "0" to parameter "P-0-4079, Field bus: Baud rate" or by triggering the command "load defaults procedure". The search is carried out directly after switch-on. The first baud rate with which searching takes place after switching on again is the last one found. Baud rate search is signaled by both LED displays flickering. Baud rates which were found by baud rate search are displayed as negative numbers in parameter P-0-4079.

If baud rate search is not desired, it can be deactivated by writing the baud rate as a positive number to parameter P-0-4079. During operation it is possible to activate the baud rate search again or deactivate it after having switched on.

Baud Rate Input

Manual input of a different baud rate is possible during baud rate search and in the CANopen states "Initialised" (with CAN warning present) and "Stopped".

Configuring the Cyclic Data

The parameters for configuring the cyclic data (P-0-4080 and P-0-4081) contain 16 elements each of which four each have been reserved for each PDO. The data length of the configured PDOs may be 8 bytes as a maximum. "S-0-0000, Dummy parameter" as an empty parameter must be assigned to entries which are not used. If a PDO only consists of empty parameters, it is deactivated.

Element in P-0-4080	PDO (tx)		Element in P-0-4081	PDO (rx)
0	PDO1 (tx)		0	PDO1 (rx)
1			1	
2			2	
3			3	
4	PDO2 (tx)		4	PDO2 (rx)
5			5	
6			6	
7			7	
8	PDO3 (tx)		8	PDO3 (rx)
9			9	
10			10	
11			11	
12	PDO4 (tx)		12	PDO4 (rx)
13			13	
14			14	
15			15	

Tab. 4-49: Configuring the Cyclic Data

4.11.3 Specifying the CANopen Interface

General Information

There are 11 bits "CAN Identifier" used for transmission.

Network Management Services

The network knows the following states:

- Initialising
- Pre-Operational
- Operational
- Stopped

A change of state is triggered by reception of an NMT telegram or a reset. The current state is transmitted in the NMT error telegram and displayed by the "Run" LED (H4) at the drive. In addition, it can be read from the parameter for the diagnostic field bus message (P-0-4073).

After having been switched on, the drive is in the "Initialising" state. After initialization has been completed, the drive transmits an NMT error telegram (boot-up telegram) and automatically goes to the "Pre-Operational" state.

Overview of Network States (Allowed Telegrams)

Telegram type	Initialising	Pre-Operational	Operational	Stopped
NMT	--	■	■	■
SYNC	--	■	■	--
NMT_Error	■	■	■	■
EMCY	--	■	■	--

Telegram type	Initialising	Pre-Operational	Operational	Stopped
SDO	--	■	■	--
PDO	--	--	■	--

Tab. 4-50: Network States and Telegrams for CANopen

NMT Telegrams

The NMT telegram consists of 2 bytes. The first byte contains the command, the second byte the address. The node accepts all telegrams which either contain "0" (the command is destined for all nodes) or its own node ID in the second byte.

- Start Remote Node (command byte = 1)
  → Node is brought to "Operational" state.
- Stop Remote Node (command byte = 2)
  → Node is brought to "Stopped" state.
- Enter Pre-Operational (command byte = 128)
  → Node is brought to "Pre-Operational" state.
- Reset Node (command byte = 129)
  Reset Communication (command byte = 130)
  → Node is brought to "Initialising" state and after initialization goes to "Pre-Operational" state.

Node monitoring

Types of Node Monitoring

Node monitoring is carried out by heartbeat telegrams or the so-called "Node Guarding".

Heartbeat Mechanism

With the heartbeat mechanism, each node transmits an NMT error telegram in intervals which have been set. Monitoring takes place independently of the master, as the node number of the node it monitors can be set in each node.

The heartbeat mechanism used ensures the following conditions:

- The physical availability of the transmitter.
- The bus load, as transmission takes place with the lowest priority.
- The network state of the transmitter.
- The availability of the transmitter and its data (watchdog).

The heartbeat telegrams transmit a 1-byte data:

- 0 → Boot-up message
- 4 → Node is in "Stopped" state
- 5 → Node is in "Operational" state
- 127 → Node is in "Pre-Operational" state

Heartbeat Interval

The calculation of the heartbeat interval uses the number of nodes at the bus and the baud rate. As an estimated value, 1500 bit times can be provided for each node (including master). The interval is calculated according to the following relationship:

$$T = \frac{1500 \times n}{f}$$

T Interval
n Number of nodes in network (incl. master)
f Baud rate

Fig. 4-42: Calculating the Heartbeat Interval

An interval should have a minimum duration of 10 ms. At least the double value should be selected as monitoring time for received heartbeat telegrams (consumer). The table below contains some combinations of node number and baud rate to determine the transmission interval.

	Baud rate (in kBaud)				
Number of nodes	20	125	250	500	1000
2	150 ms	24 ms	12 ms	10 ms	10 ms
3	225 ms	36 ms	18 ms	10 ms	10 ms
4	300 ms	48 ms	24 ms	12 ms	10 ms
5	375 ms	60 ms	30 ms	15 ms	10 ms
10	750 ms	120 ms	60 ms	30 ms	15 ms
15	1125 ms	180 ms	90 ms	45 ms	23 ms
20	1500 ms	240 ms	120 ms	60 ms	30 ms
30	2250 ms	360 ms	180 ms	90 ms	45 ms
40	3000 ms	480 ms	240 ms	120 ms	60 ms
50	3750 ms	600 ms	300 ms	150 ms	75 ms
60	4500 ms	720 ms	360 ms	180 ms	90 ms
70	5250 ms	840 ms	420 ms	210 ms	105 ms
80	6000 ms	960 ms	480 ms	240 ms	120 ms
90	6750 ms	1080 ms	540 ms	270 ms	135 ms
100	7500 ms	1200 ms	600 ms	300 ms	150 ms
127	9525 ms	1524 ms	762 ms	381 ms	191 ms

Tab. 4-51: Combinations of Node Number, Baud Rate and Transmission Interval

When the drive has been configured as heartbeat consumer and the transmitter is not in the "Operational" state, this is signaled by the "Error" LED (H5) flashing twice.

If after the Heartbeat Consumer Time there hasn't any NMT error telegram been received from the node to be monitored, a "Heartbeat Event" is triggered which in most cases results in the error message "F4009 Bus failure" (see Troubleshooting Guide for F4009).

Node Guarding

With the Node Guarding method, the master queries the individual nodes one after the other with an RTR request with regard to the NMT error telegram. The node replies with a Node Guard Telegram (NMT error).

The Node Guarding mechanism used ensures the following conditions:

- For the master:
  - Physical availability of the node which has been queried
  - Bus load, as transmission takes place with the lowest priority
  - Network state of the node which has been queried
  - Availability of the node which has been queried and its data (watchdog)
- For the node which has been queried:
  - Physical availability of the master
  - Bus load, as the request takes place with the lowest priority
  - Availability of the master and its data (watchdog)

The Node Guard Telegrams transmit a 1-byte data to the master with the following significance:

- 0 → Boot-up message
- 4 → Node is in "Stopped" state
- 5 → Node is in "Operational" state
- 127 → Node is in "Pre-Operational" state

Configuring the Node Monitoring

The behavior of node monitoring is configured in parameter "P-0-3610, CANopen: Heartbeat/NodeGuard Configuration". The required data are stored in this parameter as a 2-byte list containing 5 elements:

- Element 0

  → Heartbeat Producer Time (in ms); function is switched off with default value "0"
- Element 1

  → Heartbeat Consumer Time (in ms); monitoring is switched off with default value "0"
- Element 2

  → Node ID of the node to be monitored (valid values are 1 to 127); default value is "127"
- Element 3

  → Node Guard Time (in ms); function is switched off with default value "0"
- Element 4

  → Life Time Factor (valid values 1 to 255); default value is "3"

Only one of the two monitoring types may have been activated. Therefore, a check is run when writing data to the parameter P-0-3610 to find out whether either "Heartbeat" was switched off (elements 0 and 1 at "0") or "Node Guarding" was deactivated (element 3 at "0").

4.11.4 Cyclic Communication via Process Data Channel (PDO)

Characteristics of PDO Communication

The drive firmware supports 4 PDO(tx) and 4 PDO(rx) which can be freely configured:

- PDO1(tx) to PDO4(tx)

  → Data length 2 to 8 bytes; can be configured via P-0-4080
- PDO1(rx) to PDO4(rx)

→ Data length 2 to 8 bytes; can be configured via P-0-4081

List of Transmission Types

The transmission types are set in parameter "P-0-3612, CANopen: Transmission Types". The individual elements of the list parameter have the following significance:

Element	Description	Valid values
0	PDO1 (tx)	0, 1, 252, 253 and 254
1	PDO1 (rx)	0, 1, 252, 253 and 254
2	PDO2 (tx)	0, 1, 252, 253 and 254
3	PDO2 (rx)	0, 1, 252, 253 and 254
4	PDO3 (tx)	0, 1, 252, 253 and 254
5	PDO3 (rx)	0, 1, 252, 253 and 254
6	PDO4 (tx)	0, 1, 252, 253 and 254
7	PDO4 (rx)	0, 1, 252, 253 and 254

Tab. 4-52: List of Transmission Types in Parameter P-0-3612

Transmission Type "254"

The transmission type corresponding to value "254" has the following characteristics:

- PDO(rx) is applied with every "command value copying cycle" on the time base of "P-0-4076, Field bus: Process data - updating clock".
- PDO(tx) is updated with every "actual value copying cycle" on the time base of "P-0-4076, Field bus: Process data - updating clock"; current data can be queried by means of RTR.
- PDO(tx) is transmitted in the following cases:
  – Data of an event parameter was changed, see "P-0-3613, CANopen: List of the Event Parameters"

  - or -

  – Four-fold heartbeat or node guard time has passed since last transmission (heartbeat or node guard time must have been set greater than zero)

  - or -

  – The application-related event was switched from "ChangeOfState" to "cyclic" ("P-0-4088, Master communication: Drive configuration"). With a cyclic event, the corresponding PDOtx are transmitted in the clock of "P-0-4076, Field bus: Process data - updating clock", independently of any change of the data.

Transmission Type "253"

The transmission type corresponding to value "253" has the following characteristics:

- PDO(rx) is applied with every "command value copying cycle" on the time base of "P-0-4076, Field bus: Process data - updating clock".
- PDO(tx) is updated with every "actual value copying cycle" on the time base of "P-0-4076, Field bus: Process data - updating clock".
- PDO(tx) is transmitted as soon as data are queried by means of RTR

Transmission Type "252"

The transmission type corresponding to value "252" has the following characteristics:

- See transmission type "253"

- **Additionally**, SYNC telegram tries to synchronize internal clock of the drive controller

Transmission Type "1"

The transmission type 1 can be operated in the following 2 versions:

- PLL synchronization activated ("P-0-4089.0.5, Master communication: Configuration" bit 0 = 0) with the following characteristics:
  - SYNC telegram tries to synchronize the internal clock of the drive controller; in the case of double telegram failure, error message "F4001 Sync telegram failure+" is generated
  - PDO(rx) is applied with every "command value copying cycle" (is in last position loop clock before SYNC telegram) on the time base of "P-0-4076, Field bus: Process data - updating clock"
  - PDO(rx) reception is monitored

    → In the case of one-time failure, new command values are calculated from the previous values; in the case of double failure, the error message "F4002 RTD telegram failure" is generated.
  - PDO(tx) is updated with every "actual value copying cycle" (is in first position loop clock after SYNC telegram) on the time base of "P-0-4076, Field bus: Process data - updating clock"
  - PDO(tx) is transmitted in interval of field bus cycle time; transmission starting time is directly after update of data
  - Only PDO1 is supported
- PLL synchronization deactivated ("P-0-4089.0.5, Master communication: Configuration" bit 0 = 1) with the following characteristics:

  In the next position loop clock after the received Sync telegram
  - the command values are applied from the last RxPDO and
  - the actual values are registered and transmitted as TxPDO.

Transmission Type "0"

The transmission type corresponding to value "0" has the following characteristics:

- See transmission type "1", but PDO(rx) reception is **not monitored**

> ☞ With IndraDrive devices, the last position loop clock is considered as blocking time in which it is not allowed to transmit any synchronous process data object (PDO).

Minimum Supported Cycle Time (Bus Cycle Time)

Depending on the position loop clock, the IndraDrive firmware supports the following minimum cycle times:

Position loop clock (in ms)	Min. bus cycle time (in ms)
0.125	1
0.250	1
0.500	2
1	4

Tab. 4-53: Bus Cycle Time Depending on Position Loop Clock

List of the Event Parameters

All parameters of the drive which are suited for event-controlled transmission are listed in parameter "P-0-3613, CANopen: List of the Event Parameters". If one of these parameters has been configured as actual value, the corresponding PDO is immediately transmitted when the data is changed. The minimum possible interval between two telegrams is determined with "P-0-4076, Field bus: Process data - updating clock".

List of COB-IDs

The COB-IDs used (the CAN identifiers used by these telegrams) are stored in parameter "P-0-3611, CANopen: COB-IDs". When the most significant bit (inactivity bit) has been set, the telegram is deactivated. This bit is set depending on the PDOs required for cyclic communication.

Element of parameter	PDO	Standard value
0	PDO1 (tx)	0x180 + node ID
1	PDO1 (rx)	0x200 + node ID
2	PDO2 (tx)	0x280 + node ID
3	PDO2 (rx)	0x300 + node ID
4	PDO3 (tx)	0x380 + node ID
5	PDO3 (rx)	0x400 + node ID
6	PDO4 (tx)	0x480 + node ID
7	PDO4 (rx)	0x500 + node ID
8	EMCY	0x080 + node ID
9	SYNC	0x080 (rx) or 40000080 (tx)

Tab. 4-54: Assignment of Elements of Parameter P-0-3611

The drive can work both as SYNC consumer (rx) and as SYNC producer (tx).

SYNC Consumer

As soon as a synchronous transmission type has been selected and SYNC-COB-ID is at "0x80" (rx), the drive during the transition "PM → OM" switches to synchronous operation and tries to synchronize to a SYNC telegram. As soon as this has happened, the drive switches to operating status "bb".

If a different IndraDrive device is used as SYNC producer in the network, the bus runtime of the SYNC telegram can be corrected with a PLL offset. This PLL offset is activated via bit 8 of parameter "P-0-4088, Master communication: Drive configuration".

SYNC Producer

If the SYNC-COB-ID is at "0x40000080" (tx) and a synchronous transmission type has been selected, the drive during the transition "PM → OM" switches to synchronous operation and transmits a SYNC telegram to synchronize the other bus nodes to itself. As the drive itself is a SYNC producer, it immediately switches to the operating status "bb".

☞ In the network, only one node may have been configured as "SYNC producer".

4.11.5 Acyclic Parameter Access (SDO)

All parameters of the drive can be reached by means of SDO access. The following COB-IDs are assigned in a fixed way (conforming to standard):

- SDO(tx) → 0x580 + Node-ID
- SDO(rx) → 0x600 + Node-ID

The following SDO services are supported:

- SDO Download

→ To write a maximum of 4 bytes of data to the drive

- Initiate SDO Download

  → To write more than 4 bytes of data to the drive (with "Initiate" the length of the data is transmitted)

- Download SDO Segment

  → To transmit a fragment with data to the drive

- SDO Upload

  → To transmit a maximum of 4 bytes of data from drive to master

- Initiate SDO Upload

  → To transmit more than 4 bytes of data from drive to master (drive informs master of length of response data)

- Upload SDO Segment

  → To transmit a fragment with data from drive to master

- Abort SDO Transfer

  → To report errors and abort SDO accesses

☞ It is not possible to parameterize the field bus control word via acyclic SDO services. To allow axis control, the cyclic data channel must be used by means of PDOs in the higher-level control unit or the corresponding logic must be programmed with permanent control in MLD. If the control unit does not have a cyclic data channel, axis control cannot take place without MLD.

4.11.6 CANopen Objects

Communication Objects (0x1000 to 0x1FFF)

The communication objects are described in the CANopen standard DS301. Within the CANopen communication, these objects have one of the following functions:

- Access to drive parameters
- Constants
- Read-only objects

The table below contains an overview of the **objects specified** for CANopen communication:

Index	Subindex/ SubNumber	Description	Parameters
0x1000	0x00	ParameterName = Device Type ObjectType = 0x7 DataType = 0x7 DefaultValue = 0x00000192 AccessType = ro	0x00FF0192
0x1001	0x00	ParameterName = Error Register ObjectType = 0x7 DataType = 0x5 AccessType = ro	

Index	Subindex/ SubNumber	Description	Parameters
0x1018	5	ParameterName = Identity Object ObjectType = 0x9	
	0x00	ParameterName = Number Of Entries DataType = 0x5 DefaultValue = 4 AccessType = ro	
	0x01	ParameterName = Vendor ID DataType = 0x7 DefaultValue = 0x24 AccessType = ro	36
	0x02	ParameterName = Product Code DataType = 0x7 DefaultValue = 0x4 AccessType = ro	4
	0x03	ParameterName = Revision Number DataType = 0x7 AccessType = ro	P-0-1509: Element 5 (release)
	0x04	ParameterName = Serial Number DataType = 0x7 AccessType = ro	P-0-1509: Element 3 (serial no.)

Tab. 4-55: Specified CANopen Objects

☞ Other communication objects of CANopen Interface are listed in the relevant EDS file.

Manufacturer-Specific Objects (0x2000 to 0x3FFF)

Manufacturer-Specific Objects

All parameters of the drive can be reached via the manufacturer-specific objects. The S-parameters are addressed via the objects 0x2000 to 0x2FFF, the P-parameters via the objects 0x3000 to 0x3FFF. The manufacturer-specific objects have the following structure:

Subindex	Description
0	Number of parameter sets (1 or 8)
1	Operating data block 0
2	Operating data block 1 (if available)
3	Operating data block 2 (if available)
4	Operating data block 3 (if available)
5	Operating data block 4 (if available)
6	Operating data block 5 (if available)
7	Operating data block 6 (if available)

Subindex	Description
8	Operating data block 7 (if available)
10	Index of list pointer
11	List element to which element 10 points (only for list parameter)
12...18	List element to which element 10 points (if 8 parameter sets available); only for list parameter
21	Name of parameter
22…28	Name of parameter (if 8 parameter sets available)
31	Attribute of parameter
32…38	Attribute of parameter (if 8 parameter sets available)
41	Unit of parameter
42…48	Unit of parameter (if 8 parameter sets available)
51	Minimum value of parameter
52…58	Minimum value of parameter (if 8 parameter sets available)
61	Maximum value of parameter
62…68	Maximum value of parameter (if 8 parameter sets available)
71	Maximum length of list parameter
72…78	Maximum length of list parameter (if 8 parameter sets available)
81	Actual length of list parameter
82…88	Actual length of list parameter (if 8 parameter sets available)

Tab. 4-56: Structure of Manufacturer-Specific Objects

List Access

The complete list of a list parameter can be read or written by accessing the operating data of the parameter.

To access individual list elements, it is possible to set a list index (subindex 10) and access the respective list element of the list index via subindex 11 (to subindex 18). With each access via subindex 11 (to subindex 18), the list index is incremented by one element. This allows processing a continuous part of a list in the case of repeated access to subindex 11 (to subindex 18).

With one of the following actions, the list index is reset to the first element:

- Change of parameter set
- Change of parameter
- Abortion of connection

For each list element access which does not start from the first element, it is therefore necessary to set the list index.

If the length of the list has to be changed, this can be corrected by changing the actual length of the list parameter (subindex 81…88).

The maximum list length can be read via the subindices 71…78.

With one of the following actions, the parameter value is stored:

- Writing to last element
- Change to a different parameter
- Change of parameter set

- Reading the same parameter
- Abortion of connection

The changes are discarded when the control voltage fails.

4.11.7 Notes on Commissioning

Commissioning the CANopen interface requires the following individual steps:

1. To set address (see also section "Setting the Axis Address"), it is advantageous not yet to connect CAN connector to drive controller. In this case, drive always is in a state in which address may be changed.
2. If baud rate is known, it should be preset in parameter P-0-4079. Drive thereby establishes communication faster. In addition, this helps avoid possible problems of master with nodes of automatic baud rate detection in network.
3. Configure cyclic data (see also section "Profile Types (with Field Bus Interfaces)").
4. If node monitoring is desired, it should be configured (see "Node Monitoring" above).
5. Transmit a "Start Remote Node" telegram (see "NMT Telegrams" above) for drive or for all nodes. After that, cyclic data are exchanged by PDOs.

4.11.8 Diagnostic Messages and Monitoring Functions

Diagnostic LED

The diagnostic LED displays are controlled according to standard DS303-3 V1.2. There are two LEDs at the front of the optional module CO; with master communication "CANopen" their displays have the significances described below.

LED Display "Run" (H4, Green)

Behavior of "Run" LED (H4; green) according to DS303-3:

Behavior of LED "H4"	Status	Significance
LED flickers	Auto-baudrate	Drive searches baud rate.
LED flashes	Pre-Operational	Drive is in CANopen state "Pre-Operational".
LED flashes shortly	Stopped	Drive is in CANopen state "Stopped"
LED permanently lit	Operational	Drive is in CANopen state "Operational".

Tab. 4-57: Behavior and Significance of "Run" LED (H4)

LED Display "Error" H5 (H5, Red)

Behavior of "Error" LED (H5; red) according to DS303-3:

Behavior of LED "H5"	Status	Significance
LED off	No error	CANopen interface works without error.
LED flickers	Auto-baudrate	Drive searches baud rate.
LED flashes once	Warning	CAN controller detected many errors during transmission or reception of telegrams.

Behavior of LED "H5"	Status	Significance
LED flashes twice	Node monitoring	Master no longer transmits heartbeat telegram (or no longer transmits NodeGuard request) or is not in "Operational" state while drive is in "Operational".
LED flashes three times		MST failure
LED permanently lit	Bus-Off	CAN controller detected too many errors during transmission or reception of telegrams and has switched off.

Tab. 4-58: Behavior and Significance of "Error"-LED (H5)

CANopen - Diagnostic Messages

Depending on the CANopen status and the transmission errors on the CAN bus, a diagnostic message is generated which can be read via parameter "P-0-4073, Field bus: Diagnostic message".

Diagnostic message	Significance
CANopen: Offline	CANopen task is initialized.
CANopen: Auto Baudrate Detection	Drive searches baud rate (see "Baud Rate Search/Baud Rate Input").
CANopen: Initialised	Initialization was run after switch-on or after a reset, a boot-up telegram is to be transmitted.
CANopen: Initialised CAN-Warning	In "Initialized" state, too many errors were detected on CAN bus, CAN interface is in "Warning" state. This state mostly means that boot-up telegram could not be transmitted. Possible causes: Drive (currently) is only node at bus or there is node with different baud rate at bus.
CANopen: Pre-Operational	Boot-up telegram was transmitted, drive now is in "Pre-Operational" state. Parameters can be read and written by means of SDO.
CANopen: Pre-Operational CAN-Warning	In "Pre-Operational" state, too many errors were detected on CAN bus, CAN interface is in "Warning" state.
CANopen: Operational	Drive exchanges cyclic data (see "List of Transmission Types").
CANopen: Operational (only producer)	By received heartbeat telegram, master detected that heartbeat transmitter does not send any PDO due to network state.
CANopen: Operational CAN-Warning	In "Operational" state, too many errors were detected on CAN bus, CAN interface is in "Warning" state.
CANopen: Stopped	Drive is in "Stopped" state. In this state, drive only receives NMT commands. It is now possible to change basic communication parameters, such as baud rate or address.
CANopen: Stopped CAN-Warning	In "Stopped" state, too many errors were detected on CAN bus, CAN interface is in "Warning" state.

Master Communication

Diagnostic message	Significance
CANopen: BUS-OFF	CAN interface detected too many transmission errors and received incorrect telegrams. Possible causes are, among other things, disturbances on bus cable, short circuits, interruptions of bus cable or nodes with different baud rates at bus.
CANopen: BUS-OFF (RxCounter = 0)	CAN interface detected too many transmission errors. Most likely there wasn't any telegram received or received telegrams were not error-free.

Tab. 4-59: Overview of Diagnostic Messages for CANopen Communication

Emergency Object

When an error occurs or is cleared, an EMCY telegram is transmitted. The EMCY telegram transports 8-byte data.

0	1	2	3	4	5	6	7
0xFF00		0x81	P-0-0009		S-0-0390 (three least significant bytes)		

Tab. 4-60: Error Telegram

0	1	2	3	4	5	6	7
0x0000		0x00	P-0-0009		S-0-0390 (three least significant bytes)		

Tab. 4-61: Error-Cleared Telegram

IndraDrive - Diagnostic Error Messages

IndraDrive's diagnostic error messages and their significances in conjunction with CANopen master communication:

- F4001 Sync telegram failure

  → In two successive cycles, there hasn't any SYNC telegram been received.

- F4002 RTD telegram failure

  → In two successive cycles, there hasn't any cyclic PDO telegram been received.

- F4009 Bus failure

  → Within the "Heartbeat Consumer Time", there hasn't any heartbeat telegram been received.

  - or -

  → Within the "Life-Time-Counter"-fold "Node-Guarding-Time", there hasn't any Node Guarding request been received.

  Note: With the corresponding setting in parameter "P-0-4088, Master communication: Drive configuration" (bits 1 and 2), this error message can be replaced by the warning "E4005 No command value input via master communication" (see also "Emergency Mode (When Master Communication has Failed)").

- F4012 Incorrect I/O length

  → A PDO telegram was received which had a different length than the configured length.

4.12 Analog interface

4.12.1 Brief Description

Overview

Apart from the digital master communication interfaces (sercos, PROFIBUS…), the drive controllers of the IndraDrive range provide an interface for analog master communication (analog interface). This allows assigning an analog command value to a drive parameter (e.g. "S-0-0036, Velocity command value").

The figures below illustrate the structure of drive solutions with analog interface and open-loop or closed-loop operation.

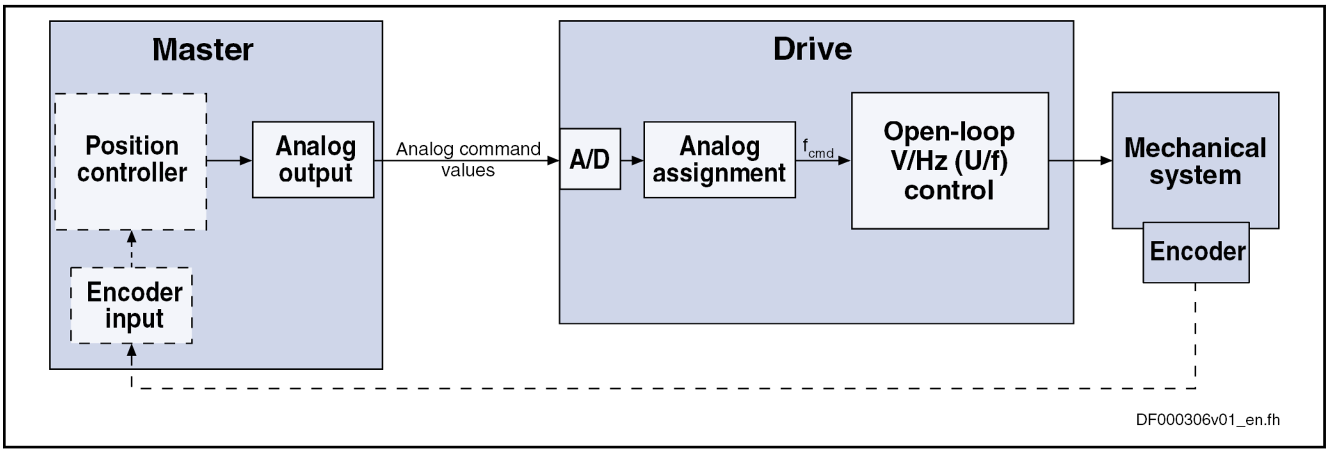


Fig. 4-43: Open-Loop Operation with Analog Interface (with Optional Position Feedback to Open-Loop Control)

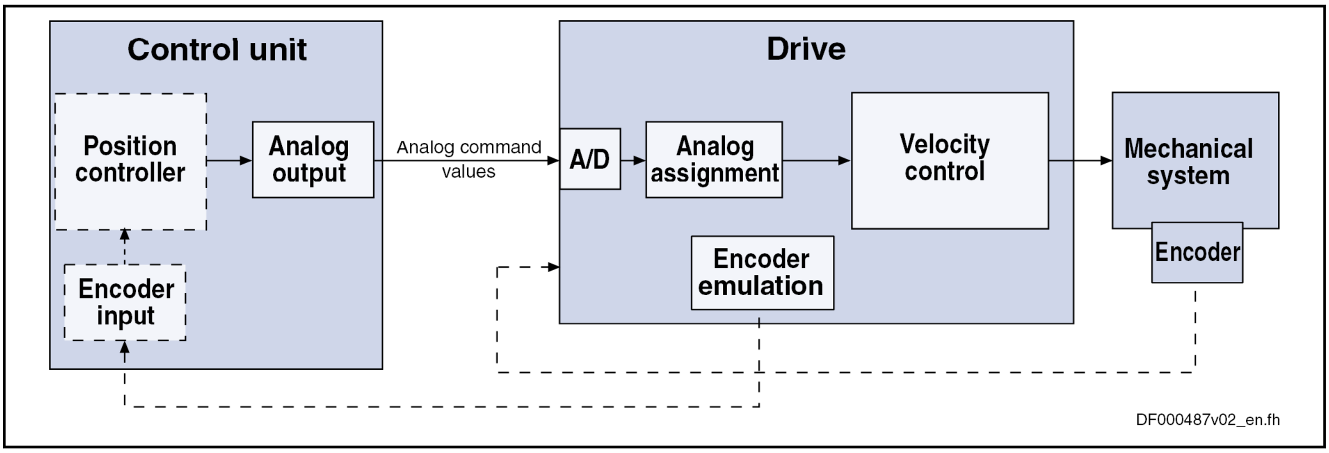


Fig. 4-44: Closed-Loop Operation with Analog Interface (with Analog Command Value Input and SSI Emulation)

This section describes the basic functions of the analog interface and contains notes on commissioning and parameterization. The single function used, "Analog inputs", is described separately.

See also "Analog Inputs"

Features

The analog interface is an interface for master communication with analog command values and digital inputs/outputs (drive enable, Drive Halt, …).

Features of the **analog inputs**:

- Analog inputs (14 bit) which can be assigned to parameters, with smoothing to be set (number of analog inputs depending on control section design)

- Sampling of the analog inputs in the position controller clock $T_{position}$ (see "Performance Data"

Features of the **analog assignment**:

- Two assignments to parameters are possible; offset and scaling of the analog input can be set for each assignment
- Sampling rates for analog input assignment:
  - Assignment channel A → assignment in position controller clock $T_{position}$
  - Assignment channel B → assignment in clock of 2 ms

Features of the **digital inputs/outputs**:

- Digital control and status information determined via configuration of the digital inputs of the control section:
  - **Digital control inputs** for analog master communication:
    - "Drive enable" and "Drive Halt" signals
    - Zero switch, limit switch (+/-); clearing errors and E-Stop
  - **Digital status outputs** for analog master communication:
    - Ready and warning output
    - Relay output for readiness for operation

Availability

All drive controllers except for KSM02.1 and KMS02.1 provide the possibility of analog operation. For this purpose, the master communication must be de-activated by means of "P-0-4089.0.1, Master communication: Protocol".

The Multi-Ethernet interface can still be used for engineering and diagnostic purposes.

Pertinent Parameters

Control and status parameters:

- P-0-0115, Device control: Status word
- P-0-0116, Device control: Control word
- P-0-4028, Device control word

Digital inputs/outputs:

- P-0-0300, Digital inputs, assignment list
- P-0-0301, Digital inputs, bit numbers
- P-0-0303, Digital inputs, input image of device
- P-0-0304, Digital outputs, output image of device
- P-0-0306, Digital inputs, assignment connector and pin
- P-0-0307, Digital inputs, input image sub-device
- P-0-0310, Digital outputs, assignment list
- P-0-0311, Digital outputs, bit numbers
- P-0-0312, Digital outputs, assignment sub-device
- P-0-0313, Digital outputs, output image sub-device
- P-0-0316, Digital outputs, assignment connector and pin

Analog inputs:

- P-0-0210, Analog input 1
- P-0-0212, Analog input, list of assignable parameters
- P-0-0213,

- P-0-0214, Analog input, assignment A, scaling
- P-0-0215, Analog input, assignment A, signal value at 0
- P-0-0216, Analog input, assignment A, dead zone
- P-0-0217, Analog input 1, time constant input filter
- P-0-0218, Analog input, control parameter
- P-0-0219,
- P-0-0220,
- P-0-0236,
- P-0-0237, Analog input, assignment B, scaling
- P-0-0238, Analog input, assignment B, signal value at 0
- P-0-0239, Analog input, assignment B, dead zone
- P-0-3901, Adjustment values of control section

Encoder emulation:

- P-0-0900, Encoder emulation signal selection list
- P-0-0901.x.1, Encoder emulation signal selection
- P-0-0901.x.2, Encoder emulation control parameter
- P-0-0901.x.3, Encoder emulation resolution
- P-0-0901.x.4, Encoder emulation zero pulse offset

4.12.2 Functional Description

Control

With the analog interface, the drive is controlled via the digital inputs. The pins are assigned to the drive parameters via the list parameter "P-0-0300, Digital inputs, assignment list". For all device types (HCS01, HCQ/HCT), there is a default assignment of parameters to the pins of the terminal strips. The preset default assignment can be modified according to the application-specific requirements.

See Parameter Description "P-0-0030, Digital inputs, assignment list"

See also "Overview of Functions and Interfaces" in the documentation "Control Sections for Drive Controllers; Project Planning Manual"

Drive enable

The activation of the drive requires a positive edge of the "drive enable" signal (connector pin assignment see corresponding section in the documentation "Control Sections for Drive Controllers; Project Planning Manual").

The "drive enable" signal is mapped to the parameters "P-0-4028, Device control word" and "P-0-0116, Device control: Control word".

See also "Device Control and State Machines"

The enable signal is accepted, i.e. the drive switches from its de-energized state to its energized state, when the following conditions have been fulfilled:

- There mustn't be any drive error present.
- The drive must be in the operating mode (phase 4).
- Power must have been switched on and the DC bus voltage must be above the defined minimum threshold.

The drive displays this state on the control panel with "Ab". The diagnostic drive message in parameter "S-0-0095, Diagnostic message" is "A0012 Control and power sections ready for operation".

"Drive Halt" Signal

When drive enable is set and the "Drive Halt" signal is active (P-0-4028 or P-0-0116, bit 13 = 0),

- the display of the control panel changes to "AH" and
- the diagnostic drive message then is "A0010 Drive HALT" and thereby signals the activation of "Drive Halt".

If afterwards the "Drive Halt" signal is deactivated (P-0-4028 or P-0-0116, bit 13 = 1),

- the display of the control panel changes to "AF" and
- the diagnostic drive message depends on the active operation mode (see description of the respective diagnostic message in the separate documentation "Troubleshooting Guide (description of diagnostic messages)")

☞ The "Drive Halt" signal is state-controlled and active when the signal = 0 V; this means that for signal =0 V the drive is in the "Drive Halt" state.

Clear error

A positive edge at the "clear error" input starts the command for error clearing. For this purpose, the command C0500 has to be assigned to a digital input:

- Configure parameter "S-0-0099, C0500 Reset class 1 diagnostics" in "P-0-0300, Digital inputs, assignment list"
- In parameter "P-0-0301, Digital inputs, bit numbers", set bit 0 for the element of S-0-0099

See also "Digital Inputs/Outputs"

☞ All drive errors are cleared by activating the command for error clearing!

Analog Command Value Input

The analog inputs, or one analog input with HCS01, are used to input the analog command value.

For IndraDrive devices, the analog inputs are cyclically sampled and evaluated:

- Assignment channel A works in position controller clock (see "Performance Data")
- Assignment channel B works in 2 ms clock

See "Analog inputs"

4.12.3 Notes on Commissioning/Parameterization

Analog Inputs

If the higher-level master and the drive have not been synchronized, beat effects can occur during sampling due to the different clock rates. Rexroth therefore recommends not to use the analog interface in high end applications, but in these cases use digital interfaces.

For inputting the cyclic command value, you should preferably use assignment channel A as it has a higher sampling rate than assignment channel B.

In spite of their high degree of functionality and performance, the analog inputs available for IndraDrive devices are subject to certain restrictions. These restrictions are explained in detail in section "Analog Inputs".

See also "Analog Inputs"

If the drives with analog command value input have not been synchronized, beat effects can occur during sampling in spite of the 8-fold oversampling. Rexroth therefore recommends not to use the analog interface in high end applications, but in these cases use digital interfaces.

4.12.4 Diagnostic and Status Messages

Information on General Drive State

All important status bits of the state machine of the drive are mapped to parameter "P-0-0115, Device control: Status word". Reading and interpreting parameter P-0-0115 provides information on the current state of the drive.

See Parameter Description "P-0-0115, Device control: Status word"

Status of Digital Inputs/Outputs and Analog Inputs

All digital and analog input values can already be read via parameters before they are assigned to the internal drive parameters. The following applies:

- Digital inputs/outputs of the control module are mapped to parameter "P-0-0303, Digital inputs, input image of device"
- Analog input values are displayed in parameter "P-0-0210, Analog input 1"

See also "Diagnostic and Status Messages" in the following sections:

- "Digital Inputs/Outputs"
- "Analog Inputs"

4.13 RIL_ModbusTCP

The field bus protocol "Modbus TCP" is used to exchange data between Ethernet devices which support the Modbus protocol.

In this case, the drive-internal PLC assumes the role of the "Modbus TCP" server (master) to which the "Modbus TCP" clients (slaves) can connect.

By means of the function blocks contained in the "RIL_ModbusTCP" library, both a "Modbus TCP" server and a "Modbus TCP" client can be implemented.

The library is supported by several targets and therefore is described in the documentation "Basic Libraries, IndraLogic 2G".

5 Motor, Mechanical Axis System, Measuring Systems

5.1 Safety Instructions

⚠ WARNING **Dangerous movements! Danger to life, risk of injury, serious injury or property damage!**

- Keep free and clear of the ranges of motion of machines and moving machine parts.
- Prevent personnel from accidentally entering the machine's range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

5.2 General Information on Operation of Motors with IndraDrive

5.2.1 Basics on the Motors to be Controlled

Brief Description

With the controllers of the IndraDrive range it is possible to control both synchronous motors and asynchronous motors.

Types of Construction

The following types of construction are possible:

- Rotary motors
- Linear motors

Both types can be used in housing design (motor with an output shaft that includes the bearing) or in kit design (stator and rotor as individual components).

Thermal Monitoring

When IndraDrive is used, the controlled motors are protected against thermal damage when they are provided with a temperature sensor connected to the controller. The controllers are equipped for evaluating the following temperature sensors:

- NTC thermistor K227 (manufacturer: Siemens)
- PTC thermistor KTY84 (manufacturer: Siemens)
- Thermal switch SNM150DK (manufacturer: Thermik)

In addition, it is possible to evaluate temperature sensors not listed above, but their specific resistance characteristics have to be entered manually!

Diagnostic Data for Motor Operation

The firmware provides the option to collect dynamic operating data of the motor and store them (operating hours counter, thermal and mechanical operating data, operational performance).

Adjusting Mains Voltage / Motor

Motors the winding insulation of which is not suited for the maximum nominal DC bus voltage of DC750V, can be protected against inadmissibly high voltage by specifying the maximum DC bus voltage allowed for these motor types. The braking resistor threshold is adjusted to the value of this parameter and the DC bus voltage is limited to this value ("output stage locked"). If the DC bus voltage to be expected is higher than the one allowed for the motor, you must check whether the DC bus voltage can be dropped to a value allowed for the motor by reducing the mains voltage.

Adjusting Motor/Controller

The IndraDrive controllers are adjusted to the motor to be controlled by providing or inputting the motor-specific data.

- In the case of **Rexroth motors**, this can be done without any problem, because the manufacturer provides a specific data set for adjusting each motor type. The data are documented by the manufacturer as parameter values, stored and made available in motor-specific parameters.
- In the case of **third-party motors**, it is necessary to check, by means of the motor data and the data of the possibly available motor encoder, whether they are basically suited for operation with IndraDrive. The parameter values for adjusting the controller have to be specifically determined for each motor.

☞ Rexroth motors, by motor-specific parameter values made available and temperature evaluation adjusted in an optimum way, guarantee easy commissioning, full drive performance and a high degree of operational safety!

Motor Holding Brakes

IndraDrive allows controlling and monitoring holding brakes that are mechanically connected to the motor:

- Electrically releasing brakes (self-holding)
- Electrically holding brakes (self-releasing)

Hardware Data

For the electrical connection of the motors to the controller, see the Project Planning Manuals for the IndraDrive controllers. A complete connection diagram for the use of Rexroth motors is contained in the respective Project Planning Manual.

Pertinent Parameters

Motor parameters:

- S-0-0109, Motor peak current
- S-0-0111, Motor current at standstill
- S-0-0113, Maximum motor speed
- S-0-0141, Motor type
- P-0-0018, Number of pole pairs/pole pair distance
- P-0-0051, Torque/force constant
- P-0-0510, Rotor inertia
- P-0-0640, Cooling type
- P-0-0853, Max. DC bus voltage, motor
- P-0-4014, Type of construction of motor
- P-0-4048, Stator resistance

Synchronous motor parameters:

- P-0-4016, Direct-axis inductance of motor
- P-0-4002, Charact. of quadrature-axis induct. of motor, inductances
- P-0-4003, Charact. of quadrature-axis inductance of motor, currents
- P-0-4005, Flux-generating current, limit value
- P-0-4013, Current limit value of demagnetization

Asynchronous motor parameters:

- P-0-0532, Premagnetization factor
- P-0-4004, Magnetizing current
- P-0-0529, Scaling of stall current limit
- P-0-0530, Slip increase
- P-0-4039, Stator leakage inductance
- P-0-4040, Rotor leakage inductance
- P-0-4041, Motor magnetizing inductance
- P-0-4042, Characteristic of motor magnetizing inductance
- P-0-4043, Rotor time constant

Field-weakening range parameters:

- P-0-0533,
- P-0-0534, Voltage loop integral action time
- P-0-0535, Motor voltage at no load
- P-0-0536, Maximum motor voltage

Other Motor-Relevant Parameters

In connection with the motor, there are other important parameters of the following parameter groups:

- Measuring system parameters
- Motor holding brake parameters
- Temperature sensor parameters
- Motor temperature model parameters
- Default control loop parameters

5.2.2 Motor Temperature Monitoring

Brief Description

See "Basics on the Motors to be Controlled"

Pertinent Parameters

- S-0-0201, Motor warning temperature
- S-0-0204, Motor shutdown temperature
- S-0-0383, Motor temperature
- P-0-0512, Temperature sensor
- P-0-0513,

Pertinent Diagnostic Messages

- E2021 Motor temperature outside of measuring range
- E2051 Motor overtemp. prewarning
- F2019 Motor overtemperature shutdown
- F2021 Motor temperature monitor defective

Functional Description

Motors can be thermally monitored by the controller and thereby protected against damage by overload.

The motor is protected against thermal overload by

- monitoring the motor temperature by means of a sensor

  and
- limiting the motor current by means of a temperature model.

For this purpose, there are the following prerequisites:

- The motor has a built-in temperature sensor.

- Motor-specific parameter values are active in the motor temperature model.
- The ambient temperature is in the specified range.

Monitoring the motor temperature by means of a sensor is the most reliable way of protecting the motor against inadmissible temperature rise. Temperature sensors, however, might possibly be unsuitable to protect the motor in the case of high overload and very slow speeds, therefore, the motor temperature model should be additionally used to protect the motor.

> The limitation of the motor current by means of the motor temperature model is described in the section "Current and Torque/ Force Limitation".

The monitoring of the motor temperature is activated by entering the sensor type in the parameter "P-0-0512, Temperature sensor".

The current motor temperature is output in the parameter "S-0-0383, Motor temperature" and monitored for the following threshold values:

- Motor warning temperature (S-0-0201)
- Motor shutdown temperature (S-0-0204)

The threshold values have to be entered in the respective parameters, depending on the thermally restricting material properties and constructional features. Thermally restricting properties can be:

- Insulation class of the motor
- Type and construction of the bearing
- Allowed thermal effect on the machine design, etc.

If the temperature sensor has not been connected, this is detected by the motor temperature monitor, too.

Depending on the sensor type, motor temperature monitoring has the following states:

Thermal state	Motor temperature...	Message and reaction
Thermal range not allowed, temperature sensor possibly not connected.	... for 30 s ≤ -40°C	**Error:** F2021 Motor temperature monitor defective
		Only with sensor **KTY84**: **Warning:** E2021 Motor temperature outside of measuring range
		Only for sensors with **switch contact**: The measuring range is not checked.
Allowed thermal range	... < value of S-0-0201	No specific message or reaction!
Thermal range allowed, but warning temperature exceeded, because temperature has fallen below the minimum distance to the upper limit.	... ≥ value of S-0-0201	**Warning:** E2051 Motor overtemp. prewarning

Thermal state	Motor temperature...	Message and reaction
Upper limit of allowed thermal range reached!	... ≥ value of S-0-0204	**Error:** F2019 Motor overtemperature shutdown
Only with sensor **KTY84**: Short circuit or conductor break detected		Only with sensor **KTY84**: **Error:** F2021 Motor temperature monitor defective

Tab. 5-1: States of the Thermal Motor Monitoring

Rexroth Motors

Rexroth motors are equipped with standard type sensors. The respective parameter values for the temperature sensor, as well as for the motor shutdown temperature, are automatically set correctly when loading the motor parameters!

☞ For motors equipped with temperature sensors with switching properties, the signaling and shutdown threshold can **not** be set via parameters S-0-0201 and S-0-0204.

The mentioned temperature sensors are not suited for measuring the temperature and only used to switch off the motor in the case of overtemperature.

Third-Party Motors

Third-party motors may include temperature sensors that do not correspond to the standard type sensors. This is parameterized via "P-0-0512, Temperature sensor". The respective resistance temperature characteristic then has to be input manually as a table of values in parameter "P-0-0513, ".

See also "Third-Party Motors at IndraDrive Controllers"

Motors without Temperature Sensor

Motors without built-in temperature sensor can also be operated with IndraDrive controllers. However, they are only protected against thermal overload by the firmware-side motor temperature model! In this case, temperature monitoring must be switched off.

Notes on Commissioning

Relevant Parameters

For the following parameters, it is necessary to replace the default value by an adjusted value during commissioning.

Motor type	Temperature sensor characteristic number	P-0-0512	P-0-0513	S-0-0201	S-0-0204
Rexroth motor	1, 4	*)			
Rexroth motor	2, 3, 5			x	
Third-party motor	2, 3, 5	x		x	x
Third-party motor	6	x			
Third-party motor	100	x	x	x	x

*) No setting needed, motor temperature monitoring is automatically parameterized

Tab. 5-2: Parameterization of thermal motor monitoring

☞ The value in parameter S-0-0201 must be lower than the value of parameter S-0-0204!

Activating/Deactivating the Function

The monitoring of the motor temperature is activated by entering the sensor type in the parameter "P-0-0512, Temperature sensor". The value "0" deactivates motor temperature monitoring.

When the function has been activated, the following diagnostic messages are possible:

- E2021 Motor temperature outside of measuring range
- E2051 Motor overtemp. prewarning
- F2019 Motor overtemperature shutdown
- F2021 Motor temperature monitor defective

Querying the current motor temperature (not in the case of the characteristic temperature sensor numbers "1" or "4"):

- S-0-0383, Motor temperature

5.3 Rexroth Motors

5.3.1 Basics on RexrothMotors

Brief Description

Classification

In the "Electric Drives and Controls" technology field, Rexroth offers a wide range of motors for equipping machines and installations with drives.

Due to their types of construction, Rexroth electric motors can be divided into:

- Housing motors with output shaft and flange or mounting supports
- Kit motors to be installed in machines and installations; consisting of individual components that are mounted to a moving and a static part of the mechanical system

Adjusting Motor/Controller

The controllers can be adjusted to Rexroth motors without any problem because the manufacturer provides the respective data set for each motor type. These data are available as parameter values.

- In the case of housing motors with data memory in the motor encoder, the parameter values are delivered as an integral part of the motor. At the initial commissioning they are automatically loaded to the controller.
- In the case of kit motors (individual components) and housing motors without data memory in the motor encoder, the respective motor parameters are not supplied with the motor. They can be easily loaded to the controller, however, from a database in the "IndraWorks Ds/D/MLD" commissioning tool.

The motor parameter values determined by the manufacturer guarantee that the motor can be loaded in accordance with its operating characteristic, if the required current and the corresponding power are provided by controller and supply unit.

The motor-specific parameter values of Rexroth motors can be loaded to the controller in different ways:

- Automatically for housing motors with encoder data memory
- Supported by a database for kit motors when using the commissioning tool "IndraWorks Ds/D/MLD"
- File-supported by loading a drive parameter set
- Manually by entering the parameter values based on a motor-specific data list

For automatic, database-supported and file-supported loading procedures, the motor-specific parameter values are written to a memory range of the controller that maintains the data unchanged, similar to a conventional "type plate". The data, which if applicable are converted depending on the scaling, are copied from this "type plate" memory range to the parameters active for control. In the case of manual data input, the parameters of the "type plate" memory range should be written.

Thermal Motor Monitoring

Rexroth motors are thermally monitored by the controller and protected against overheating. For this purpose, the current motor temperature is determined by thermo sensors installed in the motor winding. Depending on temperature thresholds that can be set, the controller generates a warning or switches the motor off.

☞ Due to the availability of motor parameters and perfectly adjusted temperature evaluation, Rexroth motors guarantee easy commissioning, full drive performance and a high degree of operational safety!

Measuring system

As a standard, Rexroth housing motors are equipped with a position measurement system. The individual motor series have different measuring systems which allows providing cost-efficient motors depending on the application.

The following measuring systems of Rexroth housing motors are supported by this firmware

- Encoders with sine signal and HIPERFACE® interface (1 Vpp)
- Encoders with sine signals (1 Vpp) and EnDat2.1 interface
- Encoders with sine signals (1 Vpp)
- Encoders of MSM motors with digital interfaces

Various encoder systems can be used together with Rexroth kit motors:

- Encoders with sine signals (1 Vpp) and EnDat2.1 interface, Heidenhain standard
- Encoders with sine signals (1 Vpp) and HIPERFACE® interface (IndraDrive-compatible HIPERFACE® encoders (DE_EN_FAQ_IndraDrive_unterstützte_Geber...) and HIPERFACE® encoders with "0xFF" type ID)
- Encoder with sine signals, 1Vpp, Heidenhain standard
- Encoder with square-wave signals, TTL, Heidenhain standard

Pertinent Parameters

The "type plate" memory range contains the parameters listed below, among others. The parameters, which if applicable are converted depending on the scaling, are automatically copied to the parameters active for control (see "Pertinent Parameters" under "Basics on the Motors to be Controlled").

General motor parameters:

- P-0-2109, Motor peak current, type plate
- P-0-2111, Motor current at standstill, type plate
- P-0-2113, Maximum velocity of motor, type plate
- P-0-2141, Motor type, type plate
- P-0-3000, Module code of motor, type plate
- P-0-3002, Number of pole pairs/pole pair distance, type plate
- P-0-3003, Rotor inertia, type plate
- P-0-3005, Torque/force constant, type plate

- P-0-3007, Stator resistance, type plate
- P-0-3008, Commutation offset, type plate

Synchronous motor parameters

- P-0-3008, Commutation offset, type plate
- P-0-3015, Flux-generating current, limit value, type plate
- P-0-3016, Direct-axis inductance of motor, type plate
- P-0-3017, Quadrature-axis inductance of motor, type plate
- P-0-3018, Charact. quadr.-axis induct. of motor, induct., type plate
- P-0-3019, Charact. quadr.-axis induct. of motor, currents, type plate
- P-0-3023, Current limit value of demagnetization, type plate
- P-0-3044, Motor torque at nominal current with reluctance, type plate
- P-0-3045, Motor torque at maximum current with reluctance, type plate
- P-0-3046, Reluctance angle at nominal motor current, type plate
- P-0-3047, Reluctance angle at maximum motor current, type plate
- P-0-3048, Motor control configuration, type plate

Asynchronous motor parameters

- P-0-3032, Premagnetization factor, type plate
- P-0-3014, Magnetizing current, type plate
- P-0-3029, Scaling of stall current limit, type plate
- P-0-3039, Stator leakage inductance, type plate
- P-0-3040, Rotor leakage inductance, type plate
- P-0-3041, Motor magnetizing inductance, type plate
- P-0-3042, Characteristic of motor magnetizing inductance, type plate
- P-0-3043, Rotor time constant, type plate

Field weakening range parameters

- P-0-3033, Voltage loop proportional gain, type plate
- P-0-3034, Voltage loop intergral action time, type plate
- P-0-3035, Motor voltage at no load, type plate
- P-0-3036, Maximum motor voltage, type plate

Parameters for measuring system:

- P-0-1000, Kind of encoder 1, encoder memory
- P-0-1001, Encoder 1 resolution, encoder memory

Only for absolute encoders (multi-turn):

- P-0-1002, Absolute encoder offset 1, encoder memory

Parameter for motor holding brake (if available):

- P-0-3010, Torque of motor holding brake, type plate
- P-0-3011, Holding brake current, type plate
- P-0-2206, Drive On delay time, type plate
- P-0-2207, Drive Off delay time, type plate

Default control loop parameters:

- P-0-2100, Velocity loop proportional gain, type plate
- P-0-2101, Velocity loop integral-action time, type plate
- P-0-2104, Position loop Kv-factor, type plate

- P-0-2106, Current loop proportional gain 1, type plate
- P-0-2107, Current loop integral-action time 1, type plate
- P-0-3004, Speed controller smoothing time constant, type plate

☞ At a command, the default control loop parameters and, where required, the delay times for the holding brake (P-0-2206, P-0-2207) can be loaded to the drive controller. They are useful start values for further optimization.

Pertinent Diagnostic Messages

- C0700 Load defaults proced. command (motor-spec. controller val.)
- C0702 Default parameters not available
- C0703 Default parameters invalid
- C0704 Parameters not copyable
- C0706 Error when reading the controller parameters
- F2008 RL The motor type has changed.
- F2104 Commutation offset invalid

Functional Description

Application-Dependent Motor Parameters for Asynchronous Motors

With asynchronous Rexroth motors of the MAD, MAF, MAL and 1MB series, a value adjusted to the application must be written to the parameter "P-0-0532, Premagnetization factor".

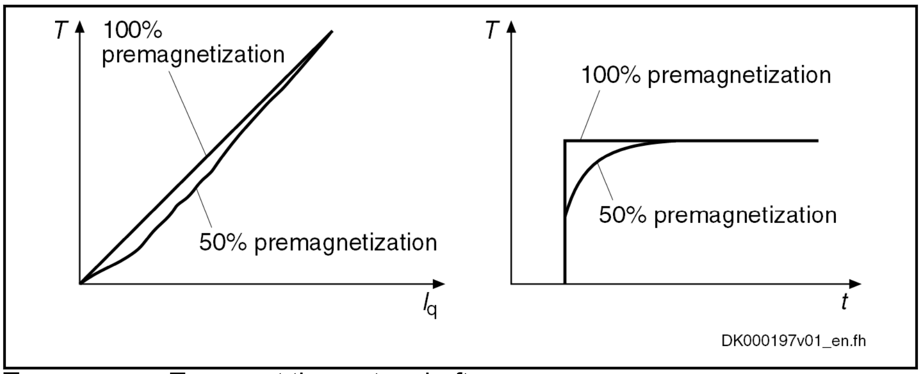
The premagnetization factor influences the "magnetizing current" motor parameter:

$$\text{Effective magnetizing current} = \frac{(\text{P-0-0532})}{100\ \%} \times (\text{P-0-4004})$$

P-0-0532 Premagnetization factor
P-0-4004 Magnetizing current

Fig. 5-1: Setting the Effective Magnetizing Current for Asynchronous Motors

The magnetizing current value determined for Rexroth motors by the manufacturer ensures perfect torque development (maximum torque/force constant, according to the value of P-0-0051) and minimum delay when making available the torque in the case of abrupt load.



T Torque at the motor shaft
Iq Torque-generating component of the motor current

Fig. 5-2: Influence of the Premagnetization Factor on the Torque

Notes on Commissioning

Parameter Values Made Available

For Rexroth motors without encoder data memory, the motor-specific parameter values made available, such as

- Motor parameters
- Temperature sensor parameters

can either be input manually by means of a list (e.g., via the control terminal) or loaded from a database via the "IndraWorks Ds/D/MLD" commissioning tool.

Setting the Premagnetization Factor

The table below contains the recommended setting for the parameter "P-0-0532, Premagnetization factor", depending on the application.

Usage	Value of P-0-0532 in %	Effect
Servo drive	100	Torque generation free of delay in the case of acceleration or sudden load variation
Main drive	50	Less power dissipation in no-load operation, noise level reduced

Tab. 5-3: Recommended Setting for Parameter P-0-0532

With values between 50% and 100%, it is possible to obtain a compromise between the mentioned effects.

It is therefore necessary to make sure you obtain the desired results for processing or acceleration/deceleration procedures after the premagnetization factor has been reduced.

☞ The selection lists for motor/controller combinations with asynchronous Rexroth motors published by Rexroth refer to a premagnetization of 100%.

With lower values, you have to expect deviation from these data.

Check DC Bus Voltage

Check whether the DC bus voltage U_dc to be expected is smaller than "P-0-0853.0.0, Max. DC bus voltage, motor"

The value of the Max. DC bus voltage, motor is as follows:

- with regulated supply (HMV-R): U_dc = 750V
- with unregulated supply (other): U_dc = 1.41*U_network

If the DC bus voltage to be expected is higher than the one allowed for the motor, you must check whether the DC bus voltage can be dropped to a value allowed for the motor by reducing the mains voltage. If necessary, reduce the mains voltage by means of a transformer.

5.3.2 Rexroth Housing Motors

Rexroth Housing Motors with Encoder Data Memory

Motor Series

The following Rexroth housing motors that are supported by this firmware are equipped with an encoder data memory:

- MSK, MSM
- MAD, MAF

Brief Description

See section "Basics on the Rexroth Motors"

Pertinent Parameters

See "Pertinent Parameters" in the section "Basics on the Rexroth Motors"

In addition to the parameters listed above there are other parameters for the data transfer from the encoder data memory to the parameter memory of the controller (administration parameters that users cannot interpret, the number of which depends on the number of encoder interfaces present):

- P-0-1031, Content of encoder memory optional slot 1
- P-0-1032, Content of encoder memory optional slot 2
- P-0-1033, Content of encoder memory optional slot 3
- P-0-1034, Content of encoder memory optional slot 4
- P-0-1035, Content of encoder memory optional slot 5
- P-0-1036, Content of encoder memory optional slot 6

Pertinent Diagnostic Messages

See "Pertinent Diagnostic Messages" in the section "Basics on the Rexroth Motors"

Notes on Commissioning

Initial Commissioning

In the case of Rexroth housing motors with encoder data memory, the values for the motor parameters stored in the encoder, the measuring system parameters and, where required, the motor holding brake parameters are automatically loaded to the "type plate" parameters of the controller when the drive is switched on.

When a drive is commissioned for the first time, first the error message "F2008 RL The motor type has changed." appears. This message only means that this motor has not yet been connected to the controller.

By clearing this error message (reset via control panel or command "S-0-0099, C0500 Reset class 1 diagnostics"), the command "S-0-0262, C07_x Load defaults procedure command" is automatically started. In this way, default control loop parameter values for this motor are loaded from the "type plate" parameters to the active parameters of the controller.

☞ With the command " C07_x Load defaults procedure command" (S-0-0262), depending on the setting in "P-0-4090, Configuration for loading default values", the following parameter values are loaded:

- Default control loop parameter values (default setting)
- Default values of the firmware (factory settings)
- MLD default values
- SMO default values
- Field bus profile settings

In the case of motors with integrated holding brake, the brake type and the activation of brake control is automatically set in "P-0-0525, Holding brake control word".

In the case of motors with several cooling type variants (MSK), the load data can be referred to the realized cooling type by entering the corresponding value in "P-0-0640, Cooling type".

Recommissioning

During servicing the motor can be replaced by a motor of the same type without any problem. The adjustment to the controller does not need to be repeated. In the case of an absolute motor encoder, it is only necessary to make an adjustment to the machine axis by establishing the position data reference.

If the motor type connected to the controller has changed, the controller signals this with "F2008 RL The motor type has changed." and requests the default values of the control loop parameters and the motor-specific parameters to be loaded. In the case of a desired motor change, initial commissioning of the new axis motor is necessary. Otherwise, there is an assembly error that has to be corrected!

Diagnostic Messages

In conjunction with the loading and verifying of parameter values from the encoder data memory, the following messages might possibly be generated:

- When the default control loop parameter values and the motor-specific parameters are loaded

  → C07_0 Command for loading default values
- If the parameter values in the encoder data memory cannot be read

  → C0706 Error when reading the controller parameters
- If the motor type connected to the controller has changed

  → F2008 RL The motor type has changed.
- If an invalid value for the commutation offset is contained in the encoder memory

  → F2104 Commutation offset invalid

Rexroth Housing Motors without Encoder Data Memory

Motor Series

The following Rexroth housing motor supported by this firmware does not have an encoder data memory:

- MAL

Brief Description

See section "Basics on the Rexroth Motors"

Pertinent Parameters

See "Pertinent Parameters" in the section "Basics on the Rexroth Motors"

Pertinent Diagnostic Messages

See "Pertinent Diagnostic Messages" in the section "Basics on the Rexroth Motors"

For further information, see section "Basics on the Rexroth Motors"

5.3.3 Rexroth Kit Motors

General Information

Kit motors consist of individual components that are mounted to a moving and as static part of the machine's mechanical system and functionally put together to form a motor.

A kit motor consists of the following components:

- Electrically active part with thermo sensor
- Electrically passive part
- Measuring system
- Storage

The electrical parts of the kit motor are supplied by Rexroth, the measuring system and the bearing are provided on the machine side.

Rexroth kit motors are built according to the functional principles associated with "asynchronous motors" or "synchronous motors". With regard to control, the functional principles have different requirements:

- In the case of synchronous motors, the current in the windings of the stator must have a fixed allocation to the permanent magnetic field of the rotor so that the maximum torque or the maximum force is generated.
- In the case of asynchronous motors there is no fixed allocation between stator and rotor required in order to generate the maximum torque or the maximum force.

Rexroth Kit Motors, Synchronous

Brief Description

The following Rexroth kit motors are manufactured according to the functional principle "synchronous motor":

- Linear motors MLF and MCL
- Rotary motors MBS and MBT

As the motor is assembled in the machine, stator, rotor and measuring system can only be put together on site. The electric-magnetic-mechanical allocation of the synchronous motor is therefore only to be made on site. This is done by determining and setting the commutation offset.

The measuring system should be realized with high resolution and as a motor encoder to be evaluated in absolute form (see also "Absolute Measuring Systems"). If it is necessary to use an incremental measuring system, using encoders with square-wave signals should be avoided!

Determining the Commutation Offset

The commutation offset can be determined with different methods. The method is chosen in accordance with the axis geometry, the practicability and the chances of success of the respective method depending on the mechanical axis system:

- **Measuring method** for motor encoders that can be evaluated in absolute form

  → Distance measurement, currentless (only possible for linear Rexroth kit motors)
- **Saturation method** (axis needs to be blocked or at standstill)

  → With current (possible with all types of construction in combination with motor encoders that can be evaluated in absolute form or with relative motor encoders)
- **Sine-wave method** (requires unrestricted movement of axis)

  → With current (possible with all types of construction in combination with motor encoders that can be evaluated in absolute form or with relative motor encoders)

In the case of absolute measuring systems, the commutation offset only has to be determined once (at initial commissioning), in the case of incremental measuring systems this has to be done each time the drive is switched on again!

For the description of the methods for commutation setting, see "Drive Control: Commutation Setting"

Pertinent Parameters

See "Pertinent Parameters" in the section "Basics on the Rexroth Motors"

Pertinent Diagnostic Messages

See "Pertinent Diagnostic Messages" in the section "Basics on the Rexroth Motors"

For further information, see section Basics on the Rexroth Motors

Rexroth Kit Motors, Asynchronous

Brief Description

The following Rexroth kit motors are manufactured according to the functional principle "asynchronous motor":

- Rotary motors 1 MB

As the motor is assembled in the machine, stator, rotor and measuring system can only be put together on site. After loading the specific parameter values for motor and measuring system the assembled motor can be put into operation independent of rotor position and allocation of the measuring system.

The measuring system should be realized with high resolution! Avoid using encoders with square-wave signals!

Pertinent Parameters

See "Pertinent Parameters" in the section "Basics on the Rexroth Motors"

Pertinent Diagnostic Messages

See "Pertinent Diagnostic Messages" in the section "Basics on the Rexroth Motors"

For further information, see section "Basics on the Rexroth Motors"

5.4 Third-Party Motors at IndraDrive Controllers

5.4.1 General Information on Third-Party Motors

Today, machine axes are mainly moved with electric drives. Motors of standard design are used in most cases, as this is the most cost-efficient solution.

Special Requirements

Due to special requirements at machine axes, constructional or safety-related aspects, it may be necessary for the machine manufacturer to use a motor construction diverging from the standard.

Motor Designs not Included in Product Range

For these cases there is the demand on the drive supplier to realize, apart from the deliverable standard drive consisting of (standard) motor, controller, cable and, if required, machine control unit, drives with motors that are not included in his own product range due to the special design.

With Rexroth controllers of the IndraDrive range, it is also possible to control third-party motors.

Checking Whether Third-Party Motors Can be Controlled

For successfully and fail-safely controlling a third-party motor, it is necessary to check beforehand

- whether the third-party motor to be controlled meets the requirements of the controller,
- whether the third-party motor has the required minimum inductance,
- whether the mounted position measuring system can be evaluated by the controller or which position measuring system can be selected for kit motors,
- whether the motor can be protected against inadmissible temperature rise in the case of overload,
- which controller, including supply, is suitable due to the motor power to be delivered.

How to do Project Planning? The requirements relevant in the system combination are documented in the Project Planning Manual of the drive system.

The filled out "Forms for Required Manufacturer-Side Motor Data" are to be made available for the motor suitability test!

See the documentation "Rexroth IndraDrive Drive System, Project Planning Manual" (DOK-INDRV*-SYSTEM*****-PR**-EN-P; mat. no.: R911309636)!

How to Commission? First, the motor parameter values must be determined (see the section "Determining the Parameter Values for Motor and Motor Control"). The parameter values of motor control are calculated by command internally in the firmware.

The determined motor parameter values are to be documented in the forms included in the section "Forms for Parameter Values".

5.4.2 General Information on Controlling Third-Party Motors

Pertinent Parameters and Diagnostic Messages

See "Automatic Setting of Motor Control"

Hardware Data

For the electrical connection of the motors to the controller, see the Project Planning Manuals for the IndraDrive Controllers. A complete connection diagram for the use of Rexroth motors is contained in the respective Project Planning Manual.

5.4.3 Determining the Parameter Values of Third-Party Motors

General Information on How to Determine the Parameter Values

As Rexroth cannot make available parameter values for motor control of third-party motors, these values have to be determined before or during the commissioning of the third-party motor. The determination of these parameter values is supported by commands:

- Asynchronous motors
  - Recommendation:

    "C3200 Command Calculate motor data", drive-internal calculation of the values for the motor and motor control parameters from the type plate data

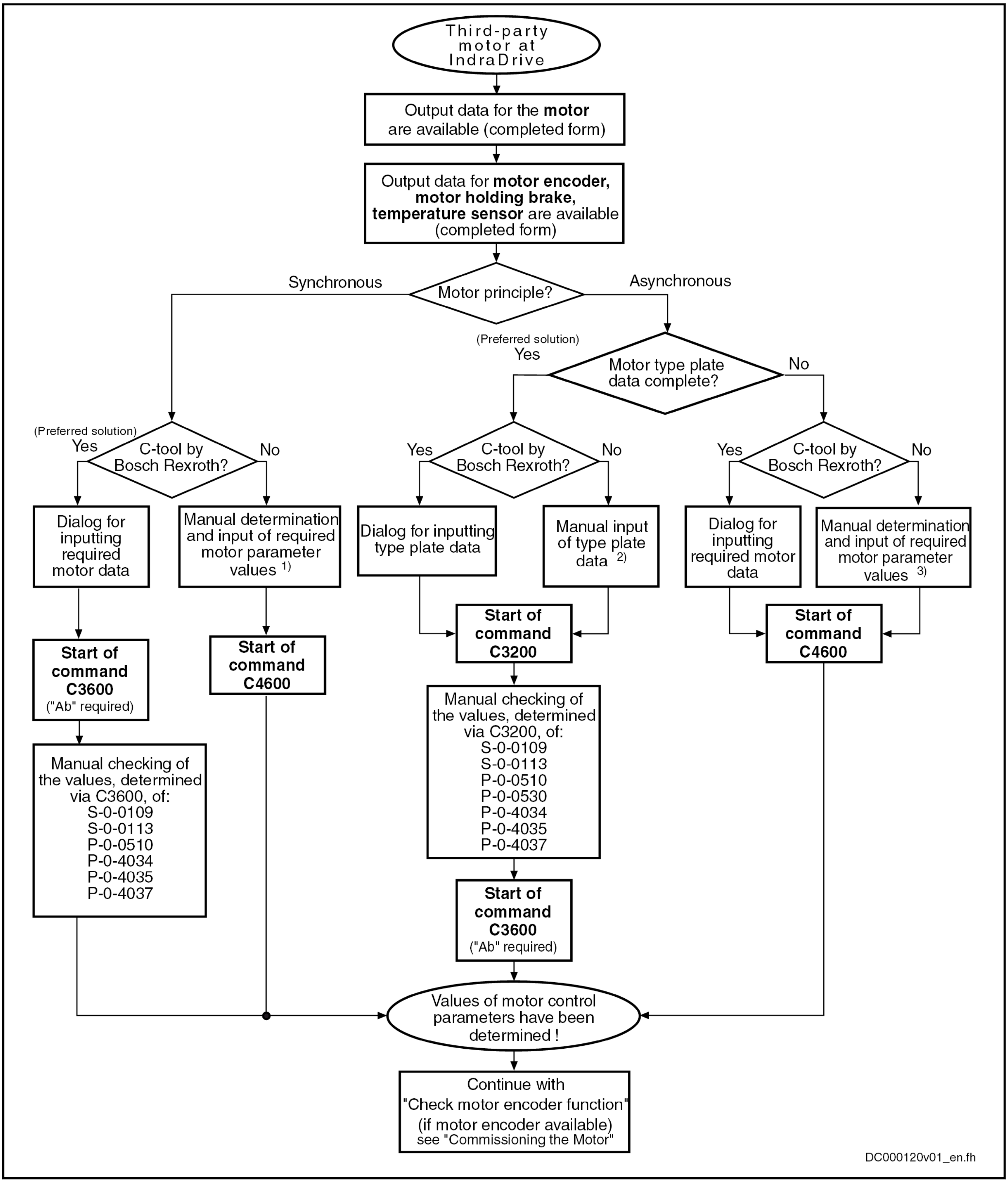
    "C3600 Command Motor data identification", optimization of the parameter values calculated via C3200 by experimentally supplying current and, if necessary, motor motion
  - Alternative:

    "C4600 Command Calculate motor control parameters", calculation of the motor and motor control parameters from motor-specific data (see forms for "Motor Parameters for Asynchronous Motors")
- Synchronous motors
  - Recommendation:

    "C3600 Command Motor data identification", drive-internal determination of the values for the motor and motor control parameters from few characteristic motor data by means of calculation, experimentally supplying current and, if necessary, motor motion
  - Alternative:

"C4600 Command Calculate motor control parameters": Calculation of the motor and motor control parameters from motor-specific data (see forms for "Motor Parameters for Synchronous Motors")

The specific motor data must be made available by the motor manufacturer. To collect all required manufacturer-side data of the motor, use the appropriate forms to copy below.



1)	According to form "Motor Parameters for Synchronous Motors"
2)	In parameter "P-0-4032, Motor type plate data"
3)	According to form "Motor Parameters for asynchronous Motors"
C-tool	Commissioning tool (e.g. IndraWorks Ds/D/MLD)

Fig. 5-3: Determining the Values for the Motor Control Parameters

For detailed explanations on the scope of functions of the mentioned commands see "Automatic Setting of Motor Control"!

Determining the Motor Parameter Values for Manual Input (for Command C4600 as an Alternative Solution)

On the basis of the motor-specific data made available by the manufacturer, you have to determine the motor parameter values for third-party motors.

Procedure without "IndraWorks Ds/D/MLD"

The collection of the motor parameter values to be determined is supported by the forms "Motor Parameters for Synchronous Motors" and "Motor Parameters for Asynchronous Motors".

Procedure with "IndraWorks Ds/D/MLD"

If you use the "IndraWorks Ds/D/MLD" commissioning tool, the motor parameters, after the required data have been input (according to the completed form "Manufacturer-Side Data of Synchronous Motors" or "Manufacturer-Side Data of Asynchronous Motors"), are input by means of the corresponding dialog.

Type of construction of motor

The functional principle and type of the third-party motor has to be entered in parameter "P-0-4014, Type of construction of motor".

☞ In parameter P-0-4014, the bits for further settings have to be set to "0", because the respective functions generally cannot be used for third-party motors!

Number of pole pairs/pole pair distance

Take the value for parameter "P-0-0018, Number of pole pairs/pole pair distance" from the completed form "Manufacturer-Side Data of Synchronous Motors" or "Manufacturer-Side Data of Asynchronous Motors".

Rotor inertia

For the setting of parameter "P-0-0510, Rotor inertia" take the values from the completed form "Manufacturer-Side Data of Synchronous Motors" or "Manufacturer-Side Data of Asynchronous Motors".

Motor peak current

The rms value of the maximum allowed total motor current (magnetic-field-generating and torque-generating current) has to be set in parameter "S-0-0109, Motor peak current".

For asynchronous motors, there usually isn't any value given for the maximum allowed peak current.

☞ For synchronous motors, see manufacturer's specification for the value of the maximum allowed peak current.

If there hasn't any value been specified for the maximum allowed peak current, we recommend its limitation according to the following relationships for thermal reasons:

Rotary motors $(S\text{-}0\text{-}0109) = f \times I_N$

Linear motors $(S\text{-}0\text{-}0109) = f \times I_d$

S-0-0109	Motor peak current (rms value of maximum total motor current in A)
f	Safety factor 1.1 … 2.5
I_N	Rated current (rms value in A)
I_d	Continuous current at standstill (rms value in A)

Fig. 5-4: Recommendation for Value of Parameter S-0-0109

Motor current at standstill

The motor current at standstill is the rms value of the torque-generating component of the continuous motor current.

The value entered in parameter "S-0-0111, Motor current at standstill" is the 100% reference value for the torque/force limit parameters S-0-0092 and P-0-0109 with percentage-based scaling (see below).

$$\text{Rotative synchronous motors} \quad (S\text{-}0\text{-}0111) = I_N$$
$$\text{Linear synchronous motors} \quad (S\text{-}0\text{-}0111) = I_d$$

S-0-0111	Motor current at standstill (rms value)
I_N	Rated current (rms value, acc. to motor data)
I_d	Continuous current at standstill (rms value, acc. to motor data)

Fig. 5-5: Calculating the Value of Parameter S-0-0111 for Synchronous Motors

$$\text{Rotary asynchronous motors} \quad (S\text{-}0\text{-}0111) = I_N \times \cos\varphi$$

S-0-0111	Motor current at standstill (rms value)
I_N	Rated current (rms value, acc. to motor data)
$\cos\varphi$	Power factor

Fig. 5-6: Calculating the Value of Parameter S-0-0111 for Asynchronous Motors

Maximum Motor Speed

The velocity command value that is output by the controller is limited to the value of parameter "S-0-0113, Maximum motor speed". The value mustn't be higher than the maximum allowed velocity (speed)!

Torque/force constant

Calculating the value for parameter "P-0-0051, Torque/force constant" with motor at operating temperature and rated current or continuous current at standstill:

$$\text{Rotary synchronous motors} \quad (P\text{-}0\text{-}0051) = \frac{M_N}{I_N}$$
$$\text{Linear synchronous motors} \quad (P\text{-}0\text{-}0051) = \frac{F_N}{I_d}$$

P-0-0051	Torque/force constant (in Nm/Arms for rotary motors; in N/Arms for linear motors)
T_N	Rated torque (acc. to motor data)
I_N	Rated current (rms value, acc. to motor data)
F_N	Rated force (acc. to motor data)
I_d	Continuous current at standstill (rms value, acc. to motor data)

Fig. 5-7: Calculating the Value of Parameter P-0-0051 for Synchronous Motors

$$\text{Rotary asynchronous motors} \quad (P\text{-}0\text{-}0051) = \frac{M_N}{I_N \times \cos\varphi}$$

P-0-0051	Torque/force constant (in Nm/Arms for rotary motors; in N/Arms for linear motors)
T_N	Rated torque (acc. to motor data)
I_N	Rated current (rms value, acc. to motor data)
$\cos\varphi$	Power factor

Fig. 5-8: Calculating the Value of Parameter P-0-0051 for Asynchronous Motors

Stator Resistance

Calculating the value of parameter "P-0-4048, Stator resistance":

$$(P\text{-}0\text{-}4048) = (R_{U\text{-}V} + 2 \times R_{Dr} + 2 \times R_{Lt})$$

P-0-4048 Stator resistance (total resistance of the connected motor in Ω)
$R_{U\text{-}V}$ Resistance of the motor between the terminals at 20°C (in Ω)
R_{Dr} Phase resistance of a possibly required choke at 20°C (in Ω)
R_{Lt} Resistance of a power cable strand at 20°C (in Ω), possibly relevant for open-loop operation of asynchronous motors with long motor line

Fig. 5-9: Calculating the Value of Parameter P-0-4048

By menu prompt via dialogs, the "IndraWorks Ds/D/MLD" commissioning tool supports the input of the motor parameter values of third-party motors by means of the forms "Manufacturer-Side Data of Synchronous Motors" and "Manufacturer-Side Data of Asynchronous Motors" completed by the motor manufacturer!

Manual Input of the Motor Parameter Values for Synchronous Motors (for Command C4600 as an Alternative Solution)

Based on the motor-specific data made available by the manufacturer, the motor parameter values specific to synchronous motors are determined.

Direct-Axis Inductance of Motor and Quadrature-Axis Inductance of Motor

For motors with reluctance property, different values are observed when the inductance is measured, depending on the position of the primary part of the motor with regard to the secondary part of the motor. The values are fluctuating between a minimum and a maximum value:

- The minimum value is relevant to the direct-axis inductance of the motor.
- The maximum value is relevant to the quadrature-axis inductance of the motor.

Even if the reluctance property of synchronous third-party motors cannot be used (respective bit in parameter "P-0-4014, Type of construction of motor" must not have been set!), it is advantageous to use the mentioned values for current control!

Direct-axis inductance of motor

To determine the parameter value for "P-0-4016, Direct-axis inductance of motor", use the minimum value of motor inductance for calculation, as indicated in the completed form "Manufacturer-Side Data of Synchronous Motors":

$$(P\text{-}0\text{-}4016) = L_{(U\text{-}V)min} \times 0{,}5$$

P-0-4016 Direct-axis inductance of motor
$L_{(U\text{-}V)min}$ Value acc. to motor data

Fig. 5-10: Calculating the Value of Parameter P-0-4016

Quadrature-axis inductance of motor

To determine the parameter value for "P-0-4017, Quadrature-axis inductance of motor", use the maximum value of motor inductance for calculation, as indicated in the completed form "Manufacturer-Side Data of Synchronous Motors":

$$(P\text{-}0\text{-}4017) = L_{(U\text{-}V)max} \times 0{,}5$$

P-0-4017 Quadrature-axis inductance of motor
$L_{(U\text{-}V)max}$ Value acc. to motor data

Fig. 5-11: Calculating the Value of Parameter P-0-4017

Characteristic of Quadrature-Axis Inductance of Motor, Inductances

List parameter "P-0-4002, Charact. of quadrature-axis induct. of motor, inductances":

→ Enter the value "1,0" in each of the five lines

Characteristic of Quadrature-Axis Inductance of Motor, Currents

List parameter "P-0-4003, Charact. of quadrature-axis inductance of motor, currents":

→ Enter the value "1,0" in each of the five lines

Flux-generating current, limit value

Calculating the value for parameter "P-0-4005, Flux-generating current, limit value":

$$(P\text{-}0\text{-}4005) = -(S\text{-}0\text{-}0109)$$

or

$$(P\text{-}0\text{-}4005) = -[2 \times (S\text{-}0\text{-}0111)]$$

P-0-4005	Flux-generating current, limit value
S-0-0109	Motor peak current
S-0-0111	Motor current at standstill

Fig. 5-12: Calculating the Value of Parameter P-0-4005 (Value with Smaller Absolute Value has to be Entered with Negative Sign in Parameter P-0-4005)

☞ The "IndraWorks Ds/D/MLD" commissioning tool supports the input of the motor parameter values of synchronous third-party motors by means of the form "Manufacturer-Side Data of Synchronous Motors" completed by the motor manufacturer by menu prompt via the corresponding dialogs!

Manual Input of the Motor Parameter Values for Asynchronous Motors (for Command C4600 as an Alternative Solution)

Based on the motor-specific data made available by the manufacturer, the motor parameter values specific to asynchronous motors can also be manually determined.

Magnetizing current

The value for parameter "P-0-4004, Magnetizing current" is the rms value of the motor magnetizing current:

$$(P\text{-}0\text{-}4004) = I_{Mag}$$

P-0-4004	Magnetizing current (rms value in A)
I_{Mag}	Indicated magnetizing current (rms value in A)

Fig. 5-13: Value for Parameter P-0-4004 acc. to Manufacturer's Specification

If there hasn't any value been indicated in the manufacturer-side data of the asynchronous motor, the following approximation can be used for calculation:

$$(P\text{-}0\text{-}4004) = \sqrt{1 - (\cos\varphi)} \times I_N$$

P-0-4004	Magnetizing current (rms value in A)
I_N	Rated current of the motor (rms value in A)
cos φ	Power factor at rated load

Fig. 5-14: Calculating the Value of Parameter P-0-4004 by Means of Approximation

Rated Motor Speed

Take the value for parameter "P-0-4036, Rated motor speed" from the completed form "Manufacturer-Side Data of Asynchronous Motors".

Stator and Rotor Leakage Inductance; Motor Magnetizing Inductance

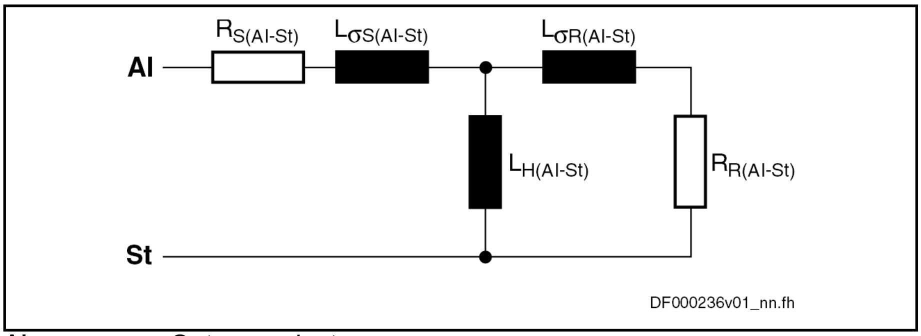
The values for the parameters P-0-4039, P-0-4040, P-0-4041 refer to the single-phase equivalent circuit diagram of asynchronous motors with star point reference (see below).

From the data of the stator and rotor leakage inductance and the motor magnetizing inductance, it is possible to determine more exact motor parameter values than from the type plate data. It is therefore advantageous to have these data supplied by the motor manufacturer and contained in the completed form "Manufacturer-Side Data of Asynchronous Motors".

$$(P\text{-}0\text{-}4039) = L_{\sigma S(Al\text{-}St)}$$
$$(P\text{-}0\text{-}4040) = L_{\sigma R(Al\text{-}St)}$$
$$(P\text{-}0\text{-}4041) = L_{H(Al\text{-}St)}$$

P-0-4039	Stator leakage inductance (in mH)
P-0-4040	Rotor leakage inductance (in mH)
P-0-4041	Motor magnetizing inductance (in mH)
$L_{\sigma S(Al\text{-}St)}$	Leakage inductance of stator
$L_{\sigma R(Al\text{-}St)}$	Leakage inductance of rotor
$L_{H(Al\text{-}St)}$	Motor magnetizing inductance

Fig. 5-15: Values of Parameters P-0-4039, P-0-4040 and P-0-4041 acc. to Manufacturer's Specification



Al	Outer conductor
St	Star point
$R_{S(Al\text{-}St)}$	Ohmic resistance of stator at 20°C
$R_{R(Al\text{-}St)}$	Ohmic resistance of rotor at 20°C
$L_{\sigma S(Al\text{-}St)}$	Leakage inductance of stator
$L_{\sigma R(Al\text{-}St)}$	Leakage inductance of rotor
$L_{H(Al\text{-}St)}$	Motor magnetizing inductance

Fig. 5-16: Equivalent Circuit Diagram of Asynchronous Machine, Single-Phase, with Star Point Reference

Characteristic of Motor Magnetizing Inductance

List parameter "P-0-4042, Characteristic of motor magnetizing inductance":

→ Unless otherwise specified, enter the value "1,0" in each of the five lines

Rotor time constant

Take the value for parameter "P-0-4043, Rotor time constant" from the completed form "Manufacturer-Side Data of Asynchronous Motors".

If the value is not available, it can be calculated by means of approximation:

$$(P\text{-}0\text{-}4043) = \frac{L_{\sigma R(Al\text{-}St)} + L_{H(Al\text{-}St)}}{R_{R(Al\text{-}St)}} = \frac{(P\text{-}0\text{-}4040) + (P\text{-}0\text{-}4041)}{R_{R(Al\text{-}St)}}$$

P-0-4043	Rotor time constant (in ms)
$L_{H(Al\text{-}St)}$	Motor magnetizing inductance
$R_{R(Al\text{-}St)}$	Ohmic resistance of rotor at 20°C
$L_{\sigma R(Al\text{-}St)}$	Leakage inductance of rotor
P-0-4040	Rotor leakage inductance (in mH)
P-0-4041	Motor magnetizing inductance (in mH)

Fig. 5-17: Calculating the Value of Parameter P-0-4043 by Means of Approximation

☞ By menu prompt via dialogs, the "IndraWorks Ds/D/MLD" commissioning tool supports the input of the motor parameter values of asynchronous third-party motors by means of the form "Manufacturer-Side Data of Asynchronous Motors" completed by the motor manufacturer!

☞ For project planning and commissioning of a third-party motor the required, manufacturer-specific motor data must always be available!

5.4.4 Forms for Required Manufacturer-Side Motor Data

Form for Manufacturer-Side Data of Synchronous Motors

Manufacturer, Motor type: ______________________ Customer, Installation, Axis designation:
____

Motor characteristic	Symbol/short form	Unit	Value
Rated power	P_N	kW	
Rated torque or rated force [1)]	T_N / F_N	Nm / N	
Rated current	I_N	A_{rms}	
Rated speed or rated velocity [1)]	n_N / v_N	min^{-1} / m/min	
Rated voltage	U_N	V_{rms}	
Continuous current at standstill [1)]	I_d	A_{rms}	
Inertia or mass	J / m	_	
Rated force [1)]	F_N	N	
Permissile maximum current	I_{max}	A_{rms}	
Maximum torque or maximum force [1)]	T_{max} / F_{max}	Nm / N	
Maximum speed or maximum velocity [1)]	n_{max} / v_{max}	min^{-1} / m/min	
Number of pole pairs (rotary) or pole pair distance (linear)	PPZ / PWT (N-N-pol)	-- / mm	
Insulation class	Isol.Kl.	--	
Motor inductance, minimum value	$L_{U-V, min}$	mH	
Motor inductance, maximum value	$L_{U-V, max}$	mH	
Motor inductance, average value	L_{U-V}	mH	
Winding resistance (20°C)	R_{U-V}	Ω	
Allowed periodic peak voltage	$û_{max\_perm.}$	$V_{pp/2}$	
Allowed rate of rise of voltage	$dv/dt_{perm.}$	kV/µs	
Maximum allowed DC bus voltage	U_dc_max	V	
Cooling type (without/with fan; liquid cooling)	--	--	
Thermal time constant of motor (see "Limitations")	T_{Motor}	min	
Thermal time constant of winding (see "Limitations")	$T_{Winding}$	s	
Thermal short-time overload of winding (see "Limitations")	$k_{Overload}$	--	
Type of construction of motor (rotary/linear)	--	--	
Type of winding (distributed winding/toothed winding)	--	--	
Winding body material (iron/ironless)	--	--	

1) Only for linear motor

Tab. 5-4: Motor Data of Synchronous Motors

Name Data Signature

☞ Take form "Manufacturer-Side Data of Motor Temperature Sensor, Motor Encoder and Motor Holding Brake" into account, too!

Form for Manufacturer-Side Data of Asynchronous Motors

Manufacturer, Motor type: ______________________ Customer, Installation, Axis designation:
____

Motor characteristic	Symbol/short form	Unit	Value
Rated power 1)	P_N	kW	
Rated torque	T_N	Nm	
Rated current 1)	I_N	A_{rms}	
Power factor 1)	cos φ	--	
Magnetizing current	I_{Mag}	A_{rms}	
Rated speed 1)	n_N	min^{-1}	
Rated frequency 1)	f_N	Hz	
Rated voltage 1)	U_N	V_{rms}	
Inertia	J	_	
Maximum speed	n_{max}	min^{-1}	
Number of pole pairs	PPZ	--	
Insulation class	Isol.Kl.	--	
Motor inductance (minimum/maximum/average value)	$L_{U-V, min}$/ $L_{U-V, max}$/ L_{U-V}	mH	
Stator leakage inductance 2)	$L_{\sigma S(Al-St)}$	mH	
Rotor leakage inductance 2)	$L_{\sigma R(Al-St)}$	mH	
Motor magnetizing inductance 2)	$L_{H(Al-St)}$	mH	
Stator resistance (20°C) 2)	$R_{S(Al-St)}$	Ω	
Rotor resistance (20°C) 2)	$R_{R(Al-St)}$	Ω	
Rotor time constant 2)	T_R	ms	
Winding resistance (20°C)	R_{U-V}	Ω	
Allowed periodic peak voltage	$\hat{u}_{max\_perm.}$	$V_{pp/2}$	
Allowed rate of rise of voltage	$dv/dt_{perm.}$	kV/µs	
Maximum allowed DC bus voltage	U_dc_max	V	
Cooling type (without/with fan; liquid cooling)	--	--	
Thermal time constant of motor (see "Limitations")	T_{Motor}	min	
Thermal time constant of winding (see "Limitations")	$T_{Winding}$	s	
Thermal short-time overload of winding (see "Limitations")	$k_{Overload}$	--	
Type of construction of motor (rotary/linear)	--	--	
Does rotor/secondary part have closed slots?	--	Yes/no	

1) Data on type plate of rotary motor
2) Helpful but not obligatory data

Tab. 5-5: Motor Data of Asynchronous Motors

Name	Data	Signature

☞ Take form "Manufacturer-Side Data of Motor Temperature Sensor, Motor Encoder and Motor Holding Brake" into account, too!

Form for Manufacturer-Side Data of Motor Temperature Sensor, Motor Encoder and Motor Holding Brake

Temperature Sensor Data

PTC? NTC? Switch contact?	
Type designation?	
How many and where installed?	
Characteristics available?	

Tab. 5-6: Data of Temperature Sensor

Motor Encoder Data (if available)

Type/standard?	
Signal amplitude?	
Signal shape?	
Cycles/revolution? Division period/µm?	
Manufacturer?	
Type of construction?	

Tab. 5-7: Data of Motor Encoder

Motor Holding Brake Data (if available)

Manufacturer		
Type designation		
Holding torque/force	Nm / N	
Rated voltage	V	
Rated current	A	
Inertia/moved mass	kgm^2/kg	
Clamping delay	ms	
Release delay	ms	
Mass	kg	

Tab. 5-8: Data of Motor Holding Brake

Name	Data	Signature

5.4.5 Forms for Parameter Values

Form "Motor Parameters for Synchronous Motors"

☞ Determine the values according to the description in the section "Determining the Motor Parameter Values for Manual Input (for Command C4600 as an Alternative Solution)".

Manufacturer, Motor type: ______________________ Customer, Installation, Axis designation: ________________________________

Parameter IDN	Parameter name	Input value	Unit
P-0-4014	Type of construction of motor		
P-0-0018	Number of pole pairs/pole pair distance		PPZ / mm
P-0-0510	Rotor inertia		(Scaling-dependent)
S-0-0109	Motor peak current		A
S-0-0111	Motor current at standstill		A
S-0-0113	Maximum motor speed		(Scaling-dependent)
P-0-0051	Torque/force constant		(Scaling-dependent)
P-0-4048	Stator resistance		Ω
P-0-4016	Direct-axis inductance of motor		mH
P-0-4017	Quadrature-axis inductance of motor		mH
P-0-4002	Charact. of quadrature-axis induct. of motor, inductances	[0] [1] [2] [3]	
P-0-4003	Charact. of quadrature-axis inductance of motor, currents	[0] [1] [2] [3]	
P-0-4005	Flux-generating current, limit value		A
P-0-0853.0.0	Max. DC bus voltage, motor		V

Tab. 5-9: Motor Parameters for Synchronous Motors

Form "Motor Parameters for Asynchronous Motors"

☞ After having entered the data from the type plate (in P-0-4032) and executed the command C3200, the parameter values contained in this list are automatically determined. If you want to enter the data manually, determine the values according to the description in the section "Determining the Motor Parameter Values for Manual Input (for Command C4600 as an Alternative Solution)".

Manufacturer, Motor type: ________________________ Customer, Installation, Axis designation: __________________________________			
Parameter IDN	Parameter name	Input value	Unit
P-0-4014	Type of construction of motor		--
P-0-0018	Number of pole pairs/pole pair distance		PPZ / mm
P-0-0510	Rotor inertia		(Scaling-dependent)
S-0-0109	Motor peak current		A
S-0-0111	Motor current at standstill		A
S-0-0113	Maximum motor speed		(Scaling-dependent)
P-0-0051	Torque/force constant		(Scaling-dependent)
P-0-4048	Stator resistance		Ω
P-0-4004	Magnetizing current		A
P-0-4036	Rated motor speed		1/min
P-0-4039	Stator leakage inductance		mH
P-0-4040	Rotor leakage inductance		mH
P-0-4041	Motor magnetizing inductance		mH
P-0-4042	Characteristic of motor magnetizing inductance	[0] [1] [2] [3] [4]	
P-0-4043	Rotor time constant		ms
P-0-0853.0.0	Max. DC bus voltage, motor		V

Tab. 5-10: Motor Parameters for Asynchronous Motors

Form "Parameters for Temperature Monitoring, Motor Encoder and Motor Holding Brake"

Manufacturer, Motor type: ______________________ Customer, Installation, Axis designation: ________________________________

Parameter IDN	Parameter name	Input value	Unit
Temperature monitoring			
P-0-0512	Temperature sensor		--
P-0-4034	Thermal time constant of motor		min
P-0-4035	Thermal time constant of winding		s
P-0-4037	Thermal short-time overload of winding		--
S-0-0201	Motor warning temperature		°C
S-0-0204	Motor shutdown temperature		°C
Motor Encoder			
P-0-0074	Encoder type 1 (motor encoder)		
S-0-0116	Resolution of feedback 1		
S-0-0277	Position feedback 1 type		
Motor holding brake			
S-0-0206	Drive on delay time		ms
S-0-0207	Drive off delay time		ms
S-0-0273	Maximum drive off delay time		ms
P-0-0525	Holding brake control word		

Tab. 5-11: Parameters for Temperature Monitoring, Motor Encoder and Holding Brake

5.4.6 Notes on Commissioning

For commissioning third-party motors the required, manufacturer-side motor data, the motor encoder data and temperature sensor data always have to be available (entirely completed forms).

- By menu prompt via the corresponding dialogs, the "IndraWorks Ds/D/MLD" commissioning tool simplifies the commissioning of third-party motors.
- The procedure for commissioning of third-party motors is explained in detail in Technical Note "DE_TN43_IndraDrive_Getting_Started_Asy_Sy_Fremdmotor_V__.pdf". It is contained in the "Automation Portal" (you may need to contact Sales).

See also "Commissioning Motors"

Basic Commissioning Steps for Third-Party Motors

The commissioning of a third-party motor (synchronous or asynchronous motor) starts with the following basic steps:

1. First check whether third-party motor has been connected according to manufacturer's specification.

2. Check whether the DC bus voltage U_dc to be expected is smaller than "P-0-0853.0.0, Max. DC bus voltage, motor"

   The value of the Max. DC bus voltage, motor is as follows:

   - with regulated supply (HMV-R): U_dc = 750V
   - with unregulated supply (other): U_dc = 1.41*U_network

   If the DC bus voltage to be expected is higher than the one allowed for the motor, you must check whether the DC bus voltage can be dropped to a value allowed for the motor by reducing the mains voltage. If necessary, reduce the mains voltage by means of a transformer.

3. Enter type designation of third-party motor in parameter "S-0-0141, Motor type". For motors with motor encoder (closed-loop operation), make the settings in the corresponding parameters:

   - S-0-0116, Resolution of feedback 1
   - S-0-0277, Position feedback 1 type
   - P-0-0074, Encoder type 1 (motor encoder)

4. Settings for motor temperature sensor and motor temperature model have to be made in the corresponding parameters:

   - S-0-0201, Motor warning temperature
   - S-0-0204, Motor shutdown temperature
   - P-0-0512, Temperature sensor
   - P-0-4034, Thermal time constant of winding
   - P-0-4035, Thermal time constant of motor
   - P-0-4037, Thermal short-time overload of winding

5. If a motor holding brake is controlled by controller, it is necessary to make further parameter settings:

   - S-0-0206, Drive on delay time
   - S-0-0207, Drive off delay time
   - S-0-0273, Maximum drive off delay time
   - P-0-0525, Holding brake control word

☞ Further commissioning steps for asynchronous third-party motors and synchronous third-party motors are supported by:

- Dialogs of the commissioning tool and
- Standard control panel or the small operator terminal (optional additional component).

Synchronous Third-Party Motors

After the basic commissioning steps (1 to 4; see above), there are further steps required for synchronous third-party motors:

1. The following motor data have to be entered in motor parameters by means of completed form " Form for Manufacturer-Side Data of Synchronous Motors":

   - P-0-0018, Number of pole pairs/pole pair distance
   - P-0-4036, Rated motor speed
   - S-0-0111, Motor current at standstill

2. Afterwards, start drive-internal determination of motor and motor control parameters with "P-0-0565, C3600 Command Motor data identification". For this purpose, drive must be in "ready for power output" state ("Ab").

The command C3600 can be configured for turning motors or motors in standstill (P-0-0601, Configuration motor data identification). If necessary, the motor is actively put into rotation. This increases the precision of the determined values.

For motor data identification with a turning motor, the motor in approx. 1 second is accelerated to 50% of the nominal speed. If the acceleration ramp is too steep, due to high load inertia, for example, it can be decreased by accordingly reducing the "P-0-0569, Maximum stator frequency slope". P-0-0569 is the limit value of the acceleration ramp for motor data identification with motion!

3. By executing command C3600, some parameters are set to default values, as they require data that cannot be identified by the command. Before continuing commissioning of drive, these parameters have to be checked and, if necessary, set to correct value by means of data of completed form:
   - S-0-0109, Motor peak current
   - S-0-0113, Maximum motor speed
   - P-0-0510, Rotor inertia
   - P-0-4034, Thermal time constant of winding
   - P-0-4035, Thermal time constant of motor
   - P-0-4037, Thermal short-time overload of winding

   Initial commissioning for initial start of motor can now be continued.

   See "Commissioning Motors: Initial Start with the Commissioning Tool"

With synchronous third-party motors, the commutation offset must be set before the initial start when they are operated in "field-oriented current control (FOC, with motor encoder)". In this case, the motor is only operational and safe to operate when the commutation offset has been set correctly!

See also "Commutation Setting"

If the procedure with C3600 does not result in operational motor and motor control parameters, the procedure with C4600 can be used as an alternative. For this purpose, the completed form "Motor Parameters for Synchronous Motors" must be available!

If the motor ultimately is not operational, carry out the "validation check" (C3600, P-0-0601). During this procedure, the controller checks whether the parameterization of motor and the motor encoder is plausible and checks their rotational direction.

Asynchronous Third-Party Motors

After the basic commissioning steps (1 to 4; see above), there are further steps required for asynchronous third-party motors:

1. Rated data according to completed form or type plate have to be entered in "P-0-4032, Motor type plate data" (data can already be entered in communication phase "P2").
2. With "P-0-4033, C3200 Command Calculate motor data", start calculation of values of motor and motor control parameters.

3. Then optimize parameter values calculated via command C3200 with "P-0-0565, C3600 Command Motor data identification". To do this, put drive in "ready for power output" state ("Ab"); then start command.

☞ The command C3600 can be configured for turning motors or motors in standstill (P-0-0601, Configuration motor data identification). If necessary, the motor is actively put into rotation. This increases the precision of the determined values.

☞ For motor data identification with a turning motor, the motor in approx. 1 second is accelerated to 50% of the nominal speed. If the acceleration ramp is too steep, due to high load inertia, for example, it can be decreased by accordingly reducing the "P-0-0569, Maximum stator frequency slope". P-0-0569 is the limit value of the acceleration ramp for motor data identification with motion!

4. By executing command C3200, some parameters are set to default values, as they require data that cannot be identified by the command. Before continuing commissioning of drive, these parameters have to be checked and, if necessary, set to correct value by means of data of completed form:
   - S-0-0109, Motor peak current
   - S-0-0113, Maximum motor speed
   - P-0-0510, Rotor inertia
   - P-0-0530, Slip increase
   - P-0-4034, Thermal time constant of winding
   - P-0-4035, Thermal time constant of motor
   - P-0-4037, Thermal short-time overload of winding

Initial commissioning for initial start of motor can now be continued. See Commissioning Motors: "Initial Start with the Commissioning Tool"

☞ If the procedure with C3200, C3600 does not result in operational motor and motor control parameters, the procedure with C4600 can be used as an alternative. For this purpose, the completed form "Motor Parameters for Asynchronous Motors" must be available!

If the motor ultimately is not operational, carry out the "validation check" (C3600, P-0-0601). During this procedure, the controller checks whether the parameterization of motor and the motor encoder is plausible and checks their rotational direction.

5.5 Motor holding brake

5.5.1 Brief Description

Motor holding brakes are used to hold axes with drive enable having been switched off. This is particularly important for non-equilibrated, vertical axes. With IndraDrive controllers it is possible to control and monitor motor holding brakes in a wear-resistant way.

The following motor holding brake types are possible:

- Electrically releasing brakes (self-holding) for servo drives
- Electrically holding brakes (self-releasing) for main drives

The motor holding brake can be directly mounted on the motor shaft, e.g. in the case of Rexroth housing motors, or directly connected to the mechanical axis system, e.g. in the case of linear kit motors.

IndraDrive controllers include application-specific control of the holding brake in order to minimize wear of the brake in the case of error. The following two functional principles of holding brake control are supported:

- Control of holding brake for **servo drives**
- Control of holding brake for **main drives**

5.5.2 Monitoring the Brake Current

Brief Description

Fields of Application

Base package of all firmware variants in **open-loop and closed-loop** characteristic

Monitoring for wire break, brake current and short circuit is only available with HCS01 devices!

Background

Particularly with vertical servo axes, the reliable function of a holding brake is fundamentally important to the operational safety of a machine. The "Function Check of Motor Holding Brake" can be used to check the holding brake for wear and corrosion; however, the use of this function check is left to the user.

Even with a cyclical function check, wire break occurring in the meantime would cause the brake to be accidentally applied and possibly destroyed before the malfunction could be recognized by the next function check. Between the function check intervals, the monitoring of the brake current, which is always active, detects faults with the holding brake control and signals them immediately.

Overview of Functions

Operating Principle

The controller monitors the current that flows through the terminals on the controller side to operate the brake. The brake current monitoring recognizes these states:

- Wire break (brake current less than 100 mA)
- Brake current ok
- Short circuit

In case of "wire break" or "short circuit", the error message "F2068, Brake error" is generated. The monitoring is active as soon as an existing holding brake is entered in "P-0-0525, Holding brake control word".

The wire break monitoring can be deactivated, e.g. due to brake control via relays.

The status of the monitoring of the holding brake current is displayed in "P-0-0539, Holding brake status word"; for IndraDrive Cs, the measured holding brake current is displayed in "P-0-0527, Actual holding brake current".

For HCQ, holding break current output is not possible!

Hardware Requirements

The "brake current monitoring" function does not require any specific hardware!

For Rexroth motors with encoder data memory, the presence of a motor holding brake is automatically recognized; brake current monitoring is automatically activated. To activate the function for third-party motors and motors with external holding brakes, the presence of a holding brake must be entered in the holding brake control word.

Pertinent Parameters

- P-0-0525, Holding brake control word
- P-0-0539, Holding brake status word
- P-0-0527, Actual holding brake current

Pertinent Diagnostic Messages

- F2068 Brake error

Notes on Commissioning

Activation

The dialogs for the holding brake are accessible via the "project explorer" of "IndraWorks Ds/D/MLD":

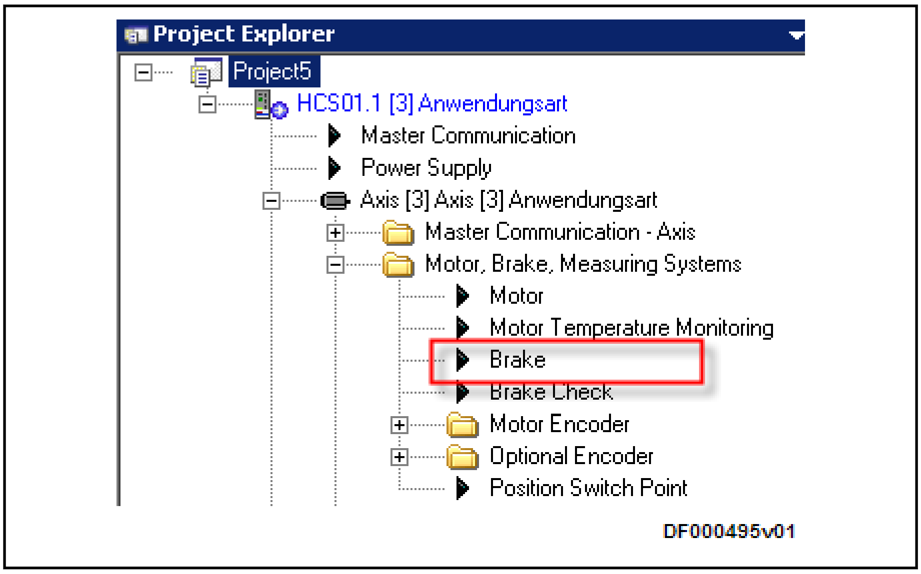


Fig. 5-18: Accessing the Holding Brake Dialog in "IndraWorks Ds/D/MLD"

The brake current monitoring is active as soon as the existence of a holding brake has been entered in the "IndraWorks Ds/D/MLD" dialog or in the holding brake control word (P-0-0525).

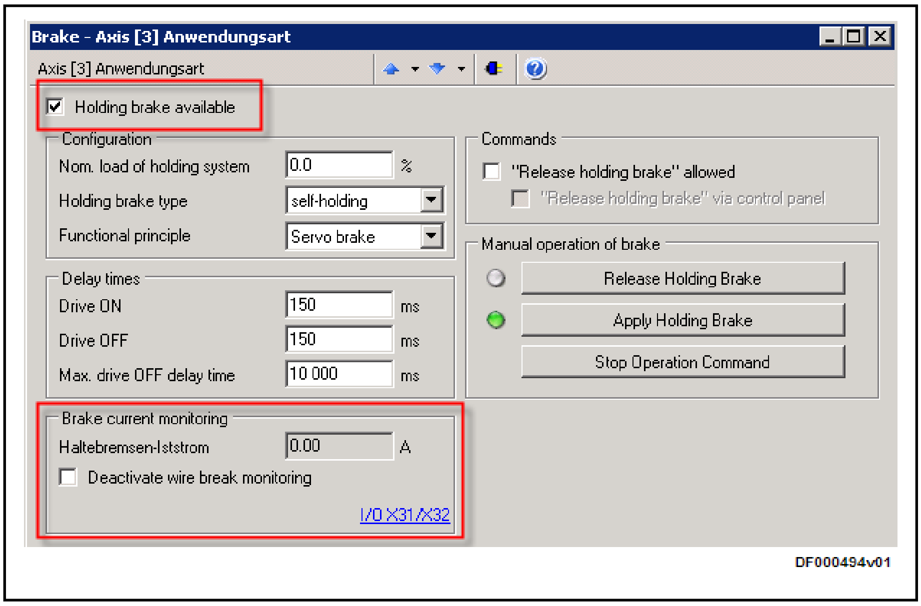


Fig. 5-19: "IndraWorks Ds/D/MLD" Dialog for the Holding Brake, Registration of the Holding Brake, Current Monitoring

With Rexroth motors with encoder data memory, a holding brake that might exist is registered automatically; with other motors, the existence of a motor holding brake must be confirmed manually (P-0-0525, Holding brake control word).

If with HCS01.1 controllers, the measured actual holding brake current (P-0-0527) displayed in the dialog is smaller than 100 mA (possibly in case of control via a relay), the wire break monitoring must be deactivated so that in this case, "F2068 Brake error" will be suppressed.

☞ With other controllers than HCS01.1, wire break monitoring is not possible as the actual holding brake current is not measured. With these controllers, the dialog part "Brake current monitoring" is thus omitted in "IndraWorks Ds/D/MLD".

Diagnostics, Status Message

In case of short circuit or wire break in the holding brake control, the message "F2068, Brake error" is output and the error reaction that had been set is triggered. The check status of the braking current monitoring is also displayed in "P-0-0539, Holding brake status word".

5.5.3 Operating Behavior of the Motor Holding Brake

Brief Description

Motor holding brakes are used to hold axes with drive enable having been switched off. This is particularly important for non-equilibrated vertical axes. With IndraDrive controllers it is possible to control and monitor motor holding brakes in a wear-resistant way.

NOTICE

Holding brakes at Rexroth motors normally aren't designed for decelerating when in operation. Increased wear caused by deceleration in operation can destroy the holding brake at an early stage!

The following motor holding brake types are possible:

- Electrically releasing brakes (self-holding) for servo drives
- Electrically holding brakes (self-releasing) for main drives

The motor holding brake can be directly mounted on the motor shaft, e.g. in the case of Rexroth housing motors, or directly connected to the mechanical axis system, e.g. in the case of linear kit motors.

IndraDrive controllers include application-specific control of the holding brake in order to minimize wear of the brake in the case of error. The following two functional principles of holding brake control are supported:

- Control of holding brake **for servo drives**
- Control of holding brake **for main drives**

Control of the holding brake is linked with drive enable, considering clamping and releasing delays. In special cases it may be appropriate to avoid this programmed link and release or apply the holding brake independently. This, too, is possible with IndraDrive!

Hardware Requirements

The motor holding brake is controlled via a controller-internal relay contact. Power supply is realized by the controller via the 24V control voltage. The holding brake must be suited for the voltage that is output, the holding brake current is not permitted to exceed the allowed maximum value of the respective device (see documentation "Supply Units and Power Sections; Project Planning Manual for Controllers"); if necessary the holding brake must be controlled separately.

☞ The optionally available holding brakes for Rexroth motors can be directly controlled via the drive controller!

Pertinent Parameters

- S-0-0206, Drive on delay time
- S-0-0207, Drive off delay time
- S-0-0273, Maximum drive off delay time
- P-0-0525, Holding brake control word
- P-0-0539, Holding brake status word
- P-0-0540, Torque of holding brake
- P-0-0542, C2000 Command Release holding brake
- P-0-0543, C3800 Command Apply holding brake

Pertinent Diagnostic Messages

- C2000 Command Release motor holding brake
- C2001 Command not enabled
- C3800 Command Apply motor holding brake
- F6024 Maximum braking time exceeded

Functional Description

With IndraDrive it is possible to control both self-releasing (electrically clamping) and self-clamping (electrically releasing) motor holding brakes. The controller is informed of the brake type via the respective bit in "P-0-0525, Holding brake control word".

☞ If the SBC safety function is used, only self-clamping (electrically releasing) motor holding brakes can be used.

Releasing the Holding Brake

When drive enable (AF = "Antriebsfreigabe") is set by the control unit, the releasing of the holding brake is activated. The brake is released with a delay, due to the inductance of the brake winding. The controller is informed of this delay via "S-0-0206, Drive on delay time".

"S-0-0206, Drive off delay timeDrive on delay time" and "S-0-0207, " for Rexroth motors with encoder data memories are only overwritten with values from the device memory with "C0700 Load defaults procedure command (motor-spec. controller values)". Otherwise, the default value is effective.

The values of S-0-0206 and S-0-0207 can be adjusted by the user on request axis-specifically.

To prevent wear to the opening brake, the command value acceptance is locked within "S-0-0206, Drive on delay time". Only then does the controller indicate, by means of a bit in the respective status word (e.g. "S-0-0135, Drive status word" SERCOS), that it is ready to move.

See also "Basic Functions of Master Communication: Device Control and State Machines"

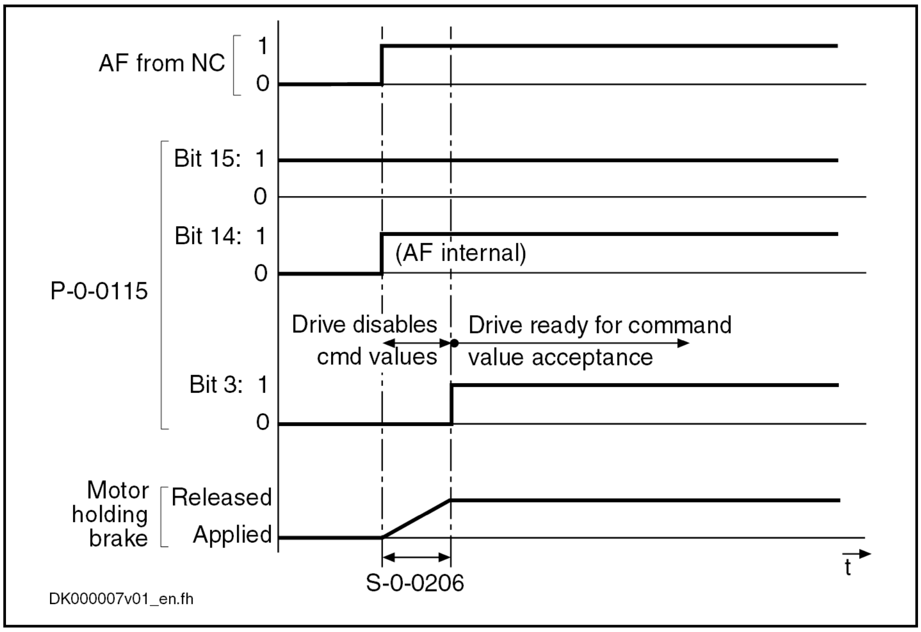


Fig. 5-20: Time Response when Releasing the Holding Brake

Applying the Holding Brake

When "AF" (drive enable) is reset by the master, the applying of the brake is activated. The brake is applied with a delay, due to the inductance of the brake winding. The controller is informed of this delay via "S-0-0207, Drive off delay time".

In order to avoid, for example, a non-equilibrated vertical axis in standstill moving down because of the force due to weight, "AF" (drive enable) is internally reset by "S-0-0207, Drive off delay time" later. During this delay the velocity command value is internally set to zero.

Behavior of the Holding Brake Control in the Case of Error

In the case of interruptions and errors that can suddenly occur for different causes during normal operation, in most of the cases there is a demand to quickly shut down the mechanical system for reasons of personnel and installation safety. This is done, if possible, by actively braking the drive.

In the case of error it is decisive whether the drive is able by itself to decelerate. This is the case when the drive comes to a standstill within an axis-specific maximum braking time. The controller is informed of this time via parameter "S-0-0273, Maximum drive off delay time".

☞ The "maximum drive off delay time" is the time that the drive needs to shut down the axis out of maximum velocity at maximum inertia (or inertial mass) with maximum allowed brake torque (or brake force).

If the drive is unable to shut down the mechanical system within the maximum braking time, the drive at least reacts with the most convenient control of the holding brake. What is decisive for the control in this case is whether the customer determined the application type to be "servo drive" or "main drive".

You have to distinguish the following situations in the case of error:

Error Situation 1

- Drive remains fully operational; "velocity command value reset with or without ramp and filter" was set as the error reaction (F2xxx, F4xxx, F6xxx error or NC-side drive enable reset in the case of axis motion).

Error Situation 2

- Drive defect (F8xxx error) or "torque or force disable of the motor ("coasting")" was set as the error reaction (F2xxx, F4xxx, F6xxx error or NC-side rive enable reset in the case of axis motion).

☞ The error reaction is set in parameter "P-0-0119, Best possible deceleration".

Errors can possibly cause damage to machines or drive components. Depending on the application, the following strategies are used to minimize damage:

Holding Brake Control for Servo Drives

In the case of servo drives that mostly drive linear axes with limited travel distances, the protection of the machine is preferred to the drive in the case of error situation 2. The controller, according to the setting made by the customer (in "P-0-0525, Holding brake control word"), therefore tries to realize the shortest possible braking distances, even if this damages the holding brake.

Holding Brake Control for Main Drives

Main drives are rotary axes with "unlimited" travel distance, such as spindle motors of milling and turning machines. Due to high speed and high inertia most of these axes produce kinetic energies in operation that often exceed the allowed energy absorption capacity of holding brakes integrated in the motor. In the case of error situation 2, shutdown realized by the holding brake only could destroy the brake very easily. Due to the unlimited travel distance there normally isn't any danger of damaging the machine. The controller therefore, when determined by the customer (P-0-0525), prevents the holding brake from applying and gives priority to friction braking.

P-0-0525, Holding brake control word

The required functionality of the holding brake, depending on the application type of the drive (servo or main drive), is determined by the respective bit in parameter P-0-0525.

Holding Brake Control with Error Situation 1

If the drive cannot shut down the mechanical system within the time after occurrence of the error entered in parameter S-0-0273, the motor holding brake is applied after motor standstill, independent of the application (servo or main drive).

Depending on the error reaction, motor standstill means:

- Falling below a velocity threshold (in the case of "velocity command value reset" error reaction, with or without ramp)
- Target position reached and actual velocity value lower than the value of "S-0-0124, Standstill window"

See also "Error Reactions"

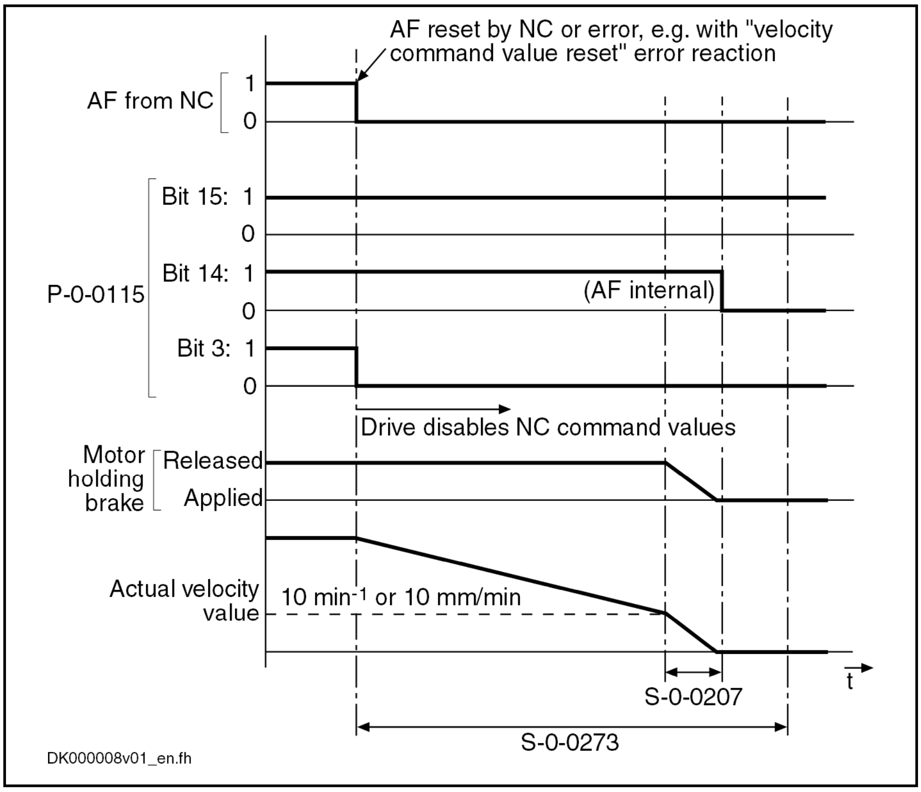


Fig. 5-21: Holding Brake Control with Error Situation 1 and Braking Time < S-0-0273 (Error Reaction "Velocity Command Value Reset")

If the drive cannot shut down the mechanical system within the time after occurrence of the error entered in parameter S-0-0273, the motor holding brake is controlled depending on the application (servo or main drive):

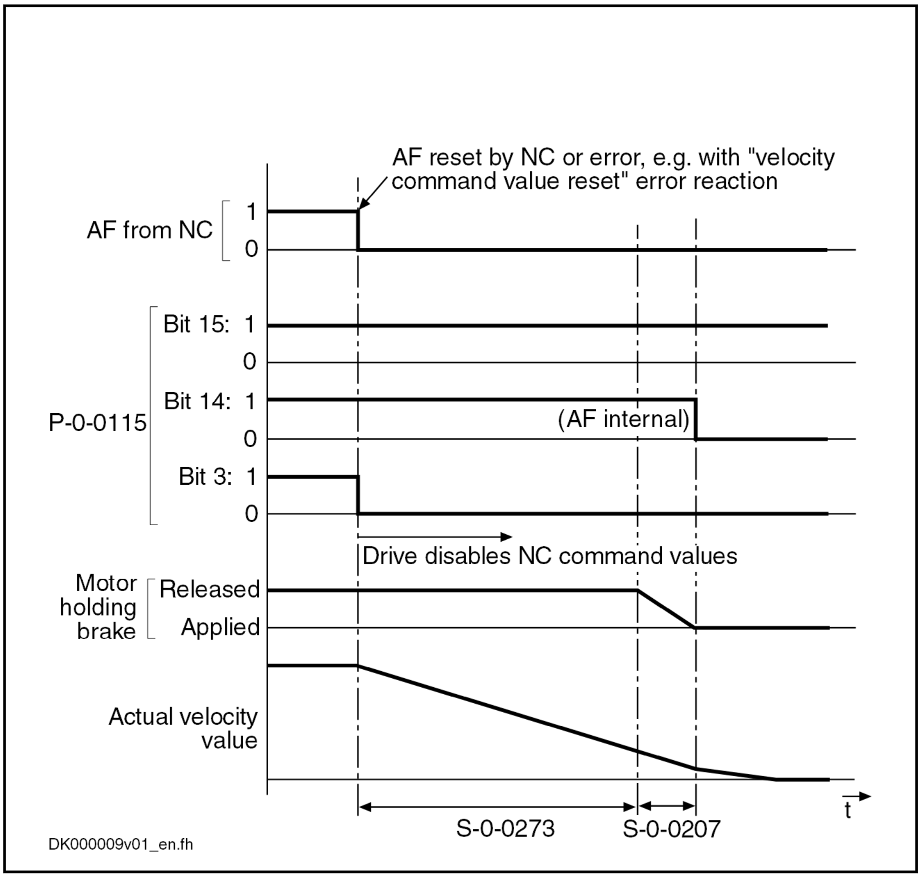


Fig. 5-22: Holding Brake Control with Error Situation 1 and Braking Time > S-0-0273 for Servo Drives

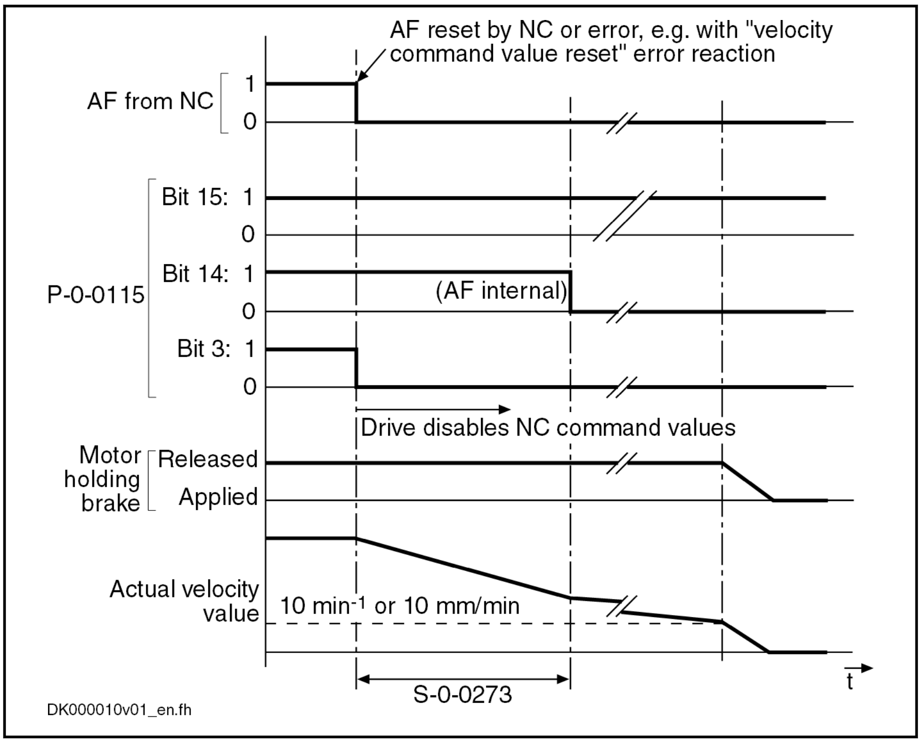


Fig. 5-23: Holding Brake Control with Error Situation 1 and Braking Time > S-0-0273 for Main Drives

Holding Brake Control with Error Situation 2

In the case of error situation 2, the drive becomes torque-free or force-free after the error event. The braking effect, in addition to the axis friction, can only be achieved by means of the holding brake. To limit the damage, the holding brake is controlled depending on the application (servo or main drive).

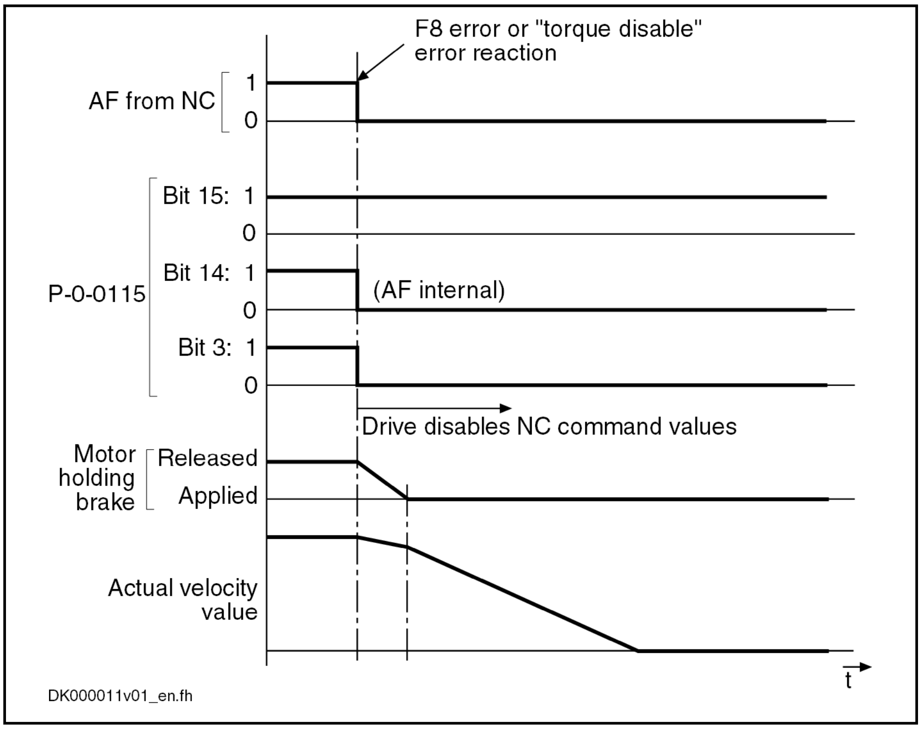


Fig. 5-24: Holding Brake Control with Error Situation 2 for Servo Drives

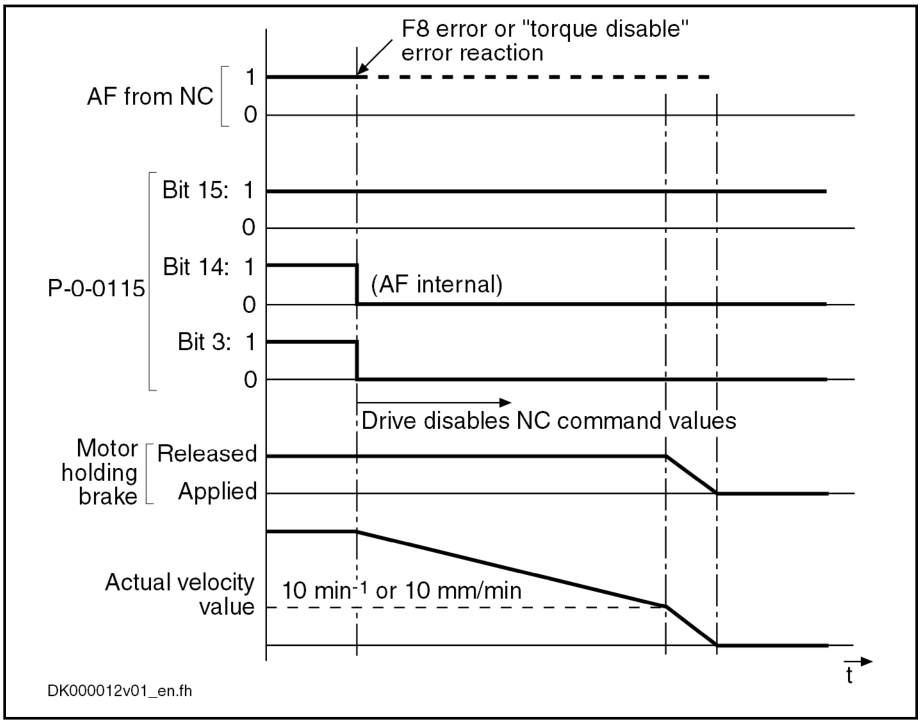


Fig. 5-25: Holding Brake Control with Error Situation 2 for Main Drives

"Release Holding Brake" Command

In special cases, it can be convenient to release the holding brake even if the drive is not in "AF" (drive enable). This is possible by activating "P-0-0542, C2000 Command Release holding brake". This command, however, must firstly be enabled by the respective bit in "P-0-0525, Holding brake control word"!

☞ When using safety technology/SBC, see documentation "Rexroth IndraDrive Integrated Safety Technology "Safe Torque Off" (as of MPx-16), Application Manual" (DOK-INDRV*-SI3-**VRS**-AP; Mat. No.: R911332634).

NOTICE **Property damage caused by movement of non-equilibrated axes when releasing the holding brake!**

⇒ Before starting the command, move the axis to a noncritical position!

Upon completion of the command, the brake is applied again. When drive enable is set and then reset with the command being active, the holding brake is applied again when resetting "AF" (drive enable)!

☞ The command for releasing the holding brake can also be started via the control panel, when the corresponding bit has been set in parameter "P-0-0525, Holding brake control word".

"Apply Holding Brake" Command

In special cases, it can be convenient to apply the holding brake if the drive is in an active state ("AF", drive enable). This is possible by activating "P-0-0543, C3800 Command Apply holding brake"!

NOTICE **Damage to the holding brake!**

If the axis is moved with the holding brake applied, the brake can become prematurely worn!

⇒ In case of doubt start "P-0-0541, C2100 Holding system check command"!

Influence of Drive Enable on Command "Apply Holding Brake"

If drive enable ("AF") is reset and set again when the command is active, the brake releases when drive enable is set although the command is still active!

When the command is completed, the brake releases again if the drive is still active ("AF").

When the command is completed, the brake remains applied if drive enable was reset during the execution of the command!

Notes on Commissioning

Relevant Parameters

Enter application-dependent parameter values:

- S-0-0273, Maximum drive off delay time

In this parameter, enter the determined time that the drive needs in order to stop the axis out of maximum velocity at maximum inertia or inertial mass with maximum allowed brake torque or brake force. If necessary, increase the determined time to make sure the axis really stops!

NOTICE **Danger of damaging the motor brake when value in S-0-0273 is too low!**

⇒ The value for "S-0-0273, Maximum drive off delay time" must always be set higher than the time needed to decelerate the axis by velocity command value reset (if necessary with ramp), taking the maximum possible velocity into account.

Enter data of holding brake:

- S-0-0206, Drive on delay time
- S-0-0207, Drive off delay time
- P-0-0540, Torque of holding brake

For the simple display where the holding brake is still ok, parameter "P-0-0539, Holding brake status word", bit 7, indicates whether the nominal torque of the holding brake was reached or not during the last brake test. The bit is "1" when the nominal torque of the holding brake has been reached. The bit is deleted at the beginning of the brake test.

☞

- The wait times S-0-0206, S-0-0207 are overwritten with values from the encoder memory for Rexroth engines **with** encoder data memory only with "C0700 Load defaults proced. command (motor-spec. controller val.)". The value from P-0-0540, however, is always loaded from the encoder memory.
- The holding brake data are entered automatically with Rexroth motors **without** encoder data memory when loading the motor-specific parameter values from the database of the commissioning tool "IndraWorks Ds/D/MLD"!

Configure holding brake control in:

- P-0-0525, Holding brake control word

Activating the Holding Brake Function

The holding brake control is linked with drive enable and does not have to be separately activated.

"Release Holding Brake" Command

The control unit can release the holding brake by means of the following command:

- P-0-0542, C2000 Command Release holding brake

NOTICE **Property damage caused by movement of non-equilibrated axes when releasing the holding brake!**

⇒ Before starting the command, move the axis to a noncritical position!

"Apply Holding Brake" Command

The control unit can apply the holding brake by means of the following command when the drive is active:

- P-0-0543, C3800 Command Apply holding brake

NOTICE **Damage to the holding brake!**

If the axis is moved with the holding brake applied, the brake can become prematurely worn!

⇒ In case of doubt start "P-0-0541, C2100 Holding system check command"!

Operating status

Displaying the operating status:

- P-0-0539, Holding brake status word

Signaling the readiness to accept command values:

- S-0-0135, Drive status word

Error

- F6024 Maximum braking time exceeded

Command error

- C2001 Command not enabled

5.5.4 Function Check of Holding Brake, Drive-Controlled

Brief Description

If the braking torque of holding brakes is too low due to wear and corrosion, this can interrupt the service and endanger safety in machines and installations. IndraDrive controllers have the advantage of monitoring the effectiveness of the holding brake upon a command of the control master and recording the monitoring intervals.

This allows cyclic brake check according to EN-954-1, cat. 2 or dynamization/check of one of two redundant holding systems according to EN-954-1, cat. 3.

Requirements

The function check is only possible in the case of motor control with motor encoder, not for sensorless motors! The holding brake must be controlled by the drive controller (if necessary via relay, if the required brake current cannot be supplied via the drive controller).

Application

The function check can also be carried out for an axis-side, external braking device, if it is controlled by the drive controller. The measuring system used for the function check (motor encoder or external encoder) must be connected stiffly and in a backlash-free way to the holding brake. Tolerated motion range with the holding brake applied:

- Rotary motor: Max. 2° of a motor revolution (360°)
- Linear motor: Max. 1/180 of a pole pair distance (in mm)

In the case of corrosion, the effectiveness of the holding brake can be reestablished by a drive-controlled "resurfacing procedure".

Pertinent Parameters

- P-0-0525, Holding brake control word
- P-0-0539, Holding brake status word
- P-0-0540, Torque of holding brake
- P-0-0541, C2100 Holding system check command
- P-0-0544, C3900 Command Holding brake resurfacing
- P-0-0545, Test torque for releasing holding system
- P-0-0546, Starting torque for releasing holding system
- P-0-0547, Nominal load of holding system
- P-0-0549, Oper. hours control sec. at last succ. holding system check

- P-0-0550, Time interval holding system check
- P-0-0554, Current torque value of the motor holding brake
- S-0-0084, Torque/force feedback value
- S-0-0135, Drive status word

Pertinent Diagnostic Messages

- C2100 Command Holding system check
- C2101 Holding system check only possible with drive enable
- C2103 Holding brake: Torque too low
- C2104 Command execution impossible
- C2105 Load of holding system greater than test torque
- C2106 Test torque of holding system not reached
- C3900 Command Holding brake resurfacing
- C3901 Resurfacing of holding brake only possible with drive enable
- C3902 Error during resurfacing of holding brake
- C3903 Command execution impossible
- E3115 Prewarning, end of brake check time interval
- F3115 Brake check time interval exceeded

Functional Description

Monitoring the Holding Brake

The controller can check the effectiveness of the holding brake and its released state by starting "P-0-0541, C2100 Holding system check command":

If the holding brake is all right, the drive is operational after the routine is over. Otherwise, the controller will output the corresponding message.

The relevant bits for the desired kind of brake monitoring have to be set in "P-0-0525, Holding brake control word".

"Holding System Check" Command

The automatic monitoring of the brake at each switch-on and switch-off of drive enable significantly delays this process, which is why it is preferable in most cases only to initiate monitoring cyclically by the command. When starting "P-0-0541, C2100 Holding system check command", the drive must be in "AF" (drive enable); apart from that, it should be in standstill so that the holding system check takes place under defined basic conditions. Firstly, the motor generates a torque or force; this sets the motor slightly in motion if the state of the holding brake is without error. For this check, the drive uses the value of "P-0-0545, Test torque for releasing holding system". The torque is determined during initial commissioning and entered in the parameter (described in the Notes on Commissioning for function check of holding brake).

If the motor does not move during this check, the command is output with the command error "C2108 Error when releasing the holding system".

Then, the holding brake is applied and a torque or force is generated that mustn't yet set the motor in motion if the state of the holding system is correct. The value of this torque or force is defined with "P-0-0547, Nominal load of holding system" and "P-0-0553, Test torque factor for brake check". The value for the nominal load "P-0-0547, Nominal load of holding system" can be determined during initial commissioning (description in the Notes on Commissioning for Function Check of Holding Brake).

When the check has been completed successfully, this is positively acknowledged in "P-0-0539, Holding brake status word". If the holding brake check has not been successful, the cause is displayed by means of a diagnostic command message (C21xx) and the torque or the force at which the motor moves is stored in "P-0-0554, Current torque value of the motor holding brake". By clearing the command, possible error messages are cleared, as well. The cause of the negative brake check must be remedied immediately (see "chapter "Functional Description" on page 234").

NOTICE

If drive enable "AF" is deactivated while the command "C2100 Command Holding system check" is executed, the brake is applied; there is, however, no positive acknowledgement.

NOTICE

Possible property damage caused by vertical axis moving down!

Take constructional precautions!

☞ To test the displacement during the holding system check, the encoder selected by "S-0-0520, Axis control word" is used. To check the motor brake, the motor encoder should be used. The actual displacement during the brake system check is recorded in"P-0-0526, Displacement during brake check".

The check can be made in both force directions or in one preselected direction only. This can be preselected in parameter "P-0-0525, Holding brake control word".

Detection of Wear

To increase the availability of the axis and detect wear or defects of the holding system at an early stage, the following value must be determined:

- The presently maximum holding torque of the brake

or

- The maximum distance by which the axis was moved with the holding brake applied

For this purpose, the following data are determined during the holding system check and made available to the user:

- "P-0-0546, Starting torque for releasing holding system": Evaluating this parameter allows detecting at an early stage whether the friction of the axis has increased, or whether the holding brake is still entirely released. To evaluate "P-0-0546, Starting torque for releasing holding system", the value of the error-free axis must be determined during initial commissioning.
- "P-0-0554, Current torque value of the motor holding brake": This parameter displays the torque which the holding brake held during the holding system check. To determine the current maximum holding torque of the holding brake, the factor in "P-0-0553, Test torque factor for brake check" can be increased. In this case, the drive in P-0-0554 records the torque starting from which the holding brake no longer holds the axis. As holding brake wear increases, this value will decrease.

☞ Danger of accidental axis motion. Only execute the test at an appropriate position.

For an evaluation, the value of the error-free axis must be determined and recorded during initial commissioning.

- "P-0-0526 Displacement during brake check": This parameter indicates the distance by which the axis moved during the holding system check with the holding brake applied. (The motion is recorded separately for each direction.) As holding brake wear increases, this erroneous distance will increase. To evaluate P-0-0526, the value of the error-free axis must be determined during initial commissioning.

Detecting wear by regularly checking the displacement

With wedge brakes, the wear can be recognized by the increasing displacement at unchanged test torque. The check with increased torque is not suitable for this brake type.

Detecting wear by increasing the test torque

With friction surface brakes, the wear can be recognized by a brake check with a moderately (e.g. +20%) increased test torque threshold (P-0-0553). The value in P-0-0553 should be determined with the brake being intact and selected such that the nominal torque of the holding brake is not exceeded and the command C2100 is not yet aborted with the error message C2103/C2107. As holding brake wear increases, only the check with the increased torque will fail, whereas the brake will still pass the check with the regular test torque. In this case, it is possible to initiate the maintenance or replacement of the brake in due time.

☞ Danger of accidental axis motion. Only execute the test at an appropriate position.

Load Torque Monitoring

Within the scope of the holding system check, the current load torque of the axis is determined and displayed in "P-0-0551, Current load torque". If the determined load torque is greater than the test torque for the holding system check, the holding system check is aborted with the command error "C2105 Load of holding system greater than test torque".

Time Interval of Holding Brake Check

At the activation of the time interval for brake check (in parameter "P-0-0525, Holding brake control word"), the interval since the last successful brake check is measured and compared to the value of parameter "P-0-0550, Time interval holding system check". The monitoring function with regard to this value might possibly generate the following messages:

- If the measured interval draws up to 15 min nearer to the interval set in parameter P-0-0550, the warning "E3115 Prewarning, end of brake check time interval" is output.
- If the measured interval exceeds the value in parameter P-0-0550, the error message "F3115 Brake check time interval exceeded" is generated.

☞ The output of the warning "E3115" and of the error "F3115" can be deactivated in the parameter "P-0-0525, Holding brake control word". In this case, only the "status of holding brake check" is set to "not successful" after the time interval has expired.

The warning E3115 disappears automatically when the brake check is successfully carried out within 15 min after the message had been generated. This is done, for example, by starting "C2100 Command Holding system check" or, if automatic brake check was preset, by resetting drive enable.

If the drive switches off with the error message F3115, the user, after having reset this message, has 15 min to carry out the brake check, e.g. by starting "C2100 Command Holding system check". After successful execution, the "status of holding brake check" and the "status of holding torque check" is set to "1" in parameter "P-0-0539, Holding brake status word". The time of the brake check is stored in parameter "P-0-0549, Oper. hours control sec. at last succ. holding system check" and the time interval measurement is restarted!

If the brake check is not carried out or cannot be successfully carried out, the drive switches off with the error message "F3115 Brake check time interval exceeded", at the latest 15 min after drive enable had been set.

⚠ WARNING

For safety-related use of axis holding systems, observe the respective regulations of the concerned institution for statutory accident insurance and prevention ("Berufsgenossenschaft") with regard to sizing and testing!

Reestablishing the Holding Brake Torque

For re-establishing the brake torque, "C3900 Command Holding brake resurfacing" (P-0-0544) can be started. To do this, drive enable ("AF") must have been set! After the command was started, the drive is accelerated to 100 rpm or 100 mm/min. Active acceleration and deceleration ramps, as well as filters (P-0-1201, P-0-1202, P-0-1203, P-0-1211, P-0-1213 and P-0-1222) are taken into account! When the motor has reached the command velocity, the brake is applied for 400 ms. After the command has been completed, the motor has been stopped by velocity control with command value "0".

With the execution of command C3900 there is no check run as to whether the resurfacing of the brake was successful! It is therefore recommended to execute command C2100 (brake check) after command C3900! In this context, it is particularly the value of "P-0-0554, Current torque value of the motor holding brake" that is useful, as with C2100 the currently effective torque value of the holding brake is entered in this parameter (as a maximum, 1.3 x "P-0-0547, Nominal load of holding system").

NOTICE

Property damage caused by drive-controlled axis motion when executing the commands for brake check and for resurfacing of the brake!

Before starting the command, move the axis to a noncritical position!

Diagnosing the Brake Check

The result of the brake check and the operating status of the holding brake are displayed in the respective bits of "P-0-0539, Holding brake status word".

Notes on Commissioning

"Brake Check" Command

The control unit can activate the brake check by means of a command:

- P-0-0541, C2100 Holding system check command

NOTICE

Property damage caused by drive-controlled axis movements during brake check!

Before starting the command, move the axis to a noncritical position!

Presetting the Brake Check

Check for brake released:

The "holding brake released" state is checked by the motor generating a torque or force that sets the motor slightly in motion. The maximum value can be preset in

- P-0-0545, Test torque for releasing holding system

The appropriate value for P-0-0545 can be determined on the basis of the value displayed in

- P-0-0546, Starting torque for releasing holding system

When the value "0" is entered in parameter P-0-0545 (or the value remains "0"), the releasing of the holding brake is checked with regard to the value in parameter "P-0-0540, Torque of holding brake"!

☞ The value of P-0-0546 should be provided with a safety factor if used for P-0-0545!

See also the respective Parameter Description

Check for sufficient holding torque of the brake:

The holding torque of the brake is checked by the motor generating a torque or force with the brake having been applied. The maximum test torque or force can be preset via the parameters

- P-0-0547, Nominal load of holding system and
- P-0-0553, Test torque factor for brake check

The criterion for which the check is to be carried out is decisive for determining an appropriate value for P-0-0547 and P-0-0553:

- Nominal torque or force of the holding brake
- Holding torque or force for fixing the axis
- Increased holding torque or force

Criterion "Nominal Torque or Nominal Force"

The nominal torque or force of the holding brake from "P-0-0540, Torque of holding brake" can be activated for the check. To do this, enter the value "0" in parameter P-0-0547 (or leave it at "0")!

ℹ See Parameter Description "P-0-0547, Nominal load of holding system". With the configuration of P-0-0547 = "0", the factor in P-0-0553 is no longer taken into account for the holding system check.

Criterion "Fixing the Axis"

The torque or force required for fixing the axis can be determined on the basis of "S-0-0084, Torque/force feedback value". To do this, bring the axis to the position with the highest load due to weight and write the value of [S-0-0084 × safety factor (>1)] to parameter "P-0-0547, Nominal load of holding system"!

NOTICE

For the criterion "fixing the axis", the required holding torque or holding force, with the holding brake having been sufficiently dimensioned, is smaller than the nominal torque or nominal force of the brake. This expands the tolerance range for detection of holding brake wear and therefore increases the service life of the holding brake.

Criterion "Increased Holding Torque or Force"

The safety-relevant dimensioning of the holding brake normally requires a higher holding torque than the holding torque necessary to fix the axis. In this case, the holding torque or holding force must be entered in the parameter P-0-0547 and the safety factor for the holding system check in P-0-0553!

NOTICE	The maximum value for parameter "P-0-0547, Nominal load of holding system" is limited by the value of "P-0-0540, Torque of holding brake"! The "test torque" (P-0-0547 x P-0-0553) may not be greater than the value of the parameter P-0-0540; otherwise, the holding system check is aborted with the error message "C2103 Holding brake: Torque too low"!

Criterion "Time Interval Brake Check"

The criterion "time interval brake check" is activated via the respective bit in "P-0-0525, Holding brake control word". The maximum allowed interval to the next brake check has to be entered in parameter "P-0-0550, Time interval holding system check".

"Brake Resurfacing" Command

By starting a command it is possible to reestablish, by removing the oxide film (resurfacing of the brake), the holding torque or the holding force of a holding brake that has not yet become worn.

- P-0-0544, C3900 Command Holding brake resurfacing

"Brake Resurfacing" Result Check

After brake resurfacing, trigger the command "P-0-0541, C2100 Holding system check command" again. Afterwards, check the parameter "P-0-0554, Current torque value of the motor holding brake", as with C2100 the currently effective torque value of the holding brake is entered in this parameter.

Operating status

Displaying the monitoring function:

- P-0-0539, Holding brake status word

Signaling the readiness to accept command values:

- S-0-0135, Drive status word

Command error

- C2101 Holding system check only possible with drive enable
- C2103 Holding brake: Torque too low
- C2104 Command execution impossible
- C2105 Load of holding system greater than test torque
- C2106 Test torque of holding system not reached
- C3901 Resurfacing of holding brake only possible with drive enable
- C3902 Error during resurfacing of holding brake
- C3903 Command execution impossible

5.6 Measuring Systems

5.6.1 Basics on Measuring Systems, Resolution

Brief Description

Control Loops and Measuring Systems

Operating drives in the closed control loop requires measuring systems in order to metrologically acquire the current state of the physical value to be controlled, the so-called actual value.

The following drive control loops are distinguished:

- Torque/force control loop

→ Actual value by evaluating the current measuring system and converting the value

- Velocity control loop

  → Actual value by evaluating the position measurement system and time-derivation

- Position control loop

  → Actual value by evaluating the position measurement system

The actual value of the torque/force control loop is generated by means of the internal current measurement. The measuring system is inaccessible for the user and has a fixed configuration.

Possibilities of Position Measurement

For acquiring the actual values of the velocity and position control loop there are position measurement systems available that provide the user possibilities of configuration. Position measurement can be carried out:

- At the motor only (measurement via motor encoder)

- or -

- Both at the motor and at the mechanical axis system (measurement via motor encoder and "external" or "optional" encoder).

☞ Position measurement via motor encoder is always required, measurement at the mechanical axis system is optional, the encoder at the mechanical axis system is therefore called "optional encoder". It is also called "external encoder" because this encoder is not installed internally at the motor, but externally at the axis.

Types of Position Measurement Systems

Position measurement systems are available for the different kinds of motion in adapted types of construction:

- Rotary encoders
- Linear encoders

With the appropriate signal specification, encoders in both types of construction can be evaluated by IndraDrive controllers.

Evaluating Position Measurement

Depending on their design and the mechanical arrangement at the axis, the position encoders can be evaluated as

- relative encoders (incremental encoders)
- Absolute encoders (absolute value encoders).

The position information of the encoder can be represented as

- two analog voltage signals with sinusoidal profile at constant velocity and a 90° phase offset ("analog encoder")
- digital encoder signal with defined number of increments per encoder revolution ("digital encoder")

Relative Position Measurement

In the case of relative position measurement, only position differences can be evaluated by means of the measuring system. The actual position values signaled by the measuring system refer to the (mostly undefined) position at the time the drive is switched on. To operate the drive within a limited travel range, a position reference must be established ("homing") each time after the drive has been switched on again.

Absolute Position Measurement

In the case of absolute position measurement, the encoder signals actual position values with a fixed encoder-dependent reference point to the controller. After the drive is switched on, the correct actual position value is immediately available for each axis position. Due to the mostly undefined mounting situation of the encoder to motor or mechanical axis system, it is necessary to determine the position offset ("setting the absolute value") once at the initial commissioning.

Precision, Resolution

The precision of the position measurement depends on:

- The resolution of the measuring system (division periods (DP) for analog encoders; increments/revolution for digital encoders)
- The absolute encoder precision
- The digitalization quality of analog encoder signals
- The dimension of the travel range of the axis

Monitoring Functions

Correct position information is of fundamental importance for reliable drive behavior and motion according to contour. The encoder signals are therefore monitored for validity and compliance with the allowed tolerances.

In addition, it is possible to monitor drives with an encoder that can be evaluated in absolute form for compliance with the position when switching on compared to the last time the drive was switched off.

It is also possible to monitor the difference between the actual position values of motor encoder and external encoder.

See also "Monitoring the Measuring Systems"

Hardware Requirements

For connecting the measuring systems to the controller there are two optional interfaces available. The parameters "P-0-0077, Assignment motor encoder->optional slot" and "P-0-0078, Assignment optional encoder->optional slot" define the interface to which the respective encoder is connected.

ⓘ See also the documentation "Rexroth IndraDrive Cs, Drive Systems" and "Rexroth IndraDrive HCQ, Drive Systems"

☞ The following points apply to the parameters P-0-0077 and P-0-0078:

- For motors with motor encoder data memory, the value for parameter P-0-0077 is automatically set correctly.
- For motors without motor encoder data memory (e.g. Rexroth kit motors), the value for parameter P-0-0077 must be set manually.
- In the case of optional encoders, the value for parameter P-0-0078 must be set manually, too.

Pertinent Parameters

- S-0-0051, Position feedback value 1
- S-0-0053, Position feedback value 2
- S-0-0115, Position feedback 2 type
- S-0-0116, Resolution of feedback 1
- S-0-0117, Resolution of feedback 2
- S-0-0256, Multiplication 1 (motor encoder)
- S-0-0257, Multiplication 2 (optional encoder)
- S-0-0277, Position feedback 1 type
- S-0-0278, Maximum travel range
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0075, Encoder type 2 (optional encoder)
- P-0-0129, Internal position data format

Functional Description

Absolute Encoder Precision

The absolute precision is a feature of the encoder and is determined by its construction and the quality of its components. The data for the absolute precision are given by the manufacturer of the encoder.

Resolution

The resolution of the measuring system is entered in the following parameters:

- S-0-0116, Resolution of feedback 1
- S-0-0117, Resolution of feedback 2

> ☞ Generally, the following applies:
>
> → **Encoder 1** refers to "motor encoder"
>
> → **Encoder 2** refers to "external or optional encoder"

With analog encoders, the value of S-0-0116 or S-0-0117 means:

- In the case of rotary motor encoders or external rotary encoders, the number of division periods or cycles per encoder revolution (DP/revolution)
- In the case of linear motor encoders (used for linear motors) or external linear encoders, the length of the division period in mm (mm/line count)
- In the case of rotary motor encoders or external rotary encoders, the number of increments per encoder revolution (DP/revolution)

With digital motor encoders, the value of S-0-0116 means:

- Number of position increments per encoder revolution

The significance of the value of S-0-0116 is determined in parameter "P-0-4014, Type of construction of motor" (rotary or linear motor).

> ☞ With Rexroth housing motors with motor encoder data memory and with Rexroth kit motors with EnDat2.1 encoder, or with IndraDrive-compatible HIPERFACE® encoders (see FAQ on supported encoders, "DE_EN_FAQ_IndraDrive_unterstützte_Geber_Vx.x") or HIPERFACE® encoders with the type ID "0xFF", the correct value is automatically written to the parameter S-0-0116.

Maximum Encoder Resolution after Digitalization (Analog Encoders)

With analog encoders, the signals are converted to digital position data via A/D converter. This increases the resolution of the position data available for the axis compared to the resolution of the measuring system (see above)!

Motor encoder (rotary)	(S-0-0116)	$\times\ 2^{15}$
External encoder (rotary)	(S-0-0117)	$\times\ 2^{15}$

S-0-0116 Resolution of feedback 1
S-0-0117 Resolution of feedback 2

Fig. 5-26: Maximum Possible Resolution of Rotary Analog Encoders

$$\text{Motor encoder (linear)} \quad \frac{\text{(S-0-0116)}}{2^{15}}$$

$$\text{External encoder (linear)} \quad \frac{\text{(S-0-0117)}}{2^{15}}$$

S-0-0116	Resolution of feedback 1
S-0-0117	Resolution of feedback 2

Fig. 5-27: Maximum Possible Resolution of Linear Analog Encoders

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Depending on the type of motion of the encoder, the "maximum encoder resolution after digitalization" is given in different units:

- Rotary encoders → Position information/encoder revolution
- Linear encoders → mm (length of the shortest measurable distance)

Internally, the value range of the encoder position data is "$\pm 2^{31}$", i.e. the encoder position range can be resolved to "2^{32}" data. By digitalization, a multitude of position data results from one division period. By means of adjusted multiplication, the range of encoder position data of "$\pm 2^{31}$" values, referring to the travel range of the axis (S-0-0278), is complied with.

The resulting drive-internal encoder resolution is as follows:

Drive-Internal Encoder Resolution, Rotary Analog Encoders

$$\text{Motor encoder (rotary)} \quad \text{(S-0-0116)} \times \text{(S-0-0256)}$$

$$\text{External encoder (rotary)} \quad \text{(S-0-0117)} \times \text{(S-0-0257)}$$

Auxiliary calculation and internal limiation:

$$\text{(S-0-0256)} = \frac{2^{30} \times c_{\_axis\_G1}}{\text{(S-0-0116)} \times \text{(S-0-0278)}} \leq 2^n \qquad n \leq 15 \text{ (in round numbers)}$$

$$\text{(S-0-0257)} = \frac{2^{30} \times c_{\_axis\_G2}}{\text{(S-0-0117)} \times \text{(S-0-0278)}} \leq 2^n \qquad n \leq 15 \text{ (in round numbers)}$$

S-0-0116	Resolution of feedback 1
S-0-0256	Multiplication 1 (motor encoder)
S-0-0117	Resolution of feedback 2
S-0-0257	Multiplication 2 (optional encoder)
S-0-0278	Maximum travel range (± travel range)
$c_{\_axis\_G1}$	Axis motion range / motor encoder revolution
$c_{\_axis\_G2}$	Axis motion range / revolution of external encoder

Fig. 5-28: Drive-Internal Resolution of Rotary Analog Encoders

Drive-Internal Encoder Resolution, Linear Analog Encoders

Motor encoder (linear) $\frac{(S\text{-}0\text{-}0116)}{(S\text{-}0\text{-}0256)}$

External encoder (linear) $\frac{(S\text{-}0\text{-}0117)}{(S\text{-}0\text{-}0257)}$

Auxiliary calculation and internal limitation:

$$(S\text{-}0\text{-}0256) = \frac{2^{30} \times (S\text{-}0\text{-}0116)}{(S\text{-}0\text{-}0278)} \leq 2^n \qquad n \leq 15 \text{ (in round numbers)}$$

$$(S\text{-}0\text{-}0257) = \frac{2^{30} \times (S\text{-}0\text{-}0117)}{(S\text{-}0\text{-}0278)} \leq 2^n \quad \text{(load reference)} \qquad n \leq 15 \text{ (in round numbers}$$

$$(S\text{-}0\text{-}0257) = \frac{2^{30} \times (S\text{-}0\text{-}0117)}{(S\text{-}0\text{-}0278) \times c_{\_bef\_M}} \leq 2^n \qquad \text{(motor reference)} \qquad n \leq 15 \text{ (in round numbers}$$

S-0-0116 Resolution of feedback 1
S-0-0256 Multiplication 1 (motor encoder)
S-0-0117 Resolution of feedback 2
S-0-0257 Multiplication 2 (optional encoder)
S-0-0278 Maximum travel range (± travel range)
$c_{\_bef\_M}$ Infeed length / motor revolution

Fig. 5-29: Drive-Internal Resolution of Linear Analog Encoders

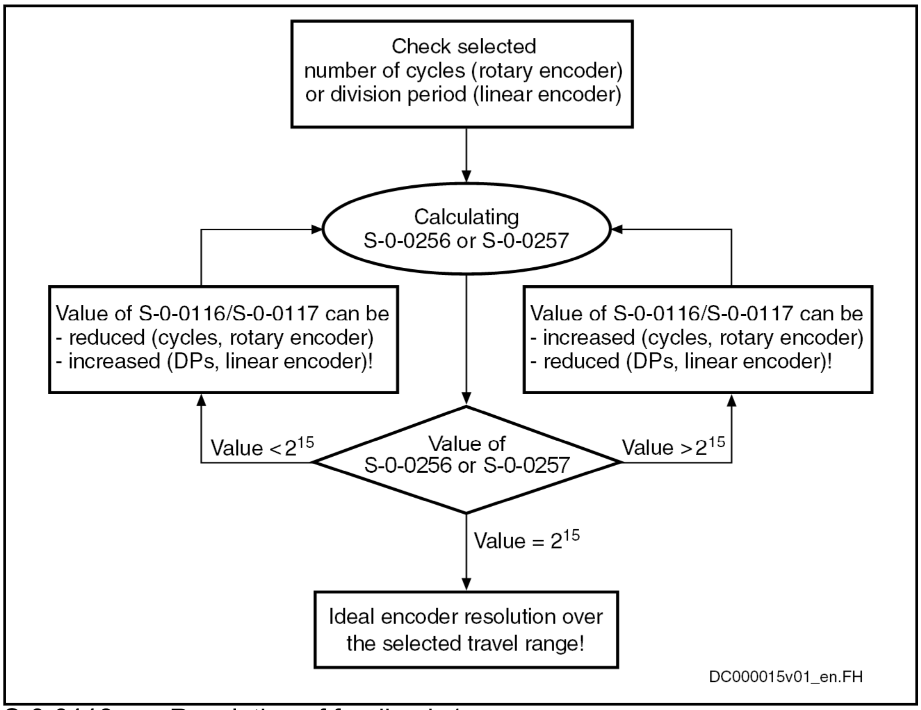
Internally, the multiplication (S-0-0256 and S-0-0257) is automatically determined taking the value of parameter S-0-0278 into consideration.

Drive-Internal Encoder Resolution, Rotary Digital Motor Encoder

The position information of a digital encoder is already read in by the controller in binary form. Thus, the drive-internal encoder resolution corresponds to the value of S-0-0116, the value for "S-0-0256, Multiplication 1 (motor encoder)" is "1" (cf. analog encoders).

Encoder Dimensioning

With analog encoders, the multiplication value (S-0-0256 and S-0-0257) calculated according to the formulas "Drive-Internal Resolution of Rotary Encoders" or "Drive-Internal Resolution of Linear Encoders", characterizes the encoder dimensioning.



S-0-0116 Resolution of feedback 1
S-0-0117 Resolution of feedback 2

Fig. 5-30: Checking the Selected Resolution and Determining the Ideal Resolution for Analog Encoders (Encoder 1 or Encoder 2)

☞ The calculated value of the parameters S-0-0256 or S-0-0257 normally will never exactly correspond to "2^{15}" (= 32768). With results "≥2^{15}", the conditions with regard to the possibilities of encoder evaluation are ideal!

Internal Resolution of the Position Data

Position control itself works with the resolution displayed in parameter "P-0-0129, Internal position data format". The value refers to one motor revolution (rotary motor) or one pole pair distance (linear motor) and is limited to "2^{28}". In addition, it is influenced by the setting in parameter "S-0-0278, Maximum travel range".

$$(P\text{-}0\text{-}0129) = \frac{2^{30}}{n_{(S\text{-}0\text{-}0278)}} \leq 2^{28}$$

P-0-0129 Internal position data format
$n_{(S-0-0278)}$ Number of motor revolutions for (S-0-0278)
S-0-0278 Maximum travel range (± travel range!)

Fig. 5-31: Drive-Internal Resolution of the Position Data for Rotary Motors

$$(P\text{-}0\text{-}0129) = \frac{2^{30} \times (P\text{-}0\text{-}0018)}{(S\text{-}0\text{-}0278)} \leq 2^{28}$$

P-0-0129 Internal position data format
P-0-0018 Pole pair distance of linear motors
S-0-0278 Maximum travel range (± travel range!)

Fig. 5-32: Drive-Internal Resolution of the Position Data for Linear Motors

Real Resolution of Analog Encoders

The lower value from drive-internal encoder resolution and "maximum encoder resolution after digitalization" is the real resolution of the position data of a rotary or linear analog encoder.

☞ The "maximum encoder resolution after digitalization" is the maximum possible, real encoder resolution. It is limited on the hardware side! If the number of encoder division periods over the travel distance of the axis is accordingly high, the real encoder resolution can also be lower!

Real Resolution of Digital Encoders

The ideal resolution of a digital rotary encoder corresponds to the value of "S-0-0116, Resolution of feedback 1", resolution per encoder revolution. It is reduced by the number of increments resulting from the "noise" of the less significant bits with the mechanical axis system at standstill.

Notes on Commissioning

Dialog-Supported Configuration

With "IndraWorks Ds/D/MLD", the configurations relevant for the measuring system can be carried out in a dialog-supported form:

- Encoder type and encoder interfaces of the controller
- Encoder type and resolution, as well as other settings
- Encoder gearbox, if available

The dialog shows whether absolute encoder evaluation is possible with the selected travel range and the existing encoder configuration. If this is not possible, however required under defined basic conditions, absolute encoder evaluation can be forced, referring to the applicable risks.

The dialogs are accessible via the "project explorer" of "IndraWorks Ds/D/MLD":

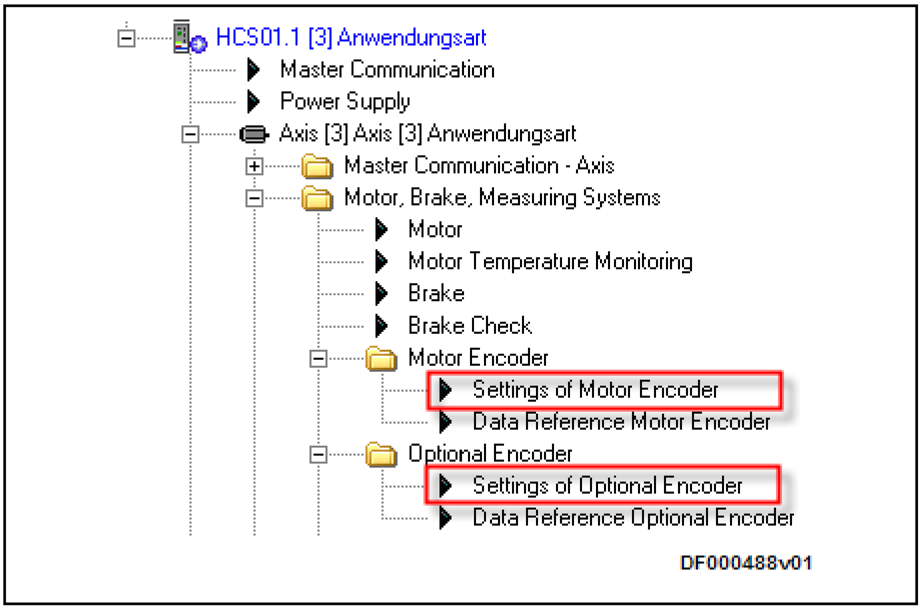


Fig. 5-33: Accessing the Dialogs for the Settings of Motor Encoder and Optional Encoder in "IndraWorks Ds/D/MLD"

Motor Encoder

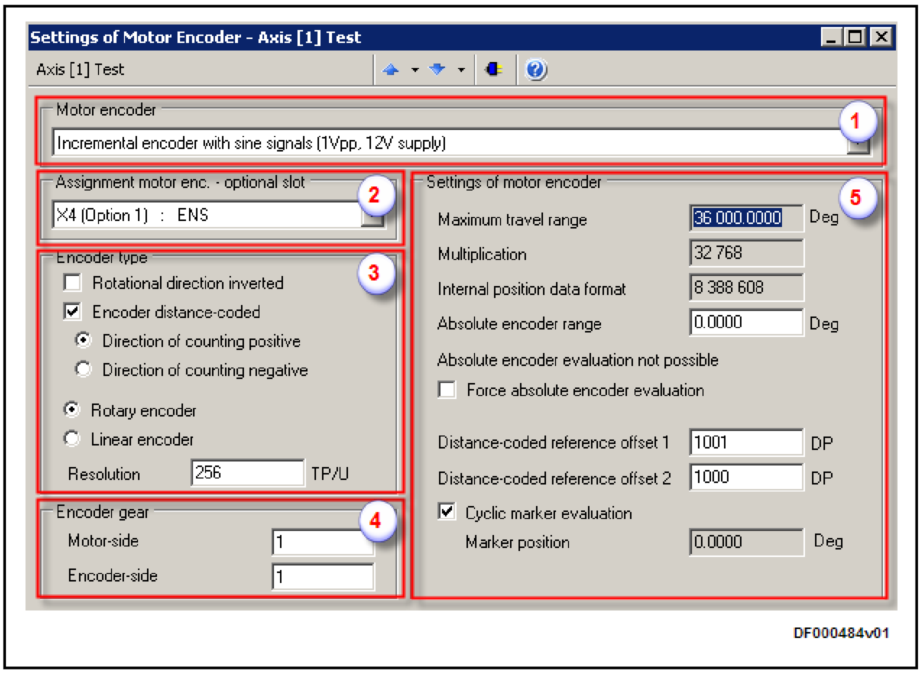


Fig. 5-34: "IndraWorks Ds/D/MLD" Dialog for the Motor Encoder with Exemplary Values of a Distance-Coded Incremental Encoder

Steps for configuring the motor encoder (encoder 1)

1. Select the motor encoder type

   (P-0-0074, Encoder type 1 (motor encoder))

2. Assign the encoder to the optional slot (interface)

   (P-0-0077, Assignment motor encoder->optional slot)

3. Set encoder resolution, encoder design and rotational direction

- Resolution
  (S-0-0116, Resolution of feedback 1)
- Encoder design and rotational direction
  (S-0-0277, Position feedback type 1)

4. Set the encoder gearbox (if available)
   - (P-0-0121, Gear 1 motor-side (motor encoder))
   - (P-0-0122, Gear 1 encoder-side (motor encoder))
5. Make further settings depending on the encoder type
   With distance-coded encoders, enter the distance-coded reference offset 1 and 2 ("S-0-0165, Distance-coded reference offset A" and "S-0-0166, Distance-coded reference offset B")

With Rexroth housing motors with motor encoder data memory, steps 1, 2, 3 are performed automatically; with Rexroth kit motors with EnDat2.1- or IndraDrive-compatible HIPERFACE® encoder, the resolution from step 3 is automatically written with the correct value.

Information on Position Evaluation

Multiplication of the motor encoder:

- S-0-0256, Multiplication 1 (motor encoder)

When the value "32768" is contained in "S-0-0256, Multiplication 1 (motor encoder)", the encoder evaluation is ideal. When the value is lower, the maximum travel range (S-0-0278) has to be checked for correct input!

Optional Encoder

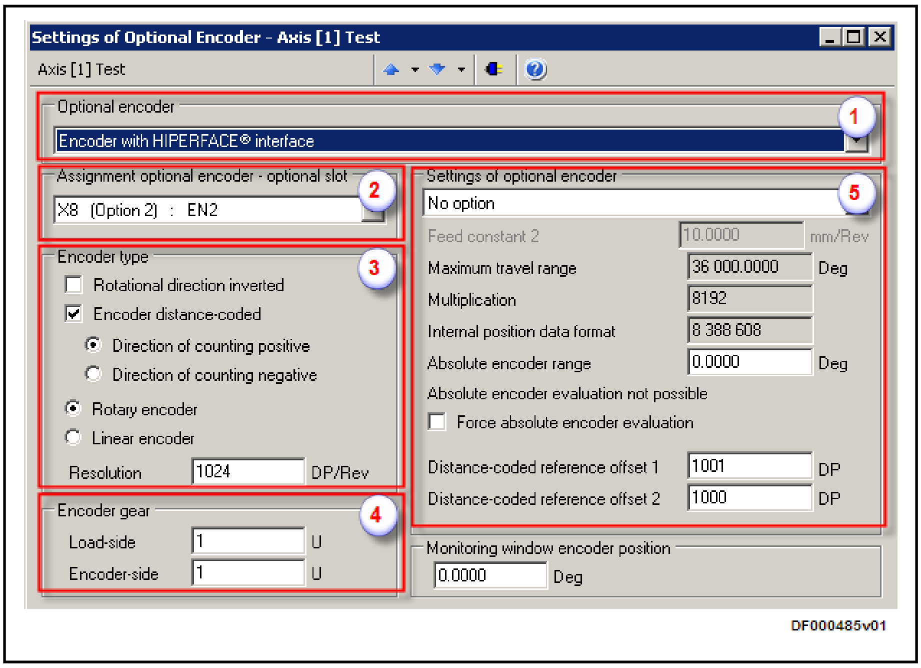


Fig. 5-35: "IndraWorks Ds/D/MLD" Dialog for the Optional Encoder with Exemplary Values of a Distance-Coded Incremental Encoder

Steps for configuring the optional encoder (encoder 2)

1. Select the encoder type
   (P-0-0075, Encoder type 2 (optional encoder))

2. Assign the encoder to the optional slot (interface)

   (P-0-0078, Assignment optional encoder->optional slot)
3. Set encoder resolution, encoder design and rotational direction
   - Resolution

     (S-0-0117, Resolution of feedback 2)
   - Encoder design and rotational direction

     (S-0-0277, Position feedback 2 type)
4. Set the encoder gearbox (if available)
   - (P-0-0124, Gear 2 load-side (optional encoder))
   - (P-0-0125, Gear 2 encoder-side (optional encoder))
5. Make further settings depending on the encoder type

   With distance-coded encoders, enter the distance-coded reference offset 1 and 2 ("S-0-0165, Distance-coded reference offset A" and "S-0-0166, Distance-coded reference offset B")

☞ With EnDat2.1- or IndraDrive-compatible HIPERFACE® encoders, the resolution from step 3 is automatically written with the correct value.

Information on Position Evaluation

Multiplication of the optional encoder:

- S-0-0257, Multiplication 2 (optional encoder)

When the value 32768 is contained in the multiplication, the encoder evaluation is ideal. When the value is lower, the parameter S-0-0279 has to be checked for correct travel range input!

5.6.2 Monitoring the Measuring Systems

Brief Description

Monitoring the Encoder Signals

Correct position information is the prerequisite for reliable drive behavior and motion according to contour. In order to guarantee best possible position evaluation the encoder signals are therefore monitored for validity and compliance with the allowed tolerances.

Monitoring the encoder signals allows detecting faulty states, such as:

- Encoder is dirty
- Noise injection in the case of inappropriate wire routing or wire design
- Exceeding the max. allowed encoder velocity (limit frequency of the encoder signals)
- Wire break or short circuit on wire

Monitoring the Axis Position when Switching On

In addition it is possible to monitor drives with an encoder that can be evaluated in absolute form for compliance with the position when switching on compared to the last time the drive was switched off. This allows detecting, for example, whether a vertical axis moved down after the machine was switched off or whether an axis was moved away from the position it had when the machine stopped.

Monitoring Mechanical Transfer Elements

It is also possible to monitor the difference between the actual position values of motor encoder and external encoder, as well as the percentage of slip. This allows, for example, detecting elasticity or slip due to wear in mechanical transfer elements between motor and axis at an early stage.

Monitoring the Position Data Reference

If the loss of the position data reference of absolute encoders (motor encoder or optional encoder) is detected due to changes in parameter values, e.g. of the mechanical drive system, the drive will signal this faulty state.

Pertinent Parameters

- S-0-0391, Monitoring window feedback 2
- P-0-0095, Absolute encoder monitoring window for motor encoder
- P-0-0096, Absolute encoder monitoring window for opt. encoder
- P-0-0177, Absolute encoder buffer 1 (motor encoder)
- P-0-0178, Absolute encoder buffer 2 (optional encoder)
- P-0-0185, Control word of encoder 2 (optional encoder)
- P-0-0391, Actual position value difference encoder1 - encoder2

Pertinent Diagnostic Messages

- E2074 Encoder 1: Encoder signals disturbed
- E2075 Encoder 2: Encoder signals disturbed
- F2036 Excessive position feedback difference
- F2042 Encoder 2: Encoder signals incorrect
- F2048 Low battery voltage
- F2074 Actual pos. value 1 outside absolute encoder window
- F2075 Actual pos. value 2 outside absolute encoder window
- F2174 Loss of motor encoder reference
- F2175 Loss of optional encoder reference
- F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)

Functional Description

IndraDrive Cs and multi-axis controllers can evaluate signals of the following encoder types:

- Sine encoder 1 V_{pp} with EnDat2.1 interface (Heidenhain standard)
- Sine encoder 1 V_{pp} with HIPERFACE® interface (Stegmann standard)
- Sine encoder 1 V_{pp} (Heidenhain standard)
- Square-wave encoder 5V TTL (Heidenhain standard)
- Resolver encoder (without encoder data memory)

Signal Monitoring for Sine Encoders

Analog sine encoder signals are monitored with regard to two criteria:

- Monitoring the signal amplitude
- Monitoring the quadrant allocation

The signals are monitored on the hardware side and on the firmware side. The signal amplitude must be within the allowed voltage range:

$$0{,}2 \times U_{A,B\_nom} \leq \sqrt{U_A^{\,2} + U_B^{\,2}} \leq 1{,}4 \times U_{A,B\_nom}$$

U_{A,B_nom}	Nominal amplitude value of the encoder tracks, in this case 1.0 Vpp
U_A	Amplitude of encoder track A
U_B	Amplitude of encoder track B

Fig. 5-36: Allowed Voltage Range for the Signal Amplitudes of Sine Encoders

The quadrant allocation is checked by counting the zero crossings of the sine or cosine signal. In the case of trouble-free operation, the count is changed by the value "±1" at every zero crossing of a track.

When the encoder signals temporarily leave (e.g. due to interference injection or local accumulation of dirt on the code disk) the allowed voltage range that is monitored in the hardware side, the controller outputs the respective warning:

- E2074 Encoder 1: Encoder signals disturbed
- E2075 Encoder 2: Encoder signals disturbed

The warning remains active until the drive is switched off or switched to communication phase P2!

Incorrect counts caused by injected noise and permanently reduced signal amplitudes caused by dirty code disks can be the reason why an error message for the motor encoder or the external encoder is generated:

- F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)
- F2042 Encoder 2: Encoder signals incorrect

The drive then reacts with the error reaction that has been set.

Signal Monitoring for Square-Wave Encoders

Monitoring the signals of square-wave encoders with regard to amplitude and quadrant allocation is not possible with IndraDrive controllers!

Signal Monitoring for Digital Encoders

The signals of digital encoders are monitored by means of a checksum test.

Actual Value Monitoring with Encoders with EnDat2.1 and with HIPERFACE® Interface

Encoders with EnDat2.1 or with HIPERFACE® interface provide analog and digital position information. During initialization of the encoder, the digital absolute actual position value is transmitted serially to the controller. Motor control is performed via the analog relative sine signals of the encoder, as they can be largely read free of delay compared with the serial transmission of the absolute actual position values.

The absolute actual position value is formed by the absolute initial position value and an additive relative actual position value. The absolute value calculated in this way is cyclically compared with the digital serial absolute value in order to recognize and signal (warning E2074) possible error measurements by redundant position checking.

Monitoring the Axis Position when Switching On

When the drive is switched off the current encoder data of the absolute motor encoder and/or of the absolute external encoder are stored:

- P-0-0177, Absolute encoder buffer 1 (motor encoder)
- P-0-0178, Absolute encoder buffer 2 (optional encoder)

When switching on a drive with an absolute motor encoder and/or an absolute external encoder, a check is run to determine in how far the current actual position value differs from the actual position value at the time of the last switch off. The maximum allowed difference is set in the following parameters:

- P-0-0095, Absolute encoder monitoring window for motor encoder
- P-0-0096, Absolute encoder monitoring window for opt. encoder

When the difference exceeds the determined value, the respective error message is output:

- F2074 Actual pos. value 1 outside absolute encoder window
- F2075 Actual pos. value 2 outside absolute encoder window

This monitoring function can be deactivated!

Checking Mechanical Transfer Elements for Position Difference

For axis drives that are equipped with an external encoder, the controller provides the possibility of monitoring the difference of the actual position values of motor encoder and external encoder with regard to a maximum value that can be set.

The maximum allowed difference of the actual position values of both encoders is defined in parameter "S-0-0391, Monitoring window feedback 2". When this value is exceeded the "F2036 Excessive position feedback difference" error message is generated. This monitoring is active from communication phase 4 on and can be deactivated by the value "0" in S-0-0391.

Checking Mechanical Transfer Elements for Slip

For axis drives that are equipped with an external encoder, the controller provides the possibility of monitoring, by means of the encoder provided in addition to the motor encoder, any possible mechanical slip of the axis with regard to a maximum value that can be set. The slip that has occurred is displayed in "P-0-0243, Maximum occurred actual slip value".

The maximum allowed slip is defined in parameter "P-0-0244, Monitoring window of slip". When this value is exceeded the "F2036 Excessive position feedback difference" error message is generated.

☞ 100% slip means:

- With rotary external encoders: 1 encoder revolution
- With linear external encoders: Position displacement from the value of the feed constants (S-0-0123)

Slip monitoring becomes active with drive enable ("AF"), the value of "P-0-0243, Maximum occurred actual slip value" starts at "0". Slip monitoring can be deactivated by the value "0" in "P-0-0244, Monitoring window of slip".

Slip monitoring is automatically switched off in the following cases:

- If the maximum encoder input frequency of a spindle encoder (P-0-0185, Control word of encoder 2 (optional encoder)) is exceeded (see below, "Monitoring for Spindle Encoders" on page 251).
- If parameter set switching is performed.

Slip monitoring is automatically reactivated if the spindle is positioned or its position data reference is reestablished. The value of "P-0-0243, Maximum occurred actual slip value" is then reset to "0".

Monitoring the Position Data Reference

The position data reference of absolute encoders gets lost when:

- The parameter values of the mechanical drive system have been changed
- The encoder resolutions have been changed
- The scalings of the physical data have been changed
- The maximum travel range of an axis has been changed
- Hybrid position control has been activated ("measuring wheel mode")

During the transition from communication phase P2 to P4 (bb), the drive recognizes that the former position data reference of the encoder does no longer exist. It sets the parameter "S-0-0403, Position feedback value status" of the encoder or encoders to "relative" and signals the loss of position data reference by the following error messages:

- F2174 Loss of motor encoder reference
- F2175 Loss of optional encoder reference

Monitoring for Spindle Encoders

In the case of spindles, it is mostly high-resolution, external encoders that are used for C-axis operation, in order to obtain the required machining quality for interpolating operation (with low speeds).

In the case of regular spindle operation (high speeds), it is possible that the maximum input frequency of the respective encoder input is exceeded.

☞ For positioning processes, the reference must be reestablished with relative measuring systems, e.g. by means of "C0900 Position spindle command" or by means of "C0600 Drive-controlled homing procedure command".

The external encoder is only required for C-axis operation, but would make regular spindle operation impossible. The encoder monitor can therefore be switched off in this case by the respective value in parameter "P-0-0185, Control word of encoder 2 (optional encoder)".

Determining the maximum frequency of the encoder (encoder output frequency):

$$f_{cut} = \frac{TP \times n_{max}}{60000 \frac{s}{min}}$$

f_{out} Encoder output frequency in kHz

DP Number of lines of encoder per revolution

n_{max} Maximum speed of spindle in 1/min

Fig. 5-37: Calculating the Output Frequency of the Encoder

In the firmware there are, for the different encoder types, maximum frequencies stored up to the values of which troublefree signal evaluation is guaranteed.

Value of P-0-0075	External encoder used	Maximum frequency stored in firmware
2	Incremental encoder with sine signals (signal specification, Heidenhain)	200 kHz
4	Encoder with HIPERFACE® interface from Stegmann	200 kHz
5	Incremental encoder with square-wave signals (signal specification, Heidenhain)	500 kHz
8	Encoders with EnDat2.1 interface from Heidenhain	200 kHz
9	Motor encoder of MSK motors	No limitation

Tab. 5-12: Maximum Frequencies for Troublefree Encoder Evaluation

If the maximum encoder output frequency reaches or exceeds the maximum frequency entered in the firmware, there is neither an error message/reaction nor is a warning output. Only the position data reference is lost.

☞ The maximum frequency stored in the firmware has a "safety distance" to the maximum input frequency of the respective optional input module (see separate documentation "Control Sections for Drive Controllers; Project Planning Manual").

Notes on Commissioning

See also Notes on Commissioning in section "Basics on Measuring Systems, Resolution"

The dialogs are accessible via the "project explorer" of "IndraWorks Ds/D/MLD":

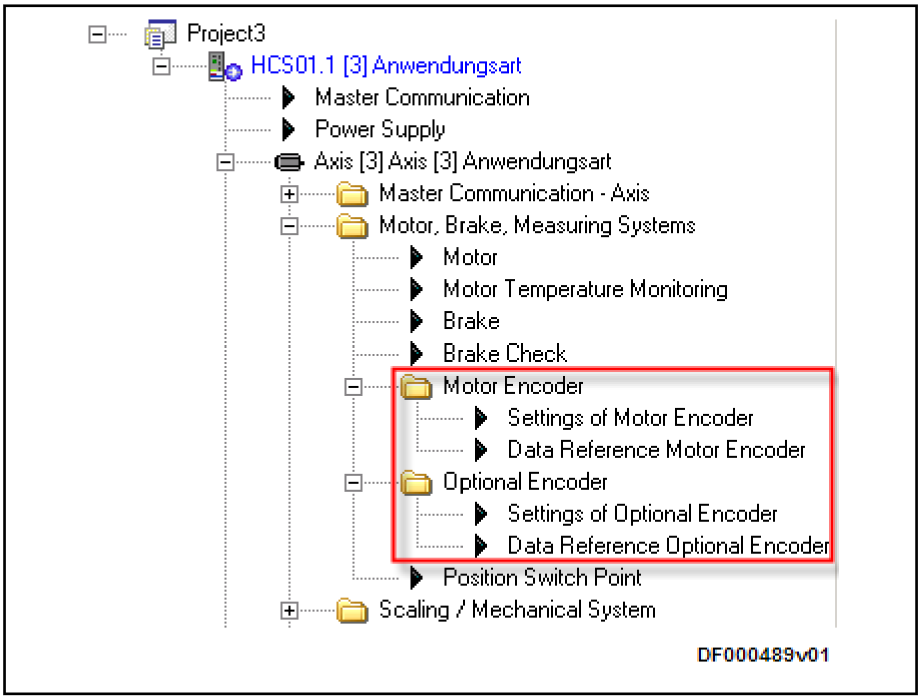


Fig. 5-38: Accessing the Dialogs of Motor Encoder and Optional Encoder in "IndraWorks Ds/D/MLD"

Setting the Axis Position Monitor (Only with Absolute Encoder)

If monitoring the axis position is desired when the drive is switched on, the value for the monitoring window has to be entered:

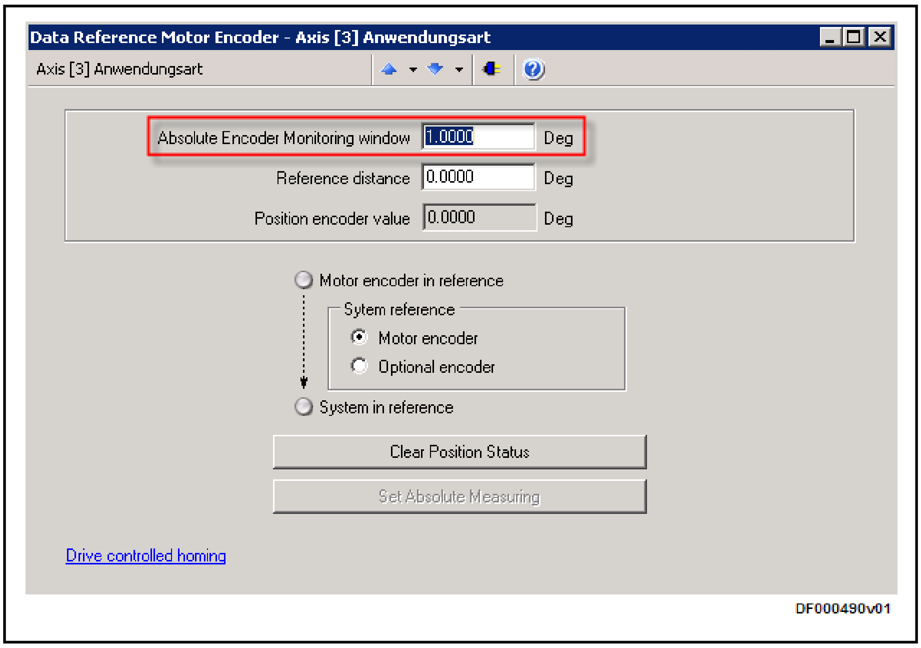


Fig. 5-39: "IndraWorks Ds/D/MLD" Dialog for Absolute Encoder Monitoring of the Motor Encoder

The absolute encoder monitoring can be activated as an alternative or also simultaneously for the external encoder:

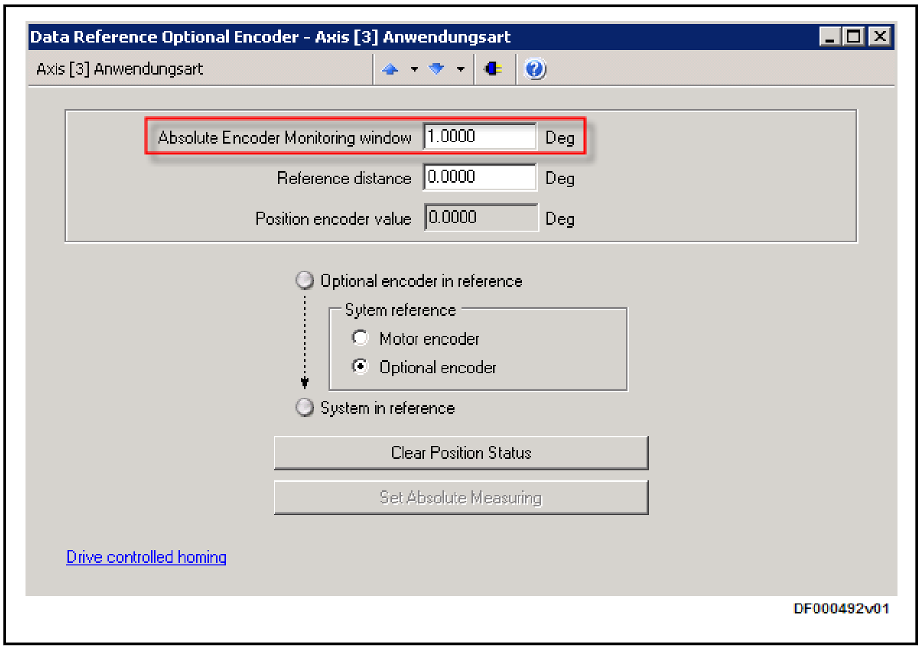


Fig. 5-40: "IndraWorks Ds/D/MLD" Dialog for Absolute Encoder Monitoring of the Optional Encoder

The unit is that of the actual position value. The size of the monitoring window depends on application-specific aspects of operational safety. If this monitoring function is not desired you have to enter the value "0".

- Absolute encoder monitoring window for motor encoder (P-0-0095)
- Absolute encoder monitoring window for opt. encoder (P-0-0096)

Setting the Position Difference Monitor

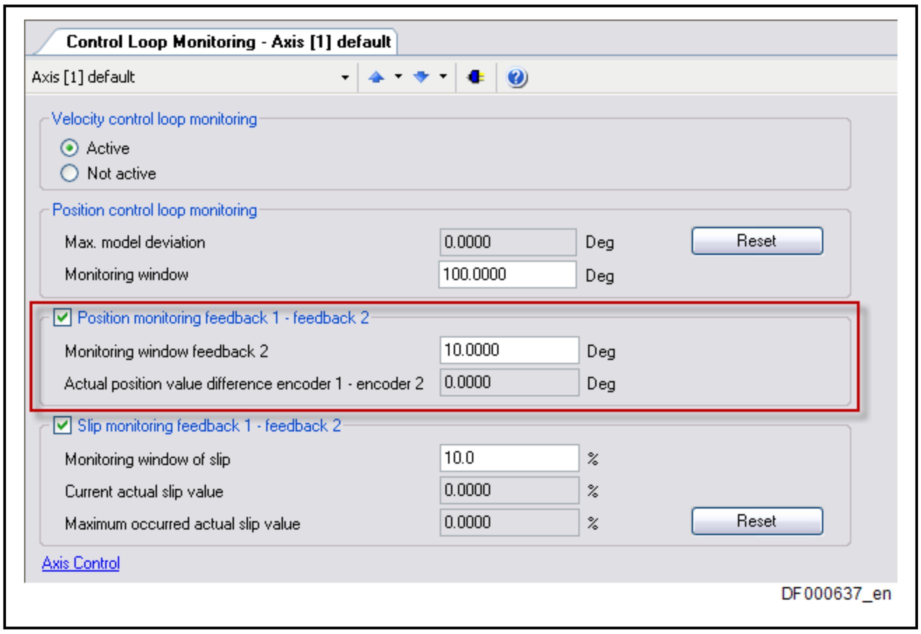


Fig. 5-41: "IndraWorks Ds/D/MLD" Dialog for Position Difference Monitoring of Motor and Optional Encoder with Exemplary Values

If the actual position value difference of motor encoder and external encoder is to be monitored, you first have to determine a useful value for the "Monitoring window encoder position", according to the following procedure:

1. Accelerate the axis to maximum velocity with maximum acceleration, then decelerate it with maximum deceleration. If possible, let the maximum stationary machining load operate on the mechanical axis system.
2. Read the occurred maximum value of the actual position value difference in the display window of " Actual position value difference encoder1 - encoder2" (P-0-0391).
3. Multiply this value with a safety factor (recommended: 2-fold value) and enter it in the "monitoring window encoder position" (S-0-0391, Monitoring window feedback 2). The unit is that of the actual position value.

If this monitoring function is not desired, you have to enter the value "0" in the "monitoring window encoder position".

Setting Slip Monitoring

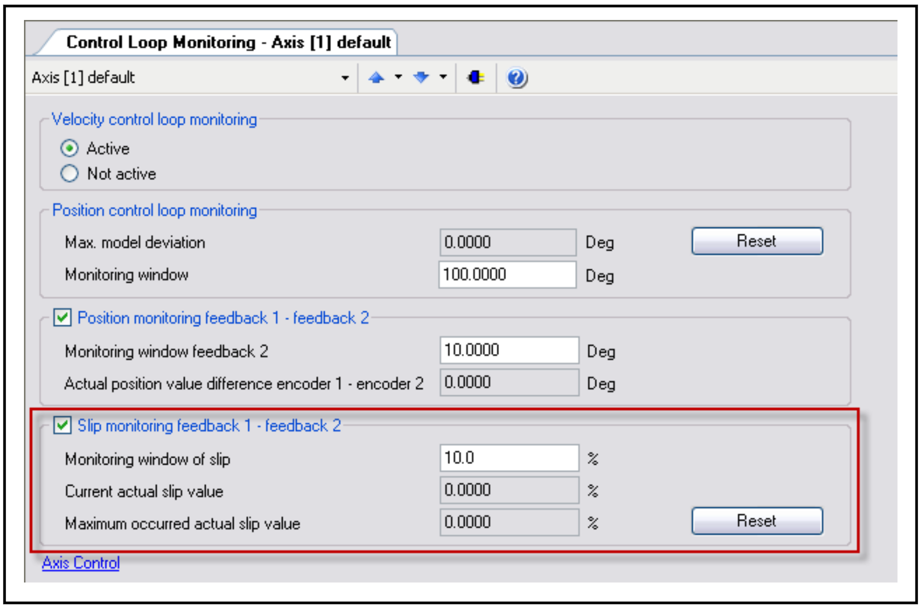


Fig. 5-42: "IndraWorks Ds/D/MLD" Dialog for Slip Monitoring of Motor Encoder and Optional Encoder with Exemplary Values

If the slip occurred between the motor encoder and external encoder is to be monitored, first a useful value for the "monitoring window for slip" has to be defined based on the following procedure:

1. Accelerate the axis to maximum velocity with maximum acceleration, then decelerate it with maximum deceleration. If possible, let the maximum stationary machining load operate on the mechanical axis system.
2. Read the maximum value of the slip in the display window of "Maximum occurred actual slip value" (P-0-0243).
3. Multiply this value with a safety factor (recommended: 2-fold value) and enter it in the "monitoring window for slip" (P-0-0244).

If this monitoring function is not desired, enter the value "0" in the "Monitoring window for slip".

Diagnostic message

If the actual position value difference between the motor encoder and external encoder (P-0-0391) exceeds the value of the monitoring window for encoder 2 (S-0-0391) or if the occurred slip is higher than the value of "Monitoring window for slip in %" (P-0-0244), then the drive generates the error message

- F2036 Excessive position feedback difference.

Configuring the Spindle Encoder

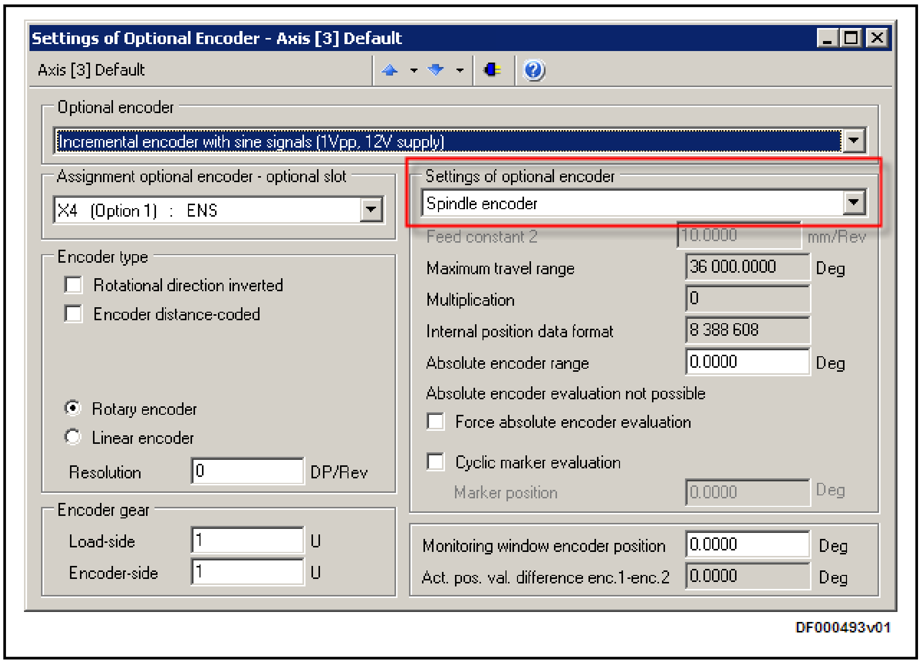


Fig. 5-43: "IndraWorks Ds/D/MLD" Dialog for Configuring the Spindle Encoder

For a spindle encoder (optional encoder for spindle positioning, C-axis encoder), you have to check whether with maximum spindle speed, an error message is generated, because the max. input frequency of the encoder input is exceeded. This error message can be suppressed, if the encoder 2 has been configured as "spindle encoder" (P-0-0185, Control word of encoder 2 (optional encoder)).

If the error message has actually been suppressed, a position data reference of the encoder that might exist is lost as it has not been possible to correctly generate the actual position value of encoder 2. As a precaution, check the behavior and reestablish the position data reference before position-controlled operation modes:

- Establish and check the position data reference for the spindle encoder (see "Establishing the Position Data Reference")
- Accelerate spindle to maximum speed
- Check position data reference of the spindle encoder in "S-0-0403, Position feedback value status"

If, when switching the drive on, the loss of the position data reference of absolute encoders (motor encoder or optional encoder) is detected due to changes in the mechanical parameters, for example, the drive signals

- F2174 Loss of motor encoder reference

\- or -

- F2175 Loss of optional encoder reference.

When temporarily incorrect encoder signals are detected, the drive generates the warning

- E2074 Encoder 1: Encoder signals disturbed

\- or -

- E2075 Encoder 2: Encoder signals disturbed.

The warning remains active until the drive is switched off or switched to communication phase P2!

When incorrect encoder signals are detected the drive generates the error message

- F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)

- or -

- F2042 Encoder 2: Encoder signals incorrect.

When the voltage of the battery of the encoder data memory has fallen below the determined limit value, the drive generates the following error message:

- F2048 Low battery voltage.

See also "Error Reactions"

5.6.3 Absolute Measuring Systems

Brief Description

Evaluating Position Measurement

Depending on their design and the mechanical arrangement at the axis, position encoders can be evaluated by IndraDrive controllers as

- relative encoders (incremental encoders)

or as

- absolute encoders (absolute value encoders)

if they have the required signal specification.

Both Rexroth position encoders and motor encoders of Rexroth housing motors are available in one of the two designs:

- Single-turn encoders (absolute actual position values over one encoder shaft revolution)
- Multi-turn encoders (absolute actual position values over 4096 encoder shaft revolutions).

These encoders can be evaluated as absolute encoders if the travel range of the axis can be represented within the absolute actual position value range of the encoder:

- In the case of single-turn encoders within one encoder shaft revolution
- In the case of multi-turn encoders within 4096 encoder shaft revolutions

Encoders of Rexroth Housing Motors

As a standard, Rexroth housing motors are equipped with a position measurement system. The individual motor series have different measuring systems which allows offering cost-efficient motors depending on the application.

The following measuring systems are supported by this firmware:

- Motor encoder option S1 or M1: HIPERFACE® encoder, single- or multi-turn type
- Motor encoder option S2 or M2: EnDat2.1 encoder, single- or multi-turn type

Absolute Encoders for Kit Motors and External Encoders

For kit motors or directly at the mechanical axis system, the following measuring systems, that can be evaluated in absolute form, can be used:

- EnDat2.1 linear encoder (Heidenhain) or HIPERFACE® linear encoder [Stegmannn, IndraDrive-compatible types (DE_EN_FAQ_IndraDrive_unterstützte_Geber...) or encoders with "FF" type ID] for linear motors or linear axes

- Rotary EnDat2.1 encoder (Heidenhain) or rotary HIPERFACE® [Stegmannn, IndraDrive-compatible types (DE_EN_FAQ_IndraDrive_unterstützte_Geber...) or encoders with "FF" type ID] for rotary kit motors or rotary axes

Establishing Axis-Related Absolute Distance

The actual position values of an absolute encoder first only relate to the encoder itself. Due to the mostly undefined mounting situation of the encoder at the motor or mechanical axis system, it is necessary to determine the position offset between encoder and axis zero point once at the initial commissioning (see also "Establishing the Position Data Reference: Establishing Position Data Reference for Absolute Measuring Systems").

Hardware Requirements

The signal specification of third-party encoders for position and homing signals with regard to amplitude and phase angle can be found in the documentation "Control Sections for Drive Controllers; Project Planning Manual".

> ☞ Rexroth encoders comply with the required signal specification!

Pertinent Parameters

- S-0-0115, Position feedback 2 type
- S-0-0277, Position feedback 1 type
- S-0-0278, Maximum travel range
- S-0-0378, Absolute encoder range of motor encoder
- S-0-0379, Absolute encoder range of optional encoder
- P-0-0019, Initial position value

Functional Description

Absolute Encoder Range and Absolute Encoder Evaluation

Absolute encoders can only display a limited position range in absolute values. For encoders that can be evaluated in absolute form, the drive, depending on the connection of the encoder or the encoders to the axis and on the position data scaling, calculates the travel range of the axis that can be displayed in absolute actual position values.

The following parameters indicate the maximum extent of the travel range that can be selected so that an absolute motor encoder can be evaluated in absolute form:

- S-0-0378, Absolute encoder range of motor encoder
- S-0-0379, Absolute encoder range of optional encoder

On the user side, the travel range of the axis is fixed:

- S-0-0278, Maximum travel range

When the travel range is smaller than the absolute encoder range determined by the drive, the respective control encoder (motor encoder or external encoder; according to the selected operating mode) can be evaluated as an absolute encoder.

This is displayed in the respective bits of the following parameters:

- S-0-0277, Position feedback 1 type
- S-0-0115, Position feedback 2 type

> ☞ If absolute evaluation of an encoder is possible but not desired, the absolute evaluation can be switched off by setting the respective bit in the S-0-0277 or S-0-0115 parameters! The encoder can then only be evaluated in relative form!

Checking the Dimensioning Regarding Absolute Encoder Evaluation

To dimension absolute encoders it is necessary to check by the way of calculation whether the intended travel range of the axis, considering all mechanical transfer elements, can be displayed within the absolute encoder range.

The following condition must be fulfilled:

- Rotary encoders → Travel range of axis requires less encoder revolutions than preset in absolute encoder range!
- Linear encoders → Travel range of axis is smaller than preset in absolute encoder range!

Actual Position Value of Encoders To Be Evaluated in Absolute Form After Switching On

The actual position value of an absolute measuring system must be adjusted to the mechanical axis system once at initial commissioning.

☞ The adjustment is made by determining an actual position value, related to the axis zero point, given a defined axis position (parameter "S-0-0447, C0300 Set absolute position procedure command"). Thereby the offset between the actual position value that first is encoder-related and the required axis-related actual position value is internally determined and permanently stored! The respective encoder then is "in reference".

If only one absolute encoder (motor encoder) is available, there are the following cases to be distinguished for the actual position value after the drive has been switched on:

Absolute evaluation (S-0-0277, bit 6 and 7)	Actual pos. value of motor encoder when switching on (S-0-0051)	Notes on the commissioning status	Current position status (S-0-0403, bit 0 … 2)
Active → Evaluation as absolute measuring system	**Original position** of motor encoder	Initial commissioning not yet carried out, motor encoder not "in reference".	0b … 000
	Absolute value of motor encoder	Initial commissioning was carried out, the motor encoder was set "in reference".	0b … 01x
Inactive → Evaluation as relative measuring system intended	P-0-0019	Initial commissioning not yet carried out, motor encoder is not "in reference".	0b … 000
Not possible → Evaluation as relative measuring system, e.g. due to length of travel range	P-0-0019	Initial commissioning not yet carried out, motor encoder is not "in reference".	0b … 000

P-0-0019 Initial position value (can be defined by user)

Tab. 5-13: Actual Position Value when Switching on a Drive with Absolute Motor Encoder (without Optional Encoder)

At first the actual position value is only encoder-related. If the drive has been equipped, for example, with only one measuring system (motor encoder can be evaluated in absolute form), the controller sets the actual position value to the original encoder position (the original encoder position is the addition of absolute position of the encoder and absolute encoder offset).

In the case of absolute evaluation, the absolute encoder offset 1 or 2 is stored in the encoder (P-0-1002 or P-0-1012). For modulo-scaled, absolute measuring systems, the absolute encoder offset is stored in parameter "P-0-0177, Absolute encoder buffer 1 (motor encoder)" or "P-0-0178, Absolute encoder buffer 2 (optional encoder)".

Initial position value

If the actual position value is to be initialized with an initial position value defined by the user, this can be done via parameter "P-0-0019, Initial position value" in conjunction with bit 6, bit 7 and bit 8 of the corresponding parameter for the type of position encoder.

If the drive, apart from the motor encoder, is equipped with an external encoder and at least one encoder can be evaluated in absolute form, the following actual position values, depending on the reference status of the encoder, are resulting after switching on:

Absolute evaluation		Actual position values when switching on			
Motor encoder (S-0-0277) Bit 8/7/6	External encoder (S-0-0115) Bit 8/7/6	Motor encoder (S-0-0051)	External encoder (S-0-0053)	Notes on the commissioning status	Current position status (S-0-0403)
001 or 100 (active)	001 or 100 (active)	**Original position** of motor encoder	**Original position** of external encoder	Initial commissioning has not been carried out, none of the encoders has "reference".	0b … 000
		Absolute value of motor encoder	Absolute value of motor encoder	During the initial commissioning only the motor encoder was set "reference".	0b … 01x
		Absolute value ext. encoder	Absolute value ext. encoder	During the initial commissioning only the external encoder was set "reference".	0b … 10x
		Absolute value of motor encoder	Absolute value ext. encoder	During the initial commissioning both encoders were set "reference".	0b … 111
001 or 100 (active)	011 (inactive)	**Original position** of motor encoder	**Original position** of motor encoder	Initial commissioning not yet carried out, motor encoder not "reference".	0b … 000
		Absolute value of motor encoder	Absolute value of motor encoder	Initial commissioning was carried out, the motor encoder was set "reference".	0b … 01x
001 or 100 (active)	000 (not possible)	**Original position** of motor encoder	**Original position** of motor encoder	Initial commissioning has not been carried out, none of the encoders has "reference".	0b … 000
		Absolute value of motor encoder	Absolute value of motor encoder	During the initial commissioning only the motor encoder was set "reference".	0b … 10x
011 (inactive)	001 or 100 (active)	**Original position** of external encoder	**Original position** of external encoder	Initial commissioning has not been carried out, none of the encoders has "reference".	0b … 000
		Absolute value ext. encoder	Absolute value ext. encoder	During the initial commissioning the external encoder was set "reference".	0b … 010x

Absolute evaluation		Actual position values when switching on			
Motor encoder (S-0-0277) Bit 8/7/6	External encoder (S-0-0115) Bit 8/7/6	Motor encoder (S-0-0051)	External encoder (S-0-0053)	Notes on the commissioning status	Current position status (S-0-0403)
000 (not possible)	001 or 100 (active)	Original position of external encoder	Original position of external encoder	Initial commissioning has not been carried out, none of the encoders has "reference".	0b … 000
		Absolute value ext. encoder	Absolute value ext. encoder	During the initial commissioning the external encoder was set "reference".	0b … 10x
000 (not possible)	000 (not possible)	P-0-0019	P-0-0019		0b … 000

P-0-0019 Initial position value (can be defined by user)

Tab. 5-14: Actual Position Values when Switching on a Drive with Encoders to be Evaluated in Absolute Form

> The parameter "S-0-0403, Position feedback value status" displays whether the encoders connected to the drive and the reference encoder selected via "S-0-0147, Homing parameter" are in reference.

> After the measuring systems to be evaluated in absolute form were set "in reference" during the initial commissioning of the drive, their actual position values in the operational status of the drive, related to the mechanical system, are always absolute values. This is so, even when the drive is switched off and on again!

Notes on Commissioning

> The Notes on Commissioning for "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems" must be observed, too!

Setting the Travel Range

Enter the travel range of the axis:

- S-0-0278, Maximum travel range

Check the absolute encoder range of the respective control encoder:

- S-0-0378, Absolute encoder range of motor encoder
- S-0-0379, Absolute encoder range of optional encoder

> The travel range and the absolute encoder ranges have the same position reference! They refer, depending on the scaling that was set, to the motor or to the load!

Absolute Encoder Evaluation Possible?

When the travel range is smaller than the absolute encoder range of the control encoder (determined by the active operating mode) the encoder can be evaluated as an absolute encoder. This is also displayed in the respective bits of the following parameters:

- S-0-0277, Position feedback 1 type
- S-0-0115, Position feedback 2 type

By means of these parameters, it is possible to deactivate the absolute evaluation of an encoder. The actual position values then are only relative, i.e. the encoder has to be homed again each time the machine is restarted!

If the absolute encoder range of the control encoder is smaller than the value of S-0-0278, you have to check whether the travel range was correctly input or whether the default value is active!

Setting the Initial Position Value

If desired, it is possible to enter a defined initial position value for the actual position value of the encoder or the encoders in parameter "P-0-0019, Initial position value". For encoders that can be evaluated in absolute form, this value is only active the first time the drive is switched on. After an encoder that can be evaluated in absolute form was set "in reference", this value is insignificant even when the drive is switched on again!

C0220 when Switching on a Third-Party Motor with HIPERFACE® Encoder

For commutation reasons, many motor manufacturers shift the digital absolute track compared to the incremental analog signals with HIPERFACE® encoders. This can cause an initialization error with IndraDrive. This initialization error can be avoided by position initialization without incremental track, to be activated in the position feedback type parameter (S-0-0277, Position feedback 1 type).

5.6.4 Relative Measuring Systems

Brief Description

Evaluating Position Measurement

IndraDrive controllers can evaluate the signals of both absolute and relative measuring systems, if the encoder signals correspond to the specification.

The **disadvantages** of relative encoders as opposed to encoders that can be evaluated in absolute form are as follows:

- Axes with relative position encoder must go through a homing procedure after switching on so that they can be operated in position control.
- Relative encoders are unsuitable as motor encoders for synchronous motors because each time the drive is restarted it has to go through a procedure for setting the commutation offset. Therefore, the immediate readiness for operation is not guaranteed for synchronous motors!

The **advantages** of relative encoders as opposed to encoders that can be evaluated in absolute form are as follows:

- Longer travel distances are possible for linear encoders.
- The costs of the encoder are mostly lower given equal absolute precision and number of lines or division period length.

Aspects of Use

Due to the above disadvantages, relative measuring systems are not used as motor encoders for synchronous Rexroth housing motors. For asynchronous motors there aren't any disadvantages when using relative motor encoders.

For kit motors it can be necessary, however, to use relative encoders as motor encoders if absolute encoders of the required design are not available:

- Great encoder lengths for long travel distances in the case of linear motors
- Hollow-shaft encoders with special drill diameters or encoders for high maximum speeds in the case of rotary kit motors

Establishing Axis-Related Absolute Distance

The actual position values of relative encoders first do not have any position reference. In any axis position the actual position value of the respective relative encoder, when switching the drive on, is written with the so-called initial position value, if no other encoder being in reference has been connected.

There are two ways to establish the axis-related absolute distance:

- Moving to a defined axis position with reproducible precision.

- or -

- Detecting a defined axis position by "passing" two distance-coded reference marks of the encoder.

At a defined position, the actual position value of the encoder to be homed is written with the corresponding absolute value of the axis (see "Establishing the Position Data Reference: Establishing Position Data Reference for Relative Measuring Systems").

Hardware Requirements

The signal specification for position and homing signals with regard to amplitude and phase angle can be found in the documentation "Control Sections for Drive Controllers; Project Planning Manual".

Pertinent Parameters

- S-0-0115, Position feedback 2 type
- S-0-0116, Resolution of feedback 1
- S-0-0117, Resolution of feedback 2
- S-0-0165, Distance-coded reference offset A
- S-0-0166, Distance-coded reference offset B
- S-0-0277, Position feedback 1 type
- S-0-0440, Marker position feedback 1
- S-0-0441, Marker position feedback 2
- S-0-0442, Counter marker position feedback 1
- S-0-0443, Counter marker position feedback 2
- P-0-0019, Initial position value

Functional Description

Initial position value

When the drive is switched on, the actual position values of relative encoders are written with the initial position value (P-0-0019), if none of the encoders is an absolute value encoder that has already been set in reference.

Absolute evaluation possible?		Actual position values when switching on			
Motor Encoder	External encoder	Motor encoder (S-0-0051)	External encoder (S-0-0053)	Notes on the operating status	Current position status (S-0-0403, bit 0..2)
No	No	P-0-0019	P-0-0019	Axis has not moved after switching on, axis has not yet been homed.	0b … 000
		Absolute value of motor encoder	Absolute value of motor encoder	Axis was homed via motor encoder; at the home point, S-0-0053 is set to the value of S-0-0051.	0b … 01x
		Absolute value ext. encoder	Absolute value ext. encoder	Axis was homed via external encoder; at the home point, S-0-0051 is set to the value of S-0-0053.	0b … 10x
		Absolute value of motor encoder	Absolute value ext. encoder	Axis was homed via motor encoder and external encoder.	0b … 111

P-0-0019 Initial position value

Tab. 5-15: Actual Position Values after Switching on Resp. after Homing (Drive with Exclusively Relative Encoders)

> ☞ The parameter "S-0-0403, Position feedback value status" displays whether the encoders connected to the drive and the reference encoder selected via "S-0-0147, Homing parameter" are in reference.

Reference Marks

In order to establish the axis-related absolute distance ("reference"), the controller monitors the signals of the relative encoder or of the axis sensors that contain absolute position information regarding the axis:

- Reference marks of the encoder, if necessary in combination with home point switch of the axis
- Distance-coded reference marks of the encoder
- Home point switch of the axis

The controller is told via the parameters "S-0-0277, Position feedback 1 type" and "S-0-0115, Position feedback 2 type" which homing signals the connected measuring system makes available.

Reference Marks, Not Distance-Coded

During the homing procedure, the controller automatically detects the reference mark if its signal corresponds to the specification and the reference mark is to be evaluated to establish the reference (see "Establishing the Position Data Reference: Establishing Position Data Reference for Relative Measuring Systems").

If a relative encoder has several reference marks over the travel distance, a reference mark is to be identified by means of a home point switch at the axis for establishing the position reference (see "Establishing the Position Data Reference: Establishing Position Data Reference for Relative Measuring Systems").

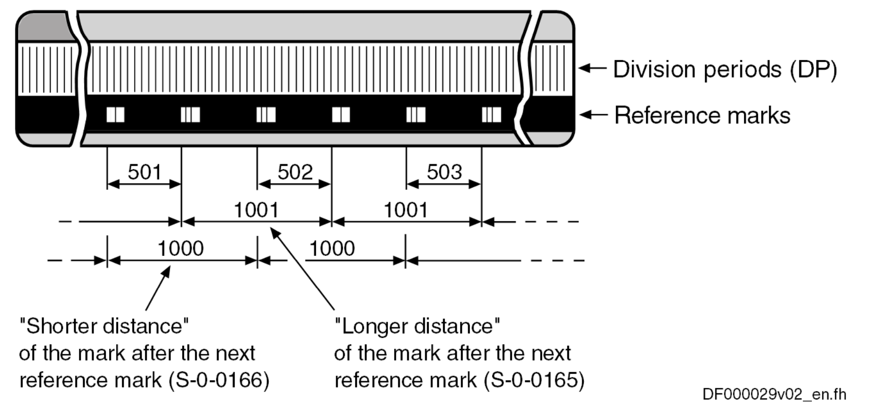
Cyclic Marker Evaluation

In the position feedback type 1 (S-0-0115, bit 9 = "1", cyclic marker evaluation active) or position feedback type 2 (S-0-0277, bit 9 = "1", cyclic marker evaluation active), the marker evaluation for the motor encoder or for the external encoder can be enabled. After the marker has been detected, the calculated position value is entered in the parameter "S-0-0440, Marker position feedback 1" or in the parameter "S-0-0441, Marker position feedback 2". To detect overflow during marker transmission, the counter "S-0-0442, Counter marker position feedback 1" or the counter "S-0-0443, Counter marker position feedback 2" is incremented with every error-free marker. Therefore, the control unit can make sure to process two successive marker positions, even in the case of telegram failure.

> ☞ For the firmware of the MPE-16 variant, the cyclic marker evaluation can only be enabled for motor encoders.

Distance-Coded Reference Marks

In the case of relative encoders with distance-coded reference marks, several reference marks are distributed in equal distances over the entire travel distance. There is a "shorter distance" and a "longer distance" between one reference mark and the mark after the next. The values of these two distances are available to the controller in the parameters "S-0-0165, Distance-coded reference offset A" and "S-0-0166, Distance-coded reference offset B".



S-0-0165 Distance-coded reference offset A
S-0-0166 Distance-coded reference offset B

Fig. 5-44: Reference Mark Distances in the Case of a Distance-Coded Linear Encoder with a Distance Difference of 1 DP

☞ The values for "distance-coded reference distance A" and "distance-coded reference distance B" have to be indicated by the manufacturer!

Determining the "Distance-Coded Reference Distance A"

If the value of "distance-coded reference offset A" is not directly given in the data sheet of the distance-coded encoder, the value can also be determined by means of calculation if the travel distance for establishing the absolute position data reference is given in the data sheet of the encoder:

Linear Encoders

General $$\text{S-0-0165} = \frac{x_{ref} + n \times DP}{DP}$$

Motor encoder $$\text{S-0-0165} = \frac{x_{ref} + n \times (\text{S-0-0116})}{(\text{S-0-0116})}$$

External encoder $$\text{S-0-0165} = \frac{x_{ref} + n \times (\text{S-0-0117})}{(\text{S-0-0117})}$$

S-0-0165 Distance-coded reference offset A (in number of DP)
x_{ref} Travel distance for establishing the absolute position data reference (in mm)
n Number of DP of the distance difference (longer-shorter distance)
DP Division period of the relative linear encoder (in mm)
S-0-0116 Feedback 1 resolution (division period in mm)
S-0-0117 Feedback 2 resolution (division period in mm)

Fig. 5-45: Determining the Value for the "Longer Distance" of the Distance-Coded Reference Marks with a Relative Linear Encoder

Rotary Encoders

$$\text{General} \quad \text{S-0-0165} = \frac{N_{zyk} \times \varphi_{ref}}{360°} + z$$

$$\text{Motor encoder} \quad \text{S-0-0165} = \frac{(\text{S-0-0116}) \times \varphi_{ref}}{360°} + z$$

$$\text{External encoder} \quad \text{S-0-0165} = \frac{(\text{S-0-0117}) \times \varphi_{ref}}{360°} + z$$

S-0-0165	Distance-coded reference offset A (in number of cycles)
N_{cyc}	Number of cycles of the rotary encoder (per 360°)
φ_{ref}	Travel angle for establishing the absolute position data reference (in degrees)
z	Number of cycles of the distance difference (longer-shorter distance)
S-0-0116	Feedback 1 resolution (per 360°)
S-0-0117	Feedback 2 resolution (per 360°)

Fig. 5-46: Determining the Value for the "Longer Distance" of the Distance-Coded Reference Marks with a Relative Rotary Encoder

Determining the "Distance-Coded Reference Distance B"

If the value of "distance-coded reference offset B" is not directly given in the data sheet of the distance-coded encoder, the value can only be determined by means of calculation if the distance difference (longer distance – shorter distance) is given in the data sheet of the encoder:

Linear Encoders

$$\text{General} \quad \text{S-0-0166} = \frac{x_{ref}}{DP}$$

$$\text{Motor encoder} \quad \text{S-0-0166} = \frac{x_{ref}}{(\text{S-0-0116})}$$

$$\text{External encoder} \quad \text{S-0-0166} = \frac{x_{ref}}{(\text{S-0-0117})}$$

S-0-0166	Distance-coded reference offset B (in number of DP)
x_{ref}	Travel distance for establishing the absolute position data reference (in mm)
DP	Division period of the relative linear encoder (in mm)
S-0-0116	Feedback 1 resolution (division period in mm)
S-0-0117	Feedback 2 resolution (division period in mm)

Fig. 5-47: Determining the Value for the "Shorter Distance" of the Distance-Coded Reference Marks with a Relative Linear Encoder

Rotary Encoders

General $$S\text{-}0\text{-}0166 = \frac{N_{cyc} \times \varphi_{ref}}{360°}$$

Motor encoder $$S\text{-}0\text{-}0166 = \frac{(S\text{-}0\text{-}0116) \times \varphi_{ref}}{360°}$$

External encoder $$S\text{-}0\text{-}0166 = \frac{(S\text{-}0\text{-}0117) \times \varphi_{ref}}{360°}$$

S-0-0166	Distance-coded reference offset B (in number of cycles)
N_{cyc}	Number of cycles of the rotary encoder (per 360°)
φ_{ref}	Travel angle for establishing the absolute position data reference (in degrees)
S-0-0116	Feedback 1 resolution (per 360°)
S-0-0117	Feedback 2 resolution (per 360°)

Fig. 5-48: Determining the Value for the "Shorter Distance" of the Distance-Coded Reference Marks with a Relative Rotary Encoder

Notes on Commissioning

☞ The Notes on Commissioning in the sections "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems" must be observed, too!

Setting the Initial Position Value

If the actual position value of relative encoders is not to be written with the default value "0" when the drive is switched on, "P-0-0019, Initial position value" has to be changed to have the desired value.

In the Case of Distance-Coded Measuring System

If the relative encoder possesses distance-coded reference marks, the controller is informed on this by the respective bit in the following parameters:

- S-0-0277, Position feedback 1 type
- S-0-0115, Position feedback 2 type

The value for the "longer distance" of the distance-coded reference marks has to be entered in parameter "S-0-0165, Distance-coded reference offset A".

The value for the "shorter distance" of the distance-coded reference marks has to be entered in parameter "S-0-0166, Distance-coded reference offset B".

5.6.5 Digital Encoders and Combined Encoders

Brief Description

Fields of Application

Digital encoders provide absolute position information within the absolute measuring range of the respective encoder. The signal transmission is serial. The main field of application of serial encoders in the electric drive technology is the position control loop; the advantage of the absolute position information outweighs the possible disadvantage of greater time intervals required to make actual values available due to the serial transmission of the absolute position. In many applications, particularly with master-side cycle times in the range of milliseconds, the quality of the actual position values made available by serial encoders is perfectly sufficient.

For high quality motor control, the encoders that function serially are only suitable in certain cases because the provided position information must be as up-to-date as possible, i.e. it must be provided as quickly as possible.

For synchronous motors, however, the absolute serial encoder information is advantageous, because it allows the drive controller to unequivocally determine the commutation angle for motor control when the drive is switched on again. Therefore, the combination of a serial encoder with an incremental measuring system with analog encoder tracks (e.g. 1 Vpp) is the cost-efficient solution for an absolute measuring system (e.g. "combined encoder for SSI") for motor control, which uses standardized components. In this case, the absolute value of the SSI encoder is used for the commutation angle, the analog signals (e.g. sine encoder, 1 Vpp) are used for motor control.

SSI encoders cannot be evaluated as measuring encoders!

Features

The encoder signals are evaluated in accordance with an innovative encoder evaluation concept. This concept includes two levels for making available the actual position values of the encoder to be evaluated:

- Interface-related actual values of the encoder without function-related scaling or conversion. The index of the corresponding parameters (after the first point of the IDN) is the number of the device interface ("Basic evaluation").
- Function-related actual values, e.g. for motor control, such as motor velocity, actual position values of the motor shaft taking a possibly available encoder gearbox etc. into account. The corresponding parameters correspond to the parameters previously used, like for example "S-0-0040, Velocity feedback value", "S-0-0051, Position feedback value 1" etc. ("Extended evaluation").

Hardware Requirements

Both the serial encoder and the combined encoder require only one encoder interface at the device ["EC" for interface 1 (X4) or interface 2 (X8)]. It is possible to evaluate encoders with DC5V and DC12V supply.

Pertinent Parameters

Physical encoder data (for Basic evaluation)

IDN	Name
S-0-0602.x.01	Phys. Encoder type
S-0-0602.x.02	Phys. Encoder properties
S-0-0602.x.03	Phys. Encoder resolution (incremental)
S-0-0602.x.04	Phys. Encoder resolution (absolute)

IDN	Name
S-0-0602.x.07	Phys. Encoder protocol configuration
The wild card "x" (structure index) is the number of the device interface to which the encoder is connected: • 1: X4 (single-axis device), X4.1 (double-axis and multi-axis device) • 2: X8 (single-axis device), X4.2 (double-axis and multi-axis device) • 3: X10 (single-axis device), X8.1 (double-axis device), X4.3 (multi-axis device) • 4: X4.4 (multi-axis device) • 5: X8 (multi-axis device) • 6: X8.2 (double-axis device)	

Parameters of encoder evaluation on Basic level

IDN	Name
S-0-0600.x.20	Encoder data out container
S-0-0601.x.01	Encoder data out configuration
S-0-0601.x.02	Resolution of position
S-0-0601.x.06	Absolute position range
S-0-0601.x.08	Command value set position
S-0-0601.x.09	Position zero point offset
S-0-0601.x.10	Overflow threshold position
S-0-0601.x.11	Encoder available data out
S-0-0601.x.12	Encoder refresh time data out
The wild card "x" (structure index) is the number of the device interface to which the encoder is connected: • 1: X4 (single-axis device), X4.1 (double-axis and multi-axis device) • 2: X8 (single-axis device), X4.2 (double-axis and multi-axis device) • 3: X10 (single-axis device), X8.1 (double-axis device), X4.3 (multi-axis device) • 4: X4.4 (multi-axis device) • 5: X8 (multi-axis device) • 6: X8.2 (double-axis device)	

Parameters for Extended encoder evaluation

IDN	Name
S-0-0610.x.2	Position unscaled (input)
S-0-0610.x.20	Encoder data out container (input)
S-0-0611.x.01	Encoder data out configuration (input)
S-0-0611.x.02	Resolution position (input)
S-0-0611.x.06	Absolute position range (input)
S-0-0611.x.10	Overflow threshold position (input)
S-0-0611.x.11	Encoder available data out (input)

IDN	Name
S-0-0611.x.12	Encoder refresh time data out (input)
The number of the function is assigned to the wild card "x" (structure index) (motor encoder: "0"; optional encoder: "1")	

Functional Description

Basic-Extended Encoder Evaluation

Digital encoder evaluation is performed based on a new process with which in the future encoders can be evaluated simultaneously by several drives. With sercos master communication, the pieces of information immediately made available by the encoder are available on the master communication level and therefore are available to each drive in the sercos ring for evaluation.

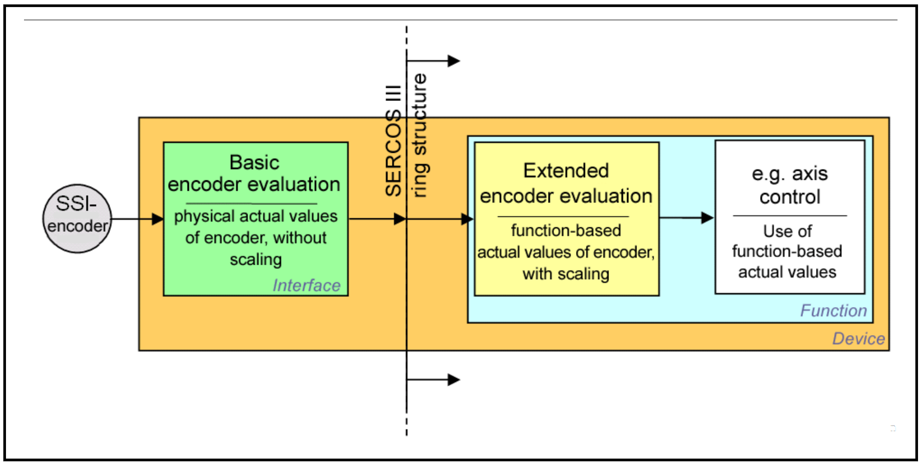


Fig. 5-49: Principle of Encoder Evaluation Based on sercos, as an Example of an SSI Encoder Connected to a Device Interface

"Basic" Encoder Evaluation

"Basic" encoder evaluation provides the following data with regard to the connected encoder:

- Physical actual position, encoder-based

☞ No separate parameter is used for this value, it is contained in "S-0-0600.x.20, Encoder data out container"!

- Position resolution
- Encoder status, error codes
- Absolute encoder range, overflow threshold for position values
- Cycle time for encoder output data

The "basic" encoder evaluation must be informed of the physical data of the connected encoder:

- Encoder Type
- Encoder properties, like rotary encoder or linear encoder
- Encoder resolution
- Possible distance-coded reference dimension A and B
- Possible transmission protocol configuration of encoder actual values

"Extended" Encoder Evaluation

"Extended" encoder evaluation reads the output data of the "basic" encoder evaluation and makes it available with the required scalings to the axis control, for example:

- Motor or load reference
- Rotary or linear scaling (mapping of motor - load mechanical transmission)
- SI units or others

"Extended" encoder evaluation can access every encoder the "basic" output data of which are made available via sercos.

EnDat 2.2

An EnDat 2.2 encoder transmits absolute position information serially in digital format. It is characterized by the following data:

- Position data range of values for rotary encoders: maximum 31 bits (including error and test bits), single-turn range up to 31 bits, multi-turn range up to 15 bits (the number of position bits results as the sum of the multi-turn bits and the number of bits for encoder resolution/revolution)
- Position data range of values for linear encoders: maximum 31 bits (including error and test bits)
- Resolution of linear encoders: mm/bit
- Resolution of rotary encoders: Increments/revolution
- Coding: Binary code
- Error bit (power fail etc.)
- Test bits (parity etc.)
- Data transfer frequency (Baud rate)

☞ The maximum number of position bits is 31. This value is reduced by the total number of error and test bits possibly made available by the encoder.

Basic level and also extended evaluation parameters are used to parameterize the EnDat 2.2 encoder. The corresponding basic and extended parameters are automatically written simultaneously, if possible. Parameterization is supported by dialogs in IndraWorks.

The EnDat 2.2 encoder data is entered into different parameters:

- S-0-0602.x.01, Phys. Encoder type
- S-0-0602.x.02, Phys. Encoder properties
- S-0-0602.x.04, Phys. Encoder resolution (absolute)
- S-0-0602.x.07, Phys. Encoder protocol configuration

  In this parameter, characteristic properties of the encoder are saved on the manufacturer-side. They are read-only:

  – Baud rate (125 KHz to 8MHz)
  – Coding
  – Position bit
  – Different turns (Multiturn range)
  – Status Bits
  – Checkbits

The time offset between the recording of actual position data and the availability for drive control due to the serial transmission of data via the EnDat2.2 format is sufficiently small.

SSI Encoder

An SSI encoder transmits absolute position information serially in digital format. It is characterized by the following data:

- Position data range of values for linear encoders: maximum 31 bits (including error and test bits)
- Position data range of values for rotary encoders: maximum 31 bits (including error and test bits), single-turn range up to 31 bits, multi-turn range up to 15 bits (the number of position bits results as the sum of the multi-turn bits and the number of bits for encoder resolution/revolution).
- Resolution of linear encoders: mm/bit
- Resolution of rotary encoders: Increments/revolution
- Coding: Binary or Gray code
- Error bit (power fail etc.)
- Test bits (parity etc.)
- Data transmission frequency

☞ The maximum number of position bits is 31. This value is reduced by the total number of error and test bits possibly made available by the encoder.

Basic level and also extended evaluation parameters are used to parameterize the SSI encoder. The corresponding basic and extended parameters are automatically written simultaneously, if possible. Parameterization is supported by dialogs in IndraWorks.

The SSI encoder data is entered into different parameters:

- S-0-0602.x.01, Phys. Encoder type
- S-0-0602.x.02, Phys. Encoder properties
- S-0-0602.x.04, Phys. Encoder resolution (absolute)
- S-0-0602.x.07, Phys. Encoder protocol configuration

There is time displacement between the recording of actual position data and their availability for drive control due to the serial transmission of the position data. An SSI encoder is not suitable for motor control.

SSI Combined Encoder

With SSI combined encoders, the absolute actual position value is digitally transmitted in an SSI format during encoder initialization, position evaluation is performed following initialization by two analog sinusoidal encoder tracks (1 Vpp signals). This makes time-synchronized recording of actual position values possible, as the actual position value can be displayed in absolute form by the absolute value of encoder initialization.

The same applies to the parameterization of the SSI combined encoder as did to the SSI encoder, there is however a further entry for the incremental track:

- S-0-0602.x.01, Phys. Encoder type
- S-0-0602.x.02, Phys. Encoder properties
- S-0-0602.x.03, Phys. Encoder resolution (incremental)

- S-0-0602.x.04, Phys. Encoder resolution (absolute)
- S-0-0602.x.07, Phys. Encoder protocol configuration

For the SSI combined encoder, both encoder components have to be connected via a connector:

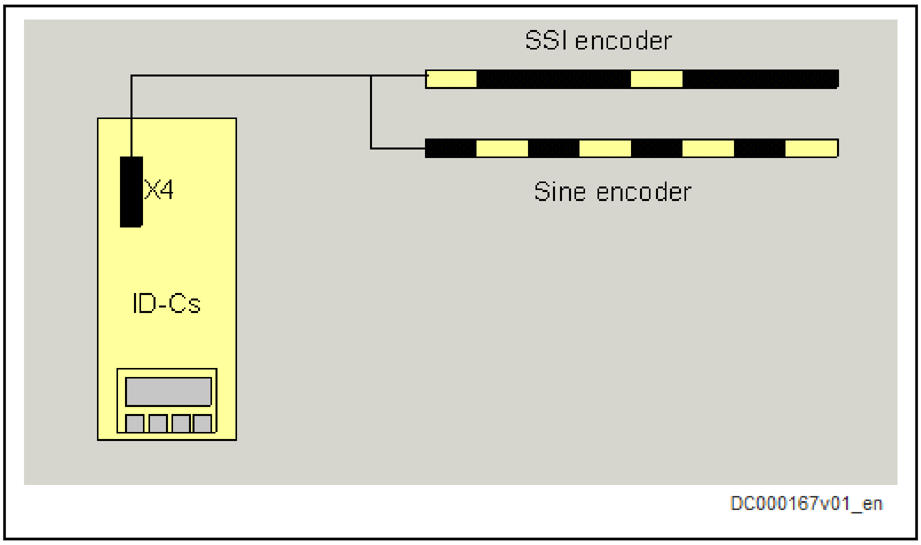


Fig. 5-50: Connection of an SSI combined encoder, for example at interface X4

Notes on Commissioning

EnDat 2.2

EnDat2.2 encoders are parameterized in dialog "Motor encoder" or "Optional Encoder" from IndraWorks as "sercos encoder (digital)". The slot used for encoder connection must be selected under "Optional slot". It is not necessary to make any entries in the dialog window "Position encoder type", the position resolution is automatically determined and entered by the controller through the change from PM to OM or bb, Ab.

Settings can however be made in the dialog window "Absolute encoder evaluation" and where necessary "Use" (for optional encoder only). The actual configuration of the EnDat2.2 combined encoder takes place in a subdialog opened with the "Configuration" button.

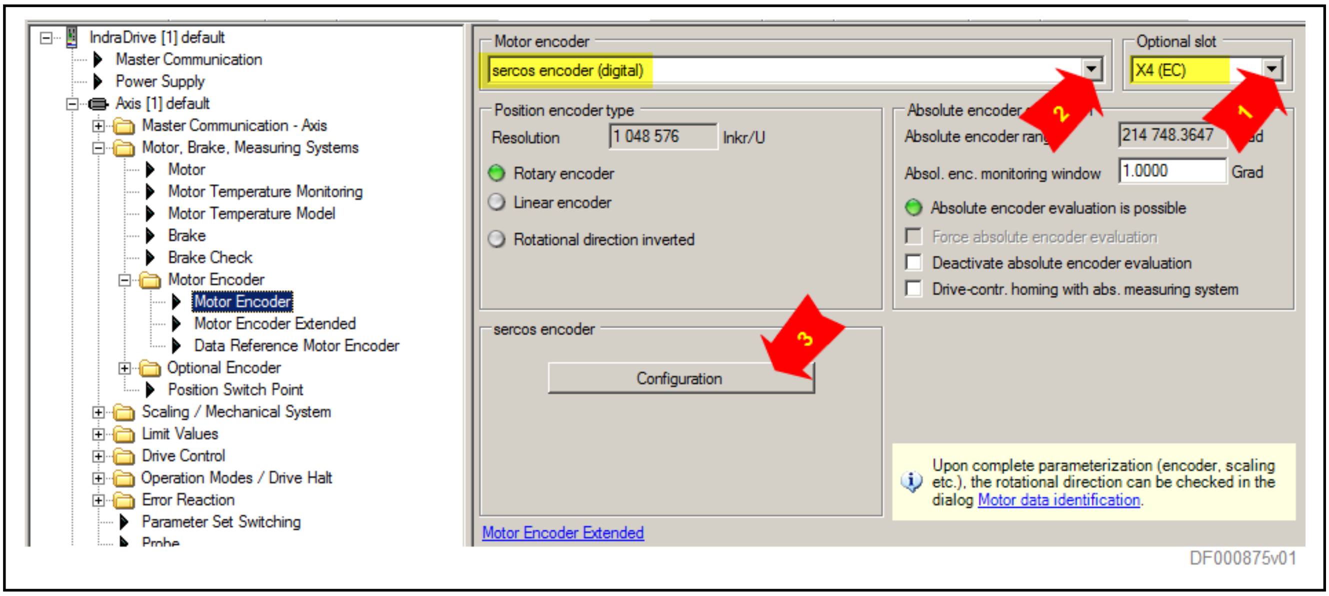


Fig. 5-51: IndraWorks dialog for parameterization of a EnDat2.2 encoder (example as a motor encoder)

The EnDat2.2 encoder is selected in the sub-dialog "Physical Encoder Data" (tab):

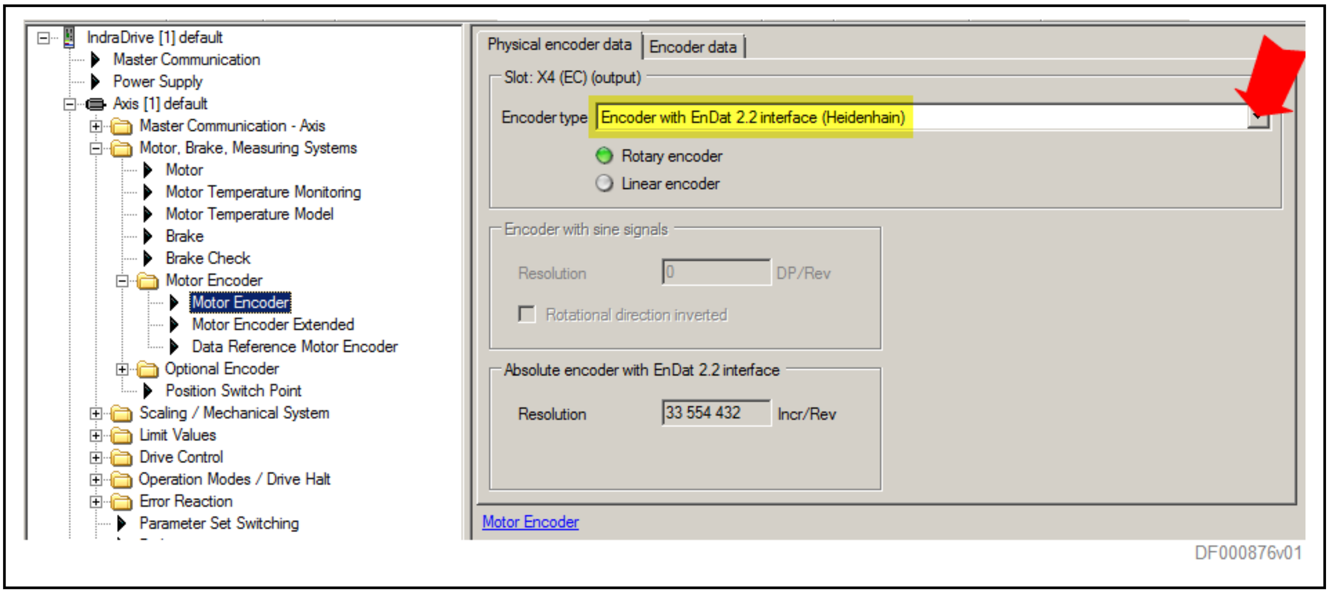


Fig. 5-52: IndraWorks dialog for selecting a EnDat2.2 encoder

It is the encoder type connected to the slot (here: EnDat2.2) from the drop-down menu and it offers other supported encoder types for the selection.

The encoder data memory of the EnDat2.2 encoder delivers all encoder-specific required information to the controller, including the mechanical execution of the encoder.

The "Encoder Data" tab page only shows the properties of the encoder and the data which take effect in drive control.

SSI Encoder

SSI encoders are parameterized as sercos encoders (digital) in the "Optional Encoder" dialog of IndraWorks. The slot used for encoder connection must be selected under "Optional slot". It is not necessary to make any entries in the dialog window "Position encoder type", the position resolution is automatically determined and entered by the controller through the change from PM to OM or bb, Ab.

In the dialog windows "Absolute encoder evaluation" and "Usage", however, settings can be made. The actual configuration of the SSI combined encoder takes place in a subdialog opened with the "Configuration" button.

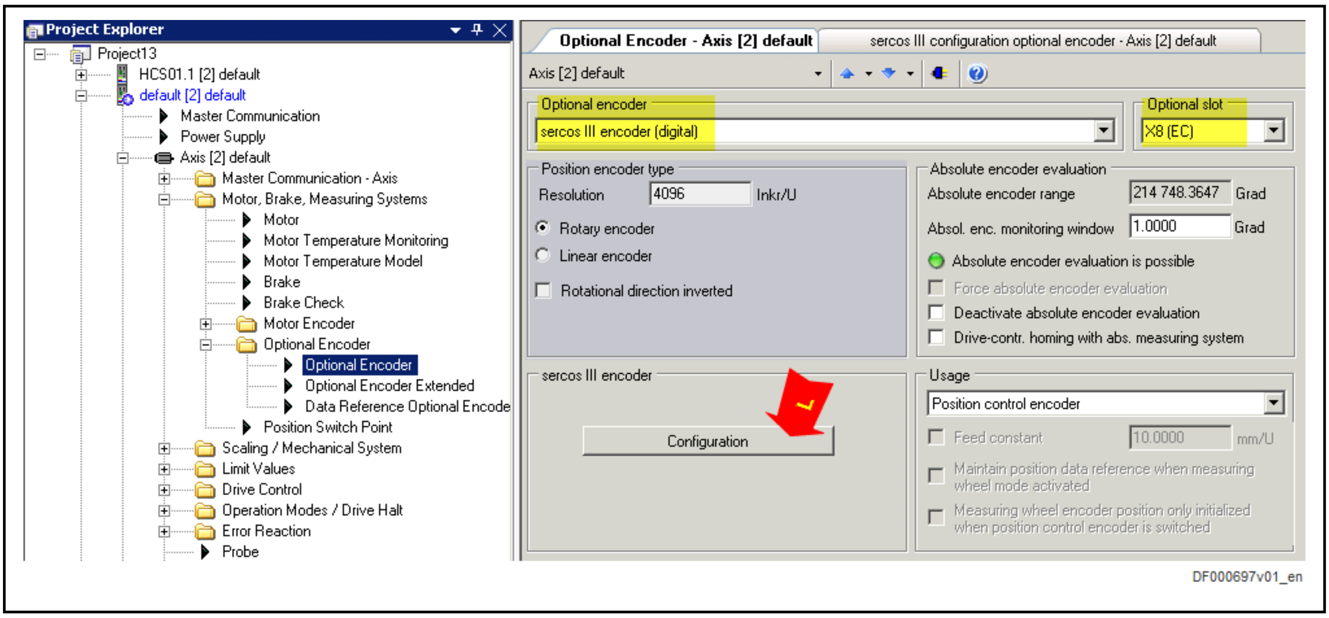


Fig. 5-53: IndraWorks Dialog for Parameterizing an SSI Encoder (only Possible as Optional Encoder)

The SSI combined encoder is configured in the "Physical encoder data" subdialog:

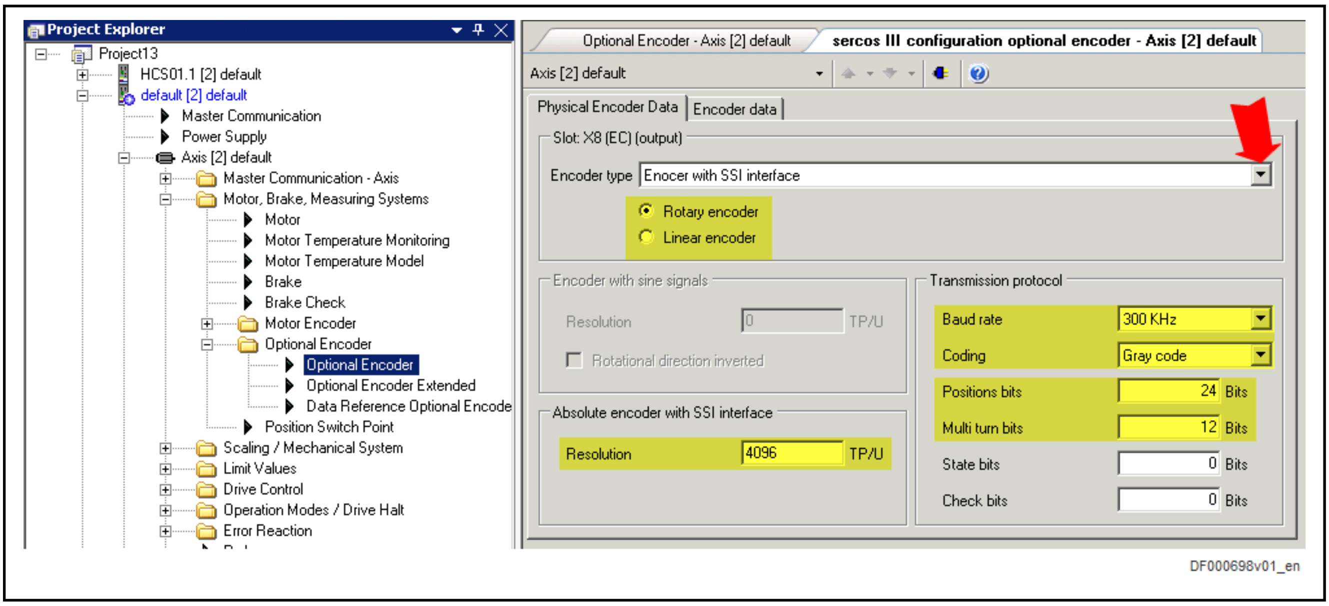


Fig. 5-54: IndraWorks Dialog for Entering the Physical Encoder Data of the SSI Encoder

From the drop-down menu, select the encoder type connected at the slot; where applicable, the menu provides a selection of supported encoder types. The mechanical design must be selected in rotary or linear form.

From the encoder data sheet or the type plate label, further data must be taken and entered:

- Quantity of position information per encoder revolution for the absolute encoder resolution of the SSI interface
- Type of coding of the absolute actual SSI position values, as well as the number of multi-turn bits

---

☞ Multi-turn bits are only possible with rotary encoders!

The number of position bits results as the sum of the multi-turn bits and the number of bits for the encoder resolution/revolution (12 bits in the example: 4096/rev. = 2^{12}/rev.).

☞ The maximum number of position bits is 31. This value is reduced by the total number of state and check bits possibly made available by the encoder.

The baud rate is the transmission velocity of the digital absolute position information. It can be set in four steps: 100 kHz, 200 kHz, 300 kHz and 400 kHz. It is basically preferable to select the highest possible baud rate so that the pieces of position information are transmitted with the shortest delay. Lower baud rates can be necessary for error-free transmission of the position data, in the case of long cables, for example.

When changing from PM to OM or bb, Ab, the controller determines the position resolution.

The "Encode data" tab page only shows the properties of the encoder and the data which take effect in drive control.

SSI Combined Encoder

SSI combined encoder (1 Vss and SSI) are parameterized in IndraWorks in the dialog "Motor encoder" or "Optional encoder" as "sercos encoder (digital)". The encoder can be connected to the optional slot X4(EC) or X8(EC). It is not necessary to make any entries in the dialog window "Position encoder type", the position resolution is automatically determined and entered by the controller through the change from PM to OM or bb, Ab.

In the dialog window "Absolute encoder evaluation", however, settings can be made. The actual configuration of the SSI combined encoder takes place in a subdialog opened with the "Configuration" button.

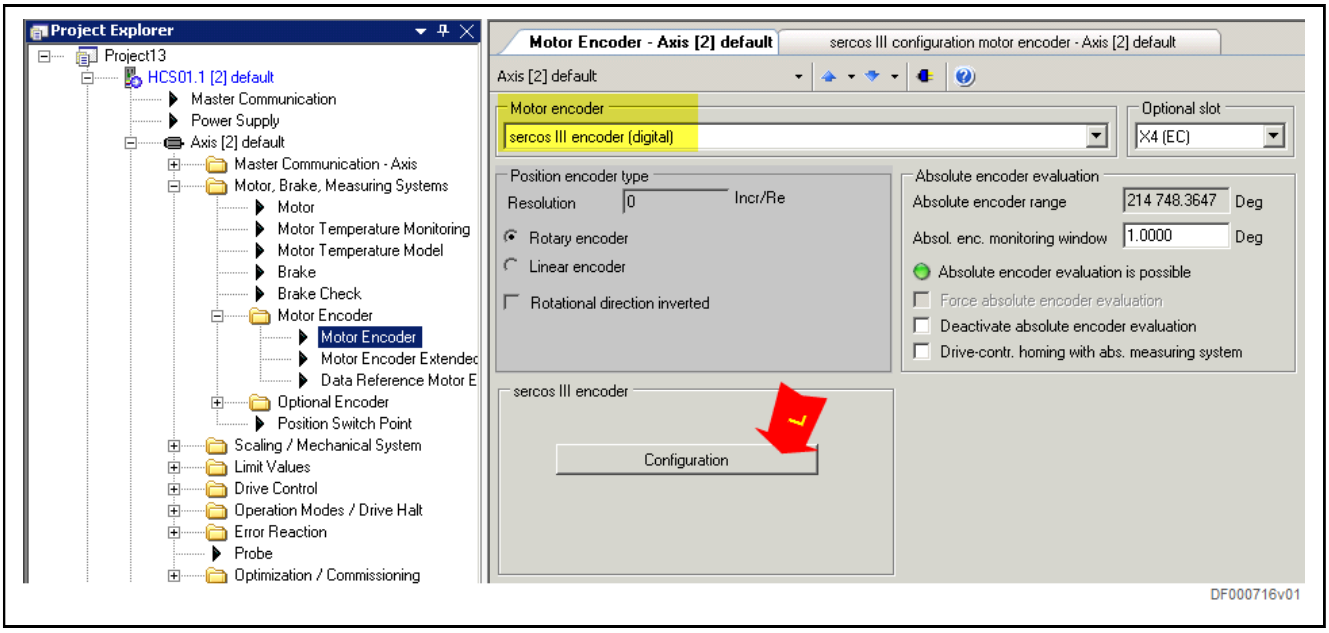


Fig. 5-55: IndraWorks Motor Encoder Dialog, Procedure for Parameterizing an SSI Combined Encoder

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☞ The SSI combined encoder can be used as a motor encoder and an optional encoder.

The SSI combined encoder is configured in the subdialog "Physical encoder data":

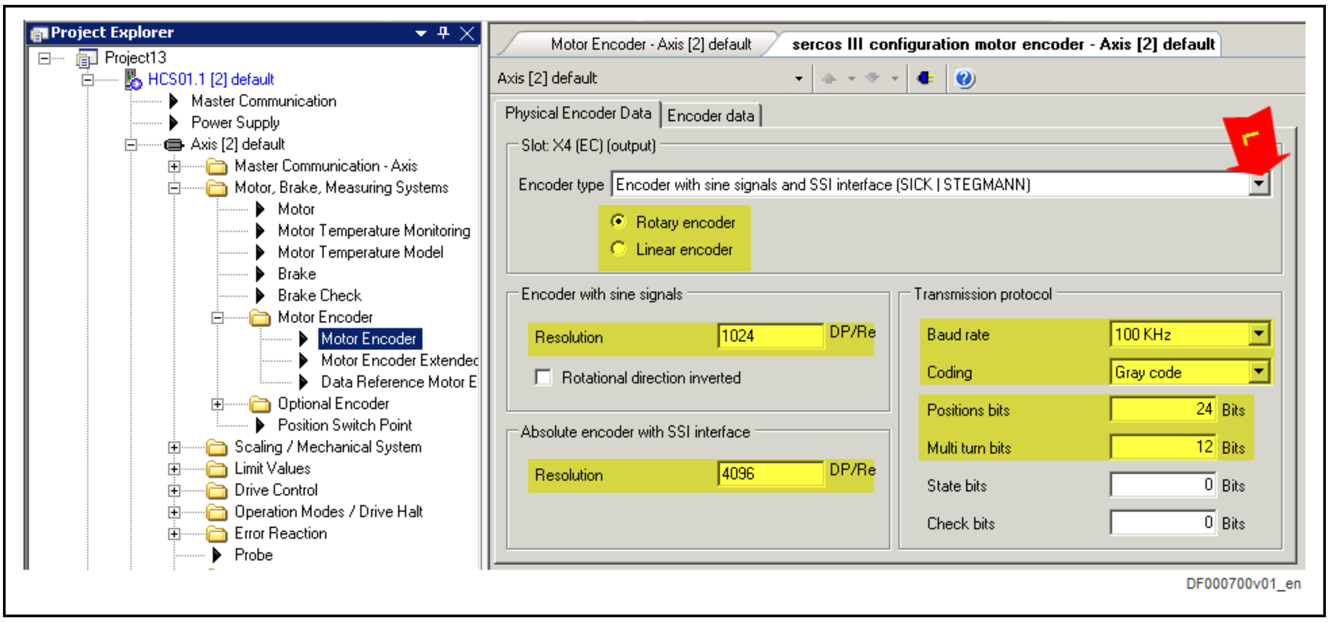


Fig. 5-56: Entering the Physical Encoder Data and the Transmission Protocol

From the drop-down menu, select the encoder type connected at the slot; the menu provides a selection of supported encoder types. The mechanical design must be selected in rotary or linear form.

From the encoder data sheet or the type plate label, further data must be taken and entered:

- Number of 1 Vpp sine or cosine signals per encoder revolution

- Quantity of position information per encoder revolution for the absolute encoder resolution of the SSI interface
- Type of coding of the absolute actual SSI position values, as well as the number of multi-turn bits

---

☞ Multi-turn bits are only possible with rotary encoders!

The number of position bits results as the sum of the multi-turn bits and the number of bits for the encoder resolution/revolution (12 bits in the example: 4096/rev. = 2^{12}/rev.).

☞ The maximum number of position bits is 31. This value is reduced by the total number of state and check bits possibly made available by the encoder.

The baud rate is the transmission velocity of the digital absolute position information. It can be set in four steps: 100 kHz, 200 kHz, 300 kHz and 400 kHz. It is basically preferable to select the highest possible baud rate so that the pieces of position information are transmitted with the shortest delay. Lower baud rates can be necessary for error-free transmission of the position data, in the case of long cables, for example.

The position resolution is to be entered via the parameterization editor in "S-0-0601.0.2, Resolution of position". When changing from PM to OM or bb, Ab, the controller checks the entered value.

Position Resolution with a Rotary Encoder

When the position resolution entered for a rotary encoder is higher than the resolution the controller can display, it is reduced to the maximum possible value. To determine the highest possible resolution, an excessively high value must be entered in the corresponding parameter before changing from PM to OM.

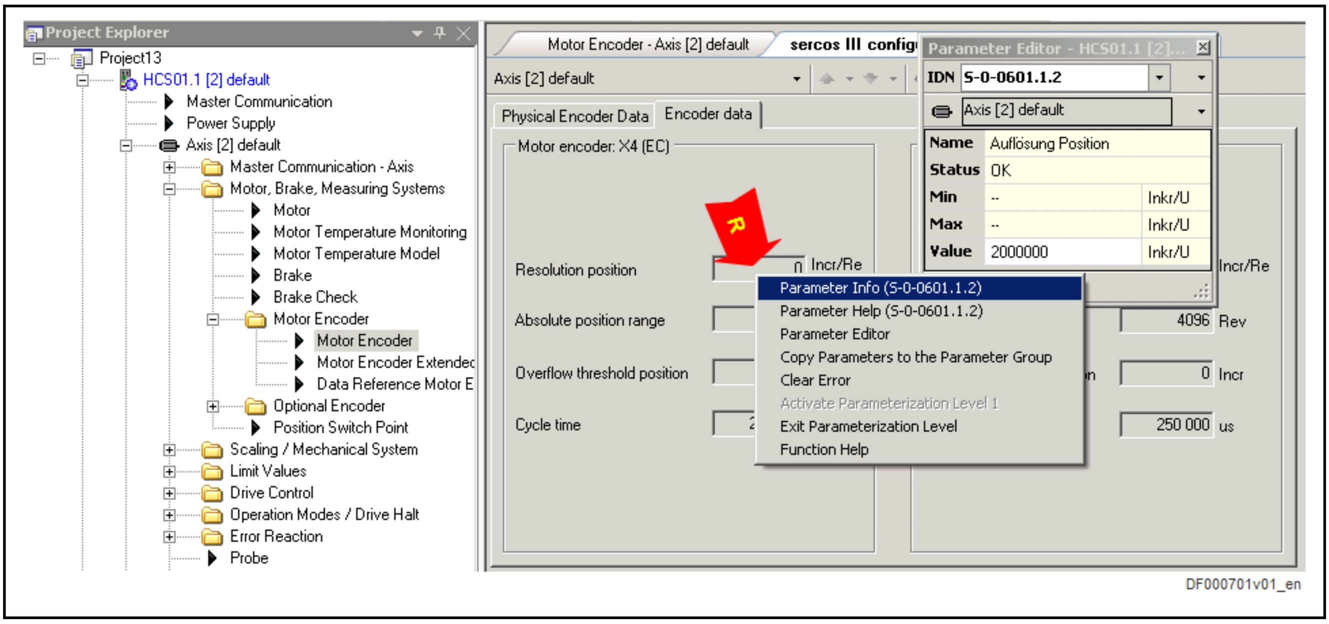


Fig. 5-57: Entering an Excessively High Position Resolution with Rotary Encoder, Calling the Parameter by Right-Clicking the Display Field

☞ If exactly the same value as the one entered before is displayed, you can increase the resolution. To obtain the maximum resolution, increase the input value until the value determined by changing from PM to OM is lower!

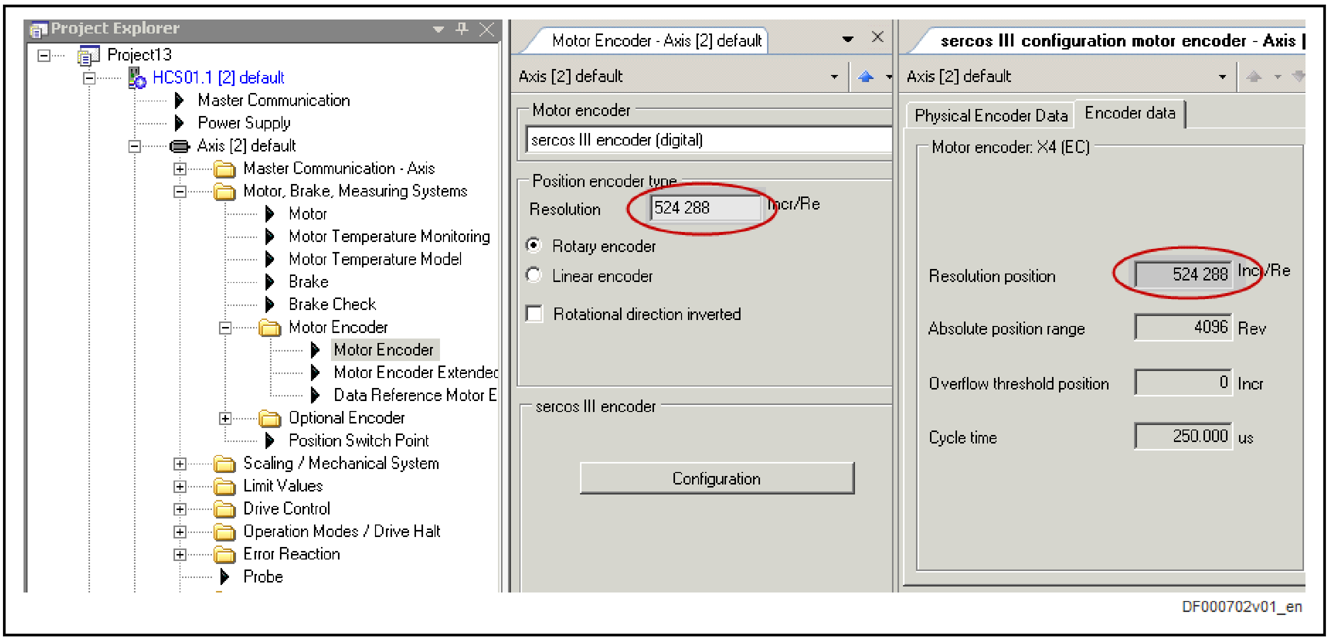


Fig. 5-58: Displaying the Determined Resolution in "bb" or "Ab" in the Motor Encoder Dialog and in the Encoder Data Tab Page

Position Resolution with a Linear Encoder

When the position resolution entered for a linear encoder is lower than the resolution the controller can display, it is increased to the minimum possible value. Hereby, the highest resolution is set [in nanometers (nm)/increment].

☞ The most convenient thing to do with a linear encoder is to enter the value "0" in the corresponding parameter before changing from PM to OM!

5.6.6 Establishing the Position Data Reference

General Information on Establishing the Position Data Reference

Brief Description

During the initial commissioning of a drive the actual position values transmitted by the measuring systems do not yet have any reference to the machine axis. This applies to

- Relative measuring systems and
- Absolute measuring systems

For more detailed information on relative and absolute evaluation of measuring systems, see "Absolute Measuring Systems"

Relative Measuring Systems

The position data reference of a relative measuring system to the axis has to be reestablished after each time the drive is switched on or after the position data reference is lost. For this purpose, it is necessary to move to a defined axis position and set the actual position value to an axis-related value at a defined position (exception: For relative encoders with distance-coded reference marks, movement is only required over two marks!)

Absolute Measuring Systems

The position data reference of an absolute measuring system to the axis has to be established once during initial commissioning after replacing the motor or encoder (motor encoder or external encoder) and changes in the mechanical axis system. The position data reference still is maintained and the actual position values are axis-related immediately after the drive is switched on.

Establishing the Position Data Reference, Drive-Controlled

For establishing the position data reference in a drive-controlled way, the position data reference is automatically established by the drive by master-side triggering of a command. The procedure depends on the kind of measuring system:

- In the case of a relative measuring system without distance-coded reference marks, the axis moves to the reference point or to a dedicated point and then automatically switches to axis-related actual position values.
- In the case of a relative measuring system with distance-coded reference marks, the axis moves between two reference marks and then automatically switches to axis-related actual position values.
- In the case of an absolute measuring system, the automatic switching to the axis-related actual position value is carried out with the axis in standstill.

The presettings for establishing the position data reference are made via assigned parameters.

Establishing the Position Data Reference, NC-Controlled

For establishing the position data reference in an NC-controlled way, the drive makes available three commands to the master. The master has to generate the travel motion for searching the mark:

- The master starts the "NC-controlled homing" command and, for searching the reference point or dedicated point, must move the axis by inputting command values.
- To calculate the offset and switch to axis-related actual position values it is necessary to start further commands.

The presettings for establishing the position data reference are made via assigned parameters.

Displaying the Position Data Reference

A position status parameter shows whether the position data reference of a measuring system evaluated by the controller has been established.

Motor Encoder and External Encoders

In addition to the motor encoder an external (optional) encoder can be available. Both encoders, in any combination of relative and absolute measuring systems, can

- have position data reference to the axis independently of each other (both encoders have different actual position values)

- or -

- have position data reference to the axis depending on each other (both encoders have the same actual position values).

This is configured via parameters and realized with the commands for establishing the position data reference.

Actual Position Value Offset

The difference of the actual position value before and after establishing the position data reference is displayed, related to the motor encoder or external encoder, in one parameter respectively.

See also the following sections:

- "Establishing Position Data Reference for Absolute Measuring Systems"
- "Establishing Position Data Reference for Relative Measuring Systems"

Pertinent Parameters

- S-0-0115, Position feedback 2 type
- S-0-0175, Offset parameter 1
- S-0-0176, Offset parameter 2
- S-0-0277, Position feedback 1 type
- S-0-0403, Position feedback value status
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0075, Encoder type 2 (optional encoder)

Functional Description

Supported Encoder Types

IndraDrive controllers can evaluate a multitude of typical position encoders on the market. The encoder types that can be evaluated are listed in the descriptions of the following parameters (see documentation "Parameter Description"):

- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0075, Encoder type 2 (optional encoder)

Procedures for Establishing the Position Data Reference

The type of encoder and the travel range that has been set (S-0-0278) determine whether absolute evaluation is possible for this encoder. This is displayed by the respective bits of the following parameters:

- S-0-0277, Position feedback 1 type
- S-0-0115, Position feedback 2 type

Depending on relative or absolute evaluation of the motor encoder or external encoder, the controller makes available different procedures for establishing the position data reference:

- "Set absolute position" for encoders to be evaluated in absolute form
- "Drive-controlled homing procedure" for relative encoders
- "NC-controlled homing procedure" for relative encoders

> After having successfully established the position data reference, the actual position value of the respective encoder refers to the axis. The encoder then is "in reference" or has been "homed".

See also "Absolute Measuring Systems" and "Relative Measuring Systems"

State Check of Position Data Reference

The current state of the position data reference of motor encoder and external encoder is displayed in parameter "S-0-0403, Position feedback value status" via the respective bits. They can be mapped to the drive status word (S-0-0135) by means of assignment. This enables the master to check the validity of the position data in every communication cycle!

> The following applies to masters which check the validity of the actual position values via bit 0 of S-0-0403:
>
> - The "encoder selection" in "S-0-0147, Homing parameter" determines the encoder of which the value of the respective position status bit is mapped to bit 0 of S-0-0403!

Position Data Reference with Motor Encoder and External Encoder

If an external encoder is connected to the controller in addition to the motor encoder, there are the following possibilities for establishing the position data reference, independent of the evaluation (relative/absolute) of the encoder:

- The position data reference was only established for one of the two encoders. The actual position value of the other, non-homed encoder is set to the value of the homed encoder.

- The position data reference was established for both encoders. The actual position value of each encoder is an individual value that can be identical, but does not need to be identical.

Encoder evaluation		Current position status	Actual position values when switching on		
Motor Encoder	External encoder	(S-0-0403, bit ..2,1,0)	Motor encoder (S-0-0051)	External encoder (S-0-0053)	Notes on the commissioning status
Relative/ absolute	Relative/ absolute	0b … 01x	Absolute value of motor encoder	Absolute value of motor encoder	Position data reference only established for motor encoder.
Relative/ absolute	Relative/ absolute	0b … 10x	Absolute value ext. encoder	Absolute value ext. encoder	Position data reference only established for external encoder.
Relative/ absolute	Relative/ absolute	0b … 11x	Absolute value of motor encoder	Absolute value ext. encoder	Position data reference established for motor encoder and external encoder.
Relative/ absolute	Relative/ absolute	0b … 000	See also "Absolute Measuring Systems" or "Relative Measuring Systems"		Position data reference was established neither for motor encoder nor for external encoder.

Tab. 5-16: Actual Position Values after Establishing the Position Data Reference for Motor Encoder and External Encoder

Actual Position Value Offset Before/After Establishing Position Data Reference

When the position data reference was established for an encoder there mostly is a step change of the actual position value. The difference between the new and the old actual position value is displayed in the following parameters:

- S-0-0175, Offset parameter 1
- S-0-0176, Offset parameter 2 (external encoder)

The respective values are written to the offset parameters each time the position data reference is established. After the drive was switched on the value, however, is undefined, even if the position data reference has already been established!

Notes on Commissioning

Checking the Possibility of Absolute Encoder Evaluation

The possibility of absolute evaluation of motor encoder or external encoder is displayed by the respective bits of the following parameters:

- S-0-0277, Position feedback 1 type (motor encoder)
- S-0-0115, Position feedback 2 type (external encoder)

Checking whether Position Data Reference was Established

The position status of motor encoder and external encoder is displayed in:

- S-0-0403, Position feedback value status

If required by the master, the position status of one of the two encoders can be mapped to bit 0 of S-0-0403. This is done by setting the bit for encoder selection in "S-0-0147, Homing parameter".

☞ If

- on the master side the validity of the actual position values is checked via bit 0 of S-0-0403

and

- motor encoder and external encoder have been homed,

the encoder selection in S-0-0147, in the position-controlled modes, should also be changed accordingly when changing the position encoder.

Actual Position Value Offset

The change in the actual position value by establishing the position data reference is displayed in the following parameters:

- S-0-0175, Offset parameter 1 (motor encoder)
- S-0-0176, Offset parameter 2 (external encoder)

Mapping the Position Reference Bits to the Drive Status Word

The respective bits of parameter "S-0-0403, Position feedback value status" can be assigned to the real-time status bits of "S-0-0135, Drive status word", if required.

Clearing the Position Data Reference

By activating the parameter "S-0-0191, C1500 Cancel reference point procedure command", it is possible to clear the position data reference of the encoder selected via bit 3 of "S-0-0147, Homing parameter". The respective bits of parameter "S-0-0403, Position feedback value status" are thereby reset (cleared), too.

Establishing Position Data Reference for Absolute Measuring Systems

Brief Description

Base package of all variants in **closed-loop** characteristic.

See also the section "General Information on Establishing the Position Data Reference"

The position data reference of an absolute measuring system to the axis has to be established once during initial commissioning, after replacing the motor or encoder (motor encoder or external encoder) and changes in the mechanical axis system.

Establishing Position Data Reference via Drive Commands

In the case of measuring systems to be evaluated in absolute form, the position data reference can be automatically established by the drive by starting the command

- "C0300 Set absolute position procedure command"

- or -

- "C0600 Drive-controlled homing procedure command".

The position data reference once established is maintained until one of the two commands is started again. The actual position values therefore are axis-related ("homed") immediately after the drive is switched on.

Motor Encoder and External Encoder

If two absolute measuring systems have been connected to the controller, the position data reference can be separately established for both measuring systems. If the position data reference was only set for one of the measuring systems, both actual position values are equal at the position at which the position data reference was established.

☞ If the position data reference was only set for one encoder, the actual position values of both encoders remain equal as long as mechanical axis system and encoder systems are mechanically connected without slip (slip control is possible!).

"Set Absolute Position" Command

It is recommended to start the "set absolute position" command when the axis is in standstill without drive enable. In the cases in which the axis, for establishing the position data reference, is to be brought to a defined position on the master side and be held in this position by the drive, "set absolute position" can also be executed with the active drive.

"Drive-Controlled Homing Procedure" Command

When the command "C0600 Drive-controlled homing procedure command" is started without an existing reference, the drive moves the axis independently as defined in parameter "S-0-0147, Homing parameter" and establishes the position data reference. If the drive's position system already has a reference when the command "C0600 Drive-controlled homing procedure command" is started, the reference point already determined is approached and the commanded is acknowledged positively.

For absolute encoders, the "drive-controlled homing procedure" command can be advantageously used after loss of position data reference after:

- Encoder replacement in conjunction with a home switch or
- Encoder error with peripheral causes in the case of modulo-scaled axes (e.g. encoder cable damage).

☞ "Active drive" means the drive that is in control. Drive enable (AF) has been set.

Assigning the Axis-Related Actual Position Value with "Set Absolute Position"

By starting the "set absolute position" command, the previous actual position value of an encoder at a dedicated position of the axis is set to a new value. This value is the current axis position related to the coordinate system of the machine.

The dedicated position is defined by:

- the current axis position

- or -

- the positioning of the axis at a "striking" axis position (e.g. value "0").

The required assignments and configurations for "setting absolute position" are made via parameter settings.

Assigning the Axis-Related Actual Position Value with "Drive-Controlled Homing Procedure"

By starting the "drive-controlled homing procedure" command, the previous actual position value of an encoder at a dedicated position of the axis is set to a new value. This value is the current axis position related to the coordinate system of the machine.

The required assignments and configurations for the "drive-controlled homing procedure" are made using parameter settings (see the information regarding "Drive-Controlled Homing Procedure" in the section "Establishing Position Data Reference for Relative Measuring Systems").

Pertinent Parameters

- S-0-0052, Reference distance 1
- S-0-0054, Reference distance 2
- S-0-0148, C0600 Drive-controlled homing procedure command
- S-0-0447, C0300 Set absolute position procedure command
- S-0-0448, Set absolute position control
- P-0-0177, Absolute encoder buffer 1 (motor encoder)
- P-0-0178, Absolute encoder buffer 2 (optional encoder)

- P-0-1002, Absolute encoder offset 1, encoder memory
- P-0-1012, Absolute encoder offset 2, encoder memory

Pertinent Diagnostic Messages

- C0300 Set absolute position procedure command
- C0301 Measuring system unavailable
- C0302 Absolute evaluation of measuring system impossible
- C0303 Absolute encoder offset cannot be saved
- C0304 Command cannot be executed under drive enable
- C0600 Drive-controlled homing procedure command
- C0601 Homing only possible with drive enable
- C0602 Distance home switch - reference mark erroneous
- C0603 Homing impossible with optional encoder
- C0606 Reference mark not detected
- C0607 Reference cam input not assigned
- C0608 Pos. stop a. HW lim. switch not allowed f. modulo axes
- C0609 Different travel directions parameterized
- C0610 Absolute encoder offset could not be saved

Functional Description

"Drive-Controlled Homing Procedure" Command with Absolute Measuring Systems

Application-Related Aspect

The "drive-controlled homing procedure" command is mainly used for homing relative measuring systems. The position data reference of a relative encoder must be reestablished each time the drive is switched on again (or when changing from communication phase "P2" to "bb" or "Ab" or when changing from PM to OM).

☞ The "drive-controlled homing procedure" function is described in section "Establishing Position Data Reference for Relative Measuring Systems".

In the case of absolute measuring systems, the position data reference to the axis only has to be established once during initial commissioning (or after encoder replacement or encoder error, for example).

If "S-0-0148, C0600 Drive-controlled homing procedure command" is to be used for homing an absolute measuring system, the corresponding bit must have been set in parameter "S-0-0448, Set absolute position control".

Absolute Offset

When "C0600 Drive-controlled homing procedure command" was successfully completed, it had been possible to determine an absolute offset value. This value is used for calculation together with the encoder-side absolute values, stored in the encoder and the reference bit is set in parameter "S-0-0403, Position feedback value status". The position data reference has now been established and the actual position value is valid. This, too, applies immediately each time after the drive has been switched on again.

"Set Absolute Position" Command

Dedicated Position

By starting the "C0300 Set absolute position procedure" command, the previous actual position value of an encoder at a dedicated position of the axis is set to a new value. The dedicated position corresponds to the current axis position at the start of the command.

The new actual position value at the dedicated position after "set absolute position" is the value of parameter

- "S-0-0052, Reference distance 1" (for motor encoder)

- or -

- S-0-0054, Reference distance 2 (for external encoder).

Motor encoder	$S\text{-}0\text{-}0051_{new}$	=	S-0-0052
External encoder	$S\text{-}0\text{-}0053_{new}$	=	S-0-0054

S-0-0051 Position feedback value 1
S-0-0052 Reference distance 1
S-0-0053 Position feedback value 2
S-0-0054 Reference distance 2

Fig. 5-59: Actual Position Values after "Set Absolute Position"

Selecting the Absolute Encoder to be Homed

If several encoders to be evaluated in absolute form are connected to the controller, it is possible to select, via "S-0-0448, Set absolute position control", the encoder for which the "set absolute position procedure" command is to take effect.

Storing the Absolute Encoder Offset

In order that an encoder to be evaluated in absolute form maintains the position data reference to the axis after "set absolute position", the absolute encoder offset is stored in the encoder data memory (P-0-1002/P-0-1012) and in the parameter memory (P-0-0177/P-0-0178).

☞ Storing the absolute encoder offset in the encoder data memory and in the parameter memory allows recognizing whether the absolute encoder that was homed was replaced!

Possible Operating States before "Set Absolute Position"

The "C0300 set absolute position procedure" command can be activated in the following operating states:

- Drive is ready for operation, but not active ("OM", "bb", "AB")
- Drive is active in position control ("AF")
- Drive is active and in "Drive Halt" ("AH")

☞ For the last two cases, if the drive is active, bit 2 "set absolute position upon drive enable (AF)" of parameter "S-0-0448, Set absolute position control" has to be set.

Sequence of "Set Absolute Position" with Inactive Drive ("OM", "bb", "AB") or in "Drive Halt (AH)"

When the "C0300 Set absolute position procedure" command is started, the reference of the selected encoder is cleared first (S-0-0403).

After the reference was cleared, the new actual position value (S-0-0051/ S-0-0053), with inactive drive ("OM", "bb" or "AB") and with drive in "Drive Halt (AH)", is set according to the preselected dedicated position (see formula "Actual Position Values After "Set Absolute Position")". The new position reference takes immediate effect.

Sequence of "Set Absolute Position" with Drive Enable ("AF")

When the "C0300 Set absolute position procedure" command is started, the reference of the selected encoder is cleared first (S-0-0403).

After the reference was cleared, there are the following possibilities, with active drive, regarding the switching of the actual position value to the new position reference:

- Deactivating drive enable

→ When the drive goes to the inactive state, the new actual position value (S-0-0051/S-0-0053) is set according to the preselected dedicated position (see formula ""Dedicated Position" on page 285").

- Starting the "drive-controlled homing procedure" command

  → The drive no longer follows the command values. The new position command value (S-0-0051/S-0-0053) is set (see formula ""Dedicated Position" on page 285") and the "drive-controlled homing procedure" command is signaled by the drive to have been executed. The master now has to "synchronize" to the new actual position value of the encoder used in the active operation mode. After the master cleared the "drive-controlled homing procedure" command, the drive returns to master-controlled operation.

Sequence of "Set Absolute Position" after Established Position Reference

When the "C0300 Set absolute position procedure" command is started, the reference of the selected encoder is cleared first (S-0-0403).

When the new position reference of the selected encoder has been established, the reference of the respective encoder is displayed in "S-0-0403, Position feedback value status" and the absolute encoder offset is stored. Finally, the "set absolute position" command has to be cleared by the master!

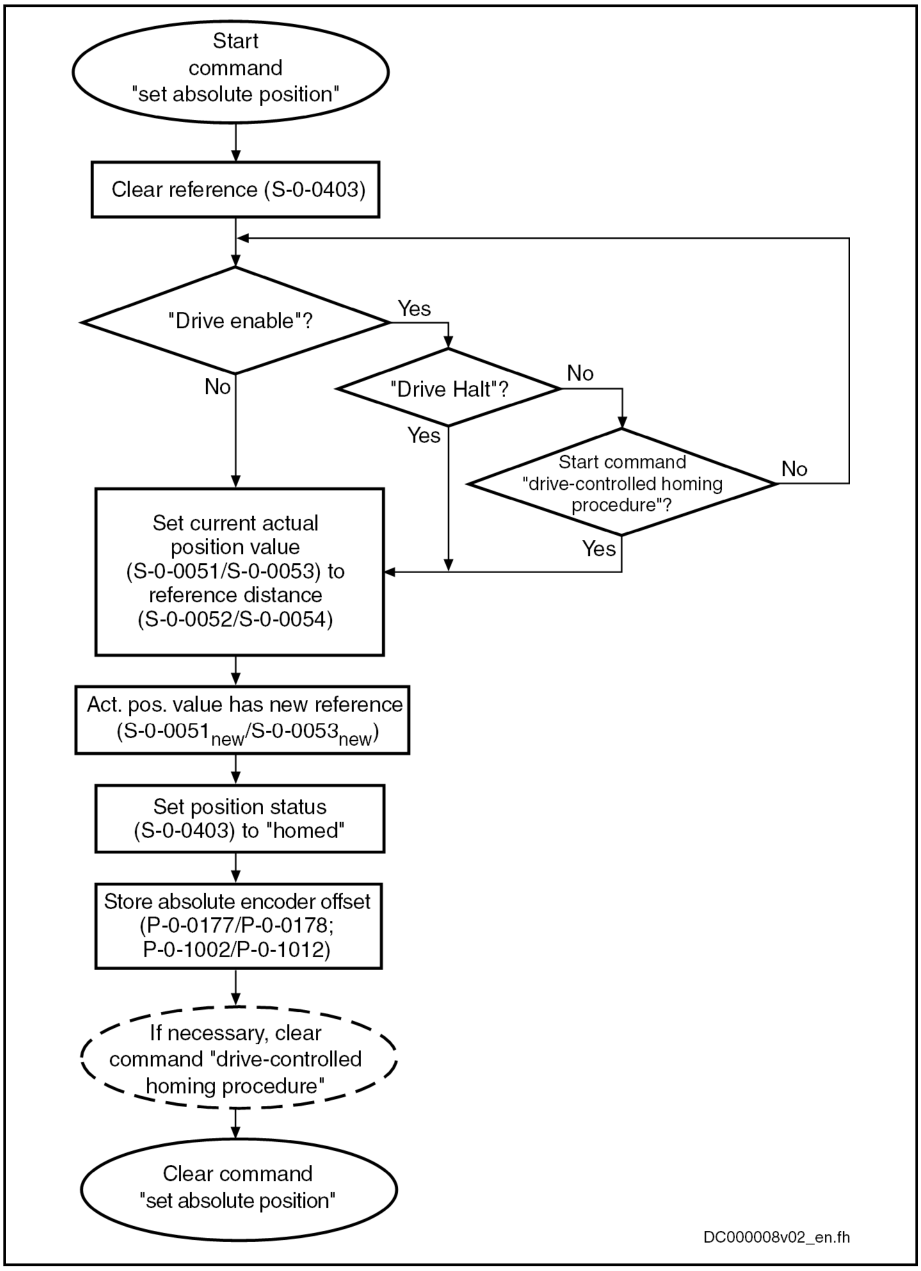


Fig. 5-60: Sequence of the Execution of the "Set Absolute Position Procedure" Command

Notes on Commissioning

See also Notes on Commissioning for "General Information on Establishing the Position Data Reference"

Checking the Possibility of Absolute Encoder Evaluation

The possibility of absolute evaluation of motor encoder and external encoder is displayed by the respective bits of

- "S-0-0277, Position feedback 1 type" (motor encoder)

- or -

- "S-0-0115, Position feedback 2 type" (external encoder).

See also "Absolute Measuring Systems" and "Relative Measuring Systems"

Presetting

In "S-0-0448, Set absolute position control" presettings for "set absolute position" have to be made:

- Determine the encoder for "set absolute position".
- Determine whether the execution of the "C0300 Set absolute position procedure command" command is also allowed with drive enable (AF) and whether the execution of "S-0-0148, C0600 Drive-controlled homing procedure command" is to be possible with absolute measuring systems.

See Notes on Commissioning for "drive-controlled homing procedure" in section "Establishing Position Data Reference for Relative Measuring Systems"

Starting "Set Absolute Position"

Start command "S-0-0447, C0300 Set absolute position procedure command".

See also "Command Processing"

Starting "Drive-Controlled Homing Procedure", if Necessary

If "set absolute position" is to be carried out with active drive, you either have to start the command "S-0-0148, C0600 Drive-controlled homing procedure command" or bring the drive to the "Drive Halt" (AH) state to switch the actual position value. Removing drive enable (inactive drive), too, causes the actual position value to be switched (see "chapter "Set Absolute Position Command" on page 285").

Procedure:

Set drive to drive enable (AF) and start "S-0-0447, C0300 Set absolute position procedure command", further procedure as follows:

- Start "S-0-0148, C0600 Drive-controlled homing procedure command"

  or
- Trigger "Drive Halt" (AH)

  or
- Remove drive enable (AF)

Each of the above-mentioned options sets the current actual position value to a new value:

- In accordance with "C0600 Drive-controlled homing procedure command"
- In accordance with "S-0-0052 Reference distance 1" or "S-0-0054, Reference distance 2" with "AH" or removing "AF"

After the actual position value has been switched, reset the command C0300.

See also "Command Processing"

Checking whether Position Data Reference was Established

The respective bit of parameter "S-0-0403, Position feedback value status" displays whether the encoder selected via "S-0-0448, Set absolute position control" has been homed.

☞ If the absolute encoder had already been homed, the respective bit only changes for a short time during command execution!

When "set absolute position" was executed again for an absolute encoder, a value for the "offset" of the actual position values before and after command execution is entered in:

- "S-0-0175, Offset parameter 1" (motor encoder)
- "S-0-0176, Offset parameter 2" (external encoder)

Clearing the Executed Commands

After the commands have been executed (diagnosis possible via parameter "S-0-0403, Position feedback value status"), the commands started have to be cleared again in reverse order when "set absolute position" is carried out via the "drive-controlled homing procedure" command.

Detecting Encoder Replacement

If an absolute encoder was replaced, the following error message is generated:

- F2074 Actual pos. value 1 outside absolute encoder window

- or -

- F2075 Actual pos. value 2 outside absolute encoder window

The position data reference must be established again!

Establishing Position Data Reference for Absolute Measuring Systems (Referencing)

Brief Description

Base package of all firmware variants in **closed loop** characteristic.

See also the section "General Information on Establishing the Position Data Reference"

Actual Position Value of Relative Measuring Systems when Switching On

After the drive has been switched on, the actual position values signaled by relative measuring systems do not yet have any reference to the machine axis. Measuring systems can be installed at the motor (motor encoder) and directly at the mechanical axis system (external or optional encoder).

For information on encoder arrangement and mechanical axis system see also "Mechanical Axis System and Arrangement of Measuring Systems"

The position data reference of relative measuring systems to the axis has to be established again each time after the drive was switched on or after all procedures that cause the position data reference to get lost (homing procedure).

Establishing the Position Data Reference, Drive-Controlled

After start of the respective command by the master, the drive can automatically establish the position data reference.

To do this, the drive moves the axis until the controller can detect a dedicated point. The actual position values then are automatically switched to axis reference. The presettings for the sequence for establishing the position data reference are made via assigned parameters.

Establishing the Position Data Reference, NC-Controlled

As an alternative to establishing the position data reference in a drive-controlled way, the NC ("master") can control the homing procedure.

In this case, the master inputs the command values for moving the axis to the dedicated point and controls the homing procedure via commands and assigned parameters.

The NC-controlled homing procedure can be advantageous for drives with a rigid mechanical connection (e.g. for Gantry axes), because the master can input coordinated command values for the drives for the homing motion.

Dedicated Point for Establishing the Position Data Reference

The dedicated point for establishing the position data reference, in the case of linear axes, is at one end of the travel range. This allows finding the dedicated point from any axis position (situation when switched on) by moving in a defined direction. Rotary axes do not have an axis end position, the dedicated point is at a defined position within the travel range.

Reference Mark for Relative Measuring Systems

The precision with which this dedicated point is detected considerably influences the absolute precision of the axis. Apart from the signals for position detection, relative measuring systems therefore also provide a signal for exact determination of a dedicated point. This signal is called "reference mark". Depending on their type, relative measuring systems have one or several reference marks over the range of measurement.

Reference Mark and Home Switch

Especially in the case of rotary measuring systems (e.g. motor encoder) at axes moved in a linear way, the reference mark of the encoder can occur several times over the entire travel range. In this case it is required, by axis-side activation of a switch contact at the end of the travel range, to identify **one** reference mark signal. This defines an unequivocal dedicated point that can be found with reproducible precision. This switch contact is called "home switch". A possibly available travel range limit switch can be used like a home switch, too.

In addition, a reference mark signal can be identified by detecting axis blocking when positive stop at the end of the axis has been reached.

Independent of the number of reference marks over the travel range, an axis-side additional device (home switch or travel range limit switches or positive stop), is indispensable for linear axes for detecting the axis end position!

If only one reference mark occurs over the travel range in the case of rotary axes, the home switch in most cases is not required!

Dedicated Point and Reference Point of an Axis

The dedicated point identified by an encoder reference mark and, if necessary, by a home switch, in most cases is not identical to the reference point of the axis. The distance between reference point and zero point normally is determined on the machine side. Especially in the case of series machines, this distance should be equal for axes of the same kind. The position of the dedicated point, however, is influenced by the kind of encoder arrangement and therefore differs from axis to axis.

Reference Offset

The position difference between dedicated point and reference point of the axis can be compensated by an offset value (reference offset).

See also the section "General Information on Establishing the Position Data Reference"

☞ The initial speed of the operation mode can be limited, for one axis with safety technology, to an additional speed value [product from "SMO: active speed threshold" (P-0-3238) and "SMO: evaluation factor speed limit "(P-0-3218)] when activated in the parameter "SMO: Configuration support functions" (P-0-3219), see also the separate documentation "Rexroth IndraDrive, Integrated Safety Technology "Safe Motion" (as of MPx-18)" (DOK-INDRV*-SI3*SMO-VRS-AP**-EN-P; Mat. No. R911338920), chapter "Additional and auxiliary functions".

Pertinent Parameters

Parameters for relative measuring systems:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- S-0-0052, Reference distance 1
- S-0-0054, Reference distance 2
- S-0-0108, Feedrate override
- S-0-0147, Homing parameter
- S-0-0148, C0600 Drive-controlled homing procedure command
- S-0-0150, Reference offset 1
- S-0-0151, Reference offset 2
- S-0-0173, Marker position A
- S-0-0174, Marker position B
- S-0-0191, C1500 Cancel reference point procedure command

- S-0-0298, Reference cam shift
- S-0-0299, Home switch offset
- S-0-0349, Bipolar jerk limit
- S-0-0400, Home switch
- S-0-0403, Position feedback value status
- P-0-0153, Optimum distance home switch-reference mark

Parameters for NC-controlled homing:

- S-0-0146 C4300 NC-controlled homing procedure command
- S-0-0171, C4400 Calculate displacement procedure command
- S-0-0172, C4500 Displacement to referenced system procedure command
- S-0-0175, Offset parameter 1
- S-0-0176, Offset parameter 2
- S-0-0404, Position command value status
- S-0-0407, Homing enable
- S-0-0408, Reference marker pulse registered

Parameters for relative measuring systems, distance-coded:

- S-0-0165, Distance-coded reference offset A
- S-0-0166, Distance-coded reference offset B
- S-0-0177, Absolute offset 1
- S-0-0178, Absolute offset 2

Parameters for homing at travel range limit switches:

- S-0-0532, Travel range limit parameter
  (Alias: P-0-0090, Travel range limit parameter)
- P-0-0222, Travel range limit switch inputs

Parameters for homing at positive stop:

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0331, Status "n_feedback = 0"
- S-0-0333, Status "T >= Tx"

Pertinent Diagnostic Messages

Diagnostic messages for drive-controlled homing:

- C0600 Drive-controlled homing procedure command
- C0601 Homing only possible with drive enable
- C0602 Distance home switch - reference mark erroneous
- C0606 Reference mark not detected
- C0607 Reference cam input not assigned

Diagnostic messages for NC-controlled homing:

- C4302 Distance home switch - reference mark erroneous
- C4304 Homing impossible with absolute encoder

- C4306 Reference mark not detected
- C4307 Reference cam input not assigned
- C4308 Pos. stop a. HW lim. switch not allowed f. modulo axes
- C4400 Calculate displacement procedure command

Functional Description

General Information

Type and Arrangement of Reference Marks

With regard to the type and arrangement of the reference marks, relative measuring systems can be divided into 4 groups:

- Group 1

  → Single-turn measuring systems with absolute range, such as single-turn HIPERFACE® or Singleturn-EnDat2.1 encoders. These measuring systems have an absolute position measuring range of one encoder revolution and do not have their own reference mark signal. The controller, however, recognizes the zero position (0 dgr) of the actual position value as the reference mark signal.

  These properties apply to:

  – Single-turn motor encoders for Rexroth motors with motor encoder option S1 or S2
  – Single-turn encoders from Stegmann (with HIPERFACE® interface)
  – Single-turn encoders from Heidenhain (with EnDat2.1 interface)

- Group 2

  → Incremental rotary measuring systems with one reference mark per encoder revolution, such as the ROD or RON types from Heidenhain

- Group 3

  → Incremental linear measuring systems with one or several reference marks, such as the LS linear scales from Heidenhain

- Group 4

  → Incremental measuring systems with distance-coded reference marks, such as the LSxxxC linear scales from Heidenhain

For measuring systems with distance-coded reference marks, see also "Relative Measuring Systems"!

Action of the Axis Drive to Establish Position Data Reference

In order to establish the position data reference of relative measuring systems, the drive has to be able to identify an unequivocal dedicated point within the travel range of the axis. To do this, the axis has to carry out the following motion (drive-controlled or NC-controlled):

- Pass the dedicated point (encoders of group 1, 2 or 3)

- or -

- Pass two neighboring distance-coded reference marks (encoders of group 4)

Motion Range for Homing

The motion range required for homing depends on the encoder used:

- For encoders of group 1, 2 or 3, motion over the entire travel distance of the axis might be required.
- With encoders of group 4, the axis has to maximally pass twice the reference mark distance (see "chapter "General Information" on page 293").

☞ For encoders of group 4 it is possible to calculate the position of the dedicated point on the basis of the detected position difference of two neighboring distance-coded reference marks!

Identifying a Dedicated Point

To identify a dedicated point of an axis, the following signals can be used:

- Reference marks of the encoder
- Home switch at the axis
- Travel range limit switches
- Axis blocking when positive stop at the end of travel range has been reached (positive stop detection)

The reference mark signal of an encoder is generally used for detecting the position of the dedicated point because this signal allows detecting the position within the scope of the encoder precision.

Depending on the encoder type and the mechanical arrangement of the encoder in the mechanical drive system, reference mark signals can occur **once or several times** within the travel range of an axis.

If the reference marks occur several times, only one reference mark signal may determine the dedicated point at unequivocal axis position. Identifying a mark signal requires one of the following axis-side additional devices:

- Travel range limit switches
- Home switch (if there isn't any travel range limit switch available)
- Positive stop at the end of the axis (if there isn't any switch to be used)

☞ The mentioned axis-side additional devices are also used for detecting the end of the axis during the homing procedure.

	Number of reference mark signals occurring over the travel range			
	One signal		Several signals	
Relative encoder of …	Rotary axis	Linear Axis	Rotary axis	Linear Axis
… group 1, 2 (rotary encoder)	AD: No	AD: Yes	AD: Yes (home switch)	AD: Yes
… group 3 (linear encoder)	---	AD: Yes	---	AD: Yes
… group 4 (rotary/linear encoder)	---	---	AD: No	AD: Yes

TU Additional device

Tab. 5-17: Recommendation for Axis-Side Additional Devices (AD) for Determining the Dedicated Point

In "S-0-0147, Homing parameter" select which signals are to be evaluated by the controller for determining the dedicated point (reference marks and/or home switches, travel range limit switches or positive stop).

☞ If there isn't any reference mark signal available on the encoder side, the edge reversal of the home switch signal or the travel range limit switch signal or the detection of positive stop can also be used for detecting the dedicated point. This has to be set in parameter S-0-0147 by deactivating the reference mark evaluation (only possible with drive-controlled homing!).

Reference Point, Axis Zero Point and Dedicated Point for Encoders of Groups 1, 2, 3

The axis zero point and the reference point are positions determined on the machine side. The position of the dedicated point ideally is identical to the reference point, the position of the dedicated point, however, mostly is influenced by the encoder arrangement. The position difference between reference point and dedicated point is transmitted to the controller via the so-called reference offset.

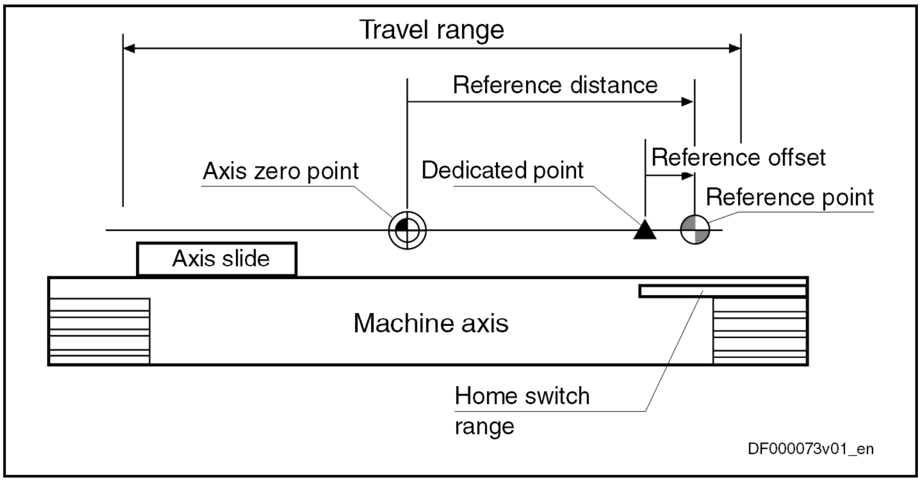


Fig. 5-61: Example of Positions of Axis Zero Point, Dedicated Point and Reference Point for Encoders of Groups 1, 2, 3

As the position data reference can be established both for the motor encoder and for the external encoder, there is one independent parameter available for the respective reference offset of both encoders:

- S-0-01750 Reference offset 1 (motor encoder)
- S-0-0151, Reference offset 2 (external encoder)

The reference distance is the distance between the reference point and the axis zero point. There is one independent parameter available for the respective reference distance of both encoders:

- S-0-0052, Reference distance 1 (motor encoder)
- S-0-0054, Reference distance 2 (external encoder)

Axis Zero Point, Encoder Zero Point and Dedicated Point for Encoders of Group 4

For distance-coded measuring systems (of group 4) the axis-side reference point is not used. The controller can calculate the position of the dedicated point (in this case the encoder zero point) on the basis of the detected position difference of two neighboring distance-coded reference marks. The position difference between axis zero point and encoder zero point is transmitted to the controller via the so-called absolute offset.

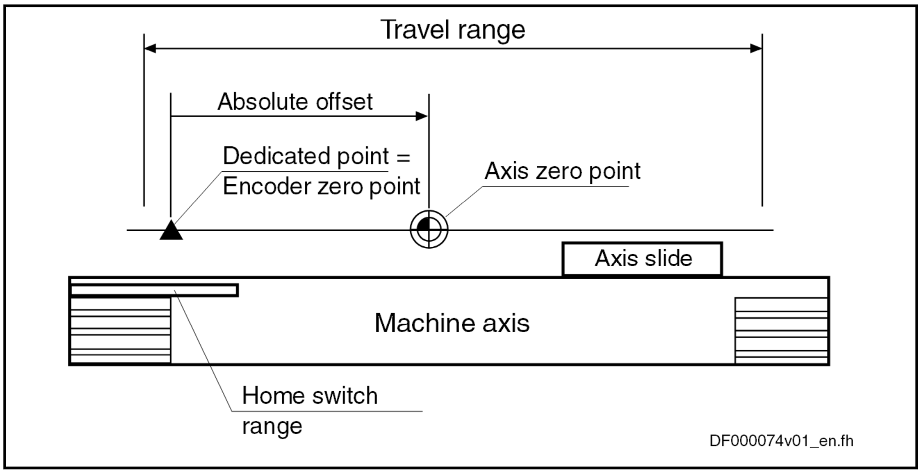


Fig. 5-62: Example of Positions of Axis Zero Point and Dedicated Point for Encoders of Group 4

As motor encoder and external encoder can be realized as distance-coded measuring system and the position data reference can be established for both encoders, there is one parameters for the absolute offset available for each encoder:

- S-0-0177, Absolute offset 1 (motor encoder)
- S-0-0178, Absolute offset 2 (external encoder)

☞ Only one distance-coded measuring system can be connected!

Motion Range for Encoders with Distance-Coded Reference Marks

For the homing procedure, relative measuring systems with distance-coded reference marks require a motion range corresponding as a maximum to the double distance of two neighboring reference marks.

Reference Mark Distance of Linear Encoders

Distances of neighboring reference marks of encoders with distance-coded reference marks:

$$\text{Motor Encoder} \quad s_{RefMarks} = S\text{-}0\text{-}0165 \times S\text{-}0\text{-}0116$$

$$\text{External Encoder} \quad s_{RefMarks} = S\text{-}0\text{-}0165 \times S\text{-}0\text{-}0117$$

$s_{RefMarks}$	Distance of neighboring reference marks
S-0-0165	Distance-coded reference offset A
S-0-0116	Resolution of feedback 1
S-0-0117	Resolution of feedback 2

Fig. 5-63: Distance of Neighboring Reference Marks of Linear Encoders with Distance-Coded Reference Marks

Reference Mark Distance of Rotary Encoders

Motor Encoder $$s_{RefMarks} = \frac{S\text{-}0\text{-}0165 \times 360°}{S\text{-}0\text{-}0116}$$

External Encoder $$s_{RefMarks} = \frac{S\text{-}0\text{-}0165 \times 360°}{S\text{-}0\text{-}0117}$$

$s_{RefMarks}$	Distance of neighboring reference marks
S-0-0165	Distance-coded reference offset A
S-0-0116	Resolution of feedback 1
S-0-0117	Resolution of feedback 2

Fig. 5-64: Distance of Neighboring Reference Marks of Rotary Encoders with Distance-Coded Reference Marks

Motion Range for Homing

The actual motion range for homing the axis corresponds either

- to the distance of neighboring, distance-coded reference marks including the distance until detection of the first reference mark and the braking distance at the end of the homing procedure, when the "stop" option was selected in parameter S-0-0147:

Linear scaling $$s_{Ref\_max} = s_{Ref\_1} + s_{RefMarks} + \frac{v^2}{2 \times a}$$

Rotary scaling $$s_{Ref\_max} = s_{Ref\_1} + s_{RefMarks} + \frac{\omega^2}{2 \times \alpha}$$

s_{Ref_max}	Maximum motion range
s_{Ref_1}	Distance to the first reference mark
sRefMarks	Distance of neighboring reference marks
v, ω	Homing velocity (S-0-0041)
a, α	Homing acceleration (S-0-0042)

Fig. 5-65: Maximum Motion Range for Homing Encoders with Distance-Coded Reference Marks in Case of "Stop" (S-0-0147)

☞ The motion range for "stop" is

- between the single and double reference mark distance plus the braking distance!

- or -

- the double reference mark distance plus the braking distance at the end of the homing procedure, when "run path" was selected in parameter S-0-0147.

Linear scaling $$s_{Ref\_max} = 2 \times s_{RefMarks} + \frac{v^2}{2 \times a}$$

Rotary scaling $$s_{Ref\_max} = 2 \times s_{RefMarks} + \frac{\omega^2}{2 \times \alpha}$$

s_{Ref_max} Maximum motion range
sRefMarks Distance of neighboring reference marks
v, ω Homing velocity (S-0-0041)
a, α Homing acceleration (S-0-0042)

Fig. 5-66: Maximum Motion Range for Homing Encoders with Distance-Coded Reference Marks in Case of "Run Path" (S-0-0147)

The motion range of the axis in the case of "run path" is always the same! This is advantageous for homing Gantry axes!

Detecting the End of the Travel Range

When homing relative measuring systems, the axis always has to be moved in defined direction so that the dedicated point can be reliably identified. As a prerequisite the axis has to be within the allowed travel range.

But the axis, when the search of the dedicated point is started, can also already be at that end of the axis at which the dedicated point is situated. For fail-safe detection of the dedicated point the drive has to be able to recognize this situation. This is only possible by means of axis-side additional devices (AD):

- Home switch at end of axis
- Travel range limit switches
- Positive stop at end of axis for axis blocking (detection of positive stop)

One of these devices must be mounted at the end of axis of the dedicated point and its signals must be evaluated by the drive controller.

For NC-controlled homing a home switch is obligatory! For NC-controlled homing, travel range limit switches and positive stop can neither be used for detecting the end of the travel range nor for identifying the dedicated point.

The "activated" state (switching logic) of home switch and travel range limit switch is set in the following parameters:

- "S-0-0147, Homing parameter" for the home switch ("edge evaluation …")
- "P-0-0090, Travel range limit parameter" for the travel range limit switch ("signal behavior")

Identifying the Dedicated Point by Means of Reference Mark and Home Switch

Home Switch for Selecting a Reference Mark

If several reference mark signals can occur over the travel distance of an axis and the dedicated point is to be determined by one of the marks (see table "chapter "General Information" on page 293"), a home switch can be used, for drive-controlled homing, as axis-side additional device for selecting a reference mark.

An axis-side home switch is obligatory for NC-controlled homing!

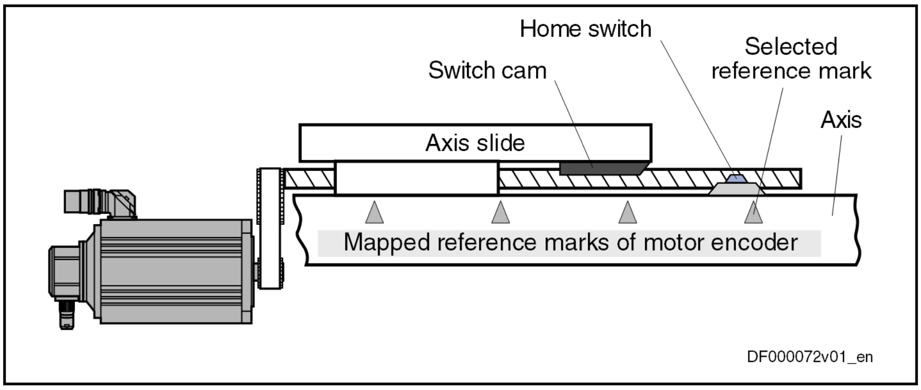


Fig. 5-67: Selecting a Reference Mark via Home Switch in the Case of a Linear Axis

After the start of the drive-controlled or NC-controlled homing, the dedicated point is detected when the first reference mark signal occurs after the "activated" signal of the home switch.

Arranging the Home Switch

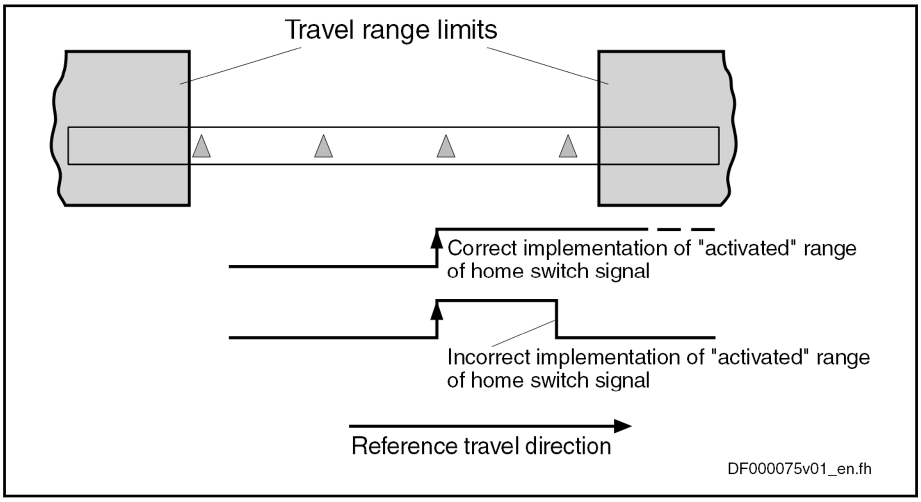


Fig. 5-68: Arranging the Home Switch with Regard to Travel Range Limits in the Case of Linear Axes

In the case of linear axes, the "activated" range of the home switch has to reach beyond the next travel range limit. The home switch signal thereby indicates the proximity of the end of the travel range if the reference travel direction was appropriately selected. The travel range limit is not passed during the homing procedure when the "activated" range of the home switch signal begins with sufficient distance to the travel range limit!

Distance Dedicated Point – Travel Range Limit for Linear Axes with Home Switch

The distance between dedicated point (first reference mark after home switch signal) and travel range limit is sufficient, if the drive can safely shutdown the axis out of maximum homing velocity (S-0-0041 for drive-controlled homing) with homing acceleration (S-0-0042 for drive-controlled homing), within the travel range. The following applies to the minimum distance home switch-travel range limit:

$$x_{HS\_TrLimit} \geq x_{RefMarks} + \frac{v^2}{2 \times a}$$

$x_{HS\_TrLimit}$	Minimum distance to travel range limit
$x_{RefMarks}$	Distance of the reference marks occurred at the axis or reference distance (S-0-0165) for distance-coded measuring system
v	Homing velocity (value of S-0-0041 or preset by NC)
a	Homing acceleration (value of S-0-0042 or preset by NC)

Fig. 5-69: Minimum Distance of Home Switch Signal to Travel Range Limit

☞ Generally, several reference marks may occur in the "activated" range of the home switch signal!

☞ For rotary axes, a home switch is only required when a gear with a gear ratio unequal "1" was mounted between axis and motor shaft!

Axis Position when Switching On, Detection of End of Travel Range

When the axis drive is switched on, the moving part of the axis can be at any position within the travel range, but it can also be at the end of the travel range. The home switch mounted at the end of the axis can be activated.

It must be possible to carry out the homing procedure even from this start position:

- In the case of drive-controlled homing, the drive, independent of the signal state and the settings for the "activated" signal of the home switch, automatically passes the dedicated point.
- In the case of NC-controlled homing, the master has to set the required command values so that the dedicated point can be unequivocally detected.

Searching for Dedicated Point for Non-Distance-Coded Encoder and Axis with Home Switch

For axes with non-distance-coded encoders, the drive has to move the axis to the end of the axis in determined reference travel direction, in order to start the search for the dedicated point after the "activated" signal was detected. The end of the travel range is also detected via the signal state of the home switch.

Determined edge evaluation (S-0-0147)	Signal state of home switch (bit in S-0-0400)	Drive action
Positive	0 ("Not activated")	motion in reference travel direction until home switch is activated, then search for dedicated point after positive signal edge was detected
Negative	1 ("Not activated")	motion in reference travel direction until home switch is activated, then search for dedicated point after negative signal edge was detected

Determined edge evaluation (S-0-0147)	Signal state of home switch (bit in S-0-0400)	Drive action
Negative	0 ("Activated")	motion against reference travel direction until home switch is not activated, then reversal of motion; search for dedicated point after negative signal edge was detected
Positive	1 ("Activated")	motion against reference travel direction until home switch isn't activated, then reversal of motion; search for dedicated point after positive signal edge was detected

Tab. 5-18: Drive Motions for Search for Dedicated Point in the Case of Non-Distance-Coded Measuring System and Home Switch, Depending on the Axis Position (Drive-Controlled or NC-Controlled)

Searching for Dedicated Point for Distance-Coded Encoder and Axis with Home Switch

For axes with distance-coded encoder, the drive has to move the axis over two neighboring distance-coded reference marks in order to find the dedicated point:

- For drive-controlled homing, if the drive has not yet detected any or only one reference mark when the home switch is activated, it changes the direction of motion. The position data reference is established over the next two detected reference marks.
- For NC-controlled homing, the drive stores the non-homed position of the first detected reference mark in parameter "S-0-0173, Marker position A", the non-homed position of the neighboring reference mark is stored in parameter

  "S-0-0174, Marker position B".

If at the start of the homing procedure the axis is already at the end of the travel range and the home switch is detected as having been "activated", a command value has to be generated that leads the axis back to the allowed travel range:

- For drive-controlled homing, the drive moves the axis against the determined reference travel direction and over the next two distance-coded reference marks determines the axis position relative to the dedicated point.
- For NC-controlled homing, the master-side command value has to move the axis against the reference travel direction determined in the NC. The next two distance-coded reference marks are evaluated for determining the dedicated point.

Signal state of home switch (S-0-0400)	Drive action
0 ("Not activated")	Motion for search of dedicated point in determined reference travel direction
1 ("Activated")	Motion for search of dedicated point against determined reference travel direction

Tab. 5-19: Drive Motions for Search for Dedicated Point in the Case of Distance-Coded Measuring System and Home Switch, Depending on the Axis Position (Drive-Controlled or NC-Controlled)

Connecting the Home Switch

For drive-controlled homing, the home switch has to be connected to the assigned digital input of the control section of the drive controller. Observe the allowed signal levels! The signal state of the home switch is displayed in parameter "S-0-0400, Home switch".

For "NC-controlled homing", the obligatory home switch can be connected either to the drive controller or to the master (NC control unit)!

See "Digital Inputs/Outputs"

Activating the Evaluation of Reference Marks and Home Switch

The evaluation of the reference marks and the home switch signal have to be activated in the respective bit of "S-0-0147, Homing parameter". The evaluation of travel range limit switch and positive stop mustn't be activated at the same time!

> ☞ If the evaluation of the reference marks has not been activated, the dedicated point is determined only by the signal of the home switch!

Identifying the Dedicated Point by Means of Reference Mark and Travel Range Limit Switch

Travel Range Limit Switch for Selecting a Reference Mark

A travel range limit switch, too, can be used as axis-side additional device (AD) for selecting a reference mark, if several reference mark signals can occur over the travel distance of an axis and the dedicated point is to be determined by one of the marks (see table "chapter "General Information" on page 293"),.

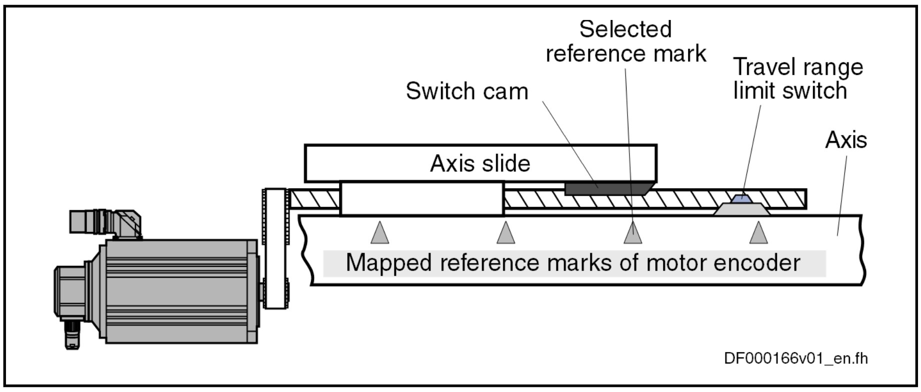


Fig. 5-70: Selecting a Reference Mark via Travel Range Limit Switch

After the start of drive-controlled homing (command C0600), the axis is moved in the determined direction of motion until the travel range limit switch is activated. The drive then changes the direction of motion, the dedicated point is detected when the first reference mark signal occurs.

☞ If the travel range limit switches for hardware-side limitation of the allowed travel range have been activated, this monitoring function is deactivated during the homing procedure!

Axis Position when Switching On; Detecting the End of the Travel Range

When the axis drive is switched on, the moving part of the axis can be at any position within the travel range, but it can also be at the end of the travel range. The travel range limit switch mounted at the end of the axis can be activated.

It must be possible to carry out the homing procedure even from this start position. In the case of drive-controlled homing, the drive, independent of the signal state and the settings for the "activated" signal of the travel range limit switches, automatically passes the dedicated point.

Searching for Dedicated Point for Non-Distance-Coded Encoder and Axis with Travel Range Limit Switch

For axes with non-distance-coded encoders, the drive has to move the axis to the end of the axis in determined reference travel direction, in order to start the search for the dedicated point after a signal change of the travel range limit switch was detected.

Determined signal behavior of travel range limit switch (P-0-0090)	Signal state of travel range limit switch (P-0-0222)	Drive action
Not inverted	0 ("Not activated")	Motion in reference travel direction when limit switch activated, reversal of motion and search for dedicated point
Inverted	1 ("Not activated")	As row above
Inverted	0 ("Activated")	Motion against reference travel direction until limit switch isn't activated, then search for dedicated point
Not inverted	1 ("Activated")	As row above

Tab. 5-20: Drive Motions for Search for Dedicated Point at Start of Command C0600 (in the Case of Non-Distance-Coded Measuring System and Use of Travel Range Limit Switches), Depending on the Axis Position

Searching for Dedicated Point for Distance-Coded Encoder and Axis with Travel Range Limit Switch

In order to find the dedicated point, the drive, for axes with distance-coded encoder, has to move the axis in the determined reference travel direction over two neighboring distance-coded reference marks.

If at the start of the drive-controlled homing procedure (command C0600) the axis is already at the end of the travel range and detects a travel range limit switch as having been "activated", a drive-internal command value is generated that leads back to the allowed travel range and the axis position relative to the dedicated point is determined over the next two reference marks.

Signal state of travel range limit switches (P-0-0222)	Drive action
0 ("Not activated")	Motion for search of dedicated point in reference travel direction
1 ("Activated")	Motion for search of dedicated point in direction of allowed travel range

Tab. 5-21: Drive Motions for Search for Dedicated Point at Start of Command C0600 (in the Case of Distance-Coded Measuring System and Use of Travel Range Limit Switches), Depending on the Axis Position

Connecting the Travel Range Limit Switches

The travel range limit switches have to be connected to the assigned digital inputs of the control section of the drive controller. Observe the allowed signal levels! The signal state of the respective travel range limit switch is displayed in parameter "P-0-0222, Travel range limit switch inputs".

See "Digital Inputs/Outputs"

Activating the Evaluation of Reference Marks and Travel Range Limit Switch

The evaluation of the reference marks and the travel range limit switch as additional devices for homing has to be activated in the respective bit of "S-0-0147, Homing parameter".

The evaluation of home switch and/or positive stop mustn't be activated at the same time!

If the evaluation of the reference marks has not been activated, the dedicated point is determined only by the signal of the travel range limit switch!

Identifying the Dedicated Point by Means of Reference Mark and Positive Stop

Positive Stop for Selecting a Reference Mark

A positive stop at an axis, too, can be used as axis-side additional device (AD) for selecting a reference mark, if several reference mark signals can occur over the travel distance of an axis and the dedicated point is to be determined by one of the marks (see table "chapter "General Information" on page 293").

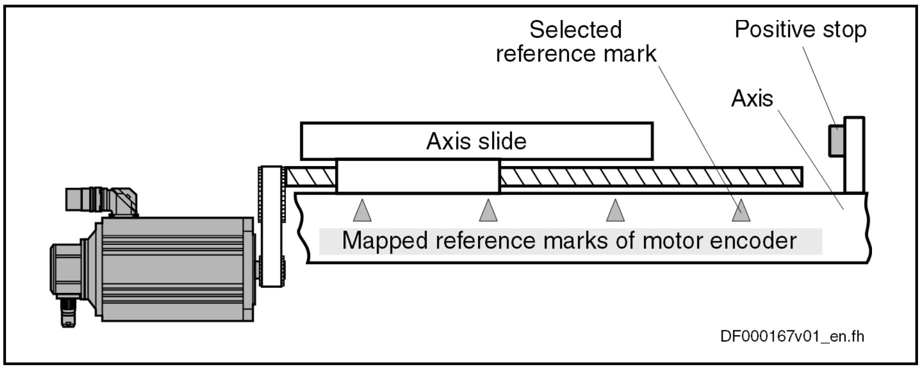


Fig. 5-71: Selecting a Reference Mark via Positive Stop at the end of the Axis

Detecting the End of Travel Range by Axis Blocking (Positive Stop)

After the start of drive-controlled homing (command C0600), the drive first moves the moving part of the axis in the determined reference travel direction (see S-0-0147). There is no switch signal required for identifying the end of the axis!

Search for Dedicated Point for Non-Distance-Coded Encoders

In the case of non-distance-coded encoders, the axis moves until it is blocked by positive stop. After the actual torque value (S-0-0084) of the drive has exceeded the torque limit value (minimum of S-0-0092 and S-0-0082 or S-0-0092 and S-0-0083) that was set and standstill of the drive was detected ("S-0-0331, Status "n_feedback = 0""), the drive changes the direction of motion; the dedicated point is determined by the occurrence of the first reference mark signal.

Search for Dedicated Point for Distance-Coded Encoders

In the case of distance-coded encoders, the axis only moves to positive stop, if there is none or only one distance-coded reference mark in the determined reference travel direction before blocking. After blocking was detected (see paragraph above), the drive changes the direction of motion and over the next two reference marks determines the axis position with regard to the dedicated point.

☞ If evaluation of the reference marks has not been activated, the dedicated point is only determined by detection of positive stop (S-0-0333, S-0-0331, see above).

Activation of Axis Blocking Detection (Positive Stop) for Homing Procedure

The evaluation of the reference marks and the positive stop as additional devices for homing has to be activated in the respective bit of "S-0-0147, Homing parameter". The evaluation of home switch and/or travel range limit switch mustn't be activated at the same time!

☞ The monitoring of position command value, actual position value and acceleration is switched off during the homing procedure!

☞ If travel range limit switches for hardware-side limitation of the allowed travel range have been activated, the monitoring of this limitation is deactivated during the homing procedure!

Requirements for Selecting a Reference Mark

If an axis-side additional device (AD), such as home switch, travel range limit switch or positive stop at the end of the axis, is to be used for selecting a reference mark signal (in the case of several signals occurring over the travel range), you have to make sure that it is always the same reference mark signal that is evaluated by the controller for detecting the position of the dedicated point!

Activation of the home switch or the travel range limit switch or detection of positive stop is detected by the controller with a position inaccuracy inherent in the system. This inaccuracy depends on the following factors:

- The input clock of the digital input via which the home switch or the travel range limit switch is evaluated (corresponding to the position loop clock when command C0600 is executed; see "Performance Data")
- Position loop clock when using a positive stop when command C0600 is executed (see "Performance Data")
- Actual velocity value at which the axis moves during the homing procedure

Within the range of inaccuracy of the position detection there mustn't occur any encoder reference mark, because reliably reproducible detection of the dedicated point is impossible within this range!

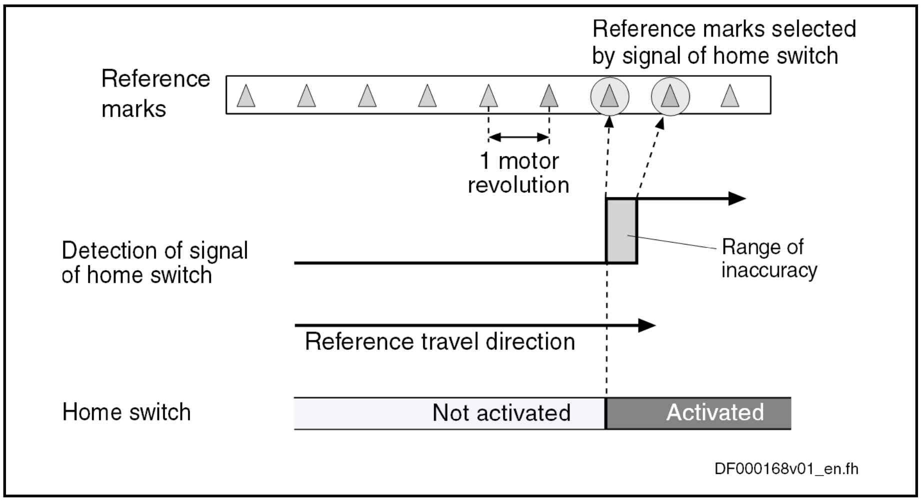


Fig. 5-72: Ambiguous Detection of Reference Marks in Range of Inaccuracy of Home Switch Detection

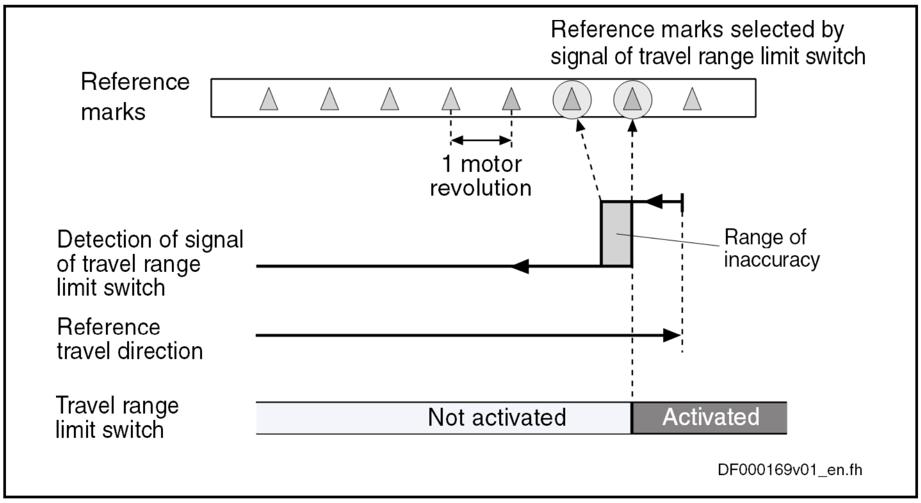


Fig. 5-73: Ambiguous Detection of Reference Marks in Range of Inaccuracy of Travel Range Limit Switch or Positive Stop Detection

Distance Monitoring Switch Edge or Positive Stop Detection/Reference Mark

Due to the range of position inaccuracy of the switch edge or positive stop detection, the distance to the position of the next reference mark is monitored. If the distance falls below a certain value, the error message "C0602 Distance home switch - reference mark erroneous" will be generated.

Classification of distance	Distance	Drive reaction
Critical distance	< 0.25 × reference mark distance	Shutdown with message C0602
Optimum distance	0.5 × reference mark distance	--
Allowed distance range	(0.25 … 0.75) × reference mark distance	--

Tab. 5-22: Data Regarding the Distance Between Switch Edge or Positive Stop Detection and Reference Mark

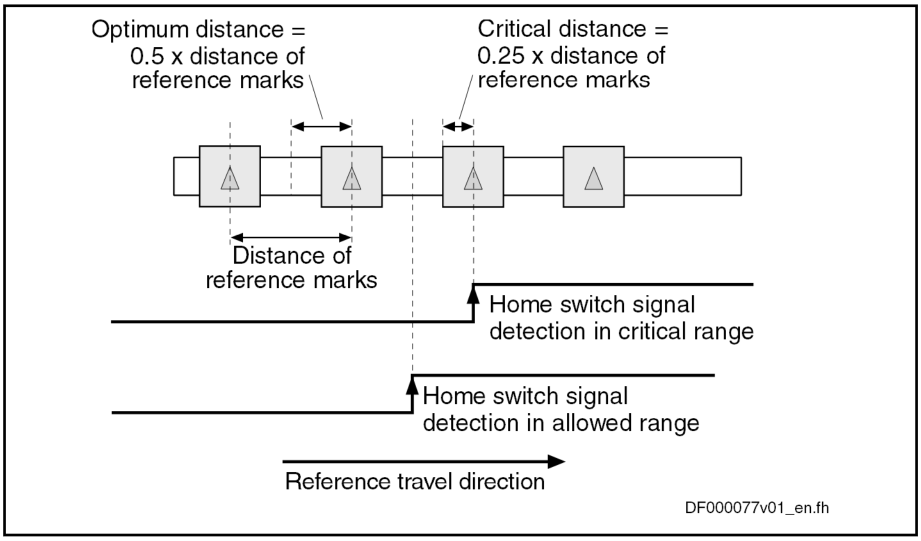


Fig. 5-74: Critical and Optimum Distance of Switch Edge and Reference Mark in the Case of the home Switch

To monitor the distance, the optimum distance has to be preset in parameter "P-0-0153, Optimum distance home switch-reference mark".

☞ When using the motor encoder of Rexroth motors with encoder data memory, the optimum distance is automatically calculated internally. The value for P-0-0153 has to be left in its default state!

ℹ For default values of P_0_0153 for distance monitoring to the next reference mark in the case of switch edge or positive stop detection, see separate documentation ""

Distance Correction

For each homing procedure with home switch, travel range limit switch or positive stop detection, as well as reference mark evaluation, the difference between the actual distance to the next reference mark and the optimum distance is monitored. This difference is stored in parameter "S-0-0298, Reference cam shift". For optimum setting of the home switch or travel range limit switch, it can be mechanically shifted by the value of S-0-0298.

The distance can also be optimized drive-internally without mechanical shifting. The controller in this case shifts the activation of the reference mark evaluation after detection of the switch edge or the axis blocking (positive stop) by the value in parameter "S-0-0299, Home switch offset". For this purpose, the value of S-0-0298 has to be entered in parameter S-0-0299.

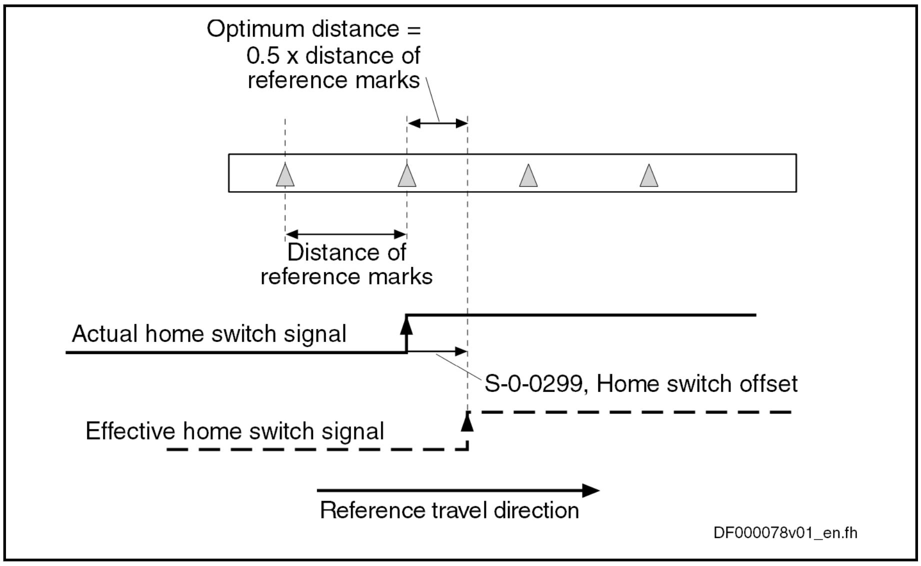


Fig. 5-75: Operating Principle of Parameter S-0-0299 in the Case of Home Switch Signal

Distance Monitoring of Reference Mark Signals

The position distance of the reference mark signals is monitored during the homing procedure. The position distance to be expected for the motor encoder or external encoder is determined by the controller, depending on the type of encoder used and the value of "P-0-0153, Optimum distance home switch-reference mark". This allows detecting:

- Parameter values for reference mark evaluation have been correctly set

- or -

- Reference mark signals are correctly input

☞ Parameter P-0-0153 refers to the encoder to be homed according to the setting in "S-0-0147, Homing parameter". If a second encoder has to be homed that requires different values in P-0-0153, the parameter P-0-0153 has to be adjusted to the respective encoder by the control master before the command C0600 is started!

Notes on Commissioning

See also Notes on Commissioning for "General Information on Establishing the Position Data Reference"

Settings for Connected Encoders

The required settings with regard to the encoders used need to have been made so that establishing the position data reference is possible.

See also Notes on Commissioning for "Basics on Measuring Systems, Resolution"

For measuring systems with distance-coded reference marks, see also Notes on Commissioning for "Relative Measuring Systems"

General Settings for Drive-Controlled Homing

In "S-0-0147, Homing parameter", it is necessary to make basic settings regarding encoder selection and use of axis-side additional devices:

- Selection of encoder to be homed

  → Select which of the connected encoders is to be homed.

- Activation/deactivation of reference mark evaluation

  → Select whether the dedicated point is determined by one encoder reference mark or by two neighboring encoder reference marks (distance-coded encoders) (to be selected for drive-controlled homing, automatically active for NC-controlled homing).

- Setting for use of axis-side additional device for identification of dedicated point:
  - Home switch

  - or -

  - Travel range limit switch as a replacement for home switch (optional for drive-controlled homing, not possible for NC-controlled homing)

  - or -

  - Activation of detection of axis blocking for positive stop drive procedure (optional for drive-controlled homing, not possible for NC-controlled homing)

Settings for Axis-Side Additional Devices (if Available)

Depending on whether axis-side additional devices are used, further settings have to be made.

Home switch:

- Activation of home switch evaluation in "S-0-0147, Homing parameter"
- Setting for edge evaluation of home switch signal in "S-0-0147, Homing parameter"

Travel range limit switch:

- Activation of travel range limit switch evaluation in "S-0-0147, Homing parameter"
- Setting of switching performance in "P-0-0090, Travel range limit parameter"

Detection of axis blocking (positive stop):

- Setting of the torque/force threshold for the detection of blocking in parameter "S-0-0092, Bipolar torque/force limit value" or "S-0-0082, Torque/force limit value positive" or "S-0-0083, Torque/force limit value negative"
- Setting of standstill threshold for detection of blocking in "S-0-0124, Standstill window"

Distance Monitoring of Reference Mark Signals

With active reference mark evaluation (obligatory for NC-controlled homing, optional for drive-controlled homing), encoder-specific values for the monitoring of the reference mark signals have to be entered in parameter "P-0-0153, Optimum distance home switch-reference mark". Monitoring takes place during the homing procedure (see Parameter Description P-0-0153).

NOTICE **Property damage at the installation caused by home switch edge incorrectly set!**

⇒ Make sure the home switch edge was correctly set and is within the travel range!

Distance Control Home Switch Edge - Travel Range Limit

In the case of home switch evaluation, first control whether the minimum distance between home switch edge and travel range limit has been complied with:

- Search for switch point of home switch, e.g. by jogging the axis to switch cam; control switch status in parameter "S-0-0400, Home switch"; retain actual position value (S-0-0051/S-0-0053)

- Jog axis to travel range limit, retain actual position value (S-0-0051/S-0-0053)

The minimum distance has to be calculated on the basis of the values for velocity and acceleration intended for the homing procedure (see also section above "Identifying the Dedicated Point by Means of Reference Mark and Home Switch"):

- For drive-controlled homing, determine the minimum distance with "S-0-0041, Homing velocity" and "S-0-0042, Homing acceleration"
- For NC-controlled homing determine the minimum distance while taking the homing velocity and homing acceleration into account

If the distance between home switch edge and travel range limit is smaller than the calculated minimum distance, the home switch has to be mechanically brought to the respective distance!

Checking and, if Necessary, Correcting the Distance to Reference Mark

When using axis-side additional devices (optional), such as home switch, travel range limit switches or positive stop (setting in parameter S-0-0147), you have to check whether the distance switch edge–reference mark or positive stop–reference mark is within the allowed range.

How to proceed for checking the distance:

- Make presettings for activation of reference marks, for use of axis-side additional devices and for encoder selection in "S-0-0147, Homing parameter"
- Make settings for respective axis-side additional device that might be used (see above)
- Check whether encoder-specific value was entered in parameter "P-0-0153, Optimum distance home switch-reference mark"

  Note: The value in parameter P-0-0153 refers to the encoder to be homed as determined in parameter S-0-0147. If a second encoder has to be homed that requires different values in P-0-0153, this parameter has to be adjusted to the respective encoder to be homed before the C0600 command is started!
- Execution of the drive-controlled homing procedure (command C0600) with "S-0-0299, Home switch offset" = 0 and the setting "stop" in parameter S-0-0147. If the distance lies within the allowed range (0.25… 0.75 × (2 × P-0-0153)), the drive will not generate a respective error message after standstill.

If the message "C0602 Distance home switch - reference mark erroneous" is generated, the distance has to be corrected:

1. Enter value of parameter "S-0-0298, Reference cam shift" in parameter "S-0-0299, Home switch offset"
2. Check: When homing is repeated, value "0" should be displayed for parameter S-0-0298.

Drive-controlled homing procedure

Brief Description

Basic Sequence of "Search for Dedicated Point"

After "S-0-0148, C0600 Drive-controlled homing procedure command" has been activated, the drive for searching the dedicated point moves the axis according to the reference travel direction set in "S-0-0147, Homing parameter". When the controller has detected the position of the dedicated point, e.g. by reference mark detection of the encoder selected in S-0-0147, the position data reference of the actual position values to the axis can be established.

Determining the homing appropriate procedure for the existing axis type (settings in S-0-0147) ensures that during the search for the dedicated point the axis only moves within the allowed travel range!

For information on the actual position value after establishing the position data reference for motor encoder and external encoder, see the section "General Information on Establishing the Position Data Reference"

Functional Description

Functional Sequence "Drive-Controlled Homing Procedure"

Command Value Profile for Homing Procedure

After activation of "S-0-0148, C0600 Drive-controlled homing procedure command", the drive moves the axis according to the reference travel direction set in "S-0-0147, Homing parameter". The command value profile generated by the controller depends on:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- S-0-0108, Feedrate override

The controller ignores command values of the control master during the execution of command C0600!

☞ If the respective encoder, at the start of command C0600, should have already been homed, the reference is cleared first!

See Parameter Description "S-0-0403, Position feedback value status"

Homing Motion

At the start of command C0600, two situations have to be distinguished with regard to the initial position of a linear axis. The moving part of the axis is

- within the travel range, the home switch or travel range limit switch has not been activated,

- or -

- near the end of the travel range, the home switch or travel range limit switch has been activated, the positive stop, possibly used for homing, is almost reached.

If the switch has not been activated or positive stop has not yet been reached, the drive moves the axis in reference travel direction.

When the home switch has already been activated, the drive moves the axis against the reference travel direction.

In the case of non-distance-coded encoders, the drive reverses the direction of motion for searching the dedicated point as soon as the home switch is detected to be "not activated".

In the case of distance-coded encoders, the search for the dedicated point is carried out against the determined reference travel direction.

When positive stop is used for homing, the search for the dedicated point, after axis blocking has been detected, is always carried out against the reference travel direction!

☞ The drive does not perform any homing motion when the dedicated point is the current actual position value of the encoder to be homed.

This means that for identifying the dedicated point

- neither the reference mark evaluation
- nor an axis-side additional device was selected.

Jerk Limitation To limit acceleration jumps it is possible to additionally activate a jerk limit. This is done by entering the value parameter "S-0-0349, Bipolar jerk limit".

Motion Range for Homing The process for searching the dedicated point requires axis motion. The axis motion to be expected depends on the selected measuring system and on the position of the axis at the start of drive-controlled homing (for information on axis motion see above under the description of the respective paragraph "Identifying the Dedicated Point by Means of …").

Maximum Velocity As in the case of all drive-controlled functions, the maximum velocity can be directly influenced with a feedrate factor when executing the homing procedure. The effective maximum velocity then results from the product of the values of "S-0-0041, Homing velocity" and "S-0-0108, Feedrate override".

> ☞ The positioning velocity can be limited with the use of the safety technology by "P-0-3238, SMO: Active velocity threshold" see also "Rexroth IndraDrive, Integrated Safety Technology "Safe Motion" (as of MPx-18)" (DOK-INDRV*-SI3*SMO-VRS-AP**-EN-P; Mat. No. R911338920).

Shutdown After the controller has detected the dedicated point of the axis by the homing procedure, the actual position values are switched to axis-related values. The drive then shuts down the axis with the homing acceleration (S-0-0042). Shutdown can be carried out as:

- "Stopping"

  → Non-target-oriented immediate braking motion that possibly is of shorter duration

- or -

- "Positioning"

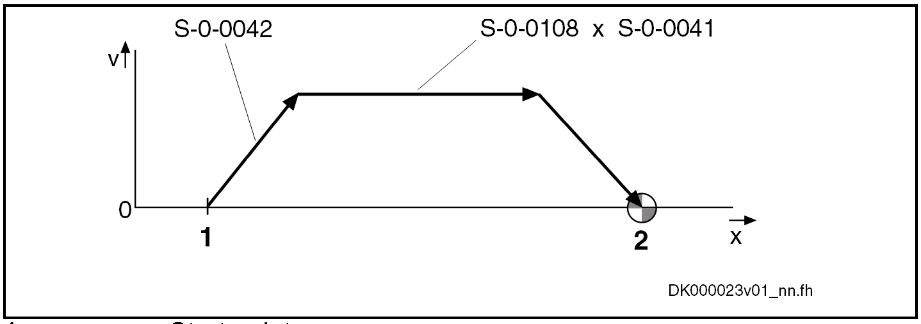
  → Target-oriented motion to the reference point (axis-related value in parameter "S-0-0052, Reference distance 1" or "S-0-0054, Reference distance 2"), if the reference point is within the allowed travel range

- or -

- "Run path" (only possible for distance-coded encoders!)

  → Moving over a defined path (double reference mark distance), even if the dedicated point had already been detected

The kind of shutdown ("positioning" or "stop" or "run path") is set in "S-0-0147, Homing parameter".



1	Start point
2	Reference point
S-0-0041	Homing velocity
S-0-0042	Homing acceleration
S-0-0108	Feedrate override

Fig. 5-76: Command Value Profile for Drive-Controlled Homing with Constant Feedrate Factor and "Positioning" Shutdown

> If parameter "S-0-0108, Feedrate override" starts with zero, the warning "E2055 Feedrate override S-0-0108 = 0" is output.

Actions of the Control Unit with "Drive-Controlled Homing"

Starting Command C0600

The control master starts the command by writing data to parameter "S-0-0148, C0600 Drive-controlled homing procedure command". The command has to be set and enabled. The command acknowledgment has to be taken from the data status of the same parameter. The command execution is completed when the command change bit in parameter "S-0-0135, Drive status word" has been set and the acknowledgment changes from "in process" to "command executed" or to "command error".

Interrupting Command C0600

If the command is interrupted by the control master during its execution, the drive reacts by activating the "Drive Halt" function. The command execution is continued by removing the interruption.

See also "Drive Halt"

Completing Command C0600

When the control master wants to operate the drive in position control after resetting command C0600, it has to read the drive-internal position command value from "P-0-0047, Position command value control" and preset it as the position command value. By resetting the command, the control master takes over the axis without jerk or position offset occurring.

Notes on Commissioning

Notes on Commissioning, General

Settings for Homing Motion

For drive-controlled homing motion, settings for kinematics have to be made:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration

Settings for Drive-Controlled Homing

Apart from general settings, further settings for drive-controlled homing have to be made in "S-0-0147, Homing parameter":

- Reference travel direction

  → Determine direction of motion in which search for dedicated point take place, if axis is not at end of axis
- Activation/deactivation of reference mark evaluation

  → Determine whether dedicated point is determined by one encoder reference mark or by two neighboring encoder reference marks (distance-coded encoders)
- Setting for use of axis-side additional device for identification of dedicated point:
  - Use of a home switch and setting for edge evaluation of home switch signal

  \- or -
  - Use of a travel range limit switch as a replacement for home switch

  \- or -
  - Activation of blocking detection for positive stop drive procedure

  Note: Only one of the possible axis-side additional devices for drive-controlled homing may be selected!
- Setting for shutting axis down after detection of dedicated point ("stop", "positioning" or "run path")

Axis-Related Settings for Establishing the Position Data Reference

Depending on the kind of reference marks of the encoder, the axis-related parameter settings for establishing the position data reference are explained in the following sections.

Notes on Commissioning with Relative Encoders (Reference Marks not Distance-Coded)

Settings for Axis-Side Position Data Reference of Actual Position Values

To establish the position data reference of an encoder (of groups 1, 2, 3) to the axis, the distance between the dedicated point identified on the drive side and the reference point of the axis, as well as the position of the reference point compared to the axis zero point have to be entered.

To do this, the following steps have to be carried out:

1. First set the following parameters to value "0":
   - S-0-0052, Reference distance 1/S-0-0054, Reference distance 2
   - S-0-0150, Reference offset 1/S-0-0151, Reference offset 2
2. If encoder reference marks are not to be evaluated, make corresponding settings in "S-0-0147, Homing parameter" (Default setting: encoder reference marks are evaluated!).
3. For initial commissioning, set parameters for homing procedure to low values:
   - S-0-0041, Homing velocity
   - S-0-0042, Homing acceleration
4. Execute "C0600 Drive-controlled homing procedure command" (S-0-0148), if drive in "AF"

NOTICE	Property damage caused by step change of actual position value!

⇒ By clearing the command, the original operation mode becomes active again. When the "drive-internal interpolation" mode was set, for example, the drive immediately moves to the position according to the value in parameter "S-0-0258, Target position". Take change in actual position value into consideration!

Axis Zero Point and Dedicated Point

After the command was executed, the axis zero point is at the same axis position as the dedicated point, because the reference distance (S-0-0052/S-0-0054) and the reference offset (S-0-0150/S-0-0151) were set to the value "0". The actual position value in parameter "S-0-0051, Position feedback value 1" or "S-0-0053, Position feedback value 2" now has absolute reference to this preliminary axis zero point.

Settings for the Reference Point

The reference point normally has an actual position value determined on the axis-side and related to the axis zero point. Ideally, the dedicated point identified on the drive-side has the same position as the reference point. As the dedicated point position is considerably influenced by the mounting situation of the encoder, dedicated point and reference point are different. The distance between dedicated point and reference point for the motor encoder or external encoder is entered in the parameter for reference offset 1 or reference offset 2.

To determine the reference offset the following steps have to be carried out, based on the initial state after the proposed identification of the dedicated point:

- Jog axis to determined reference point and enter actual position value displayed at the reference point in parameter "S-0-0150, Reference offset 1" or "S-0-0151, Reference offset 2" with same preceding sign.

In order to establish the position reference to the real axis zero point, enter the desired axis-related actual position value of the reference point in parameter "S-0-0052, Reference distance 1" or "S-0-0054, Reference distance 2". This can be directly done by entering the value defined on the axis-side, if this value is known. If not, the axis-related actual position value of the reference point has to be determined:

- Jog axis to desired axis zero point. Enter displayed actual position value in the respective reference distance parameter with inverted sign.

- or -

- Jog axis to actual position value = 0; axis then is at reference point. Axis-related position of reference point can be determined by measuring distance between current position and determined axis zero point. Enter measured distance as axis-related actual position value for reference point in respective reference distance parameter with the correct sign.

After repeated execution of the command C0600 ("drive-controlled homing procedure" command) the actual position values refer to the axis zero point.

Settings for Drive-Controlled Homing Motion

Set the parameter values reduced for initial commissioning to their definite values:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration

To control the setting, execute the command "C0600 Drive-controlled homing procedure command" again!

For non-distance-coded encoders, drive-controlled homing can be completed with "stop" or "positioning":

"Stop" after Detecting the Dedicated Point

When "stop" after detecting the dedicated point (default setting) was set in "S-0-0147, Homing parameter", the drive stops the axis after the dedicated point was detected.

"Positioning" after Detecting the Dedicated Point

If the axis, after the dedicated point was detected, is to position to the reference point, this has to be set in parameter S-0-0147. The position can be preset via "S-0-0150, Reference offset 1" or "S-0-0151, Reference offset 2" .

NOTICE

Property damage is possible at the installation, if the reference point is outside the permitted travel range and the position limit has not yet been activated!

⇒ Make sure that reference point is within the travel range and activate the position limit!

Notes on Commissioning with Relative Encoder with Distance-Coded Reference Marks

Settings for Axis-Side Position Data Reference of Actual Position Values

To establish the position data reference of an encoder with distance-coded reference marks to the axis, the position of the axis zero point related to the dedicated point defined on the encoder side (encoder zero point) has to be entered in:

- S-0-0177, Absolute offset 1 (motor encoder)
- S-0-0178, Absolute offset 2 (external encoder)

To do this, the following steps have to be carried out:

1. First set parameters for absolute offset (see above) to value "0":
2. For initial commissioning, set parameters for homing procedure to low values:
   - S-0-0041, Homing velocity (e.g. 10 rpm)
   - S-0-0042, Homing acceleration (e.g. 10 rad/s²)
3. Execute "C0600 Drive-controlled homing procedure command" (S-0-0148), if drive in "AF"

NOTICE **Property damage caused by step change of actual position value!**

⇒ By clearing the command, the original operation mode becomes active again. When the "drive-internal interpolation" mode was set, for example, the drive immediately moves to the value in "S-0-0258, Target position". Take change in actual position value into consideration!

Axis Zero Point and Dedicated Point

After the command was executed, the axis zero point is at the same axis position as the dedicated point, because the absolute offset (S-0-0177/ S-0-0178) was set to the value "0". The actual position value in "S-0-0051, Position feedback value 1" or "S-0-0053, Position feedback value 2" now has absolute reference to this preliminary axis zero point.

Settings for the Axis Zero Point

An axis-side reference point possibly available is not used for establishing the position data reference for distance-coded measuring systems. In order to establish the position reference to the real axis zero point, enter the desired axis-related actual position value of the dedicated point (encoder zero point) in parameter "S-0-0177, Absolute offset 1" or "S-0-0178, Absolute offset 2". The axis-related actual position value of the dedicated point has to be determined:

- Jog axis to desired axis zero point. Enter displayed actual position value in the respective absolute offset parameter with **inverted** sign.

- or -

- Jog axis to actual position value = 0. Axis then is at dedicated point. Determine axis-related position of dedicated point by measuring distance between current position and determined axis zero point. Enter measured distance as axis-related actual position value for dedicated point in respective absolute offset parameter with the correct sign.

After repeated execution of command "C0600 Drive-controlled homing procedure command" (S-0-0148), the actual position values refer to the axis zero point.

Settings for Drive-Controlled Homing Motion

Set the parameter values reduced for initial commissioning to their definite values:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration

To control the setting, execute "C0600 Drive-controlled homing procedure command" again!

☞ The direction of motion during the homing procedure of distance-coded measuring systems can be against the reference travel direction selected in parameter S-0-0147, if the axis is in the "activated" range of the home switch!

For distance-coded encoders, drive-controlled homing can be completed with "stop", "positioning" or "run path":

"Stop" at the End of the Homing Procedure

If the setting "stop" (default setting) was made in "S-0-0147, Homing parameter", the drive stops the axis as soon the controller has detected two neighboring reference marks. The motion range of the axis, depending on the initial position, is the single to double reference mark distance (S-0-0165).

"Positioning" at the End of the Homing Procedure

If the axis, after the dedicated point was detected, is to position to the reference point, this has to be set in parameter S-0-0147. The position can be preset via "S-0-0052, Reference distance 1" or "S-0-0054, Reference distance 2".

☞ When homing distance-coded encoders, the value in S-0-0052/S-0-0054 is insignificant for establishing the position data reference! In this case, it can possibly be used for presetting a homing target position.

NOTICE **Property damage possible at the installation, if the reference point is outside the allowed travel range and the position limit hasn't been activated yet!**

⇒ Make sure that reference point is within the travel range and activate the position limit!

"Run Path" for Homing Procedure

If the setting "run path for homing procedure" was made in "S-0-0147, Homing parameter", the motion range of the axis is always the double reference mark distance (S-0-0165) plus the braking distance for shutting the axis down. The controller therefore can always detect two neighboring reference marks which is required for establishing the position data reference.

☞ "Run path" supports homing of Gantry axes when distance-coded encoders are used for both axes!

Checking the Detection of End of Travel Range

For linear axes with distance-coded measuring system a home switch is required for detecting the end of the travel range. If the home switch is activated at the start of command C0600, the axis slide, to establish the position data reference, has to move against the reference travel direction selected in S-0-0147.

The signal state of the home switch is displayed in parameter "S-0-0400, Home switch".

Procedure for checking the detection of the end of travel range:

- Move axis to "activated" range of home switch
- Start command C0600

  → Axis now must move against reference travel direction, until position data reference has been established.

Possible Error Messages During Drive-Controlled Homing

While command C0600 is executed, the following command errors can occur:

- C0601 Homing only possible with drive enable
- C0602 Distance home switch - reference mark erroneous
- C0606 Reference mark not detected
- C0607 Reference cam input not assigned

NC-controlled homing procedure

Brief Description

Sequence of NC-Controlled Homing

For NC-controlled homing the master (NC control unit) controls the homing motion for searching the dedicated point of the axis. To do this, the master activates the parameter

- S-0-0146, C4300 NC-controlled homing procedure command

and presets the command value for axis motion, according to the active operation mode.

When the drive has detected the dedicated point, it informs the master of this fact and stores the position of the dedicated point. The master then completes the execution of command C4300 and afterwards activates the parameter

- S-0-0171, C4400 Calculate displacement procedure command.

The required displacement of the actual position values is now calculated in the drive controller, in order to establish the reference of the actual position value to the axis zero point.

When the displacement required for establishing the position data reference has been determined, the master completes the execution of command C4400 and then activates the parameter

- S-0-0172, C4500 Displacement to referenced system procedure command.

Drive-internally the actual position value now is changed by the calculated absolute displacement value and thereby the reference of the actual position value to the axis zero point is established. The master has to adjust its command value input to the changed actual position value, before it completes the NC-controlled homing procedure by deactivating command C4500.

Functional Sequence "NC-controlled Homing"

Searching the Dedicated Point, Basic Procedure

After the master has started NC-controlled homing by activating parameter "S-0-0146, C4300 NC-controlled homing procedure command", it has to preset a command value for the drive for the axis motion to identify the dedicated point.

For non-distance-coded encoders, the dedicated point can only be identified, if "S-0-0407, Homing enable" has been set on the master side. If a home switch was connected to the drive controller (setting in parameter S-0-0147), it must additionally be detected as "activated". For distance-coded encoders, the master-side homing enable (S-0-0407) is not required, because the dedicated point can be unequivocally identified by arbitrary neighboring reference marks.

For details on the search for the dedicated point in the case of NC-controlled homing, see section above "Identifying the Dedicated Point by Means of Reference Mark and Home Switch"!

When the drive has found the dedicated point of the encoder selected in "S-0-0147, Homing parameter", this is displayed in parameter "S-0-0408, Reference marker pulse registered". The position of the dedicated point or the detected reference marks is stored:

- For non-distance-coded encoders, the detected dedicated position is stored in parameter "S-0-0173, Marker position A".
- For distance-coded encoders, the first detected reference mark is stored in parameter "S-0-0173, Marker position A", the second one in parameter "S-0-0174, Marker position B".

The correct, time-optimized sequence of the execution of command C4300 requires the following assignments:

- Bit "homing enable" (S-0-0407) in real-time control bit of "S-0-0134, Master control word"
- Bit "reference mark detected" (S-0-0408) in real-time status bit of "S-0-0135, Drive status word"

When the bit "reference mark detected" (S-0-0408) has been set, the master can complete the execution of the command C4300.

Drive-Side Calculation of Actual Position Value Displacement for Zero Point Reference

By master-side activation of parameter "S-0-0171, C4400 Calculate displacement procedure command", the actual position value displacement for the encoder selected in "S-0-0147, Homing parameter" is calculated.

Basis for the calculation of displacement:

- For non-distance-coded encoders, the non-homed actual position value at the dedicated point (S-0-0173) and the values of reference distance 1/2 (S-0-0052/S-0-0054) and reference offset 1/2 (S-0-0150/ S-0-0151).
- For distance-coded encoders, the non-homed actual position values of the detected reference marks (S-0-0173 and S-0-0174) and the values of "S-0-0177, Absolute offset 1" (motor encoder) or "S-0-0178, Absolute offset 2" (external encoder).

The calculated displacement value is displayed in

- S-0-0175, Offset parameter 1 (motor encoder)

- or -

- S-0-0176, Offset parameter 2 (external encoder).

When the required displacement of the actual position value has been determined, the master can complete the execution of the command C4400.

☞ It would also be possible to calculate the displacement on the master side and directly preset it for the drive via the parameters S-0-0175 or S-0-0176. In this case the execution of command C4400 wouldn't be required!

Displacement of Actual Position Value for Zero Point Reference

To switch the actual position values to axis reference, the master now activates the parameter "S-0-0172, C4500 Displacement to referenced system procedure command". The displacement of the actual position value for the encoder selected in "S-0-0147, Homing parameter" is thereby carried out.

The calculated displacement value (S-0-0175 or S-0-0176) is now added to the non-homed actual position value; the new actual position value is displayed in:

- S-0-0051, Position feedback value 1

- or -

- S-0-0053, Position feedback value 2.

The homing status of the encoders connected to the drive is also displayed in parameter "S-0-0403, Position feedback value status". By means of this parameter the master recognizes when the position command value is to be switched to axis reference. When the switching to the homed position command value was carried out, the master indicates this to the drive in parameter "S-0-0404, Position command value status". The drive then signals the execution of command C4500 to have been completed and the master on its part can complete the execution of command C4500.

The correct, time-optimized execution of the command C4500 requires the following assignments:

- Position command value status bit (S-0-0404) in real-time control bit of "S-0-0134, Master control word"
- Reference encoder status bit (S-0-0403) in real-time status bit of "S-0-0135, Drive status word"

For information on the actual position value after establishing the position data reference for motor encoder and external encoder, see the section "General Information on Establishing the Position Data Reference"

Notes on Commissioning

Settings for NC-Controlled Homing

Apart from general settings (encoder selection, "activated" signal of home switch), further specific settings for NC-controlled homing have to be made in "S-0-0147, Homing parameter":

- Setting for whether home switch is connected to drive or master (NC control unit)
- Setting for activation of dedicated point detection:
  – Master-side homing enable

  \- or -

  – master-side homing enable and "activated" signal of home switch (for this purpose, home switch has to be connected to drive)

Axis-Related Settings for Establishing the Position Data Reference

The following axis-related parameter values have to be determined for relative, non-distance-coded measuring systems:

- S-0-0052, Reference distance 1
- S-0-0054, Reference distance 2
- S-0-0150, Reference offset 1
- S-0-0151, Reference offset 2

The following axis-related parameter values have to be determined for relative, distance-coded measuring systems:

- S-0-0177, Absolute offset 1
- S-0-0178, Absolute offset 2

Depending on the kind of reference mark of the encoder, the axis-related parameter settings for establishing the position data reference are explained in the following sections:

- "Notes on Commissioning for Drive-Controlled Homing with Relative Encoders (Reference Marks Non-Distance-Coded)", see above
- "Notes on Commissioning for Drive-Controlled Homing with Relative Encoders with Distance-Coded Reference Marks", see above

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☞ The axis-related settings for establishing the position data reference are basically the same for drive-controlled and NC-controlled homing! For determining the axis-related parameter values, it is advantageous to use "drive-controlled homing"!

Searching for the Dedicated Point

The master starts "C4300 NC-controlled homing procedure command" and sets the command value for the homing motion (if drive in "AF").

Detection of dedicated point takes place when:

- Homing enable (S-0-0407) has been set

\- or -

- "S-0-0407, Homing enable" has been set and the home switch is in the "activated" status (S-0-0400)

For non-distance-coded encoders, the non-homed position of the detected dedicated point is stored in:

- S-0-0173, Marker position A

For distance-coded encoders, the non-homed position of the detected dedicated reference marks is stored in:

- S-0-0173, Marker position A

  → First detected distance-coded reference mark

- S-0-0174, Marker position B

  → Second detected distance-coded reference mark

When the dedicated point was detected, this is displayed by a bit in parameter "S-0-0408, Reference marker pulse registered" and the master then completes the execution of command C4300.

Drive-Side Calculation of Actual Position Value Displacement for Zero Point Reference

The master starts "C4400 Calculate displacement procedure command" (S-0-0171).

The calculated displacement value is displayed in the following parameters:

- S-0-0175, Offset parameter 1 (motor encoder)
- S-0-0176, Offset parameter 2 (external encoder)

When the required displacement of the actual position value has been determined, the master completes the execution of the command C4400.

☞ It is also possible to calculate the displacement on the master side and directly preset it for the drive via the parameters S-0-0175 or S-0-0176. In this case, the execution of the drive command C4400 is not required!

Actual Position Value Displacement for Zero Point Reference

The master starts "C4500 Displacement to referenced system procedure command" (S-0-0172).

The calculated displacement value (S-0-0175 or S-0-0176) is now added to the non-homed actual position value; the new actual position value is displayed in the following parameters:

- S-0-0051, Position feedback value 1
- S-0-0053, Position feedback value 2

The actual position values thereby change from a non-homed to a homed value, because the corresponding displacement value was taken into account.

When the reference of the encoder selected in parameter S-0-0147 is displayed in "S-0-0403, Position feedback value status", the master changes the position command value from the non-homed value to the homed value:

- P-0-0047, Position command value control

In parameter "S-0-0404, Position command value status", the master at the same time signals the homed status of the position command value to the drive and completes the execution of command C4500.

Possible Error Messages During NC-Controlled Homing

While NC-controlled homing is executed, the following command errors can occur:

- C4302 Distance home switch - reference mark erroneous

- C4304 Homing impossible with absolute encoder
- C4306 Reference mark not detected
- C4307 Reference cam input not assigned

Shifting the Position Data Reference for Absolute/Relative Measuring Systems (Shift Coordinate System Procedure)

Brief Description

Fields of Application

Base package of all firmware variants in **open-loop** and **closed-loop** characteristic

The existing position data reference of the measuring systems to the axis can be shifted if the respective command was activated by the master. It is possible to shift the data reference in standstill or while the axis is moving. This does not affect the position reference of the axis because it is only the actual position values output for the master that are displayed in "shifted" form. Internally the original ("non-shifted") position data reference is maintained.

Shifting the position data reference affects the motor encoder and, if available, the external encoder, independent of which encoder is the active encoder for position control. If different actual position values are valid for the encoders (both encoders possibly have position data reference independent of each other), the actual position values of both measuring systems are shifted by the same difference.

Pertinent Parameters

- S-0-0197, C3300 Set coordinate system procedure command
- S-0-0198, Initial coordinate value
- S-0-0199, C3400 Shift coordinate system procedure command
- S-0-0275, Coordinate offset value
- S-0-0283, Current coordinate offset

Pertinent Diagnostic Messages

- C3300 Set coordinate system procedure command
- C3400 Shift coordinate system procedure command
- C0600 Drive-controlled homing procedure command

Functional Description

Operating Principle of Function "Shifting Position Data Reference"

Shifting the position data reference affects the current actual position value of the encoders connected to the drive (motor encoder and external encoder). Whether the current actual position value has position data reference to the axis or not is irrelevant for the shifting of the position data reference! The shifting is carried out on the drive-side by means of a command started by the master.

The reference state of the actual position values is not affected by the shifting of the position data reference!

If the position data reference is shifted several times in succession without the drive having been switched to communication phase 2, the shifted values act in an additive way! The total offset with regard to the original actual position value is stored in parameter "S-0-0283, Current coordinate offset".

Resetting "Shifting Position Data Reference"

The offset of the position data reference is reset by switching the drive to communication phase 2. Therefore, there cannot be any active offset of position data reference when the drive is switched on the first time, because former offsets are cleared when the drive is switched off.

After resetting the offset by switching to communication phase 2 the position data reference has to be established again for relative measuring systems, if necessary!

Establishing Position Data Reference for "Shifted" Measuring System

If the position data reference of the encoders to the axis ("C0300 Set coordinate system procedure command" or "C0600 Drive-controlled homing procedure command") is established after the actual position values have been shifted (value in parameter "S-0-0283, Current coordinate offset" not equal to "0"), the current offset of the coordinate system is cleared and the value "0" is displayed in parameter S-0-0283.

"Set Coordinate System" Command

When the control master triggers the "C3300 Set coordinate system procedure command" (S-0-0197), the drive becomes independent of the command values preset by the master and goes to standstill in a drive-controlled way. Deceleration takes place according to the "A0010 Drive HALT" function.

See also diagnosis description "A0010 Drive HALT"

In standstill, the actual position value is set to "S-0-0198, Initial coordinate value" and the difference between the new and original actual position value is stored in parameter S-0-0283. The command then is acknowledged as having been "executed".

"Shift Coordinate System" Command

When the control master triggers "C3400 Shift coordinate system procedure command" (S-0-0199), the drive also becomes independent of the command values preset by the master but maintains the current velocity by internal input of the previous velocity command value. The actual position values now are shifted by addition of "S-0-0275, Coordinate offset value". The difference between the new and original actual position values is stored in parameter S-0-0283. The command then is acknowledged as having been "executed".

Action of Control Unit after Command Acknowledgment

After the command acknowledgment the control master has to adjust to the shifted actual position values. This can be done by means of the actual position values of the encoder active for position control (S-0-0051 or S-0-0053) or the current offset value (S-0-0283). When the control master has adjusted its command values to the new actual position values, it can clear the command. The master then sets the command values again. In spite of the actual position value having been shifted with the drive active, there is no jerk when controlled!

Change in Position Data by "Shifting Position Data Reference"

Measured position values, generated by probe evaluation, for example, refer to the actual position value system in which they were measured, i.e.:

- When measured after the shifting, they refer to the "shifted" measuring system.
- When measured before the shifting, they refer to the original measuring system.

Command values (cyclic command values, target position, spindle angle position etc.) have to refer to the current actual position value system, i.e. to the possibly shifted position data reference.

Unchanged Position Data after "Shifting Position Data Reference"

Travel range limit values (S-0-0049 or S-0-0050) and **position correction values** (e.g. axis error correction values) are always in their original position data reference, i.e. the control unit, before writing these parameters, has to take the current offset into account and calculate the original position reference again.

Notes on Commissioning

Shifting the position data reference during commissioning can cause incorrect command values after the shifting has been carried out! Commissioning basically makes sense only in conjunction with the control master. Check whether the command value handling of the master is correct!

NOTICE	Property damage caused by error in command value input after shifting the position data reference!

⇒ Protect the travel range of the axis, activate axis limit switches and make sure they are working!

"Set Coordinate System"

It is recommended to begin with "set coordinate system procedure". But first the parameter "S-0-0283, Current coordinate offset" should be read. When the shifting of the position data reference has not yet been carried out after the transition from "P2" to "AF", the value has to be "0"!

With master-side command value input, the "S-0-0197, C3300 Set coordinate system procedure command" has to be started by the master.

See also "Command Processing"

Checking the Offset of Position Data Reference

When the command was acknowledged by the drive, the offset of the position data reference has to be checked:

- The actual position value (S-0-0051 and possibly S-0-0053) must correspond to "S-0-0198, Initial coordinate value".
- The parameter "S-0-0283, Current coordinate offset" has to be read. With value unequal "0" shifting took place; with value "0" shifting either has not taken place or the actual position value of the axis approximately equaled the value of S-0-0198 when the position data reference was shifted.

Checking the Command Value Input and Clearing the Command

To check the command value input the master has to preset a position command value that corresponds to the value of parameter S-0-0198. Before the master resets the executed command, it is necessary to check whether the master-side command value corresponds to the current actual position value of the encoder active in position control (S-0-0051 or S-0-0053, shifted position data reference). If not, do not clear the command but reset "AF", if necessary, and search for the cause of the incorrect command value!

"Shift Coordinate System Procedure"

With "shift coordinate system procedure" it is recommended to control the axis on the master-side with velocity command value "0" or with very low velocity. In this context, you must, however, first read parameter "S-0-0283, Current coordinate offset". When the shifting of the position data reference has not yet been carried out after the transition from "P2" to "AF", the value has to be "0"!

Subsequently, start "C3400 Shift coordinate system procedure command" on the master side.

See also "Command Processing"

Checking the Offset of Position Data Reference

When the command was acknowledged by the drive, the offset of the position data reference has to be checked:

- The values of "S-0-0283, Current coordinate offset" and "S-0-0275, Coordinate offset value" have to correspond.

Checking the Command Value Input and Clearing the Command

Before the master resets the executed command, it is necessary to check whether the master-side command value corresponds to the current actual position value of the encoder active in position control (S-0-0051 or S-0-0053, shifted position data reference). If not, do not clear the command but reset "AF", if necessary, and search for the cause of the incorrect command value!

Detecting the marker position

Brief Description

Base package of all firmware variants in **closed loop** characteristic.

With the "detect marker position" function, which is activated via the corresponding command, it is possible to check whether the reference mark of an incremental measuring system is detected without error.

A possibly available home switch is not evaluated with this function!

Pertinent Parameters

- S-0-0173, Marker position A
- P-0-0014, C1400 Command Get marker position

Pertinent Diagnostic Messages

- C1400 Command Get marker position

Functional Description

After the start of "P-0-0014, C1400 Command Get marker position", the following actions are performed:

- The diagnostic message "C1400 Command Get marker position" is generated.
- If an incremental measuring system was selected, the search for reference marks is activated and the drive waits for reaching the next reference mark.
- When a reference mark is detected (i.e., the drive passes the position of a reference mark), the actual position value of this mark is stored in parameter "S-0-0173, Marker position A" and then the command execution is signaled to be completed.

The drive does not generate any command value. The operation mode active at the start of the command remains unchanged. In order to pass the reference mark, the control master has to preset such command values (e.g., by means of jogging) that lead to a motion in direction of the reference mark to be detected.

In parameter "S-0-0173, Marker position A", the position of the reference mark is also stored during the execution of the "C0600 Drive-controlled homing procedure command" (S-0-0148). This position, however, refers to the "old" coordinate system (before switching the coordinate system when executing the homing procedure).

5.7 Mechanical Axis System and Arrangement of Measuring Systems

5.7.1 Brief Description

Motor Encoder

Controlled motor activation requires a position measurement system that measures the current rotor position or the position of the moving part as opposed to the static part of the motor.

This position measurement is required for the

- Current control loop
- Velocity control loop
- Position control loop, if applicable

The precision and resolution of the position measurement is decisive for the quality of the actual values, especially in the velocity and position control loop.

External Encoders

Depending on the mechanical properties of the mechanical system between motor output shaft and machine axis, it might be required to carry out the position control by means of an external position encoder (not integrated in the motor) directly at the moving part of the axis, e.g. in the case of

- mechanical system with slip,
- gear backlash or a low degree of stiffness of the mechanical system, etc.

The external (optional) encoder can also be used as a measuring wheel encoder (frictionally engaged on transported material).

See "Measuring Wheel Mode"

For information on encoder evaluation and encoder monitoring see also "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems"

Motor Encoders of Rexroth Housing Motors

Rexroth housing motors have integrated position measuring systems:

- EnDat2.1 encoder with 2048 increments for high precision requirements
- HIPERFACE® encoder with 128 increments for lower precision requirements

They are optionally available as

- relative measuring system ("single-turn motor encoder")

or

- absolute measuring system ("multi-turn motor encoder", range of values ±4096 motor revolutions).

The measuring systems of Rexroth housing motors support the commissioning, because the data for encoder type and resolution are stored in the encoder. They are loaded to the controller when the controller is switched on.

Motor Encoders for Rexroth Kit Motors and Third-Party Motors

Rexroth kit motors are supplied as individual components and assembled in the machine to form the motor. It consists of a moving and a static part, the bearing and the motor encoder.

The following measuring systems can be used as a motor encoder:

- Incremental encoders with sine signals (compatible with signal specification of Heidenhain)
- Encoders with EnDat2.1 interface from Heidenhain

- Encoders with HIPERFACE® interface by Stegmann, [IndraDrive-compatible HIPERFACE® encoders (DE_EN_FAQ_IndraDrive_unterstützte_Geber...) or HIPERFACE® encoders with "0xFF" type ID].
- Incremental encoders with square-wave signals (compatible with signal specification of Heidenhain)

Do not use incremental encoders with square-wave signals as motor encoders. Bad drive characteristics are to be expected.

The mentioned measuring systems can be used as motor encoders for third-party kit motors and third-party housing motors.

For synchronous kit motors or synchronous third-party motors, it is recommended that the measuring system used as a motor encoder can be evaluated in absolute form so that the commutation offset of the motor must be determined only once (during initial commissioning) (see also "Absolute Measuring Systems").

Motor Encoders with Gearbox

Especially with rotary kit motors it is sometimes impossible to connect the motor encoder directly to the motor shaft. IndraDrive provides the possibility to evaluate a motor encoder connected via a gear.

For synchronous motors in combination with a motor encoder which can be evaluated in absolute form, the advantage of setting the commutation offset only once (see above) can only be used with an encoder gear with i = "1" or when there is no encoder gear available.

As of MPx16V04:

In two special cases, however, for synchronous motors with encoder gear and a motor that can be evaluated in absolute form (rotary encoders only) the commutation setting is performed only during initial commissioning. Then, when the drive is switched on again, it is immediately ready for operation; automatic commutation setting for initial drive enabling (AF) is not required, so it is not performed in the following cases:

Case 1, Single-turn (or multi-turn) encoder:

- if an n-fold motor revolution (n is an integer) yields exactly one encoder revolution

Case 2, Multi-turn encoder:

- if exactly one motor revolution yields an m-fold encoder revolution (m is an integer)

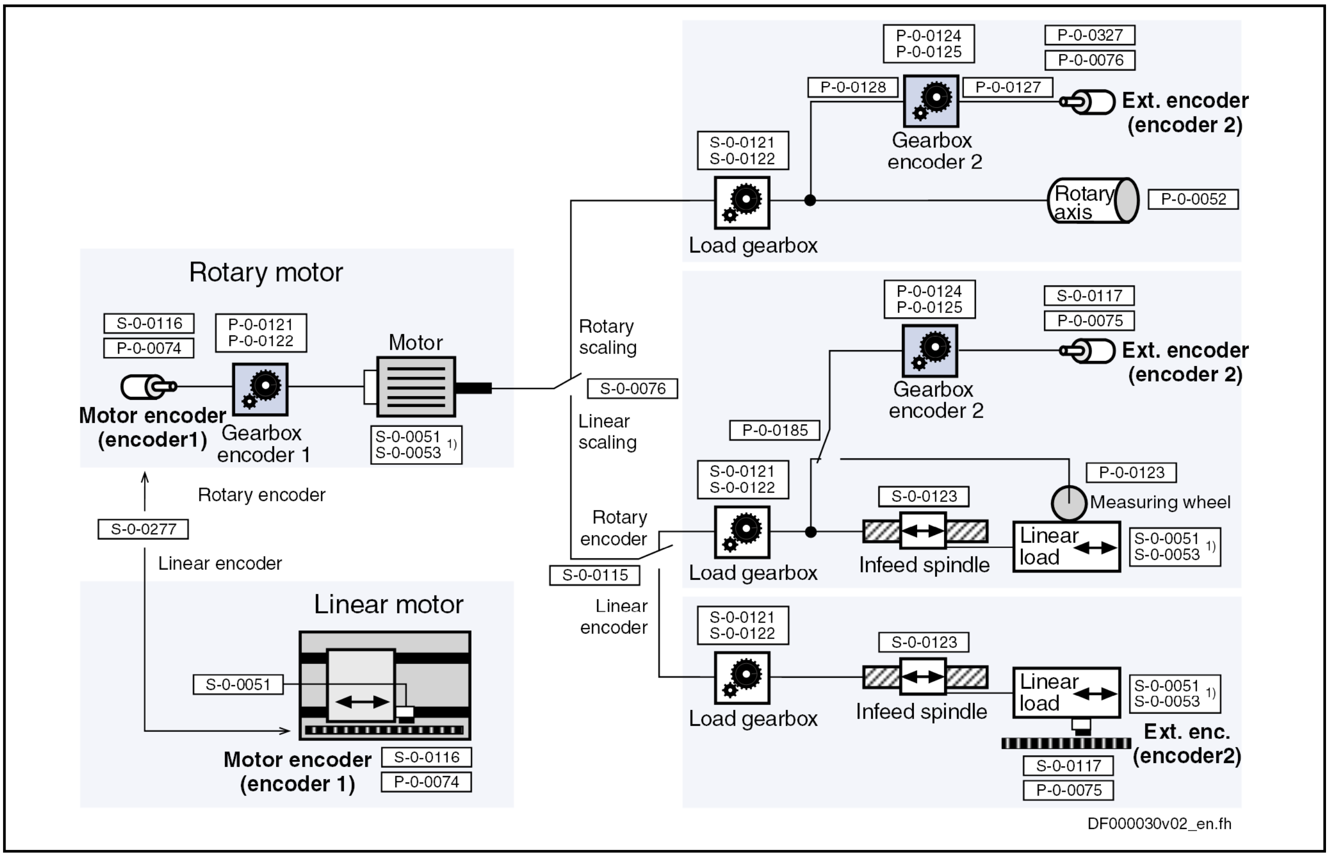
External Encoders at Machine Axes

IndraDrive controllers can evaluate the following measuring systems as external encoders:

- Incremental encoders with sine signals (compatible with signal specification of Heidenhain)
- Encoders with EnDat2.1 interface from Heidenhain
- Encoders with HIPERFACE® interface by Stegmann, [IndraDrive-compatible HIPERFACE® encoders (DE_EN_FAQ_IndraDrive_unterstützte_Geber...) or HIPERFACE® encoders with "0xFF" type ID].
- Incremental encoders with square-wave signals (compatible with signal specification of Heidenhain)

Possibilities of Arranging Measuring Systems

The figure below shows an overview of arrangement possibilities of mechanical drive system and measuring systems.



1)	S-0-0051 or S-0-0053, depending on scaling (S-0-0076)
S-0-0051	Position feedback 1 value
S-0-0053	Position feedback 2 value
S-0-0076	Position data scaling type
S-0-0115	Position feedback 2 type
S-0-0116	Resolution of feedback 1
S-0-0117	Resolution of feedback 2
S-0-0121	Input revolutions of load gear
S-0-0122	Output revolutions of load gear
S-0-0123	Feed constant
S-0-0277	Position feedback 1 type
P-0-0074	Encoder type 1 (motor encoder)
P-0-0075	Encoder type 2 (optional encoder)
P-0-0121	Gear 1 motor-side (motor encoder)
P-0-0122	Gear 1 encoder-side (motor encoder)
P-0-0124	Gear 2 load-side (optional encoder)
P-0-0125	Gear 2 encoder-side (optional encoder)
P-0-0123	Feed constant 2 (optional encoder)
P-0-0185	Control word of encoder 2 (optional encoder)

Fig. 5-77: Overview of Arrangement Possibilities of Mechanical Drive System and Measuring Systems

Hardware Requirements

For connecting the measuring systems to the controller there are 2 optional interfaces available. The parameters "P-0-0077, Assignment motor encoder->optional slot" and "P-0-0078, Assignment optional encoder->optional slot" define the interface to which the respective encoder is connected.

Pertinent Parameters

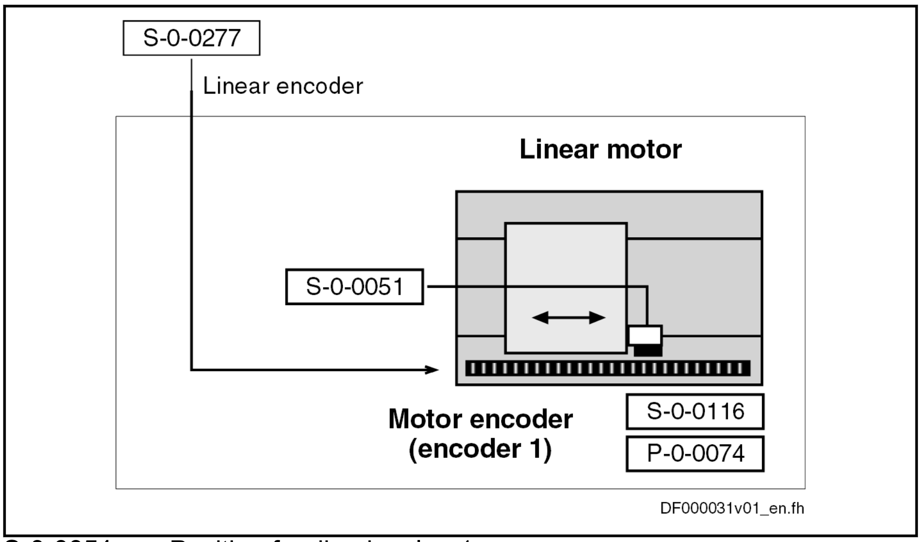
- S-0-0115, Position feedback 2 type
- S-0-0121, Input revolutions of load gear
- S-0-0122, Output revolutions of load gear
- S-0-0123, Feed constant
- S-0-0277, Position feedback 1 type
- P-0-0121, Gear 1 motor-side (motor encoder)
- P-0-0122, Gear 1 encoder-side (motor encoder)
- P-0-0123, Feed constant 2 (optional encoder)
- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)
- P-0-0185, Control word of encoder 2 (optional encoder)

5.7.2 Functional Description

Motor Encoder

The motion type of the motor encoder can either be rotary or linear. The controller is told this via parameter "S-0-0277, Position feedback 1 type".

When "linear motor encoder" is set in parameter "S-0-0277, Position feedback 1 type", the encoder 1 gearbox parameters are inactive, the actual position value reference (parameter "S-0-0076, Position data scaling type") has to be set to "motor-related" and "linear". As the actual position values are determined directly at the moving part of the axis, it does not make sense to use another external encoder!



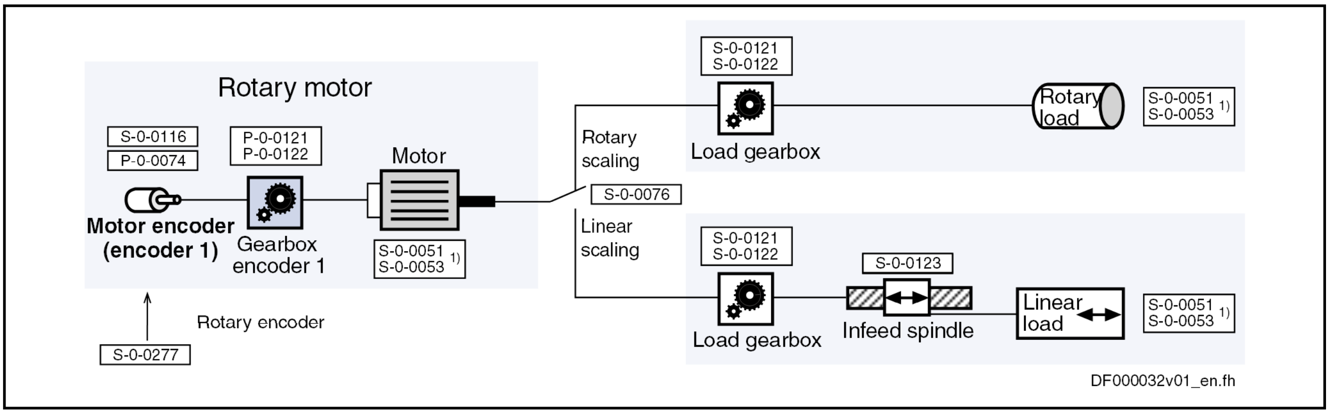
S-0-0051	Position feedback value 1
S-0-0116	Resolution of feedback 1
S-0-0277	Position feedback 1 type
P-0-0074	Encoder type 1 (motor encoder)

Fig. 5-78: Motor Encoder Arrangement for Drive with Linear Motor

When "rotary motor encoder" has been set, the controller assumes an application with a rotary motor. This means:

- In the case of rotary kit motors, the motor encoder can be connected via a gearbox; Rexroth housing motors have a direct motor encoder connection.
- The load side of the drive can be rotary or linear (S-0-0076).

Motor, Mechanical Axis System, Measuring Systems



1)	S-0-0051 or S-0-0053, depending on scaling (S-0-0076)
S-0-0051	Position feedback value 1
S-0-0053	Position feedback value 2
S-0-0076	Position data scaling type
S-0-0116	Resolution of feedback 1
S-0-0121	Input revolutions of load gear
S-0-0122	Output revolutions of load gear
S-0-0123	Feed constant
S-0-0277	Position feedback 1 type
P-0-0074	Encoder type 1 (motor encoder)
P-0-0121	Gear 1 motor-side (motor encoder)
P-0-0122	Gear 1 encoder-side (motor encoder)

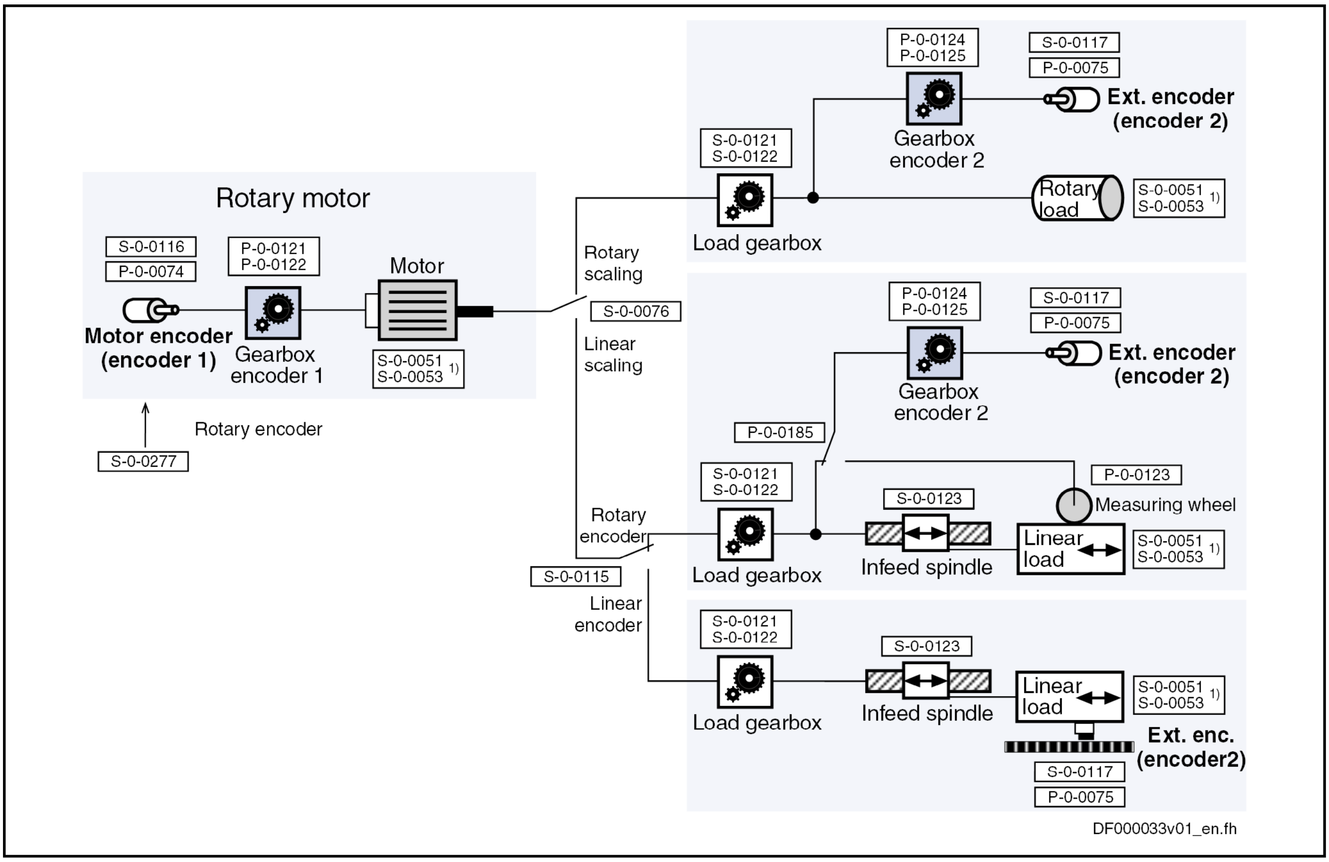
Fig. 5-79: Possible Drive Arrangements with Rotary Motor (without External Encoder)

External encoder

For drives with rotary motor, a rotary or linear load-side (external) encoder can be necessary, depending on the application:

- A rotary external encoder can be connected to the load via an encoder gearbox.
- A linear external encoder determines the actual position value directly at the linear load.

For drives with linear motor, no external encoder is possible!



1)	S-0-0051 or S-0-0053, depending on scaling (S-0-0076)
S-0-0051	Position feedback value 1
S-0-0053	Position feedback value 2
S-0-0076	Position data scaling type
S-0-0115	Position feedback 2 type
S-0-0116	Resolution of feedback 1
S-0-0117	Resolution of feedback 2
S-0-0121	Input revolutions of load gear
S-0-0122	Output revolutions of load gear
S-0-0123	Feed constant
S-0-0277	Position feedback 1 type
P-0-0074	Encoder type 1 (motor encoder)
P-0-0075	Encoder type 2 (optional encoder)
P-0-0121	Gear 1 motor-side (motor encoder)
P-0-0122	Gear 1 encoder-side (motor encoder)
P-0-0124	Gear 2 load-side (optional encoder)
P-0-0125	Gear 2 encoder-side (optional encoder)
P-0-0123	Feed constant 2 (optional encoder)
P-0-0185	Control word of encoder 2 (optional encoder)

Fig. 5-80: Possible Drive Arrangements with Rotary Motor and External Encoder

5.7.3 Notes on Commissioning

☞ The Notes on Commissioning in the sections "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems" must be observed, too!

Basic Settings

Set "linear" or "rotary" encoder type:

- S-0-0277, Position feedback 1 type

Enter encoder type, hardware assignment and resolution:

- S-0-0116, Resolution of feedback 1
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0077, Assignment motor encoder->optional slot

Settings for Rotary Motor

Enter motor encoder gear ratio:

- P-0-0121, Gear 1 motor-side (motor encoder)
- P-0-0122, Gear 1 encoder-side (motor encoder)

Enter load gear ratio:

- S-0-0121, Input revolutions of load gear
- S-0-0122, Output revolutions of load gear

For linear axes, enter the feed constant:

- S-0-0123, Feed constant

Settings for External Encoder

Set "linear" or "rotary" encoder type:

- S-0-0115, Position feedback 2 type

Enter encoder type, hardware assignment and resolution:

- P-0-0075, Encoder type 2 (optional encoder)
- P-0-0078, Assignment optional encoder->optional slot
- S-0-0117, Resolution of feedback 2

Enter gear ratio for the external (optional) encoder:

- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)

Settings for Measuring Wheel Encoder

Activate feed constant for measuring wheel:

- P-0-0185, Control word of encoder 2 (optional encoder)

Enter feed constant for measuring wheel:

- P-0-0123, Feed constant 2 (optional encoder)

5.8 Scaling of Physical Data

5.8.1 Brief Description

The controller via data maps the drive to an internal mathematical model. The status variables of the drive are determined on the basis of the following measurements:

- Position measurement
- Current measurement
- Temperature measurement

The measured values collected in this way are converted into physical data:

- Position, velocity, acceleration and jerk data
- Current data, torque and force data
- Temperature data and load data

The master transmits command values to the drive that are used by the controller for transforming them at the motor output shaft or mechanical axis system. The drive in return registers and transmits actual values, signals operating and command states and, if necessary, generates error messages and warnings.

Communication between drive and master also takes place by exchanging data.

Scaling

An operating data (numeric value) can only be evaluated as a physical value, when the numeric value is connected to a physical unit and the position of the decimal point (decimal places). The data thereby is "scaled" in a qualitative and quantitative way.

Parameters

All data are stored in parameters and transmitted as parameter values (for explanations regarding parameters see "Parameters, Basics"). The scaling of the parameters containing data of the following physical values can be defined by the customer:

- Position
- Velocity
- Acceleration
- Torque/force
- Temperature

Preferred Scaling/Parameter Scaling

To simplify the scaling definition so-called "preferred scalings" were predefined. Physical data, however, can also be exchanged in the control-internal format, i.e. without specific reference to physical units. For this purpose, the scaling for certain data can be freely set ("parameter scaling").

Linear and Rotary Data

Depending on the kind of motion of motor or load, the data can be displayed as follows:

- In linear form (linear axis or motor motion)

- or -

- In rotary form (rotary axis or motor motion)

Motor Reference/Load Reference

In the drive firmware there are mechanical transfer elements between motor and load mapped by means of mathematical models. The physical data can thereby be referred to

- the point where the load takes effect (load-side data reference)

- or -

- the point where the force is input (motor-side data reference).

Absolute/Modulo Evaluation

For technical reasons, the value range of the position data the controller can display is limited.

For axes with limited travel range (e.g. linear axes), the current axis position within the controller-side value range can be unambiguously displayed (see "Basics on Measuring Systems, Resolution").

For axes with an unlimited travel range (e.g. rotary axes), it is useful to limit the infinite value range of the position data to a finite value. With continuous motion, the value range is recurrently run from minimum to maximum value ("modulo" evaluation of the actual position value).

Pertinent Parameters

- S-0-0043, Velocity polarity parameter
- S-0-0044, Velocity data scaling type
- S-0-0045, Velocity data scaling factor
- S-0-0046, Velocity data scaling exponent
- S-0-0055, Position polarities
- S-0-0076, Position data scaling type
- S-0-0077, Linear position data scaling factor
- S-0-0078, Linear position data scaling exponent

- S-0-0079, Rotational position resolution
- S-0-0085, Torque/force polarity parameter
- S-0-0086, Torque/force data scaling type
- S-0-0093, Torque/force data scaling factor
- S-0-0094, Torque/force data scaling exponent
- S-0-0103, Modulo value
- S-0-0121, Input revolutions of load gear
- S-0-0122, Output revolutions of load gear
- S-0-0123, Feed constant
- S-0-0160, Acceleration data scaling type
- S-0-0161, Acceleration data scaling factor
- S-0-0162, Acceleration data scaling exponent
- S-0-0208, Temperature data scaling type

5.8.2 Functional Description

Position, Velocity and Acceleration Data

For position, velocity and acceleration data, there are the following basic scaling types:

- Linear
- Rotary

It is possible to choose between preferred scaling (predefined scaling) and parameter scaling (scaling can be individually defined).

Preferred Scalings (Predefined)

Depending on the scaling type setting, there are the following predefined preferred scalings:

	Preferred scaling		
	Linear	Linear	Rotary
Physical Data	for unit "m"	for unit "inch"	
Position data	0.0000 in	0.000001 in	0.0001 dgr
Velocity data	0.000 in/min	0.00001 inch/min	0.0001 1/min or 0.000001 1/s

Tab. 5-23: Overview: Preferred Scalings for Position Data and Velocity Data

	Preferred scaling			
	Linear	Linear	Rotary	Ramp time
Physical Data	for unit "m"	for unit "inch"	Unit "rad"	Unit "s"
Acceleration data	0.000 in/s^2	0.00001 inch/s^2	0.001 rad/s^2	0.001 s
Jerk data	0.000000 in/s^3	0.00001 inch/s^3	0.001 rad/s^3	0.001 s^2

Tab. 5-24: Overview: Preferred Scalings for Acceleration Data and Jerk Data

☞ The jerk data scaling is derived from the acceleration data scaling.

To be Noticed: Ramp Time Scaling Type

The acceleration data can also be scaled with reference to a velocity ramp:

$$\text{reference vel. ramp} = \frac{\text{S-0-0446}}{\text{ramp reference time}} = \frac{\text{S-0-0446}}{1.0\ \text{ms}} \quad \text{(with preferred scaling)}$$

S-0-0446 Ramp reference velocity for acceleration data

Fig. 5-81: Definition of the Velocity Reference Ramp for Scaling Acceleration Data in the Case of Preferred Scaling

Settings for Preferred Scaling

The scaling types, units and the selection of preferred scaling are determined in the respective bits of the following parameters:

- S-0-0076, Position data scaling type
- S-0-0044, Velocity data scaling type
- S-0-0160, Acceleration data scaling type

When using preferred scaling, the parameter values for scaling type, unit, scaling factor and scaling exponent as well as the number of decimal places are automatically set for the respective data. The following tables contain an overview.

Physical data	Scaling type	Unit	S-0-0076	S-0-0077	S-0-0078	Attribute number of decimal places
Position data	Linear	mm	..xx00.0001	1	-7	4
	Linear	inch	..xx01.0001	1	-6	6
	Rotary	dgr	..xx00.0010	1	-4	4

S-0-0076 Position data scaling type
S-0-0077 Position data scaling factor
S-0-0078 Position data scaling exponent

Tab. 5-25: Values of Scaling Parameters and Decimal Places of Position Data Determined by Preferred Scaling

Physical data	Scaling type	Unit	S-0-0044	S-0-0045	S-0-0046	Attribute number of decimal places
Velocity data	Linear	mm/min	..0x00.0001	1	-6	3
	Linear	inch/min	..0x01.0001	1	-5	5
	Rotary	1/min	..0x00.0010	1	-4	4
	Rotary	1/s	..0x10.0010	1	-6	6

S-0-0044 Velocity data scaling type
S-0-0045 Velocity data scaling exponent
S-0-0046 Velocity data scaling exponent

Tab. 5-26: Values of Scaling Parameters and Decimal Places of Velocity Data Determined by Preferred Scaling

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Physical data	Scaling type	Unit	S-0-0160	S-0-0161	S-0-0162	Attribute number of decimal places
Acceleration data	Linear	mm/s^2	..0x00.0001	1	-6	3
	Linear	$inch/s^2$	..0x01.0001	1	-5	5
	Rotary	rad/s^2	..0x00.0010	1	-3	3
	Ramp time	s	..0x00.0011	1	-3	3

S-0-0160 Acceleration data scaling type
S-0-0161 Acceleration data scaling factor
S-0-0162 Acceleration data scaling exponent

Tab. 5-27: Values of Scaling Parameters and Decimal Places of Acceleration Data Determined by Preferred Scaling

☞ For practical reasons, the metric measures of length in the case of preferred scaling are scaled in "mm". This when reading the respective parameter can also be seen from the corresponding "unit" data element. The decimal places are adjusted to the current unit.

Parameter Scaling (Individually Defined)

As an alternative to preferred scaling, it is possible to activate parameter scaling. For parameter scaling, the least significant bit (LSB) of the respective operating data can be individually defined.

☞ By means of parameter scaling, it is possible to modify the range of values of physical data!

Example: The maximum value for "S-0-0278, Maximum travel range" can be increased by reducing the number of decimal places of the position data.

position data, linear	$LSB = unit^{1)} \times scaling\ factor^{1)} \times 10^{SE}$
position data, rotary	$LSB = \frac{360}{rotational\ pos.\ resolution^{2)}} \times unit^{2)}$
velocity data	$LSB = \frac{unit\ (position\ data)}{TU} \times scaling\ factor \times 10^{SE}$
acceleration data (linear, rotary)	$LSB = \frac{unit\ (position\ data)}{TU^2} \times scaling\ factor \times 10^{SE}$
acceleration data (ramp time scaling)	$LSB = \frac{S\text{-}0\text{-}0446}{scaling\ factor \times 10^{SE}}$
jerk data	$LSB = \frac{unit\ (position\ data)}{TU^3} \times scaling\ factor \times 10^{SE}$

1) With scaling factor ≠ 1, the unit is no longer indicated as in S-0-0076, but only "incrementally" (control-dependent unit reference).
2) With rotational position resolutions (S-0-0079) which do not result in powers of 10 of 360, the unit is no longer angular degrees (acc. to S-0-0076) but only "incremental" (control-dependent unit reference).
LSB Least significant bit
SE Scaling exponent
TU Time unit
S-0-0446 Ramp reference velocity for acceleration data

Fig. 5-82: Defining the Least Significant Bit (LSB) for Parameter Scaling

☞ The jerk data scaling is derived from the acceleration data scaling.

Respective units of measurement and time defined in the parameters:

- S-0-0076, Position data scaling type
- S-0-0044, Velocity data scaling type
- S-0-0160, Acceleration data scaling type

Respective scaling factor and scaling exponent defined in the following parameters:

- S-0-0077, Linear position data scaling factor
- S-0-0078, Linear position data scaling exponent

- S-0-0045, Velocity data scaling factor
- S-0-0046, Velocity data scaling exponent

- S-0-0161, Acceleration data scaling factor
- S-0-0162, Acceleration data scaling exponent

For rotary position data, the value of the following parameter, in the case of parameter scaling, must be determined for defining the LSB:

- S-0-0079, Rotational position resolution

Torque/Force Data

For torque/force data there are the following basic scaling types:

- Linear
- Rotary
- Percentage-based

It is possible to choose between preferred scaling (predefined scaling) and parameter scaling (scaling can be individually defined). With percentage-based scaling, parameter scaling is not allowed.

Preferred Scalings (Predefined)

Depending on the scaling type setting, there are the following predefined preferred scalings:

Physical value	Preferred scaling, decimal places and ranges of values		
	Linear	Rotary	Percentage-based
Torque	--	0.01 Nm...3270.67 Nm or 0.1 inlbf...3276.7 inlbf	0.1%
Force	1 N...32767 N or 0.1 lbf...3276.7 lbf	--	0.1%

Tab. 5-28: Preferred Scalings for Torque/Force Data

The scaling types and units can be determined in the respective bits of parameter

- S-0-0086, Torque/force data scaling type

Respective scaling factor and scaling exponent defined in the following parameters:

- S-0-0093, Torque/force data scaling factor and
- S-0-0094, Torque/force data scaling exponent

Parameter Scaling (Individually Defined)

As an alternative to preferred scaling, it is possible to activate parameter scaling. For parameter scaling, the least significant bit (LSB) of the respective operating data can be individually defined.

Torque/force data LSB = Unit x scaling factor x 10^{SE}

= Unit x S-0-0093 x $10^{S\text{-}0\text{-}0094}$

There are the following maximum ranges of values for SI units:

Physical value	Parameter scaling with S-0-0093 = "1", S-0-0094 = 0....6; decimal places and ranges of values	
	Linear	Rotary
Torque	--	0.01 Nm...327.67 MNm
Force	1 N...32767 MN or	--

Tab. 5-29: Parameter Scaling with Torque/Force Data, System of SI Units

There are the following maximum ranges of values in the imperial system of units:

Physical value	Parameter scaling with S-0-0093 = "1", S-0-0094 = 0....6; decimal places and ranges of values	
	Linear	Rotary

Torque	--	0.1 inlbf...3276.7 kinlbf
Force	0.1 lbf...3276.7 klbf	--

Tab. 5-30: Parameter Scaling with Torque/Force Data, Imperial System of Units

☞ The number of decimal places remains constant, the abbreviation for the 1000th power of ten (kilo or mega) results in accordance with the value to be displayed.

Temperature Data

For temperature data, only the following units can be selected:

- Degrees Celsius (°C)
- Fahrenheit (F)

☞ For temperature data is it only possible to select preferred scaling (predefined scaling)!

Physical value	Preferred scaling	
	Celsius	Fahrenheit
Temperature	32.18 °F	0.1 F

Tab. 5-31: Preferred Scalings for Temperature Data

Motor Reference/Load Reference

The reference of position, velocity, acceleration, jerk and torque/force data can be selected for:

- Point where the motor force is input ("motor reference") or
- Point where the load takes effect ("load reference").

For this purpose, it is necessary to transmit the data of the mechanical transfer elements between motor, encoders and point where the load takes effect to the controller via the following parameters:

- S-0-0121, Input revolutions of load gear
- S-0-0122, Output revolutions of load gear
- S-0-0123, Feed constant
- S-0-0277, Position feedback 1 type
- S-0-0115, Position feedback 2 type
- P-0-0121, Gear 1 motor-side (motor encoder)
- P-0-0122, Gear 1 encoder-side (motor encoder)
- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)

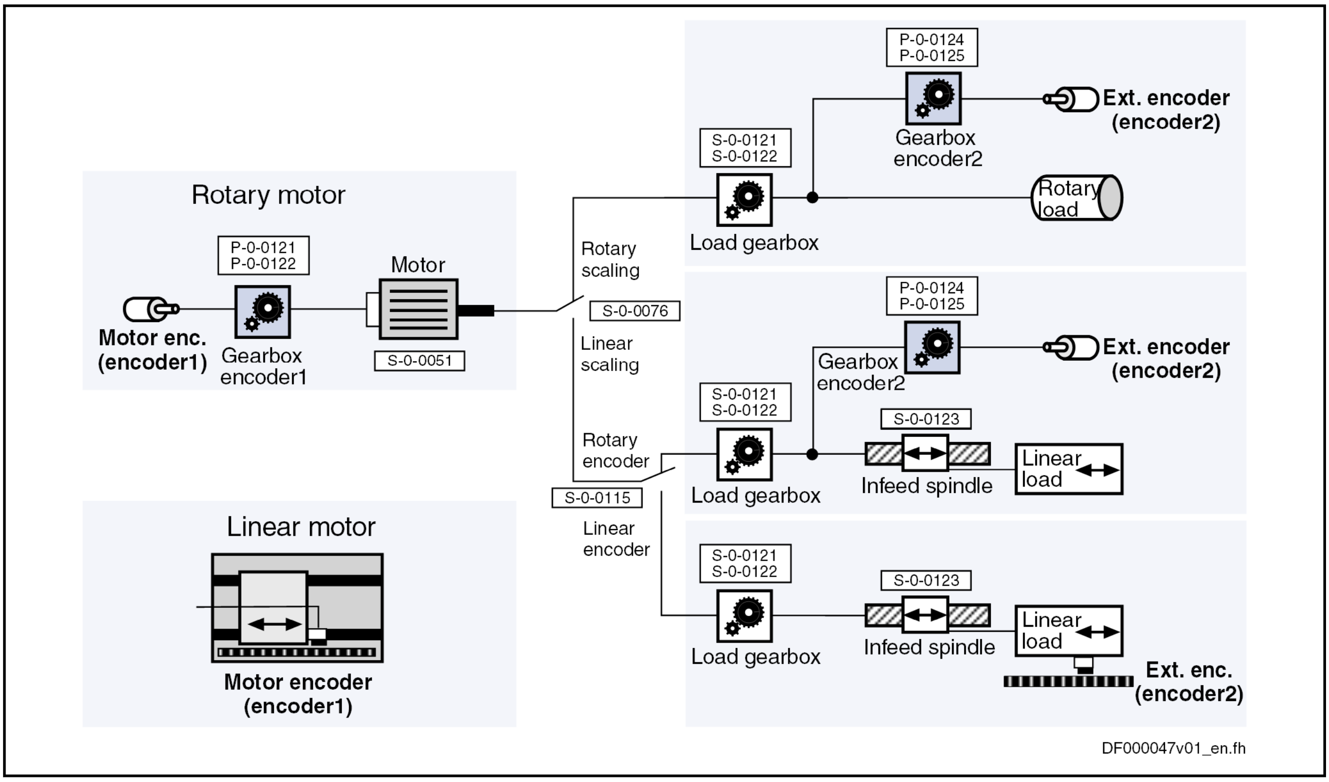


Fig. 5-83: Mechanical Transfer Elements Between Motor, Encoders and Load

☞ For linear motors, the motor reference is the same as the load reference, because the point where the force is input and point where the load takes effect are identical. There aren't any mechanical transfer elements!

Polarity

The polarity of the position, velocity and torque/force data can be changed from positive to negative polarity in the following parameters:

- S-0-0055, Position polarities
- S-0-0043, Velocity polarity parameter
- S-0-0085, Torque/force polarity parameter

Depending on the mounting situation (especially of kit motors and their respective motor encoder or external encoder), this allows determining the appropriate polarity of the respective data for the machine axis.

Modulo Scaling

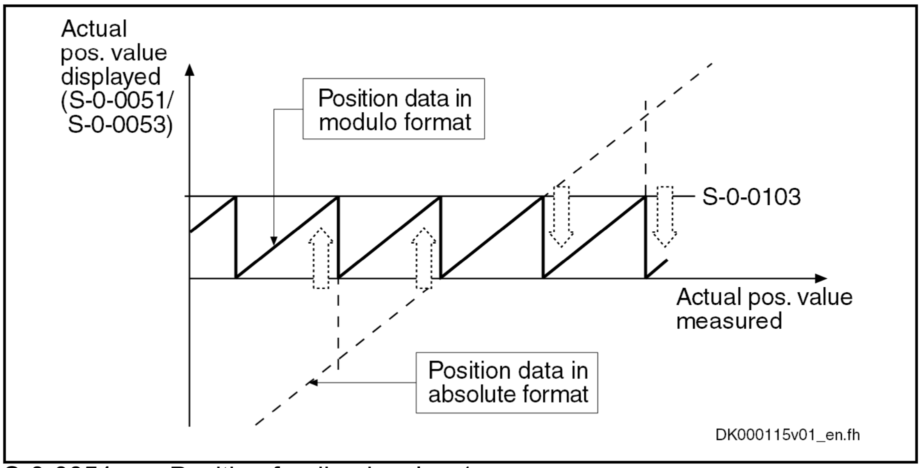
Via the respective bit of "S-0-0076, Position data scaling type", it is possible to select, for the position data format, between two formats:

- Absolute format
- Modulo format

If the position data of an axis with infinite travel range (e.g. rotary axis, spindle etc.) were processed in absolute format, the axis would risk to move beyond the value range of the position data. This would lead to invalid position data; operation modes with position control would not be safe to operate.

The value range for modulo format is limited, only position data between the value 0.00... and a maximum value to be determined in "S-0-0103, Modulo value" are possible.

When the measured actual position value exceeds the value range or falls below it, the actual position value displayed in parameter S-0-0051 or S-0-0053 behaves unsteadily, i.e. it changes by the absolute value of the modulo value range in such a way that the actual position value displayed always remains within the modulo value range.



S-0-0051	Position feedback value 1
S-0-0053	Position feedback value 2
S-0-0103	Modulo value

Fig. 5-84: Actual Position Value for Axis Motion with Constant Velocity for Absolute and Modulo Format

Modulo Format - Requirements

The "modulo format" setting for actual position values is only appropriate for rotary motors, because a mechanically unlimited travel range is only possible for axes with rotary motors. The "modulo format" therefore is only allowed for rotary motors, not for linear motors!

☞ The condition "rotary motor" for selecting "modulo format" is checked when the drive progresses to the ready-for-operation status. If the condition has not been fulfilled, an error is signaled!

Restrictions/Conditions for "Modulo Format"

When using the modulo format, you must observe and comply with the following restrictions and conditions:

- Due to the firmware-internal conversion of absolute format to modulo format, the allowed maximum velocity is as follows:

$$v_{max} = \frac{(S\text{-}0\text{-}0103)}{2\ ms}$$

v_{max}	Maximum velocity or maximum angular velocity
S-0-0103	Modulo value

Fig. 5-85: Allowed Maximum Velocity for Modulo Format

NOTICE **Possible property damage caused by errors when controlling motors and moving parts!**

⇒ The value in "S-0-0091, Bipolar velocity limit value" mustn't be higher than the allowed maximum velocity for modulo format!

- In the case of encoders evaluated in absolute form, the mechanical drive system, with the drive switched off, may as a maximum be moved by a distance or angle corresponding to half the absolute encoder range ("S-0-0378, Absolute encoder range of motor encoder" or "S-0-0379, Drive Halt acceleration bipolar")! The actual position value after switching on can otherwise be incorrect! This, however, cannot be diagnosed on the controller side!

NOTICE **Possible property damage caused by errors when controlling motors and moving parts!**

⇒ Block the mechanical system with drive switched off by self-clamping holding brake or self-locking gearbox!

See also "Absolute Measuring Systems"

- The following conditions must be complied with in the case of rotary modulo scaling:

Scaling type of position data →	Modulo scaling, rotary position reference		
External encoder →	External encoder available		No external encoder available
Type of motion of external encoder →	Rotary	Linear not possible!	
Conditions (No.) to be complied with →	1; 2; 3; 4; 5; 6	---	1; 2; 4; 5
Conditions →	No. 1: S-0-0079 × S-0-0122 ≤ 2^{64}		
	No. 2: S-0-0079 × P-0-0121 × S-0-0122 ≤ 2^{64}		
	No. 3: S-0-0079 × P-0-0124 × S-0-0121 ≤ 2^{64}		
	No. 4: S-0-0103 × P-0-0129 × S-0-0121 ≤ 2^{64}		
	No. 5: S-0-0103 × S-0-0116 × P-0-0122 × S-0-0121 ≤ 2^{64}		
	No. 6: S-0-0103 × S-0-0117 × P-0-0125 × S-0-0122 ≤ 2^{64}		

S-0-0079 Rotational position resolution
S-0-0103 Modulo value
S-0-0116 Resolution of feedback 1
S-0-0117 Resolution of feedback 2
S-0-0121 Input revolutions of load gear
S-0-0122 Output revolutions of load gear
P-0-0121 Gear 1 motor-side (motor encoder)
P-0-0122 Gear 1 encoder-side (motor encoder)
P-0-0124 Gear 2 load-side (optional encoder)
P-0-0125 Gear 2 encoder-side (optional encoder)
P-0-0129 Internal position data format

Tab. 5-32: Conditions for Modulo Scaling and Rotary Position Reference

☞ Rotary modulo scaling is impossible for linear external encoders!

- Only load reference is possible for linear modulo scaling. Depending on the use of an external encoder, the following conditions have to be complied with:

Scaling type of position data →	Modulo scaling, linear position reference			
Reference →	Motor reference not possible!	Load reference		
External encoder →	---	External encoder available		No external encoder available
Type of motion of external encoder →	---	Rotary	Linear	
Conditions (No.) to be complied with →	---	1; 2; 3; 4; 5; 6	1; 2; 3; 4; 5; 7	1; 2; 3; 4
Conditions →	**No. 1:** S-0-0103 × S-0-0121 × P-0-0129 ≤ 2^{64} **No. 2:** S-0-0123 × S-0-0122 ≤ 2^{64} **No. 3:** S-0-0103 × S-0-0121 × P-0-0122 × S-0-0116 ≤ 2^{64} **No. 4:** S-0-0123 × S-0-0122 × P-0-0121 ≤ 2^{64} **No. 5:** S-0-0103 × P-0-0125 × S-0-0117 ≤ 2^{64} **No. 6:** S-0-0123 × P-0-0124 ≤ 2^{64} **No. 7:** S-0-0103 × S-0-0077 × $10^{(S\text{-}0\text{-}0078)}$ ≤ 2^{64}			

S-0-0077 Scaling factor, linear Position data
S-0-0078 Linear data scaling exponent Position data
S-0-0103 Modulo value
S-0-0116 Resolution of feedback 1
S-0-0117 Resolution of feedback 2
S-0-0121 Input revolutions of load gear
S-0-0122 Output revolutions of load gear
S-0-0123 Feed constant
P-0-0121 Gear 1 motor-side (motor encoder)
P-0-0122 Gear 1 encoder-side (motor encoder)
P-0-0124 Gear 2 load-side (optional encoder)
P-0-0125 Gear 2 encoder-side (optional encoder)
P-0-0129 Internal position data format

Tab. 5-33: Conditions for Modulo Scaling and Linear Position Reference

Linear modulo scaling is impossible with motor reference!

5.8.3 Notes on Commissioning

General Information

Basic Scaling Settings

First make the basic scaling settings for position, velocity, acceleration and torque/force data. This is only possible in the parameter mode (communication phase 2).

You have to determine:

- Scaling type (rotary/linear/without scaling/percentage-based, if necessary)
- Unit of measurement and, if necessary, unit of time
- Data reference (motor/load)
- Absolute/modulo format for position data
- Preferred scaling (predefined) or parameter scaling (can be individually defined)

To do this, set the respective bits in the following parameters:

- S-0-0076, Position data scaling type

- S-0-0044, Velocity data scaling type
- S-0-0160, Acceleration data scaling type
- S-0-0086, Torque/force data scaling type

Settings and Tips for Modulo Scaling

When selecting "modulo format", the value range limit must be set in parameter "S-0-0103, Modulo value".

☞ For "modulo format", enter a value greater than or equal to the value of parameter S-0-0103 in "S-0-0278, Maximum travel range"!

NOTICE **Danger of incorrect actual position value of encoders evaluated in absolute form after switching the drive on, when the mechanical drive system, with the drive switched off, was moved in the case of modulo scaling!**

⇒ Make sure that the mechanical drive system, with the drive switched off, is as a maximum moved by a distance or angle corresponding to half the absolute encoder range ("S-0-0378, Absolute encoder range of motor encoder" or "S-0-0379, Absolute encoder range of optional encoder")!

Temperature Scaling

In addition, make the scaling setting for temperature data in "S-0-0208, Temperature data scaling type".

Individual Settings for Parameter Scaling

Further Settings for Parameter Scaling

Position data:

- S-0-0077, Linear position data scaling factor
- S-0-0078, Linear position data scaling exponent

- or -

- S-0-0079, Rotational position resolution

Velocity data:

- S-0-0045, Velocity data scaling factor
- S-0-0046, Velocity data scaling exponent

Acceleration data:

- S-0-0161, Acceleration data scaling factor
- S-0-0162, Acceleration data scaling exponent

Diagnostic Messages of Scaling Setting

If inadmissible scaling settings were made, they are detected when switching from parameter mode (communication phase 2) to operating mode (communication phase 4). The drive in this case does not reach the operating mode and, according to setting, displays the following command errors:

- C0272 Incorr. parameteriz. of motor enc. (mechanical system)
- C0273 Modulo value for motor encoder cannot be displayed
- C0277 Incorr. parameteriz. of opt. enc. (mechanical system)
- C0278 Modulo value for optional encoder cannot be displayed
- C0288 Rotary scaling not allowed

Examples of Scaling Settings

There are many options to make settings for the scaling type. The table below shows useful settings for which there aren't any command errors to be expected.

Mechanical system			Encoder		Useful scaling type settings		
Motor	Load gear	Feed spindle	Motor Encoder	External encoder	Motor reference	Load reference	Modulo
Rotary	Available	Not available	Rotary	No	Rotary	Rotary	Possible
Rotary	Available/not available	Available	Rotary	No	Rotary	Linear	Possible
Rotary	Available	Not available	Rotary	Rotary	Rotary	Rotary	Possible
Rotary	Available/not available	Available	Rotary	Rotary	Rotary	Linear	Possible
Rotary	Available/not available	Available	Rotary	Linear	Rotary	Linear	Possible
Linear	Not available	Not available	Linear	---	Linear	Linear	Not possible

Tab. 5-34: Useful Scaling Type Settings Depending on Mechanical Drive System and Measuring Systems

6 Drive Control

6.1 Safety Instructions

⚠ WARNING **Dangerous movements! Danger to life, risk of injury, serious injury or property damage!**

- Keep free and clear of the ranges of motion of machines and moving machine parts.
- Prevent personnel from accidentally entering the machine's range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

6.2 Overview of Drive Control

6.2.1 Brief Description

Basic Principles and Terms

The IndraDrive firmware supports the following two basic principles of drive control:

- **Open-loop axis control** (V/Hz [U/f] control)

  → Open-loop-controlled operation without encoder information
- **Closed-loop axis control** (various methods of control)
  - **With** encoder feedback

    → Closed-loop-controlled operation (position, velocity and current)
  - **Without** encoder feedback

    → Closed-loop-controlled operation with motor model (velocity and current)

☞ When selecting the functional packages, take the desired method of control into account as you have to choose between open-loop and closed-loop base package!

Operation mode / command value adjustment	Control mode	Functional principle of motor	Encoder available	Required base package	Method of control
V/Hz (U/f) control with command value adjustment of the velocity control	Voltage-controlled operation	Asynchronous	Yes	Closed-loop	Not relevant
			No	Open-loop	V/Hz (U/f) control

Drive Control

Operation mode / command value adjustment	Control mode	Functional principle of motor	Encoder available	Required base package	Method of control
Torque/force control	Field-oriented current control	Asynchronous	Yes	Closed-loop	FOC control
			No	--	No method available
		Synchronous	Yes	Closed-loop	FOC control
			No	--	No method available
Velocity control / velocity synchronization	Velocity Control	Asynchronous	Yes	Closed-loop	FOC control
			No	Open-loop	FXC control 1)
		Synchronous	Yes	Closed-loop	FOC control
			No	Closed-loop	FOCsl control
Position control, drive-controlled positioning, positioning block mode, phase synchronization, electronic Cam	Position Control	Asynchronous	Yes	Closed-loop	FOC control
			No	Closed-loop	FXC control 2)
		Synchronous	Yes	Closed-loop	FOC control
			No	Closed-loop	FOCsl control

1) Although the „Open-Loop“ functional base package of the firmware is required, the drive control works in closed-loop operation.

2) Only with external encoder

Tab. 6-1: Overview: Operation Modes and Available Control Methods

See also the section "Overview of Functions/Functional Packages"

Principles of Drive Control

Overview of Open-Loop Axis Control

Open-loop axis control (or "open-loop operation") allows open-loop-controlled operation of the drive without motor encoder (V/Hz [U/f] control).

The primary operation mode "velocity control" is configured, but only the command value processing specific to this operation mode takes effect. Closed-loop control (position and velocity) and functions and operation modes depending thereof are not possible.

See "Voltage-Controlled Open-Loop Operation (V/Hz [U/f] Control)"

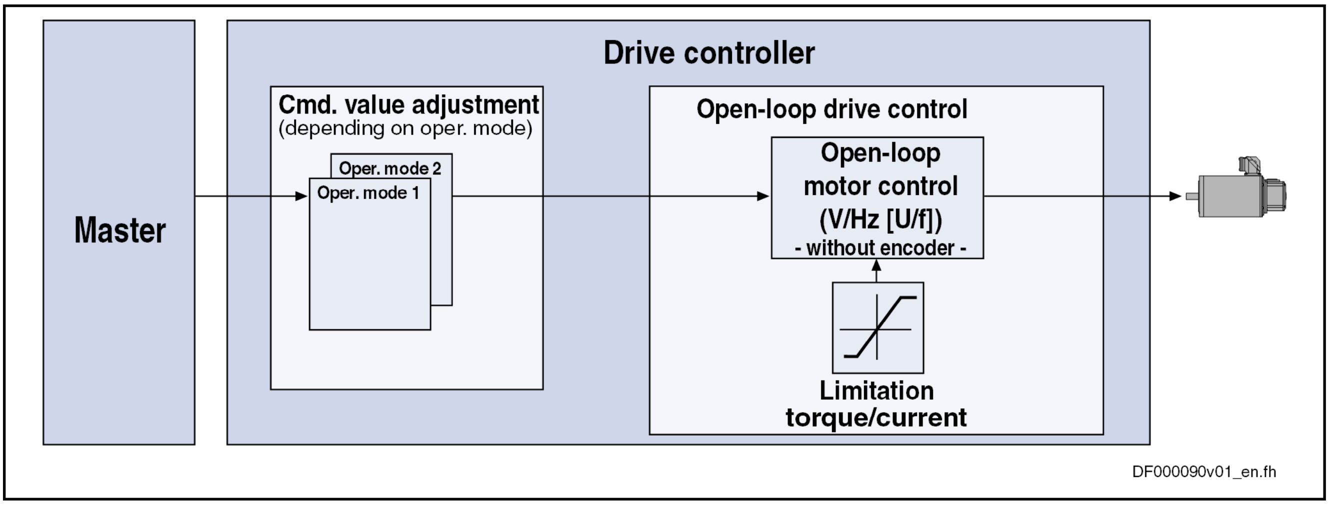


Fig. 6-1: Principle of Open-Loop Drive Control (Open-Loop Operation)

See also the section "Closed-Loop Axis Control (Closed-Loop Operation)"

See also the section "Overview of Functions/Functional Packages"

Overview of Closed-Loop Axis Control

☞ The base package "Closed-Loop" also contains the functions of the base package "Open-Loop".

Closed-loop axis control (or "closed-loop operation") allows closed-loop-controlled operation of the drive; two principles of drive control are distinguished:

- Operation with encoder

  The velocity control loop and the position control loop are closed by means of the encoder feedback so that the following operation modes are supported by field-oriented current control with encoder feedback:

  – Velocity Control
  – Position control with cyclic command value input
  – Positioning modes (drive-controlled positioning, positioning block mode)
  – Synchronization modes

- Sensorless operation

  The velocity control loop is closed by means of a motor model (monitor) so that field-oriented current control without encoder feedback supports velocity control without encoder.

See the section "Field-Oriented Current Control"

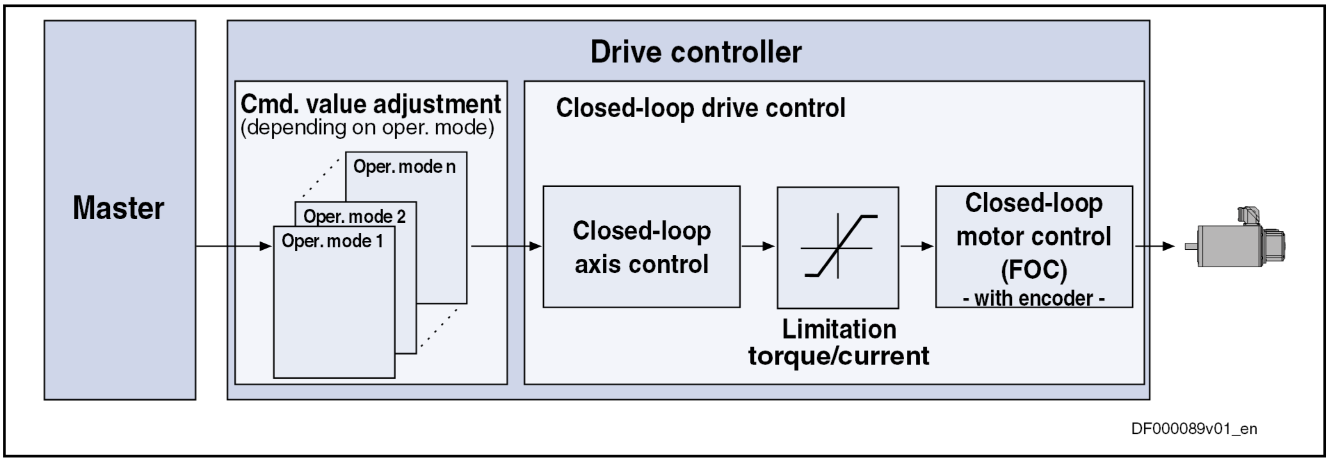


Fig. 6-2: Principle of Closed-Loop Drive Control (Closed-Loop Operation)

See also the section "Open-Loop Axis Control (Open-Loop Operation)"

See also the section "Overview of Functions/Functional Packages"

Control Loop Structure

General Information

The drive controller has a so-called cascade structure, i.e. the individual controllers (position, velocity and current) are interconnected in cascaded form. Depending on the active operation mode, only the torque/force control loop, the torque/force control loop and the velocity control loop or, in addition to these two control loops, the position control loop are closed in the drive.

Torque/force control

The "torque/force control" mode actually isn't torque or force control but current control. Therefore, only the current control loop is closed in the drive.

See also "Torque/Force Control"

Velocity Control

In the "velocity control" mode, the velocity control loop, apart form the current control loop, is closed in the drive, too.

See also "Velocity Control"

Position Control

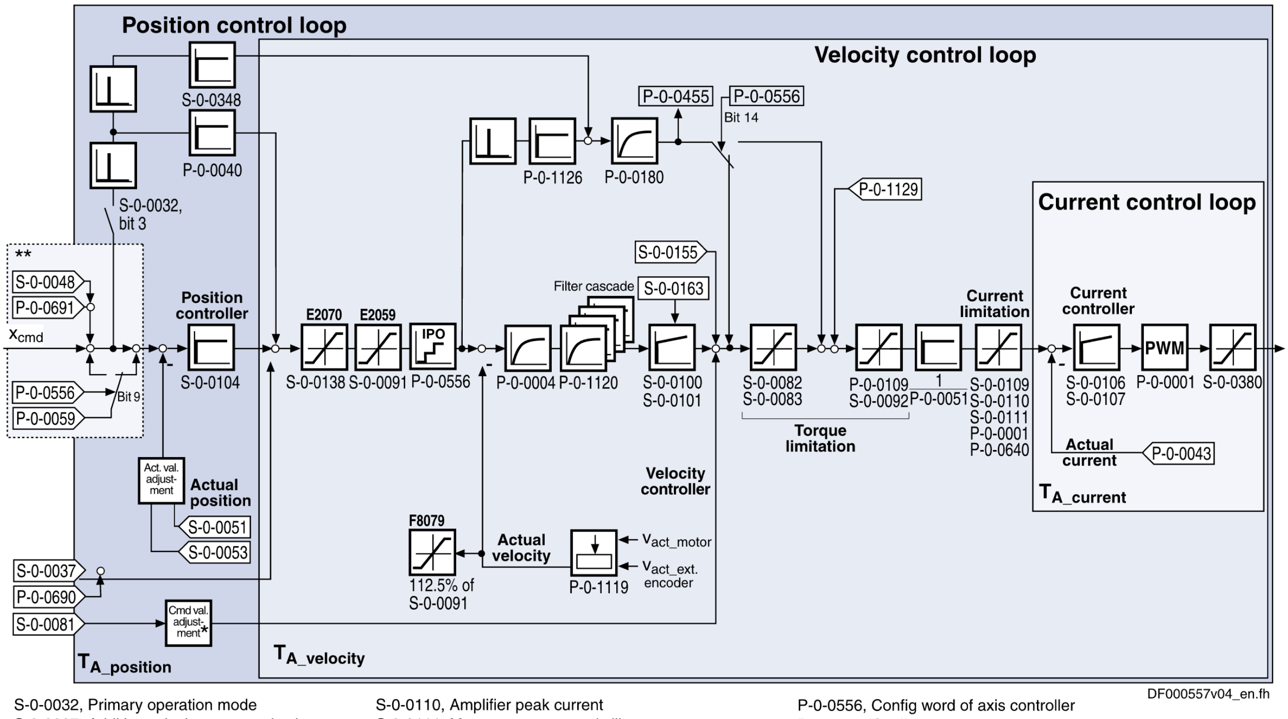
For the following position control modes, the position control loop, apart from the current and velocity control loops, is closed internally (in the drive):

- Position control with cyclic command value input
- Drive-internal interpolation
- Positioning modes (drive-controlled positioning, positioning block mode)

See also description of the respective operation mode

The figures in the following two paragraphs contain an overview of the structure and the interaction of the control loops (distinguished according to the illustration of the setting parameters and the display parameters).

Control Loop Structure with Setting Parameters



- S-0-0032, Primary operation mode
- S-0-0037, Additive velocity command value
- S-0-0048, Additive position command value
- S-0-0051, Position feedback value 1
- S-0-0053, Position feedback value 2
- S-0-0081, Additive torque/force command value
- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0091, Bipolar velocity limit value
- S-0-0092, Bipolar torque/force limit value
- S-0-0100, Velocity controller proportional gain
- S-0-0101, Velocity controller integral action time
- S-0-0104, Position controller Kv-factor
- S-0-0106, Current controller proportional gain 1
- S-0-0107, Current controller integral action time 1
- S-0-0109, Motor peak current
- S-0-0110, Amplifier peak current
- S-0-0111, Motor curent at standstill
- S-0-0138, Bipolar acceleration limit value
- S-0-0155, Friction compensation
- S-0-0163, Weight counterbalance
- S-0-0348, Acceleration feedforward gain
- S-0-0380, DC bus voltage
- P-0-0001, Switching frequency of the power output stage
- P-0-0004, Velocity controller smoothing time constant
- P-0-0040, Velocity feedforward evaluation
- P-0-0043, Torque-generating current, actual value
- P-0-0051, Torque/force constant
- P-0-0059, Additive position command value, controller
- P-0-0109, Torque/force peak limit
- P-0-0180, Acceleration feedforward smoothing time constant
- P-0-0556, Config word of axis controller
- P-0-0640, Cooling type
- P-0-0690, Additive velocity command value, process controller
- P-0-0691, Additive position command value, process controller
- P-0-1119, Velocity mix factor feedback 1 & 2
- P-0-1120, Velocity control loop filter: Filter type
- P-0-1126, Velocity control loop: Acceleration feedforward
- P-0-1129, Cogging torque compensation value
- E2059 Velocity command value limit active
- E2070 Acceleration limit active
- F8079 Velocity limit value exceeded

* only for position control mode (cyclic command value input)

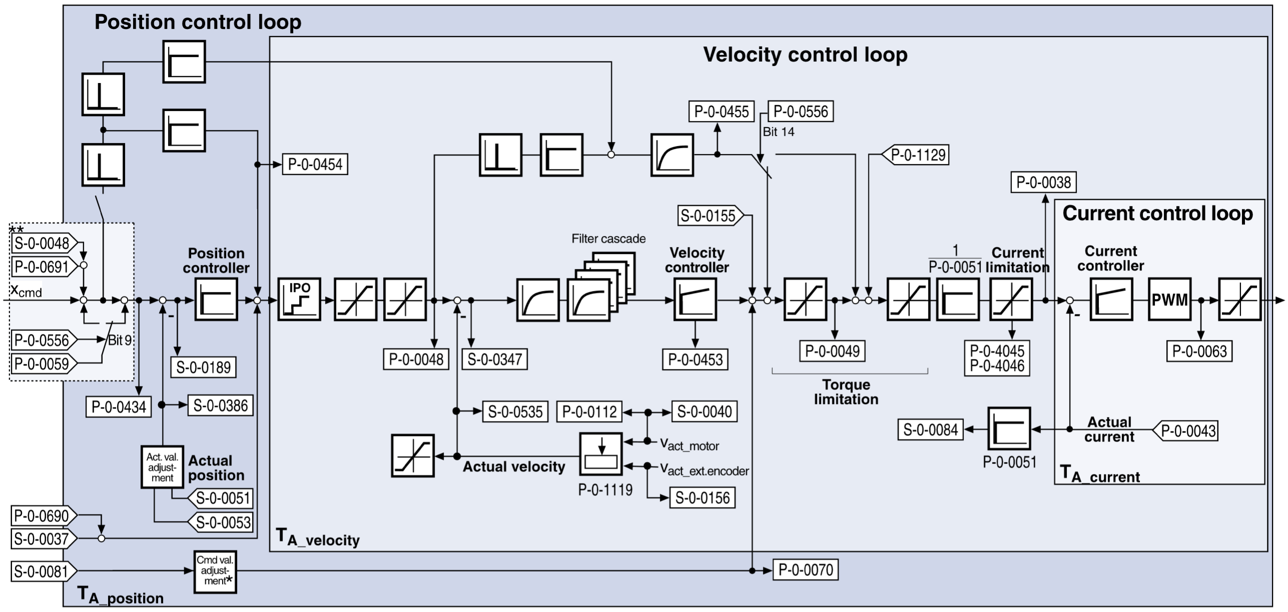
** The effectiveness of the additive command values depends on the operation mode, see parameter descriptions S-0-0048, P-0-0059, P-0-0691 and table "Additive Command Values Depending on the Operation Mode"

T_A Sampling times (see table in the section "Features of the Control Loops")

Fig. 6-3: Overall Structure of the Control Loops with Points at which the Setting Parameters Take Effect (Example for Field-Oriented Control with Encoder)

Drive Control

Control Loop Structure with Display Parameters



P-0-0038, Torque-generating current, command value
P-0-0043, Torque-generating current, actual value
P-0-0048, Effective velocity command value
P-0-0049, Effective torque/force command value
P-0-0051, Torque/force constant
P-0-0059, Additive position command value, controller
P-0-0063, Torque-generating voltage, actual value
P-0-0070, Effective additive torque/force command value
P-0-0112, Actual velocity value of motor
P-0-0434, Position command value of controller
P-0-0453, Integral-action component velocity controller
P-0-0454, Velocity feedforward actual value
P-0-0455, Acceleration feedforward actual value
P-0-0556, Config word of axis controller
P-0-0690, Additive velocity command value, process controller
P-0-0691, Additive position command value, process controller
P-0-1119, Velocity mix factor feedback 1 & 2
P-0-1129, Cogging torque compensation value
P-0-4045, Maximum possible continuous current
P-0-4046, Effective peak current

S-0-0037, Additive velocity command value
S-0-0040, Velocity feedback value
S-0-0048, Additive position command value
S-0-0051, Position feedback value 1
S-0-0053, Position feedback value 2
S-0-0084, Torque/force feedback value
S-0-0155, Friction compensation
S-0-0156, Velocity feedback value 2
S-0-0189, Following distance
S-0-0347, Velocity error
S-0-0386, Active position feedback value
S-0-0535, Active velocity feedback value

* only for position control mode (cyclic command value input)
** The effectiveness of the additive command values depends on the operation mode, see parameter descriptions S-0-0048, P-0-0059, P-0-0691 and table "Additive Command Values Depending on the Operation Mode"

T_A Sampling times (see table in the section "Features of the Control Loops")

Fig. 6-4: Overall Structure of the Control Loops with Display Parameters (Example)

Features of the Control Loops

Performance (Controller Cycle Times)

The internal controller cycle times (current, velocity and position) depend on the following conditions and parameters:

- Activation of the functional packages
- P-0-0001, Switching frequency of the power output stage
- P-0-0556, Config word of axis controller (bit 2)

Depending on these factors, the following cycle and switching times can be achieved:

	MPE	MPB	MPM
PWM switching frequency	Max. 8 kHz	Max. 16 kHz	Max. 8 kHz
Position controller clock ($T_{A\_position}$)	1000 µs	250 µs	500 µs

	MPE	MPB	MPM
Velocity controller clock ($T_{A\_velocity}$)	500 µs	125 µs	250 µs
Current controller clock ($T_{A\_current}$)	125 µs	62.5 µs	125 µs

Tab. 6-2: Cycle and Switching Times to be Achieved with IndraDrive

All performance data are summarized under "System Overview: Performance Data".

Current controller

The current controller is characterized by the following features:

- PI controller for d-axis and q-axis of the field-oriented d-q coordinate system (S-0-0106, S-0-0107)
- Inductance feedforward for decoupling d-axis and q-axis (P-0-4017, P-0-4016) for synchronous motors
- Inductance characteristic for adjusting the current loop parameters in the case of saturation phenomena
- Precontrol of e.m.f.

Velocity controller

The velocity controller is characterized by the following features:

- PI controller that can be set via the following parameters: "S-0-0100, Velocity loop proportional gain", S-0-0101, Velocity loop integral action time
- Standardization of the output value at the velocity controller to Newton (N) or Newton meter (Nm); therefore, depending on the motor type, the following unit results for the parameter "S-0-0100, Velocity loop proportional gain":
  – Rotary motor → Nm * s/rad
  – Linear motor → N * min/mm
- Filter options for filtering encoder noise and resonance frequencies are available
  – A first order filter (first order low-pass), can be parameterized via P-0-0004
  – Four second order filters (second order low-pass, band-stop filter, second order filter), can be activated via P-0-1120 with the setting parameters (P-0-1121), P-0-1122, P-0-1123, P-0-1140,P-0-1141, P-0-1143

In firmware variant MPE, only two second order filters are available.

- Acceleration feedforward can be set in parameter "P-0-1126 Velocity control loop: Acceleration feedforward"
- Option to mix the actual velocity value used for control from the actual value of the motor-side and load-side encoder using a "mix factor" "P-0-1119 Velocity mix factor feedback 1 & 2"
- Limitation of command acceleration (velocity command value modification) in velocity control by setting in parameter "S-0-0138, Bipolar acceleration limit value"

- Limitation of the command velocity using parameters
  - S-0-0113, Maximum motor speed
  - S-0-0038, Positive velocity limit value
  - S-0-0039, Negative velocity limit value
  - S-0-0091, Bipolar velocity limit value
  - P-0-0113, Bipolar velocity limit value of motor

See also "Velocity Controller (with the Respective Filters)"

Position Controller

The position controller is characterized by the following features:

- P controller, can be set using "S-0-0104 Position loop Kv-factor"
- Velocity feedforward (degree of feedforward) can be set in parameter "P-0-0040, Velocity feedforward evaluation" (0 %…100 %)
- Acceleration feedforward can be set in parameter S-0-0348
- For control, the actual value of the motor encoder or of the optional encoder can be used as the actual position value. It is possible, however, to use both actual position values for position control ("hybrid actual position value").

See also "Position Controller (with Respective Feedforward Functions and Actual Value Adjustment)"

6.2.2 General Notes on Commissioning and Application

Additive Command Values and Possibilities of Accessing Outer Control Loops

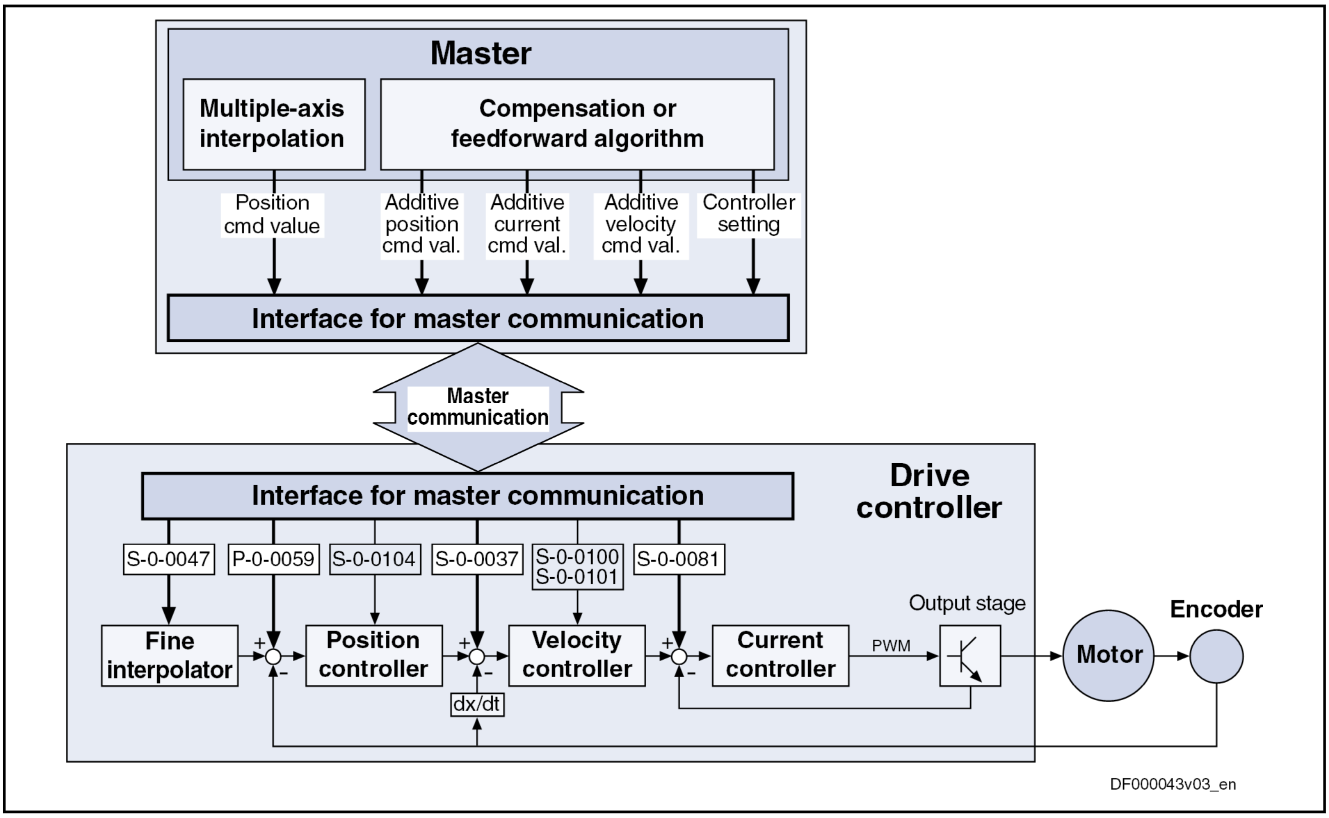
In closed-loop operation, it is possible to add command values in addition to the command values available in the control loop. Depending on the active operation mode, the following parameters are available to do this:

Operation mode	S-0-0081	S-0-0037	P-0-0059	S-0-0048	P-0-0691
V/Hz (U/f) control (command value processing in velocity control)	--	--	--	--	--
Torque/force control	■	--	--	--	--
Velocity control / velocity synchronization	■	■	--	--	--
Position Control	■	■	■	--	--
Drive-internal interpolation	■	■	■	--	--
Drive-controlled positioning	■	■	■	--	--
Positioning block mode	■	■	■	--	--
Position synchronization • Phase synchronization • Electronic cam • MotionProfile	■	■	--	■	■

S-0-0081 Additive torque/force command value
S-0-0037 Additive velocity command value
P-0-0059 Additive position command value, controller
S-0-0048 Additive position command value

Tab. 6-3: Additive Command Values Depending on the Operation Mode

In closed-loop operation, it is possible to access the outer control loops from a higher-level operation mode. The access options to the individual control loops are illustrated in the following example:



S-0-0037	Additive velocity command value
S-0-0047	Position command value
S-0-0081	Additive torque/force command value
S-0-0100	Velocity controller proportional gain
S-0-0101	Velocity controller integral action time
S-0-0104	Position controller Kv-factor
P-0-0059	Additive position command value, controller

Fig. 6-5: Structural Overview Including Access Options (Example for Operation Mode "Position Control with Cyclic Command Value Input")

Notes on Commissioning for Control Loop Setting

The control loop settings in a digital drive controller are very important for the features of the servo axis.

To optimize the control loop setting, application-specific controller parameters are available for all digital Rexroth drives.

Order of Manual Control Loop Setting

Due to the cascade structure of the control loops, it is necessary to parameterize them "from the inside to the outside". The resulting order for setting the control loops is as follows:

1. **Current control loop**

   For **Rexroth motors with motor encoder data memory** (MSK and MKE series), the optimization of the current controller is not required, as the respective parameter values (S-0-0106 and S-0-0107) are read from the motor encoder data memory.

For all **Rexroth motors without motor encoder data memory** (e.g. linear motors), the parameter settings can be taken from a central motor database via the "IndraWorks Ds/D/MLD" commissioning tool.

The commissioning of **third-party motors** (including control loop settings) is described in the respective sections on third-party motors in this documentation (see "Third-Party Motors at IndraDrive Controllers").

2. **Velocity control loop**

   The settings of the velocity controller (S-0-0100 and S-0-0101) with the respective filters (P-0-0004 and P-0-1120, P-0-1121, P-0-1122, P-0-1123, P-0-1140, P-0-1141, P-0-1142, P-0-1143) on the one hand depend on the motor parameters (inertia and torque/force constant), on the other hand they strongly depend on the mechanical properties (load inertia/mass, friction, rigidity of the connection, ...). Therefore, manual or automatic optimization is often necessary.

3. **Position control loop**

   In general, the position control loop only has to be adjusted to the dynamics of the outer velocity controller, as well as to the kind of preset command values (jerk, acceleration and interpolation procedure).

Default Settings in the Motor Encoder Data Memory [Load Defaults Procedure (Motor-Spec. controller values)]

Command "Load Defaults Procedure (Motor-Spec. controller values)"

With all Rexroth motors of the series with motor encoder data memory (e.g. MKE, MSK and possibly MAD and MAF), the basic settings for the controllers are saved and can be loaded to the drive by executing the "load defaults procedure" command (S-0-0262).

The parameter "S-0-0262, C07_x Load defaults procedure command" can be activated in two ways:

- Automatically when running up the drive by recognizing that the motor type (cf. parameter S-0-0141) has changed. The display then reads "RL" and the "load defaults procedure" command is internally started by pressing the "Esc" key on the control panel, unless this was deactivated in "P-0-0556, Config word of axis controller".
- Starting the command by writing "11b" to parameter S-0-0262.

See also "Loading, Storing and Saving Parameters"

☞ In order to start the "load defaults procedure" command, the value "0" (default setting) must have been set in parameter "P-0-4090, Configuration for loading default values".

When the motor default values are loaded, the following control loop parameters are set to their default values optimized for the respective motor:

- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- S-0-0104, Position loop Kv-factor
- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- P-0-0004, Velocity loop smoothing time constant

☞ The default settings for the current control loop (cf. S-0-0106 and S-0-0107) are automatically adjusted to the currently parameterized PWM frequency (cf. P-0-0001) and performance setting (cf. P-0-0556)!

In addition, the following control loop parameter is set to the firmware-side default value when the motor default values are loaded, although no default value has been stored for it in the motor data memory:

- S-0-0348, Acceleration feedforward gain

☞ In the majority of cases, the controller settings stored in the motor encoder data memory provide a useful and reliable control loop setting. In exceptional cases, however, it may be necessary to make the settings with regard to the specific application.

6.3 Motor control

6.3.1 General Information on Motor Control

Overview of Motor Control Methods

Classification of Motor Control Methods

There are different methods available to control the motor; the main difference between these methods is the fact whether a motor encoder is required or not.

Motor Control with Motor Encoder

Motor control with position feedback via a motor encoder (field-oriented current control → FOC) is the highest-quality method of motor control providing the best control performance. It can be used for synchronous and asynchronous motors and, within the precision and performance of motor and controller determined by the hardware, allows unrestricted motor operation in the following operation modes:

- Position control modes
- Velocity Control
- Torque/force control

Motor Control without Motor Encoder

For sensorless motor control, there are different model-based methods available for synchronous and asynchronous motors.

- For asynchronous motors:
  - Voltage-Controlled Open-Loop Operation (V/Hz [U/f] Control)
  - Flux-Controlled Operation (FXC)
- For synchronous motors
  - Flux-Controlled Operation (FXC)

Regarding the possible operation modes when using these methods, observe the following restrictions:

- Position control modes (positioning) are possible with sensorless synchronous and asynchronous motors in flux-controlled operation (FXC) in connection with an external encoder. In these cases, generally take the performance losses into account!
- Velocity control, too, can only be used with performance losses!

☞ Torque/force control cannot be used for motor control without motor encoder!

Motor Control Method and Functional Principle of Motor

Make sure that the requirements regarding functional principle of motor and motor encoder have been fulfilled for specified motor control mode. The table below contains an overview for selecting the method.

Motor encoder?	Functional principle of motor	Motor control method	Specific information for use	Possible operation modes
With Motor Encoder	Synchronous motor Asynchronous motor	FOC	Parallel operation of linear motors MLF is possible!	Position control modes Velocity Control Torque/force control
Without Motor Encoder	Asynchronous motor	FXC	Only single-motor operation!	Position control modes Velocity Control
		V/Hz (U/f) control	Parallel operation of motors is possible!	Velocity Control
Without Motor Encoder	Synchronous motor	FXC	Only single-motor operation!	Position control modes Velocity Control

Tab. 6-4: Overview of Motor Operation with and without Motor Encoder

See also "Overview of Drive Control"

Field-Oriented Current Control with Motor Encoder (FOC)

Features and Use

Field-oriented current control with position feedback via motor encoder (FOC) is characterized by the following features:

- Highest-quality method of motor control

  → To be used when there are high demands on the quality of control and the dynamic response!
- Can be used for synchronous and asynchronous motors

Operation Modes with FOC

Within the hardware-side precision and performance of motor and controller, field-oriented current control with position feedback via motor encoder allows unrestricted motor operation in the following operation modes:

- Position control modes
- Velocity Control
- Torque/force control

See the main section "Field-Oriented Current Control (FOC Control)"

Model-Based Current Control without Motor Encoder (FXC)

Features and Use

Model-based current control without motor encoder is characterized by the following features:

- Cost-saving motors, compared to the FOC method, can be used, as no motor encoder is required (however, performance losses)
- Flux-controlled method (FXC) can be used without motor-specific restrictions

Operation Modes with FXC

Current control without motor encoder allows using the following operation modes:

- Velocity control (only suited for single motors, parallel operation of motors is not possible)
- Position control modes possible with external encoder

☞ Torque/force control cannot be used for sensorless (model-based) motor control!

See the main section "Sensorless Motor Operation, Flux-Controlled (FXC Control)"

Voltage-Controlled Open-Loop Operation (V/Hz [U/f] Control)

Features and Use

Voltage-controlled motor operation without motor encoder is characterized by the following features:

- Cost-saving motors, compared to the FOC method, can be used, as no motor encoder is required (however, performance losses)
- Can only be used for asynchronous motors
- Linear or square V/Hz (U/f) characteristic can be selected

Operation Mode with V/Hz (U/f) Control

For voltage-controlled operation without motor encoder, only the "velocity control" mode with the following features can be used:

- Parallel operation of motors is possible
- Adjustment of motor control to velocity-proportional increase in load (e.g. with fans) by adjusted ("square") V/Hz (U/f) characteristic to reduce the motor losses
- Performance losses compared to velocity control with motor encoder

☞ Torque/force control and position control modes cannot be used for voltage-controlled operation without motor encoder!

See the main section "Voltage-Controlled Open-Loop Operation (V/Hz [U/f] Control)"

Notes on Selection of Motor Control Method

Motor Control Performance

The performance of motor control significantly depends on the type of control section including the corresponding firmware, as well as on the PWM frequency of the power output stage which has been set.

☞ An overview of the performance to be achieved and the clock rates depending on control section design and parameter settings is contained in the section "Performance Data".

Selection Criteria

The following criteria have to be taken into account when selecting the appropriate motor control method:

Motor type	Motor encoder available?	Parallel connection of motors?	Motor control method	Notes on use
Synchronous motor	No	No	FOC	For standard applications with medium demands on quality of control and dynamic response
	Yes	Rotary: No Linear: Yes [1)]		For standard applications with high demands on quality of control and dynamic response

Drive Control

Motor type	Motor encoder available?	Parallel connection of motors?	Motor control method	Notes on use
Asynchronous motor	No	No	FXC	For standard applications with medium demands on quality of control and dynamic response
		Yes	V/Hz (U/f) control	For standard applications with low demands on quality of control and dynamic response
	Yes	No	FOC	For standard applications with high demands on quality of control and dynamic response

1) Observe mechanical orientation according to motor data

Tab. 6-5: Basic Selection Criteria for the Motor Control Method

See also "Overview of Drive Control"

Operating Properties for Control of Synchronous Motors

Observe the following differences for controlling synchronous motors in operation with and without motor encoder:

Motor characteristic		FOC	FXC
Speed working ranges	Basic speed range	Yes	Yes
	Field weakening range	Yes	Yes
Supported operation modes	Torque/force control	Yes	No
	Velocity control (incl. synchronization)	Yes	Yes (with restrictions)
	Position control/positioning (incl. synchronization)	Yes	Yes (with restrictions, external encoder required)
Torque limitation		Yes	Yes
Maximum torque		High	Medium
Dynamic response		High	Medium to high
Running smoothness/speed quality		High (depending on measuring system, motor type, mechanical system)	Medium to high
Torque ripple		Low (< ± 5%)	Medium to high
Required accuracy of the motor parameters		Low	Medium to high
Robustness		High	Medium
Sensitivity against disturbances		Low	Medium

Motor characteristic	FOC	FXC
Validity (availability) of the position information	Absolute encoder: in PM + OM Relative encoder: in OM	Depending on load-side encoder type used

PM Parameter mode
OM Operating mode

Tab. 6-6: Comparison of Motor Control without Encoder and with Encoder for Synchronous Motors

Operating Properties for Control of Asynchronous Motors

Observe the following differences for controlling asynchronous motors as regards operation with and without encoder:

Motor characteristic		FOC	FXC	V/Hz (U/f) control
Speed working ranges	Basic speed range	Yes	Yes	Yes
	Field weakening range	Yes	Yes	Yes
Supported operation modes	Torque/force control	Yes	No	No
	Velocity control (incl. synchronization)	Yes	Yes (with restrictions)	Yes (with restrictions)
	Position control/positioning (incl. synchronization)	Yes	Only with external position encoder	No
Torque limitation		Yes	Yes	No (only stall protection controller)
Maximum torque		High	Medium	Low
Dynamic response		High	Medium	Low
Running smoothness/speed quality		High (depending on measuring system, motor type, mechanical system)	Medium	Low
Torque ripple		Low (< ± 5%)	High	High
Required accuracy of the motor parameters		Low	Low	High, if high performance must be reached
Robustness		High	Medium	Low
Sensitivity against disturbances		Low	High	High
Validity (availability) of the position information		Absolute encoder: in PM + OM Relative encoder: only in OM	Depending on load-side encoder type used	Not available

PM Parameter mode
OM Operating mode

Tab. 6-7: Comparison of Motor Control without Encoder and with Encoder for Asynchronous Motors

6.3.2 Motor Control Frequency

Brief Description

General Information

The speed of three-phase a.c. motors depends on the frequency of the voltage applied at the motor. The maximum possible frequency of the motor voltage provided by the controller depends on the PWM frequency with which the power output stage is controlled (clocked).

PWM frequency in Hz	Max. motor control frequency in Hz	
Value in P-0-0001	Static PWM*)	Dynamic PWM
2000	200	--
4000	400	665
8000	800	1330
12000	1200	2000
16000	1600	2660

*) See also "Supply Units and Power Sections, Project Planning Manual"

Tab. 6-8: PWM Frequency Settings and Maximum Motor Control Frequency with Static and Dynamic PWM

Note on Dimensioning

☞ The required PWM frequency must be observed when selecting the controller because the continuous controller current is affected by the PWM frequency setting:

- Due to continuous controller current, select the lowest possible PWM frequency
- Due to motor control frequency, select a PWM frequency that is only as high as necessary

Advantageous Behavior

Due to the continuous current reduction with PWM frequencies greater than 4 kHz, the controller can set the most advantageous PWM frequency automatically depending on the required motor control frequency.

Availability

Depending on the control section design, the following PWM frequencies are available:

Device/firmware or Control section/Firmware	Available PWM frequencies / Hz	Programmable PWM or vel.-dep. most advantageous PWM
IndraDrive-Cs with MPE firmware CDB02.1 with MPM FWA	4000 8000	No No
IndraDrive-Cs with MPB/MPC firmware CSB02.1 with MPB FWA CSH02.x with MPC FWA	2000 4000 8000 12000 16000	No Yes*) Yes Yes Yes

*) Not for MPB with "Advanced" performance

Tab. 6-9: Hardware and Firmware Dependencies of the PWM Frequency

Pertinent Parameters

- P-0-0001, Switching frequency of the power output stage

- P-0-0045, Control word of current controller

Pertinent Diagnostic Messages

The switching of the PWM frequency is displayed in the respective bit of "P-0-0046, Status word of current controller".

Functional Description

Clocking Method

In general, IndraDrive controllers can control their power output stage via:

- "Static PWM" due to speed-independent, constant PWM frequency
- "Dynamic PWM" due to variable PWM frequency depending on speed

For the mentioned clocking methods, the time period and distribution of the "support points" differ for a sine wave of the motor voltage.

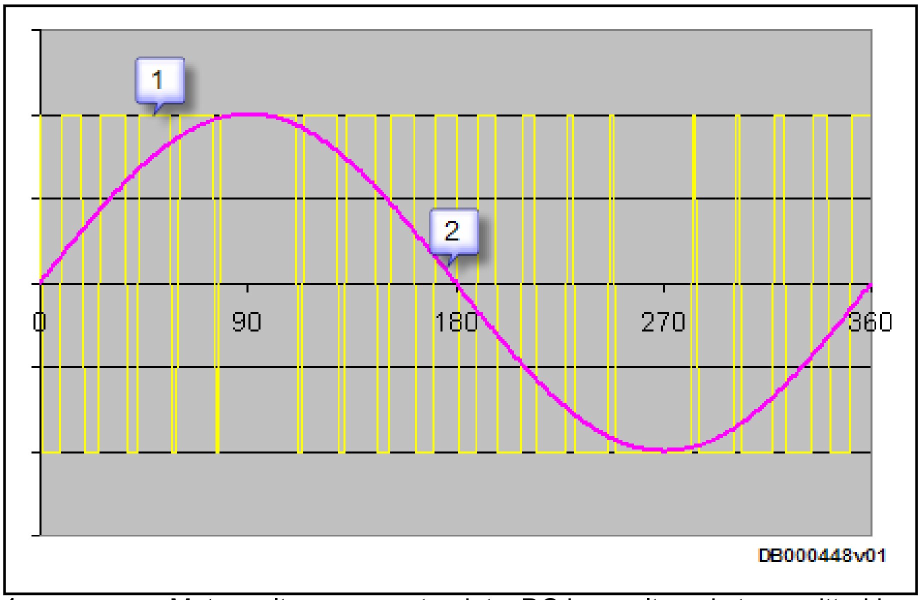
> ☞ A "support point" is a switching action of the power output stage with which the controller can influence the motor current.

The clocking method is selected in "P-0-0045, Control word of current controller".

Static PWM

"Static PWM" is characterized by a constant number of "support points" within a time interval. For different motor control frequencies, the number of support points varies for a periodic time of the motor voltage.

- With increasing motor control frequency the number of support points decreases
- With decreasing motor control frequency the number of support points increases



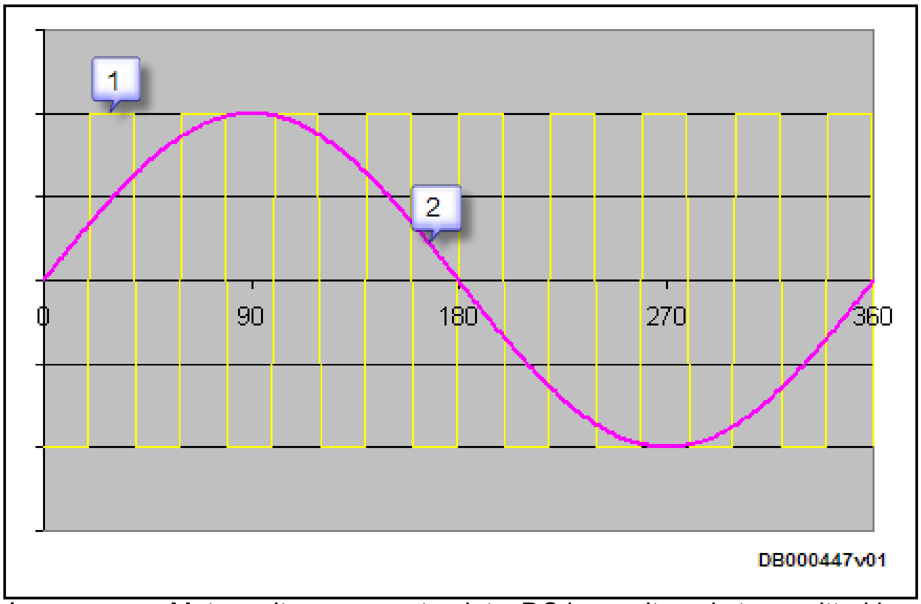
1: Motor voltage support points, DC bus voltage is transmitted by the power output stage
2: Curve of the effective motor voltage

Fig. 6-6: Control of Power Output Stage with "Static PWM", in Principle

Dynamic PWM

"Dynamic PWM" is characterized by a constant number of "support points" within a sine wave of the motor voltage. In different motor control frequency ranges, the number of support points remains constant for a periodic time of the motor voltage.

- The "dynamic PWM" does not take effect until a motor control frequency threshold is exceeded
- The number of "support points" is reduced in stages from 21 to 6 in successive output frequency intervals in ascending order



1:	Motor voltage support points, DC bus voltage is transmitted by the power output stage (9 exemplary support points)
2:	Curve of the effective motor voltage

Fig. 6-7: Control of Power Output Stage with "Dynamic PWM", in Principle

Automatic PWM Adjustment

"Most Advantageous PWM Frequency"

Due to the switching losses of the power output stage, the continuous current of the controller is reduced at a higher PWM frequency; therefore, the controller automatically selects the most advantageous PWM frequency, depending on the actual, velocity-dependent motor control frequency, if this has been set in "P-0-0045, Control word of current controller".

The PWM frequency level required for the maximum motor speed is set in "P-0-0001, Switching frequency of the power output stage". When P-0-0001 has been set to a value greater than 4 kHz, half the switching frequency takes effect below a motor control frequency threshold:

PWM frequency in Hz		Threshold Ⓐ of the motor control frequency (PWM switching) in Hz	
Value set in P-0-0001	Effective PWM frequency below threshold Ⓐ or above threshold Ⓐ	PWM switching depending on velocity	Dynamic PWM
4000	2000**) or 4000	200	95
8000	4000 or 8000	400	190

PWM frequency in Hz		Threshold Ⓐ of the motor control frequency (PWM switching) in Hz	
Value set in P-0-0001	Effective PWM frequency below threshold Ⓐ or above threshold Ⓐ	PWM switching depending on velocity	Dynamic PWM
12000*)	6000***) or 12000	600	285
16000*)	8000 or 16000	800	381

*) Depending on the control section design and the performance settings, these PWM frequencies might not be available

**) For PWM = 2,000 Hz, the controller's continuous current data of 4,000 Hz apply

***) For PWM = 6000 Hz, the controller's continuous current data of 8000 Hz apply

Tab. 6-10: PWM Frequency Settings and PWM Switching Thresholds

☞ The continuous current of a controller depends on the effective PWM frequency. Check whether the selected controller makes available sufficient continuous current for the motor or the application, both below and above the motor control frequency threshold for PWM switching! (see also "Current Limitation" in Chapter "Current and Torque/Force Limitation")!

☞ The maximum current of the controller only depends on the PWM frequency set in P-0-0001 and is not changed by the PWM frequency switched depending on the motor speed! For the selected controller and at the PWM frequency to be set, check whether sufficient peak current is available for the required maximum torque of the motor or the application (see Project Planning Manual for supply units and power sections)!

Notes on Commissioning

Setting the PWM Frequency

The PWM frequency for controlling the power output stage is set in "P-0-0001, Switching frequency of the power output stage". Depending on the control section design, different PWM frequencies are available (see above).

Selecting the PWM Adjustment

PWM adjustment is possible with PWM frequencies of 4 kHz and more. Via the corresponding bits of P-0-0045, you can choose between:

- Static PWM (default)
- PWM reduction depending on load
- PWM reduction depending on velocity
- Dynamic PWM for maximum motor control frequency

IndraWorks Dialogs for PWM Adjustment

According to the motor control mode that was set, there are different dialogs:

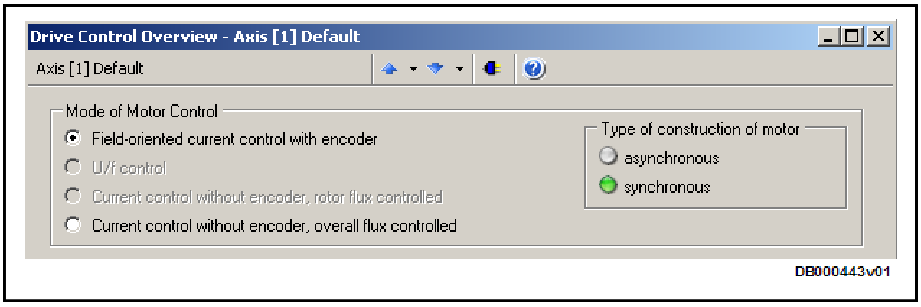


Fig. 6-8: IndraWorks Dialog "Motor Control, FOC Setting"

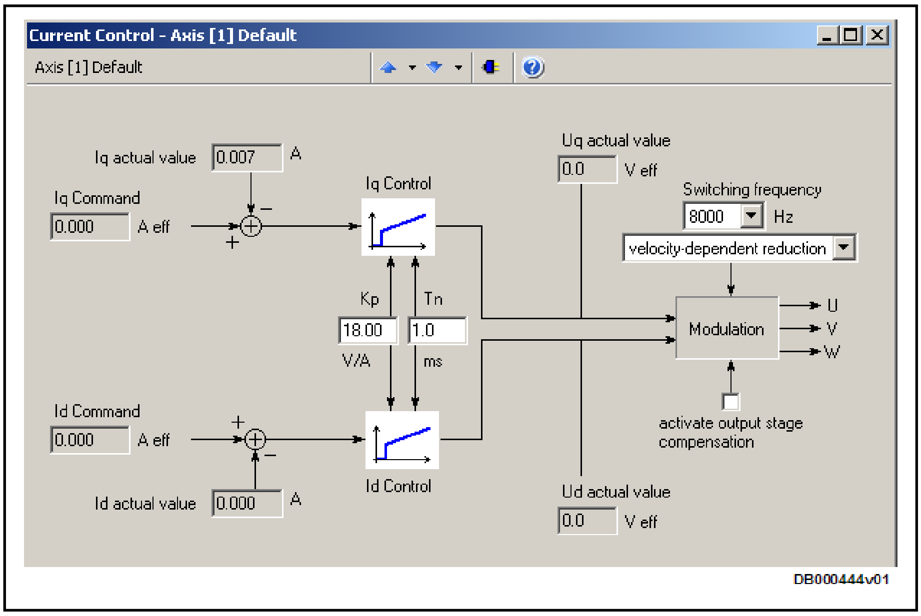


Fig. 6-9: IndraWorks Dialog for Setting the PWM Adjustment with FOC Operation

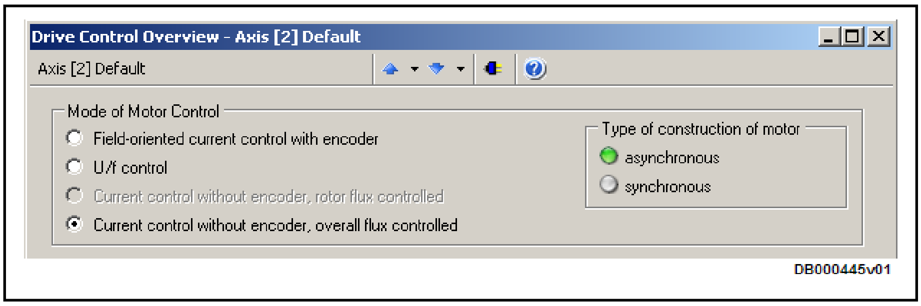


Fig. 6-10: IndraWorks Dialog "Motor Control, FXC Setting"

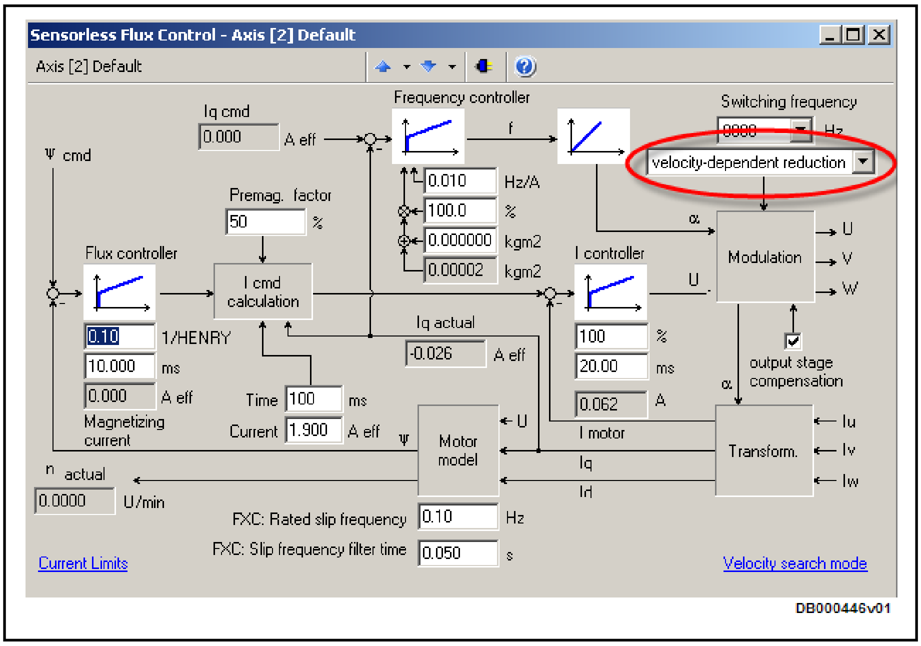


Fig. 6-11: IndraWorks Dialog for Setting the PWM Adjustment with FXC Operation

Displaying the PWM Switching

The switching of the PWM frequency to half the value of P-0-0001 is displayed in the corresponding bit of "P-0-0046, Status word of current controller".

Influence on Control Loop Parameters of PWM Frequencies Active in Motor Operation

Parameters depending on PWM setting	Rexroth motors (motor parameters and motor control parameters provided by manufacturer)	Third-party motors (without motor parameters and motor control parameters provided by manufacturer)	Notes
S-0-0106, Current loop proportional gain 1	With **"F2008 RL The motor type has changed."**, the value is automatically adjusted to the setting in **"P-0-0001, Switching frequency of the power output stage"**.	The value is calculated by means of the formula specified for S-0-0106 and, if necessary, the value is subsequently optimized.	When switching during motor operation (e.g. depending on the velocity), the value must be related to the lowest PWM frequency to be expected; otherwise, you risk instability.
P-0-0004, Velocity loop smoothing time constant	The value depends on the resolution of the motor encoder and the mechanical connection of the load to the motor.		Before optimization, set the value of S-0-0106.
S-0-0100, Velocity loop proportional gain	The value that can be set depends on the total inertia or total mass of the axis. Particularly for kit motors, adjust the default value to the mechanical properties of the axis.		Before optimization, set the values of S-0-0106 and P-0-0004.
S-0-0104, Position loop Kv-factor	The value that can be set depends on the resolution of the position control encoder and the stiffness of the connection to the motor.		Before optimization, set the values of S-0-0100 and P-0-0004.

Tab. 6-11: Table for Control Loop Parameters and PWM Frequency

☞ If PWM adjustment is to be carried out during motor operation (PWM switching depending on the load or velocity), make sure that motor control is steady at the lowest possible PWM frequency during normal operation. If necessary, establish this condition manually (by setting a fixed PWM frequency in P-0-0001) to check the settings (see above).

6.3.3 Voltage-Controlled Open-Loop Operation (U/f Control)

Brief Description

The drive function "voltage-controlled open-loop operation of asynchronous motors without encoder in V/Hz (U/f) control" is made available in the "open-loop" base package in the "velocity control" mode. When the expansion package "synchronization" has been enabled, the operation mode "velocity synchronization with real/virtual master axis" is additionally available.

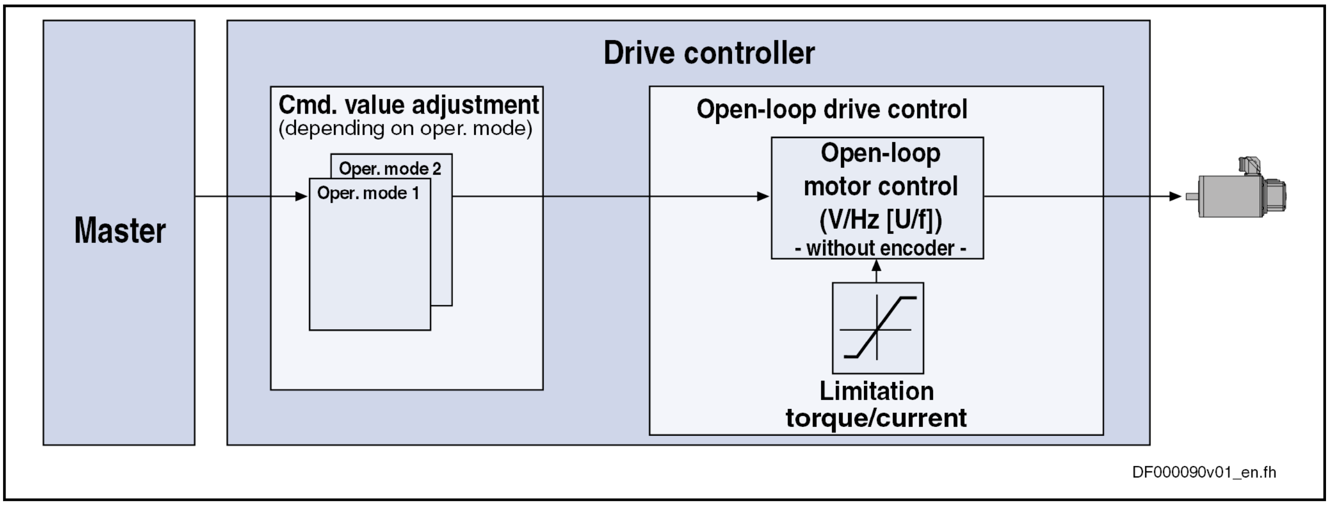


Fig. 6-12: Principle of V/Hz (U/f) Control

V/Hz (U/f) motor control is characterized by the following features or core functions:

Features

- Monitoring and **limitation** of the maximum **stator frequency slope** that results from the command velocity change
- **Stall protection controller** (PI controller that can be optionally activated to prevent breakdown of the machine when the torque limits are attained)
- **Slip compensation** (feedforward of estimated slip of the machine by means of slip compensation factor)
- Calculation of output voltage by means of **V/Hz (U/f) characteristic** based on motor model data
- Subsequent trimming of magnetization via premagnetization factor, as well as linear or square characteristic to be selected
- **IxR boost** (adjustable load-dependent feedforward of the output voltage due to the voltage drop on the motor winding resistance)
- **Oscillation damping** (adjustable load-dependent feedforward to prevent velocity oscillations in the partial load and idling ranges)
- **D.C. braking** to reach standstill more quickly
- User-side **torque/force limitation** via enabled stall protection controller

- **Velocity search mode** of a coasting machine after switching drive enable on (can be set for the preset rotational direction or both rotational directions)

Pertinent Parameters

- S-0-0040, Velocity feedback value
- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- P-0-0043, Torque-generating current, actual value
- P-0-0044, Flux-generating current, actual value
- P-0-0045, Control word of current controller
- P-0-0046, Status word of current controller
- P-0-0048, Effective velocity command value
- P-0-0063, Torque-generating voltage, actual value
- P-0-0064, Flux-generating voltage, actual value
- P-0-0065, Absolute voltage value, actual value
- P-0-0440, Actual output current value (absolute value)
- P-0-0442, Actual value torque limit positive (stationary)
- P-0-0443, Actual value torque limit negative (stationary)
- P-0-0532, Premagnetization factor
- P-0-0556, Config word of axis controller
- P-0-0568, Voltage boost
- P-0-0569, Maximum stator frequency slope
- P-0-0570, Stall protection loop proportional gain
- P-0-0571, Stall protection loop integral action time
- P-0-0572, Slip compensation factor
- P-0-0573, IxR boost factor
- P-0-0574, Oscillation damping factor
- P-0-0575, Search mode: Search current factor
- P-0-0576, Search mode: Finding point slip factor
- P-0-0577, Square characteristic: Lowering factor
- P-0-0578, Current for deceleration, absolute value
- P-0-0579, Current for deceleration, time period
- P-0-4036, Rated motor speed
- P-0-4046, Effective peak current

Pertinent Diagnostic Messages

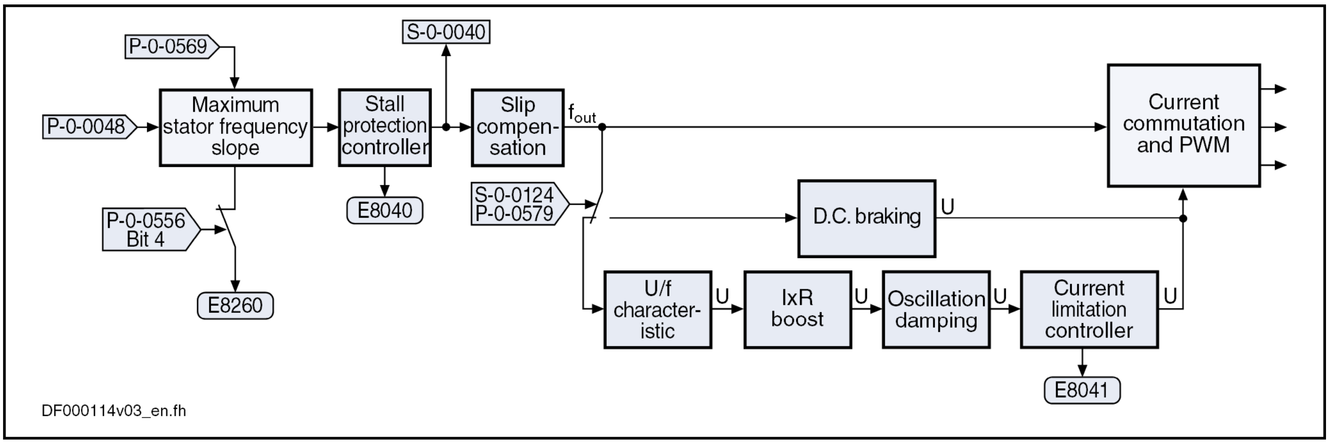
- E8040 Torque/force actual value limit active
- E8041 Current limit active
- E8260 Torque/force command value limit active

Functional Description

Overview of Core Functions

The figure below illustrates the core functions of V/Hz (U/f) control:

Drive Control



S-0-0040	Velocity feedback value
S-0-0124	Standstill window
P-0-0048	Effective velocity command value
P-0-0065	Absolute voltage value, actual value
P-0-0556	Config word of axis controller
P-0-0569	Maximum stator frequency slope
P-0-0579	Current for deceleration, time period

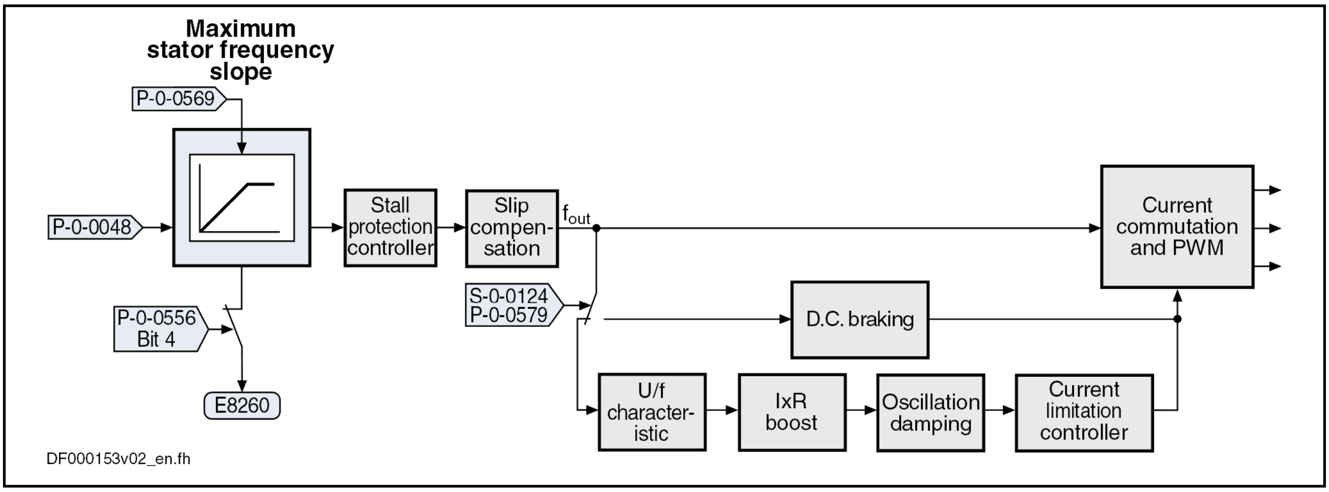
Fig. 6-13: Overview of Functions of V/Hz (U/f) Control

Maximum Stator Frequency Change

The maximum change in velocity with which the drive can follow the command values is determined by the motor and the sampling time of the stall protection controller. The limit value can be set in parameter "P-0-0569, Maximum stator frequency slope". If the acceleration capability was exceeded, the diagnostic message "E8260 Torque/force command value limit active" is output.

This message can be masked via bit 4 of parameter "P-0-0556, Config word of axis controller":

- Bit 4 = 0 → Message is displayed
- Bit 4 = 1 → Message is not displayed



S-0-0124 Standstill window
P-0-0048 Effective velocity command value
P-0-0556 Config word of axis controller
P-0-0569 Maximum stator frequency slope
P-0-0579 Current for deceleration, time period

Fig. 6-14: Core Function "Maximum Stator Frequency Slope"

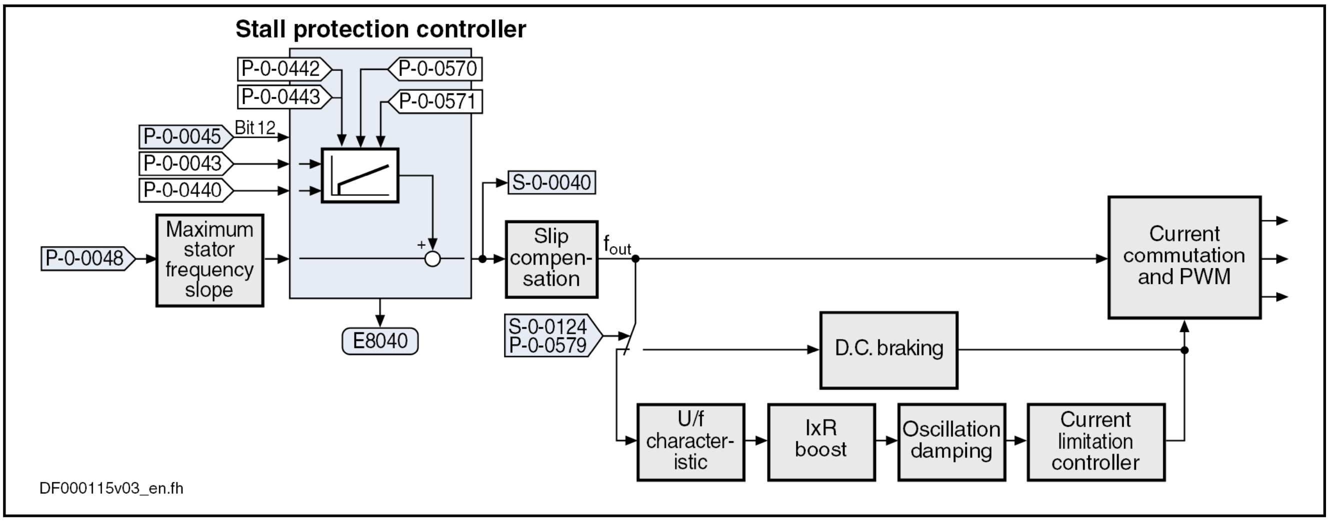
Stall Protection Controller

When the torque limits in the case of motive and regenerative load have been reached, the "breakdown" of the asynchronous motor is prevented by the so-called stall protection controller.

The stall protection controller is enabled via bit 12 of parameter "P-0-0045, Control word of current controller":

- Bit 12 = 1 → Stall protection controller enabled
- Bit 12 = 0 → Stall protection controller switched off

☞ The default setting in bit 12 of P-0-0045 is "1" (stall protection controller enabled).



S-0-0124 Standstill window
S-0-0040 Velocity feedback value
P-0-0043 Torque-generating current, actual value
P-0-0045 Control word of current controller
P-0-0048 Effective velocity command value
P-0-0440 Actual output current value (absolute value)
P-0-0442 Actual value torque limit positive (stationary)
P-0-0443 Actual value torque limit negative (stationary)
P-0-0570 Stall protection controller proportional gain
P-0-0571 Stall protection controller integral action time
P-0-0579 Current for deceleration, time period

Fig. 6-15: Core Function "Stall Protection Controller"

The input value is the result of the command value adjustment "P-0-0048, Effective velocity command value", as well as the current values in the parameters "P-0-0043, Torque-generating current, actual value" and P-0-0440, Actual output current value (absolute value).

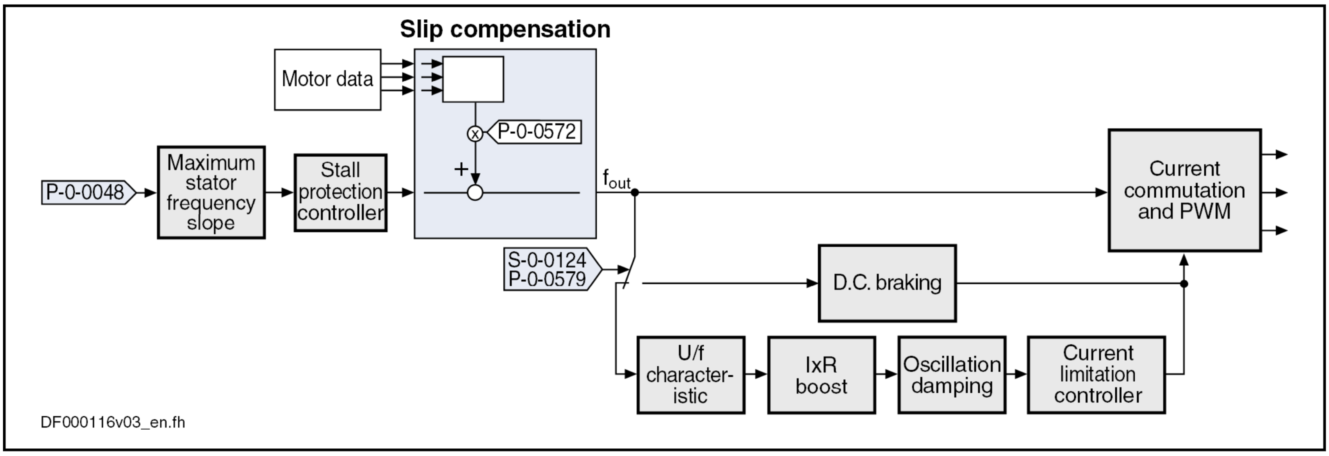
The controller is set via the following parameters:

- P-0-0570, Stall protection loop proportional gain
- P-0-0571, Stall protection loop integral action time

The values of the parameters "P-0-0442, Actual value torque limit positive (stationary)" and "P-0-0443, Actual value torque limit negative (stationary)" are the torque limits to which the stall protection controller is to limit the values.

Slip Compensation

With the slip compensation, the motor model data are used for feedforward of the estimated slip of the machine.



S-0-0124 Standstill window
P-0-0048 Effective velocity command value
P-0-0572 Slip compensation factor
P-0-0579 Current for deceleration, time period

Fig. 6-16: Core Function "Slip Compensation"

The output signal of the stall protection controller is used as the input value.

The feedforward can be set via parameter "P-0-0572 , Slip compensation factor".

☞ With a value of "0.00%" in parameter P-0-0572, the slip compensation is switched off.

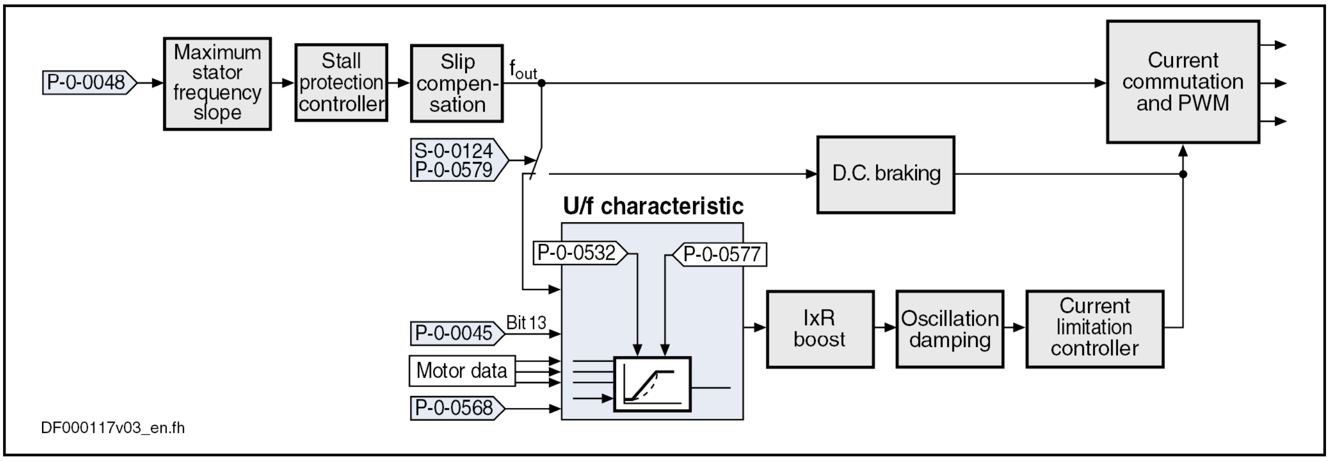
V/f-Curve

In the "V/f-curve" function, the respective voltage for the effective output frequency is calculated from the motor model data.

The form of the characteristic in the basic range of setting, i.e. up to "P-0-4036, Rated motor speed", is selected with bit 13 in "P-0-0045, Control word of current controller":

- Bit 13 = 1 → Square characteristic
- Bit 13 = 0 → Linear characteristic

☞ The default setting in bit 13 of P-0-0045 is "0" (linear characteristic).



S-0-0124 Standstill window
P-0-0045 Control word of current controller
P-0-0048 Effective velocity command value
P-0-0532 Premagnetization factor
P-0-0568 Voltage boost
P-0-0577 Square characteristic: Lowering factor
P-0-0579 Current for deceleration, time period

Fig. 6-17: Core Function "U/f Characteristic"

The output signal of the slip compensation is used as the input value for the V/Hz (U/f) characteristic.

With parameter "P-0-0568, Voltage boost", the voltage at the base point of the U/f characteristic can be increased in addition to the voltage determined by the controller on the basis of the motor data.

Due to long motor lines, for example, starting problems can sometimes occur for motors. In this case, it is possible to improve the starting behavior by means of this parameter by a value higher than 0 V.

With a square characteristic, the degree of lowering can be adjusted in the basic range of setting with the value in parameter "P-0-0577, Square characteristic: Lowering factor". The value of 100% corresponds to the original square curve. This lowering factor is reduced as the percentage value decreases.

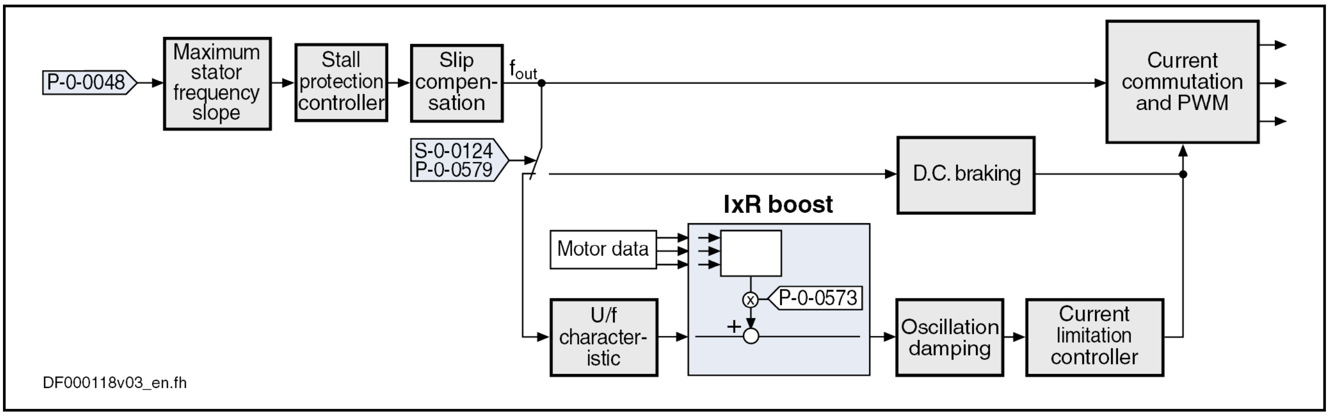
☞ The value "0.00%" in parameter P-0-0577 corresponds to the linear characteristic.

By means of parameter "P-0-0532, Premagnetization factor", it is possible to make a subsequent trimming of the machine's magnetization. This corresponds to a change in the steepness of the U/f characteristic. The parameter P-0-0532 can be configured in the MDT. If the premagnetization factor is cyclically transmitted by a higher-level master, it can precontrol the machine's magnetization in an appropriate way in the case of an expected change of load.

IxR-Boost

By means of parameter "P-0-0573, IxR boost factor", it is possible to influence the feedforward of the output voltage in a load-depending way. When the motor is under load, the output voltage can be increased by means of the parameter P-0-0573 in order to compensate for the enhanced motor-internal voltage drop.

With a value of "0.00%" in parameter P-0-0573, the feedforward is switched off.

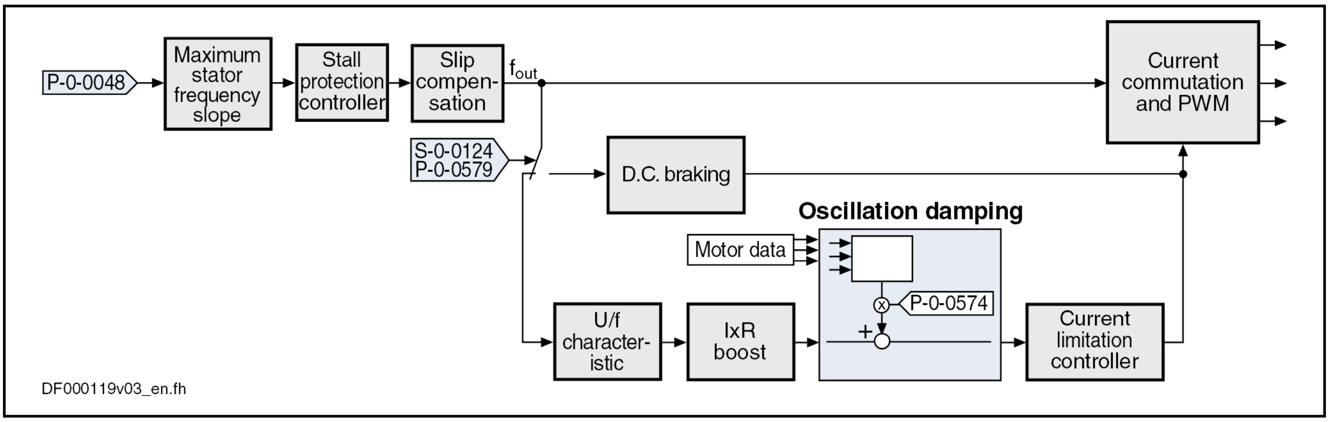


S-0-0124 Standstill window
P-0-0048 Effective velocity command value
P-0-0573 IxR boost factor
P-0-0579 Current for deceleration, time period
Fig. 6-18: Core Function "IxR Boost"

Oscillation Damping

In open-loop operation, asynchronous machines in the case of low load tend towards speed oscillations. With the oscillation damping it is possible to counteract this behavior. The feedforward can be influenced with parameter "P-0-0574, Oscillation damping factor".

With a value of "0.00%" in parameter P-0-0574, the feedforward is switched off.

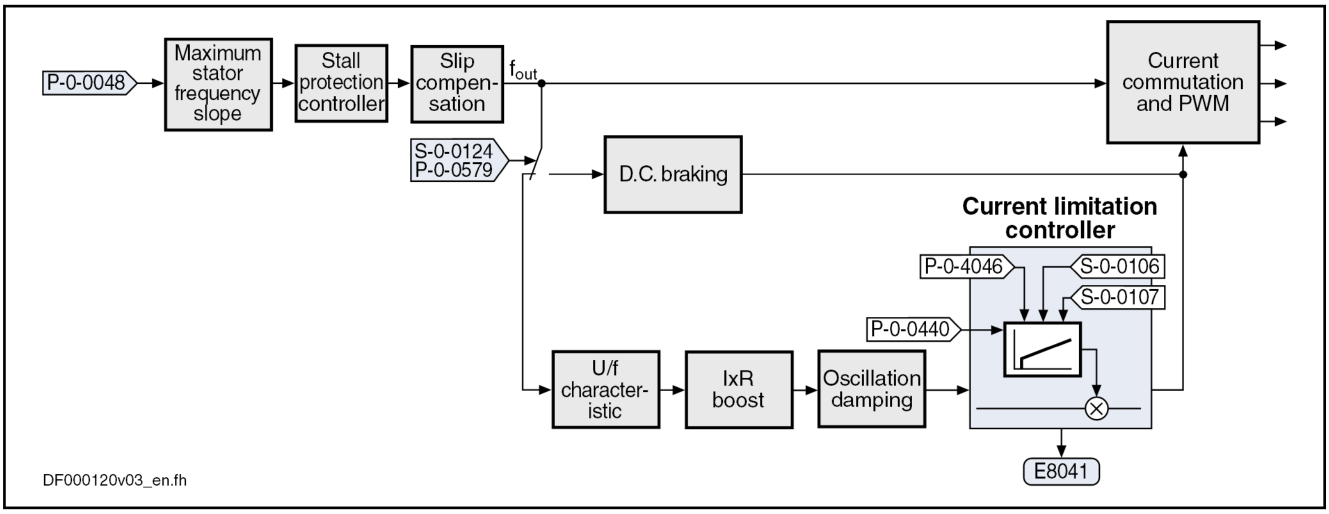


S-0-0124 Standstill window
P-0-0048 Effective velocity command value
P-0-0574 Oscillation damping factor
P-0-0579 Current for deceleration, time period
Fig. 6-19: Core Function"Oscillation Damping"

Current Limitation Controller

It is the task of the current limitation controller to limit the maximum output current by reducing the output voltage. This normally causes breakdown of the motor. In this case, however, this has to be accepted because the protection of motor and devices has the higher priority.

The current limitation controller is activated if the current in the motor exceeds the maximum current of the motor or of the drive controller. Before the activation of the current limitation controller, the activated stall protection controller already tried to reduce the motor load!



S-0-0124	Standstill window
S-0-0106	Current loop proportional gain 1
S-0-0107	Current loop integral action time 1
P-0-0048	Effective velocity command value
P-0-0440	Actual output current value (absolute value)
P-0-4046	Effective peak current
P-0-0579	Current for deceleration, time period

Fig. 6-20: Core Function "Current Limitation Controller"

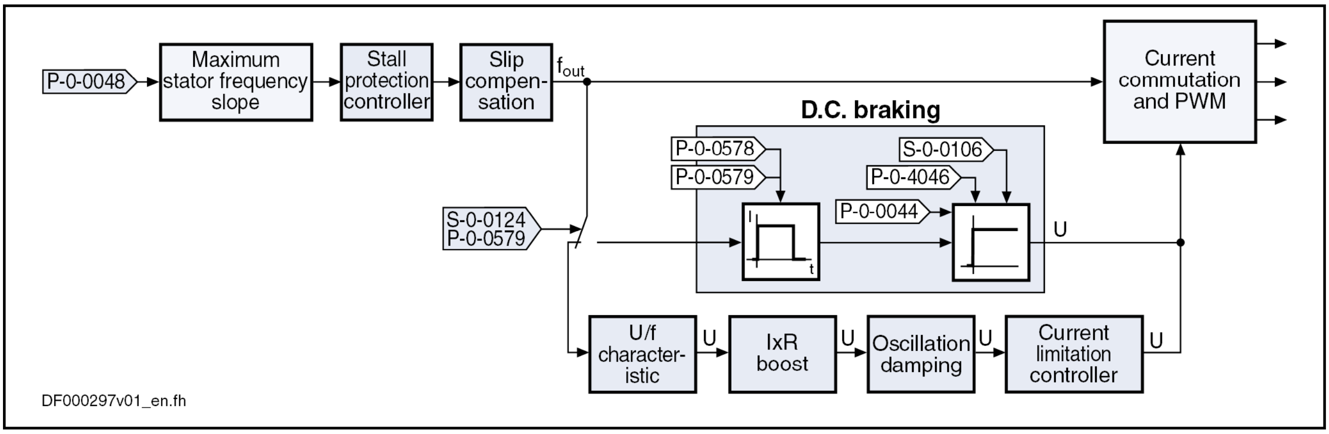
D.C. Braking

D.C. braking, which can be activated, improves motor deceleration in case the velocity command value equals zero. If the absolute value of the velocity command value and actual value falls below the value in parameter "S-0-0124, Standstill window", switching from open-loop voltage control (U/f operation) to closed-loop current control takes place and the current for deceleration is generated. The value of the current for deceleration is preset in parameter "P-0-0578, Current for deceleration, absolute value".

☞ The value of parameter P-0-0578 at least has to correspond to the value of parameter "P-0-4004, Magnetizing current" and is limited to 90% of the motor peak current (S-0-0109). In addition, the thermal limitations of motor and controller take effect!

Due to sensorless motor operation, motor standstill cannot be definitively ascertained. Therefore, the current for deceleration can be maintained, with the value of parameter "P-0-0579, Current for deceleration, time period", beyond the internally detected motor standstill (velocity command value and actual value equal zero), so that the deceleration of the motor is really completed.

☞ The default value of the parameter P-0-0579 is 0.5 s. The parameter value must be adjusted to the deceleration behavior of the axis. Inputting the value "0" deactivates d.c. braking!



S-0-0106 Current loop proportional gain 1
S-0-0124 Standstill window
P-0-0044 Flux-generating current, actual value
P-0-0578 Current for deceleration, absolute value
P-0-0579 Current for deceleration, time period
P-0-4046 Effective peak current
Fig. 6-21: Core Function "D.C. Breaking"

D.C. braking is terminated when one of the following conditions has been fulfilled:

- During the deceleration process, the time period (P-0-0579) for activation of the current for deceleration has elapsed. Starting point of time is when the actual velocity value enters the standstill window (S-0-0124). After the deceleration time is over, the motor is in V/Hz (U/f) control again. At motor standstill, the parameter "P-0-0568, Voltage boost" determines the current flowing in the motor.
- The absolute value of the velocity command value again exceeds the value of the standstill window (S-0-0124). The motor is accelerated in V/Hz (U/f) control.

☞ The value for the parameter "S-0-0106, Current loop proportional gain 1" is determined at execution of the command C3200 (calculate motor data)!

Velocity Search Mode

The velocity search mode is selected and activated in parameter "P-0-0045, Control word of current controller" (bits 8, 9).

The following modes are distinguished for velocity search:

- **Velocity search after drive enable**

  After the start, the search is run up to a speed equal zero with "S-0-0091, Bipolar velocity limit value" in the rotational direction given by "S-0-0036, Velocity command value". At the current speed of the coasting machine, but at the latest at speed = 0, the search mode function is completed and the normal command value processing starts. In normal command value processing, the drive moves to the provided command value with the ramp-function generator.
- **Velocity search after drive enable, bidirectional**

  After the start, the search is run up to a speed equal zero with "S-0-0091, Bipolar velocity limit value" in the rotational direction given by "S-0-0036, Velocity command value". If the speed of the machine has not been found up to speed = 0, there is another search with the rotational direction changed. At the current speed of the coasting machine or at the latest at speed = 0, the search mode function is completed and the normal command value processing starts. In normal command value processing, the drive moves to the provided command value with the ramp-function generator.

During the search process, the current given by "P-0-0575, Search mode: Search current factor" is generated. It is defined as the percentage value of the magnetizing current (P-0-4004).

As soon as the machine has been found, the rated slip is added to the speed at the "finding point". 100% correspond to the rated slip of the machine. This added value is subsequently trimmed with "P-0-0576, Search mode: Finding point slip factor".

Notes on Commissioning

Sensorless motors are for the most part third-party motors. A Technical Note is available, especially for commissioning third-party motors. This Note can be requested from Service or Sales: "Rexroth IndraDrive, Third-party motor Commissioning Manual" (EN_TN4_IndraDrive_Getting_Started_Asy_Sy_Fremdmotor_Vx.y).

Diagnostic and Status Messages

Monitoring the Stator Frequency

The limit value for the maximum change in velocity with which the drive can follow the command values is set in parameter "P-0-0569, Maximum stator frequency slope".

When the limitation of the maximum stator frequency slope takes effect, the diagnostic message "E8260 Torque/force command value limit active" is generated. As soon as the stator can follow the required frequency slope again, the message is reset.

This message can be masked via bit 4 of parameter "P-0-0556, Config word of axis controller":

- Bit 4 = 0 → Message is displayed
- Bit 4 = 1 → Message is not displayed

Status of Stall Protection Controller

The activation of the stall protection controller is displayed in parameter "P-0-0046, Status word of current controller" (bit 12: Stall protection controller):

- Bit 12 = 1 → Stall protection controller active

  In addition, the diagnostic message "E8040 Torque/force actual value limit active" is generated.
- Bit 12 = 0 → Stall protection controller not active

Status of Current Limitation Controller

The activation of the current limitation controller is displayed in parameter "P-0-0046, Status word of current controller" (bit 13: Current limitation controller):

- Bit 13 = 1 → Current limitation controller active

  In Addition, the diagnostic message "E8041 Current limit active" is generated.
- Bit 13 = 0 → Current limitation controller not active

Status of Velocity Search Mode

The status of the velocity search mode can be read in parameter "P-0-0046, Status word of current controller" (bit 14: search mode):

- Bit 14 = 1 → Search mode active
- Bit 14 = 0 → Search mode not active

6.3.4 Field-Oriented Current Control (FOC Control)

Brief Description

Base package of all firmware variants in **closed-loop** characteristic

The current controller was preset for all Rexroth motors and the parameter values have been stored in the motor encoder data memory or in the commissioning tool ("IndraWorks Ds/D/MLD", "DriveTop").

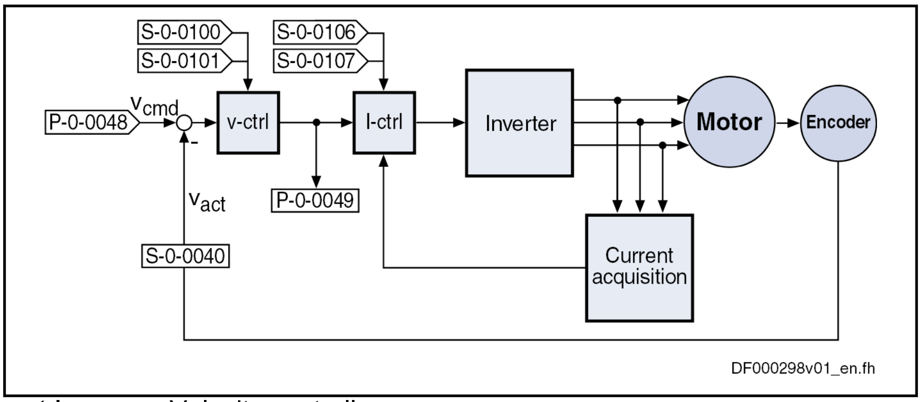
For information regarding the commissioning of the current controller for third-party motors, see "Third-Party Motors at IndraDrive Controllers"!

Principle of Field-Oriented Current Control

In the case of field-oriented current control, the internal control task consists in generating the transformed currents I_d and I_q in controlled form:

- I_d (flux-generating current) → PI controller for I_d
- I_q (torque-generating current) → PI controller for I_q

The figure below illustrates the principle of field-oriented current control for operation with motor encoder:



v-ctrl Velocity controller
I-ctrl Current controller

Fig. 6-22: Simplified Schematic Diagram for Field-Oriented Current Control with Higher-Level Velocity Control

Working Ranges

Field-oriented current control of asynchronous and synchronous motors allows operation in the entire speed range.

The speed range is divided into the following working ranges:

- Basic speed range → **constant torque**
- Field weakening range 1 → **constant power**
- Field weakening range 2 → **power limit range**

General Features

Field-oriented current control has the following general features:

- Control of the motor current according to the principle of field orientation, i.e. separate control of the torque-generating current and the flux-generating current
- Compensation of the cross coupling of the d and q axes to increase dynamics
- Voltage controller for operation in the field weakening range

- Activation of the optimum current controller proportional gain value, depending on the current PWM frequency when loading the default values (motor-specific controller values)

Features of Synchronous Motor Control

In the case of **synchronous motors**, field-oriented current control additionally has the following features:

- Limitation of the I_q command value at the voltage limit for protection against too little control margin
- Utilization of the reluctance effect to increase the available torque in the basic speed range
- Support of synchronous motors with reluctance torque, i.e. motors with significantly different inductances in the d and q axes

Features of Asynchronous Motor Control

In the case of **asynchronous motors**, field-oriented current control has the following features in addition to the general features:

- Optimum torque linearity, even in the field weakening range, by:
  - Permanent correction of the torque constant and the slip factor by means of the currently calculated rotor flux
  - Rotor flux model taking temperature and saturation behavior of the magnetizing inductance into account
- Improved dynamic behavior by:
  - Voltage- and load-dependent flux feedforward
  - Voltage controller for correcting the flux feedforward
  - Flux controller for dynamically generating the rotor flux
- Possibility of reducing the magnetizing current for low-loss operation at no load or in partial load range

Pertinent Parameters

Current controller setting:

- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- P-0-0001, Switching frequency of the power output stage
- P-0-0045, Control word of current controller
- P-0-4002, Charact. of quadrature-axis induct. of motor, inductances
- P-0-4003, Charact. of quadrature-axis inductance of motor, currents

Voltage controller setting:

- P-0-0533,
- P-0-0534, Voltage loop integral action time
- P-0-0535, Motor voltage at no load
- P-0-0536, Maximum motor voltage

Rotor flux control for asynchronous motors:

- P-0-0528, Flux control loop proportional gain
- P-0-0529, Scaling of stall current limit
- P-0-0530, Slip increase
- P-0-0532, Premagnetization factor

Power monitoring:

- S-0-0158, Power threshold Px
- S-0-0337, Status "P >= Px"
- S-0-0382, DC bus power

Display parameters:

- S-0-0380, DC bus voltage
- P-0-0046, Status word of current controller
- P-0-0063, Torque-generating voltage, actual value
- P-0-0064, Flux-generating voltage, actual value
- P-0-0065, Absolute voltage value, actual value

Pertinent Diagnostic Messages

- C0132 Invalid settings for controller cycle times
- E8025 Overvoltage in power section
- E8028 Overcurrent in power section
- F2077 Current measurement trim wrong
- F8060 Overcurrent in power section

General Function of Field-Oriented Current Control

Torque/Force Control

In contrast to the functional principle called "torque/force control" mode, this actually is current control, as the actual current value is measured and not the force or the motor torque. This means that control of torque/force takes place, the torque or the force being directly connected to the torque-/force-generating current via the torque/force constant:

$$M_i = K_M \times I_q$$

The so-called torque/force constant "K_M", however, is not a static value, it is changed by:

- Amount of the actually flowing current: Reduction of currents larger $I_{nominal}$
- Temperature change of motor winding and rotor: Reduced when temperature rises

This causes deviations of the torque at the motor shaft compared with the value displayed on the drive side. In the case of torque/force scaling in the physical units "Nm" and/or "N", the value on the drive side differs from the actual effect of the motor; in the case of percentage-based scaling, the displayed value is only correct for the current ratio.

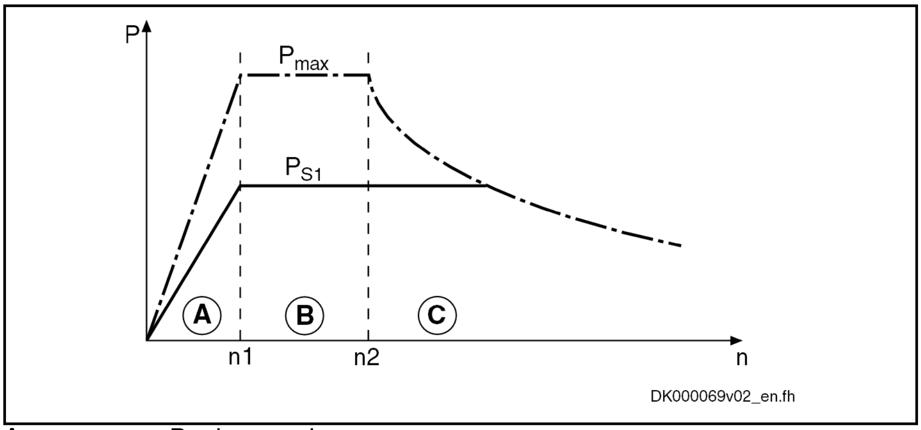
With synchronous motors, the specified influencing factors can be corrected on the drive side so that a more precise torque/force constant takes effect for the torque/force calculation, see also "Compensation functions / correction of the torque/force constants"

In the case of asynchronous motors, the torque constant is only corrected according to the current rotor flux.

Field Weakening Operation

With the firmware it is possible to operate asynchronous and synchronous motors in the entire speed range (including field weakening range).

We basically distinguish 3 working ranges that are illustrated in the following figure and described below.



A Basic speed range
B Field weakening range 1
C Field Weakening Range 2 (Power Limit Range)

Fig. 6-23: Three Working Ranges of the Speed Range

Basic speed range

The basic speed range is characterized by constant torque and a speed-independent torque/force constant (P-0-0051).

In the case of asynchronous motors, the programmed, effective magnetizing current flows in no-load operation. The motor voltage is less than the maximum controller output voltage. The corner speed n1 is directly proportional to the DC bus voltage.

Field Weakening Range 1 (Constant Power)

The field weakening range 1 is characterized by constant power, the motor voltage is kept constant. In the case of asynchronous motors, the no-load current is reduced as the speed increases. This reduces the magnetization and the torque constant, the slip increases accordingly. The adjustment of magnetizing current and slip is automatically carried out by the voltage controller.

Field Weakening Range 2 (Power Limit Range)

The field weakening range 2 is the range of decreasing peak power. An asynchronous motor works at the stall current limit in this range, through vector control the current is maintained at an efficient and stable level. The peak current is reduced in such a way that the point of maximum power is not exceeded. Further increase in current would only lead to increased power dissipation and less shaft output. The peak power in range 3 is proportional to the square of the DC bus voltage. It is ensured that the maximum possible power is reached for each DC bus voltage without parameter adjustment.

☞ Due to this causal connection, it is clear that the power in range 3 cannot be increased by using a more powerful controller. In this range, performance can only be increased by increasing the voltage of the DC bus!

In the following sections, we distinguish control of synchronous machines (with motor encoder) and asynchronous machines (with and without motor encoder).

Field-Oriented Current Control of a Synchronous Machine

☞ For synchronous motors, field-oriented current control is only possible with motor encoder (with closed-loop base package)!

Synchronous motors with a motor encoder in field-oriented current control can be operated in all available operation modes. The figure below illustrates the control loop structure and the points at which the individual parameters take effect for a synchronous machine.

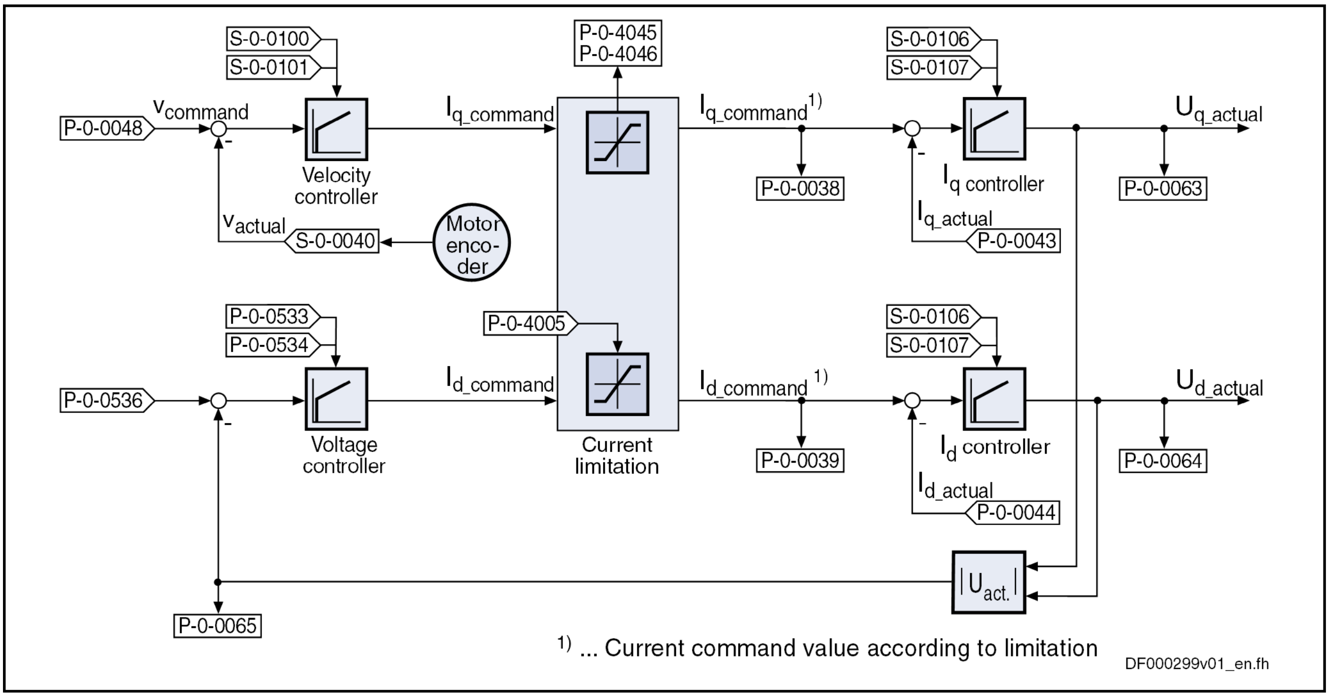


Fig. 6-24: Simplified Schematic Diagram of the Current Control Loop for a Synchronous Machine

Voltage Controller for Synchronous Motors

For field control (or voltage control), a voltage controller designed as a PI controller is used that can be set via the following parameters:

- P-0-0533,
- P-0-0534, Voltage loop integral action time

☞ The command value of the voltage controller is preset by parameter "P-0-0536, Maximum motor voltage".

The voltage controller becomes active when the current controller output exceeds a defined absolute voltage value (cf. "P-0-0536, Maximum motor voltage"). By generating a field counteracting the permanent field-linked direct-axis flux (→ negative I_d command value), the reduction of the output voltage can be obtained.

☞ The output value of the voltage controller is the command value for the field-generating component of the subsequent current controller (see figure "chapter "Field-Oriented Current Control of a Synchronous Machine" on page 382").

Field Weakening of Synchronous Motors

In the case of synchronous motors with field weakening, a command value of I_{d_cmd} = 0 is run in the basic speed range, as in the case of synchronous motors without field weakening.

When entering the field weakening, I_{d_cmd} is increased towards negative values and therefore allows higher motor velocities.

Closed-Loop Control of Synchronous Motors with Distinctive Reluctance Torque

Closed-loop control of synchronous motors with reluctance torque, i.e. motors with significantly different inductances in the d-axis and q-axis, requires the separate input of L_d and L_q in the respective parameters:

- P-0-4016, Direct-axis inductance of motor (Ld)

- P-0-4017, Quadrature-axis inductance of motor (Lq)

Additional characteristic data for the motor are required in order to use the additional reluctance torque in the best possible way:

- P-0-3940, Motor torque/force at nominal current when using reluctance
- P-0-3941, Motor torque/force at maximum current when using reluctance
- P-0-3942, Reluctance angle at nominal motor current
- P-0-3943, Reluctance angle at maximum motor current

In the case of Rexroth housing motors, these parameters are loaded into the control unit via the encoder data memory, and are activated automatically.

☞ Utilization of the reluctance effect allows increasing the available torque in the basic speed range.

Field-Oriented Current Control of an Asynchronous Machine

Field-oriented control of the asynchronous machine differs from control of the synchronous machine in the additional function blocks "flux feedforward" and "flux controller incl. field model".

The figure below illustrates the control loop structure of field-oriented current control:

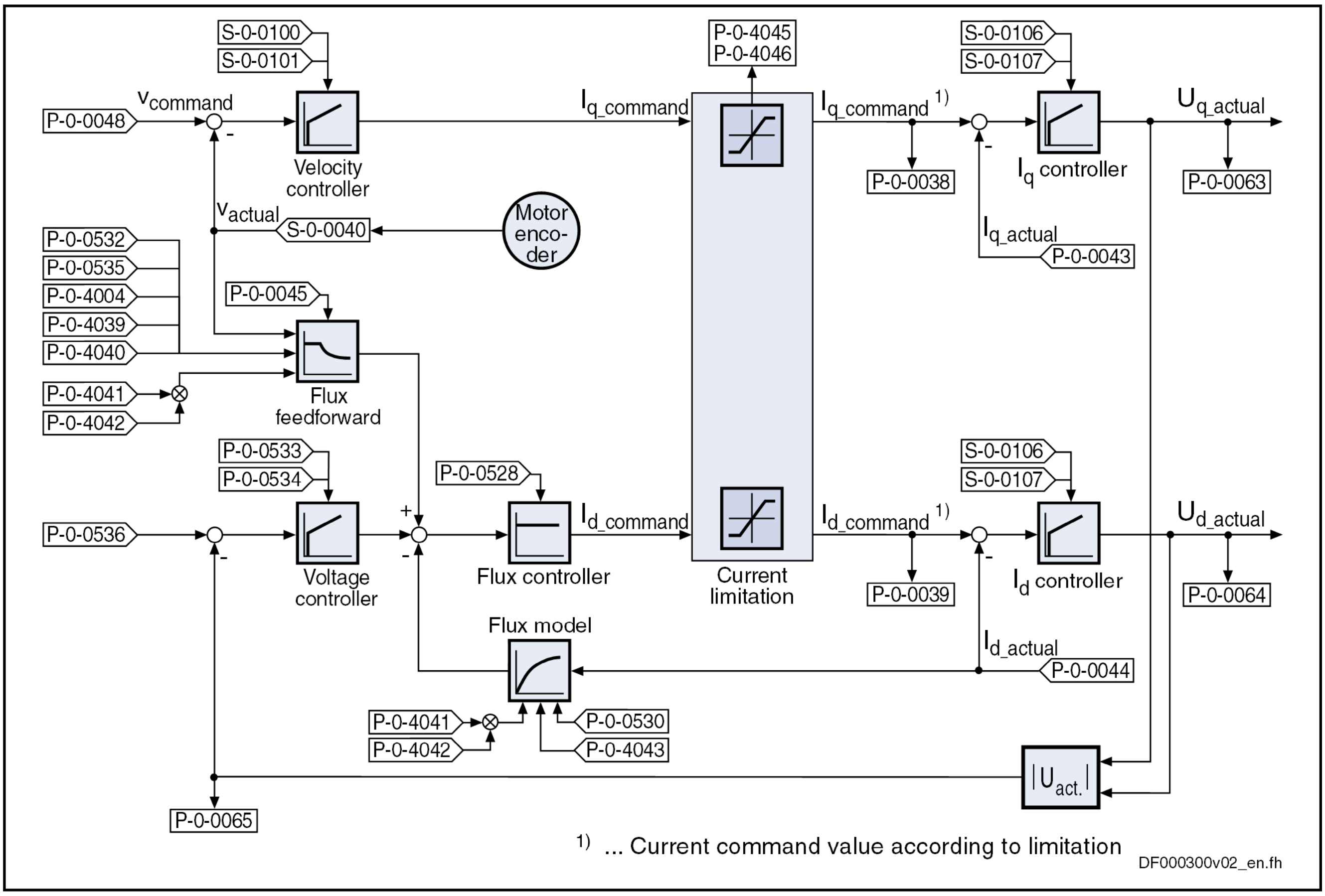


Fig. 6-25: Simplified Schematic Diagram of the Current Control Loop for an Asynchronous Machine

Flux Feedforward and Flow Model

The flux feedforward calculates the optimum rotor flux command value for each working point of the machine. The limiting variable is the motor voltage that increases with the speed. The flux feedforward uses the value in parameter "P-0-0535, Motor voltage at no load" as the limit value.

In addition, the following motor data have an influence on flux feedforward and flux model:

- P-0-4004, Magnetizing current
- P-0-4039, Stator leakage inductance
- P-0-4040, Rotor leakage inductance
- P-0-4041, Motor magnetizing inductance
- P-0-4042, Characteristic of motor magnetizing inductance
- P-0-4043, Rotor time constant

On the basis of the above motor data and the active value of the flux-generating current I_d, the flux model calculates the actual value of the rotor flux. This value is used as actual value for the flux controller (see below) and additionally determines the torque constant and the slip frequency of the asynchronous machine required for generating the torque.

Voltage Controller

The voltage controller works as a PI controller and in the absolute value limits the voltage output by the current controller to a maximum value. The setting is made via the following parameters:

- P-0-0533,
- P-0-0534, Voltage loop integral action time
- P-0-0536, Maximum motor voltage

☞ When the maximum motor voltage is exceeded, the output of the voltage controller interferes in a corrective way in the output value of the flux feedforward.

Flux Controller

The flux controller works as a P-controller with command value feedforward. It compares the actual value from the rotor flux model to the command value from flux feedforward and voltage controller and by the corresponding input of the flux-generating current component $I_{d\text{-}cmd}$ provides for rapid rotor flux generation. This is of importance for applications with dynamic speed response (field weakening range). The gain can be set in "P-0-0528, Flux control loop proportional gain".

☞ In the case of asynchronous motors, the field or rotor flux control has a decisive influence on the torque generation and dynamic response of the machine, particularly in the field weakening range.

☞ For Rexroth motors, the corresponding value is stored in the "DriveBase" database.

Stall Current Limit

The stall current limit only takes effect in the power limit range of the field weakening range (C). The maximum allowed torque-generating current is calculated by means of the active rotor flux and the motor data. This absolute limit value can be relatively changed via the setting in "P-0-0529, Scaling of stall current limit" (in percent).

☞ When operating a motor without field weakening, it is only the effective magnetizing current that is applied as the command value for the field-generating current component.

Determining the Rotor Flux Angle

For field-oriented control of an asynchronous motor, the current rotor flux angle is continuously required. This angle is generated from the position information of the motor encoder.

Drive Enable and Command Value Enable

After "AF", the asynchronous motor must be magnetized before it can deliver torque. For this purpose, 70% of the allowed maximum motor current is provided internally as the magnetizing current command value (providing this is possible on the controller side). Due to the increased magnetizing current, the magnetic field in the motor is built up faster than if only the nominal magnetizing current had been provided as the command value.

When the magnetic flux in the motor has reached 75% of the flux command value, the enable signal is set for external (master-side) command values and a holding brake, possibly controlled by the drive controller, is released.

$$\begin{aligned}\text{Magn. flux, command value} &= \text{P-0-0532} \times \text{P-0-4004} \times \text{P-0-4041}\\ &= \text{P-0-0532} \times \text{Nominal flux}\end{aligned}$$

P-0-0532	Premagnetization factor
P-0-4004	Magnetizing current
P-0-4041	Motor magnetizing inductance

Fig. 6-26: Calculating the Command Value for the Magnetic Flux

The flux command value can be reduced by the premagnetization factor. A premagnetization factor of less than 100% reduces the delay of drive enable (AF) until the master-side command value is enabled; however the immediate torque development of the asynchronous motor (starting torque) is also reduced. This effect is transient, i.e. the reduction is no longer effective in the case of stationary load.

Approximate calculation of the time delay of "AF" until command value enable:

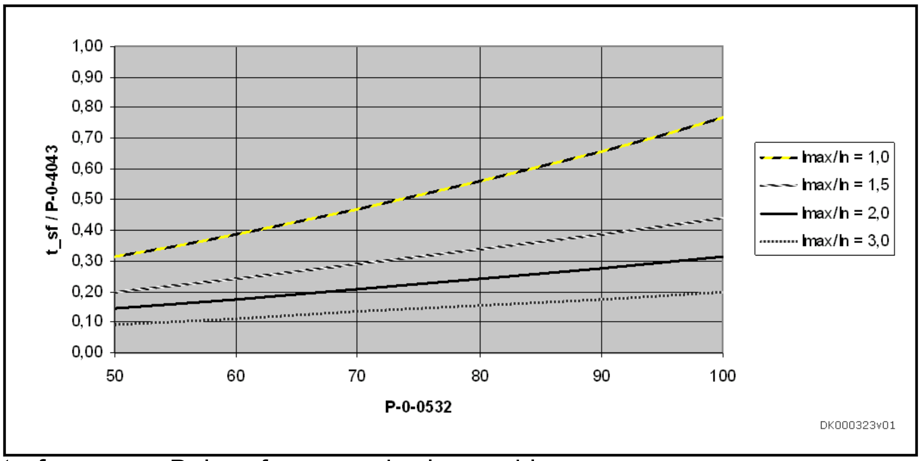
$$t\_sf = (\text{P-0-0043}) \times (-1) \times \ln(1 - \frac{0,75 * (\text{P-0-4004}) \times (\text{P-0-0532})}{0,7 \times \text{Imax}}$$

t_sf	Delay of command value enable
P-0-4043	Rotor time constant
P-0-4004	Magnetizing current
P-0-0532	Premagnetization factor
Imax	Maximum allowed or possible motor current

Fig. 6-27: Calculating, by Means of Approximation, the Delay without Taking the Magnetic Saturation in the Motor into Account

☞ If magnetic saturation of the motor has been parameterized in "P-0-4042, Characteristic of motor magnetizing inductance", the actual delay can increase as compared to the calculated value of t_sf!

Delay diagram for varying overload conditions (assumption: P-0-4004 = 0.5 x nominal motor current):



t_sf	Delay of command value enable
P-0-4043	Rotor time constant
P-0-0532	Premagnetization factor
Imax	Maximum allowed or possible motor current
In	Nominal motor current

Fig. 6-28: Delay Based on the Rotor Time Constant (P-0-4043) Depending on P-0-0532 with Varying Overload Conditions

The starting torque depends on the available or allowed maximum current. Command value enable is set when 75% of the command value for the magnetic flux have been reached. The starting torque is reduced when the delay for command value enable is shortened by reduction of "P-0-0532, Premagnetization factor".

Approximate calculation of the available starting torque at command value enable:

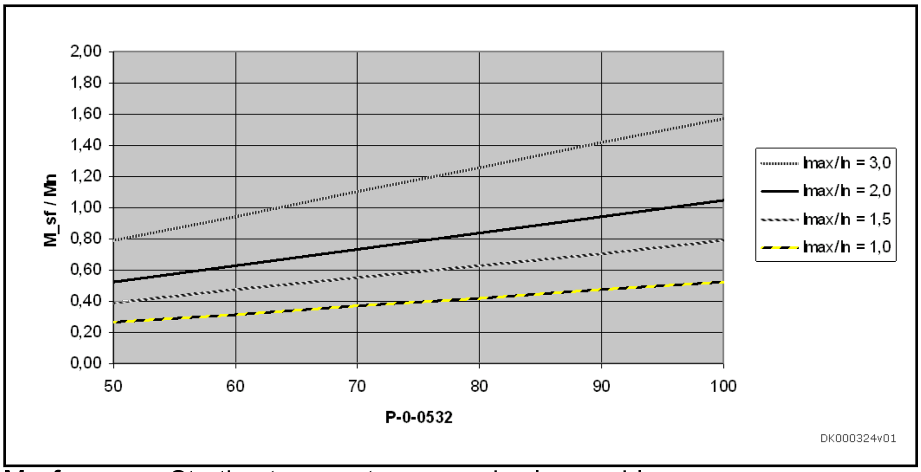
$$M\_sf = 0{,}75 * \frac{0{,}7 * Imax}{In} * \frac{P-0-0532}{100\%} * Mn$$

M_sf	Starting torque of the motor at command value enable
Mn	Nominal motor torque
Imax	Maximum allowed or possible motor current
In	Nominal motor current
P-0-0532	Premagnetization factor

Fig. 6-29: Calculating, by Means of Approximation, the Starting Torque without Taking Magnetic Saturation Effects in the Motor into Account

☞ After the start, the magnetic flux in the motor in no-load operation increases up to the flux command value. This value can be reduced by P-0-0532 < 100% compared to the nominal flux. Under load with nominal or short-time operation torque, the magnetic flux increases automatically to the nominal flux; the flux-reducing effect of P-0-0532 is ineffective under load.

Starting torque diagram for varying overload conditions (without magnetic saturation):



M_sf	Starting torque at command value enable
Mn	Nominal motor torque
P-0-0532	Premagnetization factor
Imax	Maximum allowed or possible motor current
In	Nominal motor current

Fig. 6-30: Starting torque based on the nominal torque depending on P-0-0532 with varying overload conditions

☞ In the case of motors with saturation effect, the available starting torque is reduced according to the magnetic saturation of the motor. This effect increases with higher values of P-0-0532! The saturation effect can be compensated by parameterization of the magnetic saturation of the motor in "P-0-4042, Characteristic of motor magnetizing inductance".

See also the Notes on Commissioning on this topic chapter "Notes on Commissioning" on page 388.

Notes on Commissioning

☞ The current controller was preset for all motors by Rexroth and normally does not need to be adjusted.

Current controller

The current controller for the torque- or force-generating current (I_q) designed as a PI controller can be set via the following parameters:

- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1

The respective parameter settings depend on the properties of the motor winding (L and R) and on the sampling time of the current controller.

Availability of the parameter settings for the current controller:

- For Rexroth motors with motor encoder data memory, they are stored in this memory.
- For Rexroth motors without motor encoder data memory, they can be taken from the motor data base by means of a commissioning tool.
- For third-party motors, they have to be calculated by means of the data sheet (see "Automatic Setting of Motor Control" and "Third-Party Motors at IndraDrive Controllers").

See also "Commissioning Motors"

Inductance Characteristic for Synchronous Motors

It is possible to store a characteristic of the motor quadrature-axis inductance (L_q) in the drive depending on the torque-generating current (I_q). If required (e.g. saturation phenomena), it is thereby possible to achieve the reduction of the effective current controller gain for higher currents. This function is activated by setting bit 12 in "P-0-4014, Type of construction of motor".

☞ For motors with significant saturation phenomena, it is recommended to use the inductance characteristic to achieve adjustment of the effective current controller gain!

The following parameters are used to define the characteristic:

- P-0-4002, Charact. of quadrature-axis induct. of motor, inductances
- P-0-4003, Charact. of quadrature-axis inductance of motor, currents

Both parameters have a list structure; the respective list elements form pairs of values which define the characteristic. The values in P-0-4002 are factors which refer to the value in "P-0-4017, Quadrature-axis inductance of motor". The inductance values L_q of the characteristic are resulting by multiplication with this value. The values in P-0-4003 are factors which refer to the value in "S-0-0111, Motor current at standstill". The current values I_q of the characteristic are resulting by multiplication with this value.

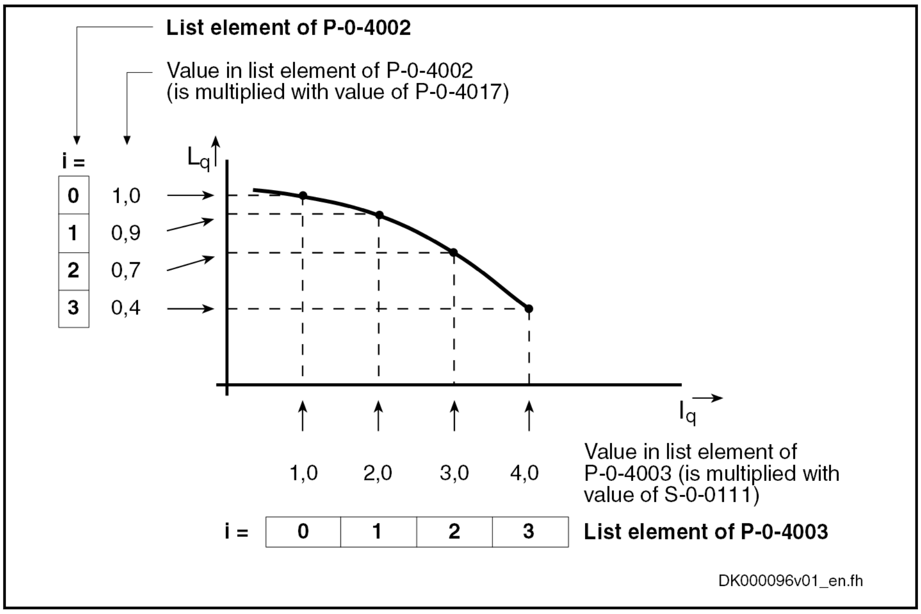


Fig. 6-31: Interaction of the Parameters for Defining the Inductance Characteristic (with Exemplary Values)

Flux Feedforward for Asynchronous Motors

Due to higher magnetization (rotor flux), the motor produces higher torque. In no-load operation, however, the magnetization produces loss which is the reason why it is useful to reduce magnetization for less dynamic applications.

☞ To reduce the magnetization, a value between 50% and 100% can be set in "P-0-0532, Premagnetization factor".

In addition, magnetization can be influenced via bit 2 in "P-0-0045, Control word of current controller":

- Bit 2 = 0 (default setting)

  → According to required torque, magnetization is increased up to nominal value; 100% are reached at nominal motor torque
- Bit 2 = 1

→ Independent of load, magnetization remains at value set in P-0-0532

The value in "P-0-0535, Motor voltage at no load" is used as limit value for the flux feedforward. The motor voltage at no load is specified in a percentage-based way and also refers to the maximum possible output voltage of the inverter.

☞ It is advisable to **set 80%** in P-0-0535.

Flux Model for Asynchronous Motors

The slip frequency used in the flux model changes with the temperature of the motor. This is compensated by measuring the motor temperature (S-0-0383) and scaling with the factor in "P-0-0530, Slip increase".

☞ The factor in P-0-0530 has to be set depending on the motor cooling type!

Activating Field Weakening with Synchronous Motors

In addition to the parameterization of the voltage controller, the following settings can be made or changed, if required:

- Via bit 0 in "P-0-0045, Control word of current controller", the field weakening can be activated.

Voltage Controller (Flux Controller)

The voltage controller designed as a PI controller (flux controller) can be set via the following parameters:

- P-0-0533,
- P-0-0534, Voltage loop integral action time

☞ The voltage controller is only active with synchronous motors when bit 0 has been set (field weakening operation active) in the control word of the current controller (P-0-0045).

The command value of the voltage controller is determined by means of "P-0-0536, Maximum motor voltage".

The input in P-0-0536 is made in percent and refers to the maximum possible output voltage of the inverter that is determined by the current DC bus voltage (see "S-0-0380; DC bus voltage").

☞ It is advisable to **set 90%** in P-0-0536.

Drive Enable and Command Value Enable with Asynchronous Motors

Drive enable (AF) and command value enable are mapped in "P-0-0115, Device control: Status word". The delay of command value enable as compared to drive enable can be measured by evaluating the affected bits.

The delay (t_sf, see above) is affected by the value in "P-0-0528, Flux control loop proportional gain". It must have a minimum value so that the expected delay t_sf (see above) is not increased:

$$\text{P-0-0528} \geq \left[\frac{0{,}7 \times I_{max}}{(\text{P-0-0532}) \times (\text{P-0-4004})} - 1 \right]$$

P-0-0528	Flux controller proportional gain
I_{max}	Maximum allowed or possible motor current
P-0-0532	Premagnetization factor
P-0-4004	Magnetizing current

Fig. 6-32: Calculating the Minimum Value of P-0-0528

☞ Check whether, with the modified value of P-0-0528, the drive behavior meets the requirements in terms of

- Delay of command value enable as compared to drive enable
- Acceleration and braking behavior in the entire velocity range

If the magnetizing inductance of the motor goes into magnetic saturation and the characteristic is known, it is to be entered in "P-0-4042, Characteristic of motor magnetizing inductance". This does increase the command value enable delay as compared to the calculated value, but the determined starting torque M_sf (see above) is more realistic.

Diagnostic and Status Messages

Status Messages

- S-0-0158, Power threshold Px

  This parameter determines the power threshold above which the drive outputs the status message "power > = Px" in "S-0-0337, Status "P >= Px"".
- S-0-0337, Status "P >= Px"

  Only bit 0 of this parameter is used. It is set when the following applies:

  "S-0-0382, DC bus power" ≥ "S-0-0158, Power threshold Px"

  Simultaneously, bit 7 is set in "S-0-0013, Class 3 diagnostics".

Display Values and Diagnostic Values

- The DC bus voltage is measured in the current controller clock and displayed in "S-0-0380, DC bus voltage".
- The effective electric power produced by the drive controller (taking the inverter losses into account) is displayed in "S-0-0382, DC bus power".

  The effective power (P_w) is calculated according to the following formula:

  $$P_w = (U_d \times I_d + U_q \times I_q) \times 1{,}5$$

  The calculated value is displayed in filtered form (T = 8 ms). When the parameterized threshold value in "S-0-0158, Power threshold Px" is exceeded, bit 0 is set in "S-0-0337, Status "P >= Px"" and bit 7 in class 3 diagnostics.
- The measured value of the torque-generating current (I_q) detected in the current controller clock is displayed in parameter "P_0_0043 Torque-generating current, actual value, actual value".
- The measured value of the field-generating current (I_d) detected in the current controller clock is displayed in "P-0-0044, Flux-generating current, actual value".
- "P-0-0046, Status word of current controller" displays the state of the current controller.

Errors, Warnings and Monitoring Functions

- C0132 Invalid settings for controller cycle times

  → An error was detected in the parameterization of the controller cycle times and PWM frequency.
- E8025 Overvoltage in power section

→ This warning is generated when the DC bus voltage exceeds a value of 870.0 V. In this case, the current controller is temporarily switched off to protect the motor.

- E8028 Overcurrent in power section

  → This warning is generated when the total current > 1.2 × minimum (S-0-0109, Motor peak current; S-0-0110, Amplifier peak current). In this case, the current controller is temporarily switched off to protect the motor (to avoid demagnetization).

- F2077 Current measurement trim wrong

  → During zero adjustment of the current measurement, a deviation outside of the tolerance range has occurred (hardware defect).

6.3.5 Motor Operation Without Encoder, Flux-Controlled (FXC Control)

Brief Description

Base package of all firmware variants in **open-loop and closed-loop** characteristic, except MPE-18VRS.

For asynchronous and synchronous motors, flux-controlled, sensorless motor operation is available in the base packages "open-loop" and "closed-loop" of all firmware variants and can be used in the "velocity control" mode and in position-controlled operation modes which use position encoder 2 (external encoder).

When using the firmware expansion package "synchronization", you can also run the operation mode "velocity synchronization with real/virtual master axis".

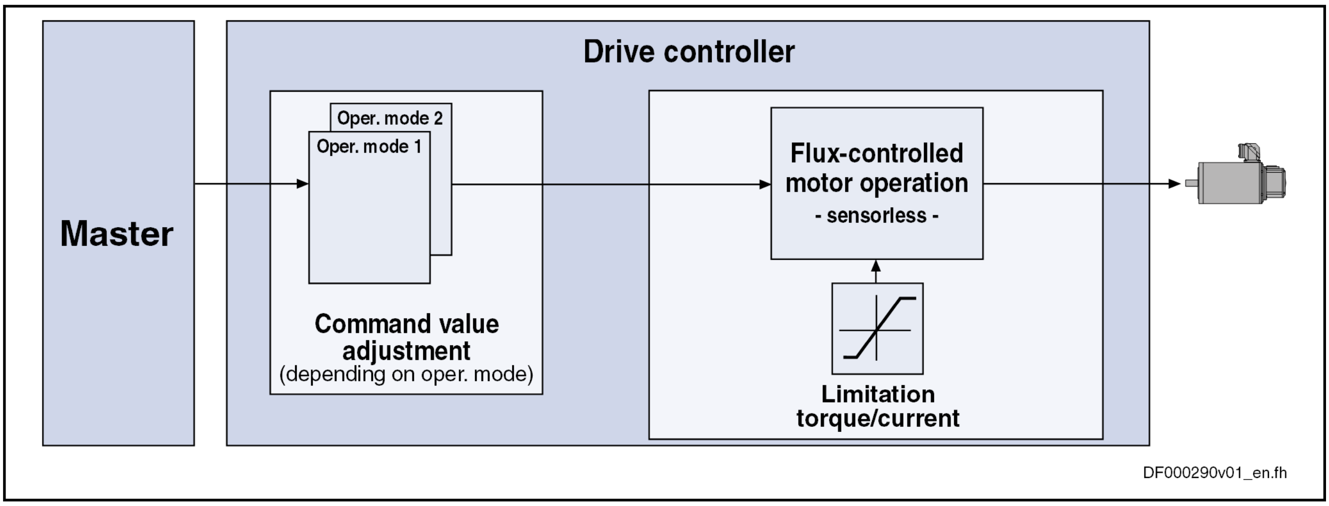


Fig. 6-33: Principle of Sensorless, Flux-Controlled Motor Operation

Features

- Limitation of the maximum **stator frequency slope** that results from the command velocity change
- "Stable" motor operation

  → To maintain the maximum possible torque

- **Slip compensation** for asynchronous motors (estimated motor slip taken into account for calculating actual velocity value)

  → To minimize the stationary speed deviations, due to slip, from the command value when the asynchronous motor is loaded

- Motor speed does not tend to oscillation in operation at partial load and no-load operation
- **Velocity search mode** of a coasting asynchronous motor after switching drive enable on
- Possibility of taking user-side **torque/force limitation** into account

Pertinent Parameters

Motor control parameters of sensorless, flux-controlled motor operation:

- P-0-4033, C3200 Command Calculate motor data
- P-0-0532, Premagnetization factor
- P-0-0565, C3600 Command Motor data identification
- P-0-0578, Current for deceleration, absolute value
- P-0-0579, Current for deceleration, time period
- P-0-0580, Motor frequency
- P-0-0594, FXC: Total flux loop integral action time
- P-0-0595, Frequency loop proportional gain (FXC)
- P-0-0596, FXC: Frequency loop scaling factor of inertia
- P-0-0597, FXC: Current loop proportional gain
- P-0-0598, FXC: Current loop integral action time
- P-0-0599, FXC: Slip frequency filter time constant
- P-0-0600, FXC: Rated slip frequency
- P-0-0602, FXC: Minimum no-load current

Motor data parameters:

- P-0-0510, Rotor inertia
- P-0-4004, Magnetizing current
- P-0-4032, Motor type plate data

Axis data parameters:

- P-0-4010, Load inertia

Control parameters:

- P-0-0045, Control word of current controller
- P-0-0601, Configuration motor data identification

Functional Description

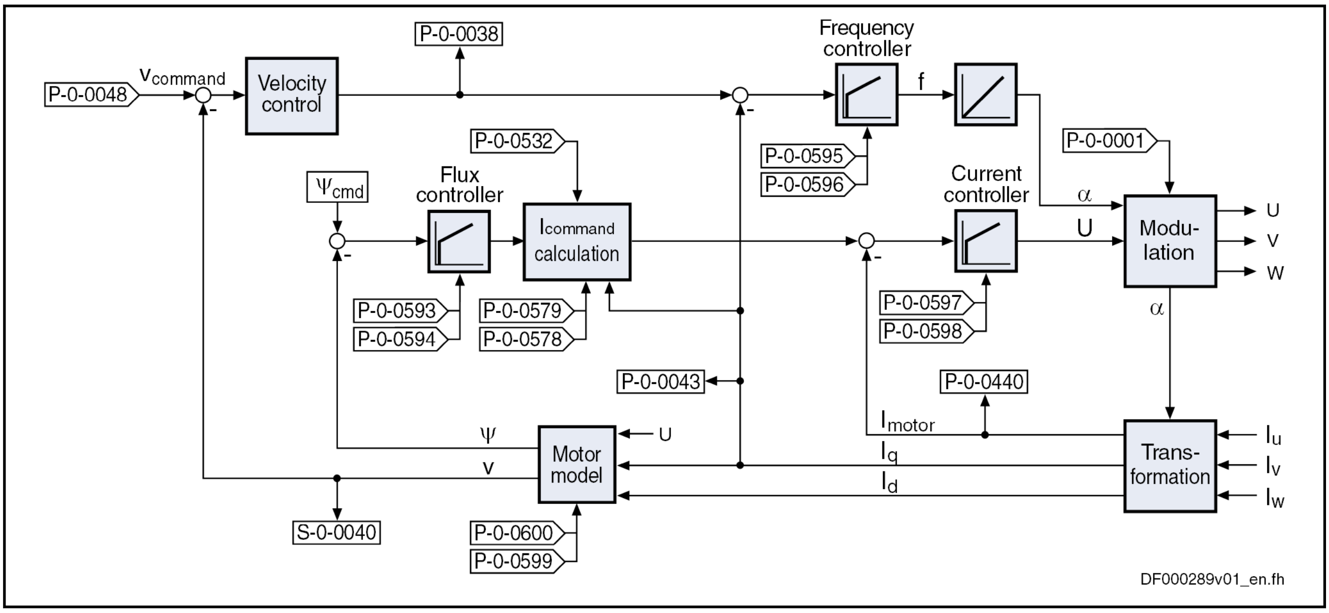


Fig. 6-34: Block Diagram of Sensorless, Flux-Controlled Motor Operation

Control Method

For controlling sensorless synchronous motors (SYM) or asynchronous motors (ASM), the control method generates a three-phase rotary field with variable voltage amplitude and rotary field frequency. The rotary field frequency depends on the velocity command value, the number of pole pairs of the motor and, in the case of ASM, on the motor load. The amplitude of the motor voltage depends on the impedances and on the magnetic flux in the motor.

The frequency of the motor voltage is given by a PI frequency loop, depending on the control difference of the torque-generating command current and actual current. It is the electrical equivalent of the velocity:

- For ASM, torque is generated by "slip" (deviation from velocity command value under load). This "slip" can be compensated for ASM via the calculated actual velocity value (motor model calculation). When the load exceeds the "pull-out slip" of the motor, it stops.
- For SYM (synchronous motors), the torque is generated by the "load angle". Its value is proportional to the load; when it remains smaller than 90° el., the actual velocity value follows the velocity command value without deviation. When the load causes a load angle greater than 90° el., the SYM stops abruptly.

The amplitude of the motor voltage is given by a PI current controller, depending on the control difference of the total motor current:

- For ASM, the required magnetic flux must be generated in the air gap. The optimum flux command value for the motor is preset drive-internally. From the current state variables, the motor model calculates the flux existing in the motor. By means of the flux deviation, the PI flux controller and a subsequent calculation function generate the command value for the total motor current.
- For SYM, the magnetic flux already exists in the air gap due to the permanent magnets. However, a command value for the total motor current is preset when the motor is in no-load operation. The impulse load stability is improved with increased no-load current, the no-load loss, however, is increased.

Deceleration, Standstill

At low speed, the determination of the actual velocity is highly inexact due to motor operation without encoder. At output frequencies below a threshold value, a current for deceleration (P-0-0578, Current for deceleration, absolute value) which can be set is therefore output during deceleration to bring the motor to standstill. During the determination of the motor parameters, the value is automatically set to the rated current of the motor.

As motor standstill cannot be reliably identified, the current for deceleration, after the velocity command value and the actual velocity value have been brought to zero, is maintained for a time which can be set (P-0-0579, Current for deceleration, time period) so that the motor really comes to standstill.

When this time is over, the current is reduced, with the drive having been enabled:

- For asynchronous motors to the magnetizing current (P-0-4004).
- For synchronous motors to the no-load current (P-0-0602).

In both cases, the current flowing in the motor when it is in standstill can be reduced more via a premagnetization factor (P-0-0532). This reduces the temperature rise of the enabled motor which is in standstill and the thermal load of the controller.

"Coasting" Motor

By means of the velocity search mode, a coasting asynchronous motor can be brought to deceleration mode and be decelerated, or run to a command value. When this is done, the control of the motor first synchronizes to the current rotational frequency of the motor, before the command value becomes active.

☞ For synchronous motors, this function is not available.

Working Ranges

The sensorless, flux-controlled synchronous or asynchronous motor works in a velocity-dependent way in the basic speed range (low speed) or in the field weakening range (high speed). For the field weakening range, it is not necessary to make any further settings.

Determining the Motor and Motor Control Parameters

On the basis of the type plate parameters, the controller can automatically determine the motor parameters for synchronous motors and asynchronous motors by executing commands.

See "Automatic Setting of Motor Control"

Frequency Controller

The frequency controller has been designed as an I controller. It limits the slope of the frequency change of the motor voltage, when accelerating and decelerating, to the steepest, stable characteristic. The slope is significantly determined by the total inertia of the axis (inertia ramp).

The maximum slope to the stator frequency can be calculated by means of the following formula:

Asynchronous motor:

$$\frac{\Delta f_{Stator}}{\Delta t} = \frac{PPZ \times M_{th}}{2 \times \pi \times J_{Axis\_MW\_FXC}} = \frac{3 \times (P\text{-}0\text{-}0018)^2 \times (S\text{-}0\text{-}0111) \times (P\text{-}0\text{-}4004) \times (P\text{-}0\text{-}4041) * 10^{-3}}{2 \times \pi \times [(P\text{-}0\text{-}0510) + (P\text{-}0\text{-}4010)]} \; [Hz/s]$$

Synchronous motor:

$$\frac{\Delta f_{Stator}}{\Delta t} = \frac{PPZ \times M_{th}}{2 \times \pi \times J_{Axis\_MW\_FXC}} = \frac{(P\text{-}0\text{-}0018) \times (P\text{-}0\text{-}0051) \times (S\text{-}0\text{-}0111)}{2 \times \pi \times [(P\text{-}0\text{-}0510) + (P\text{-}0\text{-}4010)]} \; [Hz/s]$$

Conversions:

$$\frac{\Delta \omega_{Rotor}}{\Delta t} = \frac{2 \times \pi}{(P\text{-}0\text{-}0018)} \times \frac{\Delta f_{Stator}}{\Delta t} \left[rad/s^2\right]$$

$$\frac{\Delta n_{Rotor}}{\Delta t} = \frac{60s/min}{(P\text{-}0\text{-}0018)} \times \frac{\Delta f_{Stator}}{\Delta t} = \frac{60s/min}{2 \times \pi} \times \frac{\Delta \omega_{Rotor}}{\Delta t} \left[min^{-1}/s\right]$$

f_{Stator}	Stator frequency
M_{th}	Theoretical maximum torque of the motor (internally calculated)
PPZ	Number of pole pairs of the motor
$J_{Axis\_MW\_FXC}$	Effective inertia of the axis (in frequency controller)
ω_{Rotor}	Angular frequency of the rotor (motor shaft)
n_{Rotor}	Speed of the rotor (motor shaft)
P-0-0018	Number of pole pairs/pole pair distance
S-0-0111	Motor current at standstill
P-0-4004	Magnetizing current
P-0-4041	Motor magnetizing inductance
P-0-0510	Rotor inertia
P-0-4010	Load inertia
P-0-0051	Torque/force constant

Fig. 6-35: Calculating the Stator Frequency Slope (Inertia Ramp)

Enter the motor inertia in the parameter "P-0-0510, Rotor inertia" and the axis inertia (motor-shaft-related) in the parameter "P-0-4010, Load inertia".

The motor-shaft-related total axis inertia is also determined by "C3600 Command Motor data identification" when the command was executed with a turning motor. The result can be subsequently found in "P-0-0510, Rotor inertia". If the result appears too imprecise or the command could not be executed with a turning motor, the moment of inertia can also be determined using an acceleration test:

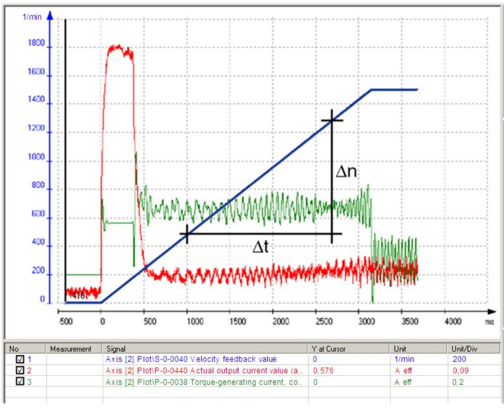


Fig. 6-36: Acceleration Curve of the Axis with the Required State Variables

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☞ Select the acceleration ramp such that the actual value of the torque-generating current (P-0-0043) is constant over the biggest possible velocity range. If applicable, a smaller ramp acceleration is to be selected!

Asynchronous motor:

$$J_{Axis\_MW} = \frac{3 \times (P\text{-}0\text{-}0018) \times (P\text{-}0\text{-}4041) \times (P\text{-}0\text{-}4004) \times (P\text{-}0\text{-}0043) \times 60s}{2 \times \pi \times 10^3 \times min} \times \frac{\Delta t}{\Delta n}$$

Synchronous motor:

$$J_{Axis\_MW} = \frac{(P\text{-}0\text{-}0051) \times (P\text{-}0\text{-}0043) \times 60s}{2 \times \pi \times min} \times \frac{\Delta t}{\Delta n}$$

J_{Axis_MW}	Inertia of the machine axis, motor-shaft-related
P-0-4041	Motor magnetizing inductance (in mH)
P-0-4004	Magnetizing current (in A)
P-0-0043	Torque-generating current, actual value (average value during the linear acceleration in A)
P-0-0018	Number of pole pairs/pole pair distance
P-0-0051	Torque/force constant
Δt	Run-up time in the range of the linear speed increase (in s)
Δn	Speed change during the run-up time (in min-1)

Fig. 6-37: Calculating the Motor-Shaft-Related Total Inertia of the Machine Axis

Enter the calculated value of the motor-shaft-related total inertia of the axis, less the rotor inertia (P-0-0510), in parameter "P-0-4010, Load inertia".

☞ If the rotor inertia is unknown, you can enter the total inertia in parameter P-0-0510 or P-0-4010.

The value of parameter "P-0-0596, FXC: Frequency loop scaling factor of inertia" influences the integral action time of the frequency controller. Only in particular cases it is necessary to change the value; the frequency controller reacts more speedily when the value is reduced.

$$T_{N\_freg\_FXC} = \frac{2\pi \times J_{Axis\_MW\_FXC} \times (P\text{-}0\text{-}0596)}{PPZ \times k_m} = \frac{2\pi \times (P\text{-}0\text{-}0510 + P\text{-}0\text{-}4010) \times (P\text{-}0\text{-}0596)}{(P\text{-}0\text{-}0018) \times (P\text{-}0\text{-}0051)}$$

$T_{N\_freg\_FXC}$	Integral Action Time of FXC Frequency Controller
$J_{Axis\_MW\_FXC}$	Effective inertia of the axis (motor-related)
P-0-0596	Frequency controller scaling factor of inertia (FXC)
PPZ, P-0-0018	Number of pole pairs of the motor
P-0-0510	Rotor inertia
P-0-4010	Load inertia (motor-related)
k_m, P-0-0051	Torque/force constant

Fig. 6-38: Integral Action Time of FXC Frequency Controller

Flux Controller

The flux controller has been designed as an I controller. It is one of the input values for calculating the current command value. The value for "P-0-0594, FXC: Total flux loop integral action time" is left as the default. The value is checked by means of run-up measurement with little acceleration and adjusted as required (see below "Notes on Commissioning").

Speed Slip Compensation (for Asynchronous Motors Only)

For speed slip compensation, the slip of the asynchronous motor to be expected under load is taken into account in the motor model for the determined current velocity. By velocity control (PI controller), the slip in comparison to the velocity command value is compensated.

Speed slip compensation is only required for drives with high demands as regards the maintaining of the velocity command value under load. It does not need to be used for standard requirements!

In the default state, speed slip compensation is inactive. It can be activated by means of the motor-specific value in parameter "P-0-0600, FXC: Rated slip frequency". The theoretical value is calculated according to the formula below:

$$P\text{-}0\text{-}0600 = f_{Nominal} - \frac{n_{Nominal} \times (P\text{-}0\text{-}0018) \times \min}{60s}$$

P-0-0600	Rated slip frequency (FXC)
$f_{Nominal}$	Rated frequency acc. to motor type plate (in Hz)
$n_{Nominal}$	Rated speed acc. to motor type plate (in 1/min)
P-0-0018	Number of pole pairs/pole pair distance

Fig. 6-39: Calculating the Value for the Slip Frequency

The value of parameter "P-0-0599, FXC: Slip frequency filter time constant" influences the reaction time of slip compensation at load impulse. Only in particular cases is it necessary to adjust the value in motor-specific form!

Reporting "blockage" or "motor stall"

As it is not really possible to check the velocity of sensorless motors, it is only due to subjective appraisal that you can deduce whether the command velocity has been maintained under load. The drive only indicates a motor shaft blockage when there is an overload or motor "stall" when the change in the velocity command value is too large. It does so via message bits in "P-0-0046, Status word of current controller" Status word of current controller:

- Blockage

  The actual velocity indicated by the controller considerably differs from the command velocity. The motor current is regulated to the maximum permissible value; the motor generates the maximum torque.

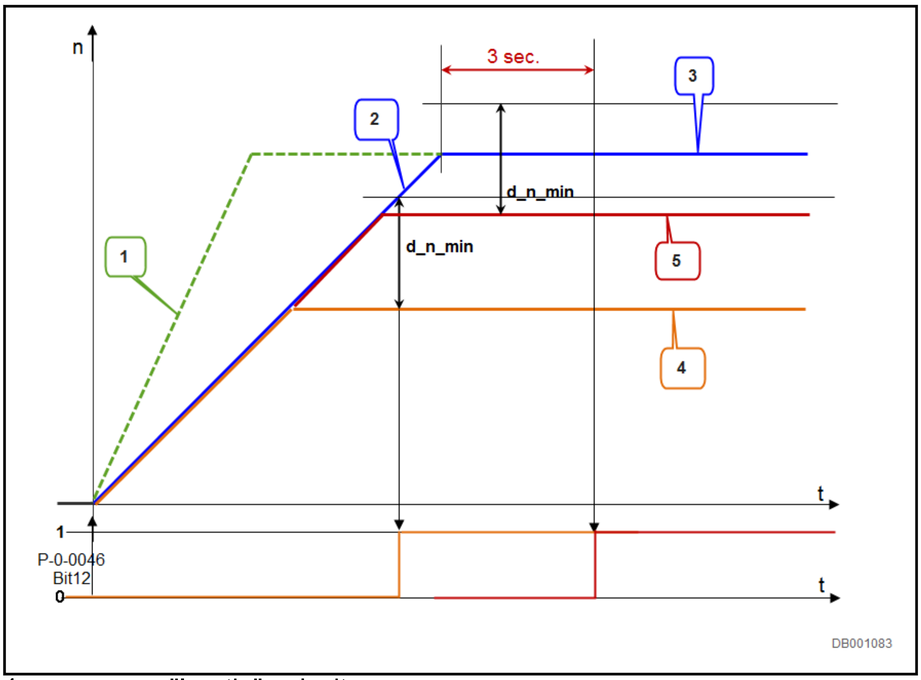
- Motor-"stall"

The actual velocity indicated by the controller corresponds to the command velocity even though the actual rotor speed is very low or zero. The motor only generates very minimal torque.

The criteria for the messages come from the difference between the command- and the actual velocity determined by the firmware's computer model. With sensorless motor operation, the command velocity must be specified in a ramp-like way to generally prevent the motor from "stalling" during the run-up time. An abrupt change to the command velocity must be converted into a ramp-shaped curve:

- By entering the motor- and load inertia, the change in the motor control frequency is limited to a value which can be withstood by the motor (inertia ramp). If the moment of inertia is unknown or if the values input are too small, there is the risk of a "motor stall".
- The command velocity must generally be specified in a ramp-like way and the gradient must not be allowed to cause the motor "to stall". For example, use the ramp function with velocity control!

Blockage of the Motor



1	"Inertia"-velocity ramp
2	Velocity command value ramp
3	Command velocity
4	Actual velocity 1
5	Actual velocity 2
d_n_min	Velocity difference for blockage detection

Fig. 6-40: Basic Representation of the Criterion "Motor Blocked"

The comparison of the actual velocity determined on the firmware side (n_actual) with the command velocity (n_cmd) is always carried out with the smallest change in the command velocity from

- Inertia ramp or
- Velocity command value ramp

Velocity difference threshold d_n_min for blockage detection:

$$d\_n\_min = 10\ min^{-1} + (2\ s^{-1} + f\_s\_nominal) \times \frac{60\ \frac{s}{min}}{PPZ}$$

d_n_min	Blockage detection threshold
f_s_nominal	Nominal slip of motor (for asynchronous motors only)
PPZ	Number of pole pairs of the motor

Fig. 6-41: Determining the Threshold Value

Blockage criterion 1: If the actual velocity differs from the command velocity by more than the threshold **d_n_min**, P-0-0045 reports that the motor is blocked:

$$|n\_cmd - n\_actual| > d\_n\_min$$

n_cmd	Command velocity
n_actual	Actual velocity
d_n_min	Blockage detection threshold

Fig. 6-42: Blockage Criterion 1

Blockage criterion 2: If the actual velocity differs from the target speed by more than 10 rpm, but less than the threshold value **d_n_min**, after 3 s P-0-0045 reports that the motor is blocked:

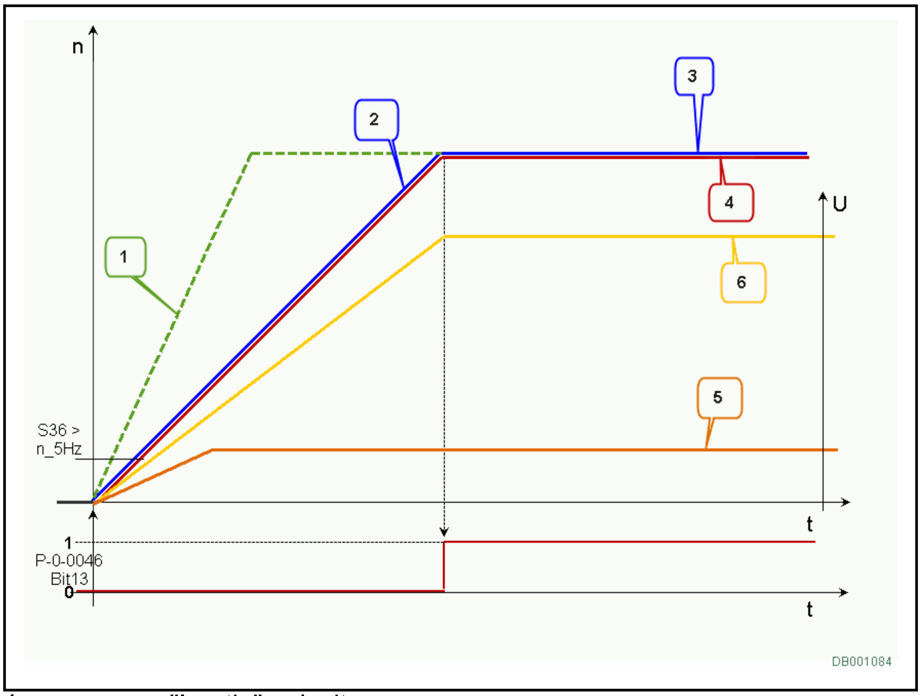
$$10\ min^{-1} < |n\_cmd - n\_actual| < d\_n\_min$$

n_cmd	Command velocity
n_actual	Actual velocity
d_n_min	Blockage detection threshold

Fig. 6-43: Blockage Criterion 2

☞ The motor generates high torque when "blocked"!

"Stalling" of the Motor



1	"Inertia"-velocity ramp
2	Velocity command value ramp
3	Command velocity
4	actual velocity determined by the controller
5	motor voltage issued by the controller
6	the motor voltage theoretically required for the actual velocity

Fig. 6-44: Basic representation of the criterion "Motor stalled"

A "stalling" of the motor can only be identified when the motor control frequency is above a threshold of 5Hz:

$$n\_actual > 5\ Hz \times \frac{60 \frac{s}{min}}{PPZ}$$

n_cmd	Command velocity
PPZ	Number of pole pairs of the motor

Fig. 6-45: Condition for Identifying Motor "Stalls"

Motor "stalling" criterion: The actual velocity determined by the control unit corresponds to the command velocity even though the rotor only turns a little or is stationary. If the motor voltage issued by the control unit is considerably lower than the theoretical motor voltage required for the actual velocity determined, P-0-0045 reports that the motor has "stalled".

☞ A "stalled" motor only develops very little torque!

Current controller

The current controller for sensorless, flux-controlled motor operation outputs the amplitude of the motor terminal voltage. It differs from the current controller of the methods for field-oriented motor control with motor encoder. The preset values of the parameters "P-0-0597, FXC: Current loop proportional gain" and

"P-0-0598, FXC: Current loop integral action time" only have to be adjusted in particular cases.

Drive Control

Notes on Commissioning

☞ Sensorless motors are the for the most part third-party motors. A Technical Note is available, especially for commissioning third-party motors. This Note can be requested from Service or Sales: "Rexroth IndraDrive, Third-party motor Commissioning Manual" (EN_TN4_IndraDrive_Getting_Started_Asy_Sy_Fremdmotor_Vx.y).

Establishing the Basic State

To establish a neutral state of the drive parameters, it is recommended that you execute the "load basic parameters" command.

Sensorless, flux-controlled motor operation (FXC) is only possible when the motor encoder input (if available) has been deactivated.

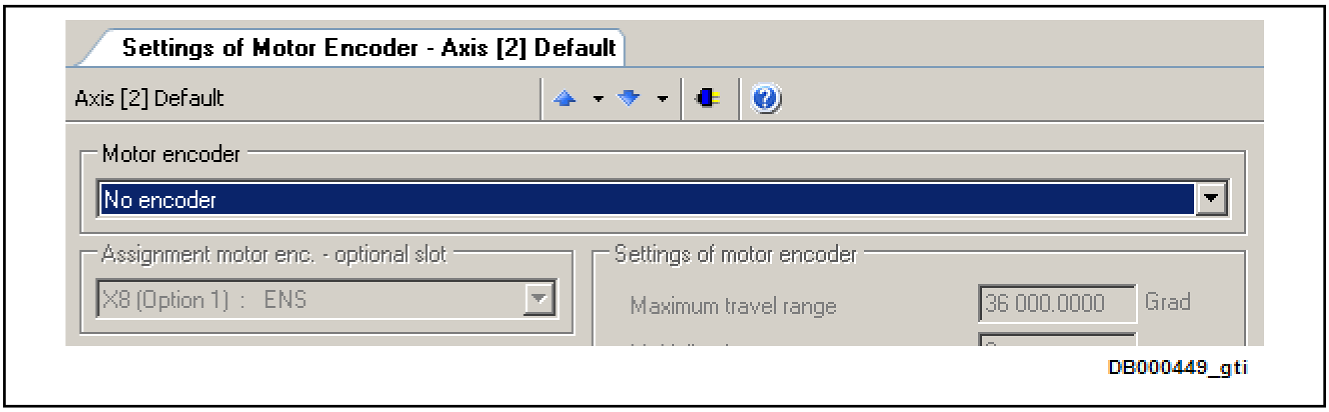


Fig. 6-46: "IndraWorks Ds/D/MLD" Dialog "Motor Encoder", Deactivation

Activating FXC Operation

When you set the type of construction of motor to "synchronous", sensorless, flux-controlled motor operation is automatically activated; with the type of construction of motor "asynchronous", you can choose between FXC operation and V/Hz [U/f] operation.

☞ You can make the settings via dialogs in "IndraWorks Ds/D/MLD", or set the corresponding bits in the control word of the current controller (P-0-0045).

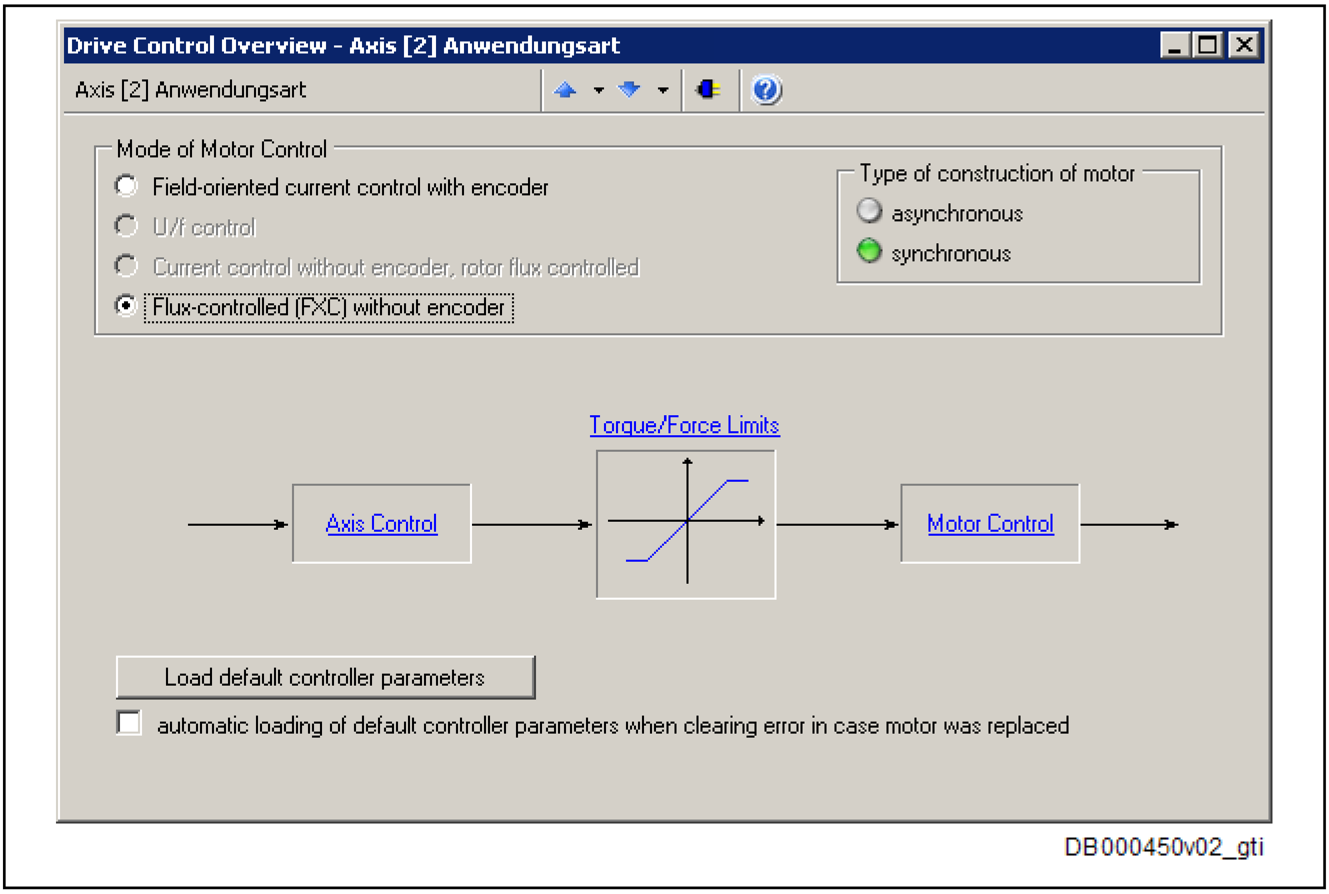


Fig. 6-47: "IndraWorks Ds/D/MLD" Dialog for Setting the Mode of Motor Control

Determining the Motor Parameters for Asynchronous Motors

For asynchronous motors, it is recommended that you have the motor parameters determined by the controller on the basis of the type plate data. For this purpose, enter the type plate data in the parameter "P-0-4032, Motor type plate data" and afterwards execute the commands " C3200 Command Calculate motor data" (P-0-4033) and " C3600 Command Motor data identification" (P-0-0565).

See also "Automatic Setting of Motor Control"

☞ When reading the type plate data, make sure the data correlate. Only enter data with the same frequency reference (in the case of data for 50Hz and 60Hz) or data with reference to the same winding connection (in the case of data for Y and Δ)!

Before you start " C3600 Command Motor data identification" (P-0-0565), check whether it is allowed to put the motor shaft into rotation. Enter the result in the parameter "P-0-0601, Configuration motor data identification". When the motor is turning, the magnetizing inductance can be determined more precisely; therefore, the motor shaft, if allowed, is brought to approx. 50% of the nominal speed by C3600.

☞ The default setting of parameter P-0-0601 is "Motor shaft **cannot** move freely".

Drive Control

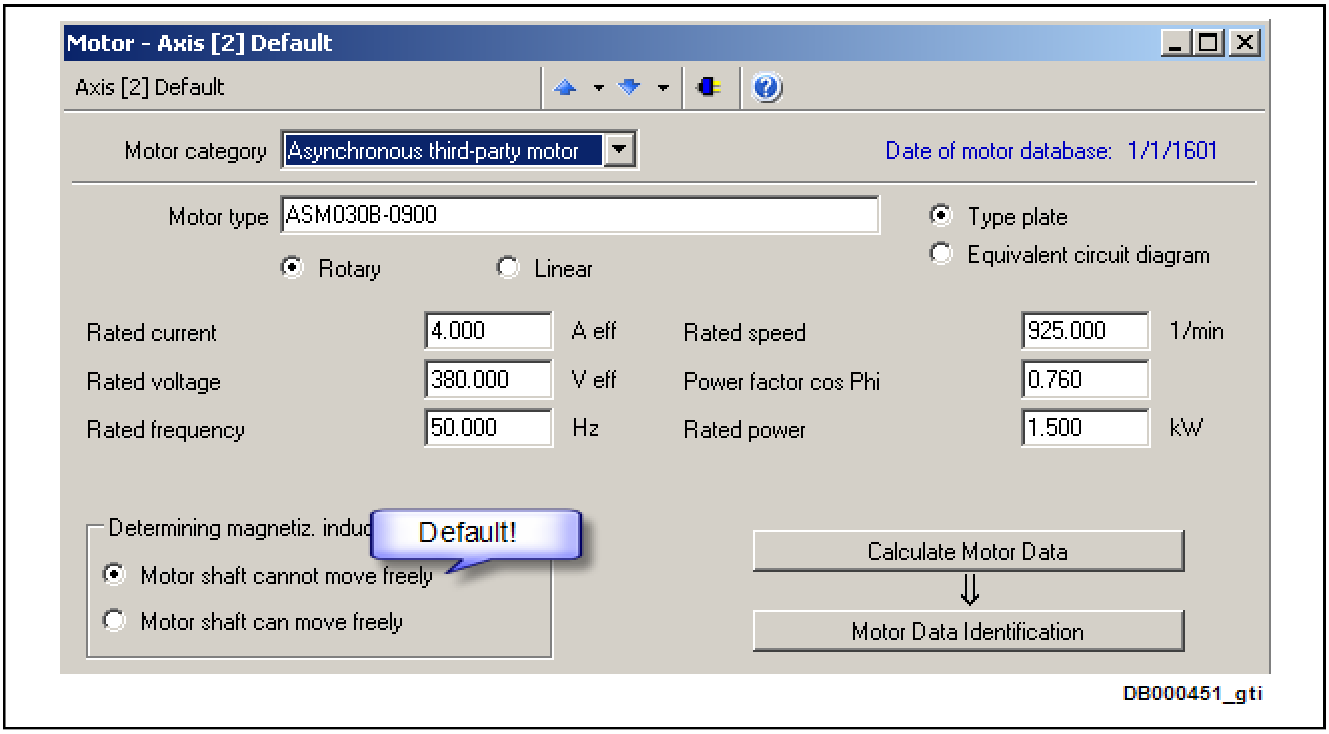


Fig. 6-48: "IndraWorks Ds/D/MLD" Dialog "Motor", Setting Type of Construction of Motor, Entering Type Plate Data of ASM, Starting Commands "Calculate Motor Data" and "Motor Data Identification" with Exemplary Values

Determining the Motor Parameters for Synchronous Motors

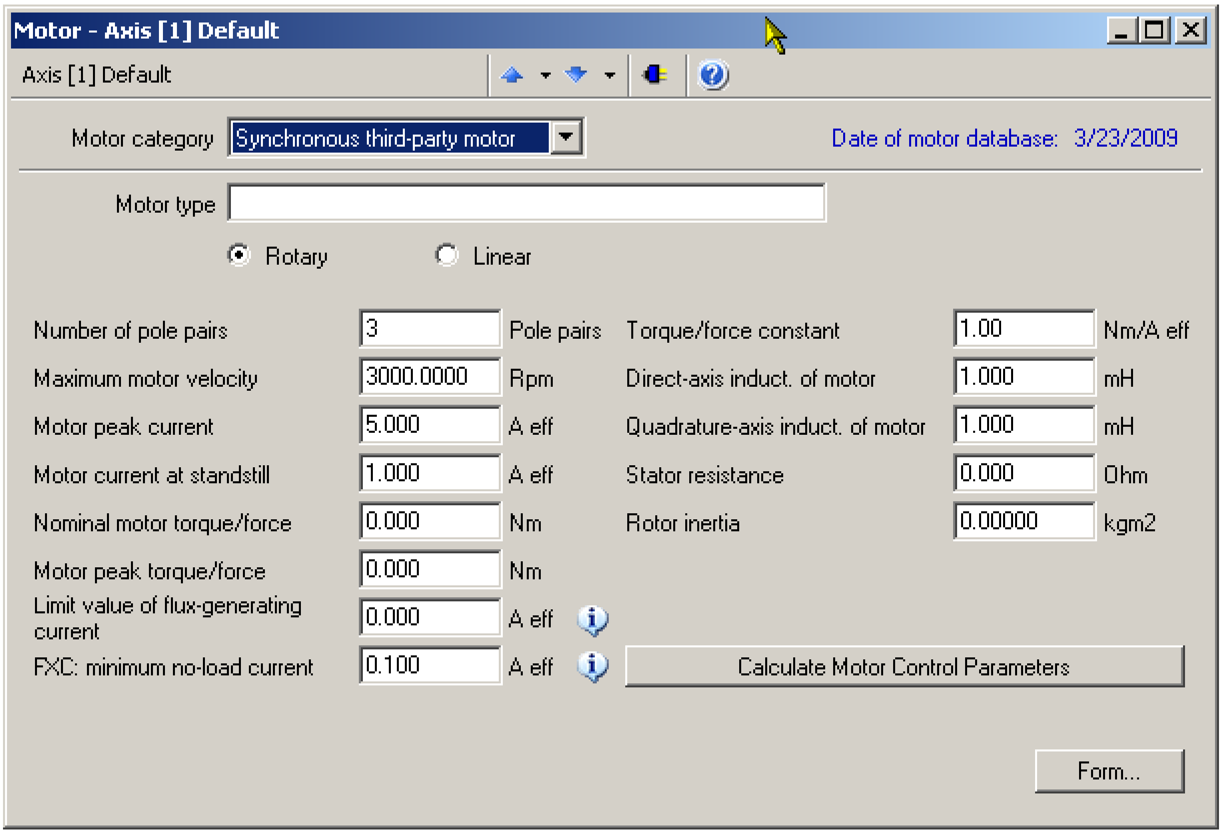
For synchronous motors, we recommend entering the following data into the "IndraWorks Ds/D/MLD" dialog "Motor", otherwise in the following parameters:

- P-0-0018, Number of pole pairs/pole pair distance
- S-0-0113, Maximum motor speed
- S-0-0111, Motor current at standstill
- S-0-0109, Motor peak current
- S-0-0533, Nominal torque/force of motor

Next, execute "C3600 Command Motor data identification" (P-0-0565). See also "Automatic Setting of Motor Control". Before starting "C3600 Command Motor data identification" (P-0-0565), check whether it is allowed to put the motor shaft into rotation. Enter the result in the parameter "P-0-0601, Configuration motor data identification". When the motor is turning, the motor data can be determined more precisely; therefore, the motor shaft, if allowed, is to be accelerated to approx. 50% of the nominal speed by C3600.

☞ The command "C4600 Command Calculate motor control parameters" is irrelevant for FXC operation of synchronous motors!

☞ The default setting of parameter P-0-0601 is "motor shaft does not move freely".



DB000455_gti

Fig. 6-49: "IndraWorks Ds/D/MLD"-dialog "Motor", Setting Type of Construction of Motor; Entering Motor Data of SM with Exemplary Values

Determining the Inertia

The frequency controller can only work correctly, if the inertia of the machine axis (motor-shaft-related) has been entered in the following parameters:

- P-0-0510, Rotor inertia
- P-0-4010, Load inertia

The motor-shaft-related total axis inertia is also determined by "C3600 Command Motor data identification" when the command was executed with a turning motor. The result can be subsequently found in "P-0-0510, Rotor inertia". If the result appears too imprecise or the command could not be executed with a turning motor, the moment of inertia can also be checked/determined using an acceleration test: For this purpose, it is advisable to accelerate the motor with a flat ramp to approx. 75% of the nominal speed.

Recommendation for setting the appropriate velocity ramp with velocity control:

$$\text{P-0-1201} = \text{P-0-1211} = \frac{\pi}{30\ \text{s/min}} \times \frac{\Delta n}{\Delta t} \approx 0{,}1 \times \frac{0{,}75 \times n_{Nominal}}{2\ \text{s}} \times \frac{\text{min}}{\text{s}}$$

$$\text{P-0-1202} \geq n_{Nominal}$$

P-0-1201 Ramp 1 pitch (in rad/s2)
P-0-1211 Deceleration ramp 1 (in rad/s2)
Δt Run-up time in the range of the linear speed increase (in s)
Δn Speed change during the run-up time (in min-1)
P-0-1202 Final speed ramp 1
$n_{Nominal}$ Rated speed acc. to type plate

Fig. 6-50: Velocity Ramp to Determine the Total Inertia of the Axis

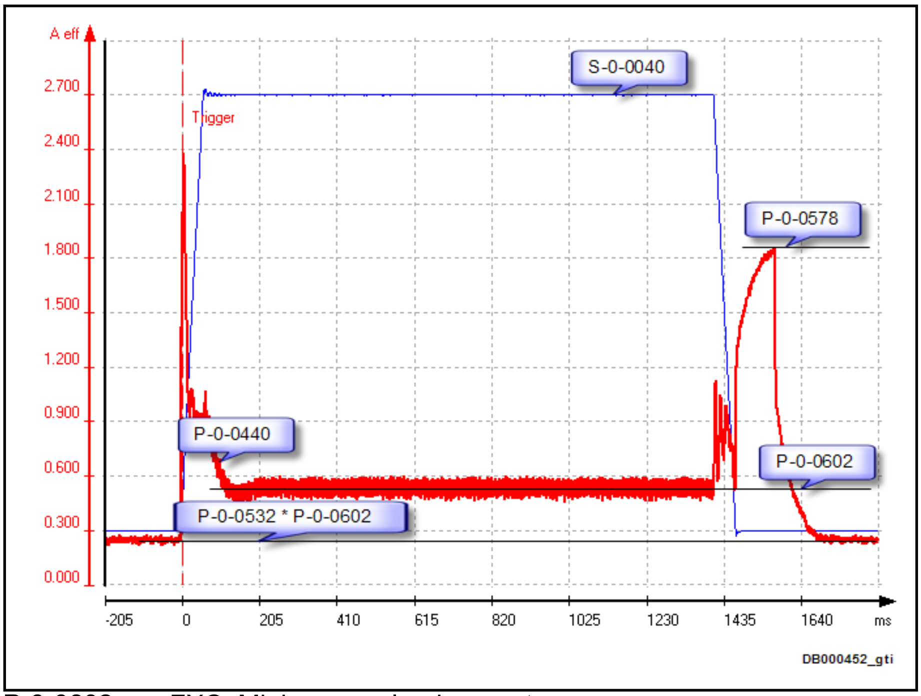
As regards data for calculating the total inertia of the axis, see above "Functional Description".

Setting the Acceleration/Deceleration Ramp

As a matter of principle, the acceleration and deceleration ramp (P-0-1201 et seq.) should be used for velocity-controlled FXC operation. It is recommended that you only use approx. 90% of the maximum possible acceleration. This results in steadier acceleration and deceleration behavior than is the case at the current limit (Determining the Acceleration/Deceleration Values "[External link could not be resolved.]").

Entering the No-Load Current

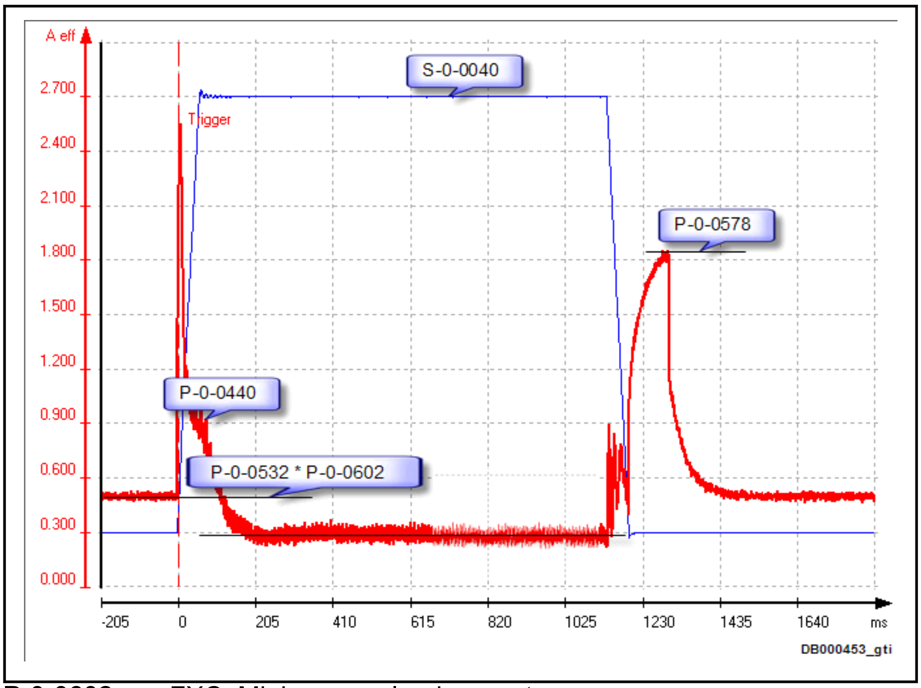
The no-load current which can be set influences the impulse load stability of the motor. The value of "P-0-0602, FXC: Minimum no-load current" can be set to values between 0.1....0.75*nominal current; via the sign, the no-load current behavior can be influenced in a speed-dependent way:



P-0-0602 FXC: Minimum no-load current
P-0-0532 Premagnetization factor
P-0-0578 Current for deceleration, absolute value
P-0-0440 Actual output current value (absolute value)
S-0-0040 Velocity feedback value

Fig. 6-51: No-Load Current with Positive Sign of P-0-0602, P-0-0532 = 50%

☞ With positive sign of P-0-0602, the no-load current of the motor is at least as high as the value of P-0-0602. At motor standstill, the no-load current can be reduced via factor P-0-0532.



P-0-0602 FXC: Minimum no-load current
P-0-0532 Premagnetization factor
P-0-0578 Current for deceleration, absolute value
P-0-0440 Actual output current value (absolute value)
S-0-0040 Velocity feedback value

Fig. 6-52: No-Load Current with Negative Sign of P-0-0602, P-0-0532 = 100%

☞ With negative value of P-0-0602, the no-load current of the motor can be reduced to a minimum of 0.1* nominal current (S-0-0111) when the motor is turning; when the motor is in standstill, control takes place with regard to the absolute value of P-0-0602 * P-0-0532. This improves the acceleration behavior and minimizes the no-load loss of the turning motor.

Checking Relevant Parameters

The parameters relevant to FXC operation are shown in a block diagram in "IndraWorks Ds/D/MLD".

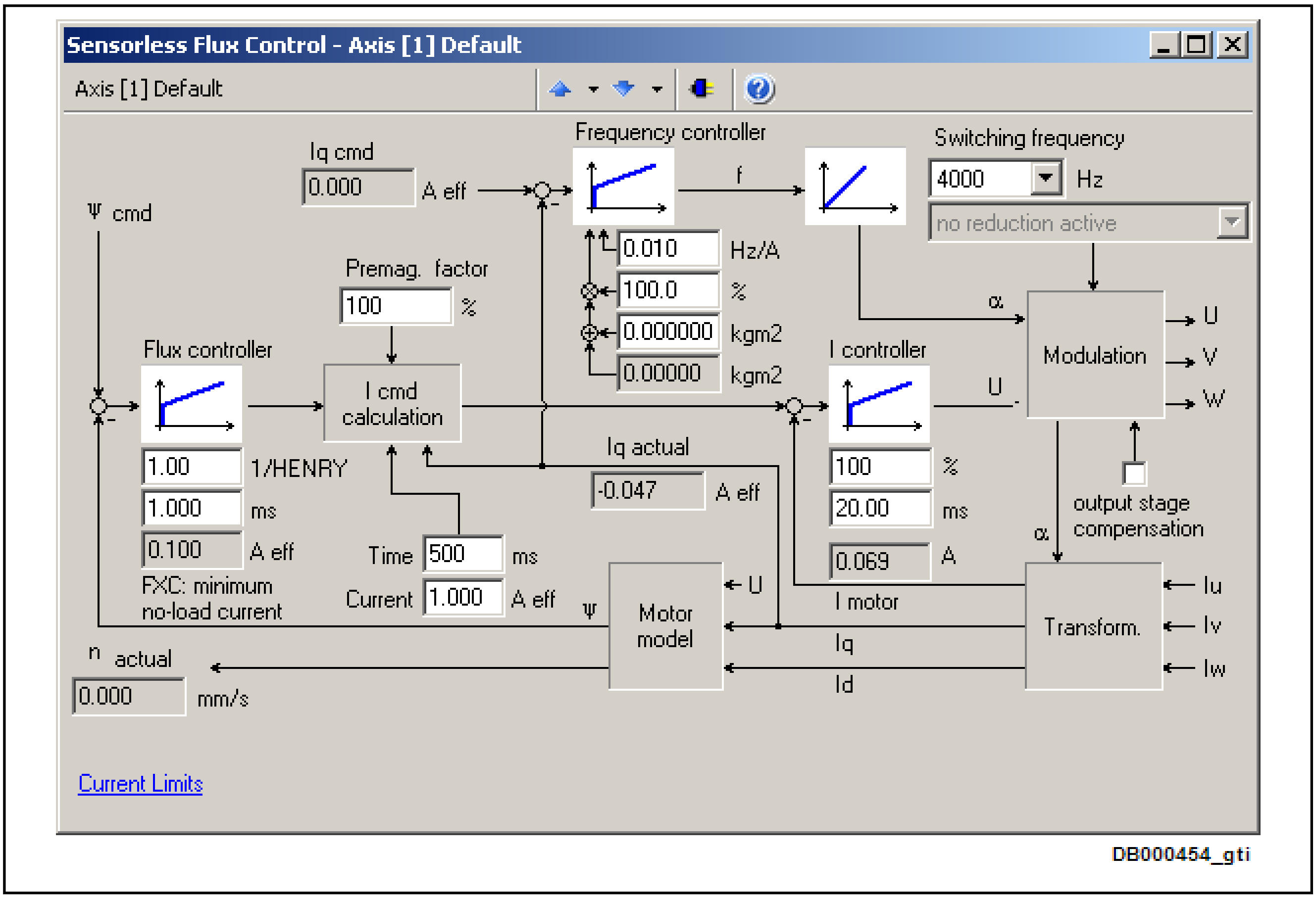


Fig. 6-53: "IndraWorks Ds/D/MLD" Dialog for FXC Operation, with Exemplary Values

Setting the Frequency Controller

With the value of the parameter "P-0-0596, FXC: Frequency loop scaling factor of inertia", you can influence the pitch of the frequency ramp of the frequency loop. The optimum value has been reached at maximum acceleration of the motor. If you continue modifying the value, this will only cause the motor temperature to rise due to increased motor currents!

Leave the value of parameter "P-0-0595, Frequency loop proportional gain (FXC)" unchanged!

Checking the Flux Controller

For the flux controller, you should check and, if necessary, adjust the value of the parameter "P-0-0594, FXC: Total flux loop integral action time". For this purpose, carry out an acceleration test with ramp-like velocity command value, for example to 75% of the rated speed in approx. 2 s (see above). After the flux controller has been activated, the total current (P-0-0440) should quickly fall to a stationary value (see "Functional Description" above). In order for the total current to fall more quickly, reduce the value of parameter P-0-0594.

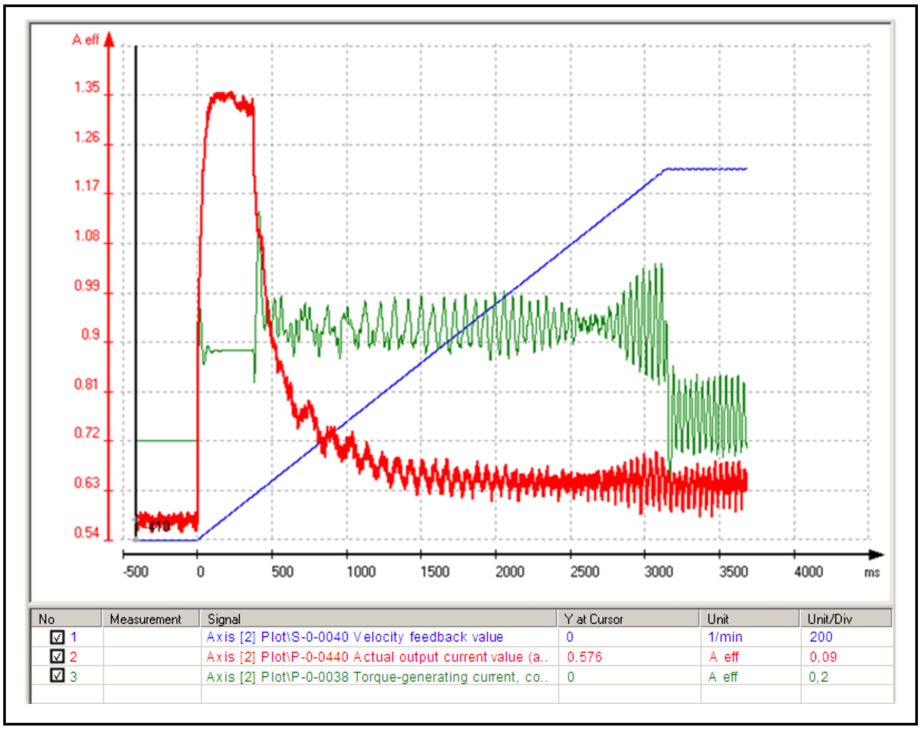


Fig. 6-54: Result of P-0-0594 Check → Value too High

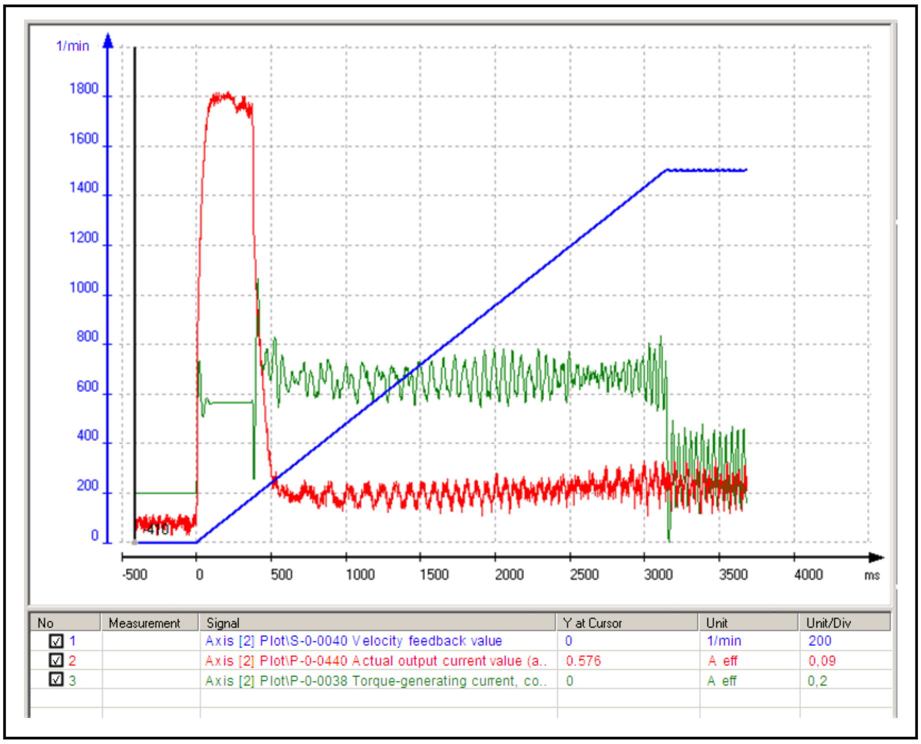


Fig. 6-55: Result of P-0-0594 Check → Value Correct

☞ The appropriate value for parameter "P-0-0594, FXC: Total flux loop integral action time" quickly causes the total current (P-0-0440) to fall to a horizontal current profile.

Current controller

Only in particular cases does the current controller require motor-specific settings.

Leave the values of the parameters "P-0-0597, FXC: Current loop proportional gain" and "P-0-0598, FXC: Current loop integral action time" unchanged!

When the current oscillates under load, you should first try to attenuate the oscillation by increasing the value of P-0-0598.

> ☞ For motors with low ohmic resistance, unstable motor movement can be improved with higher values of P-0-0597 (compared to default value)!

When overcurrent occurs during acceleration from standstill (message "F8060 Overcurrent in power section"), you should reduce the value of the parameter P-0-0597.

Speed Slip Compensation (for Asynchronous Motors Only)

For the parameter "P-0-0600, FXC: Rated slip frequency", calculate and enter the value (see "Functional Description" above).

Judge the slip compensation of the motor at constant speed under load:

- Motor speed audibly reduced → Increase value in P-0-0600
- Motor speed audibly increased → Reduce value in P-0-0600

Only in particular cases is it necessary to change the default setting of parameter "P-0-0599, FXC: Slip frequency filter time constant". You should increase the value when the motor, at load impulse, is "out-of-step" and possibly stops because the current limit of the device has been reached. The reaction time of speed slip compensation is slowed down as the values increase; this causes the current to rise less at load impulse (Requirement: The continuous current of the device must be sufficient for stationary load!).

> ☞ Using speed slip compensation is mainly advantageous in the "velocity control" mode!

Settings for Deceleration

The deceleration behavior of the drive is decisively influenced by the parameters "P-0-0578, Current for deceleration, absolute value" and "P-0-0579, Current for deceleration, time period".

When the velocity value falls below a firmware-internal threshold, the motor is taken to velocity value "zero" with the current amplitude from parameter P-0-0578. By entering a time period for the current for deceleration (P-0-0579) unequal zero, the current for deceleration is maintained for this time, after velocity command value and actual velocity value have reached "zero".

If the drive does not come to standstill, increase:

- Deceleration time (P-0-0579)

  - and/or -
- Current for deceleration (P-0-0578)

> ☞ When acceleration takes place out of standstill, the value of P-0-0578 takes effect, too, below the mentioned velocity threshold!

Using the Motor Search Mode (for Asynchronous Motors Only)

If a motor could already be in motion without control, you should activate the motor search mode in the control word of the current controller (P-0-0045). This leads the motor from uncontrolled motion to the preset command value.

NOTICE **Acceleration of the motor shafts of motors in standstill with activated motor search mode after drive enable!**

⇒ Only activate the motor search mode when arbitrary rotation of the motor shaft is safely possible!

Notes on Error Diagnostics

Sensorless, flux-controlled motor operation does not require any specific diagnostics!

Problems in the operating behavior can have the following causes:

- **Difference between actual value of no-load current and entered magnetizing current for asynchronous motors**

  Read the value of parameter "P-0-0440, Actual output current value (absolute value)" in no-load motor operation (without connected load) at 50% of the rated speed. This value must correspond to the value of the magnetizing current (P-0-4004).

  → The value of P-0-0440 can be proportionally adjusted to the value of P-0-4004 by the setting in parameter "P-0-4041, Motor magnetizing inductance".

  Note: Make sure that parameter P-0-4004 contains the **correct magnetization current** of the asynchronous motor!

- **Current limitation at motor standstill**

  If the warning "E8260 Torque/force command value limit active" appears in standstill with the drive having been enabled, the controller cannot continuously supply the required current at standstill of the motor.

  → Reduce current at standstill by smaller value in parameter "P-0-0532, Premagnetization factor".

  → Use controller with higher continuous current (type current).

- **Blockage or "stalling" of the motor**

  Due to sensorless motor operation, the controller cannot determine the actual motor speed. The actual velocity may vary from the command velocity depending on the load torque. Due to excessive overload, the motor can block or "stall", also when the change to the command velocity is too big. In both cases, the actual velocity differs considerably from the command velocity.

  → Blockage or "stalling" of the motor is displayed in "P-0-0046, Status word of current controller" Status word of current controller.

6.3.6 Automatic Setting of Motor Control

Brief Description

Base package of all firmware variants in **open-loop and closed-loop** characteristic

For operating motors, it is necessary to collect the values for motor parameters (resistance values, inductances, ...), in order to determine the motor control parameters (flux controller, voltage controller, current controller, ...) with these values.

Depending on the manufacturer and type of the motor to be controlled, the values for motor parameters and motor control parameters are made available to the drive controller in different ways.

Rexroth Motors

For Rexroth motors, the values for the motor and motor control parameters are optimized and made available by the manufacturer. The automatic setting of the motor control parameters by the drive firmware is not required and not allowed for Rexroth motors!

- For motors **with motor encoder data memory**:

  → Parameters loaded automatically when drive is switched on (see "Default Settings in the Motor Encoder Data Memory ("Loading Default Values")"
- For motors **without motor encoder data memory**:
  - Parameters loaded via the "IndraWorks Ds/D/MLD" commissioning tool from the motor data base (DriveBase)

    - or -
  - Individual parameters manually written via the Engineering Port or the master communication interface by means of a motor parameter list.

Third-Party Motors

For third-party motors, the drive firmware possesses commands by means of which the values for the motor and motor control parameters are generated depending on the available output data and the functional principle of the motor.

The following commands are available for calculating values for the motor and motor control parameters:

- C3200 Command Calculate motor data:
  1. Calculating the motor parameter values for asynchronous motors from the **data on the type plate.**
  2. Calculating the values to be set for the motor control parameters.
- C3600 Command Motor data identification:
  1. Identifying (or optimizing) the motor parameter values.

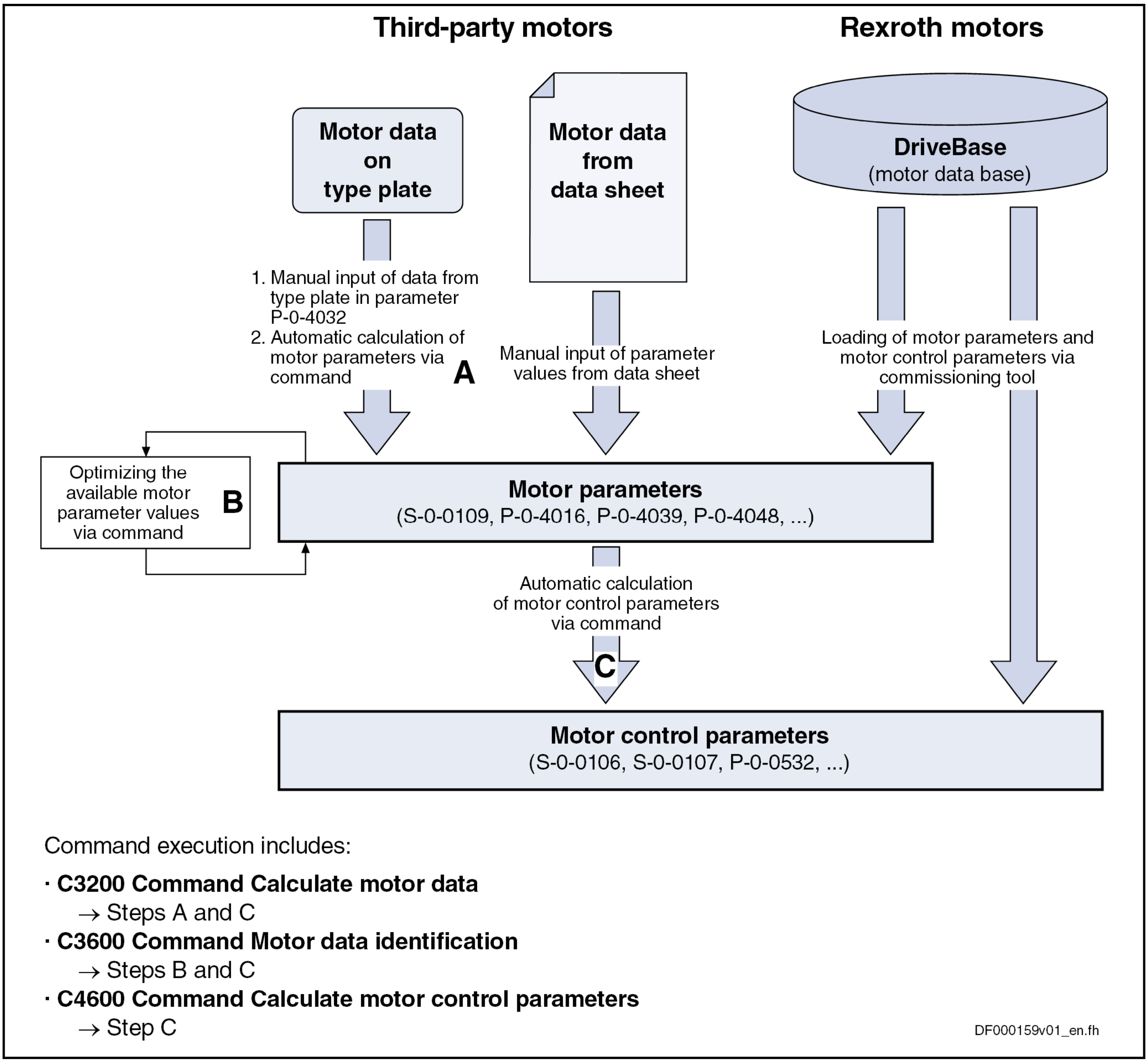
     Note: Appropriate start values already have to be available!
  2. Calculating the values of the motor control parameters.
- C4600 Command Calculate motor control parameters:

  Calculating the values of the motor control parameters from the motor parameters for synchronous motors and, if necessary, for asynchronous motors (after manual input of motor data in motor parameters)

☞ The prerequisite is the form "Manufacturer-Side Data for Synchronous Motors" or "Manufacturer-Side Data of Asynchronous Motors" to be filled out by the motor manufacturer; it can be found in the section "Third-Party Motors at IndraDrive Controllers"!

Overview

The figure below illustrates an overview of the possibilities of determining the motor and motor control parameters for motors without motor encoder data memory:



P-0-4032 Motor type plate data

Fig. 6-56: Determining Motor and Motor Control Parameters for Motors without Motor Encoder Data Memory

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☞ In addition to collecting or determining the motor and motor control parameters, further data on measuring system, temperature sensor, motor temperature model, motor holding brake and, if necessary, position and velocity controllers are required.

See "Closed-Loop Axis Control (Closed-Loop Operation)"

See the "Notes on Commissioning" in the section "Third-Party Motors at IndraDrive Controllers"

Pertinent Parameters

- P-0-0565, C3600 Command Motor data identification
- P-0-0566, C4600 Command Calculate motor control parameters
- P-0-4032, Motor type plate data

- P-0-4033, C3200 Command Calculate motor data

Pertinent Diagnostic Messages

- C3200 Command Calculate motor data
- C3201 Incorrect input for current
- C3202 Incorrect input for voltage
- C3203 Incorrect input for frequency
- C3204 Incorrect input for speed
- C3205 Incorrect input for power factor
- C3206 Incorrect input for power
- C3207 Type plate list incomplete
- C3208 Error when writing parameters (->S-0-0423)
- C3209 Command execution impossible
- C3600 Command Motor data identification
- C3601 Motor not or not correctly connected
- C3602 Determined values invalid
- C3603 Device current limit too low
- C3604 Error when writing parameters (->S-0-0423)
- C3605 Motor turning
- C3606 Type of construction of motor not allowed
- C3607 Motor revolution/motion impeded
- C3608 Incorrect motor phases or rotational direction of encoder
- C3609 Incorrect number of pole pairs or number of encoder lines
- C3610 No encoder: Validation check impossible
- C3611 Test velocity not reached
- C3612 Command execution impossible
- C4600 Command Calculate motor control parameters
- C4601 Error when writing parameters (->S-0-0423)

Overview of Motor and Motor Control Parameters

Motor parameters

The table below contains an overview of the motor parameters for synchronous and asynchronous motors:

Motor parameters	
Synchronous motor	Asynchronous motor
P-0-4014, Type of construction of motor	P-0-4014, Type of construction of motor
S-0-0109, Motor peak current	S-0-0109, Motor peak current
S-0-0111, Motor current at standstill	S-0-0111, Motor current at standstill
S-0-0113, Maximum motor speed	S-0-0113, Maximum motor speed
P-0-0018, Number of pole pairs/pole pair distance	P-0-0018, Number of pole pairs/pole pair distance
P-0-0051, Torque/force constant	P-0-0051, Torque/force constant
P-0-0510, Rotor inertia	P-0-0510, Rotor inertia
P-0-4048, Stator resistance	P-0-4048, Stator resistance
P-0-4013, Current limit value of demagnetization	P-0-0530, Slip increase

Motor parameters	
Synchronous motor	Asynchronous motor
P-0-4016, Direct-axis inductance of motor	P-0-4004, Magnetizing current
P-0-4017, Quadrature-axis inductance of motor	P-0-4036, Rated motor speed
P-0-4002, Charact. of quadrature-axis induct. of motor, inductances	P-0-4039, Stator leakage inductance
P-0-4003, Charact. of quadrature-axis inductance of motor, currents	P-0-4040, Rotor leakage inductance
P-0-4005, Flux-generating current, limit value	P-0-4041, Motor magnetizing inductance
	P-0-4042, Characteristic of motor magnetizing inductance
	P-0-4043, Rotor time constant

Tab. 6-12: Overview of Motor Parameters for Synchronous and Asynchronous Motors

Motor control parameters

The following tables contain an overview of the motor control parameters for synchronous and asynchronous motors that are used for field-oriented current control (with and without encoder) and voltage-controlled operation:

Motor control parameters for voltage-controlled operation (V/Hz [U/f])	
Synchronous motor	Asynchronous motor
	S-0-0106, Current loop proportional gain 1
	S-0-0107, Current loop integral action time 1
	P-0-0532, Premagnetization factor
	P-0-0568, Voltage boost
	P-0-0569, Maximum stator frequency slope
	P-0-0570, Stall protection loop proportional gain
	P-0-0571, Stall protection loop integral action time
	P-0-0572, Slip compensation factor
	P-0-0573, IxR boost factor
	P-0-0574, Oscillation damping factor
	P-0-0575, Search mode: Search current factor
	P-0-0576, Search mode: Finding point slip factor
	P-0-0577, Square characteristic: Lowering factor

Tab. 6-13: Overview of Motor Control Parameters for Synchronous and Asynchronous Motors and Voltage-Controlled Operation (V/Hz [U/f])

Motor control parameters for field-oriented current control (FOC)	
Synchronous motor	Asynchronous motor
S-0-0106, Current loop proportional gain 1	S-0-0106, Current loop proportional gain 1
S-0-0107, Current loop integral action time 1	S-0-0107, Current loop integral action time 1
P-0-0533,	P-0-0533,
P-0-0534, Voltage loop integral action time	P-0-0534, Voltage loop integral action time

Motor control parameters for field-oriented current control (FOC)	
Synchronous motor	Asynchronous motor
P-0-0535, Motor voltage at no load	P-0-0535, Motor voltage at no load
P-0-0536, Maximum motor voltage	P-0-0536, Maximum motor voltage
	P-0-0528, Flux control loop proportional gain
	P-0-0529, Scaling of stall current limit
	P-0-0532, Premagnetization factor

Tab. 6-14: Overview of Motor Control Parameters for Synchronous and Asynchronous Motors and Field-Oriented Current Control (FOC)

Motor control parameters for sensorless motor operation, flux-controlled (FXC)	
Synchronous motor	Asynchronous motor
	P-0-0532, Premagnetization factor
	P-0-0578, Current for deceleration, absolute value
	P-0-0579, Current for deceleration, time period
	P-0-0594, FXC: Total flux loop integral action time
	P-0-0595, Frequency loop proportional gain (FXC)
	P-0-0596, FXC: Frequency loop scaling factor of inertia
	P-0-0597, FXC: Current loop proportional gain
	P-0-0598, FXC: Current loop integral action time
	P-0-0599, FXC: Slip frequency filter time constant
	P-0-0600, FXC: Rated slip frequency

Tab. 6-15: Overview of Motor Control Parameters for Synchronous and Asynchronous Motors and Sensorless, Flux-Controlled Motor Operation (FXC)

Determining the Parameter Values by Means of Type Plate Data

Command "Calculate Motor Data" (C3200)

For asynchronous motors it is possible via "C3200 Command Calculate motor data" to calculate the values for motor parameters from the type plate data and then the values of the motor control parameters. The activation of C3200 first requires manual input of the motor data from the type plate of the asynchronous motor in "P-0-4032, Motor type plate data".

See description of "P-0-4032, Motor type plate data"

The command C3200 can only be used for asynchronous motors and can only be activated in communication phase "PM"!

The figure below illustrates the scope of functions of the command C3200:

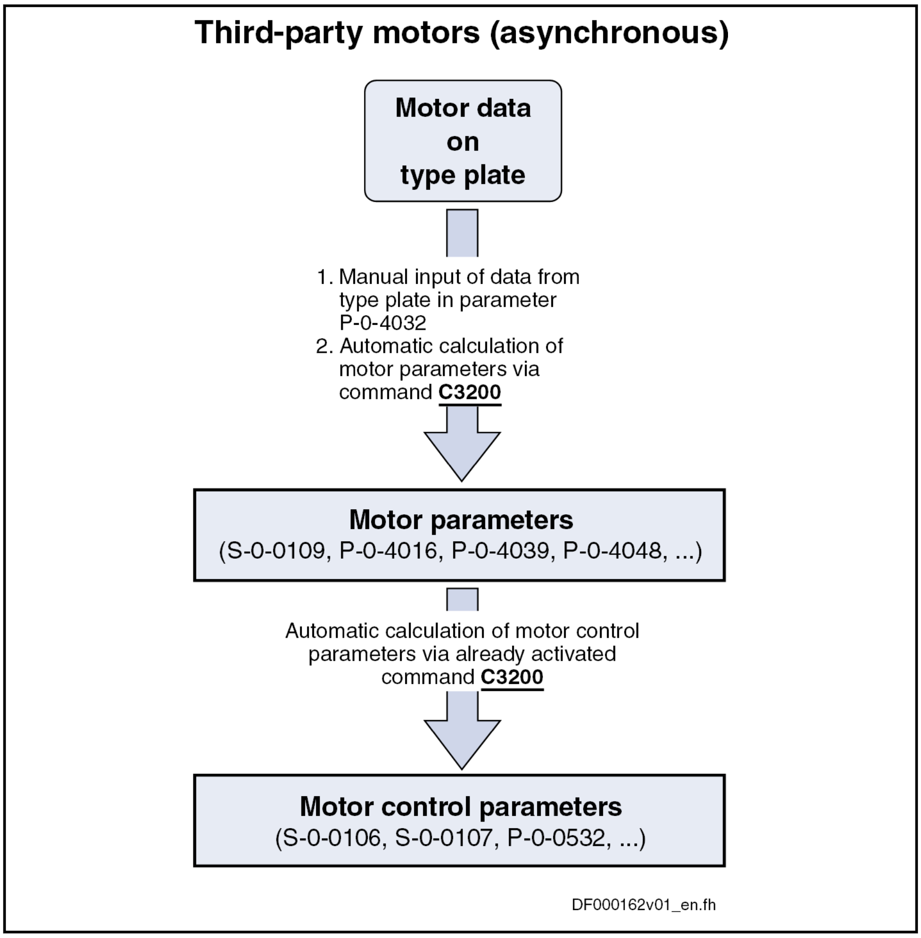


Fig. 6-57: Functions of "C3200 Command Calculate Motor Data"

☞ The type plate does not contain the complete information required for safe operation of the third-party motor!

All required data are part of the form of manufacturer-side motor data which has to be available in completed form! The additional data, however, are not required for executing the command C3200.

Internally Calculated Parameter Values

By activating the command C3200 (P-0-4033), the following parameter values are calculated from the data of the asynchronous motor entered in list parameter P-0-4032:

- Motor parameters
  - Motor parameters, general
  - Specific motor parameters for asynchronous motors
- Motor control parameters
  - Motor control parameters for voltage-controlled operation (V/Hz [U/f]) of sensorless asynchronous motors
  - Motor control parameters for field-oriented current control (FOC) of asynchronous motors
  - Motor control parameters for flux-controlled operation (FXC) of sensorless asynchronous motors

- The input in P-0-4032 is irrelevant unless the command C3200 has been started.
- When the command was processed without error, the calculated values of motor and motor control parameters are operational!

Identifying and Optimizing the Motor Parameter Values

"Command Motor Data Identification" (C3600)

For asynchronous motors, it is possible via "C3600 Command Motor data identification" to automatically identify and optimize the optimum motor and motor control parameters on the basis of appropriate start values.

The command C3600 can only be activated in the operating mode "Ab"!

The figure below illustrates the scope of functions of the command C3600:

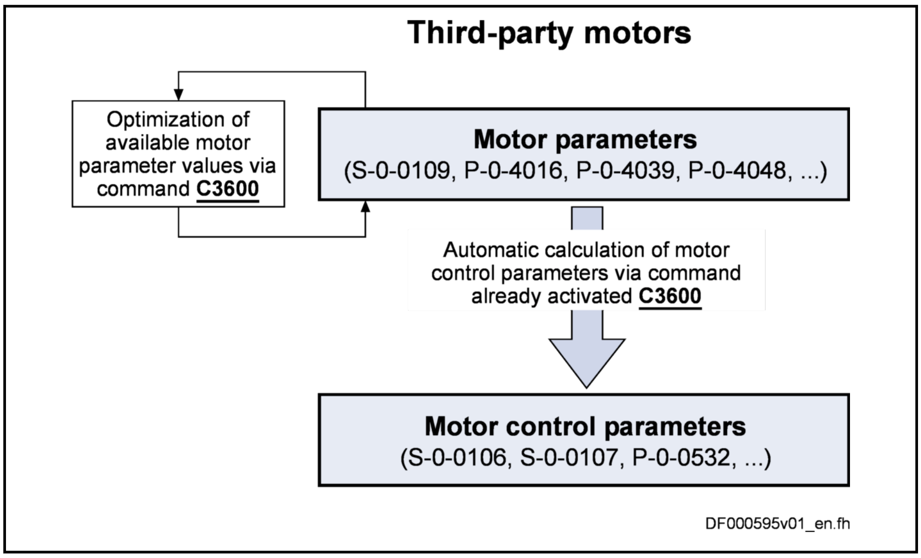


Fig. 6-58: Functions of "C3600 Command Motor Data Identification"

Requirements

To execute the command C3600, the following requirements must have been fulfilled:

- manual input of type plate data of asynchronous motors in "P-0-4032, Motor type plate data" and subsequent execution of "C3200 Command Calculate motor data"

  - or -
- manual input of motor data of synchronous or asynchronous motors according to manufacturer's specifications (completed form) into the motor parameters

Appropriate start values are set up to start the motor data identification.

Procedure

In status ("Ab"), test signals are transmitted to the motor with the execution of command C3600 (configured for motor data identification). In this way, the motor parameters are checked and, if necessary, optimized.

After having successfully completed the command execution, the motor and motor control parameters have been optimized and stored.

The following parameters are recalculated:

- Motor control parameters for voltage-controlled operation (V/Hz [U/f]) of sensorless asynchronous motors

- Motor control parameters for field-oriented current control (FOC) of synchronous and asynchronous motors
- Motor control parameters for flux-controlled operation (FXC) of synchronous and asynchronous motors

Notes on Operating Principle of C3600

The command C3600 offers multiple possibilities of identification and plausibility check; the selection is done in P-0-0601, configuration of motor data identification:

- Motor data identification with the motor in standstill or motor set in motion
- Determination of the magnetization characteristic of asynchronous motors
- Validation check of the motor and motor encoder data
- Rotational direction check of motor and motor encoder

Any holding brake which may be present is controlled by the controller in a suitable way during execution of the command.

☞
- When the command was processed without error, the calculated values of motor and motor control parameters are operational.
- If the command execution is aborted during the measurement, all motor and motor control parameters remain unchanged.

Calculating the Motor Control Parameters from the Motor Parameters

Command "Calculate Motor Control Parameters" (C4600)

For synchronous motors and in special cases (see Requirements) for asynchronous motors it is possible via "C4600 Command Calculate motor control parameters" to calculate the motor control parameters from the motor parameters.

☞ The command C4600 can only be activated in the operating mode (OM)!

→ Communication phase P4 ("bb" or "Ab")

The figure below illustrates the scope of functions of the command C4600:

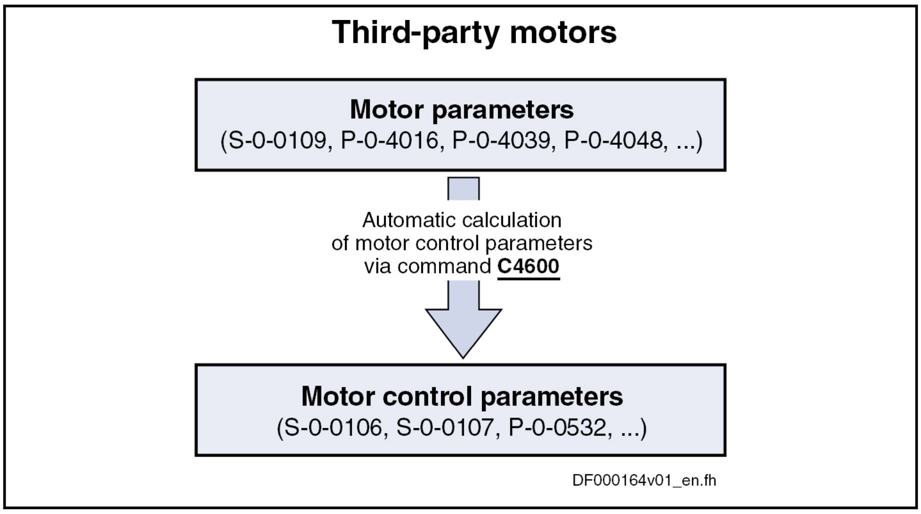


Fig. 6-59: Function of "C4600 Command Calculate Motor Control Parameters"

Requirements

To execute the command C4600, the following requirements must have been fulfilled:

- **Synchronous third-party motors** require manual input of the motor data in the motor parameters (see "Third-Party Motors at IndraDrive Controllers").
- With **third-party asynchronous motors** it only makes sense to use command C4600 when the special motor parameters (see the chapter "Form sheets for parameter values") are determined and can be entered into the parameters concerned (see the chapter "Determining the Parameter Values of Third-Party Motors"). The calculated values for the motor control parameters thereby might possibly be more exact! It is easier, however, to use the commands C3200 and C3600 (see above) for asynchronous motors.

☞

- The command C4600 has been integrated in the command "C3600, Command Motor data identification". When C3600 is executed, it is not necessary to start C4600!
- When the command was processed without error, the calculated values of motor and motor control parameters are operational.

Notes on Commissioning

Motor connected to controller				Parameter values made available	
Motor manufacturer	Motor design	Motor type	Encoder data memory	Motor parameters	Motor control parameters
Rexroth	Housing	MKE, MSK, SF, MAD, MAF	Yes	A	A
		MSD	No	M/D	M/D
	Kit	1MB, MBS, MBT, MBW, MLF, MBSxx2 (high speed)	No	M/D	M/D
Third-party motor	Housing or kit	Synchronous third-party motor	No	M	C
	Housing or kit	Asynchronous third-party motor	No	M/C	C

A Automatically after drive switched on
D Download via commissioning tool
M Manual input via control master
C Automatic determination via drive command

Tab. 6-16: Making Available Values for Motor Parameters and Motor Control Parameters

Rexroth Motors

For Rexroth motors, both the motor parameters and the motor control parameters are optimized by the manufacturer via the encoder data memory of the motor encoder or, for motors without encoder memory, are made available via the commissioning tool.

For Rexroth motors, it is not required to determine the motor or motor control parameters! The commands C3200, C3600 (configured for motor data identification in P-0-601) and C4600 mustn't be started for drives with Rexroth motors, because otherwise the values of motor and motor control parameters optimized by the manufacturer are overwritten with the values calculated by means of command. This can modify the drive characteristics in a disadvantageous way!

Rexroth-kit motors (MBS, MBT, MLF, 1MB) are not completed until installed in an axis with a motor encoder. The interaction of the motor with the motor encoder and its correct parameter settings can be checked with command C3600, configured for "Validation check" in P-0-0601. In addition, during commissioning of the synchronous kit motors, the commutation offset and/or the commutation process must be determined.

See also chapter "commutation adjustment"

Third-Party Motors

The commissioning of a third-party motor is similar to the commissioning of a Rexroth motor without motor encoder data memory. The basic difference is the fact that the motor and motor control parameters cannot be loaded from the motor parameter database of the commissioning tool, but are determined via command by the controller after manual input of the type plate data or motor parameter values

The encoder must also be parameterized for third-party motors with motor encoder. The interaction of the motor with the motor encoder and its correct parameter settings can be checked with command C3600, configured for "Validation check" in P-0-0601. In addition, during commissioning of the synchronous kit motors, the commutation offset and/or the commutation process must be determined.

See also "Third-Party Motors at IndraDrive Controllers"

See also chapter "commutation adjustment"

Diagnostic and Status Messages

If the command execution cannot be carried out successfully, diagnostic messages will be signaling the respective errors. The description of the respective command error contains information on the causes and suggests measures for remedy. If necessary, the manufacturer-side motor data have to be questioned and the motor and motor control parameters determined again!

See description of the diagnostic messages in the separate documentation "Troubleshooting Guide (description of diagnostic messages)"

6.4 Open-Loop Axis Control (Open-Loop Operation)

6.4.1 Brief Description

In sensorless operation (open-loop operation), the velocity control loop is not closed in the drive, but the drive is operated in a velocity-controlled way (without feedback) via open-loop V/Hz (U/f) control.

The method of open-loop/closed-loop motor control can be selected via bit 14 of "P-0-0045, Control word of current controller".

See also the section "Motor Control"

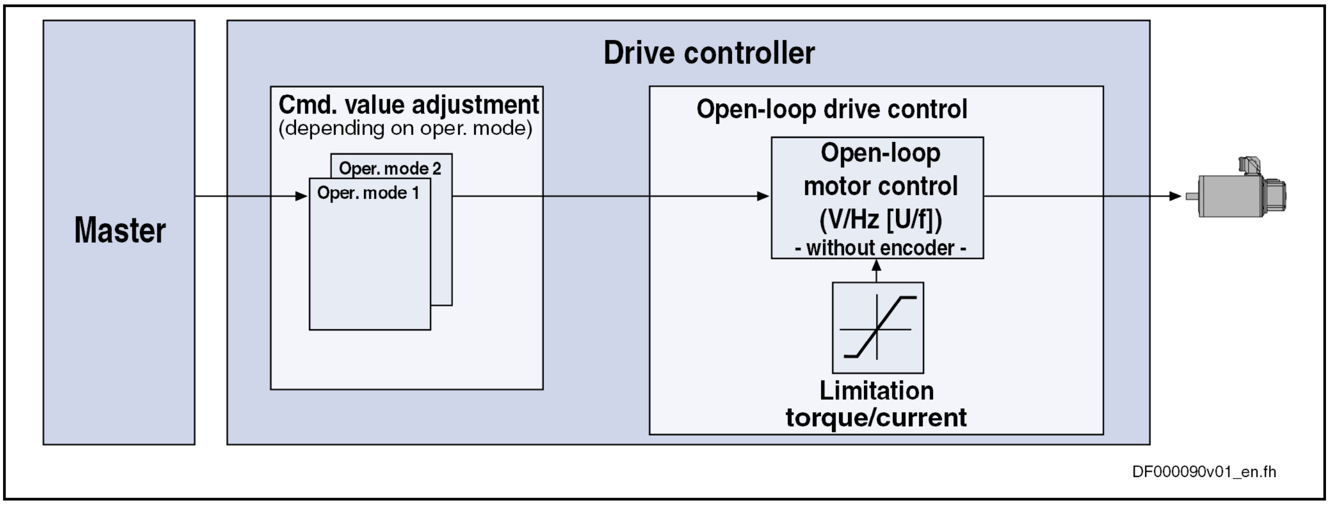


Fig. 6-60: Principle of Drive Control in Open-Loop Operation

Features

The open-loop velocity control has the following features:

- Fine interpolation of the velocity command value (can be switched off)
- Monitoring of the velocity control loop is possible (can be switched off via P-0-0556; bit 1)
- Parameterizable filtering of the actual velocity value
- Additive velocity command value (S-0-0037)
- Display of the resulting command value (in P-0-0048)
- Monitoring and **limitation** of the maximum stator frequency slope that results from the command velocity change
- **Stall protection controller** (PI controller that can be optionally activated to prevent breakdown of the machine when the torque limits are attained)
- **Slip compensation** (feedforward of estimated slip of the machine by means of rotor time constant and slip compensation factor)
- Calculation of output voltage by means of **V/Hz (U/f) characteristic** based on motor model data
- Subsequent trimming of magnetization via premagnetization factor (linear or square characteristic to be selected)
- **IxR boost** (adjustable load-dependent feedforward of the output voltage due to the voltage drop on the motor winding resistance)
- **Oscillation damping** (adjustable load-dependent feedforward to prevent velocity oscillations in the partial load and idling ranges)
- **Current limitation controller** to protect the output stage
- **Velocity search mode** of a coasting machine after switching drive enable on (can be set for one or both rotational directions)

Pertinent Parameters

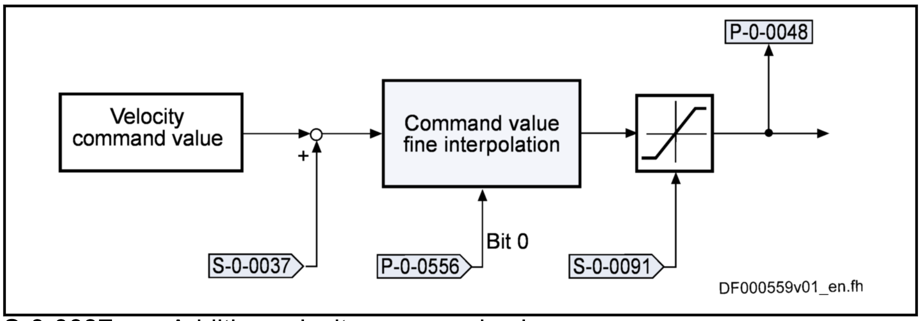
- S-0-0037, Additive velocity command value
- S-0-0040, Velocity feedback value
- S-0-0091, Bipolar velocity limit value
- P-0-0048, Effective velocity command value
- P-0-0049, Effective torque/force command value
- P-0-0555, axis controller messages
- P-0-0556, Config word of axis controller

Pertinent Diagnostic Messages

- F8079 Velocity limit value exceeded (S-0-0091)

6.4.2 Functional Description

Fine Interpolator



S-0-0037	Additive velocity command value
S-0-0091	Bipolar velocity limit value
P-0-0048	Effective velocity command value

Fig. 6-61: Fine Interpolation of the Velocity Command Value

Units of the Processed Data

The physical data for open-loop velocity control have the following units:

- Velocity data → rpm or mm/min
- Acceleration data → (rpm)/controller clock or (mm/min)/controller clock
- Torque data → Nm or N

V/Hz (U/f) control

The output value of the fine interpolator (P-0-0048) is used as the input value for the subsequent U/f control (open-loop operation) which is described in the section "Voltage-Controlled Open-Loop Operation".

6.4.3 Diagnostic and Status Messages

Monitoring the Velocity Limit Value

The actual velocity value, internally generated via the stall protection controller, is monitored for the limit value of 1.125 * S_0_0091 (bipolar velocity limit value), as soon as it is outside of the standstill window S_0_0124. When this value is exceeded, the following error message is generated:

- F8079 Velocity limit value exceeded

6.5 Closed-Loop Axis Control (Closed-Loop Operation)

6.5.1 General Information on Closed-Loop Axis Control

Control Loop Structure

The drive controller has a so-called cascade structure, i.e. the individual controllers (position, velocity and current) are interconnected. Depending on the active operation mode, there are different controller structures with different points of input and paths of the command values. Depending on the active operation mode, only the torque control loop, the torque control loop and the velocity control loop or, in addition to these two control loops the position control loop can be closed in the drive.

The structure and the interaction of the control loops are shown in two figures in the section "Overview of Drive Control" (see "Control Loop Structure with Setting Parameters" or "Control Loop Structure with Display Parameters").

Features of the Control Loops

For the simplification of the parameterization of the control loops and for an increase in performance, a number of standardizations and structural changes have been carried out.

Current controller, velocity controller and position controller are described in the section "Performance (Controller Cycle Times)" (see "Overview of Drive Control, Features of the Control Loops").

Possibilities of Accessing Outer Control Loops

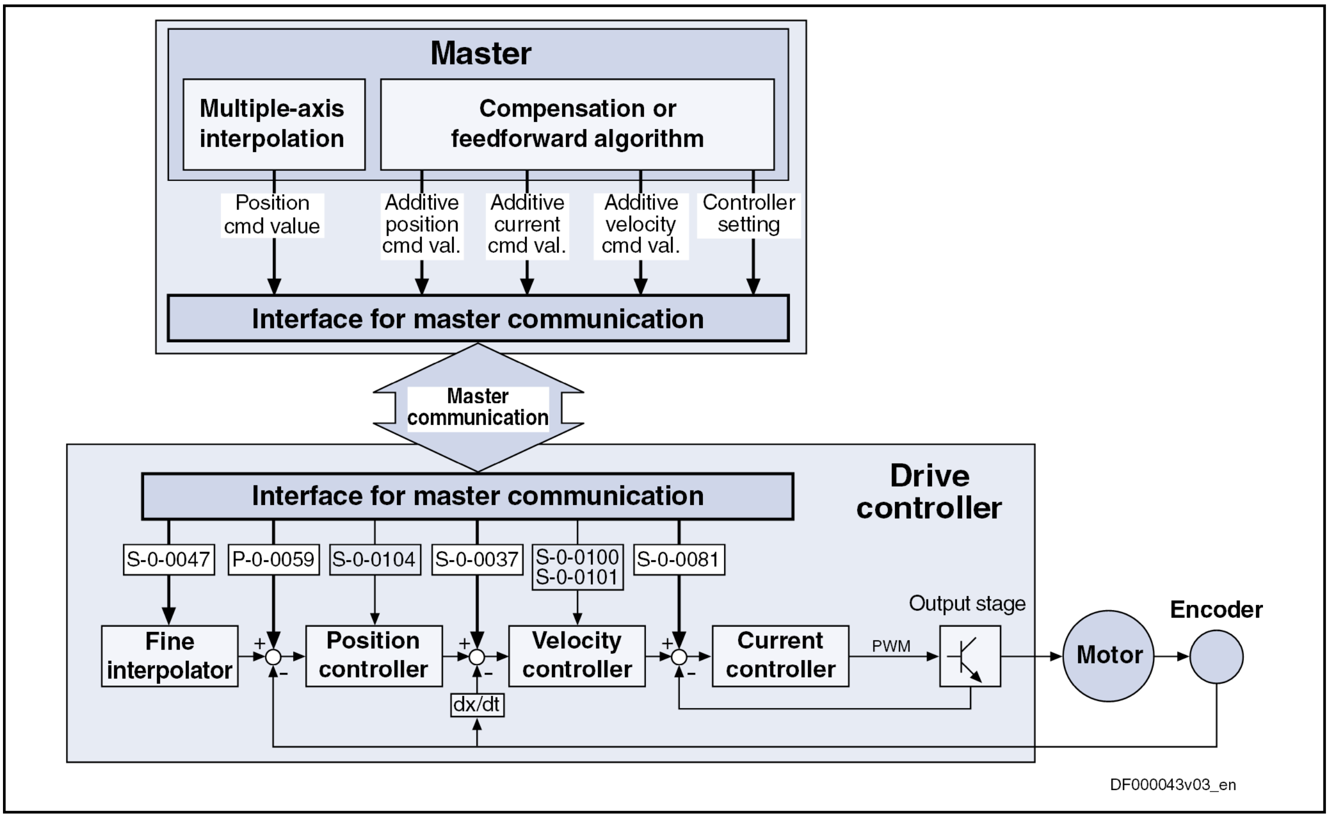
In closed-loop operation it is possible to add command values in addition to the command values available in the control loop. Depending on the active operation mode, the following parameters are available to do this:

Operation mode	S-0-0081	S-0-0037	P-0-0059	S-0-0048
V/Hz (U/f) control (command value processing in velocity control)	--	--	--	--
Torque/force control	■	--	--	--
Velocity control / velocity synchronization	■	■	--	--
Position Control	■	■	■	--
Drive-controlled positioning	■	■	■	--
Positioning block mode	■	■	■	--
Phase synchronization	■	■	--	■
Electronic cam	■	■	--	■

S-0-0081 Additive torque/force command value
S-0-0037 Additive velocity command value
P-0-0059 Additive position command value, controller
S-0-0048 Additive position command value

Tab. 6-17: Overview of the Additive Command Values Depending on the Operation Mode

In closed-loop operation, it is possible to access the outer control loops from a higher-level operation mode. The access options to the individual control loops are illustrated in the following example:



S-0-0037	Additive velocity command value
S-0-0047	Position command value
S-0-0081	Additive torque/force command value
S-0-0100	Velocity loop proportional gain
S-0-0101	Velocity loop integral action time
S-0-0104	Position loop Kv-factor
P-0-0059	Additive position command value, controller

Fig. 6-62: Structural Overview with Access Options

Command Value Processing Depending on Operation Mode

Position Control

For the following operation modes, the position control loop is closed internally (in the drive) in addition to the velocity and the current control loops:

- Position control with cyclic command value input
- Drive-internal interpolation
- Positioning modes (drive-controlled positioning, positioning block mode)

See also description of the respective operation mode.

Velocity Control

In the "velocity control" mode, the velocity control loop, apart form the current control loop, is closed in the drive, too.

See also "Velocity Control"

Torque/force control

The "torque/force control" mode actually isn't torque or force control but current control. Therefore, only the current control loop is closed in the drive.

See also "Torque/Force Control"

Notes on Commissioning for Control Loop Setting

The control loop settings in a digital drive controller are very important for the features of the servo axis.

To optimize the control loop setting, application-specific controller parameters are available for all digital Rexroth drives.

Order of Manual Control Loop Setting

Due to the cascade structure of the control loops, it is necessary to parameterize them "from the inside to the outside". The resulting order for setting the control loops is as follows:

1. **Current control loop**

   For **Rexroth motors with motor encoder data memory** (MSK and MKE series), the optimization of the current controller is not required, as the respective parameter values (S-0-0106 and S-0-0107) are read from the motor encoder data memory.

   For all **Rexroth motors without motor encoder data memory** (e.g. linear motors), the parameter settings can be taken from a central motor database via the "IndraWorks Ds/D/MLD" commissioning tool.

   The commissioning of **third-party motors** (including control loop settings) is described in the respective sections on third-party motors in this documentation (see "Third-Party Motors at IndraDrive Controllers").

2. **Velocity control loop**

   The settings of the velocity controller (S-0-0100 and S-0-0101) with the respective filters (P-0-0004 and P-0-1120, P-0-1121, P-0-1122, P-0-1123, P-0-1140, P-0-1141, P-0-1142, P-0-1143) on the one hand depend on the motor parameters (inertia and torque/force constant), on the other hand they strongly depend on the mechanical properties (load inertia/mass, friction, rigidity of the connection, ...). Therefore, manual or automatic optimization is often necessary.

3. **Position control loop**

   In general, the position control loop only has to be adjusted to the dynamics of the outer velocity controller, as well as to the kind of preset command values (jerk, acceleration and interpolation procedure).

Default Settings in the Motor Encoder Data Memory ("Load Motor Default Values")

"Load Motor Default Values" Command

For all Rexroth motors of the series with motor encoder data memory (e.g. MKE, MSK and possibly MAD and MAF), the basic settings for the controllers are stored and can be loaded to the drive by executing the "load motor default values" command (S-0-0262).

The parameter "S-0-0262, C07_x Load defaults procedure command" can be activated in two ways:

- Automatically when running up the drive by recognizing that the motor type (cf. parameter S-0-0141) has changed. The display then reads "RL" and by pressing the "Esc" button on the control panel, the "load motor default values" command is internally started unless this was deactivated in "P-0-0556, Config word of axis controller".
- Starting the command by writing "11b" to parameter S-0-0262.

See also "Loading, Storing and Saving Parameters"

☞ In order to start the "load motor default values" command, the value "0" (default setting) must have been set in parameter "P-0-4090, Configuration for loading default values".

During the load motor default values procedure, the following control loop parameters are set to their default values optimized for the respective motor:

- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time

- S-0-0104, Position loop Kv-factor
- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- P-0-0004, Velocity loop smoothing time constant

☞ The default settings for the current control loop (cf. S-0-0106 and S-0-0107) are automatically adjusted to the currently parameterized PWM frequency (cf. P-0-0001) and performance setting (cf. P-0-0556)!

In addition, when the motor default values are loaded, the following control loop parameter is set to the firmware-side default value even though no default value has been stored in the motor data memory for this parameter.

- S-0-0348, Acceleration feedforward gain

☞ In the majority of cases, the controller settings stored in the motor encoder data memory provide a useful and reliable control loop setting. In exceptional cases, however, it may be necessary to make the settings with regard to the specific application.

6.5.2 Automatic Setting of Axis Control

Brief Description

To facilitate drive parameterization, the IndraDrive firmware provides automatic axis control setting in closed-loop operation.

- Together, the settings of axis control and the axis mechanics (e.g. stiffness/elasticity and load inertia/load mass) determine the control loop dynamics to be achieved.
- The required control loop dynamics depends on the application type (such as machine tool and handling axis).
- It allows setting the control loop parameters in such a way that they are adjusted to the application type and the axis structure (such as direct connection and drive with gearbox/toothed wheel), as well as to the mechanical properties of the axis.

Features

The function has the following features:

- The function is started with the command "P-0-0162, C1800 Command Drive optimization / command value box" and controlled with the parameter "P-0-0165, Drive optimization, control word".
- With the start of the function, switching to a drive-internal operation mode takes place and the drive makes itself independent of the control unit.
- The result of the control loop setting (achieved control loop dynamics) can be influenced via "P-0-0163, Damping factor for autom. controller setting" and "P-0-0164, Application for autom. controller setting".
- Via "P-0-0165, Drive optimization, control word" it is possible, by selecting the corresponding bit, to activate the respective subfunction of the automatic setting of axis control:
  - Calculation of velocity and/or position controller parameters (drive does not move)
  - Optimization of velocity and/or position controller parameters (drive moves)

– Determination of acceleration feedforward (drive does not move)
– Determination of load inertia (drive moves)
– Determination of the maximum acceleration (drive does not move)

Depending on the settings in "P-0-0165, Drive optimization, control word", it is necessary to move the drive to carry out the automatic setting of axis control. The drive moves when the load inertia is determined and when the velocity and position control loops are optimized.

- If motion is not required, the command can already be started in phase 4 (bb: drive ready for operation).
- If motion is required, drive enable (AF) is necessary to start the command.
  – The type of motion, oscillating motion or motion in one direction, and, if applicable, the direction of motion, positive or negative direction, are automatically determined from the processing format, absolute or modulo format, of the position data, "S-0-0076, Position data scaling type" (bit 7) and the "S-0-0393, Command value mode".
  – The travel range is defined either by inputting position limits or a travel distance.

When the IndraWorks engineering tool (as of 13V06) is used to control the function, further features are available:

- Automatic determination of the mechanical properties of antiresonance and resonance frequencies:

  "P-0-0181, Drive optimization: Antiresonance frequency"

  "P-0-0182, Drive optimization: Resonance frequency"

- Automatic setting of the speed control loop filters depending on the antiresonance and resonance frequencies

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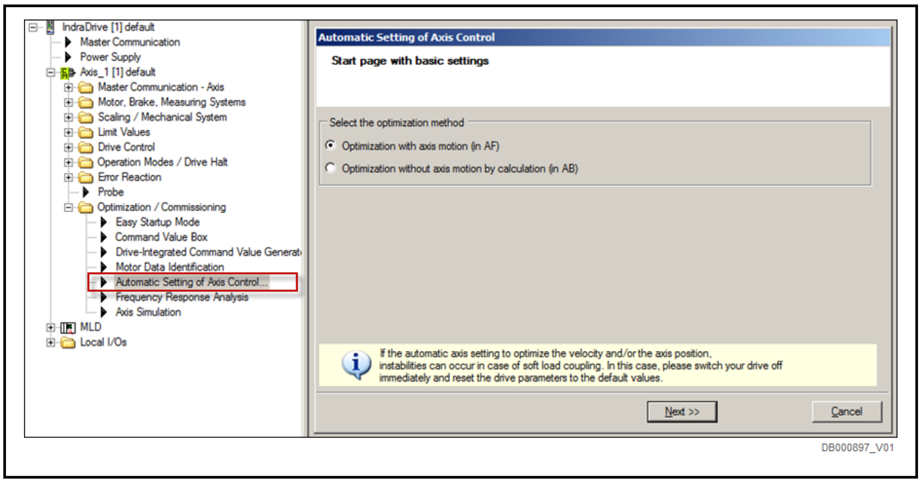


Fig. 6-63: IndraWorks Start Dialog "Automatic Setting of Axis Control"

Pertinent Parameters

- P-0-0161, Drive optimization: Periodic time
- P-0-0162, C1800 Command Drive optimization / command value box
- P-0-0163, Damping factor for autom. controller setting

- P-0-0164, Application for autom. controller setting
- P-0-0165, Drive optimization, control word
- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive
- P-0-0168, Maximum acceleration to be parameterized
- P-0-0169, Drive optimization, travel distance
- P-0-0170, Drive optimization, acceleration
- P-0-0171, Drive optimization, velocity
- P-0-0181, Drive optimization: Antiresonance frequency
- P-0-0182, Drive optimization: Resonance frequency

Pertinent Diagnostic Messages

- C1800 Command Drive optimization / command value box
- C1801 Start requires drive enable
- C1802 No useful motor data
- C1803 Inertia detection failed
- C1804 Automatic controller setting failed
- C1805 Travel range invalid
- C1806 Travel range exceeded
- C1807 Determining travel range only via travel distance
- C1808 Drive not homed
- E2049 Positioning velocity >= limit value (S-0-0091)
- E2055 Feedrate override S-0-0108 = 0

Functional Description

Requirements

NOTICE **Property damage and/or personal injury caused by drive motion!**

During the execution of "C1800 Command Drive optimization / command value box", the drive moves automatically, i. e. without external command value input.

⇒ Check and make sure that the E-Stop circuit and the travel range limit switches are working!

Loading the Default Controller Parameters

Before starting the command "automatic control loop setting", the default controller parameters stored in the motor encoder data memory should be loaded or the data of the motor data sheet should be entered in the respective parameters.

Motor control

FOC (field-oriented current control) – only possible with motor encoder – must be active as the motor control process.

Parameter Settings

All parameters used for the command "automatic control loop setting" must be determined before command start so that they take effect for the automatic control loop setting.

Settings which have an influence on control loop dynamics:

- P-0-0163, Damping factor for autom. controller setting

→ Select the desired control loop dynamics

- P-0-0164, Application for autom. controller setting

  → Take the mechanical properties for the controller optimization into account

- P-0-0165, Drive optimization, control word

  → Select the functionality (modes/sub-functions) of the automatic control loop setting and determine the general conditions

- P-0-0181, Drive optimization: Antiresonance frequency
- P-0-0182, Drive optimization: Resonance frequency

As well as these parameters which influence the result of the control circuit adjustment (control loop dynamism achieved), the settings which define the working range and the movement are required:

- P-0-0161, Drive optimization: Periodic time
- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive
- P-0-0169, Drive optimization, travel distance
- P-0-0170, Drive optimization, acceleration
- P-0-0171, Drive optimization, velocity

Define the Working/Monitoring Range

The working/monitoring range must be defined.

At least one minimum travel range is required for rotary motors, this corresponds to ¼ of a motor turn, and ¼ of a pole width for linear motors.

Start of Automatic Control Loop Setting

The automatic control loop setting is only carried out when the following requirements have been fulfilled:

- The "automatic control loop setting" function must have been configured in parameter "P-0-0165, Drive optimization, control word". In this parameter, the presettings for a total of three functions are made which operate with internal command value input:
  1. Recording the table for cogging torque compensation (highest priority)
  2. Drive-internal command value box (medium priority)
  3. Automatic control loop setting (lowest priority)

☞ The above-mentioned functions cannot be used simultaneously, although they can be selected simultaneously by means of the respective bits. The prioritization in the list applies; i.e. Bits 10, 9 and 8 in parameter "P-0-0165, Drive optimization, control word" must be "0" since the "Automatic control loop setting" has the lowest priority.

- If motion is **not** required, the command can already be started in phase 4 (bb: drive ready for operation).
- If **motion** is required, drive enable (AF) is necessary to start the command.
- Command "P-0-0162, C1800 Command Drive optimization / command value box" is started.

> ☞ Depending on the settings in "P-0-0165, Drive optimization, control word", it is necessary to move the drive to carry out the automatic setting of axis control. The drive moves when the load inertia is determined and when the velocity and position control loops are optimized.

Defining the Working/Monitoring Range

As the axis moves when the load inertia is determined and the position and/or speed controller parameters are optimized, it is necessary to define the allowed working range.

When defining the working/monitoring range, observe the following aspects:

- A minimum travel range is required - this is
  - > ¼ a mechanical motor turn for rotary motors.
  - > ¼ a pole width (P-0-0018) for linear motors.
- There are basically two options for define the monitoring range which are defined in "P-0-0165, Drive optimization, control word" (Bit 15):
  - Bit 15 = 0: Input via limits in "P-0-0166, Drive optimization, end position negative" and "P-0-0167, Drive optimization, end position positive"

    - or -
  - Bit 15 = 1: Input of a relative travel distance in "P-0-0169, Drive optimization, travel distance"
- The working range lies symmetrical in the monitoring range and is smaller by the safety distance on both sides.

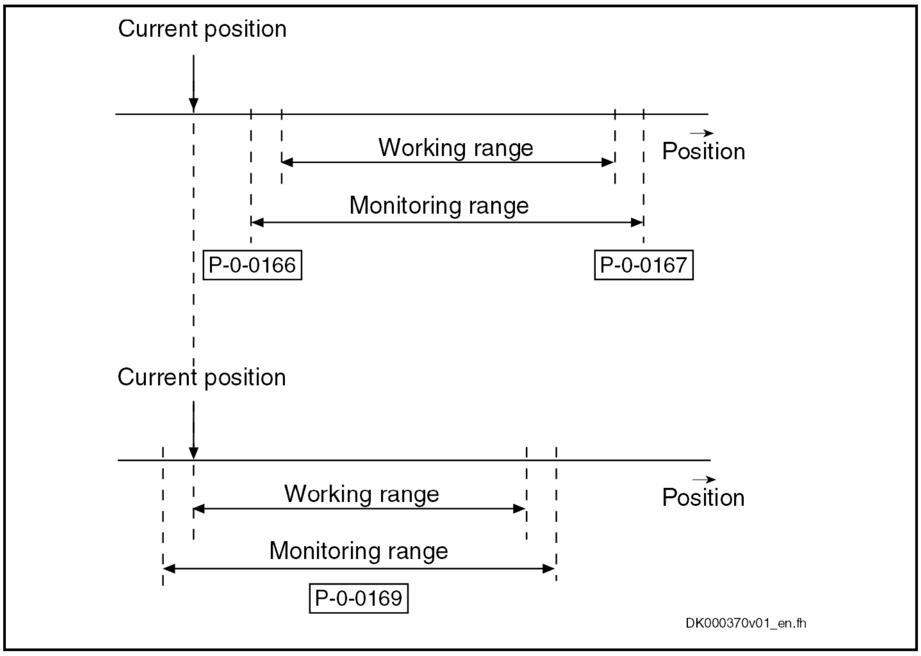


Fig. 6-64: Working/Monitoring Range when Determining over the Limits P-0-0166 / P-0-0167 (above) and over the Travel Distance P-0-0169 (below)

Motion Profile

- The motion profile (oscillating motion, motion in one direction) is derived from the axle configuration.

With the processing format from the position scaling (S-0-0076, Bit 7) a distinction is made between the absolute axis and the modular axis. The motion direction is defined via the command value mode (S-0-0393, Bit 1,0).

– Absolute axles and modulo axes with the shortest distance use the oscillating motion.

  The monitoring range can be set via the travel distance or limits.

– Modulo axes with fixed direction may only be moved in one direction and use the "Motion in one direction" as the motion profile.

  The monitoring range can only be set via the travel distance. When setting over limits, the command error "Determination of travel range only via travel distance" (C1807) is output.

Specifying Limits

- The parameter Drive optimization, end position negative (P-0-0166) and end position positive (P-0-0167) directly define the monitoring range, whereby the end position positive must be larger than the end position negative. Otherwise, the command error "Travel range invalid" (C1805) is issued.
- Setting over limits is only allowed for absolute axes and modulo axes with the shortest distance. For modulo axes with fixed direction, the command error "Determination of travel range only via travel distance" (C1807) is output.
- The current position can also lie outside of the limits.
- The oscillating motion is effective as the motion profile. At the start of motion, the axis moves from the current position to the start position which lies on the next limit of the working range.

Specifying the Travel Distance

- Input of a relative travel distance in "P-0-0169, Drive optimization, travel distance" which defines the monitoring range.
- Setting over travel distance is possible for absolute axes and modulo axes.
- Absolute axes and modulo axes with the shortest distance:
  – Motion profile the same as oscillating motion
  – The limits of the monitoring range are put into the current position depending on the sign of the P-0-0169.

    With a positive sign, the current position corresponds to the lower/left limit of working range.

    With a negative sign, the current position corresponds to the upper/right limit of working range.
- Modulo axes with one direction:
  – Motion profile same as motion in one direction
  – The limits of the monitoring range are put into the current position depending on the command value mode (S-0-0393, Bit 1,0). The sign of P-0-0169 is ignored.

    Command value mode equal to "positive direction" (S-0-0393, bit 1.0 = 00): current position matches the lower/left limit of the working range.

    Command value mode equal to "negative direction" (S-0-0393, bit 1.0 = 10): current position matches the lower/left limit of the working range.
- The starting position for the motion is the current position.

Safety Distance

The safety distance – calculated internally – ensures the working range is smaller than the monitoring range and prevents a transient oscillation of the position to the working range limit from leading to the triggering of a monitoring fault.

The safety distance can have an effect on the upper and lower limit. A safety distance is only taken into account when it is necessary to move to the working range limit. When not directly moving to the upper/lower limit, a fault is triggered if the monitoring range is violated.

Time Flow and Result

Steps of Automatic Control Loop Setting

The automatic control loop setting is carried out in the following steps:

1. Start command and make check for possible command errors
2. Moving to the start position
    - The drive only moves to the start position, if motion is required to carry out the automatic control loop setting (determination of load inertia and/or controller optimization).
    - When presetting the travel distance, the start position is the current position.
    - If limits are preset, the start position lies next to the next limit within the preset working range.
3. Determining the total inertia
    - P-0-0165, bit 4 = 1: Internal to the drive, a sinusoidal velocity profile is preset and the load inertia is determined P-0-4010 by evaluation; in other words, the axes moves.
        - The shape of the sine profile is dependent on the motion profile (oscillating motion, motion in one direction).
        - The amplitude and the offset of the sinusoidal velocity profile is dependent on
            - P-0-0171, Drive optimization, velocity
            - P-0-0165 Bit 11 (Offset sine-wave method), Drive optimization, control word
            - the motion profile (oscillating motion, motion in one direction)

              The offset cannot be deactivated for motion in one direction
        - The periodic time is preset via P-0-0161, Drive optimization: Periodic time
    - P-0-0165, bit 4 = 0: By applying parameter values P-0-0510 and P-0-4010

      Total inertia is the sum of P-0-0510 and P-0-4010; i.e. axis does not move
4. Calculation and activation of the control loop parameters in the drive without axis motion
    - P-0-0165, bit 1: Calculate speed controller parameters (0: No , 1: Yes)
    - P-0-0165, bit 2: Calculate position controller parameters (0: No , 1: Yes)

   taking the following parameters into account:

- P-0-0163, Damping factor for autom. controller setting
- P-0-0164, Application for autom. controller setting
- P-0-0510, Rotor inertia
- P-0-4010, Load inertia
- P-0-0181, Drive optimization: Antiresonance frequency
- P-0-0182, Drive optimization: Resonance frequency

The antiresonance and resonance frequency can either be input or determined automatically by measuring the frequency response with IndraWorks

5. Optimize control loop parameters with axis motion

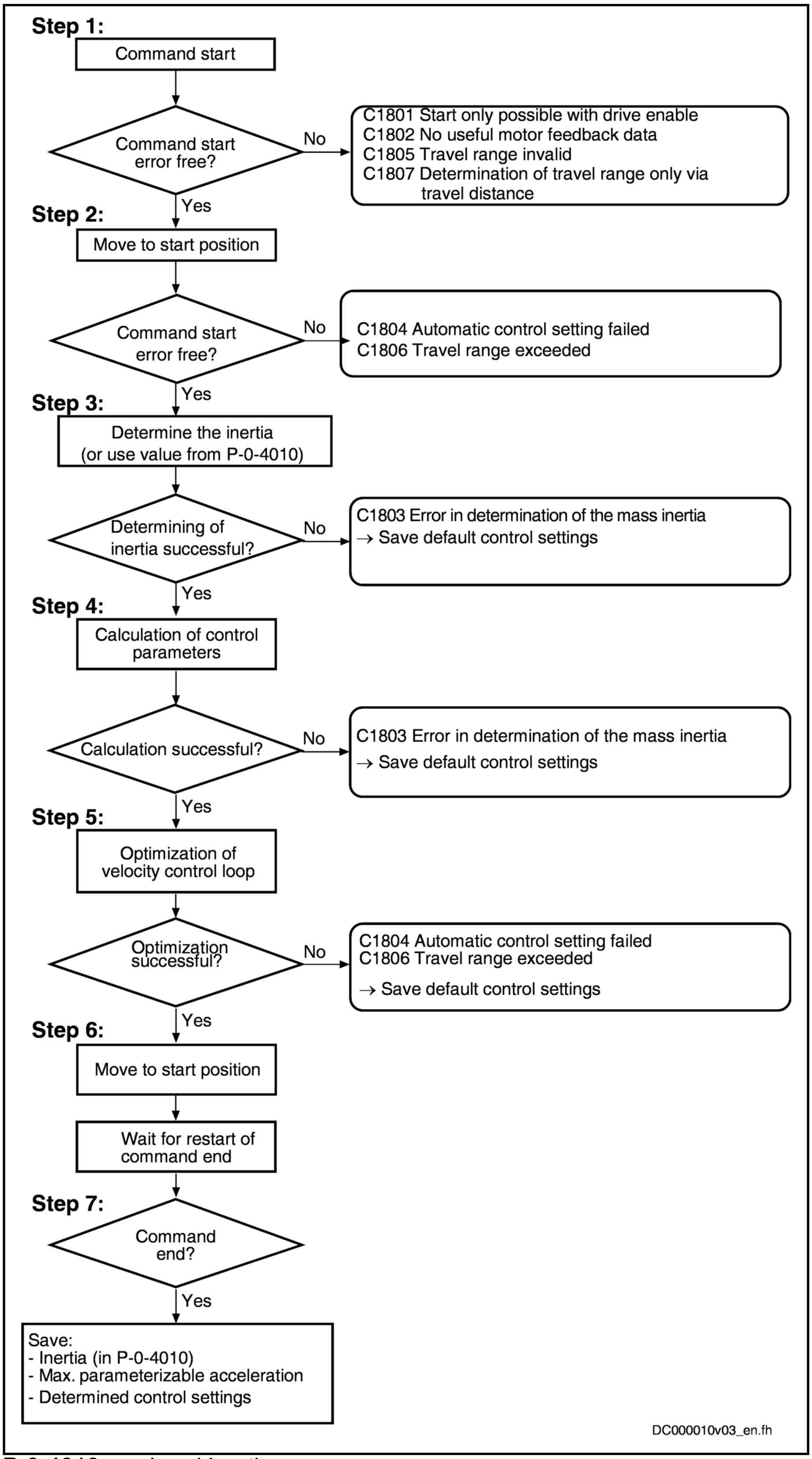
   The control loop parameters are only optimized with P-0-0165, bit 0 = 1, and at least one of the bits 2/1 set in P-0-0165

   - P-0-0165, bit 1 = 1: Check velocity control loop and optimize controller parameters, until desired behavior occurs (depends on programmed dynamics)
   - P-0-0165, bit 2 = 1: Check position control loop and optimize controller parameters, until aperiodic behavior occurs in position control loop
6. Move back to initial position (actual position at start of command)
7. Wait for possible restart or completion of command

   During this step, the drive is idle (velocity = 0) and the display reads "C1800".

   At the end of the command, the following values are stored:

   - The determined control loop settings
   - The determined load inertia
   - The max. acceleration that can be parameterized



P-0-4010 Load inertia

Fig. 6-65: Steps of Automatic Control Loop Setting

When using the auto-tuning assistant in IndraWorks (13V06 and above), the steps

- frequency response measurement (speed controlled section) with determination of the mechanical properties antiresonance (P-0-0181) and resonance properties (P-0-0182)

and

- Automatic setting of the speed control loop filters depending on the antiresonance and resonance frequencies

precedes this time flow which is started by the command processing of P-0-0162, C1800 Command Drive optimization / command value box.

In other words, the determination of the antiresonance and resonance frequency by measuring the frequency response and setting the speed control loop is a feature of IndraWorks and is **not** a constituent part of command P-0-0162

Result of Automatic Control Loop Setting

The current control loop is not affected during the automatic control loop setting, as its setting is load-independent and optimum current controller parameters were already stored in the motor encoder data memory at the factory.

See also "Default settings in the motor encoder data memory (load motor default values)"

The result of the automatic control loop setting depends on the selection made in P-0-0165.

- Bit 1

  → Calculation plus optimization (bit 0 = 1) of velocity control loop parameters (cf. S-0-0100, S-0-0101, P-0-0004)

- Bit 2

  → Calculation plus optimization (bit 0 = 1) of the position control loop parameters (cf. S_0_0104)

- Bit 3

  → Determination of the acceleration feedforward (cf. S-0-0348)

- Bit 4

  → Determination of load inertia (reduced to motor shaft) and input in P-0-4010

- Bit 6

  → Determination of maximum drive acceleration and input in P-0-0168

In addition, the Auto-Tuning assistant in IndraWorks (13V06 and above) can be used to determine the antiresonance- (P-0-0181) and resonance frequencies (P-0-0182) and optimize the speed control loop filters (P-0-1120, P-0-1140, P-0-1141, P-0-1142, P-0-1143).

Notes on Commissioning

General Information

NOTICE **The execution of the automatic control loop setting is connected with a drive motion!**

⇒ Select the travel range defined with P-0-0166 and P-0-0167 or P-0-0169 such that danger to man and machine resulting from drive motion is excluded.

☞ The parameter settings required to execute the "automatic control loop setting" command must be made prior to command start.

Drive Enable Missing

If at command start drive enable is not available, the error message "C1801 Start requires drive enable" will be displayed.

Starting the Automatic Control Loop Setting

The automatic control loop setting is started by writing the binary numeric value "3" (11b) to "P-0-0162, C1800 Command Drive optimization / command value box" (command start).

☞ During the automatic control loop setting (optimization motion), the defined travel range is permanently monitored. If the travel range is exceeded, the command error "C1806 Travel range exceeded" is output and the drive comes to a standstill in a speed-controlled way.

The defined travel range is only monitored during the execution of the "automatic control loop setting" command!

Triggering a Motion

An axis motion and thus the execution of the automatic control loop setting is only possible if the "Drive HALT" signal has not been set. If the "Drive HALT" signal has been set, the drive will acknowledge the start of "C1800 Command automatic control loop setting", but the axis will not move.

Triggering the Motion by Starting the Command C1800

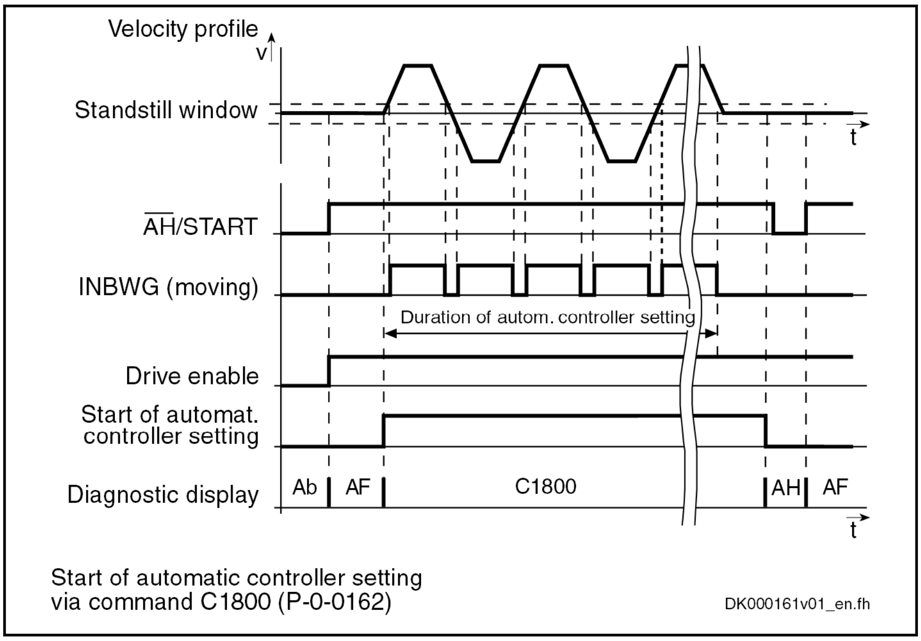


Fig. 6-66: Signal Flow Chart for Motion by Command Start

Triggering the Motion by "Drive Start"

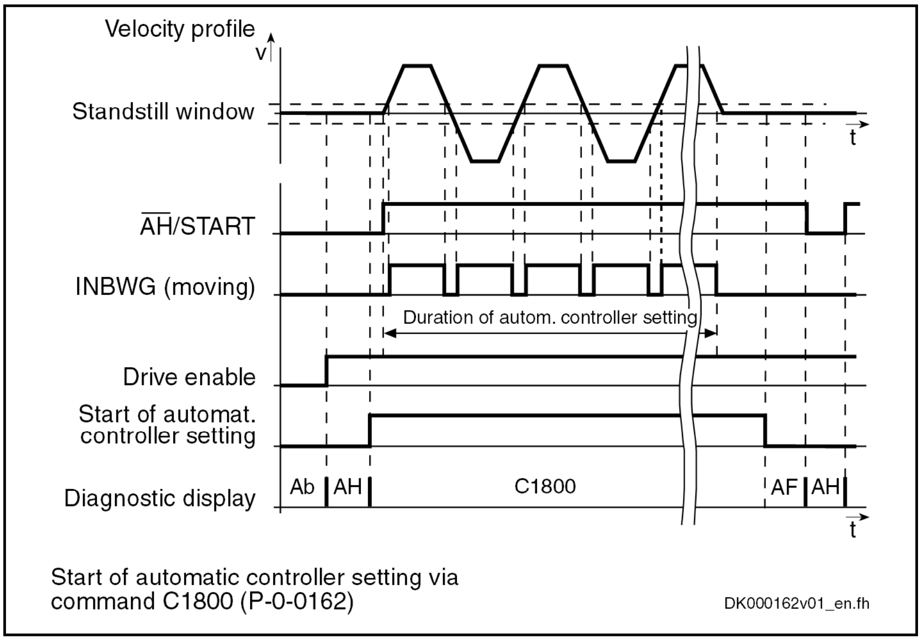


Fig. 6-67: Signal Flow Chart for Motion by "Drive Start"

Interrupting the Command with "Drive Halt"

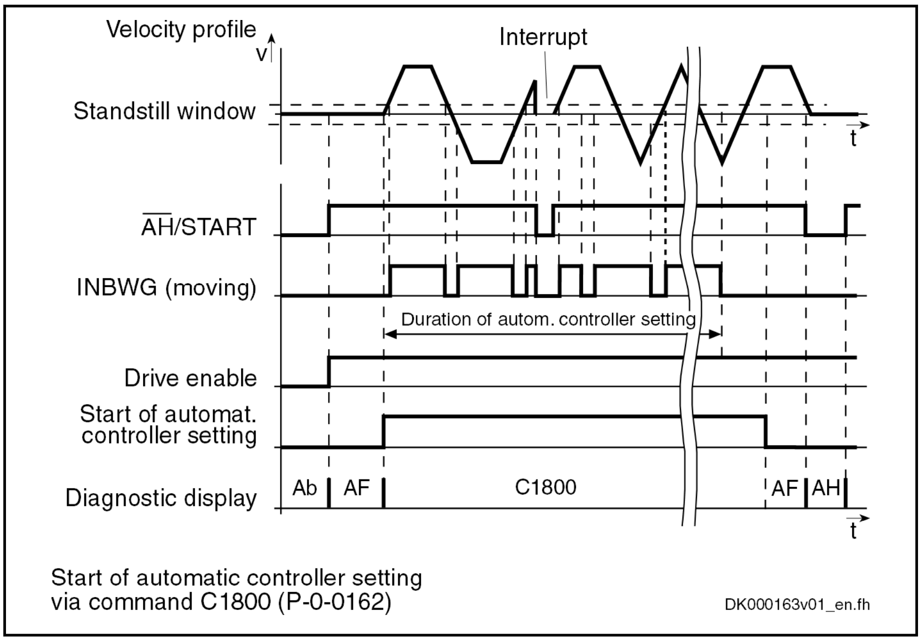


Fig. 6-68: Signal Flow Chart for Interruption by "Drive HALT"

☞ A repeated run with possibly changed settings can be carried out in two ways:

- By removing and then re-applying drive enable or the start signal ("drive start")

- By completing and then restarting command C1800

Working with IndraWorks

In the IndraWorks project explorer under "IndraDrive/Axis/Optimization Commissioning", the "Automatic Setting of Axis Control" wizard can be launched.

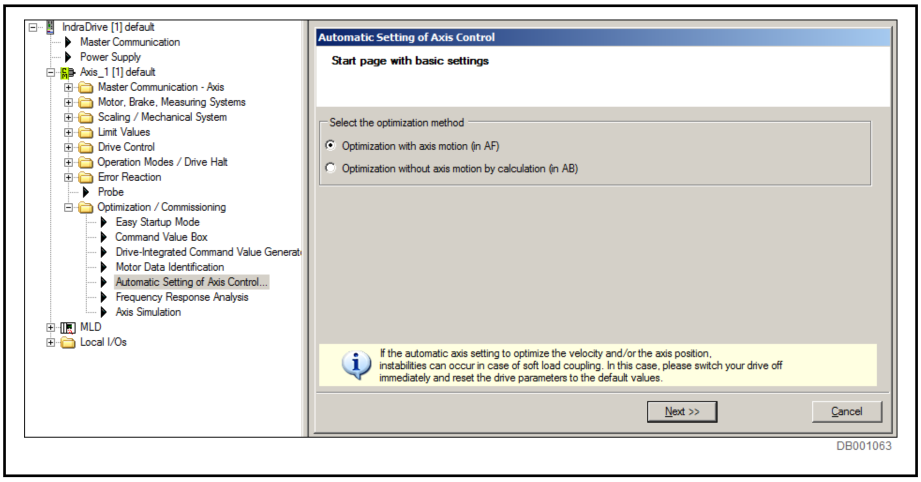


Fig. 6-69: IndraWorks Wizard "Automatic Setting of Axis Control"

You choose whether the optimization shall be done with or without an axis motion on the homepage

With Axis Motion

The process type is selected in the step "Automatic Setting of Axis Control-Step 1"

- The selection "Infinite travel" is only possible with modulo axes
- It is only possible to enter the absolute travel limits in the "Travel range" when the position limit value monitor (S-0-0055) is activated.
- It is only possible to enter the travel velocity (P-0-0171, Drive optimization, velocity) with the "Infinite travel" process type and is not required in the Travel range selection as its is set by the dialog based on the drive settings.

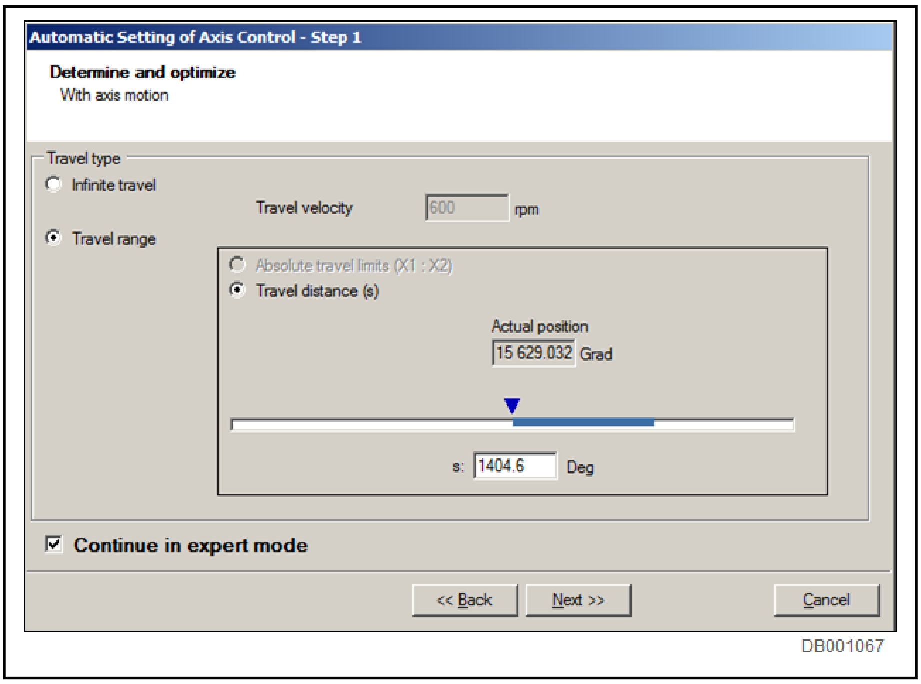


Fig. 6-70: With Axis Motion "Automatic Setting of Axis Control - Step 1"

If you activate "Next in Expert mode", application-specific settings can be made in the next step "Automatic Setting of Axis Control - Step 1 (Expert mode)".

- Setting the control dynamic (P-0-0163) by selecting the application (P-0-0164) and the axis structure
- Defining what is to be optimized and determined (P-0-0165)
  - The settings in P-0-0171, P-0-0165 Bit 11 and P-0-0161 which influence the amplitudes, offset and the periodic time of the velocity profile used to determine the load inertia, are set by IndraWorks to optimum values, based on the drive settings.

☞ The settings "Set filter(s)" and "Determining the antiresonance and resonance points" are only configurable in IndraWorks and not in the drive directly via parameters. The antiresonance and resonance points are determined by evaluation of a frequency response measurement (speed controlled section) which is configured and started by IndraWorks.

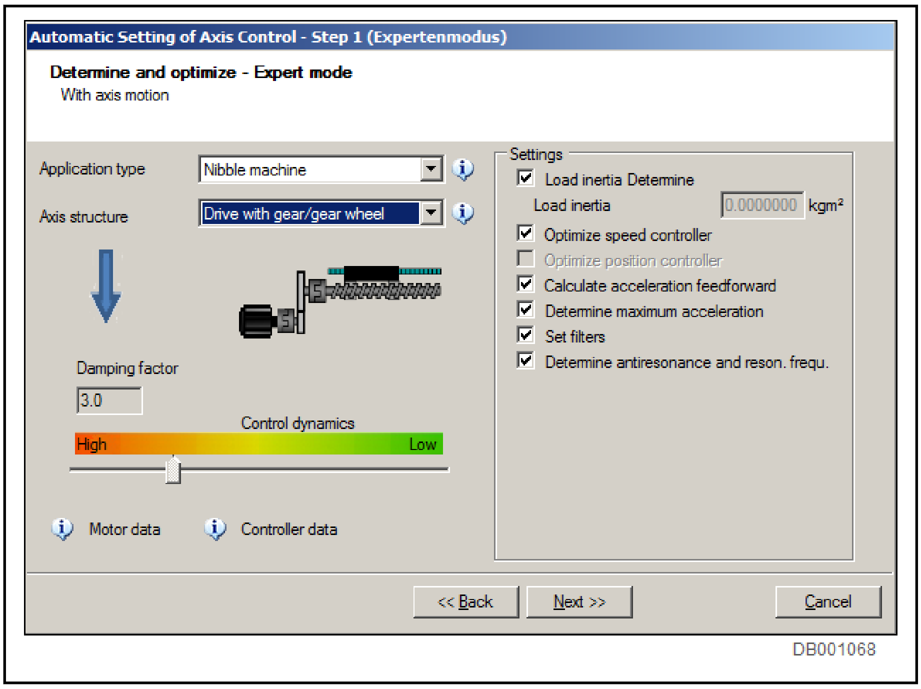


Fig. 6-71: With Axis Motion "Automatic Setting of Axis Control - Step 1 (Expert Mode)"

The optimization can be started after drive enable in the "Automatic Setting of Axis Control - Step 2" step. After optimization, the result (optimized/determined parameters) are displayed with the value before and after the optimization.

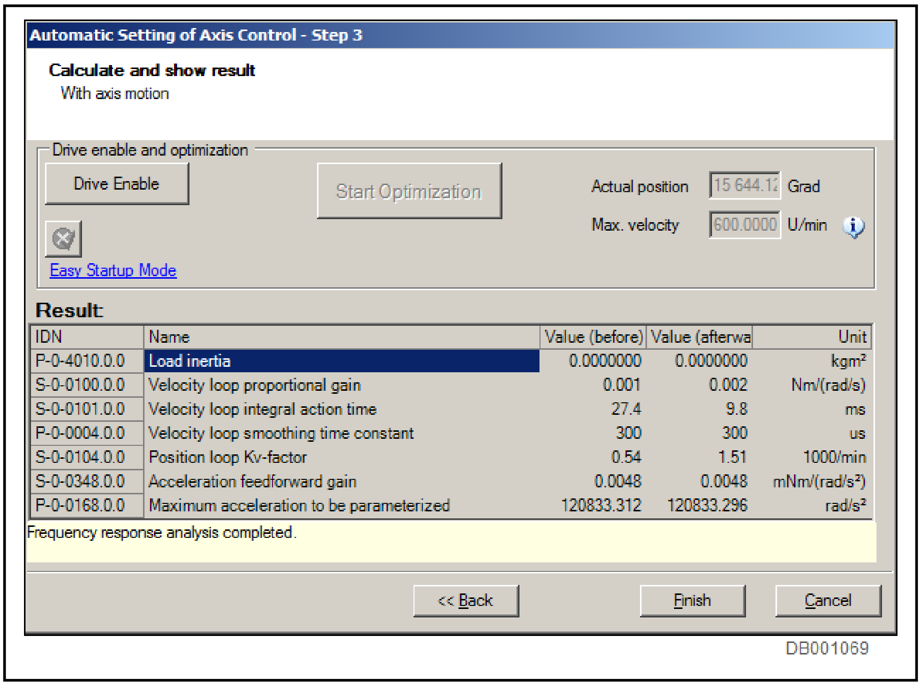


Fig. 6-72: With Axis Motion "Automatic Setting of Axis Control - Step 2 (Expert Mode)"

Pressing the "Complete" button, the optimized/determined parameter values are added to the drive parameters. These values are added to the drive parameters by pressing the "Cancel" button.

Without Axis Motion

Enter the load inertia in the "Automatic Setting of Axis Control - Step 1" step and Expert mode can be activated.

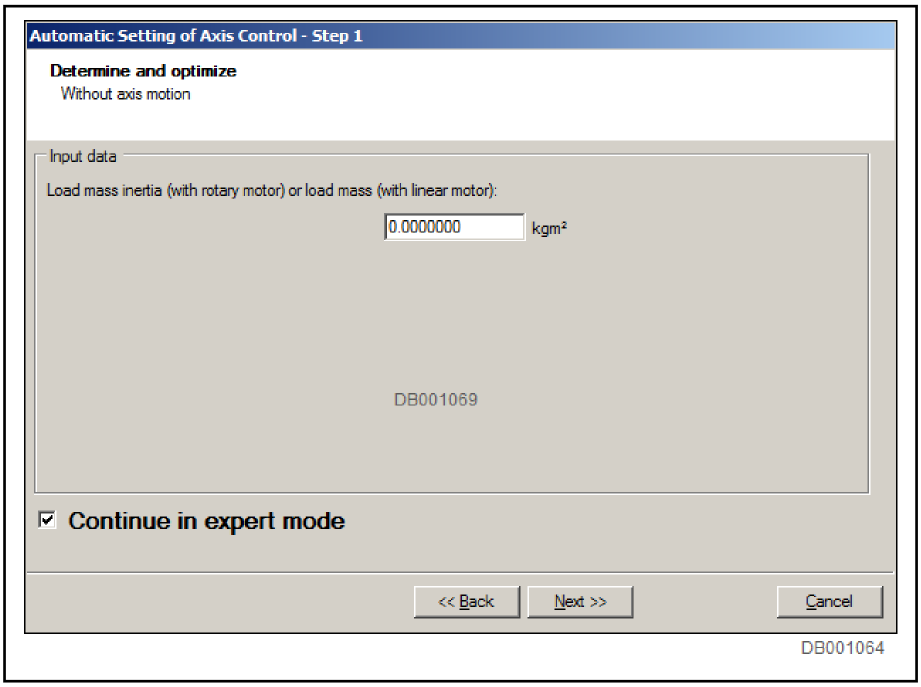


Fig. 6-73: Without Axis Motion "Automatic Setting of Axis Control - Step 1"

If you activate "Next in Expert mode", application-specific settings can be made in the next step "Automatic Setting of Axis Control - Step 1 (Expert mode)".

- Setting the control dynamic (P-0-0163) by selecting the application (P-0-0164) and the axis structure
- Selecting what is to be optimized and determined (P-0-0165)

☞ The antiresonance and resonance points which can be determined by a frequency response measurement (speed control section) with IndraWorks are in the "Set filters" selection to ensure that the speed control loop filters can be set according to the mechanical properties.

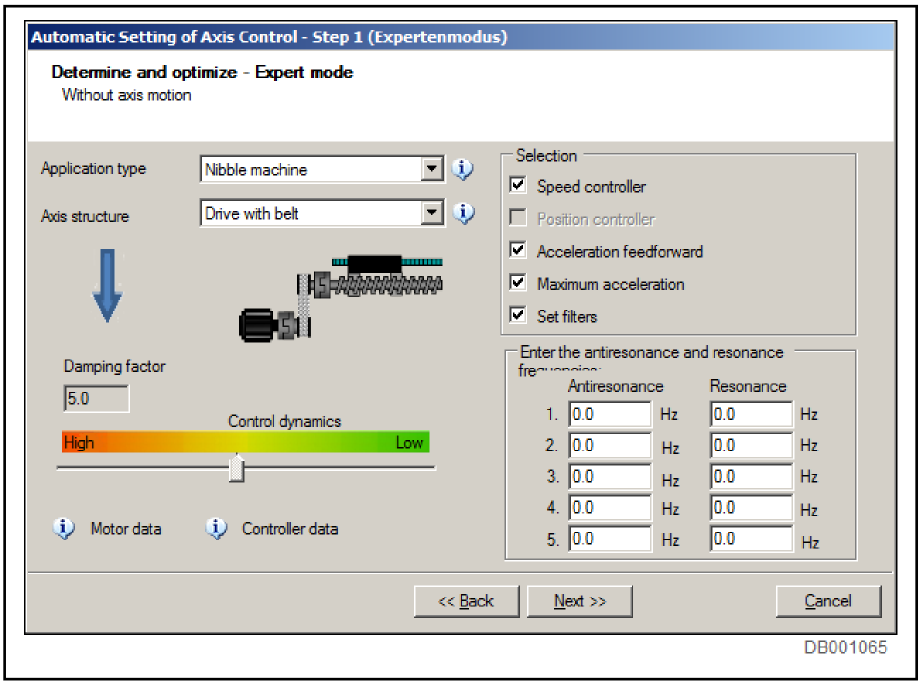


Fig. 6-74: Without Axis Motion "Automatic Setting of Axis Control - Step 1 (Expert Mode)"

The optimization can be started in the "Automatic Setting of Axis Control - Step 2" step. After optimization, the result (optimized/determined parameters) are displayed with the values before and after the optimization.

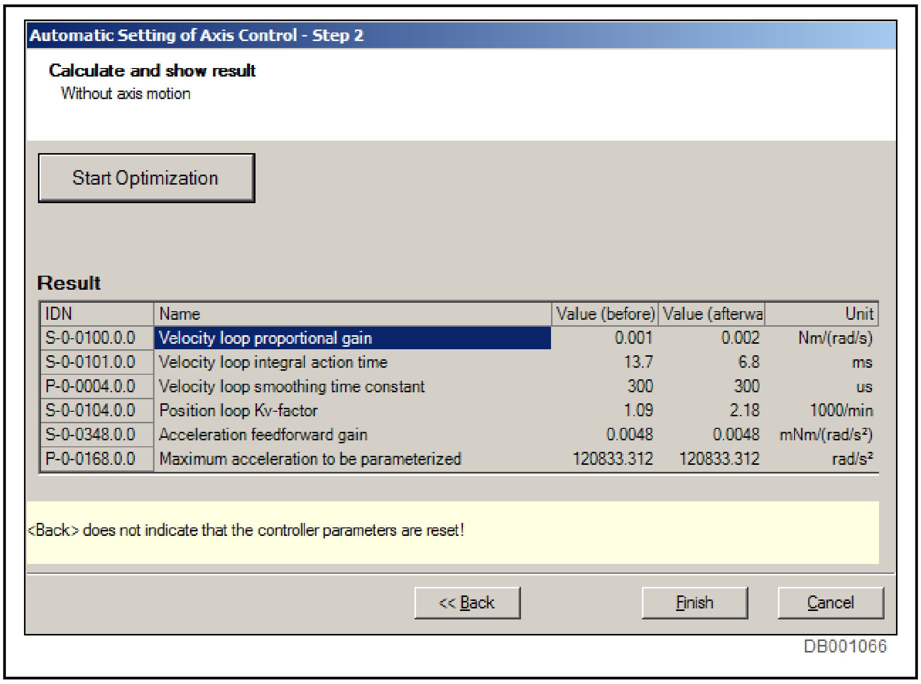


Fig. 6-75: Without Axis Motion "Automatic Setting of Axis Control - Step 2"

Pressing the "Complete" button, the optimized/determined parameter values are added to the drive parameters. These values are added to the drive parameters by pressing the "Cancel" button.

6.5.3 Velocity Controller (with Associated Filters)

Brief Description

In closed-loop operation, in addition to the field-oriented current controller, the velocity control loop is also closed in the drive by means of the drive software (PI cascade structure).

The closed-loop operation (current and velocity) can be carried for all types of motors with encoder and for asynchronous motors without encoder.

The selection of the type of motor control is carried out via the parameter "P-0-0045, Control word of current controller" (bit 14,15).

Drive Control

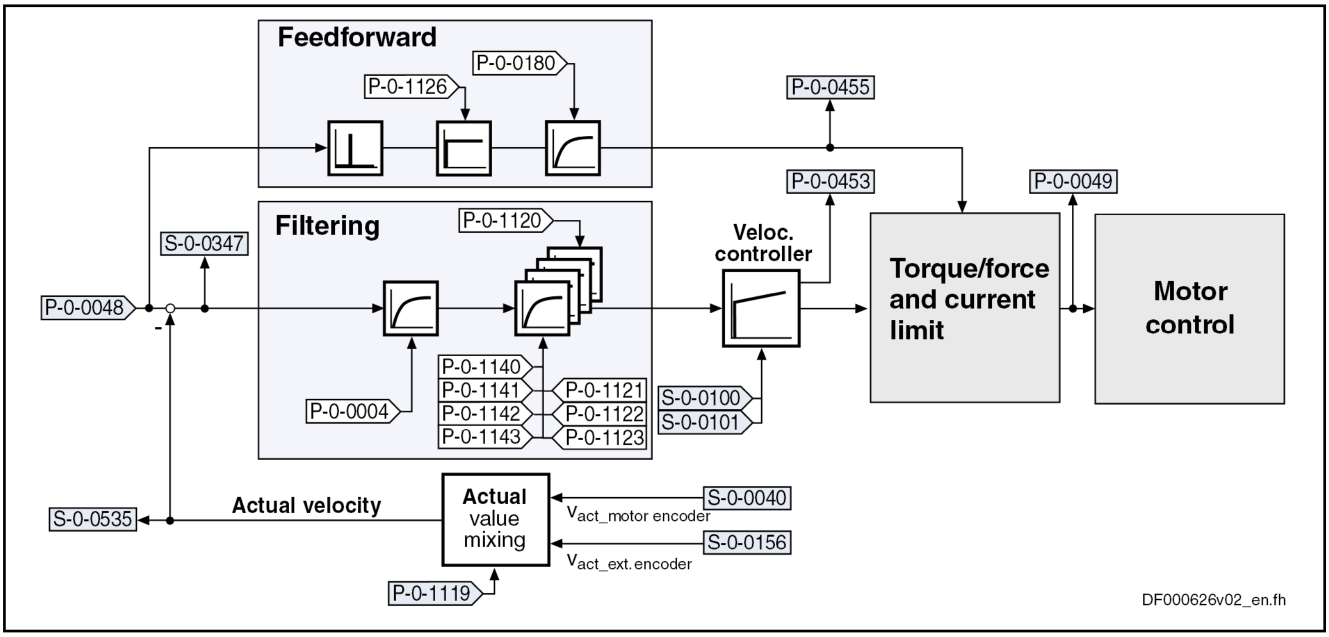


Fig. 6-76: Structure of the Velocity Controller

The following description is restricted to the velocity controller including the respective options of filtration and feedforward. The processing of the velocity command value is described within the operation mode "velocity control".

Features

- Digital PI controller with anti-windup function, can be set by means of the following parameters:
  - S-0-0100, Velocity loop proportional gain
  - S-0-0101, Velocity loop integral action time
- Setting can be carried out by
  - One time execution of the function "Load default values (motor-specific controller values)"

    - or -
  - Manual optimization (see description below)

    - or -
  - Automatic parameterization of the axis controller (see "Automatic Setting of Closed-Loop Axis Control").
- Depending on the control performance which has been set, the cycle time $T_{A\_velocity}$ is used for velocity controller calculations (see "Performance Data").
- Possibility of mixing the velocities of motor encoder and optional encoder
- 4 freely configurable 2nd order filters (e.g. band-stop filters) for filtering resonance frequencies

For firmware variant MPE, only 2 freely configurable filters are available.

- Low-pass filter to attenuate interference frequencies, to be set via P-0-0004 (VZ1)
- Fine interpolation of the command values of the position controller (can be switched on via P-0-0556, bit 0)
- Monitoring of the velocity control loop (can be switched off via P-0-0556, bit 1)
- Optional acceleration feedforward from the torque command value (with filtering option)

Pertinent Parameters

- S-0-0037, Additive velocity command value
- S-0-0040, Velocity feedback value
- S-0-0081, Additive torque/force command value
- S-0-0084, Torque/force feedback value
- S-0-0091, Bipolar velocity limit value
- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- S-0-0149, C1300 Positive stop drive procedure command
- S-0-0155, Friction compensation
- S-0-0156, Velocity feedback value 2
- S-0-0164, Acceleration feedback value 1
- S-0-0347, Velocity error
- S-0-0535, Active velocity feedback value
- P-0-0004, Velocity loop smoothing time constant
- P-0-0048, Effective velocity command value
- P-0-0049, Effective torque/force command value
- P-0-0180, Acceleration feedforward smoothing time constant
- P-0-0451, Actual acceleration torque/force value
- P-0-0452, Actual process torque/force value
- P-0-0555, axis controller messages
- P-0-0556, Config word of axis controller
- P-0-1119, Velocity mix factor feedback 1 & 2
- P-0-1120, Velocity control loop filter: Filter type
- P-0-1121, Velocity control loop filter: Limit frequency of low pass
- P-0-1122, Velocity control loop filter: Bandwidth of band-stop filter
- P-0-1123, Vel. cont. loop filter: Center frequency of band-stop filter
- P-0-1126, Velocity control loop: Acceleration feedforward
- P-0-1140, Velocity control loop filter: Numerator natural frequency
- P-0-1141, Velocity control loop filter: Denominator natural frequency
- P-0-1142, Velocity control loop filter: Numerator damping
- P-0-1143, Velocity control loop filter: Denominator damping
- P-0-2100, Velocity loop proportional gain, type plate
- P-0-2101, Velocity loop integral-action time, type plate
- P-0-3004, Speed controller smoothing time constant, type plate

Pertinent Diagnostic Messages

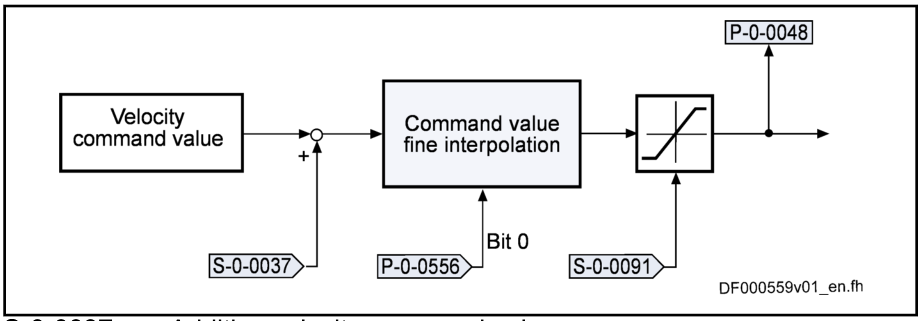
- E2059 Velocity command value limit active

- E8260 Torque/force command value limit active
- F8078 Speed loop error

Functional Description

Fine Interpolator

The velocity command value preset in the position controller clock can be linearly interpolated to the speed controller clock by a fine interpolator via 2 steps. This can be used to reduce the current command value noise, for instance in the case of big changes in the velocity command value per position controller clock. It must be noted that, when using fine interpolation, additional phase shift is introduced into the control loop structure, which can possible have a negative effect on the movement according to contour (following distance) in position-controlled operation modes.



S-0-0037 Additive velocity command value
S-0-0091 Bipolar velocity limit value
P-0-0048 Effective velocity command value
Fig. 6-77: Fine Interpolation of the Velocity Command Value

> ☞ In the default setting, the fine interpolator is switched off. It can be activated via bit 0 of parameter "P-0-0556, Config word of axis controller".

Velocity controller

The velocity controller designed as a PI controller can be set via the following parameters:

- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time

The respective parameter settings depend on the mechanical properties (mass inertia, stiffness,...) of the motor and the connected mechanical system.

- For Rexroth motors with motor data memory (e.g., IndraDyn S motor series), a default controller setting suitable for most standard applications is stored in this memory.
- For Rexroth motors without motor data memory and for third-party motors, the controller settings must be determined at the commissioning, as they strongly depend on loads, especially for kit motors.

See also "Velocity Controller: Notes on Commissioning"

Velocity Mix Factor

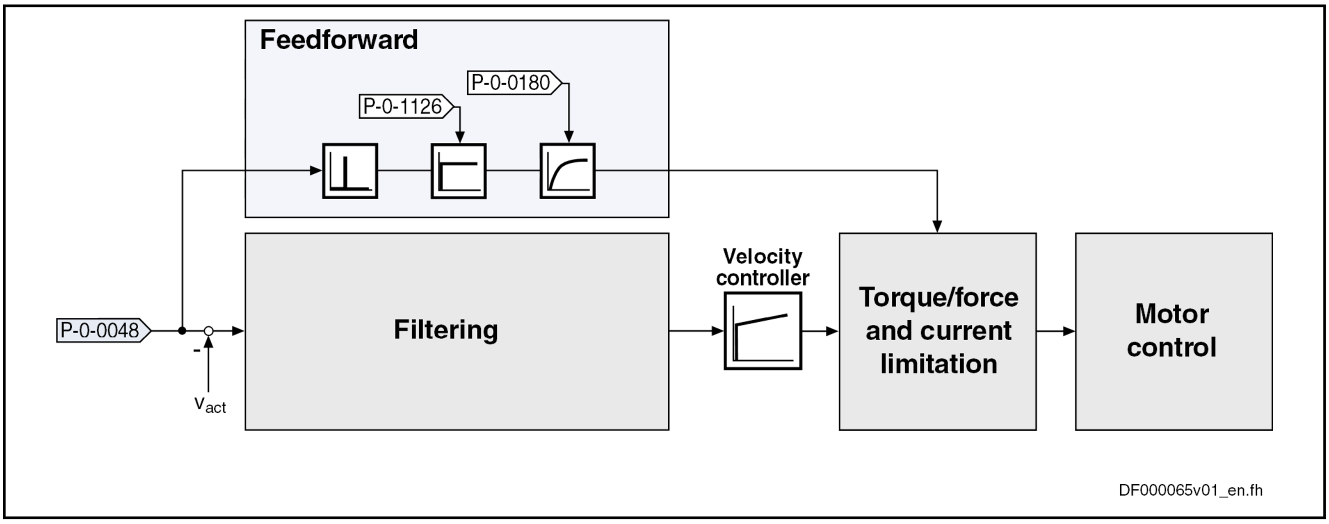
In the velocity control loop, when using a load-side encoder, it is possible to generate the actual velocity value used for control via a "mix factor" (see description of parameter P-0-1119), from the actual velocity values of the motor encoder and of the load-side encoder (see also fig. "Structure of the Velocity Controller").

> ☞ Combining the actual values of motor encoder and load-side encoder via a mix factor can be very advantageous for controlling systems with a low degree of stiffness of connected load.

Acceleration Feedforward

In the velocity control loop, it is additionally possible to configure the the control performance of the velocity controller more dynamically by using the so-called acceleration feedforward. The command value for the current controller then, to the greatest possible extent, is directly derived from the velocity command value. The velocity controller will then only be required for correcting disturbances.

The figure below illustrates the feedforward of the controller:



P-0-0048 Effective velocity command value
P-0-0180 Acceleration feedforward smoothing time constant
P-0-1126 Velocity control loop: Acceleration Feedforward
Fig. 6-78: Acceleration Feedforward in the Velocity Control Loop

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☞ This type of feedforward can be advantageous for very large mass inertia and/or low encoder resolution.

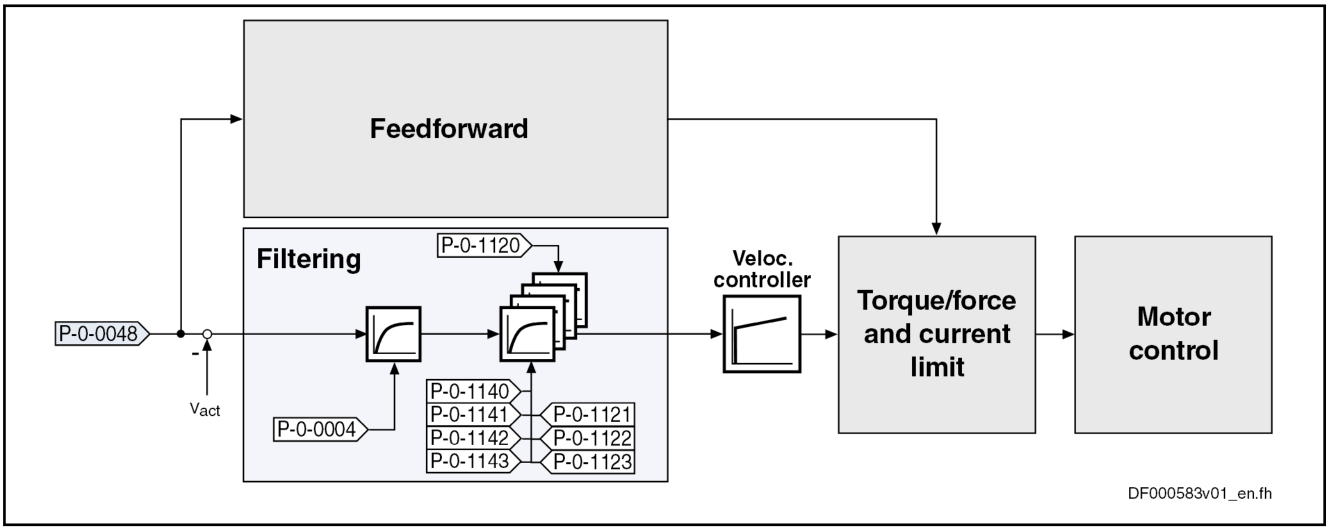
Filter Options

The following filers are available in the velocity control loop:

- Four individually configurable 2nd order filters (low pass, band-stop filter, ...)
- One 1st order low pass (PT1 element)

The figure below illustrates the position of the filters in the overall control loop:

Drive Control



P-0-0004	Speed controller smoothing time constant
P-0-0048	Effective velocity command value
P-0-1120	Velocity control loop filter: Filter type
P-0-1121	Velocity control loop filter: Limit frequency of low pass
P-0-1122	Velocity control loop filter: Bandwidth of band-stop filter
P-0-1123	Velocity control loop filter: Center frequency of band-stop filter
P-0-1140	Velocity control loop filter: Numerator natural frequency
P-0-1141	Velocity control loop filter: Denominator natural frequency
P-0-1142	Velocity control loop filter: Numerator damping
P-0-1143	Velocity control loop filter: Denominator damping

Fig. 6-79: Filtering Options in the Velocity Control Loop

In practical application there often occur resonant oscillations that mostly result from deficiencies or restrictions of the mechanical system:

- Connection of limited stiffness of the mechanical system to the motor shaft

  → Resonances in the range of 100 Hz … 1000 Hz are possible (according to stiffness of the connection and mass ratio)
- Faulty mounting of the load-side encoder

  → Resonances in the range of 1 kHz … 2 kHz are possible (according to mounting of the encoder)

This "two-mass oscillation" (or multiple-mass oscillation) mostly has one (or several) distinctive resonance frequency/frequencies that can be selectively suppressed by the filters integrated in the drive. By means of the implemented filter cascade, it is possible to selectively suppress up to 4 different resonance frequencies.

☞ The implemented filters allow suppressing resonance frequencies in the **frequency range up to max. 4000 Hz** (Advanced performance).

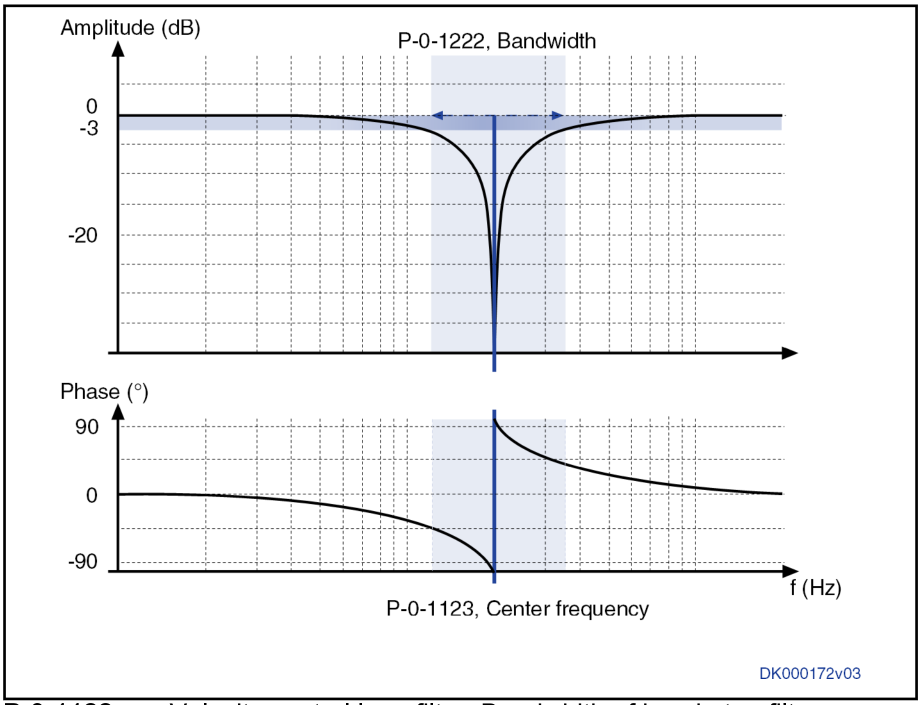
The upper limit depends on the velocity controller cycle time TAn (sampling theorem).

With the suppression of the mechanical resonance frequencies, both the dynamics of the speed control loop and the dynamics of the position control loop can be considerably improved as compared to control without the use of a filter. This leads to improved movement according to contour and smaller cycle times for positioning processes with sufficient distance to the stability limit.

Band-Stop Filter Function

Both center frequency and bandwidth can be set for band-stop filters. The attenuation of the rejection frequency is the strongest; the bandwidth determines the frequency range in which the attenuation is smaller than –3 dB.

☞ Due to the filter structure, greater bandwidth results in lower attenuation of the rejection frequency!

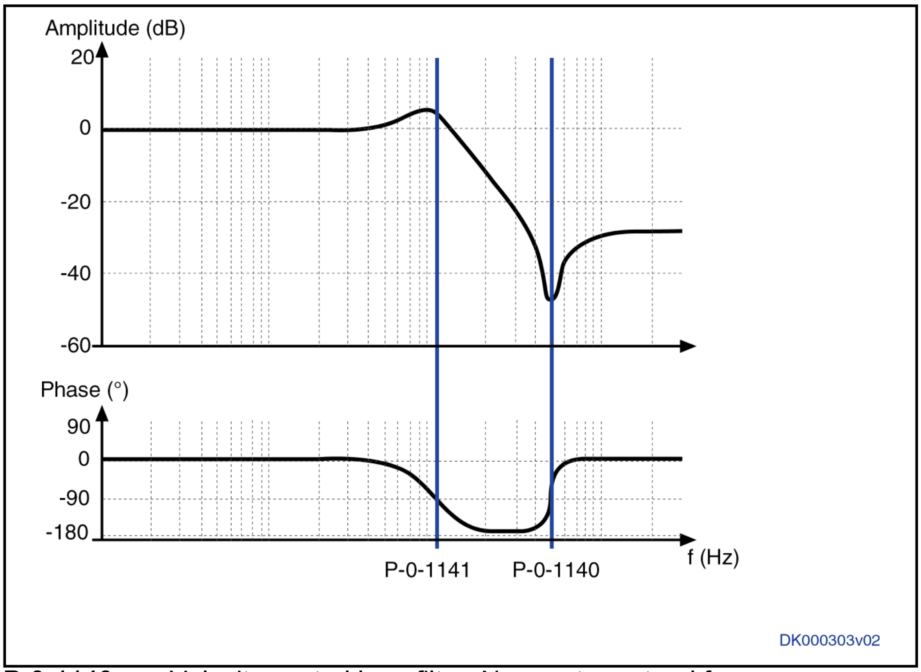


P-0-1122 Velocity control loop filter: Bandwidth of band-stop filter
P-0-1123 Velocity control loop filter: Center frequency of band-stop filter

Fig. 6-80: Band-Stop Filter Bode Diagram (Amplitude in dB and Phase in Degrees)

2nd Order Filter Function

For the 2nd order filter, it is possible to set the numerator natural frequency (P-0-1140), the denominator natural frequency (P-0-1141), the numerator damping (P-0-1142) and the denominator damping (P-0-1143).



P-0-1140 Velocity control loop filter: Numerator natural frequency
P-0-1141 Velocity control loop filter: Denominator natural frequency
P-0-1142 Velocity control loop filter: Numerator damping
P-0-1143 Velocity control loop filter: Denominator damping

Fig. 6-81: 2nd Order Filter Bode Diagram (Amplitude in dB and Phase in Degrees)

Features of 2nd order filter:

- The relationship of denominator frequency (f_N) to numerator frequency (f_Z) defines the reduction (or increase) above the two frequencies. The reduction (Abs in [dB]) is determined as follows:

$$Abs = 40 \cdot \log(f_N/f_Z); \quad \begin{cases} f_N > f_Z \rightarrow Abs > 0 \rightarrow \text{Increase} \\ f_N = f_Z \rightarrow Abs = 0 \\ f_N < f_Z \rightarrow Abs < 0 \rightarrow \text{Reduction} \end{cases}$$

Fig. 6-82: 2nd Order Filter - Reduction

- The absolute value of the denominator frequency (f_N or P-0-1141) and the numerator frequency (f_Z or P-0-1140) is calculated as

$$\left|F(f=f_Z)\right|_{\text{in dB}} = 20\log10\left(\sqrt{\frac{4D_Z^2}{\left(1-\left(\frac{f_Z}{f_N}\right)^2\right)^2+\left(\frac{2D_N f_Z}{f_N}\right)^2}}\right);$$

$$\left|F(f=f_N)\right|_{\text{in dB}} = 20\log10\left(\sqrt{\frac{\left(1-\left(\frac{f_N}{f_Z}\right)^2\right)^2+\left(\frac{2D_Z f_N}{f_Z}\right)^2}{4D_N^2}}\right);$$

Fig. 6-83: Absolute Value of Denominator Frequency f_N and Numerator Frequency f_Z

- If the attenuation D_N or D_Z is greater than 1/root(2), there is no increase or fall underneath the numerator frequency f_Z or the denominator frequency f_N (Note: The smaller the attenuations, the closer the frequencies, at which the maximum increase or the maximum fall occurs, to the numerator frequency or denominator frequency; i.e. the frequencies are identical for an attenuation equal zero)
- Implementation of a band-stop filter with defined reduction (Abs in dB) and notch depth K (fall in dB at center frequency f_M)

$$f_Z = f_m;$$

$$f_N = f_m * 10^{\frac{Abs}{40}};$$

$$D_Z = 10^{K/20} * 0.5 * \sqrt{\left(1-\frac{1}{10^{Abs/20}}\right)^2 + \frac{f_{BB}^2}{f_m^2 * 10^{Abs/10}}};$$

$$D_N = \frac{f_{BB}}{2 * f_m * 10^{Abs/40}};$$

Special case Abs=0: $f_N = f_m;$

$$D_Z = 10^{K/20} * 0.5 * \frac{f_{BB}}{f_m}; \qquad D_N = \frac{f_{BB}}{2 * f_m};$$

f_m	Center frequency [Hz]
f_{BB}	Bandwidth [Hz] (-3dB)
K	Notch depth [dB]
Abs	Reduction [dB]

Fig. 6-84: 2nd Order Filter for Band-Stop Filter with Reduction Abs and Notch Depth K

In the special case Abs = "0" and K = "-infinite", the filter acts like the band-stop filter that can be parameterized via P-0-1122 and P-0-1123.

Filtering by Means of a Multiple Smoothing Filter

Optimizing the control loop by means of a band-stop filter or a 2nd order filter does not always improve the control quality sufficiently. This is the case, for example, when the closed control loop has no distinctive resonance frequencies or when there are more than 4 resonance points. It is then possible to obtain the desired quality of control by activating several smoothing filters (with PT2 characteristics).

For this purpose, the 4 elements in "P-0-1120, Velocity control loop filter: Filter type" are set to the value "1" or "0" (see description of Parameter P-0-1120).

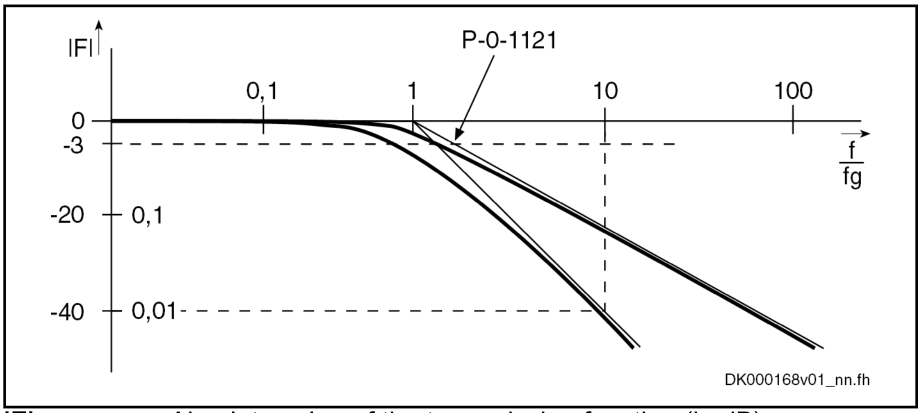
Instead of the rejection filter, smoothing filters are activated in the control loop, the smoothing time constants of which (T_{gl}) are contained in "P-0-1121, Velocity control loop filter: Limit frequency of low pass".

Together with the PT1 filter (P-0-0004, Velocity loop smoothing time constant) at the velocity controller input, you obtain filter characteristics with PT_N behavior. Frequencies higher than the limit frequency (f_g = 1/2πTgl) are suppressed much more and cannot excite the control loop oscillation.

The following applies to the filter effect:

- P-0-0004, Velocity loop smoothing time constant
  → Attenuation of 20 dB/decade
- P-0-1121, Velocity control loop filter: Limit frequency of low pass
  → Attenuation of 40 dB/decade

When activating all low-pass filters, the maximum attenuation is 180 dB/ decade. This corresponds to a very high filtering degree.



IFI Absolute value of the transmission function (in dB)
P-0-1121 Velocity control loop filter: Limit frequency of low pass
Fig. 6-85: Amplitude Characteristic of a PT1 and a PT2 Filter

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☞ When using the smoothing filters, take into account that each filter causes phase displacement in the control loop and therefore has a negative effect on the phase margin in the control loop (control loop stability).

Therefore, the following applies: "As little filtering as possible, but as much filtering as necessary!"

Notes on Commissioning

Preparations for Setting the Velocity Controller

To set the velocity controller, a number of preparations must be carried out:

- The mechanical system of the machine must be set up in its final version, in order to provide for original conditions for the determination of the parameters.

- The drive controller must be connected correctly according to instructions.
- The operatability of the safety limit switches (if available) must have been checked.
- In the drive, the "velocity control" mode must have been selected.

Start Settings

To parameterize the controller, the start setting must be made as described below:

- S-0-0100, Velocity loop proportional gain

  → Standard value of the connected motor
- S-0-0101, Velocity loop integral action time

  → For a value equal to zero → No I-component
- P-0-0004, Velocity loop smoothing time constant

  → For smoothing time constants smaller than or equal to the speed controller cycle time $T_{A\_velocity}$, the filter is switched off.

  →$T_{A\_velocity}$ = 125 µs (Advanced performance)

  →$T_{A\_velocity}$ = 250 µs (standard performance)

  →$T_{A\_velocity}$ = 500 µs (Economy performance)

  See also "Performance Data"
- P-0-1120, Velocity control loop filter: Filter type

  → With value "0000" → Filter is switched off

☞ When determining the velocity controller parameters, there mustn't have been any friction torque compensation or reversal clearance compensation activated, because it influences the control behavior.

To determine the "critical proportional gain" proceed as follows:

Determining the Critical Proportional Gain

1. Have the drive moving with a low velocity after switching on drive enable:
   - Linear motor → 1000 … 2000 mm/min
   - Rotary motor → 10 … 20 rpm
2. Increase the value in "S-0-0100, Velocity loop proportional gain" until an instable behavior (continuous oscillation) occurs.
3. The frequency of the oscillation must be recorded by oscilloscoping the actual velocity (see also "Analog Outputs" or "Oscilloscope Function"). If the frequency of the oscillation is much higher than 500 Hz, increase the value in the parameter "P-0-0004, Velocity loop smoothing time constant" until the oscillation is reduced. Subsequently, increase the value in "S-0-0100, Velocity loop proportional gain" further, until an oscillation (instability) occurs anew.
4. Decrease the value in "S-0-0100, Velocity loop proportional gain" until the continuous oscillation ceases automatically.

   The value thus determined is the so-called

   "critical velocity controller proportional gain".

☞ By using the filter cascade (P-0-1120, P-0-1121, P-0-1122, P-0-1123, P-0-1140, P-0-1141, P-0-1142, P-0-1143), other filters can be activated to attenuate resonances.

Determining the Critical Integral Action Time

To determine the

"critical integral action time", proceed as follows:

1. Set the parameter "S-0-0100, Velocity loop proportional gain" = 0.5 × "critical proportional gain"
2. Reduce the value in "S-0-0101, Velocity loop integral action time" starting with the maximum value, until an instable behavior (continuous oscillation) occurs.
3. Increase the value in "S-0-0101, Velocity loop integral action time" until the continuous oscillation ceases automatically. The value thus determined corresponds to the "critical integral action time". Common values range between 5 to 20 ms.

Calculating the Theoretical Setting Values

Based on the assumption of rigidly connected load and with some simplifications, it is possible to calculate the controller setting. The formulas below apply to the calculation of the proportional gain of the velocity controller:

$$\text{S-0-0100} = \frac{(\text{P-0-0510}) + (\text{P-0-4010})}{T_s \times \alpha} \times \frac{1}{60 \times 1000} \times \frac{\text{N min}}{\text{mm}}$$

S-0-0100	Velocity controller proportional gain
P-0-0510	Rotor inertia
P-0-4010	Load inertia
T_s	Sum of the time constants Ts = 406µs + (P-0-0004)
α	Optimization variable α = 2.5

Fig. 6-86: Calculating the Value for the Proportional Gain of the Velocity Controller for Linear Motors

$$\text{S-0-0100} = \frac{(\text{P-0-0510}) + (\text{P-0-4010})}{T_s \times \alpha} \times \text{Nm}\,\frac{\text{s}}{\text{rad}}$$

S-0-0100	Velocity controller proportional gain
P-0-0510	Rotor inertia
P-0-4010	Load inertia
T_s	Sum of the time constants Ts = 406µs + (P-0-0004)
α	Optimization variable α = 2.5

Fig. 6-87: Calculating the Value for the Proportional Gain of the Velocity Controller for Rotary Motors

$$\text{S-0-0100}_{\text{IndraDrive}} = \text{P-0-0051} \times \text{S-0-0100}_{\text{EcoDrive}}\,\frac{\text{Nmin}}{\text{mm}}$$

$$\text{S-0-0100}_{\text{IndraDrive}} = \text{P-0-0051} \times \text{S-0-0100}_{\text{EcoDrive}}\,\frac{\text{Nm}}{\text{rad}}$$

S-0-0100	Velocity controller proportional gain
P-0-0051	Torque/force constant

Fig. 6-88: Correlation of the Proportional Gain Between the IndraDrive and the EcoDrive Firmware

Characteristics of the Controller Setting

From the calculated critical values (see above), a controller setting can be derived that has the following features:

- Independent of changes at the axis due to sufficient distance to the stability limit
- Properties can be reliably reproduced in series machines

The table below shows some of the most frequent application types and the respective characteristics of the control loop setting.

Application type	Speed controller proportional gain	Speed controller integral action time	Notes
Feed axis of a standard machine tool	$K_p = 0.5 \times K_{p\_crit}$	$T_n = 2 \times T_{n\_crit}$	Good load stiffness and good control performance
Feed axis at perforating machine or nibbling machine	$K_p = 0.8 \times K_{p\_crit}$	$T_n = 0$	High proportional gain; no I-component in order to obtain short response times
Feed drive at follow-on cutting devices	$K_p = 0.5 \times K_{p\_crit}$	$T_n = 0$	Relatively non-dynamic controller setting without I-component in order to keep the material to be cut from getting distorted with the cutting device

Tab. 6-18: Features of the Controller Settings

Parameterizing the Band-Stop Filters

The band-stop filters are parameterized by means of the following parameters:

- P-0-1120, Velocity control loop filter: Filter type
- P-0-1122, Velocity control loop filter: Bandwidth of band-stop filter
- P-0-1123, Vel. cont. loop filter: Center frequency of band-stop filter

Each of these parameters have 4 elements, which results in the following allocation of the relevant filter settings:

- **Band-stop filter 1:** P-0-1120 [0], P-0-1122 [0], P-0-1123 [0]
- **Band-stop filter 2:** P-0-1120 [1], P-0-1122 [1], P-0-1123 [1]
- **Band-stop filter 3:** P-0-1120 [2], P-0-1122 [2], P-0-1123 [2]
- **Band-stop filter 4:** P-0-1120 [3], P-0-1122 [3], P-0-1123 [3]

Presetting

The following procedure is recommended to set the band-stop filter:

1. First set the rejection filter inactive.
2. Enter the following values in "P-0-1120, Velocity control loop filter: Filter type".

   - P-0-1120 [0] = 0 → Filter 1 is switched off

   - P-0-1120 [1] = 0 → Filter 2 is switched off

   - P-0-1120 [2] = 0 → Filter 3 is switched off

   - P-0-1120 [3] = 0 → Filter 4 is switched off

Determining the Resonance Frequency

The following procedure is recommended to determine the resonance frequency:

1. Use the oscilloscope function of the drive in order to display the actual velocity value. This value can be directly read by means of a fast Fourier transform (FFT) of the frequency response. For this purpose, it is necessary to use the "IndraWorks Ds/D/MLD" commissioning tool.
2. In reversing duty, increase the value in "S-0-0100, Velocity loop proportional gain" until distinctive oscillation is noticed (resonant oscillation).
3. Record the time behavior of the oscillation with the oscilloscope function (alternatively with external oscilloscope) and analyze it with regard to clearly distinctive frequencies. When using the internal oscilloscope function, the resonance frequency can be directly read via the "IndraWorks Ds/D/MLD" commissioning tool by means of the frequency display.

4. Set drive enable and optimize the velocity control loop while rejection filter is inactive.
5. Record the step response of the actual velocity value and the torque-/force-generating command current with small velocity command value step. The torque-generating command current must **not** reach the limitation!
6. Enter the frequency that emerged most noticeably in Hz in "P-0-1123, Vel. cont. loop filter: Center frequency of band-stop filter".

   Enter a minimum bandwidth (e.g. 25 Hz) in "P-0-1122, Velocity control loop filter: Bandwidth of band-stop filter".

   ⇒ Record the previous step response again!

   If the step response shows less overshooting and shorter period of oscillation:

7. Check if increasing the value in "P-0-1122, Velocity control loop filter: Bandwidth of band-stop filter" causes more improvement, or if changing the value in "P-0-1123, Vel. cont. loop filter: Center frequency of band-stop filter" causes more improvement.

   If the step response shows the same behavior:

8. Check the determined resonance frequency; if need be, considerably increase the value in "P-0-1122, Velocity control loop filter: Bandwidth of band-stop filter".
9. Optimize the velocity controller again using the pre-optimized values in "P-0-1122, Velocity control loop filter: Bandwidth of band-stop filter" and "P-0-1123, Vel. cont. loop filter: Center frequency of band-stop filter"
10. If necessary, carry out another optimization procedure for P-0-1122 and P-0-1123 due to the high-frequency or less attenuated resonance points that are now possibly occurring.

☞ If the rejection filter does not seem to show any effect, check whether the sampling time of the oscilloscope function might be too high, which means that the measured resonance frequency is merely the inverted version of the real frequency.

Diagnostic and Status Messages

Velocity Deviation

The velocity deviation (S-0-0347) is calculated by subtraction, from the effective velocity command value (P-0-0048) and the current actual velocity value (S-0-0040).

☞ The motor-related velocity (motor speed with rotary motors) is displayed in "P-0-0112, Actual velocity value of motor".

Acceleration Torque/Force

The acceleration torque is determined from the total inertia (P-0-0510 + P-0-4010) determined by the automatic control loop setting and the value in "S-0-0164, Acceleration feedback value 1" and is displayed in "P-0-0451, Actual acceleration torque/force value".

Process Torque/Force

The current process torque is determined from the current total torque in "S-0-0084, Torque/force feedback value" and the determined "P-0-0451, Actual acceleration torque/force value" and is displayed in "P-0-0452, Actual process torque/force value".

Limitation of the Current Command Value (E8260)

The output signal of the velocity controller is limited to a minimum and a maximum torque. It is a torque / force command value that already includes the additive component for the friction torque compensation.

This torque command value is limited with S-0-0082, S-0-0083 and S-0-0092. At the output of the limitation, the effective torque / force command value (P-0-0049) can be read.

> If the limitation is activated, the corresponding warning "E8260 Torque/force command value limit active" is generated and the respective bit (positive / negative limit) is set in "P-0-0555, axis controller messages".

Speed Loop Error (F8078)

The correct function of the velocity controller is monitored in the drive to avoid the so-called "runaway effect". Possible causes of errors are:

- Incorrect commutation angle
- Interchanged motor connection

In the case of error, the drive torque is immediately disabled and the error message "F8078 Speed loop error" is generated.

See also diagnosis description "F8078 Speed loop error"

6.5.4 Position Controller (with Respective Feedforward Functions and Actual Value Adjustment)

Brief Description

The following section only describes the position controller with the respective feedforward options (velocity and acceleration feedforward).

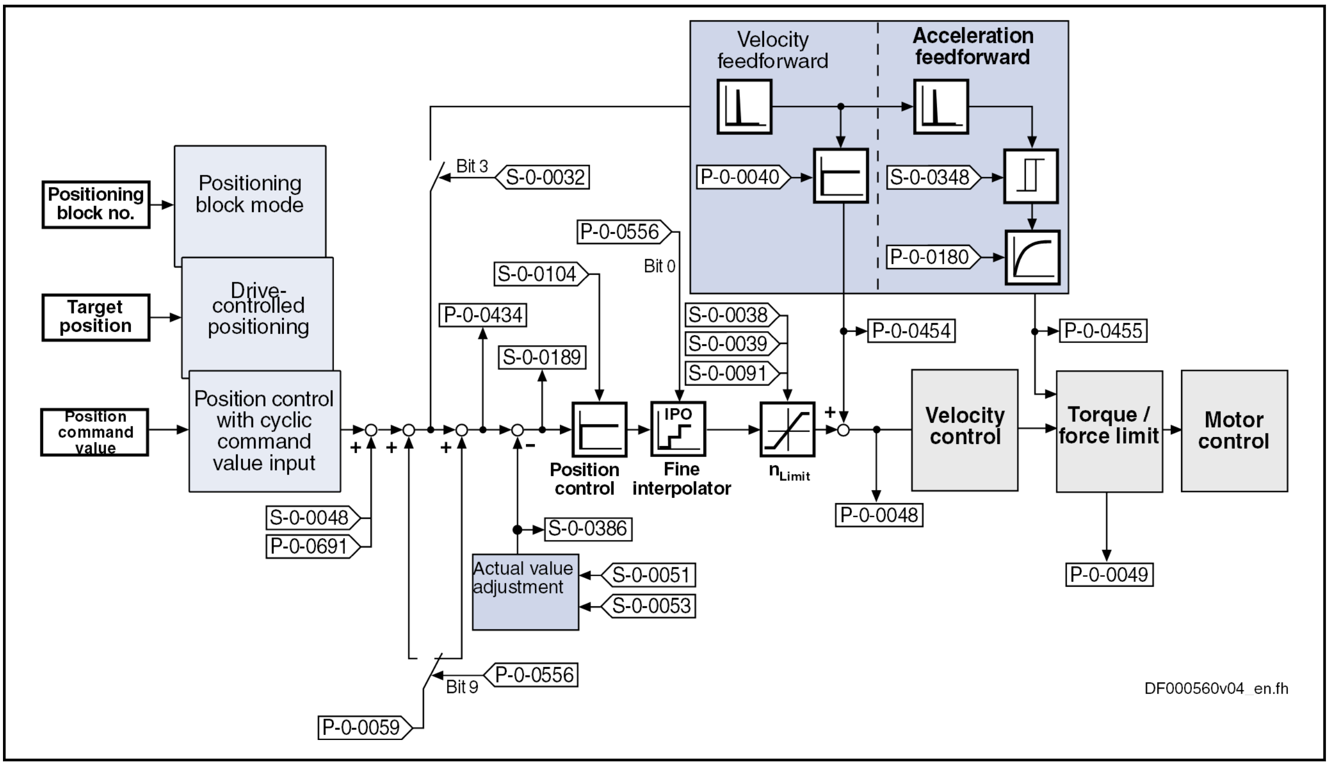


Fig. 6-89: Structure of the Position Controller

☞ The preprocessing of the position command value (command value adjustment) is described in the corresponding section of the position control mode (e.g. position control with cyclic command value input, positioning block mode, ...).

Features

- Digital proportional controller, can be set via the following parameter:
  – S-0-0104, Position loop Kv-factor
- Lag error is minimized by:
  – Variable velocity feedforward (see P-0-0040)
  - and -
  – Variable acceleration feedforward (see S-0-0348), including smoothing filter
- Depending on the control performance which has been set, the cycle time $T_{A\_position}$ is used for position controller calculations (see "Performance Data").
- With lag error or lagless, i.e. with velocity feedforward
- Model monitoring for the lag error (see also F2028)
- Possibility of evaluating a "hybrid actual position value" from motor encoder and external position control encoder (up to now only motor encoder and measuring wheel encoder)

Pertinent Parameters

- S-0-0032, Primary operation mode
  → Bit 3 = 1 → Activation of lagless operation
- S-0-0038, Positive velocity limit value
- S-0-0039, Negative velocity limit value
- S-0-0040, Velocity feedback value
- S-0-0048, Additive position command value
- S-0-0051, Position feedback value 1
- S-0-0053, Position feedback value 2
- S-0-0091, Bipolar velocity limit value
- S-0-0092, Bipolar torque/force limit value
- S-0-0104, Position loop Kv-factor
- S-0-0189, Following distance
- S-0-0348, Acceleration feedforward gain
- S-0-0386, Active position feedback value
- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0040, Velocity feedforward evaluation
- P-0-0048, Effective velocity command value
- P-0-0049, Effective torque/force command value
- P-0-0059, Additive position command value, controller
- P-0-0109, Torque/force peak limit
- P-0-0180, Acceleration feedforward smoothing time constant
- P-0-0241, Actual pos. smoothing time constant for hybrid pos. control
- P-0-0434, Position command value of controller

- P-0-0454, Velocity feedforward actual value
- P-0-0455, Acceleration feedforward actual value
- P-0-0556, Config word of axis controller
- P-0-0691, Additive position command value, process loop

Pertinent Diagnostic Messages

- F2028 Excessive deviation
- F2036 Excessive position feedback difference
- F2037 Excessive position command difference

Functional Description

☞ Activating the lagless operation causes a feedforward value determined from the position command value (velocity command value) to be added to the velocity command value at the position controller output.

Velocity Feedforward

By means of the velocity feedforward, it is possible to reduce the lag error to a minimum (ideally = 0) at constant velocity.

It is possible to include the additive position command value for the controller (P-0-0059) in the calculation of the velocity feedforward. To do this, set bit 9 of "P-0-0556, Config word of axis controller".

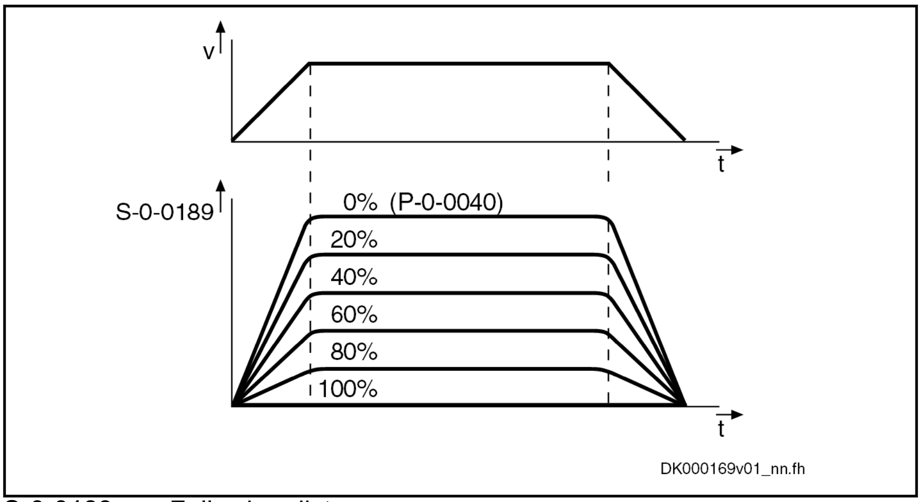
Acceleration Feedforward

To achieve a reduction of the lag error during the acceleration process, the acceleration feedforward (see S-0-0348) has to be activated. For optimum parameterization of the acceleration feedforward, the following values have to be entered in "S-0-0348, Acceleration feedforward gain":

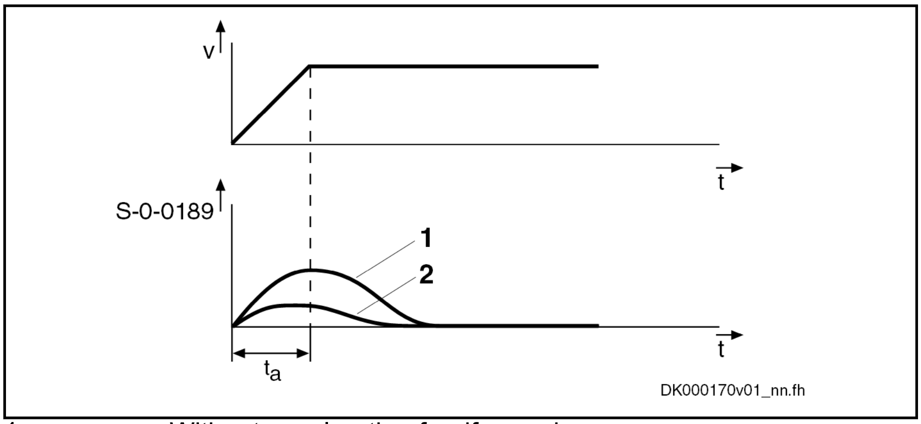
- Linear motor → Total mass (motor + load) in kg
- Rotary motor → Total mass inertia (motor + load) in gm^2

☞ Adjust the input value in "S-0-0348, Acceleration feedforward gain" in dependency of the respective local mechanical system!

The figures below exemplify the operating principle of the respective feedforward procedure.



S-0-0189 Following distance
P-0-0040 Velocity feedforward evaluation
Fig. 6-90: Operating Principle of the Velocity Feedforward



1	Without acceleration feedforward
2	With acceleration feedforward
t_a	Acceleration phase
S-0-0189	Following distance

Fig. 6-91: Operating Principle of Acceleration Feedforward (with P-0-0040 = 100%)

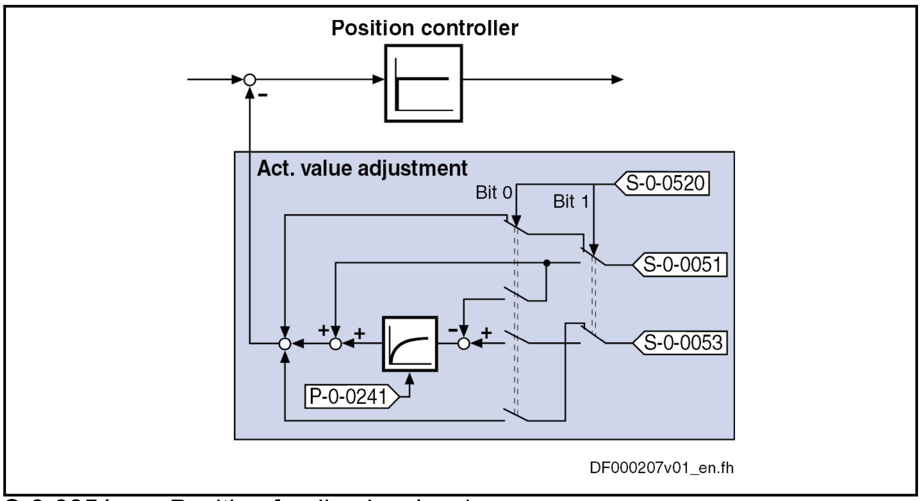
Making the Actual Position Value Available

The actual value for the position control can be made available by the motor encoder or the optional encoder. It is possible, however, to use both actual position values for position control ("hybrid actual position value").

"Hybrid Actual Position Value"

The actual position value detected by the optional encoder is added to the actual position value of the motor encoder and is used for position control as the so-called "hybrid actual position value". The difference of both actual position values is smoothed via a filter which can be set (P-0-0241) and added to the actual position value of the motor encoder.

Using the hybrid actual position value is particularly advantageous if there only is a low degree of stiffness between motor encoder and external encoder. In the case of slip between motor encoder and external encoder, it is advantageous to activate the measuring wheel mode (see also "Measuring Wheel Mode").



S-0-0051	Position feedback value 1
S-0-0053	Position feedback value 2
S-0-0520	Control word of axis controller
P-0-0241	Actual pos. smoothing time constant for hybrid pos. control

Fig. 6-92: Generating the Hybrid Actual Position Value

The generation of the hybrid actual position value is configured in "S-0-0520, Axis control word", its use for control tasks is activated in the same parameter.

To be noticed:

- By the value "0" in "P-0-0241, Actual pos. smoothing time constant for hybrid pos. control", the actual position value of the motor encoder is ignored and only the actual position value of the optional encoder is used for position control.
- If the values of S-0-0051 and S-0-0053 differ (might be the case for measuring systems to be evaluated in absolute form with different position data reference), abrupt changes in the velocity command value can occur when the hybrid actual position value is activated.

☞ The position data reference of motor encoder and optional encoder remains unchanged when the hybrid actual position value is activated. As a prerequisite the optional encoder **must not** have been activated as measuring wheel encoder in "P-0-0185, Control word of encoder 2 (optional encoder)"!

Notes on Commissioning

The cascade structures of the controllers require the optimization of the position controller to be only carried out after all outer control loops (velocity and current) have been optimized, because in the case of a cascade controller structure the dynamic response of the outer control loops limits the dynamic response of the higher-level control loops.

Determining the Critical Position Controller Kv-Factor

To determine the critical position controller Kv-factor, proceed as follows:

1. Let the drive move with low velocity in position control after switching on drive enable:
   - Linear motor → 1000 … 2000 mm/min
   - Rotary motor → 10 … 20 rpm
2. Increase "S-0-0104, Position loop Kv-factor" until instable behavior (continuous oscillation) occurs.
3. "Reduce S-0-0104, Position loop Kv-factor" until continuous oscillation decreases automatically.

   The value thus determined is the so-called "critical position controller Kv-factor".

Characteristics of the Controller Setting

From the determined critical Kv-factor (see above), it is possible to derive a controller setting with the following characteristics:

- Independent of changes at the axis due to sufficient distance to the stability limit
- Properties can be reliably reproduced in series machines

The position controller normally is checked by examining and optimizing the lag error. For this purpose, the following machine and application types have to be distinguished:

- **High-end machine tools** (e.g. grinding machines)

  → Optimization with regard to a minimum lag error characteristic by the highest possible Kv-factors
- **Standard positioning axes** (e.g. press transfer)

  → Optimization with regard to a minimum lag error characteristic is not required, the important thing is smoothest possible, jerk-free positioning.

This is achieved, among other things, by relatively low Kv-factors resulting in very stable controller settings.

Presettings for Using the Hybrid Actual Position Value

First set the relevant parameter values for the mechanical arrangement of motor, motor encoder, axis and external (optional) encoder. The external encoder must have been configured as "position control encoder" (not as "measuring wheel encoder"!) in "P-0-0185, Control word of encoder 2 (optional encoder)". Configure the hybrid actual position value in "S-0-0520, Axis control word".

Activating the Hybrid Actual Position Value

The hybrid actual position value can only be activated when the drive is ready for operation, by

- activating "hybrid actual position value" in "S-0-0520, Axis control word"

  - and -

- position-controlled operation mode of the drive.

Deactivating the Hybrid Actual Position Value

The "hybrid actual position value" option can be deactivated and switched to the actual position value of motor encoder or optional encoder by one of the following actions:

- Deactivating "hybrid actual position value" in "S-0-0520, Axis control word"
- Switching to communication phase P2 or parameter mode
- Switching the drive off

Setting the Jerk Attenuation for the Hybrid Actual Position Value

Abrupt position differences between motor encoder and optional encoder can be attenuated by inputting a value greater than zero in "P-0-0241, Actual pos. smoothing time constant for hybrid pos. control".

☞ The value "0" in P-0-0241 switches off the attenuation and causes only the actual position value of the optional encoder to be effective.

Procedure:

1. Enter value "0" in P-0-0241 and move axis at low velocity and little acceleration.
2. Increase feed velocity and acceleration up to the maximum values.

   While increasing the velocity and acceleration, also increase the value of P-0-0241, if necessary, in order to achieve a satisfactory compromise of smoothness of running and minimum lag error!

Diagnostic and Status Messages, Limitations

The following monitoring functions are carried out in the position controller:

Excessive Deviation (F2028)

- **Monitoring of lag error by means of model calculation**

  The deviation of the actual position value from the position command value is monitored by comparing an "actual position model value" internally calculated in the drive to the real actual position value (= **lag error monitoring**). If the difference of the theoretical and actual position value permanently exceeds the value of "S-0-0159, Monitoring window", it is obvious that the drive cannot follow the preset command value and the error message "F2028 Excessive deviation" is generated.

Excessive Position Feedback Difference (F2036)

- **Monitoring of position difference (encoder 1 and encoder 2)**

  When 2 measuring systems (1 motor encoder and possibly external length measuring system) are used simultaneously, the actual position value 1 and the actual position value 2, in cyclic operation (phase 4), are monitored for a maximum allowed actual position value difference indicated in "S-0-0391, Monitoring window feedback 2". If the absolute value of the difference is greater than the value of the monitoring window, the error message "F2036 Excessive position feedback difference" is generated.

☞ The current position difference is displayed in "P-0-0391, Actual position value difference encoder1 - encoder2"!

The following limitation is carried out in the position controller:

Limiting the Velocity Command Value

- The output of the position controller (P-0-0048) is limited to a maximum absolute velocity value. The output signal of the position controller is a velocity command value that already contains the additive component for velocity feedforward, plus a possibly preset additive velocity command value (S-0-0037). The limitation therefore has an effect on the sum of the different command values.

  See also "Velocity Limitation"

6.6 Commutation Setting

6.6.1 Basics on Commutation Setting

Brief Description

General Information

Significance of Commutation Offset

Three-phase synchronous motors are only operational if the current in the primary part to the magnetic field in the secondary part is correctly assigned. For this purpose, the position of the primary part (motor windings) with respect to the pole pairs of the secondary part must always be known to control. Depending on the primary part position signaled by the motor encoder, the "commutation offset" is used to generate the current in the three-phase windings such that a force effect is produced in the motor.

A synchronous motor can only produce the maximum torque or the maximum force in relation to the motor current if the value of the commutation offset is correct. Otherwise, the relation of torque/force to motor current (torque/force constant) would be lower and not optimum. A highly incorrect value implies the danger of the motor moving in an uncontrolled way.

If the motor encoder is not mounted in the defined orientation with respect to the primary and secondary part of the motor, an individual commutation offset value must be determined for each synchronous motor:

- With Rexroth synchronous motors with integrated motor encoders and encoder data memory (e.g. MSK motors), the commutation offset has already been determined at the factory and is provided in the motor encoder data memory. The user does not need to set the commutation offset!
- Synchronous Rexroth kit motors consist of motor components (primary part, secondary part). They are finally put together as an operational motor when they are installed in the machine axis and completed by the customer with a motor encoder. The commutation offset can only be determined by the user after the motor is complete.

  The following Rexroth kit motors are manufactured according to the functional principle "synchronous motor":

  - Linear motors LSF, MLF
  - Rotary motors MBS and MBT

Motor Encoders for Synchronous Motors

Ideally, absolute motor encoders should be used for synchronous Rexroth kit motors. The advantage in this case is the absolute position detection of the motor position which immediately ensures, when drive enable is set, the correct assignment of current in the primary part to the magnetic field in the secondary part if the commutation offset was determined in the initial commissioning of the motor and saved in the drive.

For some applications it is necessary to use relative motor encoders because the available length of absolute motor encoders is limited, for example. The disadvantage in this case is that absolute detection of the motor position is impossible. It is therefore necessary, after each time the drive is switched on again or after having changed the communication phase from "PM" to "OM" ("bb" or "Ab") to set the commutation offset again. For linear motors, this disadvantage can be removed by using an additional Hall sensor component or option, because with regard to commutation setting the relative motor encoder then behaves like an absolute motor encoder.

☞ If you use a relative motor encoder, using the additional Hall sensor component is absolutely recommended for linear Rexroth motors! In this way, you achieve highest safety with regard to correct motor function and compliance with the performance data!

Concerning operationally reliable drives with synchronous third-party motors and IndraDrive controllers with regard to the selected motor encoder, the same principles apply as for synchronous Rexroth kit motors (see above); however, the Hall sensor box SHL02.1 cannot be used for linear third-party motors.

Overview of the Motor Encoders Usable with Synchronous Motors

Motor Encoder	Synchronous Rexroth kit motor (rotary, linear)	Synchronous Rexroth kit motor (linear) with SHL02 or Hall unit	Synchronous third-party motor
Absolute	+	--	+
Relative	o	+	o

+ Advantageous combination
o Combination possible, initial commissioning might possibly require especially trained staff
-- Combination not useful

Tab. 6-19: Possible Combinations of Motor Encoders and Synchronous Motors for Which Commutation Setting is Required

☞ The motor encoder should be implemented with a high resolution and as a **motor encoder to be evaluated in absolute form.** If it is necessary to use a relative motor encoder, using encoders with square-wave signals should be avoided.

With synchronous motors with a gearbox between motor and motor encoder (**encoder gear**), in general an absolute motor encoder **cannot be evaluated as an absolute commutation encoder** (for special cases, see below).

For synchronous motors with relative motor encoders in combination with an additional **external encoder that can be evaluated in absolute form** installed at the axis, with a slip-free mechanical axis system the external encoder can be used as an **absolute commutation encoder** for the motor (for special cases, see below).

Pertinent Parameters

Besides the motor parameters (see overview of parameters in "Basics on the Motors to be Controlled"), other parameters are available for the commutation setting:

- P-0-0506, Amplitude for angle acquisition
- P-0-0507, Test frequency for angle acquisition
- P-0-0508, Commutation offset
- P-0-0509, Commutation offset coarse
- P-0-0517, Commutation: Required harmonics component
- P-0-0518, C5600 Command subsequent optimization of commutation offset
- P-0-0519, Commutation status word
- P-0-0521, Effective commutation offset
- P-0-0522, Control word for commutation setting
- P-0-0523, Commutation setting measured value
- P-0-0524, C1200 Commutation offset setting command
- P-0-3008, Commutation offset, type plate

Pertinent Diagnostic Messages

- C1200 Commutation offset setting command
- C1204 Error in offset calculation
- C1208 No adjustment with asynchronous motor
- C1209 Proceed to phase 4
- C1211 Commutation offset could not be determined.
- C1212 Motion range exceeded during commutation
- C1214 Command only possible with linear synchronous motor
- C1215 Command only possible in 'bb'
- C1216 Commutation determination not selected
- C1217 Setting only possible in 'Ab'
- C1218 Automatic commutation: Current too low
- C1219 Automatic commutation: Overcurrent
- C1220 Automatic commutation: Timeout
- C1221 Automatic commutation: Iteration without result
- C1222 Error when writing offset parameters
- C1223 Command execution impossible
- C5600 Command Subsequent optimization of commutation offset
- C5601 Command requires drive enable
- C5602 Axis blocked
- C5603 Timeout: Axis in motion
- F2032 Validation error during commutation fine adjustment
- F8010 Autom. commutation: Max. motion range when moving back
- F8011 Commutation offset could not be determined
- F8012 Autom. commutation: Max. motion range
- F8013 Automatic commutation: Current too low
- F8014 Automatic commutation: Overcurrent
- F8015 Automatic commutation: Timeout

- F8016 Automatic commutation: Iteration without result
- F8017 Automatic commutation: Incorrect commutation adjustment

Overview of Methods for Determining the Commutation Offset

Methods for Determining the Commutation Offset

The commutation offset can be determined with different methods. The method is chosen in accordance with the axis geometry, the practicability and the chances of success of the respective method depending on motor and mechanical axis system.

The following methods are possible:

- **Calculation method**

  → For relative motor encoder when using the additional Hall sensor component SHL02 (distance measurement, currentless → only possible with linear Rexroth kit motors, see documentation "Hall Sensor Box SHL02.1")
- **Measuring method**

  → For motor encoder that can be evaluated in absolute form (distance measurement, currentless → only possible with linear Rexroth kit motors)
- **Saturation method** (axis needs to be blocked or at standstill, with current)

  → Possible with all types of motors in combination with motor encoders that can be evaluated in absolute form and with relative motor encoders; but see "Restrictions for Saturation Method" in table below
- **Sine-wave method** (requires unrestricted movement of axis, with current)

  → Possible with all types of motors in combination with motor encoders that can be evaluated in absolute form and with relative motor encoders; but see "Restrictions for Sine-Wave Method" in table below

Determination methods, firmware dependency

Firmware variant	Method for determining the commutation offset			
	Calculation method	Measuring method	Saturation method	Sine-wave method
MPE	-	■	■	-
MPB	■	■	■	■
MPC	■	■	■	■
MPM	■	■	■	■

■ Available
- Not available

Tab. 6-20: Methods for Determining the Commutation Offset that are Available in the Firmware Variants

Recommendations for selecting the determination method:

Motor type	Determination method (and motor encoder that can be used)			
	Calculation method (relative linear encoder with additional Hall sensor component)	Measuring method (absolute linear encoders only)	Saturation method* (absolute or relative motor encoder)	Sine-wave method* (absolute or relative motor encoder)
MBSxx0	--	--	+	o
MBSxx2 (high speed)	--	--	o	+
MBT	--	--	+	o
LSF	+ (with SHL02)	+	+	o
MLF	+ (with SHL02)	+	+	o
MCL	(not required for "Hall unit..." option)	+	--	o
MSP	--	--	+	o
Sy third-party motors (rotary and linear)	--	--	+	o

+ Recommended method
o Method not recommended
-- Method not possible
* See application-related restrictions

Tab. 6-21: Recommendations for Selecting Determination Method for Commutation Offset Depending on Motor Type (for Rexroth Motors)

☞ The sine-wave method (generally requires unrestricted movement of axis) should only be used if the saturation method cannot be used!

Restrictions for saturation method

Applications of synchronous motors	Restrictions for saturation method
Third-party motors without or with only little saturation effects (e.g. ironless motors or motors with high leakage flux)	Saturation method cannot be used for determining commutation offset!
Applications with relative measuring system (without using the optimum commutation offset value with regard to the reference point)	Max. torque/force can be reduced by approx. 20% compared to the optimum value (autom. determination of commutation offset with "AF")!
Applications with relative measuring system that are using the optimum commutation offset value with regard to the reference point	Max. torque/force until reference mark is passed can be reduced by approx. 20%!
Drives that can be in motion during the determination of the commutation offset, e.g. coasting spindles, printing roller drives etc.	Saturation method is only possible for motors in standstill!

Applications of synchronous motors	Restrictions for saturation method
Drives with a low degree of overload capacity	Saturation method only possible if amplifier current is sufficiently high (2...4-fold continuous motor current required)!
Drives that are not permitted to move during determination of the commutation offset (low-friction axes with low inertia)	Saturation method (with current) can cause motor motion!

Tab. 6-22: Typical Applications and Restrictions for Saturation Method

Restrictions for Sine-Wave Method

Applications of synchronous motors	Restrictions for Sine-Wave Method
Linear axis with single motor or parallel motor	Only balanced (e.g. horizontal) axes with low friction!
Linear axes in Gantry arrangement	Only balanced (e.g. horizontal) axes with low friction! In addition, both drives have to carry out sequential commutation settings, "AF" must not be active at the other drive!
Axis with holding brake (e.g. vertical axis)	Holding brake must be released to determine the commutation offset successfully. Only balanced axes!
Rotary axes with single drive	Only balanced axes with little friction; high inertia can cause problems!
Rotary axes, mechanically connected	See above "Linear axes in gantry arrangement"!

Tab. 6-23: Typical Applications and Restrictions for Sine-Wave Method

Restrictions for Motors with Relative Motor Encoders and Digital Hall Sensors

The respective restrictions are explained in the subchapter.

Identifying the Motor Encoder

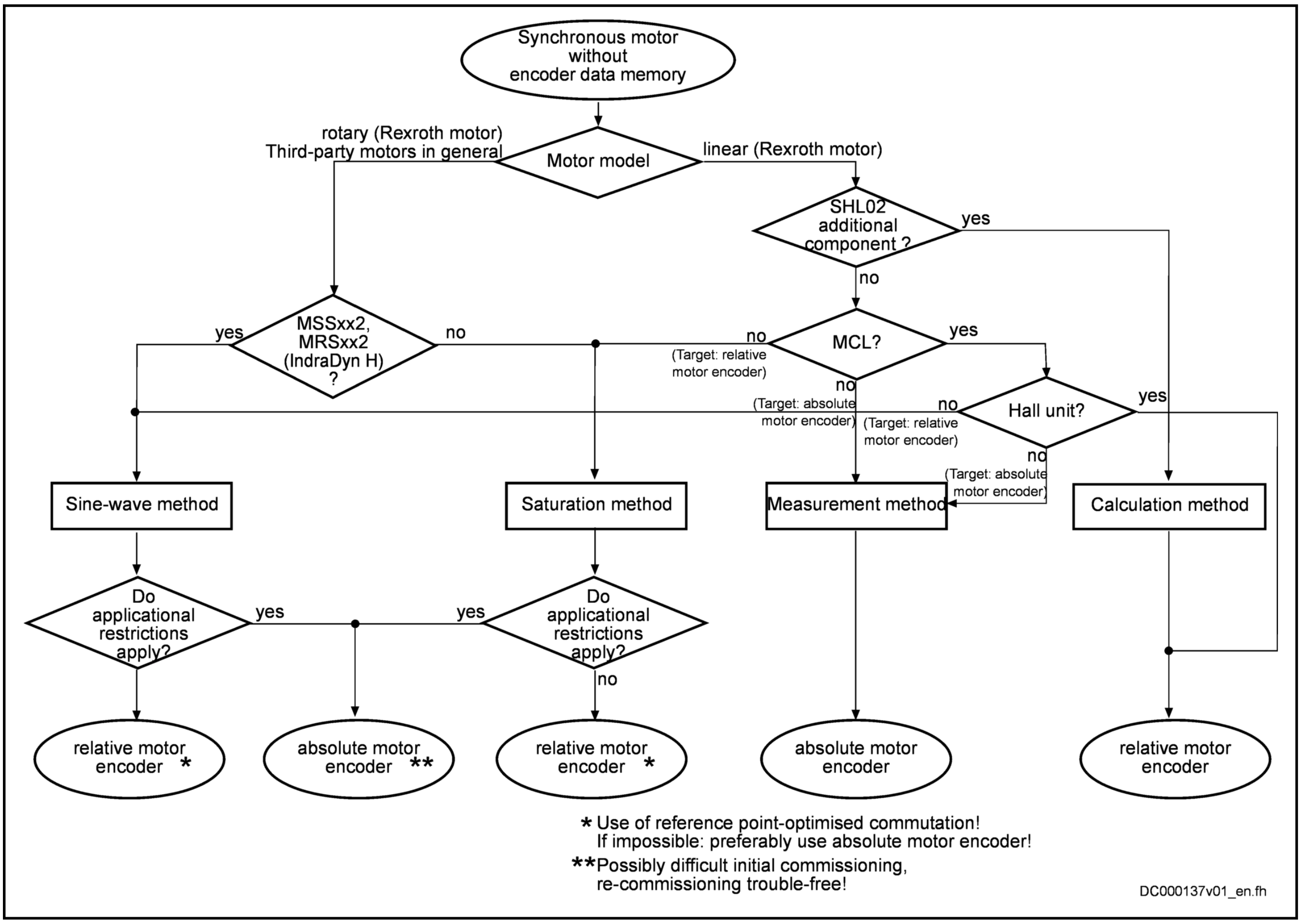


Fig. 6-93: Identifying the Absolute or Relative Motor Encoder Depending on the Motor and Application-Related Restrictions

Effect of an Encoder Gear

If a motor encoder to be evaluated in absolute form is connected via an encoder gear in the case of a synchronous motor, in general there is no unambiguous assignment of electrical angle and absolute actual position value. For this reason, the motor encoder to be evaluated in absolute form now behaves as a relative motor encoder with respect to the commutation.

In two special cases, however, absolute commutation encoder evaluation is possible for synchronous motors with encoder gear (rotary encoders only):

- Case 1, single-turn (or multi-turn) encoder:

  - If an n-fold motor revolution (n is an integer) results in exactly one encoder revolution

- Case 2, multi-turn encoder:

  - If exactly one motor revolution results in an m-fold encoder revolution (m is an integer)

Effect of an External, Absolute Encoder

For synchronous motors with relative motor encoders in combination with an additional external encoder that can be evaluated in absolute form installed at the axis, with a slip-free mechanical axis system the external encoder can be used as an absolute commutation encoder for the motor. If this is the case, the external encoder can be assigned as commutation encoder in "P-0-0185, Control word of encoder 2 (optional encoder)". Then the specifications as for a synchronous motor with a motor encoder that can be evaluated in absolute form apply.

Determining the Commutation Offset

The active commutation offset value is contained in parameter "P-0-0521, Effective commutation offset". Due to it significance for the torque/force development of the motor and the operational safety, P-0-0521 is always write-protected.

Depending on the motor encoder used, you have to determine the commutation offset for the following situations:

- With absolute motor encoder only during **initial commissioning** of the drive
- With relative motor encoder both during **initial commissioning** of the motor and each time the drive has been switched on again (**recommissioning**)

☞ With Rexroth synchronous motors with integrated motor encoders (e.g. MSK motors), the initial commissioning has already been performed at the factory and the motor-specific commutation offset has been determined and is provided in the motor encoder data memory. The user does not need to set the commutation offset!

Initial Commissioning and Recommissioning

During the initial commissioning of Rexroth kit motors and synchronous third-party motors, the commutation offset is determined during the initial commissioning of the motor with a suitable method made available by the drive. The quality of this commutation offset determination is subject to variations that can be caused by the current conditions of the mechanical axis system and electromagnetic factors. Because the torque or force development of the motor depends on the quality of the commutation offset value, however, this value should be carefully optimized during the initial commissioning of the motor.

However, to do this it is necessary to allow the parameter "P-0-0521, Effective commutation offset", which is normally write-protected, to be written so that the value can also be optimized manually if necessary. For this purpose, the drive provides the "initial commissioning mode" (activated in "P-0-0522, Control word for commutation setting").

The optimum value of the commutation offset identified during initial commissioning is displayed in "P-0-0521, Effective commutation offset" and should also be effective when the drive is switched on again (recommissioned). To do this, this value must be saved in the "initial commissioning mode" in an appropriate manner such that it is available during recommissioning:

- **For motors with absolute motor encoders as well as for relative motor encoders and analog Hall sensors (SHL02 for MLF, analog Hall unit for MCL):**

  The value of the effective commutation offset (P-0-0521) is automatically saved in "P-0-0508, Commutation offset" as well. When the drive is recommissioned, this saved value becomes effective again. If the motor encoder has a data memory, the value of P-0-0521 is also saved in "P-0-3008, Commutation offset, type plate".

- **For motors with relative motor encoders and motors with additional digital Hall sensors (digital Hall unit for MCL, third-party motors):**

  The value of the effective commutation offset (P-0-0521) is saved in reference to a fixed, reproducible motor or axis position in "P-0-0508, Commutation offset". This requires drive actions initiated by the user (drive-controlled homing or merely moving the motor). When recommissioning, after the drive is initially enabled (AF), first the automatic commutation setting of the motor is carried out or, in the case of digital Hall sensors, the acceptance of "P-0-0509, Commutation offset coarse" in P-0-0521. In turn, based on the appropriate drive actions initiated by the user (drive-controlled homing or moving the motor), the value saved in P-0-0508 becomes effective in a manner that is optimized for the automatically determined commutation offset (P-0-0521) in that a correction value is determined and added.

☞ By adding a correction value, the effective commutation offset (P-0-0521), when the motor is recommissioned, achieves the quality of the value of the initial commissioning. This results in reproducible drive behavior with respect to torque/force development. The determination of the correction value is supported by the reference mark of the motor encoder or the homing dedicated position of the axis; for this reason, the correction method is called "optimum commutation offset with regard to reference point".

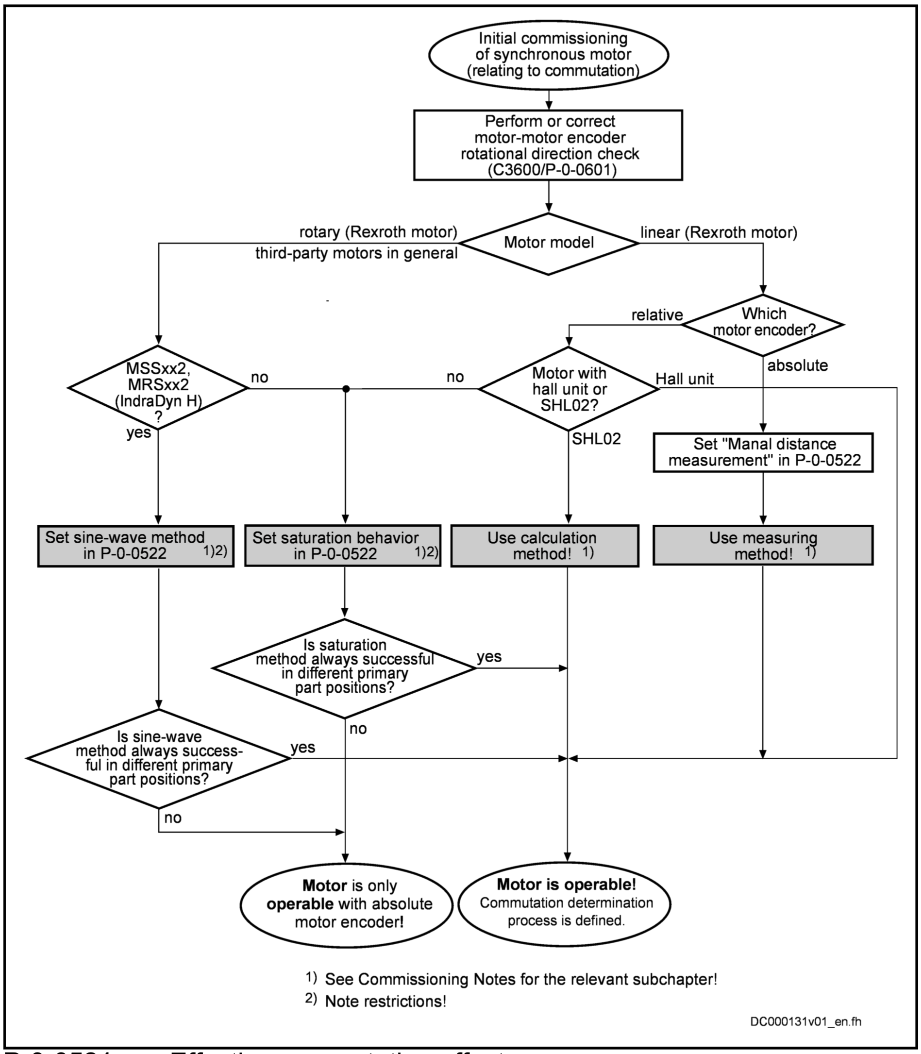
Basic Notes on Commissioning

Explanations on the Initial Commissioning of a Synchronous Motor

Determining the commutation offset during the initial commissioning of a synchronous motor is of particular relevance. Depending on the motor and motor encoder, there are different methods available or applicable for determining the commutation offset. The effectiveness of the determined value should be checked and, if necessary, optimized during initial commissioning.

Selecting the Method for Determining the Commutation Offset

After the motor had been selected and application-related restrictions of the methods for commutation setting had been checked, an absolute or relative motor encoder was selected and a method for commutation setting was determined. If the determined method is unknown at initial commissioning, the appropriate method can be identified by means of the selected motor and motor encoder:



P-0-0521 Effective commutation offset
P-0-0522 Control word for commutation setting
P-0-0601 Configuration motor data identification

Fig. 6-94: Selecting the Method for Determining Commutation Offset During Initial Commissioning of Synchronous Motor

Checking the Rotational Direction Motor - Motor Encoder

To successfully determine the commutation offset, it is imperative that the rotational direction of the motor matches the rotational direction of the motor encoder. This is the case, when the position feedback value of the motor encoder (S-0-0051) shows increasing position feedback values at positive torque/force command value (S-0-0080 or P-0-0049) (take possible negations of the polarity parameters into account!).

☞ If the rotational direction of the motor does not match the rotational direction of the motor encoder, the motor cannot follow the command value with the determined commutation offset. It moves to a close-by rest position or carries out uncontrolled movements. The error message F8010 might occur, but not necessarily!

The "check of the rotational direction" (C3600, configured in P-0-0601) requires a slight motors motion (approx. half an el. pole). A possibly available holding brake is released for this purpose. When an axis is at the mechanical limit stop, an error message is likely to occur!

☞ The "check of the rotational direction" is not suited to non-equilibrated, vertical axes! The axis will drop down when the holding brake is released after C3600 was started!

Effect of an Encoder Gearbox

In two special cases, however, for synchronous motors with encoder gear and a motor that can be evaluated in absolute form (rotary encoders only) the commutation setting is performed only during initial commissioning. Then, when the drive is switched on again, it is immediately ready for operation; automatic commutation setting for initial drive enabling (AF) is not required, so it is not performed in the following cases:

Case 1, Single-turn (or multi-turn) encoder:

- if an n-fold motor revolution (n is an integer) yields exactly one encoder revolution

Case 2, Multi-turn encoder:

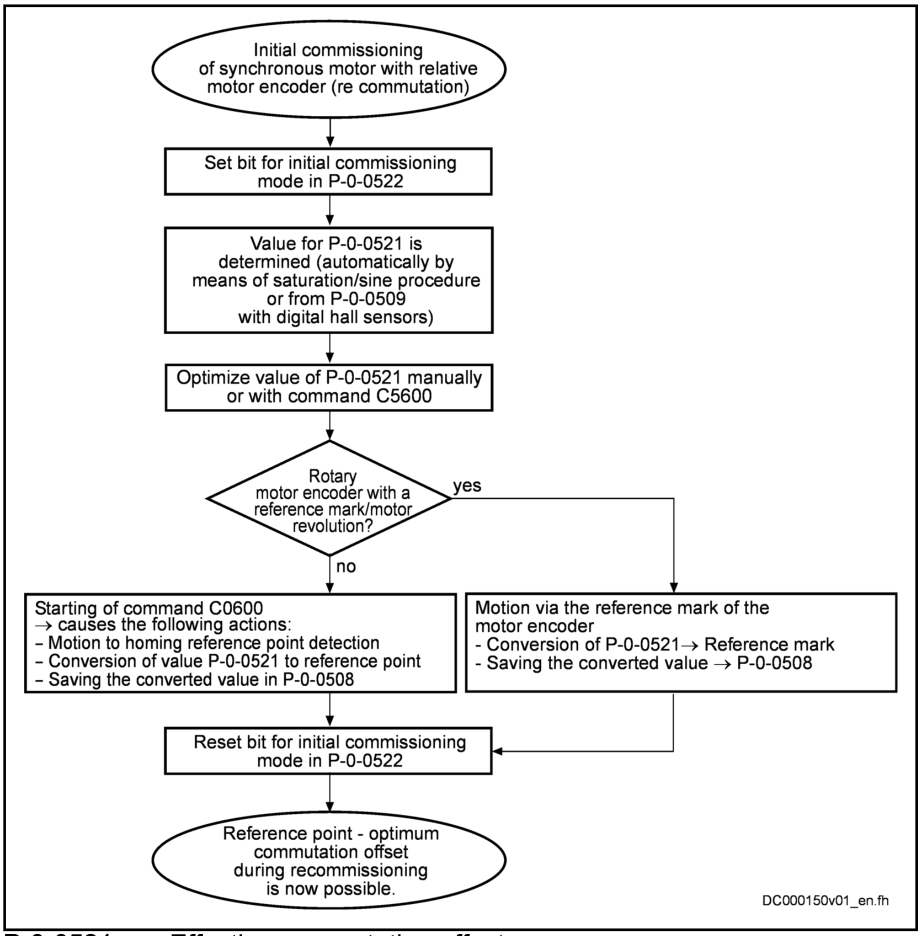
- if exactly one motor revolution yields an m-fold encoder revolution (m is an integer)

Storage Procedure of the Optimum Commutation Offset

The determined commutation offset must initially be optimized during initial commissioning to obtain the maximum torque/force development of the motor during recommissioning of the drive. For options and methods, see below.

The value of the effective commutation offset (P-0-0521), optimized if necessary, is stored in different ways, depending on the absolute or relative motor encoder, with active "initial commissioning mode":

- With an absolute motor encoder, directly in P-0-0508 or P-0-3008
- With a relative motor encoder, the optimized value is converted to a reproducible dedicated point fixed with reference to the motor and stored in P-0-0508



P-0-0521	Effective commutation offset
P-0-0522	Control word for commutation setting
P-0-0508	Commutation offset
P-0-0509	Commutation offset, coarse
C0600	Drive-controlled homing procedure command
C5600	Command subsequent optimization of commutation offset

Fig. 6-95: Storage Procedure of the Optimum Commutation Offset in P-0-0508 during Initial Commissioning for Subsequently Using the "Optimum Commutation Offset with Regard to Reference Point" during Recommissioning

Manually Optimizing the Offset Value

The automatically determined value for the commutation offset is stored in parameter "P-0-0521, Effective commutation offset". When the initial commissioning mode is active (respective bit in P-0-0522), the value of P-0-0521 can be manually optimized. Optimization should be carried out using a force measurement device.

$$(P\text{-}0\text{-}0521)_m = (P\text{-}0\text{-}0521)_a \pm 150$$

m	Manually
a	Automatically determined

Fig. 6-96: Range of Values for Optimizing the Commutation Offset

NOTICE **Property damage caused by errors when controlling motors and moving parts!**

Before manually optimizing the commutation offset, move the axis to a non-critical position!

Optimizing the Offset Value by Means of Command

The value determined for "P-0-0521, Effective commutation offset" can be checked by the controller and subsequently optimized. For this purpose, use "P-0-0518, C5600 Command subsequent optimization of commutation offset". The drive must be in drive enable ("AF") and in standstill. In addition, the axis must be able to move sufficiently (motion range see table).

Motor Design	Motion range	Reference
Rotary	± 10 angular degrees	Motor shaft
Linear	± 0.1 × pole pair distance	Primary part

Tab. 6-24: Minimum Required Motion Range for Executing Command C5600

The controller optimizes the commutation offset which is already operational (value stored in P-0-0521) by transmitting test signals to the motor. The information for improving the commutation offset is taken from the motor motion (actual position value). Upon successful execution of command C5600, an improved value is available in parameter P-0-0521.

> ☞ The execution of "C5600 Command Subsequent optimization of commutation offset" is always recommended when none of the restrictions mentioned for the sine-wave method (see above) exists!

NOTICE **Property damage caused by errors when controlling motors and moving parts!**

Before automatically optimizing the commutation offset, move the axis to a noncritical position and make sure axis can move!

Storing the "Optimum Commutation Offset with Regard to Reference Point"

For synchronous motors with relative motor encoder, the effective commutation offset (P-0-0521) is determined and, if necessary, optimized in the "initial commissioning mode" (P-0-0522). In order that the quality of the commutation offset of initial commissioning can be reproduced when the motor is recommissioned, the commutation offset is converted to a reproducible dedicated point fixed with reference to the motor and then stored in "P-0-0508, Commutation offset":

- When the drive passes the reference mark with activated "cyclic marker evaluation" (S-0-0277) in the case of rotary motors with a relative motor encoder and only one reference mark per motor revolution, the controller, in "P-0-0508, Commutation offset", stores the value of P-0-0521 converted to the mark ("Optimization of the value of P-0-0521..." must have been activated in P-0-0522).
- When the drive passes the dedicated point for homing by executing "S-0-0148, C0600 Drive-controlled homing procedure command" in the case of motors with a relative motor encoder and several reference marks or none per motor revolution or linear motor travel range, the controller, in "P-0-0508, Commutation offset", stores the value of P-0-0521 converted to this dedicated point ("Optimization of the value of P-0-0521..." must have been activated in P-0-0522).

> ☞ The reproduction of the dedicated point is realized by the reference mark of the motor encoder or the dedicated position for homing the axis. The value converted to this dedicated position is used to determine the correction value; therefore, the method was called "optimum commutation offset with regard to reference point".

Explanations on the Recommissioning of a Synchronous Motor

Readiness for operation of a synchronous motor is given after switch-on (recommissioning after initial commissioning already taken place), when the controller has determined a commutation offset value for this motor or activated a stored value.

Synchronous Motor with Absolute Motor Encoder

There is immediate readiness for operation with absolute motor encoders. The commutation offset value (P-0-0508, P-0-3008) stored in the controller or in the motor encoder during initial commissioning is activated by applying it to parameter "P-0-0521, Effective commutation offset".

Synchronous Motors with Relative Motor Encoder and Additional Hall Sensor Components (Analog and Digital)

There is immediate readiness for operation with relative motor encoders and additional Hall sensor components: "P-0-0521, Effective commutation offset" immediately gets an operational value:

- With SHL02 and Hall unit, analog: The value of P-0-0508, Commutation offset, saved during initial commissioning, is applied to P-0-0521.
- With Hall unit, digital: The value of "P-0-0509, Commutation offset coarse", supplied for MCL motors or determined and saved during initial commissioning, is applied to P-0-0521.

Synchronous Motor with Relative Motor Encoder

With relative motor encoders, the drive, at first drive enable after switch-on or after re-initialization of the measuring system, automatically determines the commutation offset. When "AF" is set, this is done by a method with current ("Overview of Methods for Determining the Commutation Offset", see above). The value is contained in parameter P-0-0521 and refers to the position of the axis at switch-on.

Optimum Commutation Offset with Regard to Reference Point

The "optimum commutation offset with regard to reference point" is only relevant to synchronous motors with relative motor encoder, also if a Hall unit, digital, is additionally used.

> ☞ With absolute motor encoders, and relative motor encoders with SHL02 or Hall units, analog, the commutation offset does not need to be corrected during recommissioning!

The "automatic optimization" of the value of "P-0-0521, Effective commutation offset" must be activated for use in "P-0-0522, Control word for commutation setting". Consequently, the value of the currently effective commutation offset (P-0-0521) converted to the same dedicated position is compared, during recommissioning, to the value stored in "P-0-0508, Commutation offset":

- For motors with one reference mark per motor revolution: When the drive has passed the reference mark of the motor encoder ("cyclic marker evaluation" must have been activated in S-0-0277!).
- For motors with several reference marks or none per motor revolution or linear motor travel range: When the dedicated point for homing has been passed after the start of "C0600 Drive-controlled homing procedure command".

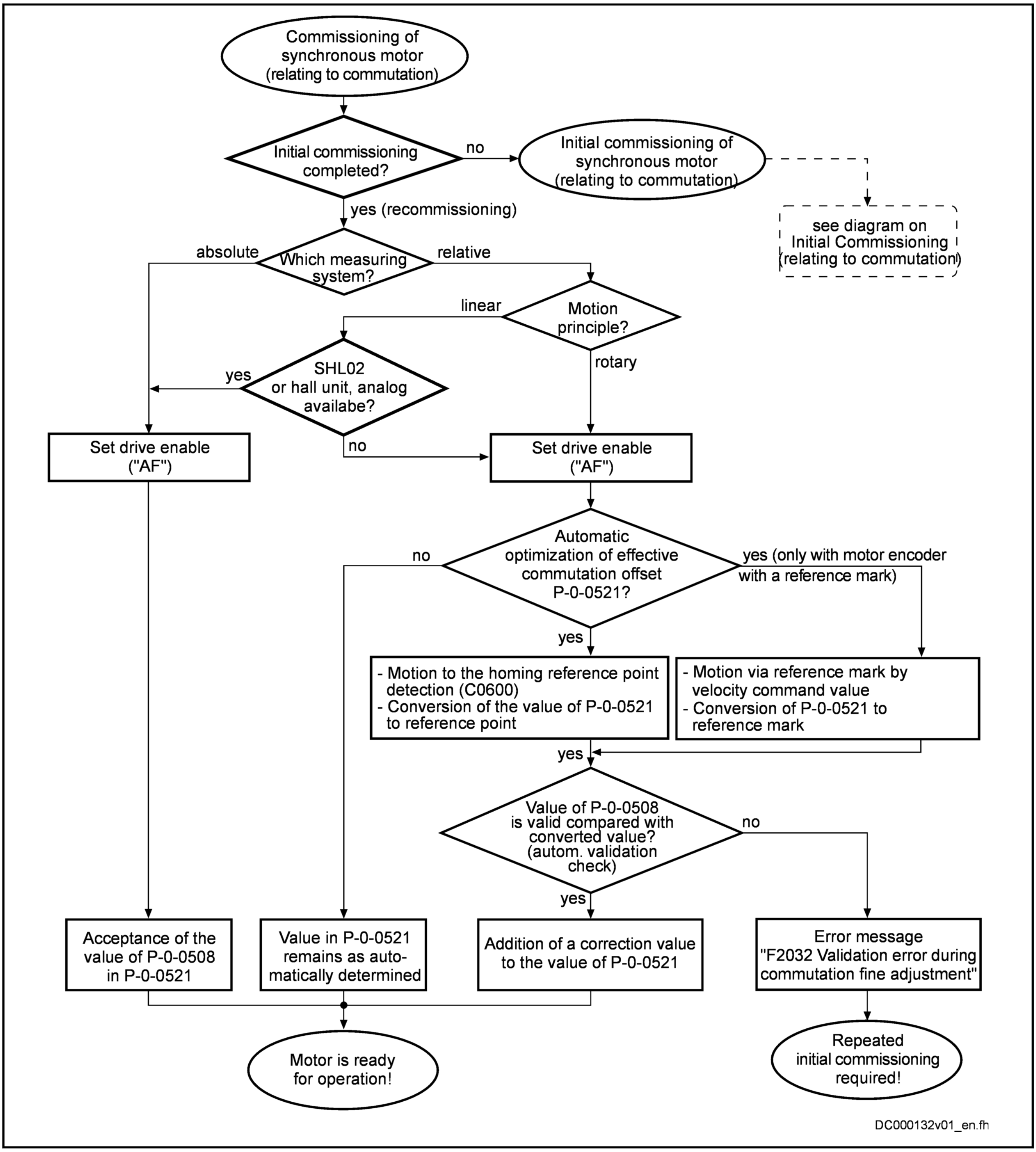
If the result of the comparison is verisimilar, the difference of the two values is added as a correction value to the current value of "P-0-0521, Effective commutation offset". In this way, the quality of the commutation offset now effective complies with the value stored during initial commissioning.

If the result of the comparison is not verisimilar, the value in parameter P-0-0508, Commutation offset might be wrong (e.g. inverted value). The error message "F2032 Validation error during commutation fine adjustment" is generated and the drive switches off.

☞ If the automatic optimization of the commutation offset is not desired, it can be deactivated via P-0-0522, Control word for commutation setting. This causes the commutation offset determined at AF to remain effective and unmodified!

☞ By using the "optimum commutation offset with regard to reference point", the effective commutation offset (P-0-0521), after the motor has been recommissioned, reaches the quality of the value stored during the initial commissioning of the drive. The resulting drive behavior is reproducible with regard to the torque/force development!

Drive Control



P-0-0521	Effective commutation offset
P-0-0522	Control word for commutation setting
P-0-0508	Commutation offset

Fig. 6-97: Recommissioning Procedure of a Synchronous Motor after Initial Commissioning has Taken Place

6.6.2 Commutation Setting for Rexroth Linear Motors MLF, MCL

Brief Description

Linear Rexroth kit motors of the MLF and MCL series are manufactured according to the functional principle "synchronous motor". For kit motors, the motor components primary part, secondary part and motor encoder are finally assembled on the customer side in the machine.

Motors with Absolute Motor Encoders

The operatability of the synchronous motor can only be established on site by determining and setting the commutation offset. For motors with a motor encoder that can be evaluated in absolute form, this is done once during initial commissioning.

Motors with Relative Motor Encoders

For synchronous motors with a relative motor encoder, it is necessary to redetermine the commutation offset each time the drive is switched on again. Deviating commutation offset values are possible due to redetermination and this can cause lower force development at the same motor current.

To prevent this, it is recommended that Hall sensor components, developed especially for linear Rexroth motors be used in addition to the relative motor encoder.

Analog Hall Sensors

Via analog signals from Hall sensors, the controller detects the position of the motor windings with respect to the magnetic field of the motor and in this way also completes the commutation setting during initial commissioning. When the drive is recommissioned, the correct commutation offset is immediately available at drive enable ("AF").

- Hall sensor box SHL02.1 for MLF motors
- Analog Hall unit (motor option) for MCL motors

☞ A second encoder input is required at the drive controller for evaluating the analog Hall sensor signals. This requires a controller with a Basic control section; an Economy control section cannot be used for this purpose!

Digital Hall Sensors

There is also a Hall unit with digital signals available as a motor option for the ironless MCL motors in Economy applications. Using three digital signals that are offset by 120° with respect to a pole pair, the controller detects the position of the motor windings with respect to the magnetic field of the motor with a precision of +/-30° (with respect to a pole pair). This enables the motor, immediately after it is switched on, to operate at at least 50% of the possible motor force.

The following homing procedure of the relative measuring system allows full motor force to be achieved again if this was prepared accordingly in the initial commissioning. The current state of the performance of the motor is diagnosed and can be queried on the control master side.

☞ To evaluate the digital Hall sensor signals, the additional component "SHL03" is required (bringing together the motor encoder and Hall sensor signals). One control section with just one encoder input is sufficient for the controller. For this reason, Economy control sections can be used!

In principle, MLF or MCL motors in combination with a relative motor encoder can also be commutated without using a Hall unit or SHL02 additional components by using the available current supply methods:

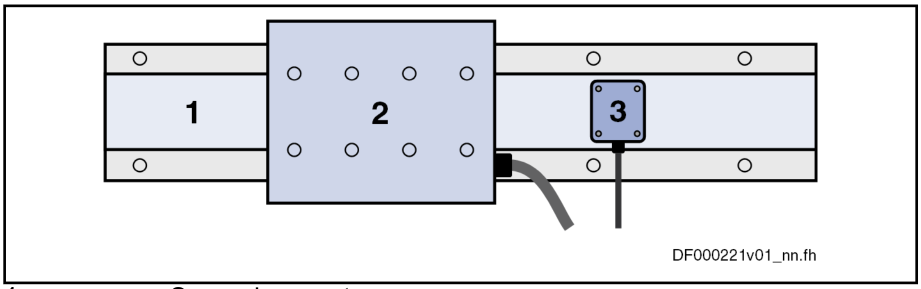
- Saturation method for MLF motors
- Sine-wave method for MCL motors

Each time the drive is switched on again, the commutation setting is performed again with the disadvantages listed above. These disadvantages can be compensated for by using the "optimum commutation offset with regard to reference point".

Application-related restrictions are to be noted for the saturation and sine-wave methods! Using the "optimum commutation offset with regard to reference point" is highly recommended! (See above!)

Hall Sensor Box SHL02.1 for MLF

The Hall sensor box SHL02.1 is an absolute measuring system, outside of the motor, within one pole pair distance of linear Rexroth MLF motors.



1 Secondary part
2 Primary part
3 Hall sensor box SHL02 (connected with the primary part)

Fig. 6-98: Linear Rexroth Motor with Hall Sensor Box SHL02

For information on mounting and connection see the documentation on Hall sensor box SHL02.1.

Hall Unit, Motor Option with MCL

The Hall unit is an absolute measuring system, integrated into the motor, within one pole pair distance of linear Rexroth MCL motors. The Hall unit is optional; it can be ordered directly or retrofitted.

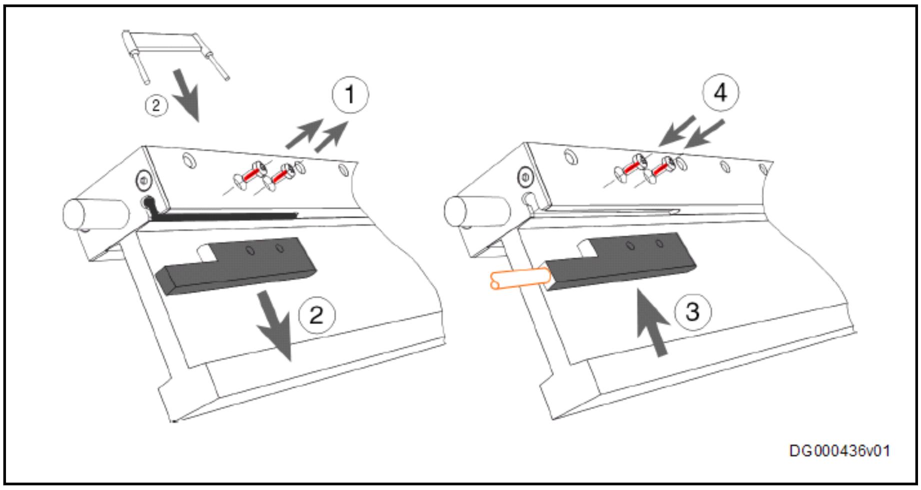


Fig. 6-99: "Hall Unit" Option for MCL Motors; Dismounting the Dummy Unit, Retrofitting the Hall Unit

Information regarding dismounting/assembly and connection is contained in the "Ironless Linear Motors MCL" documentation.

Functional Description

Commutation Offset with Absolute Motor Encoder, Measuring Method (MLF, MCL)

The measuring method for determining the commutation offset can only be used with Rexroth linear motors MLF and MCL with a linear motor encoder that can be evaluated in absolute form (e.g. EnDat2.1 encoder). The method is currentless, i.e. the motor does not generate any force. At drive enable (AF = Antriebsfreigabe), it is then immediately fully operational.

☞ With rotary synchronous Rexroth kit motors, the commutation offset can only be determined with methods with current (saturation method or sine-wave method), because there wasn't any measuring method defined.

To determine the commutation offset, the relative position of the primary part (electrically active part) must be determined with regard to the secondary part (electrically inactive part). This "relative position" is characterized by a value which has to be entered in parameter "P-0-0523, Commutation setting measured value". The value for P-0-0523 is determined by distance measurements and geometric motor data (for the measuring method, see separate motor documentation "Rexroth IndraDyn L (MLF or MCL)").

After the determined value has been entered in P-0-0523 and motor-specific data have been entered, the command "P-0-0524, C1200 Commutation offset setting command" has to be executed. The controller now calculates the value of the commutation offset, which is stored in "P-0-0508, Commutation offset" and, if available, in "P-0-3008, Commutation offset, type plate".

Commutation Offset with Relative Motor Encoder and Hall Sensor Box SHL02 (MLF only), Calculation Process

When using a linear Rexroth motor MLF with relative motor encoder and the Hall sensor box SHL02, the value for "P-0-0508, Commutation offset" depends on the motor geometry and the mounting distance of the SHL box to the primary part. The value is independent of the axis position and is determined during initial commissioning by a calculation method (for further information see documentation on Hall Sensor Box SHL02.1). During recommissioning, it is not necessary to repeat the commutation setting, the motor is immediately ready for operation.

Commutation Offset with Relative Motor Encoder and Hall Unit (MCL only)

The Hall unit of MCL motors is integrated in the primary part of the motor unlike the Hall sensor box SHL02. Due to the distance to the motor windings, depending on the motor size, the value for "P-0-0508, Commutation offset" and also for "P-0-0509, Commutation offset coarse" is a motor size-specific value, which was determined for the motor by the manufacturer and which is loaded to the drive via the IndraWorks commissioning tool with the data set for the relevant motor.

☞ In comparison to SHL02, no calculation is required to determine the commutation offset.

MCL with Analog Hall Unit

The analog Hall unit of MCL motors provides sufficiently precise motor position information for the commutation of a synchronous motor, which results in a fully operational drive in combination with the motor type-specific value of P-0-0508, when the drive is switched on.

MCL with Digital Hall Unit

☞ The additional component "SHL03" (brings motor encoder signals and Hall sensor signals together) is required to evaluate the digital Hall sensor signals!

For the commutation of a synchronous motor, the digital Hall unit of MCL motors only provides motor position information in steps of 60° with an accuracy of +/- 30° in relation to a pole pair. A commutation offset value is assigned to the center of every 60° range: "P-0-0509, Commutation offset coarse". In combination with the motor type-specific value of P-0-0509, the drive when switched on has a reduced performance, initially a minimum of 87%. However, this is improved by:

- Overrunning the next hall sensor switching edge if this takes place with an adjusted velocity. By adjusting the coarse commutation offset value, an improvement of approx. 97% is achieved, depending on the hysteresis and the position precision of the Hall sensor switching edges relative to the respective motor winding.
- The effective commutation offset (P-0-0521) is checked to see whether it matches with the value saved during first commissioning when using the "optimum commutation offset with regard to reference point" – if there is a deviation, it is corrected (100% performance, equal to the result of the first commissioning).

The status of the commutation is displayed in "P-0-0519, Commutation status word". It is possible to check on the control master side, whether the drive is currently still working with reduced or with full performance.

Notes on Commissioning

Requirements

Loading Motor Parameters

As Rexroth kit motors only consist of motor components (primary and secondary parts), they only become an operational motor when they are installed to the axis. The motor encoder is selected by the customer according to the requirements of the application. The type-specific motor parameters therefore cannot be provided in an encoder memory. During initial commissioning, they are advantageously loaded to the controller via the IndraWorks commissioning tool. The motor encoder used must also be parameterized.

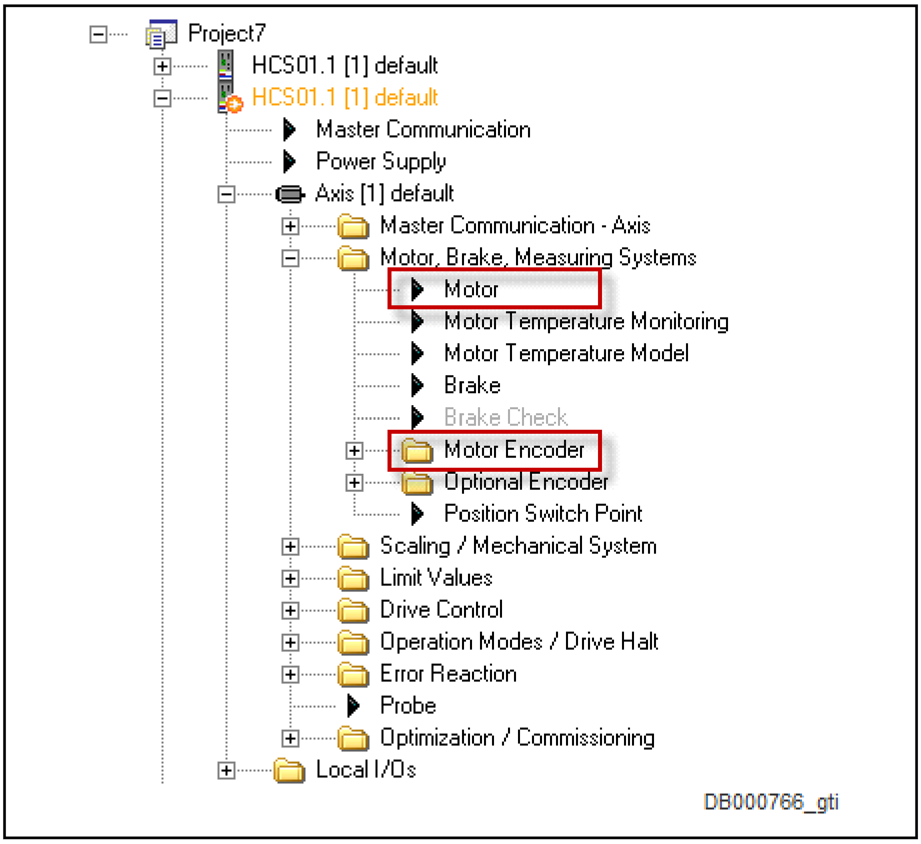
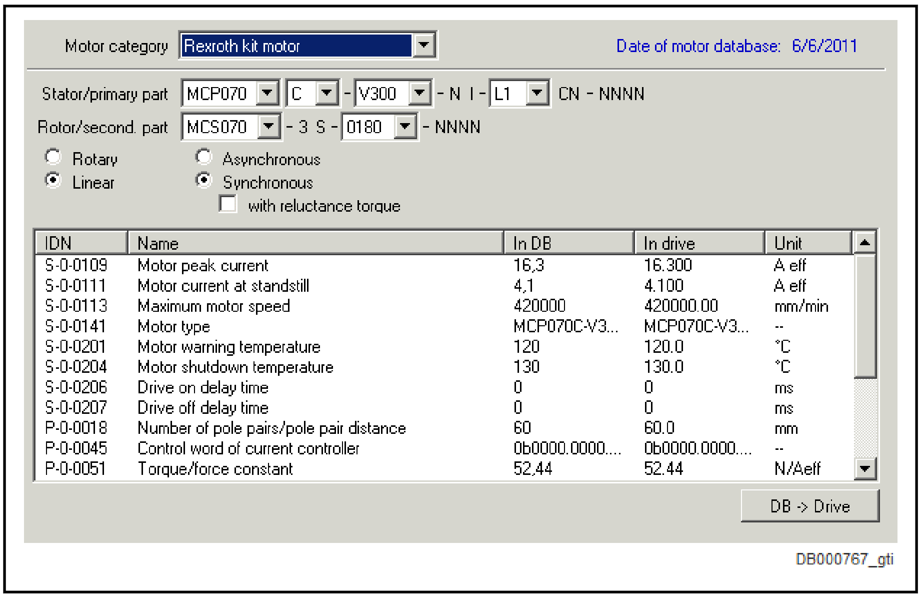


Fig. 6-100: Position of the Motor Dialog in the IndraWorks Explorer



IDN	Name	In DB	In drive	Unit
S-0-0109	Motor peak current	16,3	16.300	A eff
S-0-0111	Motor current at standstill	4,1	4.100	A eff
S-0-0113	Maximum motor speed	420000	420000.00	mm/min
S-0-0141	Motor type	MCP070C-V3...	MCP070C-V3...	--
S-0-0201	Motor warning temperature	120	120.0	°C
S-0-0204	Motor shutdown temperature	130	130.0	°C
S-0-0206	Drive on delay time	0	0	ms
S-0-0207	Drive off delay time	0	0	ms
P-0-0018	Number of pole pairs/pole pair distance	60	60.0	mm
P-0-0045	Control word of current controller	0b0000.0000....	0b0000.0000....	--
P-0-0051	Torque/force constant	52,44	52.44	N/Aeff

Fig. 6-101: IndraWorks Motor Dialog for Loading the Motor Parameters, with an Exemplary MCL Motor

Parameterizing the Motor Encoder

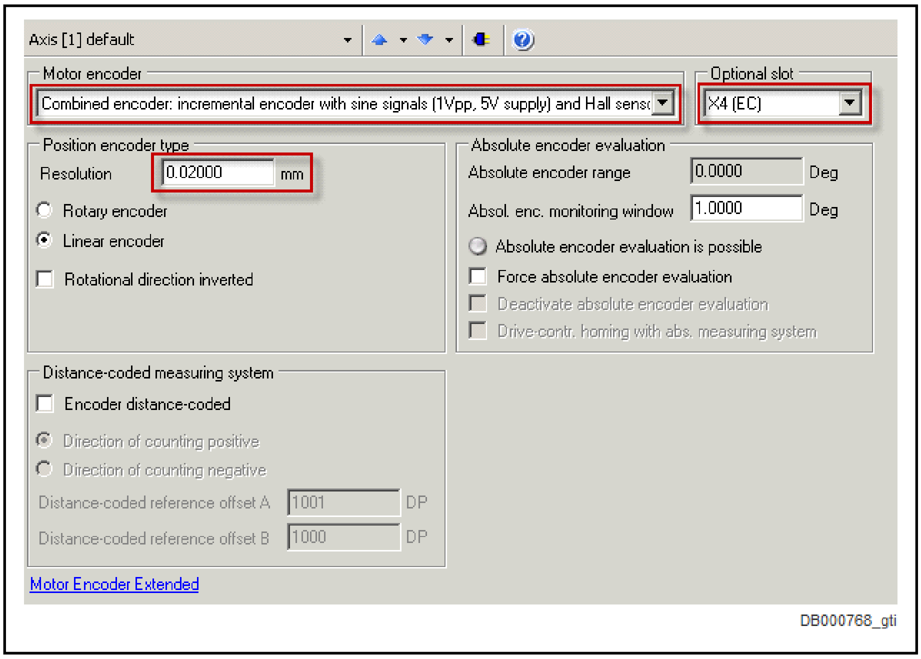


Fig. 6-102: IndraWorks Motor Encoder Dialog for Encoder Selection and Data Input

Select motor encoder used and optional slot used, enter encoder resolution!

☞ The Hall sensor box SHL02 with MLF and the Hall unit with MCL are called "combined encoders". The slot of the (relative) motor encoder is entered for combined encoders under Optional slot.

Checking the Rotational Directions of Motor and Motor Encoder

At the start of commissioning, check whether the rotational directions of motor and motor encoder are matching: The force direction of the motor must be equal to the counting direction of the motor encoder (see documentation of the motor).

Alternatively, the check of the rotational direction can also be performed by the controller ("C3600 Command Motor data identification" configured via "P-0-0601, Configuration motor data identification"). For this purpose, the drive must be in the state "A0012 Control and power sections ready for operation" (Ab).

If the rotational direction does not match, it can be inverted in the motor encoder dialog. Then repeat the rotational direction check!

Commutation Setting

The commutation setting of synchronous motors is supported by the IndraWorks commissioning tool by dialogs:

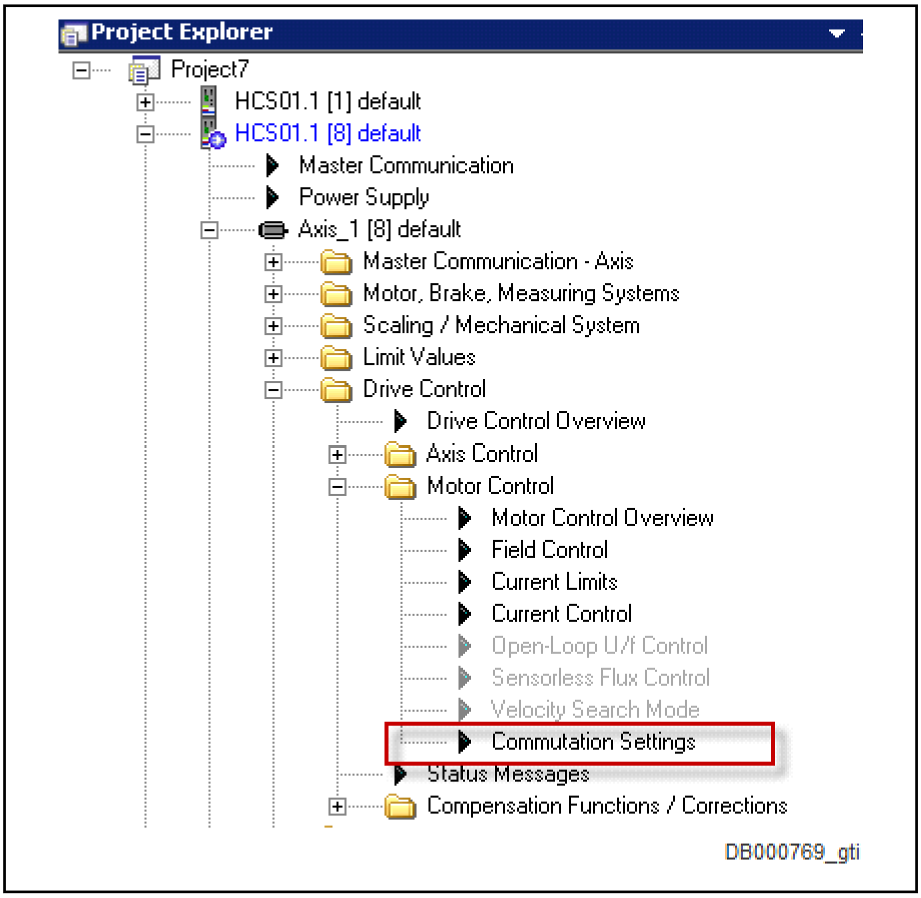


Fig. 6-103: Position of the Dialog for Commutation Setting in the IndraWorks Explorer

Measuring Method with Absolute Motor Encoder

☞ The drive is not yet to be in state "A0012 Control and power sections ready for operation" (Ab), as distance measurements have to be performed on the linear motor.

A measuring method for currentless commutation setting has been defined for absolute motor encoders. The following steps have to be carried out for commissioning:

1. Enter the value for the relative position of the primary part compared to the secondary part in "P-0-0523, Commutation setting measured value" and enter the motor constant "kmx" (for how to determine this value, see separate motor documentation for "Rexroth IndraDyn L").

☞ The position of the primary part or the slide must no longer change after the required distance measurements.

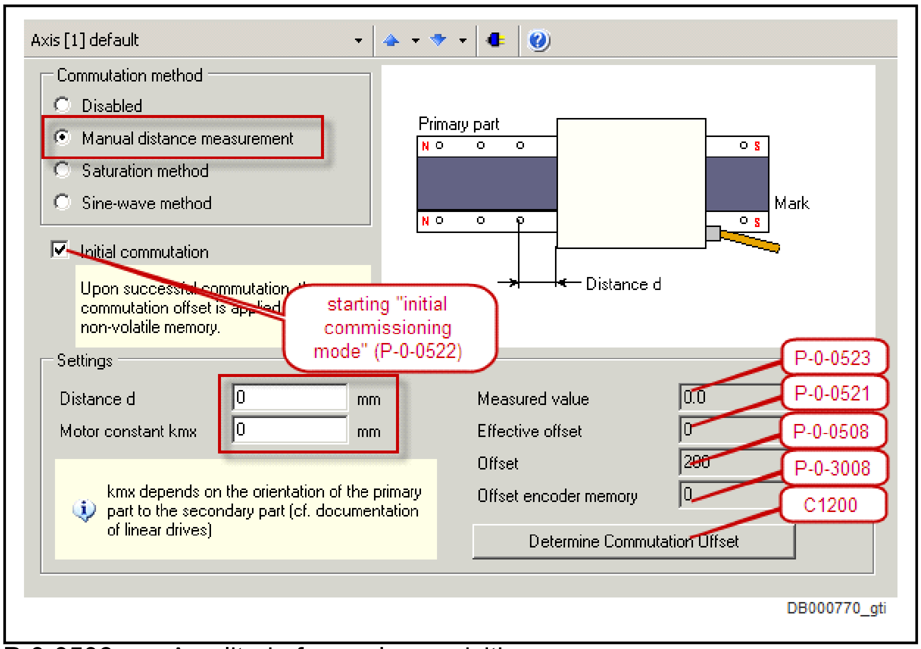
2. Activation of the command parameter "P-0-0524, C1200 Commutation offset setting command"
3. The determined value for the commutation offset is entered by the controller in "P-0-0521, Effective commutation offset" and applied by "P-0-0508, Commutation offset" and, if present, in "P-0-3008, Commutation offset, type plate".

Drive Control

☞ It is recommended that the determined commutation offset value be optimized. This can be done automatically by activating "C5600 Command Subsequent optimization of commutation offset", if the sine-wave method is possible without restrictions for this axis. Otherwise, the commutation offset value should be manually optimized (see section "Basics on Commutation Setting"). The readiness for power output of the drive is required for this purpose ("Ab").

4. Then reset command C5600 and set initial commissioning mode to "inactive" again in P-0-0522.

IndraWorks Dialog for the Measuring Method



P-0-0506	Amplitude for angle acquisition
P-0-0507	Test frequency for angle acquisition
P-0-0508	Commutation offset
P-0-0521	Effective commutation offset
P-0-0522	Control word for commutation setting
P-0-0523	Commutation setting measured value
P-0-3008	Commutation offset, type plate
C1200	Commutation offset setting command

Fig. 6-104: IndraWorks Dialog for the Measuring Method with Linear Rexroth Motors

Using the Hall Sensor Box SHL02 with MLF (Calculation Method)

When using the Hall sensor box SHL02, the affected combined encoder must first be parameterized as a motor encoder (see above under "Requirements"), otherwise the Hall sensor box SHL02 is not evaluated. The following steps have to be carried out for commissioning:

1. Determine the value for "P-0-0508, Commutation offset" based on the calculation method in the documentation on the Hall sensor box SHL02.1 and enter it in "P-0-0521, Effective commutation offset". For this purpose, the drive must be in the parameter mode (PM).

☞ It is recommended that the determined value of the commutation offset be optimized! This can be done automatically by activating "C5600 Command Subsequent optimization of commutation offset", if the sine-wave method is possible without restrictions for this axis. Otherwise, the commutation offset value is to be manually optimized (see section "Basics on Commutation Setting"). The readiness for power output of the drive is required for this purpose ("Ab").

2. Then reset command C5600 and set initial commissioning mode to "inactive" again in P-0-0522.

Using the Analog Hall Unit with MCL

With linear Rexroth motors MCL with an analog Hall unit, the value of "P-0-0508, Commutation offset" depends on the motor size. It is a motor data and is loaded to the drive via the IndraWorks tool together with the motor parameters in the parameter mode (PM) during initial commissioning. When using the analog Hall unit, the affected combined encoder must first be parameterized as a motor encoder (see above under "[External link could not be resolved.]"), otherwise the analog Hall unit is not evaluated.

When the motor is switched on again, and during transition form "PM" to "Bb" or "Ab", the value of P-0-0508 is applied to "P-0-0521, Effective commutation offset". The drive is thereby immediately ready for operation at full performance. Settings for the velocity control loop and position control loop may possibly need to be adjusted.

Using the Digital Hall Unit with MCL

With linear Rexroth motors MCL with a digital Hall unit, the relevant value of "P-0-0509, Commutation offset coarse" depends on the motor size. It is a motor data and is loaded to the drive via the IndraWorks tool together with the motor parameters in the parameter mode (PM) during initial commissioning. When using the digital Hall unit, the affected combined encoder must first be parameterized as a motor encoder (see above under "[External link could not be resolved.]"), otherwise the digital Hall unit is not evaluated.

When the motor is switched on again, and during transition form "PM" to "Bb" or "Ab", the value of P-0-0509 is applied to "P-0-0521, Effective commutation offset". The drive is thereby immediately ready for operation, but owing to the inaccuracy of the motor position detection of +/- 30° (in relation to pole pair) only with reduced performance. Full performance can be achieved by using the "optimum commutation offset with regard to the reference point":

Procedure during initial commissioning

1. Activate "Initial commissioning mode" in "P-0-0522, Control word for commutation setting":
2. Make drive ready for operation (Ab).
3. Optimize value of P-0-0521, Effective commutation offset! This can be done automatically by activating "C5600 Command Subsequent optimization of commutation offset" or manually (see section "Basics on Commutation Setting").
4. As regards commutation, the motor has now been now optimized, but it might be necessary to adjust the settings of the velocity control loop and position control loop in order to move the drive.
5. Activate the optimization of the value of P-0-0521 in "P-0-0522, Control word for commutation setting".
6. Start in "S-0-0148, C0600 Drive-controlled homing procedure command".

The drive now performs the homing motion and moves over the dedicated point for homing. The value of P-0-0521 is thereby converted to the dedicated point for homing, due to the active initial commissioning mode, and stored in "P-0-0508, Commutation offset".

7. Exit the "initial commissioning mode":

   Deactivate the corresponding bit in "P-0-0522, Control word for commutation setting"! The value in P-0-0508 is now write-protected.

☞ The signal state of the digital Hall sensors is displayed with active "initial commissioning" mode in "P-0-0519, Commutation status word". This allows ascertaining whether the signals have been correctly generated and detected by the controller.

Procedure during recommissioning

See also chapter "Re-commissioning for Third-Party Motors with Digital Hall Sensors and Relative Motor Encoder" on page 514 and "Basics on Commutation Setting".

6.6.3 Commutation Setting by Saturation Method

Brief Description

For rotary synchronous Rexroth kit motors and synchronous third-party motors, IndraDrive controllers only provide methods with current to determine the commutation offset. The saturation method, which requires that the motor does not move, is among these methods. A possibly available holding brake should remain applied!

☞ For synchronous Rexroth motors with integrated motor encoder (MSK, MKE motors), it is not necessary to set the commutation offset! The correct value is provided in the motor encoder data memory and is automatically activated.

The saturation method is also relevant for linear synchronous Rexroth kit motors if they are equipped only with a relative motor encoder or for motors with a motor encoder that can be evaluated in absolute form if distance measurement at the axis is not possible due to installation issues.

As a prerequisite for successful application of the saturation method, the iron material of the motor must be magnetically saturated when current is supplied, i.e. the controller must be able to provide sufficiently high current to the motor. For synchronous motors which are not magnetically saturated at maximum allowed current, this method is unsuited for determining the commutation offset!

☞ If the saturation method cannot be used, the controller provides the sine-wave method (works with current, too) for determining the commutation offset.

The saturation method is suitable for both the initial commissioning and the recommissioning, although the restrictions must be observed.

☞ The restrictions to be observed when using the saturation method are described in the section "Basics on Commutation Setting". This section outlines the different methods which can be used for determining the commutation offset.

Functional Description

Method

By a test signal the voltage and frequency of which requires motor-specific values ("P-0-0506, Amplitude for angle acquisition", "P-0-0507, Test frequency for angle acquisition"), the controller determines the commutation offset of the synchronous motor. It is therefore necessary that the generated test current causes magnetic saturation effects in the motor.

The motor-specific setting of voltage and frequency of the test current is carried out automatically when the value "0" has been entered in P-0-0506 at the start of "P-0-0524, C1200 Commutation offset setting command". The detected motor-specific values for P-0-0506 and P-0-0507 are stored and used for commutation setting for future operations.

☞ If the test current does not cause any magnetic saturation effects in the motor, the method can only be used for commutation setting with restrictions.

→ If the maximum current of the controller is not sufficient to cause magnetic saturation in the motor (e.g. with command error C1218), use a controller with higher type current.

→ If the generated test current is too low in spite of sufficient controller type current (e.g. with command error C1218), measures should be taken, as described for the diagnostic message "C1218 Automatic commutation: Current too low"! (See also "Notes on Commissioning")

Should it be impossible to determine a commutation angle in spite of these measures (e.g. command error C1221), the saturation method cannot be used for commutation setting of the affected motor.

Notes on Commissioning

IndraWorks Dialogs for the Saturation Method

The commutation setting of synchronous motors is supported by the IndraWorks commissioning tool by dialogs:

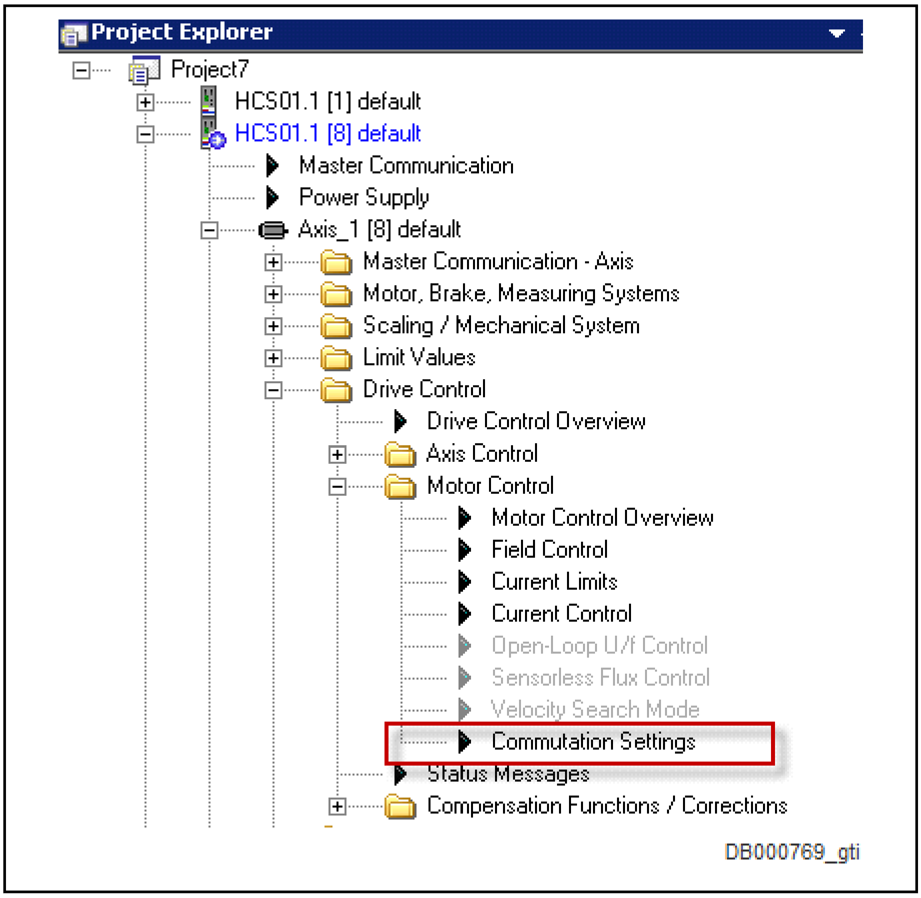
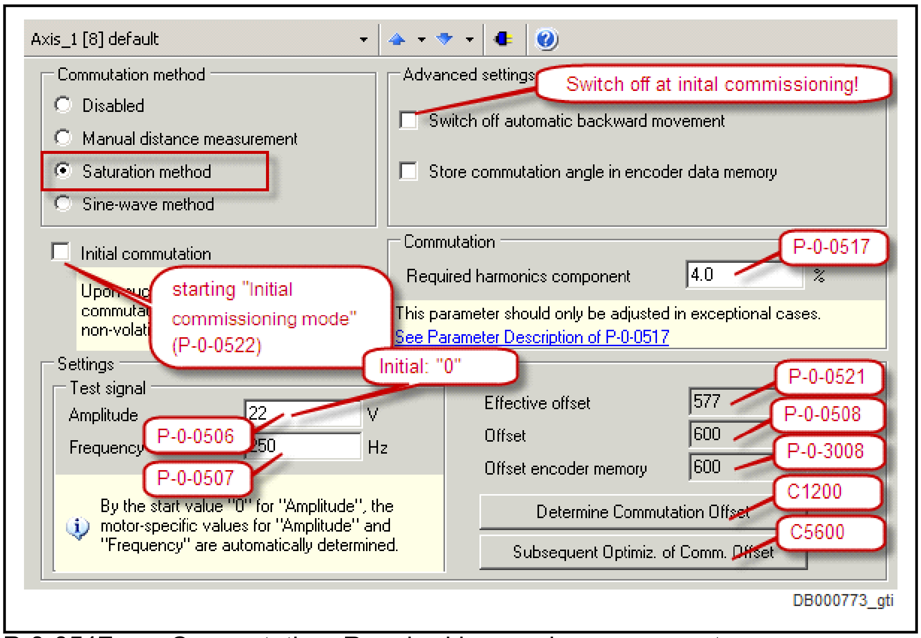


Fig. 6-105: Position of the Dialog for Commutation Setting in the IndraWorks Explorer



P-0-0517	Commutation: Required harmonics component
P-0-0521	Effective commutation offset
P-0-0522	Control word for commutation setting
P-0-0506	Amplitude for angle acquisition
P-0-0507	Test frequency for angle acquisition
P-0-0508	Commutation offset
P-0-3008	Commutation offset, type plate
C1200	Commutation offset setting command
C5600	Command subsequent optimization of commutation offset

Fig. 6-106: IndraWorks Dialog for the Saturation Method

Saturation Method with Synchronous Motors with Absolute Motor Encoder

With synchronous motors with absolute motor encoder, the saturation method is started by a command **only during initial commissioning** and the value of the commutation offset is determined. This value is stored in the controller or in the encoder data memory. In addition, the value is to be manually or automatically optimized during initial commissioning.

Initial Commissioning

Sequence of initial commissioning

1. Activation in "P-0-0522, Control word for commutation setting":
   - Initial commissioning mode

     \- and -
   - Saturation Method

☞ Deactivate the return to the start position for initial commissioning due to possible contra-rotating rotational direction of the motor and motor encoder!

2. Make presettings for automatic determination of motor-specific parameter values (P-0-0506, P-0-0507) of test signal required for determining the commutation offset:
   - Enter the value "0" in "P-0-0506, Amplitude for angle acquisition"

3. Switch drive to operating mode (Ab); first carry out rotational direction check of the motor and motor encoder (P-0-0601, Configuration motor data identification), and correct if necessary.
4. Start saturation method by "P-0-0524, C1200 Commutation offset setting command"
5. After current was supplied and commutation offset value has been successfully determined, this value, due to initial commissioning mode, is simultaneously stored in the following parameters with absolute motor encoders:
   - P-0-0508, Commutation offset
   - P-0-0521, Effective commutation offset
   - P-0-3008, Commutation offset, type plate (if available)

   The execution of the command is now completed, it can be reset. The drive now is operational.

   If error message "F8013 Automatic commutation: Current too low" occurs, but the deviation of P-0-0521 is within the allowed range of values (< approx. ±30), further measures can be taken as described for the diagnostic message "F8013 Automatic commutation: Current too low"!

☞ With drives with minimal overload capacity, temperature model-based current limits may occur, which can also lead to F8013.

Recommendation: Optimize the determined value for commutation offset! This can be done automatically by activating "C5600 Command Subsequent optimization of commutation offset", if the sine-wave method is possible without restrictions for this axis. Otherwise, the commutation offset value should be manually optimized (see section "Basics on Commutation Setting").

6. Exit the "initial commissioning mode":

   Deactivate the corresponding bit in "P-0-0522, Control word for commutation setting". Value in P-0-0508 resp. P-0-3008 is now read-only.

☞ Reactivate return to the start position at the end of initial commissioning!

Recommissioning

Each time the drive is switched on again or the measuring system is initialized, the value stored in "P-0-0508, Commutation offset" or "P-0-3008, Commutation offset, type plate" is applied to "P-0-0521, Effective commutation offset" and becomes effective as the commutation offset.

Saturation Method with Synchronous Motors with Relative Motor Encoder

With synchronous kit motors with relative motor encoders, the saturation method is automatically started when drive enable is set for the first time after the drive is switched on again or after every initialization of the measuring system ("PM" -> "OM"). The drive is operational only after the commutation offset has been successfully determined.

☞ By using the "optimum commutation offset with regard to reference point", the effective commutation offset (P-0-0521), after the motor has been recommissioned, reaches the quality of the value stored during the initial commissioning of the drive. This results in reproducible drive behavior with respect to torque/force development.

Initial Commissioning

Sequence of initial commissioning

1. Activation in "P-0-0522, Control word for commutation setting":
   - Initial commissioning mode

     - and -
   - Saturation Method

☞ Deactivate the return to the start position for initial commissioning due to possible contra-rotating rotational direction of the motor and motor encoder!

2. Make presettings for automatic determination of motor-specific parameter values (P-0-0506, P-0-0507) of test signal required for determining the commutation offset:
   - Enter the value "0" in "P-0-0506, Amplitude for angle acquisition"
3. Switch drive to operating mode (Ab); first carry out rotational direction check of the motor and motor encoder (P-0-0601, Configuration motor data identification), and correct if necessary.
4. Start saturation method by "P-0-0524, C1200 Commutation offset setting command"
5. After the current was supplied and the commutation offset value has been successfully determined, the value is contained in "P-0-0521, Effective commutation offset". The drive now is operational. In addition, the motor-specific values for P-0-0506 and P-0-0507 were stored.

☞ The motor-specific values for P-0-0506 and P-0-0507 are to be checked for their safe function. To do so, set the axis to several different positions within one pole pair or pole pair distance, execute command C1200 each time and write down the value of P-0-0521. If P-0-0521 shows great deviations (> approx. ±30) or error messages are generated, the values of P-0-0506 and P-0-0507 have to be automatically generated again (see above) or subsequently manually optimized:

- With "F8013 Automatic commutation: Current too low"

  → Increase voltage (P-0-0506), reduce frequency (P-0-0507)
- With "F8014 Automatic commutation: Overcurrent"

  → Reduce voltage (P-0-0506), increase frequency (P-0-0507)

If error message "F8013 Automatic commutation: Current too low" occurs, but the deviation of P-0-0521 is within the allowed range of values (< approx. ±30), further measures can be taken as described for the diagnostic message "F8013 Automatic commutation: Current too low"!

☞ With drives with minimal overload capacity, temperature model-based current limits may occur, which can also lead to F8013.

Recommendation: Optimize the determined value for commutation offset! This can be done automatically by activating "C5600 Command Subsequent optimization of commutation offset", if the sine-wave method is possible without restrictions for this axis. Otherwise, the commutation offset value should be manually optimized (see section "Basics on Commutation Setting").

6. Now switch drive to parameter mode ("PM"). After switching back to operating mode, set "AF" and check function of drive. This automatically starts determination of commutation offset with stored parameters (P-0-0506, P-0-0507, P-0-0517). Motor is supplied with current and commutation offset determined again.

   Check commutation behavior of drive at several different positions. If it is not satisfactory, repeat manual optimization of P-0-0506, P-0-0507 and P-0-0517 as described above!

☞ If inadmissible values are generated for "P-0-0521, Effective commutation offset" and therefore the message "F8078 Speed loop error" appears, although there was no error signaled during commutation offset determination, increase the value of "P-0-0517, Commutation: Required harmonics component" and return to 4.!

7. With synchronous motors with relative motor encoder and one reference mark per revolution:
   - In "S-0-0277, Position feedback 1 type", set the bit for "cyclic marker evaluation".
   - In "P-0-0522, Control word for commutation setting", activate optimization of the value of P-0-0521 for rotary synchronous motors.

   On the user-side, make the motor move over the reference mark of the encoder: Travel the drive or move it manually. The value of P-0-0521 is thereby converted to the reference mark, caused by the active initial commissioning mode, and is stored in "P-0-0508, Commutation offset" and possibly in "P-0-3008, Commutation offset, type plate".

8. Synchronous motors with relative motor encoder with several reference marks or none per motor revolution or linear motor travel range:
   - Activate the optimization of the value of P-0-0521 in "P-0-0522, Control word for commutation setting".
   - Start "S-0-0148, C0600 Drive-controlled homing procedure command".

   The drive now performs the homing motion and moves over the dedicated point for homing. The value of P-0-0521 is thereby converted to the dedicated point for homing, due to the active initial commissioning mode, and is stored in "P-0-0508, Commutation offset" and possibly in "P-0-3008, Commutation offset, type plate".

9. Exit the "initial commissioning mode":

   Deactivate the corresponding bit in "P-0-0522, Control word for commutation setting"! Value in P-0-0508 resp. P-0-3008 is now read-only.

☞ Reactivate return to the start position at the end of initial commissioning!

Recommissioning

Using the "optimum commutation offset with regard to reference point":

Each time the drive is switched on or the measuring system is initialized, a value for the commutation offset is automatically determined at the first drive enable (AF). It is related to the motor position at switch-on.

☞ The determination of the commutation offset starts with the currently available values of "P-0-0506, Amplitude for angle acquisition" and "P-0-0507 Test frequency for angle acquisition". If it had been impossible to determine the commutation offset with these start values, the values of these parameters are automatically modified in the possible range of values until it has been possible to determine the commutation offset.

The value of "P-0-0521, Effective commutation offset" is optimized by the addition of a correction value. This correction value is the difference between the value in P-0-0508 and the value of P-0-0521 converted to the dedicated point of P-0-0508.

Rotary synchronous motors with relative motor encoder and one reference mark per revolution

Required parameter settings:

- In "S-0-0277, Position feedback 1 type", the bit for "cyclic marker evaluation" must be set.
- In "P-0-0522, Control word for commutation setting", activate the optimization of the value of P-0-0521 for rotary synchronous motors.

When the motor moves over the reference mark, for example by the setting of the command values, the correction value is determined and automatically added to P-0-0521. The effective commutation offset thereby corresponds to the value stored in P-0-0508.

Synchronous motors with relative motor encoder with several reference marks or none per motor revolution or linear motor travel range

Required parameter settings:

- The optimization of the value of P-0-0521 has to be activated in "P-0-0522, Control word for commutation setting".

When the motor moves over the dedicated point for homing by the start of "S-0-0148, C0600 Drive-controlled homing procedure command", the correction value is determined and automatically added to P-0-0521. The effective commutation offset thereby corresponds to the value stored in P-0-0508.

See also "Basics on Commutation Setting".

☞ With relative motor encoders, using the "optimum commutation offset value with regard to the reference point" is fundamentally recommended when the motor is recommissioned. This generates a reproducible torque/force development based on the initial commissioning of the motor. Otherwise, the automatically determined commutation offset value will be retained. It can be of a comparatively poor quality.

6.6.4 Commutation Setting By Sine-Wave Method

Brief Description

For synchronous motors, in addition to the saturation method, IndraDrive controllers provide the sine-wave method, also with current, to determine the commutation offset.

Application-Related Aspect

The sine-wave method for determining the commutation offset can be used for all types of synchronous motors.

The disadvantage of the sine-wave method is that the motor has to be put into motion by supplying current. Limitations of the motivity (e.g. friction or blocking) can reduce the quality of offset determination or even cause offset determination to fail! See the section "Basics on Commutation Setting"

Before using the sine-wave method, carefully check whether it is possible to use the saturation method, because unrestricted movement of the axis generally causes problems. For the saturation method movement of axis is not necessary, it should be blocked, if possible.

The sine-wave method is suitable for both the initial commissioning and the recommissioning, although the restrictions must be observed.

☞ The restrictions to be observed when using the sine-wave method are described in the section "Basics on Commutation Setting". This section outlines the different methods which can be used for determining the commutation offset.

Functional Description

Method

By a sinusoidal test signal, the voltage and frequency of which require motor-specific settings (P-0-0506, Amplitude for angle acquisition, P-0-0507, Test frequency for angle acquisition), the controller determines the commutation offset of the synchronous motor. It is therefore necessary that the generated test current puts the motor into motion.

☞ The maximum motion range with the sine-wave method is ±45° electrically with rotary motors and ½ pole pair distance with linear motors.

The motor-specific setting of voltage and frequency of the test current is carried out automatically when the value "0" has been entered in P-0-0506 at the start of "P-0-0524, C1200 Commutation offset setting command". The detected motor-specific values for P-0-0506 and P-0-0507 are stored and used for future commutation setting operations.

Notes on Commissioning

IndraWorks Dialogs for the Sine-Wave Method

The commutation setting of synchronous motors is supported by the IndraWorks commissioning tool by dialogs:

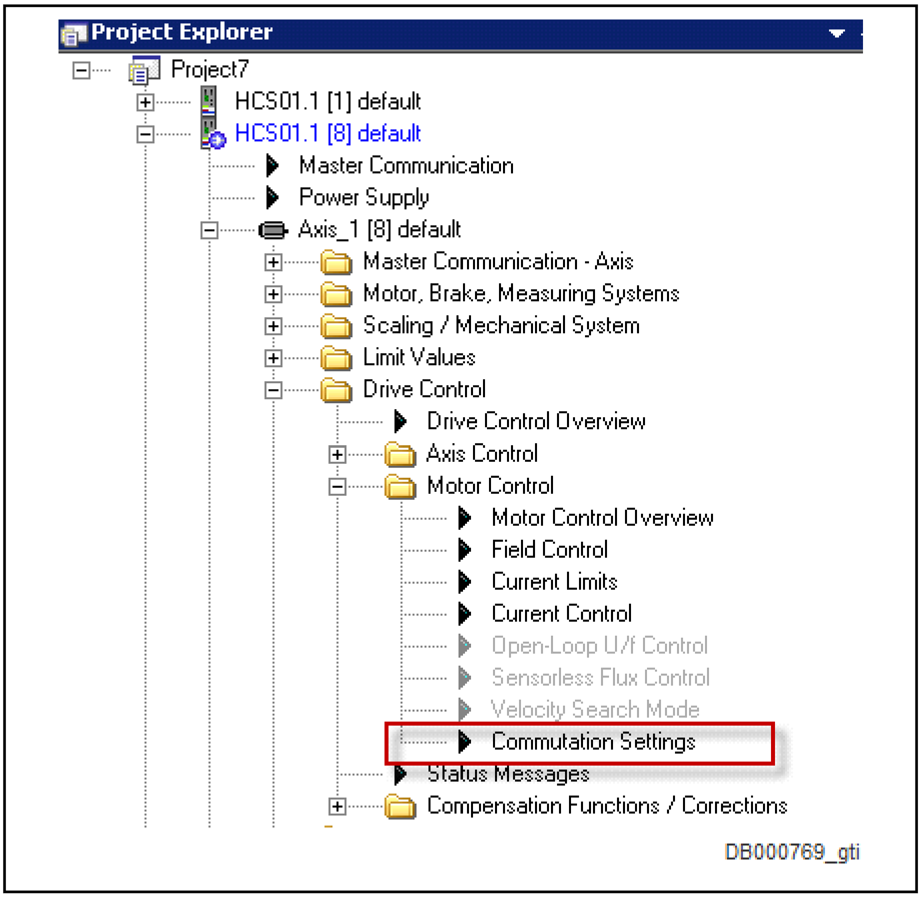
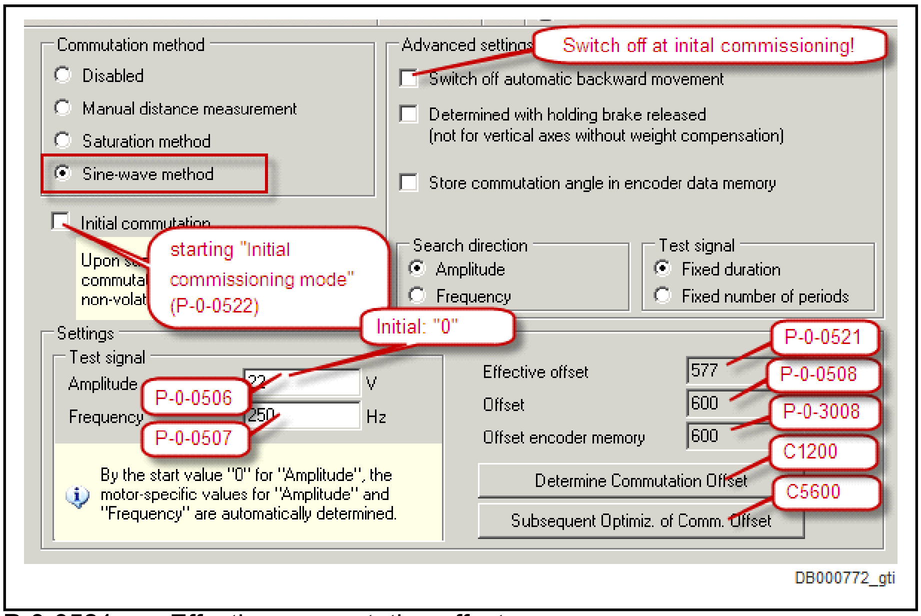


Fig. 6-107: Position of the Dialog for Commutation Setting in the IndraWorks Explorer



P-0-0521	Effective commutation offset
P-0-0522	Control word for commutation setting
P-0-0506	Amplitude for angle acquisition
P-0-0507	Test frequency for angle acquisition
P-0-0508	Commutation offset
P-0-3008	Commutation offset, type plate
C1200	Commutation offset setting command
C5600	Command subsequent optimization of commutation offset

Fig. 6-108: IndraWorks Dialog for the Sine-Wave Method

Sine-Wave Method with Synchronous Motors with Absolute Motor Encoder

With synchronous motors with absolute motor encoder, the sine-wave method is started by a command **only during initial commissioning** and the value of the commutation offset is determined. This value is stored in the controller or in the encoder data memory. In addition, the value is to be manually or automatically optimized during initial commissioning.

Initial Commissioning

Sequence of initial commissioning

1. Activation in "P-0-0522, Control word for commutation setting":
   - Initial commissioning mode

     - and -
   - Sine-Wave Method

☞ Deactivate the return to the start position for initial commissioning due to possible contra-rotating rotational direction of the motor and motor encoder.

2. Make presettings for automatic determination of motor-specific parameter values (P-0-0506, P-0-0507) of test signal required for determining the commutation offset:
   - Enter the value "0" in "P-0-0506, Amplitude for angle acquisition".
3. Switch drive to operating mode (AB); first carry out rotational direction check of the motor and motor encoder (P-0-0601, Configuration motor data identification), and correct if necessary.

4. Start sine-wave method via "P-0-0524, C1200 Commutation offset setting command".
5. After current was supplied and commutation offset value has been successfully determined, this value, due to initial commissioning mode, is simultaneously stored in the following parameters with absolute motor encoders:
   - P-0-0508, Commutation offset
   - P-0-0521, Effective commutation offset
   - P-0-3008, Commutation offset, type plate (if available)

   The execution of the command is now completed, it can be reset. The drive now is operational.

Recommendation: Optimize the determined value for commutation offset! This can be done automatically by activating "C5600 Command Subsequent optimization of commutation offset". Otherwise, the commutation offset value should be manually optimized (see section "Basics on Commutation Setting").

---

6. Exit the "initial commissioning mode":

   Deactivate the corresponding bit in "P-0-0522, Control word for commutation setting". Value in P-0-0508 resp. P-0-3008 is now read-only.

Reactivate return to the start position at the end of initial commissioning.

Each time the drive is switched on again or the measuring system is initialized, the value stored in P-0-0508 and/or P-0-3008 is applied to P-0-0521 and becomes effective as the commutation offset value.

Sine-Wave Method with Synchronous Motors with Relative Motor Encoder

With synchronous kit motors with relative motor encoders, the sine-wave method is automatically started when drive enable is set for the first time after the drive is switched on again or after every initialization of the measuring system ("PM" -> "OM"). The drive is operational only after the commutation offset has been successfully determined.

By using the "optimum commutation offset with regard to reference point", the effective commutation offset (P-0-0521), after the motor has been recommissioned, reaches the quality of the value stored during the initial commissioning of the drive. This results in reproducible drive behavior with respect to torque/force development.

Initial Commissioning

Sequence of initial commissioning

1. Activation in "P-0-0522, Control word for commutation setting":
   - Initial commissioning mode

     - and -
   - Sine-Wave Method

Deactivate the return to the start position for initial commissioning due to possible contra-rotating rotational direction of the motor and motor encoder.

2. Make presettings for automatic determination of motor-specific parameter values (P-0-0506, P-0-0507) of test signal required for determining the commutation offset:
   - Enter the value "0" in "P-0-0506, Amplitude for angle acquisition"
3. Switch drive to operating mode (Ab); first carry out rotational direction check of the motor and motor encoder (P-0-0601, Configuration motor data identification), and correct if necessary.
4. Start sine-wave method via "P-0-0524, C1200 Commutation offset setting command".
5. After the current was supplied and the commutation offset value has been successfully determined, this value is displayed in "P-0-0521, Effective commutation offset". The drive now is operational. In addition, the motor-specific values for P-0-0506 and P-0-0507 were stored.

If the drive does not find a valid value for P-0-0521 and aborts the execution of the command with an error message, modified settings with regard to the search mode can lead to success:

- If the mechanical axis system shows distinctive friction, the settings for the search direction in P-0-0522 should be made for "increase of amplitude with priority".
- If the mechanical axis system shows resonances in the search range of P-0-0507 and develops heavy noise when the amplitude is increased, the settings for the search direction in P-0-0522 should be made for "increase of frequency with priority".

Recommendation: Optimize the determined value for commutation offset! This can be done automatically by activating "C5600 Command Subsequent optimization of commutation offset" (see section "Basics on Commutation Setting").

6. With synchronous motors with relative motor encoder and one reference mark per revolution:
   - In "S-0-0277, Position feedback 1 type", set the bit for "cyclic marker evaluation".
   - In "P-0-0522, Control word for commutation setting", activate optimization of the value of P-0-0521 for rotary synchronous motors.

   On the user-side, make the motor move over the reference mark of the encoder: Travel the drive or move it manually. The value of P-0-0521 is thereby converted to the reference mark, caused by the active initial commissioning mode, and is stored in "P-0-0508, Commutation offset" and possibly in "P-0-3008, Commutation offset, type plate".
7. Synchronous motors with relative motor encoder with several reference marks or none per motor revolution or linear motor travel range:
   - Activate the optimization of the value of P-0-0521 in "P-0-0522, Control word for commutation setting".

- Start "S-0-0148, C0600 Drive-controlled homing procedure command".

The drive now performs the homing motion and moves over the dedicated point for homing. The value of P-0-0521 is thereby converted to the dedicated point for homing, due to the active initial commissioning mode, and is stored in "P-0-0508, Commutation offset" and possibly in "P-0-3008, Commutation offset, type plate".

8. Exit the "initial commissioning mode":

   Deactivate the corresponding bit in "P-0-0522, Control word for commutation setting"! Value in P-0-0508 resp. P-0-3008 is now read-only.

☞ Reactivate return to the start position at the end of initial commissioning.

Recommissioning

Using the "optimum commutation offset with regard to reference point":

Each time the drive is switched on or the measuring system is initialized, a value for the commutation offset is automatically determined at the first drive enable (AF). It is related to the motor position at switch-on.

☞ The determination of the commutation offset starts with the currently available values of "P-0-0506, Amplitude for angle acquisition" and "P-0-0507, Test frequency for angle acquisition". If it had been impossible to determine the commutation offset with these start values, the values of these parameters are automatically modified in the possible range of values until it has been possible to determine the commutation offset.

The value of "P-0-0521 Effective commutation offset" is optimized by the addition of a correction value. This correction value is the difference between the value in P-0-0508 and the value of P-0-0521 converted to the dedicated point of P-0-0508.

Rotary synchronous motors with relative motor encoder and one reference mark per revolution

Required parameter settings:

- In "S-0-0277, Position feedback 1 type", the bit for "cyclic marker evaluation" must be set.
- In "P-0-0522, Control word for commutation setting", activate the optimization of the value of P-0-0521 for rotary synchronous motors.

When the motor moves over the reference mark, for example by the setting of the command values, the correction value is determined and automatically added to P-0-0521. The effective commutation offset thereby corresponds to the value stored in P-0-0508.

Synchronous motors with relative motor encoder with several reference marks or none per motor revolution or linear motor travel range

Required parameter settings:

- The optimization of the value of P-0-0521 has to be activated in "P-0-0522, Control word for commutation setting".

When the motor moves over the dedicated point for homing by the start of "S-0-0148, C0600 Drive-controlled homing procedure command", the correction value is determined and automatically added to P-0-0521. The effective commutation offset thereby corresponds to the value stored in P-0-0508.

See also "Basics on Commutation Setting".

☞ With relative motor encoders, using the "optimum commutation offset value with regard to the reference point" is fundamentally recommended when the motor is recommissioned. This generates a reproducible torque/force development based on the initial commissioning of the motor. Otherwise, the automatically determined commutation offset value will be retained. It can be of a comparatively poor quality.

6.6.5 Commutation Setting of Motors with Digital Hall Sensors

Brief Description

General Information

Digital Hall Sensors for Three-Phase Synchronous Motors

In addition to the typical absolute measuring systems on the market, for three-phrase synchronous motors the position of the motor windings with respect to the magnetic field of the motor can also be identified using three digital signals that are offset by 120° with respect to a pole pair. The precision of +/-30° with respect to a pole pair is low; however, with respect to the commutation offset it is still sufficient for use.

In combination with a relative motor encoder, for synchronous motors an absolute motor measuring system can be realized with respect to the commutation offset; this system can be evaluated by IndraDrive controllers. To do this, the additional component "SHL03" is required, which brings both measuring systems together on the hardware side and enables the connection to just one encoder input of the controller.

Rexroth MCL Motors, "Hall Unit, Digital" Option

Digital Hall sensors are available for the ironless linear Rexroth MCL motors. They can be ordered as the motor option "Hall sensor, digital" and are integrated into the primary part of the motor. An additional relative motor encoder and the SHL03 component are required!

☞
- For information regarding the commutation setting of MCL motors, see the chapter "Commutation Setting for Rexroth Linear Motors MLF, MCL"
- See also the documentation "Rexroth IndraDyn L, Ironless Linear Motors MCL; Project Planning Manual"

Third-Party Motors with Digital Hall Sensors

General conditions

- Three-phase synchronous motor with a fixed interconnection (star or delta connection)
- Three Hall sensor signals offset by 120° (with respect to a pole pair) for motor commutation
- Relative motor encoder for motor operation

☞ When using an encoder combination of a relative motor encoder and digital Hall sensors, it is impossible to use an SSI encoder as the possibly required external encoder!

Hardware-side features and requirements

- Supply voltage for the motor encoder: DC 5V

- Supply voltage for the Hall sensors: DC12V
- Voltage level of the Hall sensor signals: 5VTTL
- Additional component SHL03 for bringing together the motor encoder and Hall sensor signals for connection to an encoder input of the drive controller.

☞ For more information regarding the technical data, see the documentation "IndraDrive Cs Drive Systems; Project Planning Manual"

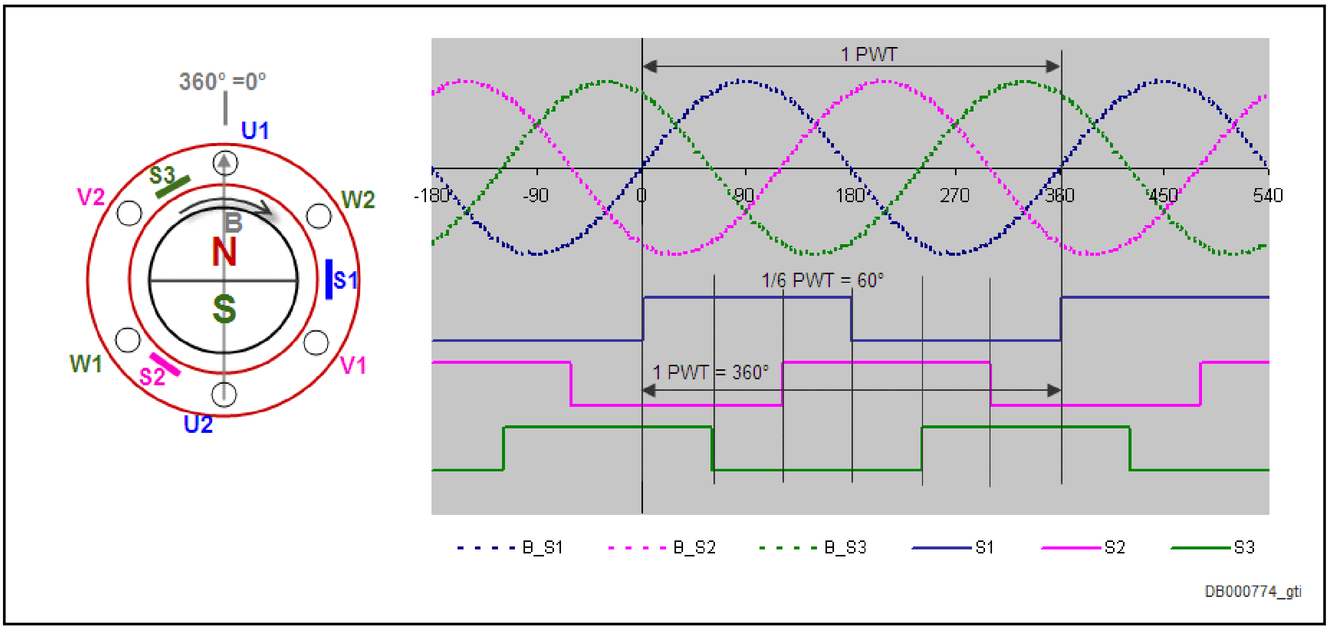
Functional Description

Determining Position of Motor

To achieve maximum force effect in the primary part, the control must generate the current at the right phase angle compared to the permanent magnetic field in the secondary part of the motor. For this purpose, the control must identify the position of the motor windings compared to the magnetic field of the motor; the right phase angle of the current is produced by the commutation offset.

Digital Hall Sensors

With synchronous three-phase a.c. motors, the position of the motor windings compared to the magnetic field of the motor can be identified via three digital signals offset by 120° in relation to a pole pair, apart from by an absolute motor encoder. Each Hall sensor has two switching states ("high" and "low") over a pole pair or a pole pair distance, depending on the direction of the magnetic flux that takes effect in the Hall sensor. Due to the three digital signals offset by 120°, 6 ranges can be identified, each of which has 60° of a pole pair or a pole pair distance:



PPD	Pole pair distance or pole pair (corresponds to 360° electrical)
B_S1, B_S2, B_S3	Magnetic flux density in the Hall sensors
S1, S2, S3	Hall sensors and their signals
U1, U2, V1, V2, W1, W2	Three-phase winding of primary part of motor
N, S	North and south pole of secondary part of motor

Fig. 6-109: Position Detection by Digital Hall Sensors Based on the Example of a Single Pole-Paired Rotary Three-Phase AC Motor

Position Detection by Digital Hall Sensors, Motor Performance

The position detection of only 60° ranges of a pole pair only offers a precision of +/-30° with respect to the center of the 60° range identified by the sensor signals. This, indeed, is low, but nevertheless sufficiently useable with regard to the commutation offset:

- If the commutation offset relates precisely to the center of the 60° ranges, the inaccuracy of position detection of max. 30° leads to a maximum torque or force reduction of up to 87%.
- If the commutation offset related precisely to an edge of the 60° ranges, the inaccuracy of position detection of max. 60° would lead to a maximum torque or force reduction of up to 50%.

☞ The performance data relate to correctly consecutive, exact 60° ranges. The performance of the motor can be additionally reduced by unfavorable circumstances when determining the commutation offset, due to switching hystereses of the Hall sensors, mechanical mounting inaccuracies and differences in the flux density of the motor's magnets.

The Hall sensors offset by 3x120° to each other can also be shifted as a whole in relation to the motor windings. This can be caused both by the mounting conditions between or even outside of the windings, as well as by different winding connections (star or delta).

Initial Commissioning and Recommissioning, Commutation Status

The saturation method and the sine-wave method are available for the commutation setting for **initial commissioning**, whereby the determined and possibly optimized commutation offset value is to be stored based on the reference mark of the motor encoder or the dedicated point for homing (see also chapter on "Basics on Commutation Setting").

When the motor is switched on again (**Re-commissioning** after a successful initial commissioning), the value of "P-0-0509, Commutation offset coarse" initially becomes effective in P-0-0521, with regards to the position detection by the Hall sensor signals. Depending on the motor position, this value initially offers a drive performance of at least 87%, but this can be improved by:

- Overrunning the next hall sensor switching edge if this takes place with an adjusted velocity. By adjusting the coarse commutation offset value, an improvement of approx. 97% is achieved, depending on the hysteresis and the position precision of the Hall sensor switching edges relative to the respective motor winding.
- The effective commutation offset (P-0-0521) is checked to see whether it matches with the value saved during first commissioning when using the "optimum commutation offset with regard to reference point" – if there is a deviation, it is corrected (100% performance, equal to the result of the first commissioning).

The current status of the commutation setting is displayed in "P-0-0519, Commutation status word". The relevant bits indicate whether the drive only works with Coarse Commutation Value (P-0-0509), adjusted or "optimum commutation setting with regard to reference point".

☞ The torque and force reduction must be taken into account when carrying out project planning for synchronous motors with digital Hall sensors and relative motor encoder directly after switching off, particularly for non-equilibrated axes (e.g., vertical axes without weight compensation)!

Notes on Commissioning

Initial Commissioning for Third-Party Motors with Digital Hall Sensors and Relative Motor Encoder

First the motor parameters of third-party motors are determined in accordance with the chapter "Third-Party Motors on IndraDrive Controllers". For the motor encoder, select "Encoder combination: Encoder with sine signals (1 Vpp, 5 V supply) and digital Hall sensors (12 V supply), connection via SHL03". A synchronous motor with motor encoder only becomes operational by commutation offset. The determination is supported by the IndraWorks commissioning tool:

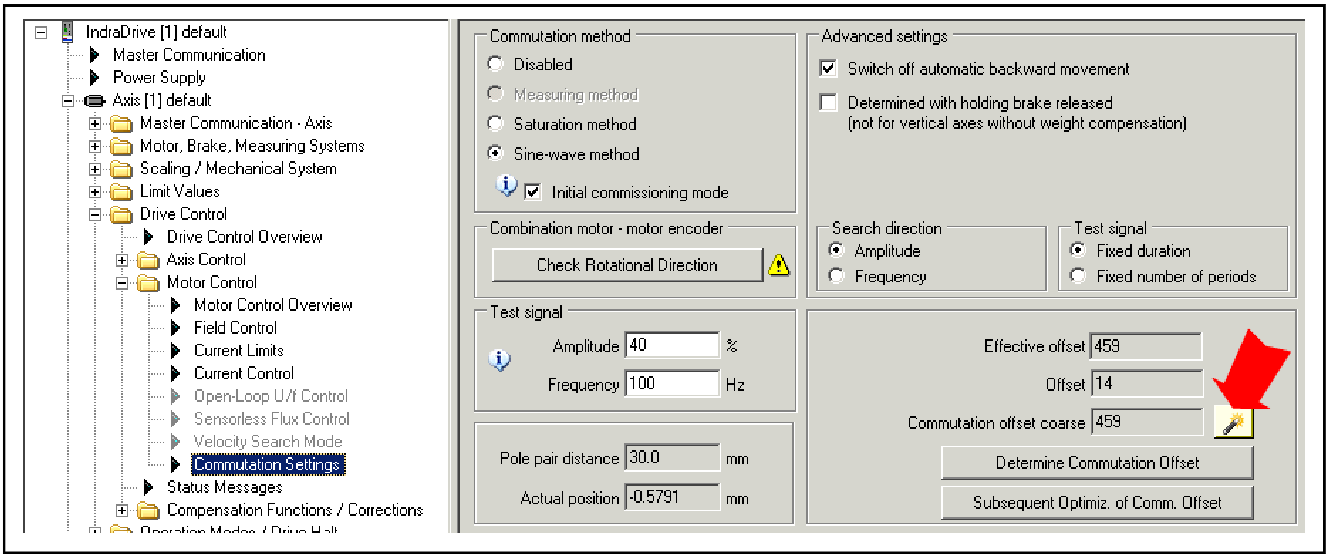


Fig. 6-110: IndraWorks Dialog for Commutation Setting with Indication on Start Button for the Subdialog for Determining the "Commutation Offset Coarse"

To ensure that the synchronous motor is immediately operational by evaluation of the digital Hall sensors when drive enable ("AF") is set for the first time, a suitable value for "P-0-0509, Commutation offset coarse" must be determined. This happens by "saturation method", with ironless motors by "sine-wave method".

The "initial commissioning mode" must be activated (P-0-0522). In this mode, the value can be optimized in "P-0-0521, Effective commutation offset" when the drive is active, and "P-0-0509, Commutation offset coarse" described.

Switch the drive to operating mode ("Ab"); first carry out "rotational direction check" of the motor and motor encoder (via IndraWorks dialog, see above, or by "C3600, Motor data identification command" with the corresponding setting of "P-0-0601, Motor data identification command"). In the event of a corresponding error message, invert the rotational direction either of the motor or of the encoder.

- Interchange two motor phases - or -
- Invert the rotational direction of the motor encoder in "S-0-0277, Position feedback 1 type"

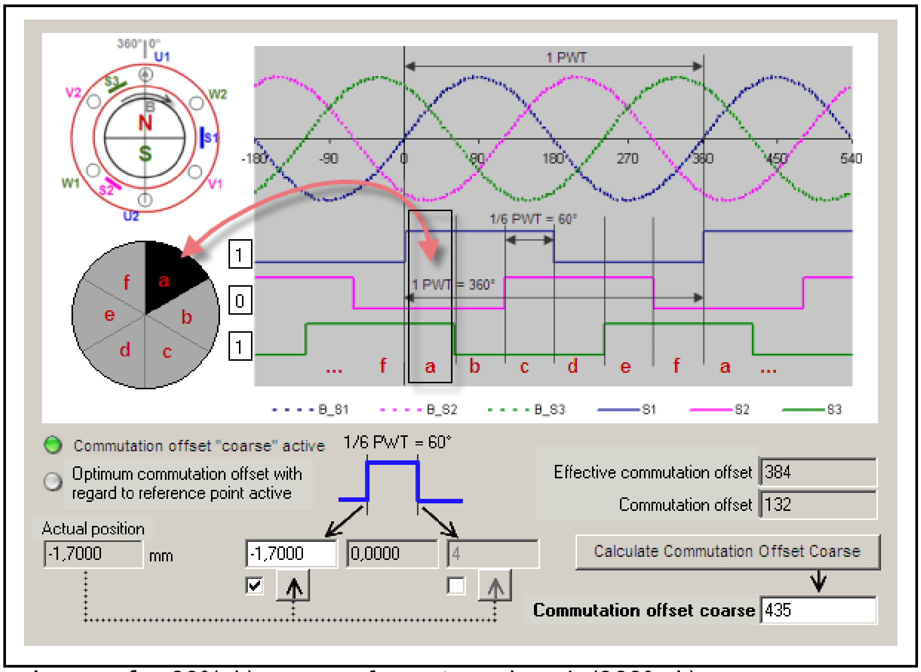
Note on Connecting Hall Sensors

☞ The motor windings and the digital signals of the Hall sensors are to be connected in such a way that the sequence of the Hall sensor signals is cyclically ascending with a positive torque and force command value or positive velocity (S1->S2->S3->S1->....) and the motor encoder displays increasing actual position values!

Drive Control

Determine Coarse Commutation Offset

The determination of the value for "P-0-0509, Commutation offset coarse" ideally follows in the center of one of the 60° ranges that are detected by Hall sensor signals. The signal state of the Hall sensor signals is displayed in the relevant bits of "P-0-0519, Commutation status word" in the IndraWorks subdialog:



a, b, c, ... f 60°(el.) ranges of a motor pole pair (360° el.)
S1, S2, S3 Hall sensors and their signals
[1], [0], [1] Signal state of the Hall sensors, in this case the rotor position in sector "a"

Fig. 6-111: Portrayal of signal states of the hall sensor signals in the subdialog of "commutation setting", identification of "60° ranges"

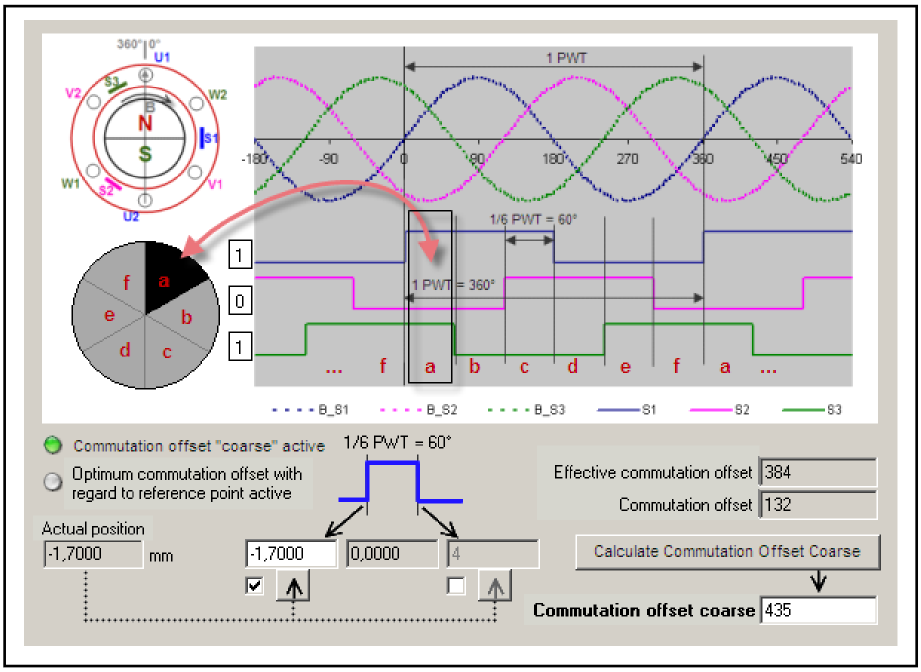


Fig. 6-112: EN: Portrayal of signal states of the hall sensor signals in the subdialog of "commutation setting", identification of "60° ranges"

Ideally position the motor manually in the center of a 60° range, observing the signal states and the actual position (S-0-0051). Carry out the **commutation offset determination** as follows and the result is entered manually in "Commutation offset coarse" (P-0-0509):

- Switch drive to parameter mode (PM) and then to operation mode (Ab) again. This reinitializes the motor measuring system at the retained center position (condition!).
- Carry out the "determine commutation offset" via the IndraWorks dialog "commutation setting" ("P-0-0524, C1200 Commutation offset setting command").

☞ Perform commutation setting with saturation method or sine-save method, see respective chapter of the Functional Description.

Recommendation: "Subsequently optimize" the determined value by activating via the IndraWorks dialog or by activation of "C5600 Command Subsequent optimization of commutation offset" (see chapter "Basics on Commutation Setting").

☞ If the currentless motor does not stand exactly in the center of a 60° range (cogging torques or external force influence (e.g., influence of the flexible cable track or force due to weight) or cannot be moved manually, the commutation setting can also be carried out at any motor position and the determined commutation offset value can be converted to the center position of the current 60° range (see below).

Calculate Coarse Commutation Offset

The "commutation offset for P-0-0509" (for procedure see above) can be determined at any motor position (observe condition Ab -> PM -> Ab!). The value based on the center of the current 60° range can be calculated using the actual position values of the limits of this 60° range. The calculation is supported by an IndraWorks dialog.

The limits of the 60° range can be determined with active drive ("AF") by a slow overrun. The change of the current 60° sector displayed in the IndraWorks dialog and the associated actual position displayed provide information about the determination of the sector limit. The respective position actual value is to be added in the IndraWorks dialog and start the calculation. The calculated value is displayed and stored directly in P-0-0509!

☞ The accuracy of P-0-0509 depends on the position of the Hall sensors, their switching hysteresis and on the accuracy of the determination of the limits of the 60° range. It is recommended to travel to the respective limit from both directions of motion and to generate the average value of the values determined for P-0-0509, if necessary several times.

Travel Velocity for Determining the Limits

The sector limits should be determined with a suitable velocity in order to determine their actual position values with sufficient precision. The signal status of the Hall sensor is only reformed in the 64ms cycle, therefore, the velocity for overrunning the sector limit should not exceed following values and the selected values should be better or considerably lower:

Drive Control

Linear motor

$$v\_max = \frac{(P\text{-}0\text{-}0018)}{0{,}064\ min}$$

Rotary motor

$$n\_max = \frac{1}{(P\text{-}0\text{-}0018) \times 0{,}064\ min}$$

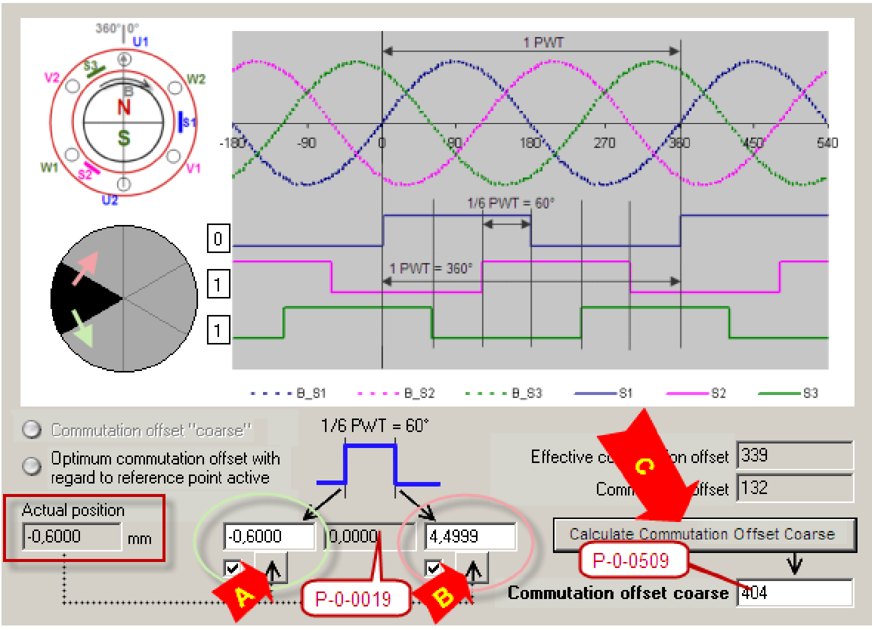
v_max Maximum tolerable value of the velocity in mm/min

n_max Maximum tolerable value of the speed in min^{-1}

P-0-0018 Pole pair distance in mm or number of pole pairs

Fig. 6-113: Highest Tolerable Values of Velocity and Speed to Determine the Sector Limits

Calculation by Means of Both Position Limits of the 60° Range



P-0-0509 Commutation offset coarse

P-0-0019 Initial position value

Arrows A and B Press the arrow field to apply the respective limit of the current 60° range

Arrow C Press the button for the calculation after applying the two limits of the current 60° range

Fig. 6-114: Calculation of "P-0-0509, Commutation offset coarse" by both limits of the current 60° range. The Initial Position Must be "P-0-0019, Initial position value"!

☞ The two sector limits must first be traveled to from inside outwards, then P-0-0509 must be determined; then the sector limits must be traveled to from outside inwards and P-0-0509 must be determined, too. Enter the average value of the two values in P-0-0509. This compensates for the switching hysteresis of the Hall sensors, which depends on the direction of movement, and improves the quality of the value of P-0-0509.

Calculation formula (alternative):

$$P\text{-}0\text{-}0509 = (P\text{-}0\text{-}0521) + d = (P\text{-}0\text{-}0521) + \frac{1024}{12}\ \frac{[x_1 + x_2 - 2\ (P\text{-}0\text{-}0019)]}{(x_2 - x_1)}$$

Condition for linear motors: $x_2 - x_1 < \frac{P\text{-}0\text{-}0018}{6}\ f\_digHS$

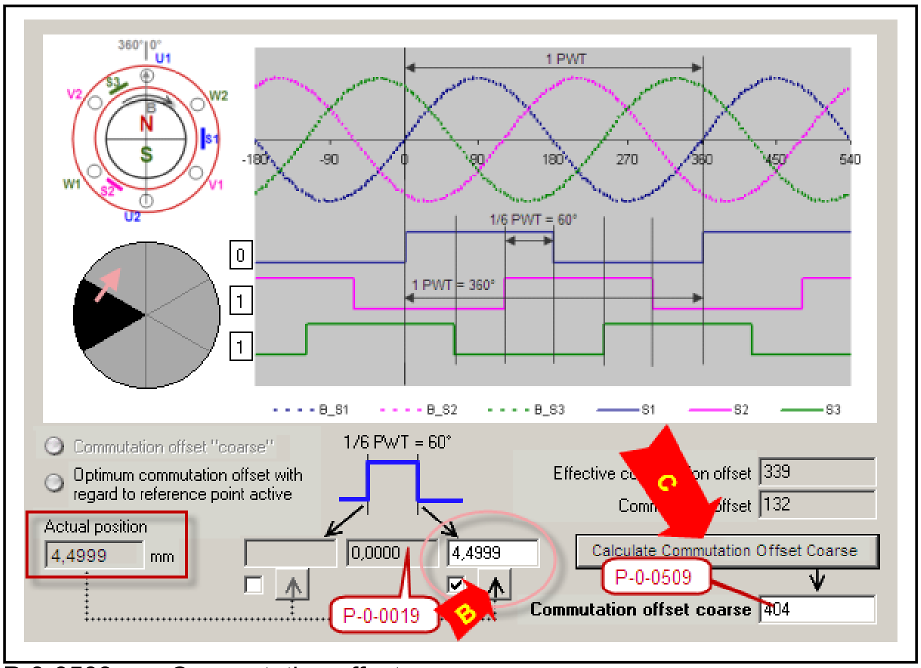
Condition for rot. motors: $x_2 - x_1 < \frac{60°(mech.)}{P\text{-}0\text{-}0018}\ f\_digHS$

f_digHS = 1 .... approx. 1,5; depending on installation accuracy of hall sensors

P-0-0509	Commutation offset coarse
P-0-0521	Effective commutation offset
P-0-0018	Number of pole pairs (rot. motor) or pole pair distance (lin. motor)
P-0-0019	Initial position value (default "0")
x_1	Maximum actual position value of the 60° range
x_2	Maximum actual position value of the 60° range

Fig. 6-115: Formula for calculating "P-0-0509, Commutation offset coarse" using both limits of the 60° range

Calculation by Means of the Number of Pole Pairs or Pole Pair Distance and Positive Position Limit of the 60° Range



P-0-0509	Commutation offset, coarse
P-0-0019	Initial position value
Arrow B	Press the arrow field to apply the positive limit of the current 60° range
Arrow C	Press the button for the calculation after applying the positive limit of the current 60° range

Fig. 6-116: Calculation of "P-0-0509, Commutation offset coarse" by the positive limit of the current 60° range. The Initial Position Must be "P-0-0019, Initial position value"!

☞ The sector limit must first be traveled to from inside outwards, then P-0-0509 must be determined, then the sector limit must be traveled to from outside inwards and P-0-0509 must be determined, too. Enter the average value of the two values in P-0-0509. This compensates for the switching hysteresis of the Hall sensor, which depends on the direction of movement, and improves the quality of the value of P-0-0509.

Calculation formula (alternative):

$$\text{rot: } P\text{-}0\text{-}0509 = P\text{-}0\text{-}0521 + d = P\text{-}0\text{-}0521 + \frac{1024}{12}\left[\frac{P\text{-}0\text{-}0018}{30°}\left(x_2 - (P\text{-}0\text{-}0019)\right) - 1\right]$$

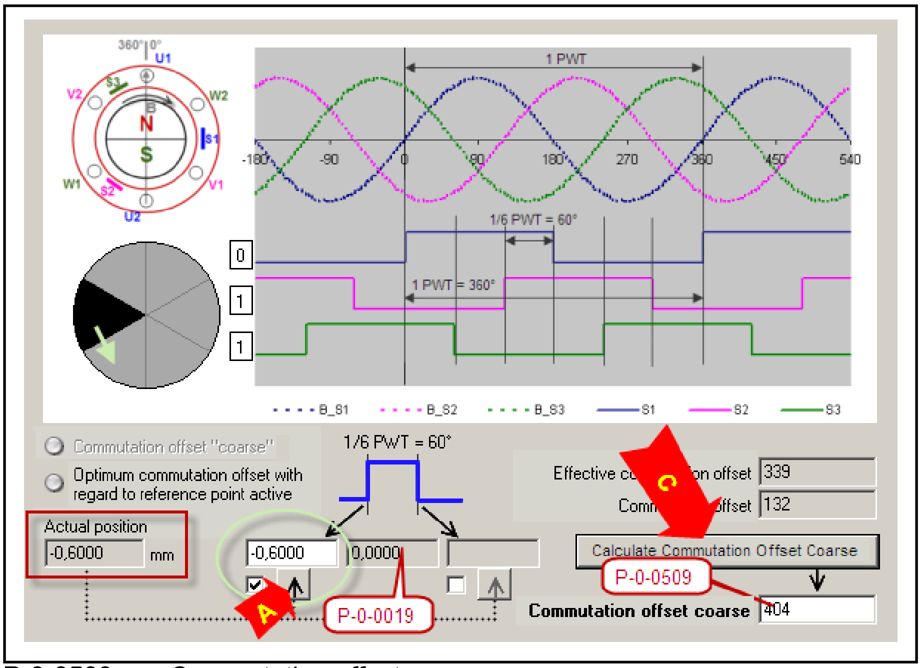
$$\text{lin: } P\text{-}0\text{-}0509 = P\text{-}0\text{-}0521 + d = P\text{-}0\text{-}0521 + \frac{1024}{12}\left[\frac{12}{P\text{-}0\text{-}0018}\left(x_2 - (P\text{-}0\text{-}0019)\right) - 1\right]$$

$$\text{Condition: } |d| \leq \frac{1024}{12}, \text{ otherwise the 60° range is not correct}$$

rot. and lin.	Formula for rotary and linear motors
P-0-0509	Commutation offset, coarse
P-0-0521	Effective commutation offset
P-0-0018	Number of pole pairs (rot. motor) or pole pair distance (lin. motor)
P-0-0019	Initial position value
x_2	Limit of the 60° range in positive direction

Fig. 6-117: Formula for Calculating "P-0-0509, Commutation offset coarse" by Means of the Pole Pair Distance and the Positive Limit of the 60° Range

Calculation by Means of the Number of Pole Pairs or Pole Pair Distance and Negative Position Limit of the 60° Range



P-0-0509	Commutation offset, coarse
P-0-0019	Initial position value
Arrow A	Press the arrow field to apply the negative limit of the current 60° range
Arrow C	Press the button for the calculation after applying the negative limit of the current 60° range

Fig. 6-118: Calculation of "P-0-0509, Commutation offset coarse" by the negative limit of the current 60° range. The Initial Position Must be "P-0-0019, Initial position value"!

☞ The sector limit must first be traveled to from inside outwards, then P-0-0509 must be determined, then the sector limit must be traveled to from outside inwards and P-0-0509 must be determined, too. Enter the average value of the two values in P-0-0509. This compensates for the switching hysteresis of the Hall sensor, which depends on the direction of movement, and improves the quality of the value of P-0-0509.

Calculation formula (alternative):

$$\text{rot: } P\text{-}0\text{-}0509 = P\text{-}0\text{-}0521 + d = P\text{-}0\text{-}0521 + \frac{1024}{12}\left[\frac{P\text{-}0\text{-}0018}{30°}\left(x_1 - (P\text{-}0\text{-}0019)\right) + 1\right]$$

$$\text{lin: } P\text{-}0\text{-}0509 = P\text{-}0\text{-}0521 + d = P\text{-}0\text{-}0521 + \frac{1024}{12}\left[\frac{12}{P\text{-}0\text{-}0018}\left(x_1 - (P\text{-}0\text{-}0019)\right) + 1\right]$$

$$\text{Condition: } |d| \leq \frac{1024}{12}, \text{ otherwise the 60° range is not correct}$$

rot. and lin.	Formula for rotary and linear motors
P-0-0509	Commutation offset, coarse
P-0-0521	Effective commutation offset
P-0-0018	Number of pole pairs (rot. motor) or pole pair distance (lin. motor)
P-0-0019	Initial position value
x_1	Limit of the 60° range in negative direction

Fig. 6-119: Formula for Calculating "P-0-0509, Commutation offset coarse" by Means of the Pole Pair Distance and the Negative Limit of the 60° Range

Store the Coarse Commutation Value

☞ Determine the value for "P-0-0509, Commutation offset coarse" using several determination and calculation procedures at slightly different positions within a pair of poles. The value can thereby be verified and an average value can be generated.

Enter the manually calculated value where required in "P-0-0509, Commutation offset coarse". It is thereby stored in the controller and is immediately available when the drive is switched on again.

Store and Activate "Optimum Commutation Offset with Regard to Reference Point"

Enter the settings for the use of the "optimum commutation offset with regard to reference point" and store the current value of P-0-0521 based on a fixed, reproducible motor or axis position:

- With synchronous motors with relative motor encoder and one reference mark per revolution:
  - In "S-0-0277, Position feedback 1 type", set the bit for "cyclic marker evaluation".

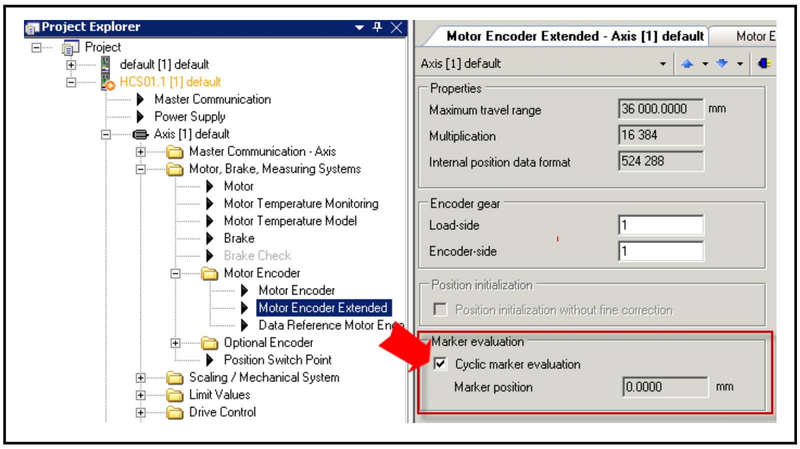


Fig. 6-120: IWD Dialog for Activation of "Cyclic Marker Evaluation"

  - In "P-0-0522, Control word for commutation setting", activate optimization of the value of P-0-0521 for rotary synchronous motors.

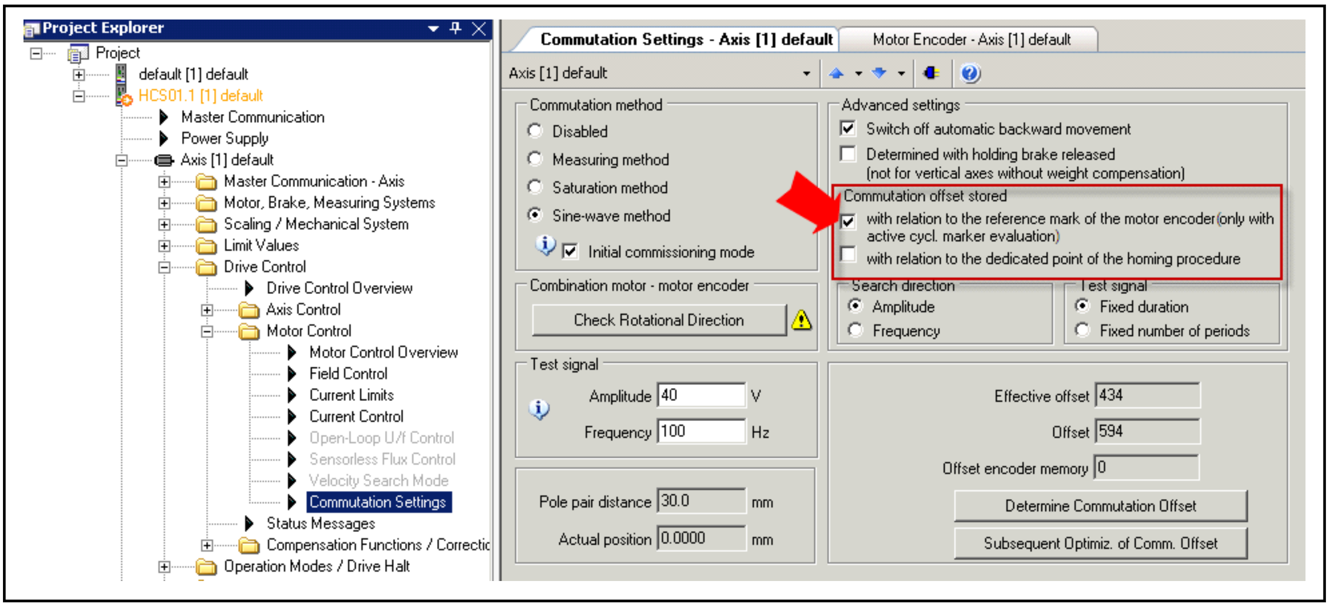


Fig. 6-121: IWD Dialog for Configuration of the "Optimum Commutation Offset with Regard to Reference Point"

On the user-side, now make the motor move over the reference mark of the encoder: Travel the drive or move it manually. The value of P-0-0521 is thereby converted to the reference mark, due to the active initial commissioning mode, and stored in "P-0-0508, Commutation offset".

- Synchronous motors with relative motor encoder with several reference marks or none per motor revolution or linear motor travel range:
  – Activate the optimization of the value of P-0-0521 in "P-0-0522, Control word for commutation setting".

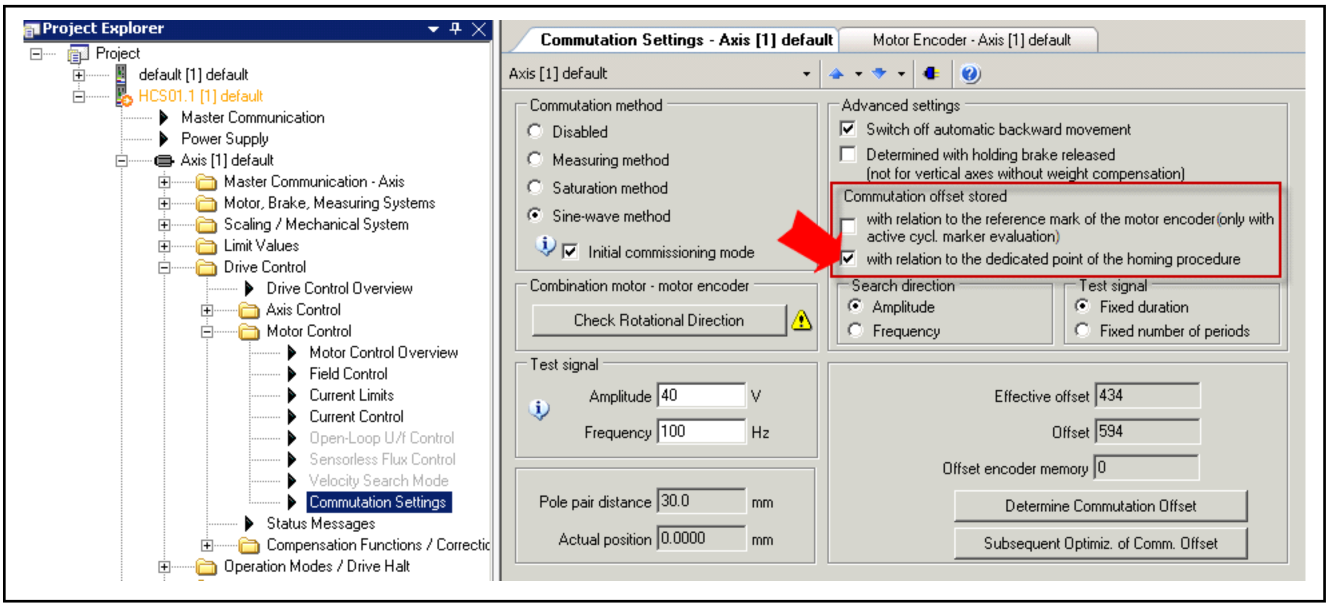


Fig. 6-122: IWD Dialog for Configuration of the "Optimum Commutation Offset with Regard to Reference Point"

– Start "S-0-0148, C0600 Drive-controlled homing procedure command".

The drive now performs the homing motion and moves over the dedicated point for homing. As a result, contingent on the active "Initial commissioning mode", the value of P-0-0521 is calculated to the dedicated point for homing and saved in "P-0-0508, Commutation offset".

Ending Initial Commissioning

- The fact that the commutation offset calculated to the reference point was correctly saved in "P-0-0508, Commutation offset", is displayed in "P-0-0519, commutation status word". Check whether the affected bit was set. If not, repeat the save process!
- After the commutation offset has been saved properly, end the "initial commissioning"! As a result, the value in P-0-0508 and P-0-0509 is protected from unwanted changes.
- After ending initial commissioning, save the axis parameter set!

Re-commissioning for Third-Party Motors with Digital Hall Sensors and Relative Motor Encoder

"Coarse commutation" after switching on

The stored value of "P-0-0509, Commutation offset coarse" is applied to "P-0-0521, Effective commutation offset" when progressing to the operating mode ("Bb" or "Ab"). At drive enable (AF), this value takes effect as the commutation offset in the drive. Depending on the motor position when it is switched on, the drive possibly and initially works with a performance reduced to 87% (see above).

Commutation Comparison by Sector Limit

When passing the next limit of the current 60° electrical range from the start position, the active coarse commutation offset which would be correct for the middle of the 60° electrical sector is automatically adjusted (adapted) to the actual starting position. As a result, the performance of the drive improves to approximately 97%.

The comparison should be made at a suitable speed to ensure that the controller can establish the sector limit with sufficient precision. The signal state of the Hall sensors is read in a 1ms cycle, the speed for passing the sector limit may not exceed the following values, and should be considerably less:

Linear motor:

$$v\_max = \frac{P\text{-}0\text{-}0018}{0{,}001\ min}$$

Rotary motor:

$$n\_max = \frac{1}{(P\text{-}0\text{-}0018) \times 0{,}001\ min}$$

v_max	Maximum value of the velocity in mm/min
n_max	Maximum value of speed in min^{-1}
P-0-0018	Pole pair distance in mm or number of pole pairs

Fig. 6-123: Maximum value of the velocity/speed when passing the sector limit for automatic comparison of the coarse commutation offset value.

If the velocity or speed exceeds the maximum value shown above when passing the sector limit, automatic adjustment of the coarse commutation offset value is not carried out! Control is possible via "P-0-0519, Commutation status word"!

☞
- On motors with an encoder combination (1Vss and dig. Hall sensors), "coarse commutation " and " commutation adjustment" are mandatory!
- "Optimum commutation offset with regard to reference point" is only effective if configured during initial commissioning and executed after appropriate preparatory work!

Optimum Commutation Offset with Regard to Reference Point

If, during initial commissioning in "P-0-0522, Control word for commutation setting" use of "optimum commutation offset with regard to reference point" was activated, after the initial drive enable (AF) and when passing the reference mark of the motor encoder or dedicated point for homing, the value of "P-0-0521 Effective commutation offset" is optimized by adding a correction value. The drive now works at maximum performance (100%). This correction value is the difference between the value in P-0-0508 and the value converted to the reference mark of the motor encoder or dedicated point homing of P-0-0521.

- Rotary synchronous motors with relative motor encoder and one reference mark per revolution:

  When the motor moves over the reference mark, for example by the setting of the command values, the correction value is determined and automatically added to P-0-0521. The effective commutation offset thereby corresponds to the value stored in P-0-0508.

- Synchronous motors with relative motor encoder with several reference marks or none per motor revolution or linear motor travel range:

  When the motor moves over the dedicated point for homing by the start of "S-0-0148, C0600 Drive-controlled homing procedure command", the correction value is determined and automatically added to P-0-0521. The effective commutation offset thereby corresponds to the value stored in P-0-0508.

☞ See also "Basics on Commutation Setting".

Status of Commutation

The current status of the commutation setting during operation of the motor is indicated by the bits from "P-0-0519, Commutation status word":

- The drive works with "P-0-0509, Commutation offset coarse" (reduced performance)
- The drive works with adjusted coarse commutation offset value (automatic adjustment via Hall sensor sector limit)
- The drive works with the "optimum commutation offset with regard to reference point" (full performance)

6.7 Limitations

6.7.1 Overview of Limitations

To protect the mechanical axis system, the controllers and the motors against overload, IndraDrive devices have different possibilities of limitation:

- Torque/force limitation
  - Axis-side torque/force limit values, depending on the preceding sign
  - Axis-side torque/force limit values, related to the absolute value (independent of the preceding sign)
- Current limitation
  - Absolute current limit values, depending on controller or motor
  - Dynamic current limitation, depending on the thermal load of controller or motor
- Velocity limitation
  - Motor-side velocity limit values
  - Axis-side velocity limit values

- Position limitation
  - Evaluation of axis-side travel range limit switches
  - Firmware-side travel range limit values

The existing limiting facilities are active depending on the method of motor control.

Voltage-Controlled Open-Loop Operation (V/Hz [U/f] Control)

With voltage-controlled, sensorless operation, the following limitations are available to protect the device or motor:

- Torque/force limitation via stall protection controller
- Current limitation via current limitation controller
- Position limitation by
  - Travel range limit switches
  - Software limit switches

Closed-Loop Operation of Motors (FXC, FOC, FOCsl)

In closed-loop operation (flux-controlled or current-controlled), there are the following parameterizable limitations to protect the device or motor:

- Torque/force limitation
- Current limitation
- Velocity limitation
- Position limitation by
  - Travel range limit switches
  - Software limit switches

6.7.2 Current and Torque/Force Limitation

Brief Description

Current limitation and torque/force limitation avoid mechanical overload of the axis and thermal overload of motor and controller.

Torque/force limit values due to axis conditions and processing take effect statically as positive and negative limits of the torque/force command value. The thermal overload protection might possibly reduce these limits dynamically, depending on the current thermal load of motor and controller.

Features

- User-side limit values for torque/force (drive-internally converted to current limit values):
  - Bipolar limit values (S-0-0092, P-0-0109)
  - Unipolar limit values (S-0-0082, S-0-0083)
- Display of the current torque/force command value in "P-0-0049, Effective torque/force command value"
- Display of the process torque or process force in "S-0-0084, Torque/force feedback value"
- Drive side, absolute current limit values in "S-0-0110, Amplifier peak current" and "S-0-0109, Motor peak current"
- Dynamic current limitation depending on work load reduces maximum current to the thermally allowed continuous current on the basis of motor and amplifier temperature model (depending on motor type and possibly selected cooling type, as well as on PWM frequency and amplifier type); currently available maximum current and thermally possible continuous current displayed in the parameters:
  - P-0-4045, Maximum possible continuous current
  - P-0-4046, Effective peak current

- Resulting torque/force limit values from the user-side torque/force limitations and the (dynamic) current limitation depending on work load are displayed in the parameters:
  - P-0-0442, Actual value torque limit positive (stationary)
  - P-0-0443, Actual value torque limit negative (stationary)
  - P-0-0444, Actual value peak torque limit
- Status word for analysis of the currently active torque/current limitation (P-0-0445)
- Display of effective torque-generating current command value ("limited" current command value) in parameter
  - P-0-0038, Torque-generating current, command value
- Display of actual current values in the parameters
  - P-0-0440, Actual output current value (absolute value)
  - P-0-0043, Torque-generating current, actual value
  - P-0-0044, Flux-generating current, actual value

Pertinent Parameters

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0109, Motor peak current
- S-0-0110, Amplifier peak current
- S-0-0111, Motor current at standstill
- S-0-0112, Amplifier nominal current
- S-0-0384, Amplifier temperature
- P-0-0001, Switching frequency of the power output stage
- P-0-0038, Torque-generating current, command value
- P-0-0049, Effective torque/force command value
- P-0-0051, Torque/force constant
- P-0-0109, Torque/force peak limit
- P-0-0141, Thermal drive load
- P-0-0440, Actual output current value (absolute value)
- P-0-0441, Thermal drive load warning threshold
- P-0-0442, Actual value torque limit positive (stationary)
- P-0-0443, Actual value torque limit negative (stationary)
- P-0-0444, Actual value peak torque limit
- P-0-0445, Status word torque/current limit
- P-0-0045, Control word of current controller
- P-0-0640, Cooling type
- P-0-4034, Thermal time constant of winding
- P-0-4035, Thermal time constant of motor
- P-0-4037, Thermal short-time overload of winding
- P-0-4045, Maximum possible continuous current
- P-0-4046, Effective peak current
- P-0-4058, Amplifier type data

- P-0-4059, Electric type data of power section

Pertinent Diagnostic Messages

- E2050 Device overtemp. prewarning
- E2051 Motor overtemp. prewarning
- E2056 Torque limit = 0
- E2061 Device overload prewarning
- E8055 Motor overload, current limit active
- E8057 Device overload, current limit active
- F2018 Device overtemperature shutdown
- F2019 Motor overtemperature shutdown
- F2021 Motor temperature monitor defective
- F2022 Device temperature monitor defective

Torque/force limitation

The torque/force limit can be freely parameterized by the user and provides bipolar and unipolar limits.

Parameters for bipolar limits:

- S-0-0092, Bipolar torque/force limit value
- P-0-0109, Torque/force peak limit

Parameters for unipolar limits:

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative

The limit value in P-0-0109 can only be entered or changed in "PM". It is the maximum value, independent of the process, allowed for the mechanical axis system. Via the master communication, the control master during operation can cyclically adjust the limit values S-0-0092, S-0-0082 and S-0-0083 to the requirements of the machining process.

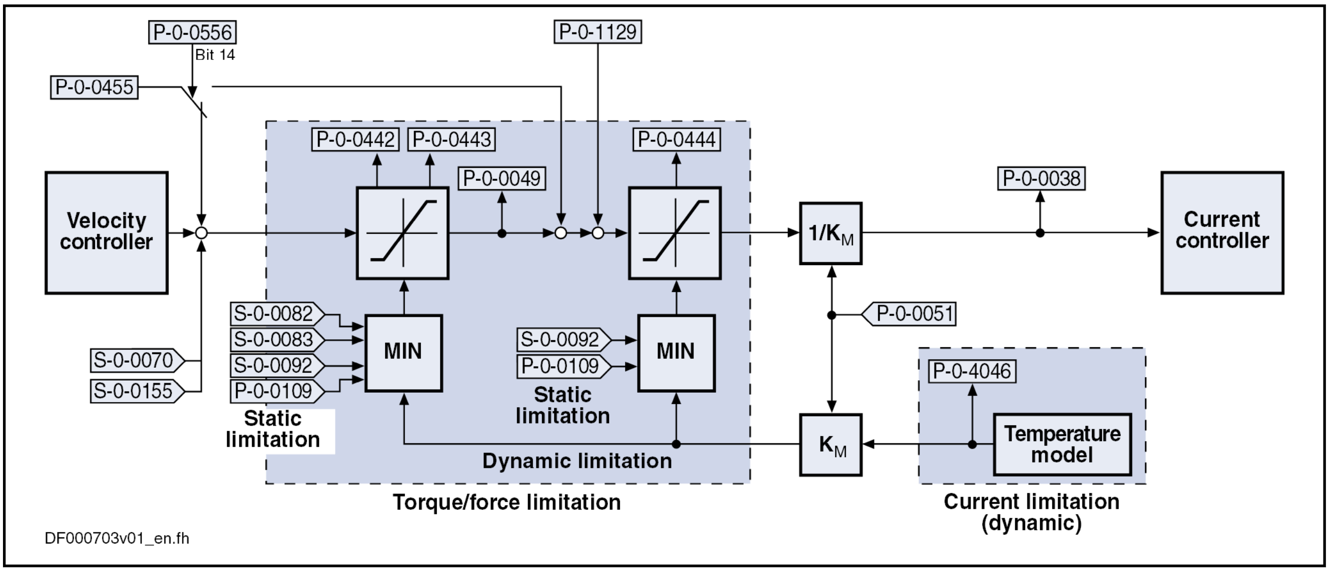
☞ It is always the lowest value of the torque/force limit values entered in the parameters S-0-0082, S-0-0083, S-0-0092 or P-0-0109 that takes effect!

Depending on the method of motor control, the torque/force limitation influences the control of the motor in different ways.

Motor Control Methods FOC, FOCsl, FXC

In closed-loop motor operation, the unipolar torque limitation takes effect on the torque command value output by the velocity controller. The bipolar torque/force limitation takes effect on the value limited in unipolar form, including possibly added feedforward values.

In addition to the user-side static limit values, the current limitation takes effect dynamically, via "P-0-4046, Effective peak current" on the resulting torque/force limit values (converted via "P-0-0051, Torque/force constant").



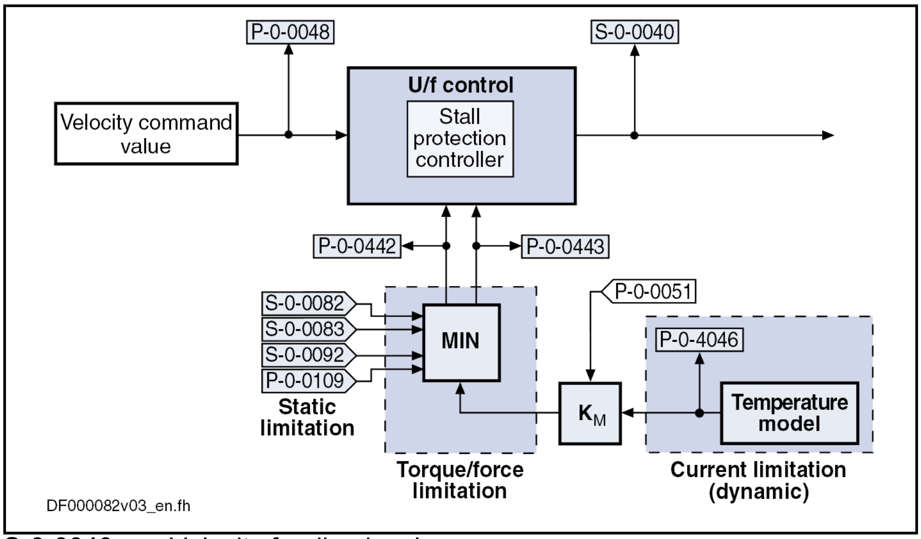
P-0-0070	Effective additive torque/force command value
S-0-0082	Torque/force limit value positive
S-0-0083	Torque/force limit value negative
S-0-0092	Bipolar torque/force limit value
S-0-0155	Friction compensation
P-0-0038	Torque-generating current, command value
P-0-0049	Effective torque/force command value
P-0-0051	Torque/force constant
P-0-0109	Torque/force peak limit
P-0-0442	Actual value torque limit positive (stationary)
P-0-0443	Actual value torque limit negative (stationary)
P-0-0444	Actual value peak torque limit
P-0-0455	Acceleration feedforward actual value
P-0-4046	Effective peak current
P-0-1129	Cogging torque compensation value

Fig. 6-124: Torque/Force Limitation with the Motor Control Methods FOC, FOCsl and FXC

V/Hz (U/f) control

In voltage-controlled, sensorless motor operation (U/f), the torque limitation only takes effect on the stall protection controller. The static negative and positive torque limit values are generated from the lowest values of the torque/force limit values entered in the parameters S-0-0082, S-0-0083, S-0-0092 or P-0-0109.

In addition to the user-side static limit values, the current limitation takes effect dynamically, via "P-0-4046, Effective peak current" on the resulting torque/force limit values (converted via "P-0-0051, Torque/force constant").



S-0-0040 Velocity feedback value
P-0-0048 Effective velocity command value
P-0-0051 Torque/force constant
P-0-0442 Actual value torque limit positive (stationary)
P-0-0443 Actual value torque limit negative (stationary)
P-0-4046 Effective peak current

Fig. 6-125: Torque/force limitation in sensorless V/Hz [U/f] operation of the motor

Current Limitation

Principles of Current Limitation

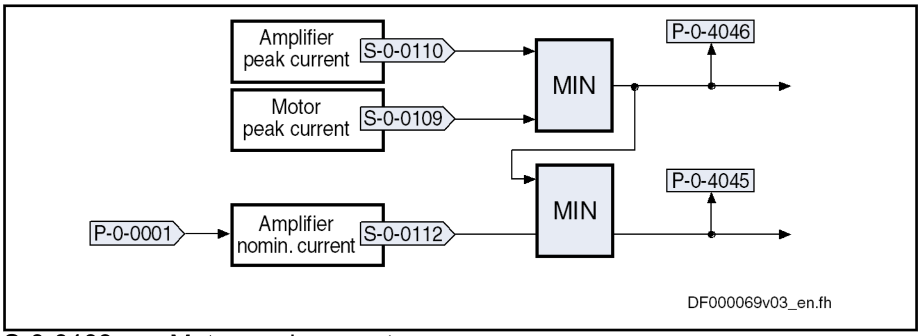
☞ The current limitation cannot be parameterized by the user; it takes effect automatically and protects the motor and the amplifier against inadmissible load.

We basically distinguish the following principles of current limitation:

- **Absolute current limitation** (depending on maximum possible peak currents and continuous currents of motor and drive controller)
- **Dynamic peak current limitation** (depending on work load, realized by motor and amplifier temperature models)

Absolute Current Limitation

The figure below illustrates the generation of the maximum values for continuous current and peak current from the motor- and controller-specific current data (without thermal load of motor and controller).



S-0-0109	Motor peak current
S-0-0110	Amplifier peak current
S-0-0112	Amplifier nominal current
P-0-0001	Switching frequency of the power output stage
P-0-4045	Maximum possible continuous current
P-0-4046	Effective peak current

Fig. 6-126: Generating the Maximum Values for Continuous Current and Peak Current

Maximum Possible Continuous Current (P-0-4045)

The maximum possible continuous current (P-0-4045) is the minimum value from the maximum allowed continuous current of the controller (S-0-0112, Amplifier nominal current) and the effective peak current (P-0-4046, Effective peak current).

The nominal current of the amplifier (S-0-0112, Amplifier nominal current) basically depends on the switching frequency of the power section (P-0-0001). With a setting of 12 kHz or 16 kHz in "P-0-0001, Switching frequency of the power output stage", the currently effective switching frequency can be reduced depending on the work load. This increases the allowed continuous current compared to the value at a higher switching frequency (see below "Continuous Current of Controller Depending on Work Load at PWM of 12 kHz or 16 kHz"). However, this increase in the continuous current, just like the reduction of the continuous current at motor standstill, is not displayed in "P-0-4045, Maximum possible continuous current".

Effective Peak Current (P-0-4046)

The output current of the controller is dynamically limited, depending on the thermal load of the motor or controller. The current limit value is displayed in parameter "P-0-4046, Effective peak current". The maximum value results from the minimum of the values of "S-0-0109, Motor peak current" and "S-0-0110, Amplifier peak current".

Dynamic Current Limitation

With dynamic current limitation, the thermal load of controller and motor is determined by means of temperature model calculation, depending on the value in parameter "P-0-0440, Actual output current value (absolute value)" and the duration of effectiveness of this current. Due to the current load, the maximum possible amplifier current or motor current can be limited to the continuously possible current (continuous current):

- **Limitation of amplifier current**

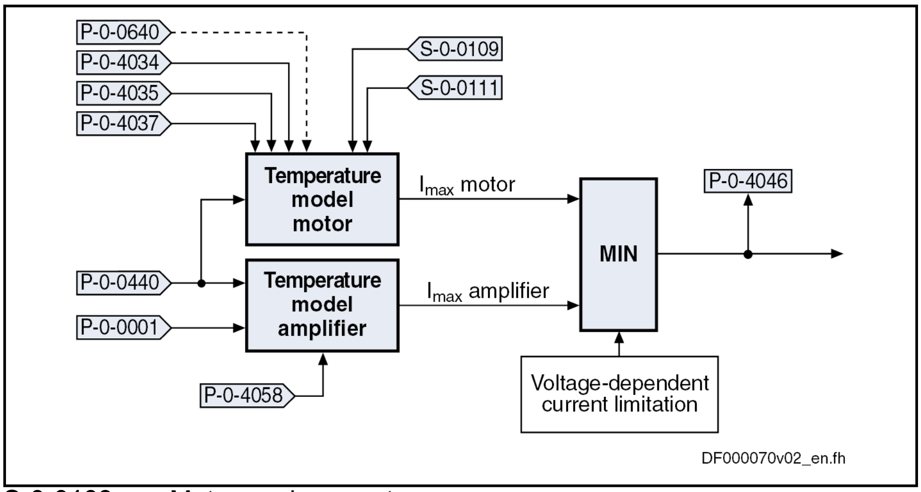
  It is used to protect the drive controller against overload. The firmware-side temperature model calculation takes place on the basis of the amplifier type data determined by the hardware.

  Note: The amplifier type data are determined at the factory and stored in parameter "P-0-4058, Amplifier type data" on the power section.

- **Limitation of motor current**

It is used for overload protection of the motor with peak load and short-time overload operation. The firmware-side temperature model calculation takes place on the basis of motor-specific temperature model data.

Note: In addition, the temperature sensor of the motor might possibly support thermal overload protection (continuous current, rms current).



S-0-0109	Motor peak current
S-0-0111	Motor current at standstill
P-0-0001	Switching frequency of the power output stage
P-0-0440	Actual output current value (absolute value)
P-0-0640	Cooling type
P-0-4034	Thermal time constant of winding
P-0-4035	Thermal time constant of motor
P-0-4037	Thermal short-time overload of winding
P-0-4046	Effective peak current
P-0-4058	Amplifier type data

Fig. 6-127: Generating the Dynamic Peak Current Limit Value (Temperature Model)

Properties

Basic properties of dynamic current limitation:

- The value taking effect is always the lowest value resulting from motor current or amplifier current limitation.
- The current, maximum possible continuous current is displayed in parameter P-0-4045, the effective peak current in parameter P-0-4046.

Depending on the method of motor control, the current limitation influences the control of the motor in different ways.

Motor Control Methods FOC, FOCsl, FXC

In closed-loop motor operation, the current limitation, via the value of parameter "P-0-4046, Effective peak current", possibly takes a reducing effect on the user-side, static torque/force limit values. The dynamic torque/force limit value resulting from the value of P-0-4046 is determined via the parameter "P-0-0051, Torque/force constant".

The current (limited) torque/force command value is displayed in parameter P-0-0049, the corresponding torque-generating command current in parameter P-0-0038.

V/Hz (U/f) control

In voltage-controlled, sensorless motor operation (V/Hz [U/f]), the current limitation takes effect on the current limitation loop and the stall protection loop:

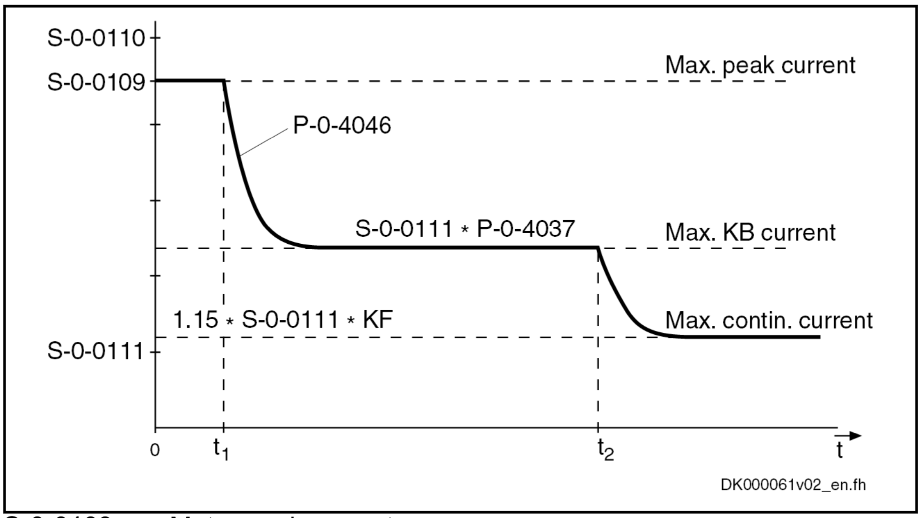
- For the **current limitation controller**, the effective peak current (P-0-4046) is the limit value to which the actual output current value (P-0-0440) is limited by reducing the motor voltage by means of a control process.

- For the **stall protection controller**, the current limitation, in addition to the user-side static limit values, takes effect dynamically via the effective peak current (P-0-4046) on the resulting positive and negative torque/force limit values (P-0-0442, P-0-0443) (converted via "P-0-0051, Torque/force constant").

> The static negative and positive torque limit values are generated from the lowest values of the torque/force limit values entered in the parameters S-0-0082, S-0-0083, S-0-0092 or P-0-0109.

Motor Temperature Model

The value of parameter "P-0-4046, Effective peak current" is only generated by the motor temperature model, if the controller has been sufficiently dimensioned compared to the motor. When the motor has not been thermally preloaded, the following curve results at full motor load:



S-0-0109	Motor peak current
S-0-0110	Amplifier peak current
S-0-0111	Motor current at standstill
P-0-4037	Thermal short-time overload of winding
P-0-4046	Effective peak current
t_1	Max. duration after which the motor temperature model reduces to the max. KB current
t_2	Max. duration after which the motor temperature model reduces to the max. continuous current
KB	Short-time operation (KB = "Kurzzeitbetrieb")
KF	Cooling type factor (see note below)

Fig. 6-128: Curve of Effective Peak Current (P-0-4046) at Motor Load, Generated by Motor Temperature Model

Depending on the load current of the motor, the times t_1 or t_2 can be determined. They apply to motors which have not been thermally loaded and therefore are theoretical maximum values. In motor operation, t_1 and t_2 depend on the following factors:

- Motor-controller combination
- Thermal preload of drive
- Load cycle

The time t_1 applies to load currents greater than, the time t_2 to load currents smaller than the maximum allowed short-time operation current. The values are determined according to the following formula:

Drive Control

$$t_1 = -\ln\left[1-\left(\frac{(P\text{-}0\text{-}4037) \times (S\text{-}0\text{-}0111)}{I_{L1}}\right)^2\right] \times (P\text{-}0\text{-}4034)$$

$$t_2 = -\ln\left[1-\left(\frac{1{,}15 \times KF \times (S\text{-}0\text{-}0111)}{I_{L2}}\right)^2\right] \times \frac{(P\text{-}0\text{-}4035)}{KF}$$

t_1	Max. duration after which the motor temperature model reduces to the max. KB current
t_2	Max. duration after which the motor temperature model reduces to the max. continuous current
I_{L1}	Assumed load current (> max. KB current)
I_{L2}	Assumed load current (max. continuous current < I_L2 < max. KB current)
S-0-0111	Motor current at standstill
P-0-4034	Thermal time constant of winding
P-0-4035	Thermal time constant of motor
P-0-4037	Thermal short-time overload of winding
KF	Cooling type factor (see note below)

Fig. 6-129: Calculating the Time for the Effective Peak Current (at Starting Condition "Motor has not been Thermally Loaded")

☞ The **cooling type factor** depends on the cooling type and the resulting setting of parameter "P-0-0640, Cooling type" (see also Parameter Description):

- 1.0 → For standard cooling (MAF, MBT, MBS, LSF, MLF) and for non-ventilated motors MHD, MSK, MKD, MKE
- 1.5 → For ventilation (only MSK, MKE)
- 1.9 → For liquid-cooling (only MSK, MKE)

At motor standstill (rotary field frequencies < 2 Hz), the motor temperature sensor does not provide sufficient protection; the reduction to the max. allowed continuous current therefore takes place for motors with motor temperature sensor, too. Additionally, the times t1 and t2 are reduced, because the load on the individual windings is higher in standstill.

☞ Specific conditions apply to the distributed servo drives IndraDrive Mi, see Project Planning Manual.

Amplifier Temperature Model

In addition to the motor temperature model, the value of parameter "P-0-4046, Effective peak current" is limited by the amplifier temperature model. The variables of the model calculation are:

- Time behavior of "P-0-0440, Actual output current value (absolute value))"
- P-0-4058, Amplifier type data
- P-0-0001, Switching frequency of the power output stage
- Output frequency of the motor voltage

The value of "S-0-0112, Amplifier nominal current" (maximum continuous current of controller) depends on the setting in parameter "P-0-0001, Switching frequency of the power output stage". At motor standstill (below an output frequency threshold), however, the allowed continuous current value is reduced, compared to the value of S-0-0112, by the temperature model calculation (dynamic reduction of continuous current at motor standstill). At the corresponding motor load, the value of parameter "P-0-4046, Effective peak current" falls below the value of S-0-0112 (unless the motor is the current-limiting component!).

The current data of the amplifiers (power sections of the IndraDrive controllers) for continuous and cyclic load are contained in the separate documentation "Supply Units and Power Sections; Project Planning Manual for Controllers".

The physical data of motor-controller combinations for servo, main drive and S1 print applications can be retrieved via the "DriveSelect" selection data program (Intranet). "DriveSelect" takes the influence of the motor and amplifier temperature models into account!

Continuous Current of Controller Depending on Work Load at PWM of 12 kHz or 16 kHz

The continuous current of the controller is reduced as the switching frequency of the power output stage (PWM frequency) is increased. When the value in parameter "P-0-0001, Switching frequency of the power output stage" has been set to 12 kHz or 16 kHz, it is possible, however, to reduce the switching frequency depending on the thermal load of the controller. This reduces the thermal load of the power output stage and increases the allowed continuous current of the controller. Make the corresponding setting in parameter "P-0-0045, Control word of current controller". This causes the following behavior:

- When the value of "P-0-0141, Thermal drive load" increases to the value set in parameter "P-0-0441, Thermal drive load warning threshold", the switching frequency is internally reduced to 8 kHz. The display "E2061 Device overload prewarning" is generated.
- When the value of "P-0-0141, Thermal drive load" falls below a controller-specific threshold, the value of the switching frequency entered in parameter P-0-0001 takes effect again. The warning "E2061 Device overload prewarning" disappears.

The reduction of the switching frequency depending on the work load only influences the allowed continuous current of the controller. The maximum output current remains at the value belonging to the switching frequency set in parameter P-0-0001! The respective documentations of the power sections contain the current data related to the controller (see "Supply Units and Power Sections; Project Planning Manual").

When the default values for the control loop parameters are loaded ("RL" or command C07_0), the values of the current controller parameters, which have been stored in the encoder data memories of the motors and relate to the PWM frequency of 4 kHz, are converted to the value set in parameter P-0-0001. When the option "reduction of switching frequency depending on work load" has been activated, conversion to the reduced switching frequency takes place!

In the case of manual optimization of the current controller parameters, select the lower switching frequency (PWM). For this purpose, enter the value "0" in parameter "P-0-0441, Thermal drive load warning threshold" before optimization! See also chapter "Motor Control Frequency"

Notes on Commissioning

Current Limitation

The user cannot parameterize the current limitation, because the limit values are resulting from the amplifier and motor data taken as a basis or the application-specific load cycle.

Bipolar Torque Limitation

Bipolar torque/force limits are generally determined to protect the mechanical system so that the allowed stress of the mechanical components (e.g. gear, coupling) cannot be exceeded. The limit value in P-0-0109 refers to the mechanical limits of the axis and can only be entered or changed in "PM".

In certain cases of application, however, the process can require realizing a variable torque limit. This can be done via "S-0-0092, Bipolar torque/force limit value", because this parameter can be cyclically transmitted via the master communication or written via an analog input.

Unipolar Torque Limitation

The unipolar torque limitation by S-0-082 and S-0-0083 only takes effect on the processing forces or processing torques. Acceleration forces / acceleration torques and the acceleration feedforward are not limited (default)! Depending on the process, the values can be cyclically written.

☞ The unipolar torque limitation values S-0-082 and S-0-0083 can have the same signs, e.g. when processing forces are limited for axes with load due to weight ("vertical" axis). The condition is S-0-082 > S-0-0083! See also "P-0-0556, Config word of axis controller"

Diagnostic and Status Messages

For diagnostic purposes, the states of all partial limits is mapped to a status word for torque/force limitation and current limitation (see Parameter Description P-0-0445). As soon as a limit value has been reached, the respective bit is set. This allows immediately recognizing the limiting value and identifying limits possibly parameterized incorrectly.

To protect the amplifier or drive controller and motor, monitoring functions have been implemented that can activate, in conjunction with the current and torque limitation, the warnings and error messages listed below.

Warnings

General:

- E2056 Torque limit = 0

Device-specific warnings:

- E2050 Device overtemp. prewarning
- E2061 Device overload prewarning
- E8057 Device overload, current limit active

Motor-specific warnings:

- E2051 Motor overtemp. prewarning
- E8055 Motor overload, current limit active

Error Messages

Device-specific error messages:

- F2018 Device overtemperature shutdown
- F2022 Device temperature monitor defective

Motor-specific error messages:

- F2019 Motor overtemperature shutdown
- F2021 Motor temperature monitor defective

6.7.3 Velocity limitation

Brief Description

Velocity limitations are implemented in the drive that allow the velocity command value to be limited to a freely definable value or to various positive and negative values.

Features

- Unipolar velocity limit values (S-0-0038, S-0-0039), scaled, with reference to load if necessary
- Cyclically configurable, bipolar velocity limit value (S-0-0091), scaled, with reference to load if necessary
- Bipolar velocity limit value (P-0-0113) of the motor, unscaled, with reference to the motor only

Pertinent Parameters

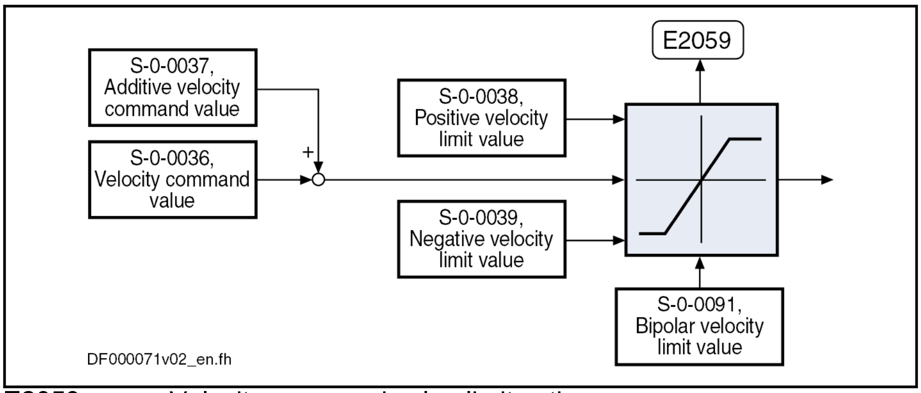
- S-0-0036, Velocity command value
- S-0-0037, Additive velocity command value
- S-0-0038, Positive velocity limit value
- S-0-0039, Negative velocity limit value
- S-0-0091, Bipolar velocity limit value
- P-0-0113, Bipolar velocity limit value of motor

Pertinent Diagnostic Messages

- E2059 Velocity command value limit active
- E2063 Velocity command value > limit value
- F8079 Velocity limit value exceeded

Functional Description

The figure below illustrates the functional principle of velocity limitation:



E2059 Velocity command value limit active

Fig. 6-130: Functional Principle of Velocity Limitation

Notes on Commissioning

The **effective limit** for the maximum allowed positive and negative velocities is determined by means of the **minimum values** of the following parameters:

- **lower (negative) limit** → produced from the minimum value of
  - S-0-0091, Bipolar velocity limit value
  - S-0-0039, Negative velocity limit value
- **upper (positive) limit** → produced from the minimum value of
  - S-0-0091, Bipolar velocity limit value
  - S-0-0038, Positive velocity limit value

- **In addition, the following motor-related limit values take effect**
  - "P-0-0113, Bipolar velocity limit value of motor" (motor-dependent)
  - "S-0-0113, Maximum motor speed" (user-dependent)
-

> The limits have to be adjusted to the mechanical properties! When determining the data, you have to take into account that all velocity command values are thereby limited to this value.
>
> This has to be taken into consideration when defining the travel profiles (target position, velocity and acceleration), because an inadmissible lag error can possibly occur due to the limitation that is taking effect.

> The default value for S-0-0038, S-0-0039 and P-0-0113 is "0". These parameters are thereby switched off. In this case, only "S-0-0091, Bipolar velocity limit value" takes effect.

Diagnostic and Status Messages

- E2059 Velocity command value limit active

  If the resulting velocity command value is within the limit, the "E2059" warning is displayed.
- E2063 Velocity command value > limit value

  "S-0-0036, Velocity command value" is limited to the effective positive and negative velocity limit, when the value in S-0-0036 is higher than this limit. In this case, the warning "E2063" is generated.
- F8079 Velocity limit value exceeded

  The value of the parameter "S-0-0040, Velocity feedback value" is monitored as soon as it is outside of the standstill window S-0-0124. When it exceeds the 1.125-fold effective positive or negative velocity limit, the error message "F8079" is generated.

6.7.4 Position Limitation/Travel Range Limit Switches

Brief Description

To avoid accidents and damages to the machine, comprehensive preventive safety precautions are provided. Part of these safety precautions is the limitation of the allowed working range (travel range) by the drive. For this purpose, position monitoring functions and position limitations have been implemented in the drive.

⚠ CAUTION

The travel range monitoring function (travel range limit switches or software limit switches) only fulfills the requirements for protecting machinery, but is not sufficient for personal protection!

Realizing Travel Range Monitoring

The drive provides two possibilities of determining and monitoring a limitation of the working range (travel range):

- Monitoring of **position limit values (software limit switches)**

  Monitoring of the motor position for exceeding one of the two position limit values (positive/negative → S-0-0049/S-0-0050) by the homed actual position value (S-0-0403), i.e. value related to the machine zero point.

- Monitoring of **travel range limit switches**

  Monitoring for activation of one of the two travel range limit switches (Limit+, Limit-) that are connected to the digital inputs of the drive.

☞ The functionality of the travel range limit switches is only guaranteed, if the corresponding digital inputs have been configured for this purpose!

See "Digital Inputs/Outputs"

Features of Travel Range Limit Switches

- 2 travel range limit switches (Limit+, Limit-) can be monitored at the drive
- Signal behavior of travel range limit switches (N/C and N/O) can be set
- Travel range limit switches activated via parameter
- Reaction (error/warning) when exceeding travel range can be set
- Status display of travel range limit switches
- Command values monitored for validity when limit switch activated
- Travel range limit switches evaluated and position limit value monitor activated in 2 ms clock

Features of Position Limit Values

- 2 position limit values ("software limit switches") can be parameterized; only operational when axis has been homed
- Reaction (error/warning) when exceeding position limit values can be set
- Position limit values activated via parameter
- Automatic reference to measuring system that has been homed
- Command values monitored for validity when position limit values exceeded

Pertinent Parameters

- S-0-0012, Class 2 diagnostics
- S-0-0049, Positive position limit value
- S-0-0050, Negative position limit value
- S-0-0055, Position polarities
- S-0-0147, Homing parameter
- S-0-0403, Position feedback value status
- S-0-0478, Position/travel range limit status

  (Alias: P-0-0091, Position/travel range limit status)
- S-0-0532, Travel range limit parameter

  (Alias: P-0-0090, Travel range limit parameter)
- P-0-0222, Travel range limit switch inputs

Pertinent Diagnostic Messages

- E2053 Target position out of travel range
- E8029 Positive position limit exceeded
- E8030 Negative position limit exceeded
- E8042 Both travel range limit switches activated

- E8043 Positive travel range limit switch activated
- E8044 Negative travel range limit switch activated
- F6028 Position limit value exceeded (overflow)
- F6029 Positive position limit exceeded
- F6030 Negative position limit exceeded
- F6042 Both travel range limit switches activated
- F6043 Positive travel range limit switch activated
- F6044 Negative travel range limit switch activated

Travel range limit switches

At the drive, 2 travel range limit switches (Limit+, Limit-) can be connected and monitored; they can be connected to the digital inputs at the control section.

☞ The travel range limit switch inputs are polled every 2 ms so that the assigned error reaction is started at the earliest approx. 3 ms after the limit switch has been activated.

Activating the Monitoring Function

Monitoring for exceeding the travel range limit switches is only carried out when the monitor was activated via bit 1 of "S-0-0532, Travel range limit parameter"

"" .

Reaction when Exceeding the Travel Range

The drive reaction to exceeding the travel range can be determined via bit 2 of "S-0-0532 Travel range limit parameter".

Exceeding Travel Range as an Error

When "0" is entered in bit 2 of S-0-0532, exceeding the travel range is handled as an error with the reaction "velocity command value reset".

Drive behavior:

- After the velocity command value has been reset, the drive switches off the internal drive enable and thus is torque-free.
- The "ready for operation" contact opens.

See also "Velocity Command Value Reset" in section "Error Reactions: Best possible deceleration"

Exceeding Travel Range as a Warning

When "1" is entered in bit 2 of S-0-0532, exceeding the travel range is handled as a warning with the reaction "velocity command value reset".

Drive behavior:

- The drive does not switch off the internal drive enable signal.
- As long as the warning condition is present, i.e. the limit switch is activated, only such command values are accepted that lead back to the allowed range. The command value check depends on the active operation mode (see "Notes on Commissioning" below).

See also "Velocity Command Value Reset" in section "Error Reactions: Best possible deceleration"

☞ Shutting down the axis using a velocity command value ramp is not possible! Shutdown always takes place in the fastest possible way with the maximum allowed torque/force.

Position Limit Values (Software Limit Switches)

Parameters for Position Limit Values

The following parameters are available to set the travel range via position limit values:

- S-0-0049, Positive position limit value
- S-0-0050, Negative position limit value

> ☞ The position limit values are monitored every 2 ms so that the corresponding error reaction is started at the earliest approx. 3 ms after the position limit has been exceeded.

Requirements for Activating the Function

Requirements for using (activating) the position limit value monitoring function:

- The position data reference of the drive must have been established (i.e. the encoder system of the active operation mode must be in reference). The status bit in "S-0-0403, Position feedback value status" then is "1".
- Monitoring of the position limit values has been activated in "S-0-0055, Position polarities" (bit 4 = 1).

Dedicated Point for Monitoring the Position Limit Values

When 2 measuring systems are used, the drive, for position limit value monitoring, automatically refers to the measuring system that has been homed.

> ☞ When two measuring systems are used and both are in reference, the encoder selected in S-0-0147 (bit 3) is used.

Exceeding the Position Limit Values

Exceeding the position limit values is detected when the actual position value of the active operation mode is outside the travel range defined by the position limit values.

Reaction when Exceeding Position Limit Values

The drive reaction to exceeding the position limit values can be determined via bit 2 of "S-0-0532, Travel range limit parameter".

Exceeding Position Limit Values as an Error

When "0" is entered in bit 2 of parameter S-0-0532, exceeding the position limit values is handled as an error with the reaction "velocity command value reset" (see also section "Error Reactions: Best Possible Deceleration".

Drive behavior:

- After the speed command value has been reset, the drive switches off the internal drive enable and thus is torque-free.
- The "ready for operation" contact opens.

See also "Velocity Command Value Reset" in section "Error Reactions: Best possible deceleration"

Exceeding Position Limit Values as a Warning

When "1" is entered in bit 2 of S-0-0532, exceeding the position limit values is handled as a warning with the reaction "velocity command value reset".

Drive behavior:

- The drive does not switch off the internal drive enable signal.
- As long as the warning condition is present, i.e. the limit switch is activated, only such command values are accepted that lead back to the allowed range. The command value check depends on the active operation mode (see "Notes on Commissioning" below).

See also "Velocity Command Value Reset" in section "Error Reactions: Best possible deceleration"

☞ Shutting down the axis using a velocity command value ramp is not possible! Shutdown always takes place in the fastest possible way with the maximum allowed torque/force.

Leaving the Inadmissible Travel Range

After the allowed travel range has been exceeded, the command values are checked for validity and only such command values are accepted that lead back to the allowed travel range.

☞ Moving to the allowed travel range is also possible in the case of error!

Notes on Commissioning

When parameterizing the position limit values, take the positions of the travel range limit switches into account. The working range defined with the two position limit values (S-0-0049, S-0-0050) should be within the working range defined with the travel range limit switches. As long as the position data reference has not been established yet (axis not homed), the function of the software limit switches (position limit values) is not yet guaranteed. Independent thereof is the function of the travel range limit switches that always causes the drive to be switched off when the defined limit is exceeded and therefore avoids collision (machine protection).

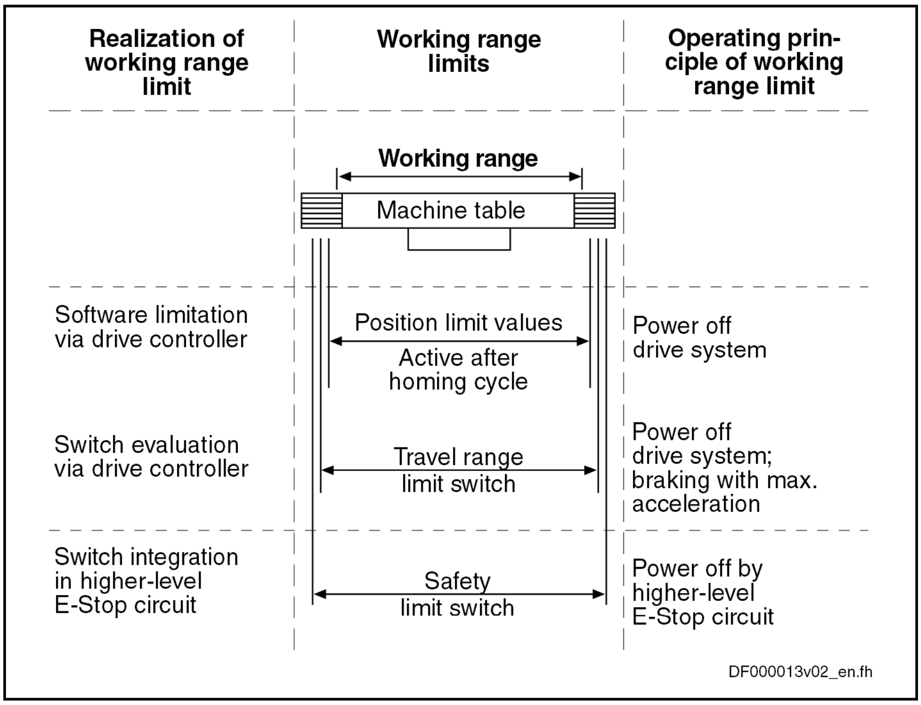


Fig. 6-131: Realizations and Operating Principles of Working Range Limitations

☞ The safety limit switches that can be included in the E-Stop circuit (see separate documentation "Project Planning Manual for Power Sections"), are the last safeguard by the drive. In addition, the control master can monitor the position limit values.

Activating the Position Limit Value Monitor

The monitor of the position limit values is activated by setting bit 4 in "S-0-0055, Position polarities".

Before activating the position limit value monitoring, it is necessary to establish the drive's position data reference, because position limit values are only useful and operational when the axis was homed.

Activating the Travel Range Limit Switches

The travel range limit switches are activated by setting bit 1 in "S-0-0532, Travel range limit parameter".

When activating the travel range limit switches, make sure that the respective digital inputs (Limit+, Limit-) were configured accordingly, because otherwise the limit switch function is not guaranteed.

See "Digital Inputs/Outputs"

Signal Behavior of Travel Range Limit Switches (N/O-N/C)

Via bit 0 of "S-0-0532, Travel range limit parameter" it is possible to set whether the connected travel range limit switches are evaluated as N/O or N/C. This allows activating an inversion of the signal.

Recommissioning in Case of Error

After a limit switch or limit value error occurred (diagnostic messages F6043/F6044 or F6029/F6030), the following steps are required for recommissioning:

- Clear the error message via the command "S-0-0099, C0500 Reset class 1 diagnostics" or by pressing the "Esc" key on the standard control panel.
- Activate the drive with a positive edge of the drive enable signal.

If the error condition is still present, i.e. the limit switch is still activated or if the position limit values are still exceeded, only such command values are accepted that lead back to the allowed range. The command value check depends on the active operation mode.

The following applies:

Operation mode	Command value check
Torque control	Polarity of the torque/force command value (S-0-0080)
All operation modes with drive-internal velocity control	Polarity of the internal velocity command value
All operation modes with drive-internal position control	Polarity of the velocity resulting from the preset position command value

Tab. 6-25: Checking the Command Values in the Case of Error

If command values leading out of the allowed travel range continue to be preset, the error message (or warning) for travel range limit switch errors/position limit value errors will be generated again!

Diagnostic and Status Messages

Diagnostic Messages when Travel Range Limit Values Exceeded

In case the position limit values are exceeded, the corresponding diagnostic message depends on the handling set in "S-0-0532, Travel range limit parameter" (bit 2):

Handling	Display	Diagnostic message
As an error (bit 2 = 0)	F6029	F6029 Positive position limit exceeded
	F6030	F6030 Negative position limit exceeded
As a warning (bit 2 = 1)	E8029	E8029 Positive position limit exceeded
	E8030	E8030 Negative position limit exceeded

Tab. 6-26: Diagnostic Messages when Position Limit Values Exceeded

E2053 Target Position out of Travel Range

When "drive-internal interpolation" is used as the active operation mode, the drive checks whether the target position is outside the position limit values (S-0-0049 or S-0-0050). If this is the case, the drive does not move. It generates the warning "E2053 Target position out of travel range" and additionally sets bit 13 in "S-0-0012, Class 2 diagnostics".

Diagnostic Messages when Travel Range Limit Switch Activated

Exceeding the travel range limit switches is detected when they are activated. When this monitor reacts, the corresponding diagnostic message depends on the handling set in "S-0-0532, Travel range limit parameter" (bit 2):

Handling	Display	Diagnostic message
	F6028	F6028 Position limit value exceeded (overflow)
As an error (bit 2 = 0)	F6042	F6042 Both travel range limit switches activated
	F6043	F6043 Positive travel range limit switch activated
	F6044	F6044 Negative travel range limit switch activated
As a warning (bit 2 = 1)	E8042	E8042 Both travel range limit switches activated
	E8043	E8043 Positive travel range limit switch activated
	E8044	E8044 Negative travel range limit switch activated

Tab. 6-27: Diagnostic Messages when Travel Range Limit Switches Exceeded

States of Travel Range Limit Switches

The states of the connected travel range limit switches are displayed in parameter "P-0-0222, Travel range limit switch inputs":

- Bit 0 → Status of the positive limit switch (Limit+)
- Bit 1 → Status of the negative limit switch (Limit-)

See also Parameter Description "P-0-0222, Travel range limit switch inputs"

Connecting the Travel Range Limit Switches

See "Digital Inputs/Outputs"

See separate documentation "Drive Controllers, Control Sections; Project Planning Manual"

6.8 Power Supply

6.8.1 Brief Description

Possibilities of Power Supply

The following IndraDrive devices are supported by this firmware:

- Single-axis converters of the IndraDrive Cs range (HCS01.1 controllers)
- Multi-axis converters (HCQ, HCT controllers)
- Single-axis converters of the IndraDrive C range (HCS02.1, HCS03.1, HCS04.2 controllers)
- Single- and double-axis inverters of the modular IndraDrive M range (HMS01.1, HMS02.1, HMD01.1 controllers)
- Single-axis inverters of the distributed IndraDrive Mi range (KSM02.1, KMS02.1 controllers)

Converters include a supply unit and an inverter unit. They are suitable for direct power supply connection, but can only be used in a single-axis design and a DC bus coupled, modular drive system.

Possible Device Combinations and Mains Connection

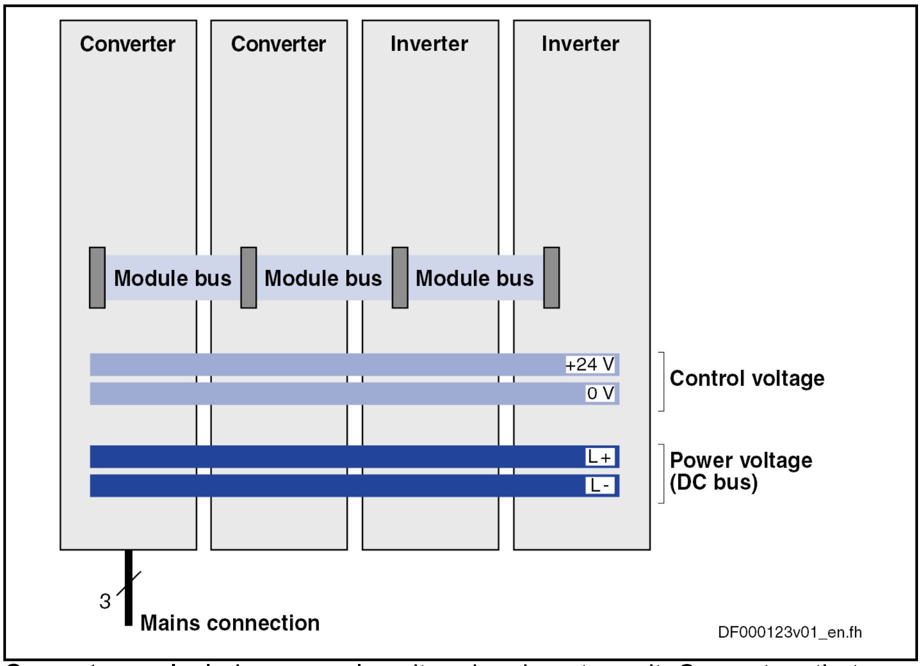
The possible device combinations are only described in principle for the purpose of explanation. As regards combinations of device types actually possible and specific facts to be observed, see the separate documentations.

Title Rexroth IndraDrive …	Kind of documentation	Document typecode[1)] DOK-INDRV*-…	Material number R911…
Cs Drive Systems with HCS01	Project Planning Manual	HCS01******-PRxx-EN-P	322210
Drive Systems with HMV01/02, HMS01/02, HMD01, HCS02/03	Project Planning Manual	SYSTEM*****-PRxx-EN-P	309636
Supply Units and Power Sections	Project Planning Manual	HMV-S-D+HCS-PRxx-EN-P	318790
Drive Controllers HCS04.2E	Project Planning Manual	HCS04.2****-PRxx-EN-P	327334
Mi Drive Systems with KCU02, KSM02, KMS02	Project Planning Manual	KCU02+KSM02-PRxx-EN-P	335703

1) In the document typecodes, "xx" is a wild card for the current edition of the documentation (example: PR01 is the first edition of a Project Planning Manual)

Tab. 6-28: Documentations for the Project Planning of Drive Systems

Central Supply The figure below illustrates the principle of central supply:



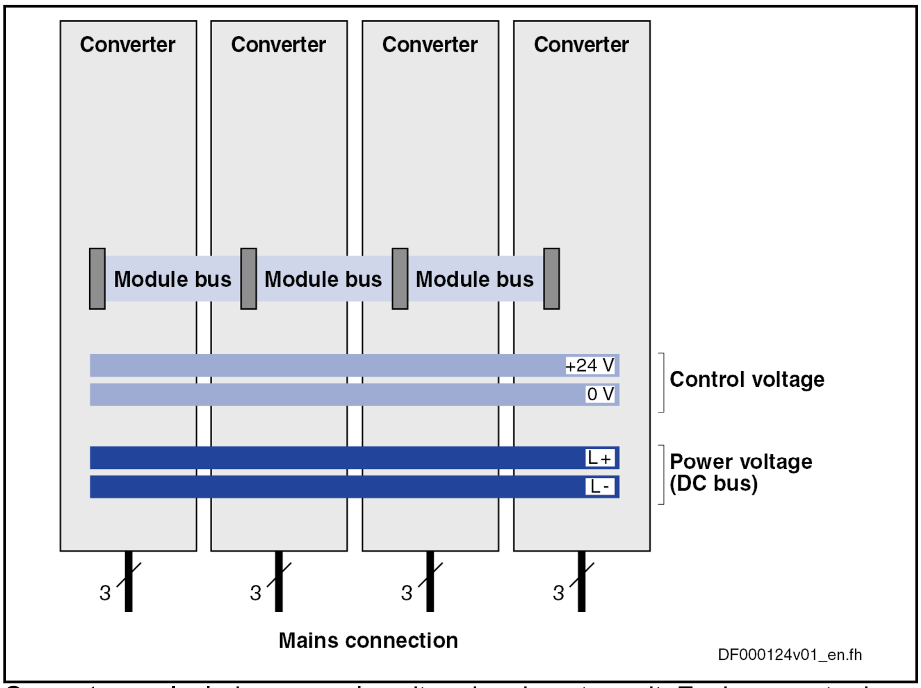
Converter Includes a supply unit and an inverter unit. Converters that are supplied via the DC bus must be operated in the inverter mode (see P-0-0860).

Inverter Only consists of the inverter unit and is always supplied supplied via the DC bus

Fig. 6-132: Mains Supply via Converter

Group Supply

The figure below illustrates the principle of group supply:



Converter Includes a supply unit and an inverter unit. Each converter is directly supplied by the mains.

Fig. 6-133: Mains Supply via all Devices

☞ With IndraDrive C and IndraDrive M, the module bus has an eight-wire design (ribbon cable) and with IndraDrive Cs it has a two-wire design. Devices with module buses of different designs cannot be operated at the common DC bus.

Communication in Drive Group

Depending on the task of a drive system or of several drives cooperating in a process, it can be appropriate to rapidly carry out a common reaction to certain events. This requires the exchange of signals (communication) between the cooperating devices:

- Multi-axis converters have an internal communication between the supply unit and the axis inverters.
- Single-axis converters (IndraDrive Cs, IndraDrive C), as well as inverters and supply units of the modular series (IndraDrive M), are interconnected via the module bus.

Note Regarding Single-Axis Converters IndraDrive Cs/C

A single-axis converter combines the supply unit and inverter in one device. In a "drive system" (several drives the DC buses and module buses of which are interconnected), a converter can fulfill the following functions:

- Supply of an integrated inverter and other inverters or converters operated as such, or
- Operation only as an inverter at a DC bus

Note Regarding Multi-Axis Converters

A multi-axis converter combines the supply unit and several inverters in one device. It always works as a "drive system" (several drives the DC buses and module buses of which are interconnected). Supply of other external inverters or converters or external module bus connection is not possible.

Regenerated Energy

In the case of regenerative operation (e.g. deceleration mode) of the motors connected to a single-axis or multi-axis converter, the regenerated energy is first absorbed by the DC bus. If the energy absorption capacity is exhausted, the energy absorbed is transformed into heat via the braking resistor.

Braking Resistor

The braking resistor is connected on the DC bus side. Depending on the device series, an internal braking resistor is available or an external braking resistor can be connected.

Module bus

The module bus is used for the communication of all nodes at the DC bus. It protects the components by switching the power off. The collective package reaction of all nodes is also initiated via the module bus. The wiring of the hardware, connections and signals is described in the documentation of the devices (Project Planning Manual).

Pertinent Parameters and Diagnostic Messages

Pertinent Parameters

- S-0-0380, DC bus voltage
- P-0-0114, Undervoltage threshold
- P-0-0118, Power supply, configuration
- P-0-0119, Best possible deceleration
- P-0-0460, Module group, control word
- P-0-0461, Module group, status word
- P-0-0806, Current mains voltage crest value
- P-0-0809, Properties of charging circuit
- P-0-0815,
- P-0-0816, Amplifier temperature 2
- P-0-0833, Braking resistor threshold

- P-0-0844, thermal load of Braking resistor
- P-0-0858, Data of external braking resistor
- P-0-0859, Data of internal braking resistor
- P-0-0860, Converter configuration
- P-0-0861, Power supply status word

Pertinent Diagnostic Messages

- E2026 Undervoltage in power section
- E2040 Device overtemperature 2 prewarning
- E2050 Device overtemp. prewarning
- E2061 Device overload prewarning
- E2086 Prewarning supply module overload
- E2810 Drive system not ready for operation
- E2814 Undervoltage in mains
- E2816 Undervoltage in power section
- E2819 Mains failure
- E2820 Braking resistor overload prewarning
- E2829 Not ready for power on
- E8025 Overvoltage in power section
- E8026 Undervoltage in power section
- E8028 Overcurrent in power section
- E8057 Device overload, current limit active
- E8058 Drive system not ready for operation
- E8819 Mains failure
- F2026 Undervoltage in power section
- F2086 Error supply module
- F2087 Module group communication error
- F2816 Softstart fault power supply unit
- F2818 Phase failure
- F2819 Mains failure
- F2820 Braking resistor overload
- F2821 Error in control of braking resistor
- F2825 Switch-on threshold braking resistor too low
- F2836 DC bus balancing monitor error

6.8.2 Functional Description

Information on Converters

In a converter the supply unit and inverter are combined in one device. As each inverter can provide or receive information via parameters, the information concerning the supply section of the converter can be queried or transmitted via parameters.

Inverter Modes

It is possible to configure a converter as a converter and also as an inverter by means of parameterization. The different inverter modes are described as follows.

Operating mode of the converter	Use	Parameterization	To be Noticed
Converter mode (default setting)	The converter is supplied with mains voltage; if applicable, other inverters, but not a DC energy store, have been connected to its DC bus.	P-0-0860, bit 0 = "0" and bit 14 = "0"	P-0-0114 can be used (it is possible to increase the undervoltage threshold).
Converter Mode with Energy Store in the DC Bus	The converter is supplied with mains voltage; if applicable, other inverters, plus a DC energy store, have been connected to its DC bus.	P-0-0860, bit 0 = "0" and bit 14 = "1"	• Setting for pitch drives of wind power stations, for example. • Status message "Ab" even without available mains voltage, as only the DC bus voltage is monitored (P-0-0114). • No error message in the event of mains failure.
Inverter mode	The converter is exclusively supplied via the DC bus connection on the DC side; a possibly available DC energy store is irrelevant to parameterization.	P-0-0860, bit 0 = "1", bit 14 is irrelevant.	P-0-0114 is unimportant

P-0-0114 Undervoltage threshold

Tab. 6-29: Differences of the Individual Operating Modes

Inverter mode

With the "**Converter in inverter mode**" setting, it is possible to operate converters of type HCS01.1 HCS02.1 as inverters. In this case, power is supplied by a DC bus (power voltage); mains voltage is not applied to the converter. Converters of the HCS03.1 type cannot be operated as inverters.

> ☞ Parameter P-0-0114 is not taken into account with inverters in inverter mode. The state change of the drive controller is carried out via the module bus signals.

Converter Mode with Energy Store in the DC Bus

Always select the "**converter mode with energy store in the DC bus**" setting if a converter is also to be operated without mains supply. The status message "Ab, ready for power output" is derived in this mode solely via parameter "P-0-0114, Undervoltage threshold".

> ☞ The undervoltage threshold must be set lower than the output voltage of the energy store.

In this mode, only the warning "E2819 Mains failure" is generated in the event of mains failure; therefore, the drive controller can continue to be operated even after mains failure, until the voltage value has fallen below the undervoltage threshold. The supply to the drive controller is maintained for a short-term via the DC energy store.

If mains voltage is available again within a short time, drive enable is switched off internally when the resumption of power supply is detected and "DC bus not OK" is transmitted via the module bus so that the soft start charging procedure for the DC bus voltage can be carried out. Other inverters connected to the DC bus perform the parameterized error reaction for undervoltage. Speed control loop monitoring is deactivated for the duration of the soft start procedure to suppress the triggering of the error "F8078 Speed loop error".

If the DC bus voltage continues to fall, when the voltage falls below the threshold for the undervoltage message, the parameterized error reaction (see P-0-0118) for DC bus voltage is generated. To prevent a soft-start fault from being generated once the mains voltage has returned, the DC bus undervoltage should be parameterized as a warning.

☞ Motor control is affected with a DC bus voltage below the minimum voltage, i.e. nominal torque and nominal speed will possibly no longer be reached.

Mains Voltage Data

When a converter is directly connected to the mains power supply (converter in infeed mode), the following mains voltage data are made available:

- P-0-0806, Current mains voltage crest value
- P-0-0815,

If the voltage falls below the minimum of the mains connection voltage, the warning "E2814 Undervoltage in mains" is issued.

Identifying the Charging Circuit for DC Bus

The converter receives data on the properties of the charging circuit hardware for the soft start via parameter "P-0-0809, Properties of charging circuit". The content of this list parameter is stored in read-only form on the hardware of the converter power section and can be displayed for test purposes.

Configuring the Power Supply

For each of the drives connected by the module bus it is possible to make basic settings for power supply in "P-0-0118, Power supply, configuration":

- Reaction to drive errors signaled via the module bus (reading state information "Inverter error")
- Individual drive errors signaled via module bus (generating state information "Inverter error")
- Drive-side handling of undervoltage in DC bus voltage
- Initiation of power shutdown in the event of an error

Status of Power Supply

The converter signals the status of power supply, mains voltage, DC bus charging state and the readiness for operation of the supply via parameter "P-0-0861, Power supply status word". This allows diagnosing the converter in the case of error.

Data Regarding the Supply Section

Supply units and the supply section of a converter provide the DC bus voltage for the inverters or the inverter section of the converter.

Power On

Mains supply power on is controlled by the "Bb" contact of the converter: If the contact is open, power on is prevented. The "Bb" contact is opened when the supply unit reports an error (F28xx) or the module bus signal "Supply error" is present.

☞ Recommendations on the hardware-side control of supply units or converters are contained in the separate documentation (see chapter "Possible Device Combinations and Mains Connection" on page 535)

Make sure that the "Bb" contact has been integrated in the mains contactor control so that power can be switched off in the event of an error.

Soft Start

When switching on the mains voltage, the DC bus is charged via a so-called "soft start device" which limits the inrush current for the initially uncharged DC bus to the value specified in the documentation of the respective device.

The soft start causes a charging time between the activation of the mains voltage and the minimum voltage in the DC bus required for power output. The charging time is monitored: when a maximum time has been exceeded, "F2816 Softstart fault power supply unit" (displayed for supply unit and converter) is signaled.

If the soft start process has been successfully completed, the supply signals via the module bus that the DC bus is ready for power output ("DC bus ok").

Minimum voltage for power output

To ensure that the drive controller changes to the "Ab, ready for power output" state, the DC bus voltage must exceed a defined minimum voltage which depends on the converter mode that has been set:

- **Converter mode** (default setting)
  - "0" <= P-0-0114 <= 66% or 75% of P-0-0815 (default setting)

    On devices that can be operated as single-phase (HCS01.1E-*-**02**, HCS02.1): Status "Ab, ready for power output", if "S-0-0380, DC bus voltage" >= **66%** of "P-0-0815, ".

    On devices that can only be operated as three-phase (HCS01.1E-*-**03**, HCS03.1, HCS04.2): Status "Ab, ready for power output", if "S-0-0380, DC bus voltage" >= **75%** of "P-0-0815, ".
  - P-0-0114 > 66% or 75% of P-0-0815

    Status "Ab, ready for power output", if "S-0-0380, DC bus voltage" >= "P-0-0114, Undervoltage threshold".
- **Inverter mode**

  Status "Ab, ready for power output", is only derived via the module bus message "DC bus_ok" (P_0_0461, bit 1 = "1").

☞ Parameterization of "P-0-0114, Undervoltage threshold" is not of interest.

- **Converter with energy store in the DC bus**
  - P-0-0114 = "0" (default setting)

    On devices that can be operated as single-phase (HCS01.1E-*-**02**, HCS02.1): Status "Ab, ready for power output", if "S-0-0380, DC bus voltage" >= **66%** of "P-0-0815, ".

    On devices that can only be operated as three-phase (HCS01.1E-*-**03**, HCS03.1, HCS04.2): Status "Ab, ready for power output", if "S-0-0380, DC bus voltage" >= **75%** of "P-0-0815, ".
  - P-0-0114 ≠ "0"

    Status "Ab, ready for power output", if "S-0-0380, DC bus voltage" >= "P-0-0114, Undervoltage threshold".

If the voltage drops below the minimum voltage, the signal "DC bus not OK" is signaled on the module bus. The inverter section of the converter or the converter connected via the module bus respond independently of "P-0-0118, Power supply, configuration" with a warning or an error.

☞ The crest value of the mains voltage is detected when the mains contactor is activated the first time. It is displayed in parameter "P-0-0815, ".

Power off

For converters, the automatic power shutdown required in the case of an error is carried out by opening the "Bb" contact that has to be available in the switch-off path of the mains contactor.

☞ Recommendations on the hardware-side control of converters are contained in the documentation for the respective devices (see chapter "Possible Device Combinations and Mains Connection" on page 535).

Criteria for opening the "Bb" contact:

- The supply section of the converter signals a supply error (F28xx).
- The inverter section of the converter or the converter connected via the module bus require a power shutdown (module bus signal"Supply error" is present).

Mains Phase Failure Detection

If a single- or two-phase mains failure lasting longer than the tolerated mains phase failure time is detected with three-phase supplied drive controllers, the drive controller signals the supply error fault "F2818 Phase failure". This error leads to a power shutdown of the supplying device and the status message "Supply error" is signaled on the module bus. Other drive controllers connected via the module bus respond with the response to undervoltage in the DC bus voltage/mains failure parameterized in "P-0-0118, Power supply, configuration".

There are various prerequisites for mains phase failure detection, depending on the differences in hardware.

- With HCS01.1- and HCQ-/HCT devices, the mains phase monitor can be deactivated via parameter "P-0-0860, Converter configuration", bit 13. A distinction is made between the following:
  - Devices that can be permanently operated in single-phase or two-phase form (HCS01.1E-*-**02**):

    Mains phase monitoring must be deactivated on these devices in order to operate the device under power voltage in single phase, otherwise the error message "F2818 Phase failure" will be generated when power voltage is switched on.
  - Devices that **cannot** be permanently operated in single-phase or two-phase form (HCS01.1E-*-**03**):

    With these devices, there is a power derating to 25% of the device's nominal power, by deactivation of mains phase monitoring, so as not to overload the rectifier. Deactivation of mains phase monitoring is undone by switching off and on the 24V control voltage.

☞ Deactivation of mains phase monitoring with devices that cannot permanently be operated in single-phase or two-phase form must **not** be parameterized in series machines, the so-called "play mobile mode" can only be activated for test purposes.

- HCS02.1 devices do not have mains phase monitoring but can be operated permanently in single-phase or two-phase form
- HCS03.1 devices do not have mains phase monitoring and **cannot** be operated permanently in single-phase or two-phase form.
- On HCS04.2 devices, mains phase monitoring cannot be deactivated because the devices cannot be operated in single-phase or two-phase form.

Mains Phase Failure Detection

The mains voltage is monitored when the mains contactor, for converters, has been switched on and drive enable has been set.

☞ The converter does not have an integrated mains contactor; the mains voltage is only applied at the mains input terminals of the converter by switching power on.

Immediate Measure at Mains Failure

When the failure of mains voltage is detected, the following immediate measures are taken:

- The warning "E2819 Mains failure" is displayed on the converter display.
- The message "Failure of DC bus supply (DC bus not OK)" is signaled by the supply section of the converter on the module bus (only for "converter operation", not for "Converter with energy store in the DC bus").

Permanent Mains Failure

In the event of permanent mains voltage failure, the DC bus voltage decreases continuously and falls below the "minimum voltage for power output" (see above). The following reactions are then triggered:

- The error message "F2026, Undervoltage in power section" is displayed on the converter display.
- The message "Failure of DC bus voltage, mains failure (DC bus not OK)" is signaled on the module bus.

☞ Exception: In the "Converter at the energy store" mode, only the warning "E2819 Mains failure" is generated. If the DC bus voltage falls below "P-0-0114, Undervoltage threshold" "DC bus not OK" is signaled on the module bus.

Temporary Mains Failure

If the duration of the mains failure lies within the tolerated mains failure time, the following responses arise:

- "E2819 Mains failure" automatically disappears from the converter display.
- The message "Ready for power output (DC bus OK)" is again signaled on the module bus.

The behavior of the drives connected via the module bus in the case of temporary mains failure depends on the reaction to undervoltage in the DC bus that was set (see "P-0-0118, Power supply, configuration").

Information on Inverters

The motors are controlled via inverters. Inverters can be designed as modular devices or be integrated in a converter together with a supply section. For motor control, the inverter converts the bus voltage into alternating voltage.

DC Bus Voltage Monitoring

By means of the DC bus voltage level, the inverter evaluates whether the connected motor can be supplied with sufficient power or not. The inverter can do this by evaluating the message "DC bus voltage error (DC bus not OK)" or "ready for power output (DC bus voltage OK)" generated by the supply section on the module bus. The response for undervoltage in the DC bus voltage is parameterizable via "P-0-0118, Power supply, configuration":

- "E2026, Undervoltage in power section" – no drive response to the drive
- "E8026, Undervoltage in power section" – the drive reacts by blocking the motive operation, only deceleration is possible.
- "F2026, Undervoltage in power section" – the drive responds with the error reaction set in "P-0-0119, Best possible deceleration".

Power off

Inverters can initiate a power shutdown via the module bus when the function "Power shutdown in the event of an error" in "P-0-0118, Power supply, configuration" is activated:

- P-0-0118, bit 7 = "0": Drive errors of an inverter are not signaled to the supply unit. Only errors of the supply section itself lead to a power shutdown (F28xx).
- P-0-0118, bit 7 = "1": A power shutdown is initiated with every drive error (inverter signals signal "Supply error" to the module bus).

If the signal "Supply error" is signaled on the module bus, the "Bb" contact of the converter is opened and the drives respond according to the response to an undervoltage in the DC bus voltage/mains failure parameterized in P-0-0118.

NOTICE	With the default parameterization, a drive error of an inverter does not cause power shutdown of the supply section. A general power shutdown in response to any errors must be parameterized explicitly.

Package reaction

To enable a joint error response of several drives connected via the module bus, the function "Package reaction" is available. The response can be configured individually for each drive in "P-0-0118, Power supply, configuration", bit 0 and bit 1:

- Taking part in the package reaction by reacting to drive errors signaled via the module bus (reading state information "Inverter error")
- Triggering the package reaction by signaling own drive errors (generating the module bus signal "Inverter error")

Participants in the package reaction display the warning "E8058, Drive system not ready for operation" while "Inverter error" is signaled on the module bus, and respond according to "P-0-0119, Best possible deceleration". If the error of the drive which triggered the package reaction is deleted, the warning will disappear. All errors of a drive that signals its own drive errors via the module bus lead to the triggering of the package reaction

Bb contact

After booting the drive, the "Bb" contact of the inverter is closed when the state machine internal to the devices are in operating mode (OM), the Field Bus State Machine is in the state "Data Exchange" and there is no drive error. Depending on "P-0-0118, Power supply, configuration" bit 7, the "Bb" contact is opened:

- P-0-0118, bit 7 = "0": The "Bb" contact only opens when there is a fault with the supply section (F28xx).
- P-0-0118, bit 7 = "1": The "Bb" contact opens in response to all faults.

☞ The Bb contact of the inverter is functionally superfluous as a power shutdown is carried out via the module bus. It is therefore not necessary to connect the "Bb" contact of the inverter.

Module bus master

If inverters are operated from a third-party supply, one of the inverters is to be configured as a module bus master within the module bus (see P-0-0860). This inverter forms the interface between the third-party supply, and the IndraDrive drive system. The following must be noted in order to enable a power switch-on to the drives and to ensure that the power switches off in the event of a fault:

- Operating the module bus signals "DC bus voltage OK" or "DC bus voltage not ok": A digital output of the third-party supply, which maps the readiness for power output of the supply, is connected to a digital output of the module bus master. This digital output is to be configured on the parameter P-0-0861, bit 3.

- Control "Bb" contact: Use the module bus master function to automatically configure the "Bb" contact to parameter P-0-0861, bit 9. To ensure a power shutdown can take place in the event of a fault, the "Bb" contact is to be connected to the switch-off path of the mains contactor.

Data Regarding the Module Bus

Function of the Module Bus

The module bus establishes the exchange of signals between the inverters or converters, or from the inverters to the supply unit. Independent of the master communication, this allows the devices to exchange information on internal status variables of the drive system and error situations without delay. Axis drives and supply units can therefore react in a coordinated way.

The module bus transmits the following pieces of information:

- With regard to the supply unit:
  - Supply unit ready for operation
  - Ready for power output
  - DC bus voltage in or outside of allowed range of values
  - Warning against overload of supply unit
  - Signal for resetting supply errors
- With regard to inverters or converters:
  - Inverters or converters ready for operation

Hierarchy of Status Information

The status information transmitted by inverter, supply unit or converter via the module bus has a hierarchical order.

Status information	Generated by				Priority
	SU	CV	IV	HLB	
Resetting of supply errors	--	■	■	■	High
Supply units or converters not ready for operation ("supply error")	■	■	■[1]	■	↑
Inverters or converters not ready for operation ("inverter error")	--	■[2]	■[2]	■	↑
Failure of DC bus supply ("DC bus not ok" in operation)	■	■	--	--	↑
"Supply overload" prewarning	■	■	--	■	↑
DC bus ready for power output ("DC bus ok", after switching power voltage on)	■	■	--	--	↑
All module bus nodes error-free	■	■	■	■	Low

SU Supply unit
CV Converters
IV Inverter
HLB DC bus resistance unit
1) Only if power off has been parameterized (see P-0-0118, bit 7)
2) Only if signaling of own drive errors has been parameterized (see P-0-0118, bit 1)

Tab. 6-30: Module Bus Status Information and its Priority in the Hierarchy

If several pieces of status information from one or several module bus nodes are present at the same time, the status information highest in hierarchy determines the signal status of the module bus.

"Ready for Operation" Message

The **supply section** of the converter signals "ready for operation" via the module bus, when the required mains voltage has been provided at the device and there is no device error. If the supply section is no longer ready for operation due to an error, the information is transmitted via the module bus with high priority, because power supply is no longer guaranteed.

The **inverter section** of the inverters or converters signals "ready for operation" via the module bus when the required control voltage has been provided at the device, the operating mode (OM) has been reached and there is no error present in the inverter section of the converter.

Voltage Messages

The supply section of the converter signals the following states via the module bus:

- After switching the mains voltage on, the voltage in the DC bus has exceeded the minimum value, the charging process has been completed and there is readiness for power output ("DC bus ok").
- In the case of load, the voltage in the DC bus has fallen below the minimum value or there is mains failure ("DC bus not ok").

When the voltage in the DC bus has fallen below the minimum value ("DC bus not OK"), this is displayed via the inverters or any other converters connected to the module bus and can be read by the control master via the master communication (warning "E2026" or "E8026" or fault "F2026", depending on the power supply configuration in P-0-0118). The control master can thereby detect imminent overload in the supply circuit (mains) and react in an appropriate way.

☞ Data of minimum voltage in DC bus and of power supply configuration (P-0-0118) are contained in the section "chapter "Data Regarding the Supply Section" on page 540".

Overload Warning

The supply section of the converter signals "supply module overload prewarning" via the module bus, if the power supply risks automatically switching off soon, due to imminent overload. The warning can be triggered due to high heat sink temperature or high braking resistor load, for example.

The message "E2086 Prewarning supply module overload" is output via the inverters or converters connected to the module bus. The control master can thereby detect imminent supply overload and react in an appropriate way.

☞ The exact causes of this warning are shown on the display of the converter by detailed diagnostic message texts.

Overload Warning of HLB

The DC bus resistor unit HLB signals "supply module overload prewarning" via the module bus, if one of the following situations occurs:

- Load of the braking resistor > 90%
- Heat sink temperature sensor signals maximum temperature
- Ambient air temperature sensor signals maximum temperature

Diagnostics of Module Bus State

The control information currently transmitted by an inverter or converter via the module bus is displayed in "P-0-0460, Module group, control word". The message currently in the module bus is displayed in "P-0-0461, Module group, status word".

Data Regarding the Braking Resistor

External/Internal Braking Resistor

Converters of the HSC01.1 and HCS02.1 type are equipped with an integrated braking resistor. As an alternative to the internal braking resistor, you may also connect an external braking resistor (additional component). The setting for whether an internal or external braking resistor is to be active is made in parameter "P-0-0860, Converter configuration".

Multi-axis converters of the HCQ/HCT type do not have an internal braking resistor; however, an external braking resistor must be connected.

Single-axis converter HCS03.1 do not have an internal brake resistor, however an external braking resistor can be connected optionally.

When an external braking resistor is used, its technical data have to be entered in parameter "P-0-0858, Data of external braking resistor". If an internal braking resistor is available, its data are contained on the manufacturer side in parameter "P-0-0859, Data of internal braking resistor" and stored in write-protected form in a parameter memory on the power section.

The external braking resistor has to be activated in parameter "P_0_0860, Converter configuration"

☞ When an external braking resistor is connected, the minimum resistance value that can be connected must be taken into consideration (see documentation of the respective device).

Switch-On/Switch-Off Threshold of Braking Resistor

The braking resistor switch-on threshold (P-0-0833, Braking resistor threshold) for converters is device-dependent. The default value is

- 390V for HCS01.1E-*-02,
- 765V for HCS04.2 and
- 820V in all other IndraDrive devices.

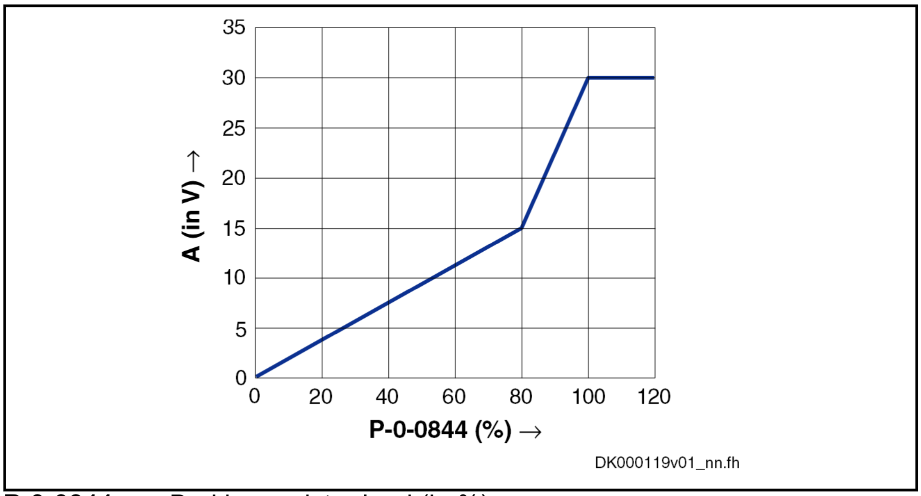
The switch-on threshold can be reduced to protect the motor via "P-0-0853, Max. DC bus voltage, motor". The reduction only becomes effective when the entered value is less than the default resistance switch-on threshold of the device. A safety distance is necessary between mains peak and braking resistance switch-on threshold to protect the device: If the parameterized value in "P-0-0853, Max. DC bus voltage, motor" is less than 130% (HCS01.1E-*-02: 108%) of the mains peak, the fault "F2825 Switch-on threshold braking resistor too low" is generated and the "Bb" contact is opened.

Dynamic Adjustment of the Switch-On Threshold

The dynamic adjustment to the current load of the braking resistor provides the following advantages:

- Protects the braking resistor from overload
- Equal load of all braking resistors active in a common DC bus

The current load of the braking resistor is displayed in parameter "P-0-0844, thermal load of Braking resistor". Depending on the load, the switch-on threshold of the braking resistor is increased according to the following characteristic:



P-0-0844	Braking resistor load (in %)
A	Adjustment value for reference value (in V)

Fig. 6-134: Increase of Switch-On Threshold of Braking Resistor Depending on the Load

The effective switch-on threshold results from the reference value of the braking resistor switching voltage; an adjustment value depending on the load (P_0_0844) is added to this reference value according to this characteristic. The effective switch-on threshold is displayed in parameter "P-0-0833, Braking resistor threshold".

- In the case of a braking resistor load of 100%, the switch-on threshold is not increased any more, because braking takes priority over the protection of the device!
- The dynamic adjustment of the switch-on threshold can be deactivated in P-0-0860.

6.8.3 Notes on Commissioning

Selecting Converter Mode

Depending on the application, one of the following three inverter modes must be selected using "P-0-0860, Converter configuration":

- Converters
- Inverter mode
- Converter with energy store in the DC bus

See also "Inverter Modes" on page 538

The "Bb" contact must be wired in accordance with the data contained in the documentation of the converter devices.

Mains Power Supply

For devices with a single-phase connection to the mains power supply, the phase monitoring of the mains voltage must be deactivated (see "P-0-0860, Converter configuration").

Selecting the Braking Resistor

For converters of the HCS01.1 and HCS02.1 type, it is possible to determine whether the internal braking resistor or an externally connected braking resistor is to be activated. The selection is made in parameter "P-0-0860, Converter configuration".

If an external braking resistor is to be used, the data required for control by the converter have to be entered in "P-0-0858, Data of external braking resistor".

Setting the Undervoltage Threshold

Different undervoltage thresholds take effect depending on the selected converter mode. If this threshold is to be adjusted, the required value must be entered in "P-0-0114, Undervoltage threshold". See also "Minimum voltage for power output" on page 541.

☞ The undervoltage threshold cannot be individually adjusted in the "inverter mode".

Configuring the Power Supply

The required or desired axis-specific settings of the power supply of the devices connected by the DC bus and module bus have to be made in parameter "P-0-0118, Power supply, configuration".

The following settings or definitions can be made:

- Reaction to drive errors signaled via the module bus
- Individual drive errors signaled via module bus
- Drive-side handling of undervoltage in DC bus voltage
- Initiation of power shutdown in the event of an error

Operating Rexroth Motors

The parameter "P-0-0853, Max. DC bus voltage, motor" is set in accordance with the version of the data structure of the encoder memory or is otherwise loaded via the DriveBase data of IndraWorks:

- Version 4 (MSK) and version 6 (SBC): 950 V
- Version 5 (MSM): 420 V
- IndraWorks (MCP: primary part of MCL motor): 420 V

Operating Third-Party Motors

⚠ WARNING **Property damage caused by inadmissibly high voltage on the motor terminals!**

With third-party motors, observe the maximum allowed terminal voltage. "P-0-0853, Max. DC bus voltage, motor" must be parameterized based on the manufacturer's data. The switch-off threshold of the braking resistor is adjusted to the value accordingly.

6.8.4 Diagnostic and Status Messages

Module bus

Displaying module bus state:

- P-0-0461, Module group, status word

Displaying device-side module bus control information:

- P-0-0460, Module group, control word

Displaying interrupted module bus communication:

- F2087 Module group communication error

Mains voltage

Diagnostic messages for mains voltage:

- P-0-0806, Current mains voltage crest value
- P-0-0815,

Mains voltage warnings:

- E2814 Undervoltage in mains
- E2819 Mains failure

Mains voltage error messages:

- F2816 Softstart fault power supply unit
- F2818 Phase failure
- F2819 Mains failure

DC Bus

Diagnostic message for DC bus:

- S-0-0380, DC bus voltage

DC bus warnings:

- E2026 Undervoltage in power section
- E2816 Undervoltage in power section
- E8025 Overvoltage in power section

DC bus error messages:

- F2026 Undervoltage in power section
- F2836 DC bus balancing monitor error

Braking Resistor

Diagnostic messages for braking resistor:

- P-0-0844, thermal load of Braking resistor
- P-0-0833, Braking resistor threshold

Braking resistor warnings:

- E2820 Braking resistor overload prewarning
- E2829 Not ready for power on

Braking resistor error messages:

- F2820 Braking resistor overload
- F2821 Error in control of braking resistor
- F2825 Switch-on threshold braking resistor too low

Power Section Supply

Power section warnings:

- E8026 Undervoltage in power section
- E8028 Overcurrent in power section
- E8057 Device overload, current limit active
- E8819 Mains failure

Power section error messages:

- F8060 Overcurrent in power section

Drive System

Reaction to signaled errors of other drives in the drive system:

- E8058 Drive system not ready for operation
- E2810 Drive system not ready for operation (for supply section only)

7 Operation modes

7.1 Safety Instructions

⚠ WARNING	Dangerous movements! Danger to life, risk of injury, serious injury or property damage!

- Keep free and clear of the ranges of motion of machines and moving machine parts.
- Prevent personnel from accidentally entering the machine's range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

7.2 General Information on the Operation Modes

7.2.1 Assignment to the Functional Packages

For the assignment to the functional packages, see chapter "Overview of Functions/Functional Packages, Supported Operation Modes".

7.2.2 Operation Mode Handling

Selecting the Operation Mode

It is possible to configure up to 8 different operation modes in the drive (depending on "S-0-0292, List of supported operation modes"). Assignment and configuration are made via the following parameters:

- S-0-0032, Primary operation mode
- S-0-0033, Secondary operation mode 1
- S-0-0034, Secondary operation mode 2
- S-0-0035, Secondary operation mode 3
- S-0-0284, Secondary operation mode 4
- S-0-0285, Secondary operation mode 5
- S-0-0286, Secondary operation mode 6
- S-0-0287, Secondary operation mode 7

☞ If the value "0" was entered in one of these parameters, the error message "F2007 Switching to non-initialized operation mode" is generated when this operation mode is activated.

Activating the Operation Mode

The operation mode is activated and controlled by the input in drive control words which depend on the type of master communication:

- S-0-0134, Master control word
- P-0-4077, Field bus: Control word
- P-0-4068, Field bus: Control word IO
- P-0-4028, Device control word

- P-0-0120, Control word easy startup

For the axis command triggering by the integrated MLD control and the use by the easy startup mode, there are 8 more internal operation modes available (permanently configured internally), so that a total of 16 operation mode preselection parameters are available. It is possible to choose between these operation modes in operation, and due to drive-controlled transition functions it is possible to switch between the operation modes in running operation.

The effective input is displayed in the bits 8, 9, 11 and 12 of the parameter "P-0-0116, Device control: Control word".

The following applies to parameter P-0-0116:

- Bits 8 and 9 → Selecting primary operation mode and secondary oper. modes 1 to 3
- Bit 11 → Selecting secondary operation modes 4 to 7 (sercos only)

☞ The secondary operation modes 4 to 7 can only be used via sercos interface. Bit 11 therefore only takes effect in the control word of the device control (P-0-0116) in conjunction with parameter S-0-0134 (master control word for sercos)!

The figure below illustrates the interrelation of the control word of the respective master communication and the device control word/device status word with regard to the operation mode selection.

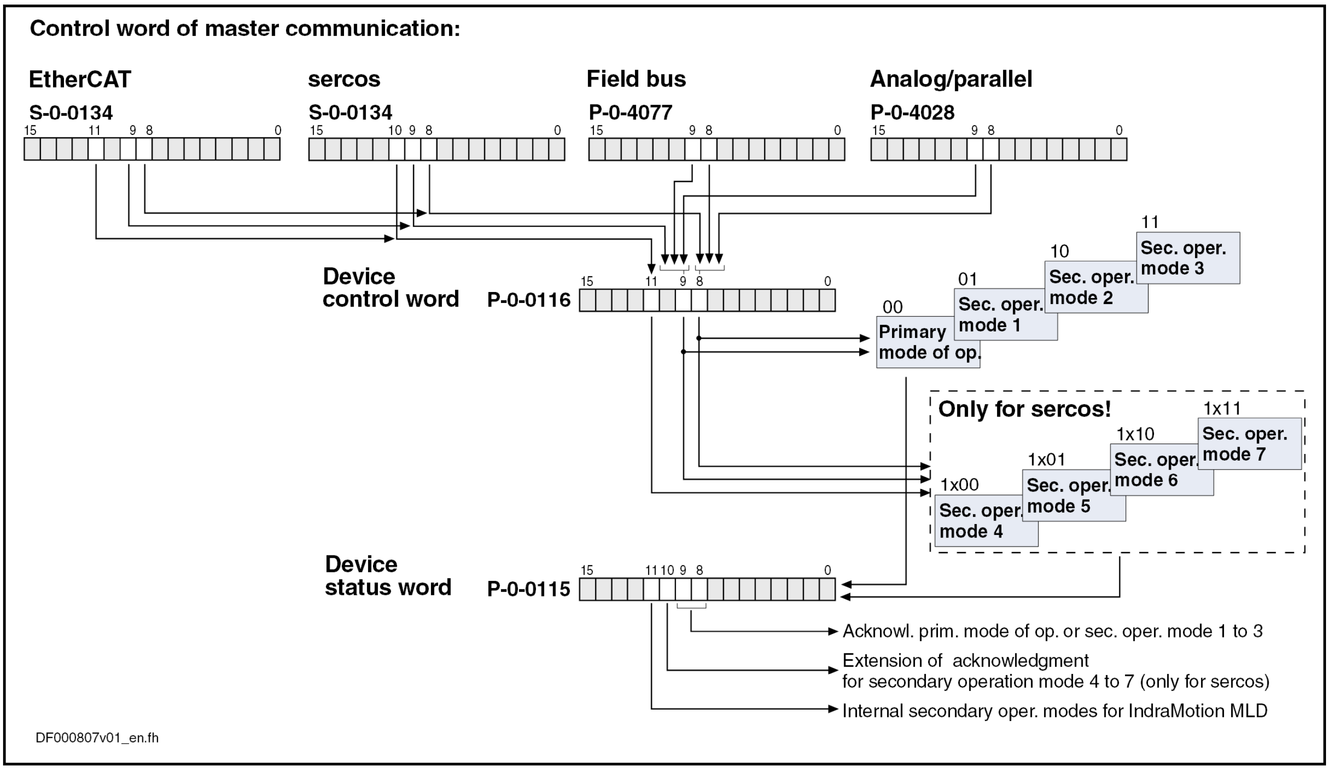


Fig. 7-1: Operation Mode Selection via Control Word

☞ The control bits (8 and 9) contained in parameter P-0-0116 are also contained in the control words depending on the master communication (cf. S-0-0134, P-0-4077, P-0-4068 and P-0-4028) and can therefore be written via the control words.

An operation mode defined via the operation mode selection is active when:

- The drive (control section and power section) is ready for operation

- and -

- The drive enable signal sees a positive edge.

Acknowledging the Active Operation Mode

As regards the activation of an operation mode, there are the following kinds of feedback:

- With active operation mode, the display of the control panel reads "AF".
- In parameter "S-0-0390, Diagnostic message number", the respective diagnostic message number of the active operation mode is displayed (e.g. "C00A0101" in "velocity control" mode).
- In parameter "S-0-0095, Diagnostic message", the active operation mode is displayed in text form (e.g. "A0101 Velocity control").
- In parameter "P-0-0115, Device control: Status word", bit 3 ("Drive follows external command values") is used to acknowledge whether the drive is running in the preset operation mode or not.
- In parameter "P-0-0115, Device control: Status word", bits 8, 9 and 10 ("Acknowledgment of operation mode") are used to signal the operation mode presently active.

☞ The status bits contained in parameter P-0-0115 (3, 8, 9 and 10) are also contained in the status words depending on the master communication (S-0-0135, P-0-4078) and can therefore be read in the status words. Bit 10, however, is only activated with sercos interface!

See also "Device Control and State Machines"

Changing the Operation Mode

When drive enable is activated, the drive, after having gone through the initialization routines, changes to the operation mode that was selected via bits 8 and 9 of the specific control word of the respective master communication (S-0-0134, P-0-4077, P-0-4068, P-0-4028 or P-0-0116).

☞ The change of operation modes is carried out within one position controller clock (Advanced: 250 µs; Basic: 500 µs). Another position controller clock passes until the command values of the activated operation mode become effective, because the initialization of the operation mode is carried out first.

Special Cases

With the following **exceptional circumstances**, the desired operation mode is not carried out in spite of the operation mode having been correctly selected:

- **Drive error** is present

  → The corresponding error reaction is carried out.
- **Fatal warning** was triggered

  → The corresponding reaction is carried out.
- A "**drive command**" (e.g. homing procedure, set absolute position, ...) is executed

  → The command started is carried out.
- **Drive Halt**

  → This drive function is carried out.

See also "Device Control and State Machines"

Drive-Controlled Change of Operation Mode

In order to achieve a quick and smooth change of operation mode in running operation, it is possible to make a "drive-controlled change of operation mode". Drive-internally this procedure ensures that, when the operation mode is changed, the transition is carried out in a synchronized way, even if the command value changes abruptly.

See also "Command Value Adjustment with Position Control"

Command Value Acceptance and Acknowledgment

Immediate Command Value Acceptance

Each preset command value is accepted immediately, when the respective command value parameter (e.g. S-0-0036, S-0-0080, S-0-0258, …) is written in the case of the operation modes:

- Torque/force control
- Velocity Control
- Position control with cyclic command value input
- Drive-internal interpolation
- Synchronization modes:
  - Velocity Synchronization with Real/Virtual Master Axis
  - Phase Synchronization with Real/Virtual Master Axis
  - Electronic Cam with Real/Virtual Master Axis
  - Electronic Motion Profile with Real/Virtual Master Axis

Command Value Acceptance After Master Request

In the **positioning modes** (drive-controlled positioning, positioning block mode), however, the command value (target position, velocity, positioning block, ...) is only accepted, when the master explicitly requests this by a "command value acceptance".

The command value acceptance is carried out in a different way, according to the positioning mode or profile type:

- Operation mode "Drive-controlled positioning"

  Acceptance of preset command value (position, velocity) by toggling bit 0 of parameter "S-0-0346, Positioning control word"

  → **Toggle mechanism**
- Operation mode "Positioning block mode"

  Acceptance of the positioning block selected via "P-0-4026, Positioning block selection" by a positive edge of bit 0 of parameter "P-0-4060, Positioning block control word", when the parallel interface or, in the case of field buses, the I/O mode is used as master communication

  → **Edge control**

☞ When the positioning block mode is used for field buses in the freely configurable operating mode (P-0-4084 = 0xFFFE) or with sercos interface, the toggle mechanism is used **in spite of the above rule.**

Command Value Acknowledgment

The explicit acknowledgment of the command value acceptance only takes place for the positioning modes (drive-controlled positioning, positioning block mode).

It is possible to check in the master whether and when the preset command value was accepted in the drive (command value acceptance handshake).

The command value acknowledgment is carried out in a different way, according to the positioning mode:

- Operation mode "Drive-controlled positioning"

The drive acknowledges the command value acceptance by toggling bit 0 of parameter "S-0-0419, Positioning command acknowledge".

- Operation mode "Positioning block mode"

  The drive acknowledges the command value acceptance by displaying the effective positioning block in parameter "P-0-4051, Positioning block acknowledgment".

In the positioning block mode, too, the acceptance of a new positioning block causes bit 0 of parameter S-0-0419 to be toggled, because in this case the internal processing of the positioning command values is identical to the "drive-controlled positioning" mode.

7.3 Torque/force control

7.3.1 Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the "torque/force control" mode, a torque/force command value is preset for the drive. If required, this command value can be filtered. When the operation mode has been activated, the diagnostic message is "A0100 Torque control".

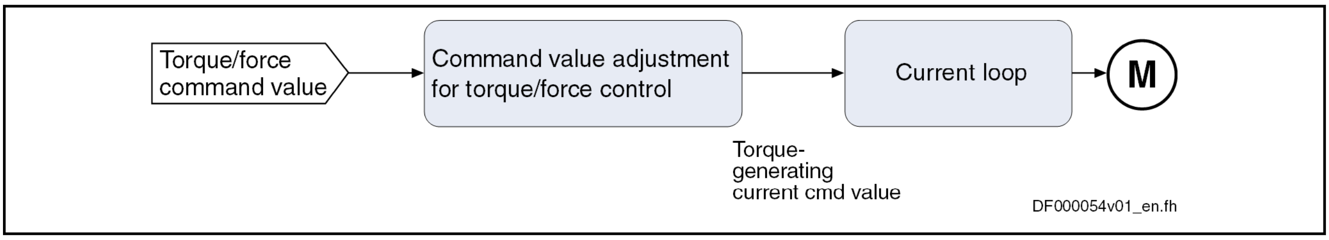


Fig. 7-2: Block Diagram, "Torque/Force Control"

Features

- Torque/force control with regard to the sum of the command values preset in parameters "S-0-0080, Torque/force command value" and "S-0-0081, Additive torque/force command value"
- Torque/force command value is generated internally by the velocity controller; value of S-0-0081 can be added as additive component
- Limitation of the preset command value to limit value that can be parameterized
- Command value filtered via "S-0-0822, Torque/force ramp" and "S-0-0823, Torque/force ramp time"

Pertinent Parameters

- S-0-0080, Torque/force command value
- S-0-0081, Additive torque/force command value
- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0109, Motor peak current
- S-0-0110, Amplifier peak current
- S-0-0111, Motor current at standstill

- S-0-0822, Torque/force ramp
- S-0-0823, Torque/force ramp time
- S-0-0824, Status "Torque/force command value attained"
- P-0-0001, Switching frequency of the power output stage
- P-0-0038, Torque-generating current, command value
- P-0-0049, Effective torque/force command value
- P-0-0051, Torque/force constant
- P-0-0109, Torque/force peak limit
- P-0-4046, Effective peak current

Pertinent Diagnostic Messages

- A0100 Torque control
- E8057 Device overload, current limit active
- E8260 Torque/force command value limit active
- F8079 Velocity limit value exceeded

7.3.2 Command Value Adjustment in Torque/Force Control

Principle of Command Value Adjustment

Filtering the Command Value

The command value preset by "S-0-0080, Torque/force command value" is filtered. The filter effect can be changed by setting of "S-0-0822, Torque/force ramp" and "S-0-0823, Torque/force ramp time".

The message "torque/force command value attained" (S-0-0824) signals that the output value of the filter has reached the input value (S-0-0080).

Additive Current Command Value

In addition, it is possible to add an unfiltered additive command value via "S-0-0081, Additive torque/force command value". If required, this value can be cyclically configured.

Command Value Limitation

We distinguish the following command value limitations:

- Torque/force limitation
- Current Limitation

On the user side, it is only possible to directly set the torque/force limits. By setting the switching frequency (P-0-0001), the value of the current limit is indirectly influenced.

Output Variable

The output variable of the command value adjustment for torque/force control is the torque-generating component of the current command value Iq_{cmd} (P-0-0038).

Block Diagram

The figure below illustrates command value processing in the "torque/force control" mode as a block diagram.

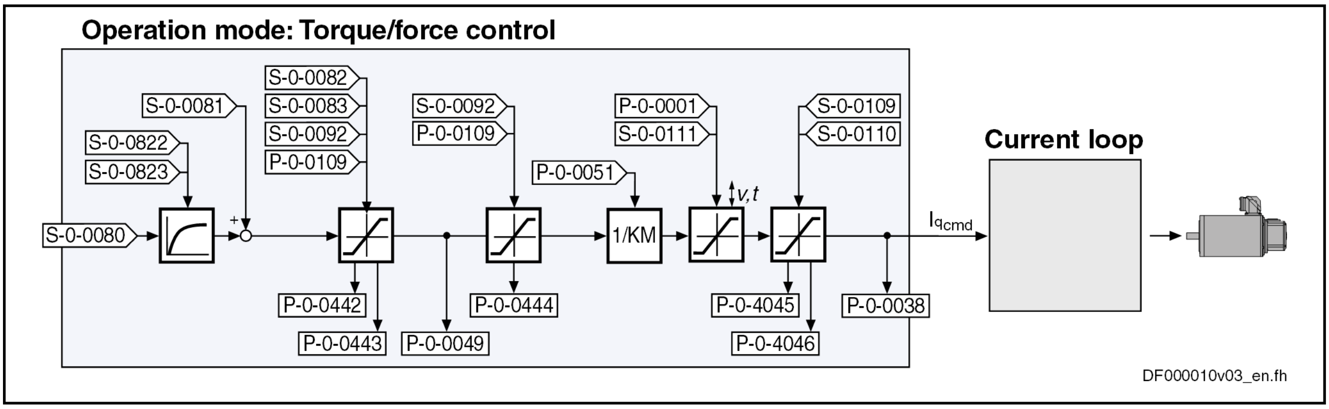


Fig. 7-3: Command Value Adjustment in Torque/Force Control

The currently effective actual limit values are displayed (P-0-0442, P-0-0443, P-0-0444; P-0-4045, P-0-4046); so is the output variable of the command value adjustment in torque/force control, the torque-generating component of the current command value (P-0-0038).

Velocity Monitor

In torque/force control, the velocity of the drive is reached depending on the component of the drive torque or the drive force acting on the acceleration. As the velocity of a motor or an axis has to stay within the allowed range in order to avoid damage, the actual velocity value is monitored, as soon as it is outside the standstill window S-0-0124.

If the value of "S-0-0040, Velocity feedback value" exceeds the 1.125-fold value of "S-0-0091, Bipolar velocity limit value", the drive generates the error message "F8079 Velocity limit value exceeded" and switches off with the error reaction that was set.

Notes on Commissioning for Command Value Limitation

On the user side, the following limitations are available:

- Maximum allowed torque/force (S-0-0092, P-0-0109)
- Motive and regenerative load at stationary velocity (S-0-0082, S-0-0083)

See also separate documentation "Rexroth IndraDrive MPx-16 and MPx-17 Parameter", (DOK-INDRV*-GEN1-PARA**-RE**-DE-P; Mat. No.: R911328651)!

It is also possible to directly view (in N or Nm) the value of "P-0-0049, Effective torque/force command value" as intermediate value.

The content of "P-0-0046, Status word of current controller" results from the current and torque limits.

See also section "Current Controller" below

7.3.3 Current controller

Operating Principle of the Current Controller

The current controller is a typical PI controller and can be set via the following parameters:

- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1

See also "Control Loop Structure"

See also "Motor Control"

In fact, the torque is not closed-loop controlled but open-loop controlled. Given the linear relation between torque and current (see P-0-0051), it is possible, however, to assume closed-loop torque/force control. Just the absolute torque precision is limited due to manufacturing tolerances of the motor (max. ±10%).

Controller Performance and Cycle Times

According to the available hardware (Basic or Advanced design), the current control loop is closed every 62.5 µs (Advanced) or 125 µs (Basic). (See also "P-0-0556, Config word of axis controller", bit 2.)

Notes on Commissioning for the Current Controller

The parameter values for the current controller of Rexroth motors are defined by the manufacturer. In the case of motors with encoder data memory, they are automatically written with the correct values during commissioning.

In the case of motors without encoder data memory, the correct values for the current controller parameters and other motor parameters can be loaded via the "IndraWorks Ds/D/MLD" commissioning tool.

7.3.4 Diagnostic Messages and Monitoring Functions

Diagnostic Status Message

The activated "torque/force control" mode is displayed by the following diagnostic message:

- A0100 Torque control

Monitoring Functions

Monitoring functions specific to the operation mode:

Device Overload

- The thermal load of the device depending on the measured current is permanently calculated by a temperature model. When a threshold value is exceeded, the warning "E8057 Device overload, current limit active" is generated (see description of diagnostic messages).

Command Value Limit Active

- If necessary, the drive firmware limits the torque/force command value in dynamic and static form. If such a limitation has been activated, this is signaled by the warning "E8260 Torque/force command value limit active".

Velocity Limit Value Exceeded

- The value of the parameter "S-0-0040, Velocity feedback value" is monitored as soon as it is outside of the standstill window S-0-0124. If it exceeds the 1.125-fold value parameterized in "S-0-0091, Bipolar velocity limit value", the error message "F8079 Velocity limit value exceeded" is generated.

7.4 Velocity Control

7.4.1 Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the "velocity control" mode, a velocity command value is preset for the drive. The velocity command value is limited by ramps and filters.

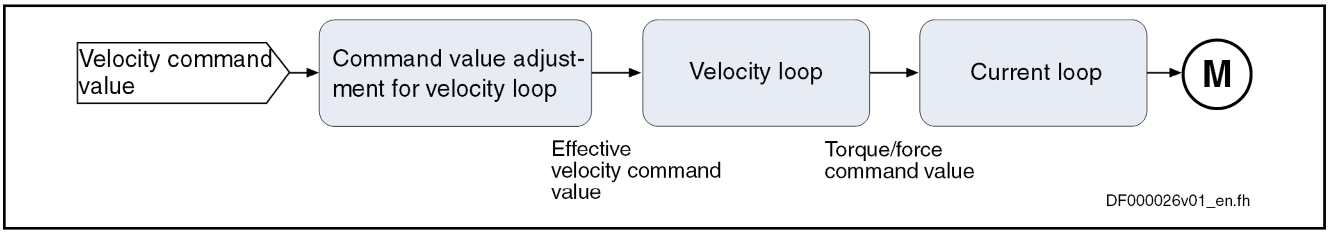


Fig. 7-4: Block Diagram, "Velocity Control"

Features

- An external velocity command value is preset (sum of

  "S-0-0036, Velocity command value" and "S-0-0037, Additive velocity command value") via analog inputs or master communication interface (sercos, field bus, ...)
- Selection of predefined and internally stored velocity command values (31 fixed values) is possible via binarily coded digital inputs (e.g. for jogging forward/backward, feeding, setting up, ...) with separately definable acceleration and deceleration ramps (31 different ramps), as well as jerk filter to be set (31 different time constants)
- Use of a drive-internal command value generator for generating command value ramps ("motor potentiometer")
- Inversion of the provided velocity command value before it is processed in the ramp-function generator
- Window comparator for masking critical velocity ranges in the command value channel (e.g., machine resonances) with corresponding acceleration adjustment (see P-0-1209)
- Ramp-function generator with separately adjustable, two-stage acceleration and deceleration limits of the preset velocity command value; switching from ramp 1 to ramp 2 takes place with selectable velocity and run-up stop that can be parameterized
- Velocity control via a digital PI controller with extensive filter measures
- Monitoring of the command velocity and actual velocity for exceeding parameter "S-0-0091, Bipolar velocity limit value"
- Additional monitoring for the motor-related limit values "S-0-0113, Maximum motor speed" and "P-0-0113, Bipolar velocity limit value of motor"
- Smoothing of velocity control loop difference via filter that can be parameterized
- Smoothing of preset command value by means of average filter (jerk limitation by means of moving average filter)
- Fine interpolation of the velocity command values; transmission of these command values in the position controller clock; the fine interpolator can be switched on or off (P-0-0556, bit 0)
- Velocity control loop monitoring (cannot be parameterized) to prevent the drive from running away; monitor can be switched on or off (P-0-0556, bit 1)
- Velocity controller internally generates the torque/force command value to which the value of the parameter can be added as an additive component
- Control word and status word especially for "velocity control" mode (P-0-1200 and P-0-1210)

Pertinent Parameters

- S-0-0036, Velocity command value

- S-0-0037, Additive velocity command value
- S-0-0040, Velocity feedback value
- S-0-0091, Bipolar velocity limit value
- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- S-0-0113, Maximum motor speed
- S-0-0156, Velocity feedback value 2
- S-0-0535, Active velocity feedback value
- P-0-0004, Velocity loop smoothing time constant
- P-0-0048, Effective velocity command value
- P-0-0113, Bipolar velocity limit value of motor
- P-0-0556, Config word of axis controller
- P-0-1119, Velocity mix factor feedback 1 & 2
  (not valid for MPE-18 firmware)
- P-0-1120, Velocity control loop filter: Filter type
- P-0-1126, Velocity control loop: Acceleration feedforward
- P-0-1200, Control word 1 velocity control
- P-0-1201, Ramp 1 pitch
- P-0-1202, Final speed ramp 1
- P-0-1203, Ramp 2 pitch
- P-0-1206, Memory of velocity command values
- P-0-1207, Lower limit of velocity masking window
- P-0-1208, Upper limit of velocity masking window
- P-0-1209, Acceleration factors for velocity masking window
- P-0-1210, Status word of velocity control mode
- P-0-1211, Deceleration ramp 1
- P-0-1213, Deceleration ramp 2
- P-0-1214, Control word 2 velocity control
- P-0-1215, Motor potentiometer, acceleration
- P-0-1216, Motor potentiometer, deceleration
- P-0-1217, Motor potentiometer, step size
- P-0-1218, Motor potentiometer, command value
- P-0-1222, Velocity command filter
- P-0-1223, List of acceleration ramps
- P-0-1224, List of deceleration ramps
- P-0-1225, List of smoothing time constants

Pertinent Diagnostic Messages

- A0101 Velocity control
- E2059 Velocity command value limit active
- E2063 Velocity command value > limit value
- E8260 Torque/force command value limit active
- F8078 Speed loop error
- F8079 Velocity limit value exceeded

7.4.2 Command Value Adjustment in Velocity Control

Overview

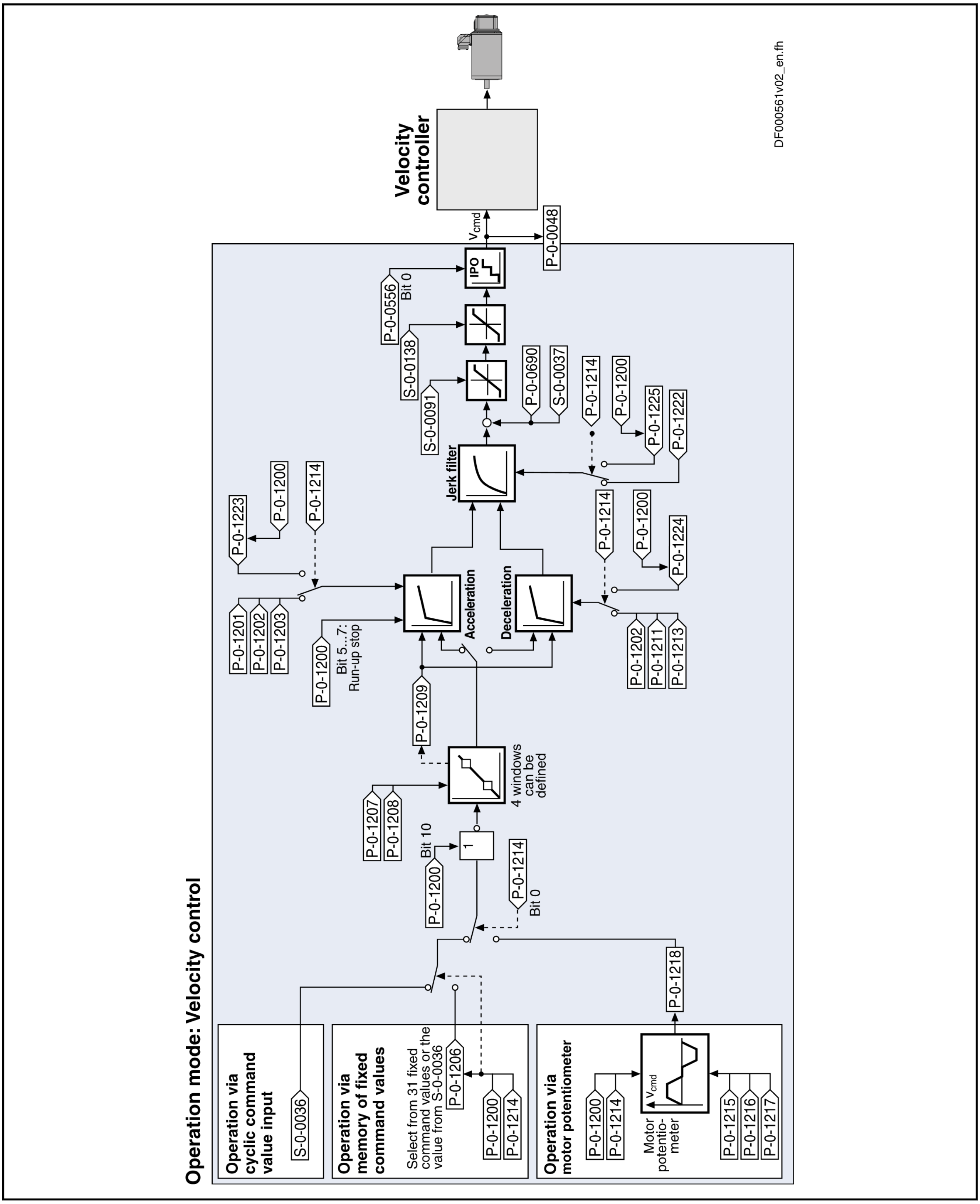


Fig. 7-5: Command Value Adjustment in Velocity Control

☞ The value of "S-0-0037, Additive velocity command value" can be added to "S-0-0036, Velocity command value" directly at the input of the velocity controller.

In the "velocity control" mode, velocity command values can be input in the following ways:

- Cyclic command value input by means of parameter "S-0-0036, Velocity command value" via the master communication (analog interface, sercos, field bus) or IndraMotion MLD
- Use of velocity command values internally stored in the drive in parameter "P-0-1206, Memory of velocity command values" (list parameter); selection via digital inputs; master communication interface (sercos, field bus) or IndraMotion MLD, for example
- Internal generation of command value ramps by a so-called motor potentiometer
- Generation of a cyclic command value by means of the drive-integrated PLC (IndraMotion MLD) in conjunction with MC blocks (cf. P-0-1460)

The velocity command value is processed by the so-called ramp-function generator.

☞ Information on the state of the ramp-function generator is contained in P-0-1210.

See Parameter Description "P-0-1210, Status word of velocity control mode"

Command Value Generation via Memory of Fixed Command Values

Via the selection bits of parameter "P-0-1200, Control word 1 velocity control" (bit 0...4), you can choose from up to 31 velocity command values (P-0-1206) stored in the drive.

☞ By default, you can only select 5 fixed command values via P-0-1200; one fixed command value is assigned to each individual bit (0...4).

Activating the Fixed Command Values

As soon as at least one of the bits 0...4 has been set in P-0-1200, the corresponding element from the list parameter "P-0-1206, Memory of velocity command values" takes effect.

The following assignment applies to the selection via bits 4…0 of P-0-1200:

- For **direct selection** (P-0-1214, bit 8 = 0)
  - 00000 → Value from S-0-0036 active
  - 00001 → Fixed value 1 from P-0-1206 selected and active
  - 00010 → Fixed value 2 from P-0-1206 selected and active
  - 00100 → Fixed value 3 from P-0-1206 selected and active
  - 01000 → Fixed value 4 from P-0-1206 selected and active
  - 10000 → Fixed value 5 from P-0-1206 selected and active
- For **binary selection** (P-0-1214, bit 8 = 1)
  - 00000 → Value from S-0-0036 active
  - 00001 → Fixed value 1 from P-0-1206 selected and active
  - 00010 → Fixed value 2 from P-0-1206 selected and active

– 00011 → Fixed value 3 from P-0-1206 selected and active
– etc.
– 11111 → Fixed value 31 from P-0-1206 selected and active

Via the same control bits of parameter P-0-1200, it is in addition possible to select ramp pitches, as well as time constants for the command value smoothing filter (see sections "Ramp-Function Generator" and "Jerk Limitation").

See also Parameter Descriptions "P-0-1200, Control word 1 velocity control" and "P-0-1214, Control word 2 velocity control"

Command Value Generation via Motor Potentiometer

In the operation mode "velocity control", the command value generator (so-called motor potentiometer) provides the possibility of generating a velocity command value characteristic (P-0-1218, Motor potentiometer, command value) via digital input signals ("ramp+" and "ramp–").

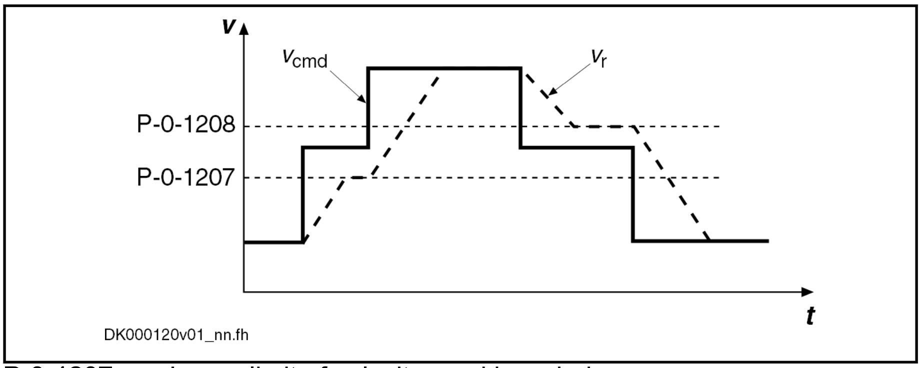
The motor potentiometer is activated by setting bit 0 = 1 in "P-0-1214, Control word 2 velocity control".

Inverting the Velocity Command Value

Before it is processed in the ramp-function generator, the provided velocity command value can be inverted. The inversion takes place by setting bit 10 = 1 in "P-0-1200, Control word 1 velocity control".

Masking the Command Value

The masking windows (max. 4) that can be defined via "P-0-1207, Lower limit of velocity masking window" and "P-0-1208, Upper limit of velocity masking window" are used to suppress resonance phenomena of a machine or in an installation. The drive should not be permanently moved at velocities within these windows. A velocity command value within the value range of one of the 4 definable windows is either reduced to the lower limit (P-0-1207) or increased to the upper limit (P-0-1208).

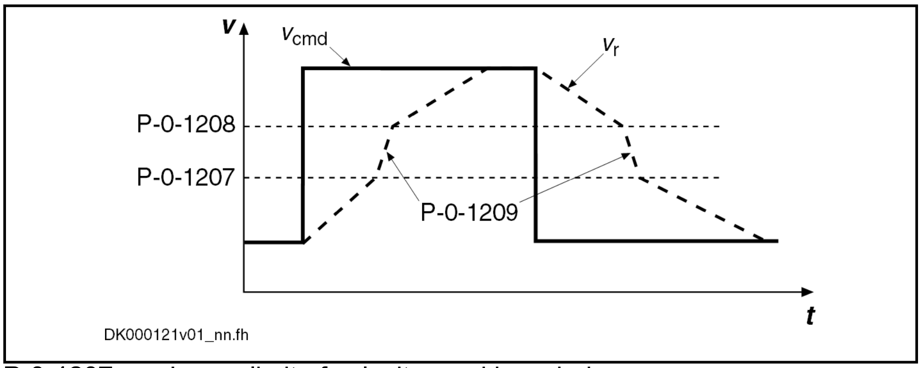


P-0-1207 Lower limit of velocity masking window
P-0-1208 Upper limit of velocity masking window
v_{cmd} Velocity command value
v_r Velocity ramp

Fig. 7-6: "Velocity Masking Window with Hysteresis" Function

See also Parameter Description "P-0-1207, Lower limit of velocity masking window" and "P-0-1208, Upper limit of velocity masking window"

The subsequent ramp-function generator passes the range of the velocity window; the values indicated in "P-0-1209, Acceleration factors for velocity masking window" have a multiplying effect on the acceleration values of the ramp-function generator (P-0-1201, P-0-1203, P-0-1211 and P-0-1213).



P-0-1207	Lower limit of velocity masking window
P-0-1208	Upper limit of velocity masking window
P-0-1209	Acceleration factors for velocity masking window
v_{cmd}	Velocity command value
v_r	Velocity ramp

Fig. 7-7: Operating Principle of the Acceleration Factors from P-0-1209

See also Parameter Description "P-0-1209, Acceleration factors for velocity masking window"

Ramp-Function Generator

For the ramp-function generator, we make the following distinction:

- Cyclic command value input via S-0-0036 or motor potentiometer

  → 2 ramps (acceleration and deceleration) and a jerk filter take effect

  Note: For command value input via S-0-0036, also the ramp pitches and the filter time constants can be selected from the list parameters P-0-1223, P-0-1224, P-0-1225 by the control bits in P-0-1200. This option is activated via Bit 9 in "P-0-1214, Control word 2 velocity control".
- Command value input via memory of fixed command values (P-0-1206)

  → 31 sets with individually definable command velocities, jerk limits and acceleration and deceleration ramps can be defined

Command Value Input via S-0-0036 or Motor Potentiometer

The increase (acceleration) and deceleration of the velocity command value input via "S-0-0036, Velocity command value" or a motor potentiometer can be limited in steps via 2 ramps.

- Acceleration process

  → In the first step, the increase of the command value is limited via "P-0-1201, Ramp 1 pitch" (acceleration ramp 1). If the command velocity exceeds the threshold entered in "P-0-1202, Final speed ramp 1" the increase of the command value is limited with the value "P-0-1203, Ramp 2 pitch" (acceleration ramp 2).
- Deceleration or braking process

  → For deceleration "P-0-1211, Deceleration ramp 1" resp. "P-0-1213, Deceleration ramp 2" are used accordingly.

☞ This allows parameterizing different ramps for the acceleration and braking process.

Command Value Input via Memory of Fixed Command Values

With command value input via the memory of fixed command values (P-0-1206), separate ramp values can be defined for each of the 31 fixed command values via the following list parameters:

- P-0-1223, List of acceleration ramps
- P-0-1224, List of deceleration ramps

These are single-step ramps, i.e. one ramp pitch applies to the entire speed range. Via control bits (bits 0…4) in "P-0-1200, Control word 1 velocity control", the single-step ramps can be selected.

> The fixed command values (P-0-1206) and the corresponding time constants of the jerk filter (P-0-1225) are selected via the control bits in P-0-1200!

The assignment of bits 0...4 of parameter P-0-1200 depends on bit 8 of parameter "P-0-1214, Control word 2 velocity control" (see "Activating the Fixed Command Values" in section "Command Value Generation via Memory of Fixed Command Values").

Run-Up Stop

When there is acceleration-dependent torque limitation occurring or due to installation-dependent failures/irregularities, it is necessary to interrupt the acceleration ramp. For this purpose, the "run-up stop" function was implemented; it is controlled via "P-0-1200, Control word 1 velocity control".

Possible settings for activating the "run-up stop" function via the respective bits of P-0-1200:

- Activation of the function without additional condition
- Triggering of torque limitation (E8260 Torque/force command value limit active)
- Triggering of command value limitation (cf. S-0-0091)
- Triggering of command value or torque limitation

> While a speed masking window is passed, the "run-up stop" function is deactivated.

Jerk Limitation

The velocity command value, the increase and maximum of which are limited, is jerk-limited by means of a 1st order low-pass filter.

For jerk limitation, we make the following distinction:

- Cyclic command value input via S-0-0036 or motor potentiometer

  → Jerk limitation takes effect as set in parameter P-0-1222
- Command value input via memory of fixed command values (P-0-1206)

  → Jerk limitation can be separately defined for each of the 31 fixed command values by an individual smoothing time constant (P-0-1225)

Command Value Input via S-0-0036 or Motor Potentiometer

The command value input via "S-0-0036, Velocity command value" or a motor potentiometer is jerk-limited according to the settings in "P-0-1222, Velocity command filter".

Command Value Input via Memory of Fixed Command Values

With command value input via the memory of fixed command values (P-0-1206), an individual filter time constant (P-0-1225, List of smoothing time constants) can be configured for each of the 31 fixed command values; the filter time constant is selected via the control bits (bits 0…4) of parameter "P-0-1200, Control word 1 velocity control".

☞ The control bits in P-0-1200 are also used to select the fixed command values (P-0-1206) and the corresponding ramp pitches (P-0-1223 and P-0-1224)!

The assignment of bits 0...4 of parameter P-0-1200 depends on bit 8 of parameter "P-0-1214, Control word 2 velocity control" (see "Activating the Fixed Command Values" in section "Command Value Generation via Memory of Fixed Command Values").

Command Value Limitation

The effective velocity command value (sum of values from S-0-0036 and S-0-0037) is limited to the value indicated in parameter "S-0-0091, Bipolar velocity limit value" resp. in the parameters "S-0-0038, Positive velocity limit value" or "S-0-0039, Negative velocity limit value".

See also "Velocity Limitation"

☞ When the limitation takes effect, the drive generates the message "E2059 Velocity command value limit active".

Fine Interpolation

The limited command value available at the output of command value processing can be adjusted, by means of linear fine interpolation, for further processing in the velocity controller. To do this, a command value input in the position controller clock is fine interpolated in the velocity controller clock.

This function has to be activated via bit 0 of parameter "P-0-0556, Config word of axis controller".

7.4.3 Velocity control loop

Velocity controller

The velocity controller is a typical PI controller and can be set via the following parameters:

- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time

See also "Control Loop Structure"

Controller Performance and Cycle Times

The minimum possible controller cycle time of the velocity controller depends

- on the existing device (Economy, Basic, multi-axis)
- on the respective firmware variant (MPE, MPB or MPM)

- and -

- in the case of variant MPB, on the parameterized performance (Basic or Advanced; see "P-0-0556, Config word of axis controller", bit 2).

See "Performance Data"

Current Controller in Velocity Control Loop

In velocity control, the outer current control loop (cascade structure), that can be set via the following parameters, always takes effect, too:

- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- P-0-0001, Switching frequency of the power output stage

See also "Torque/Force Control: Current controller"

Filter Options

To filter noise components possibly present in the actual velocity value or to attenuate resonance frequencies, the following filter settings can be made:

- Via "P-0-0004, Velocity loop smoothing time constant", the low-pass filter that filters the control difference for the velocity controller can be set.
- To filter the control deviation, it is possible to configure four filters connected in series as low-pass filters, band-stop filters or 2nd order filters with "P-0-1120, Velocity control loop filter: Filter type".

☞ "P-0-0070, Effective additive torque/force command value" is added to the output signal of the velocity controller and the resulting value is transmitted to the current and torque/force limitation (see also "Current and Torque/Force Limitation").

7.4.4 Notes on Commissioning

Memory of Fixed Command Values

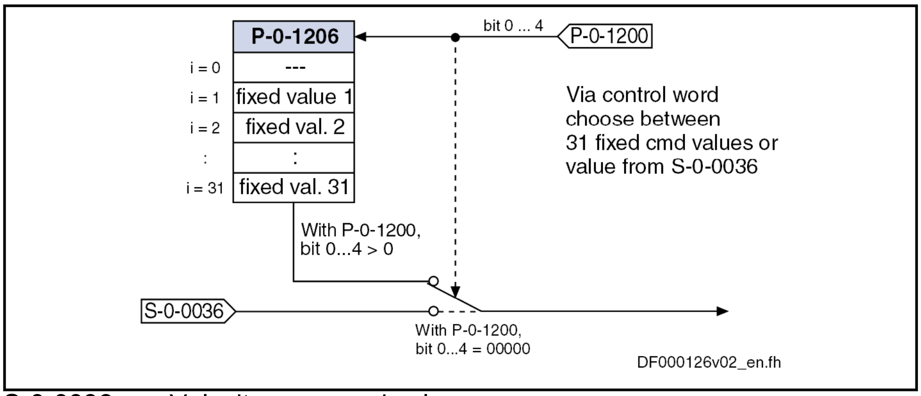
In addition to the cyclic velocity command value (S-0-0036), the drive can be moved with fixed constant velocity command values stored in the drive.

Selecting Fixed Command Values

Selecting preset fixed command values can be effectively used for applications with analog or parallel interface with which the drive is moved with constant velocity steps (e.g., jogging forward/backward, feeding, setting up, washing, …) that are to be selected via switches/pushbuttons.

Velocity Steps

The velocity steps (max. 31 values) provided for this purpose can be entered in the list parameter P-0-1206 and each of them can be individually activated via the bits 0...4 of the control word P-0-1200 (according to a binary coding). The figure below illustrates the interaction of the parameters:



S-0-0036 Velocity command value
P-0-1200 Control word 1 velocity control
P-0-1206 Memory of velocity command values

Fig. 7-8: Selecting the Internally Stored Velocity Command Values

Special Cases

Observe the following special cases for selecting the fixed command values via bit 0…4 of parameter P-0-1200:

- When all 5 bits have been set to "0", the velocity command value (S-0-0036) preset by the master is active.
- If the motor potentiometer was activated via bit 0 of "P-0-1214, Control word 2 velocity control", the selected fixed command values will not take effect.

Applying the Fixed Command Values

The command values are applied immediately, when the bit pattern is created so that you have to make sure that the bits 0...4 are, as far as possible, simultaneously updated.

If the selection of the fixed command values is switched off via bit 9 of the parameter P-0-1214, the selected fixed command values will not take effect. The command value from "S-0-0036, Velocity command value" takes effect.

Motor Potentiometer

Activating the Function

After the motor potentiometer has been activated by setting bit 0 of "P-0-1214, Control word 2 velocity control", the motor potentiometer functionality can be used.

Using and Modifying Command Value Ramps

The command value ramps are used and modified via the two control bits, bit 8 (ramp+) and bit 9 (ramp-) of "P-0-1200, Control word 1 velocity control". These bits can be written in the following ways:

- Via digital inputs

  → See "Digital Inputs/Outputs"
- Via the control panel (comfort or standard control panel)

  → See "Control Panels of the IndraDrive Controllers"
- By simple writing of the parameter via the engineering port or the interface of the master communication

Start Value or Initial Value for the Command Value Generator

Bits 1 and 2 of "P-0-1214, Control word 2 velocity control" determine the start value after the activation of drive enable (cf. P-0-0115, bit "drive on"); the following settings can be selected:

- 00 → Command value generator starting at command value "0"
- 01 → Command value generator starting with old command value (value is also stored when control voltage switched off!)
- 10 → Command value generator starting with current velocity feedback value in S-0-0040
- 11 → Selection not allowed!

Acceleration of the Ramps

Bit 3 of "P-0-1214, Control word 2 velocity control" determines the acceleration behavior; the following cases are to be distinguished:

- **Bit 3 = 0: Constant acceleration**

  → Linear adjustment of command velocity

  The velocity command value is influenced with the duty cycle of "ramp+" or "ramp-" and acceleration remains constant:

  – With the control bit "ramp+", the velocity command value is increased up to the positive limit value (= minimum value of S-0-0091 and S-0-0038), with the acceleration entered in "P-0-1215, Motor potentiometer, acceleration".

  – With the control bit "ramp-", the velocity command value is decreased up to the negative limit value (= minimum value of S-0-0091 and S-0-0038), with the deceleration entered in "P-0-1216, Motor potentiometer, deceleration".
- **Bit 3 = 1: Linearly variable acceleration**

  → Square adjustment of command velocity

  The acceleration changes in linear form with the duty cycle of "ramp+" or "ramp-":

– With the control bit "ramp+", the acceleration value within 2 s is increased up to the positive limit value ("P-0-1201, Ramp 1 pitch" or "P-0-1203, Ramp 2 pitch"), with the pitch ("P-0-1215, Motor potentiometer, acceleration").
– With the control bit "ramp-", the acceleration value within 2 s is decreased to the negative limit value ("P-0-1211, Deceleration ramp 1" or "P-0-1213, Deceleration ramp 2"), with the pitch ("P-0-1215, Motor potentiometer, acceleration").

> ☞ This allows parameterizing different ramps for the acceleration and braking process.

Evaluation Mode of Ramp Inputs

Bit 3 of "P-0-1214, Control word 2 velocity control" determines the evaluation mode of the two control inputs "ramp+" and "ramp-"; the following cases are to be distinguished:

- **Bit 4 = 0: Continuous evaluation**

  → Continuous adjustment of acceleration or velocity via "ramp+" or "ramp-"
  - As long as bit 8 ("ramp+") is set, the command value is increased.
  - As long as bit 9 ("ramp-") is set, the command value is increased.
- **Bit 4 = 1: Edge-controlled evaluation**

  → Stepwise adjustment of the velocity command value with value of parameter "P-0-1217, Motor potentiometer, step size"
  - With a positive edge of "ramp+", the command value is increased by the value of parameter P-0-1217.
  - With a positive edge of "ramp-", the command value is decreased by the value of parameter P-0-1217.

> ☞ When a control bit "ramp+" or "ramp-" is set for more than 2 s, the mode automatically changes to continuous adjustment of the command value with the corresponding acceleration/deceleration ramp.

Examples

The figures below show some examples by means of the signal characteristic:

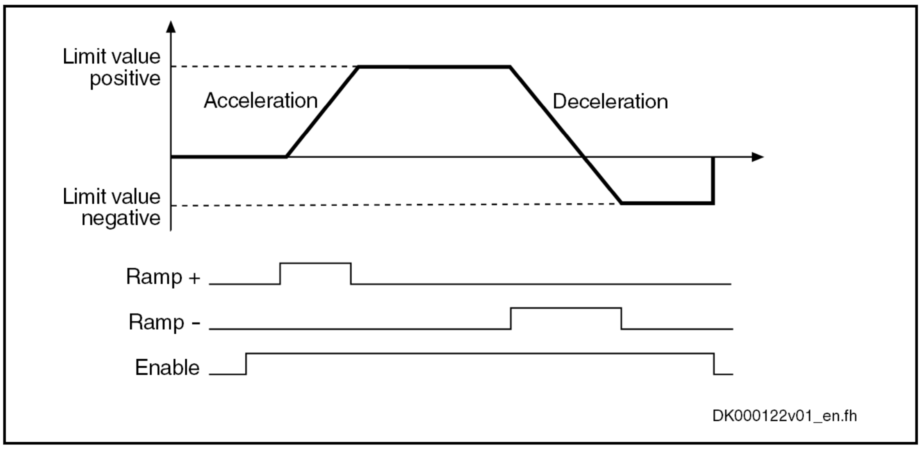


Fig. 7-9: Linear Adjustment of Command Velocity with State-Controlled Evaluation of "Ramp+" and "Ramp-"

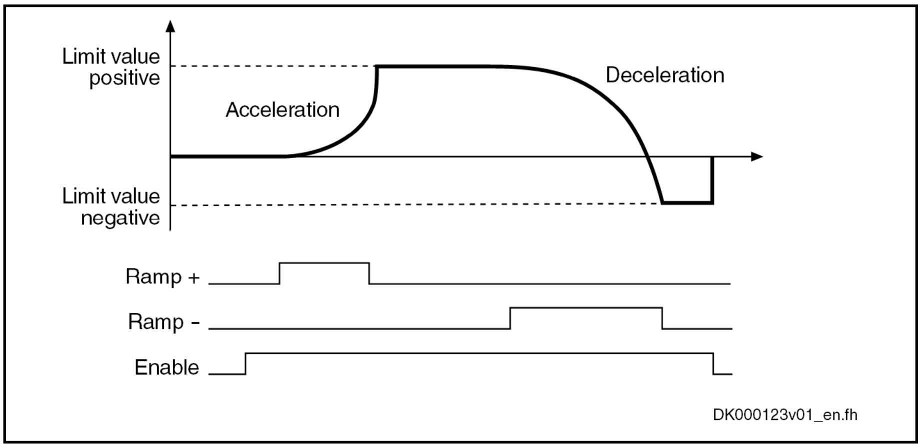


Fig. 7-10: Square Adjustment of Command Velocity with State-Controlled Evaluation of "Ramp+" and "Ramp-"

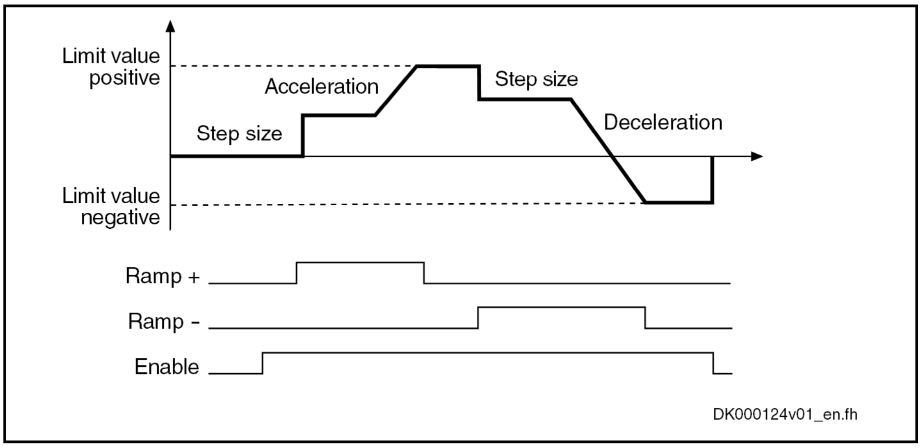


Fig. 7-11: Linear Adjustment of Command Velocity with Edge-Controlled Evaluation of "Ramp+" and "Ramp-"

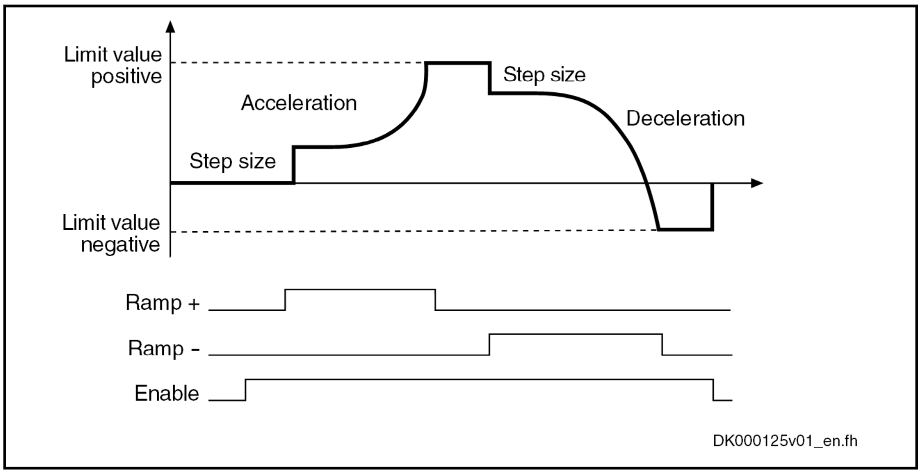


Fig. 7-12: Square Adjustment of Command Velocity with Edge-Controlled Evaluation of "Ramp+" and "Ramp-"

Velocity Mixing

"P-0-1119, Velocity mix factor feedback 1 & 2" can be used to mix the different actual encoder values in the event of control-related stability problems ("S-0-0040, Velocity feedback value" and "S-0-0156, Velocity feedback value 2").

Velocity mixing is only valid for single-axis firmware MPB and multi-axis firmware MPM

Acceleration Feedforward

To improve the control performance it is possible to add the speed command value, bypassing the velocity controller, to the velocity controller output in a derivative way and scaled via "P_0_1126, Velocity control loop: Acceleration feedforward". This differentiated command value can also be smoothed by means of a PT1 filter (cf. P-0-0180).

This kind of feedforward allows achieving sufficiently good and dynamic control performance, even with bad measuring systems or a very high degree of load inertia (or mass).

See also "Control Loop Structure"

Masking the Velocity Command Value

For each velocity window (cf. P-0-1207, P-0-1208), it is possible to define an individual acceleration factor (cf. P-0-1209) that takes effect, however, both for acceleration and for deceleration.

When parameterizing the velocity windows, the following aspects have to be taken into account:

- The list elements have to contain ascending numeric values (identical values are allowed).
- Inputs that lead to overlapping ranges (P-0-1207[n] > P-0-1208[n+1]) are not allowed.
- When identical values are input for lower and upper limit (P-0-1207[n] = P-0-1208[n]), the window is deactivated.
- If the element P-0-1207[0] = 0, the window takes effect symmetrically relative to speed zero. This prevents the velocity command value from falling below a certain minimum value.

The default values of P-0-1207 and P-0-1208 are zero which means that the speed window has not been defined.

7.4.5 Diagnostic Messages and Monitoring Functions

Diagnostic Status Message

Active Operation Mode

The activated "velocity control" mode is displayed by the following diagnostic message:

- A0101 Velocity control

Status of Ramp-Function Generator

Effective Velocity Command Value

The currently effective velocity command value at the output of command value adjustment, that is preset for the velocity controller via the fine interpolation, is mapped to "P-0-0048, Effective velocity command value".

Status of Ramp-Function Generator (Run-Up Encoder)

"Frequency converter" applications require several status messages that are contained in "P-0-1210, Status word of velocity control mode":

- Bit 0 = 1 → Command value reached

  The output of the ramp-function generator, including the jerk filter, corresponds exactly to the selected command value, i.e. either to the value of S-0-0036 or a selected fixed value from P-0-1205.

- Bit 1 = 1 → Run-up stop active

  The "run-up stop" command prevents the acceleration ramp from being integrated. The jerk filter is not stopped, the current command value for the time set in the jerk filter can change.
- Bit 2 = 1 → Acceleration active

  The absolute value of the present command value is higher than the current command value. Either the acceleration ramp is active or the jerk filter has not yet reached the final value.
- Bit 3 = 1 → Deceleration active

  The absolute value of the present command value is lower than the current command value. Either the deceleration ramp is active or the jerk filter has not yet reached the final value.
- Bit 4 = 1 → Command value within masking window

  The command value is within a masking window defined by the values of P-0-1207 and P-0-1208 and prevents the drive from moving exactly to this command value.
- Bit 5 = 1 → Velocity ramp within masking window

  The ramp-function generator goes through the range of a masking window, the increased acceleration/deceleration according to P-0-1209 is active. In addition to this message bit, either the bit "acceleration active" or "deceleration active" has been set.

Monitoring Functions

Monitoring functions specific to the operation mode:

Velocity Command Value Limit Active

- The effective velocity command value (sum from S-0-0036 and S-0-0037) is limited to the value set in "S-0-0091, Bipolar velocity limit value". When the limitation takes effect, the drive generates the message "E2059 Velocity command value limit active".

Velocity Command Value > Limit Value

- The value of the parameter "S-0-0036, Velocity command value" is limited to "S-0-0091, Bipolar velocity limit value". f the value in S-0-0036 is higher than the value in S-0-0091, the warning "E2063 Velocity command value > limit value" is generated.

Speed Loop Error

- The drive monitors the correct function of the velocity controller and in the case of fatal errors disables the drive torque with the error message "F8078 Speed loop error".

Velocity Limit Value Exceeded

- The value of the parameter "S-0-0040, Velocity feedback value" is monitored as soon as it is outside of the standstill window S-0-0124. If it exceeds the 1.125-fold value parameterized in "S-0-0091, Bipolar velocity limit value", the error message "F8079 Velocity limit value exceeded" is generated.

7.5 Position control with cyclic command value input

7.5.1 Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the "position control" mode, a cyclic position command value is preset for the drive in NC cycle time. This command value is fine interpolated in the drive and jerk-limited via filters, if necessary, before being transmitted to the position controller.

To minimize the lag error, variable acceleration feedforward is available in addition to variable velocity feedforward.

There are different forms of the "position control" mode which result in the corresponding diagnostic messages when the operation mode was activated (see "Pertinent Diagnostic Messages" below).

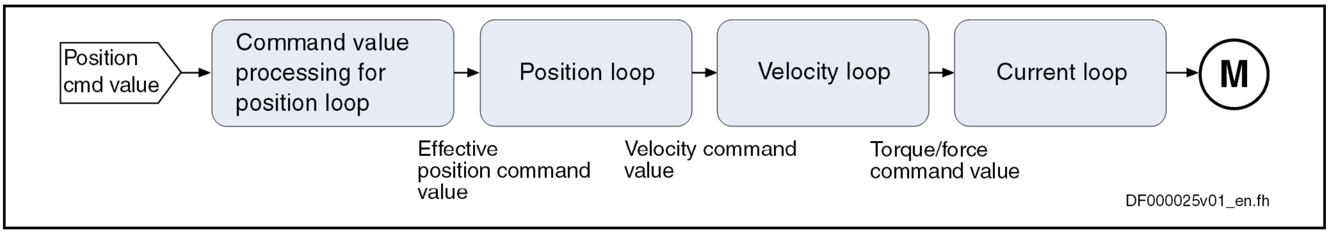


Fig. 7-13: Block Diagram, "Position Control with Cyclic Command Value Input"

Features

- Position control with regard to the command value preset in parameter "S-0-0047, Position command value"
- NC-controlled or drive-controlled position control with internal, dynamic synchronization when changing operation modes
- Timebase for cyclic command value input defined by "S-0-0001, NC cycle time (TNcyc)"
- Monitoring of the position command value difference for exceeding parameter "S-0-0091, Bipolar velocity limit value"
- Position command values of the control section smoothed by means of adjustable average value filter; calculation from acceleration and jerk limit values; displayed in parameter "P-0-0042, Current position command average value filter order"
- Fine interpolation of position command value of the control unit to position controller clock; can be switched via "P-0-0187, Position command processing mode"
- Adjustable position command value delay in position cycle times (P-0-0456, Position command value delay), maximum of 32 cycles.
- Position control with regard to actual position value encoder 1 (motor encoder) or actual position value encoder 2 [external (load-side) encoder], can be dynamically switched
- Velocity feedforward through adjustable factor of 0…150 % (default = 100 %)
- Cyclic acceptance of an additive torque/force command value of the control unit (external acceleration feedforward)

☞ The condition for this operation mode is synchronous communication between the control unit and the drive, as is the case with sercos interface, for example.

Pertinent Parameters

- S-0-0047, Position command value
- S-0-0081, Additive torque/force command value
- S-0-0091, Bipolar velocity limit value
- S-0-0138, Bipolar acceleration limit value
- S-0-0520, Axis control word
- P-0-0010, Excessive position command value
- P-0-0011, Last valid position command value

- P-0-0041, Position command average value filter time constant
- P-0-0042, Current position command average value filter order
- P-0-0047, Position command value control
- P-0-0059, Additive position command value, controller
- P-0-0070, Effective additive torque/force command value
- P-0-0099, Position command smoothing time constant
- P-0-0142, Synchronization acceleration
- P-0-0143, Synchronization velocity
- P-0-0187, Position command processing mode
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0458, Delay of add. command values
- P-0-0556, Config word of axis controller

Pertinent Diagnostic Messages

- A0102 Position mode, encoder 1
- A0103 Position mode, encoder 2
- A0104 Position mode lagless, encoder 1
- A0105 Position mode lagless, encoder 2
- A0154 Position mode drive controlled, encoder 1
- A0155 Position mode drive controlled, encoder 2
- A0156 Position mode lagless, encoder 1 drive controlled
- A0157 Position mode lagless, encoder 2 drive controlled
- F2036 Excessive position feedback difference
- F2037 Excessive position command difference

☞ The error message F2037 can also be configured as a warning. In this case, there is no error reaction on the drive side. The user is then responsible for initiating an appropriate reaction via the control master.

7.5.2 Command Value Adjustment in Position Control

NC-Controlled or Drive-Controlled Position Control

We distinguish the following characteristics of the operation mode "position control with cyclic command value input":

- **NC-controlled position control** (cf. A0102 to A0105)

  The drive generally follows the position command values cyclically input by the master in the NC cycle.

- **Drive-controlled position control** (cf. A0154 to A0157)

  In the case of a change of operation mode to cyclic position control, the drive realizes the corresponding synchronization process, i.e. it generates, internally by means of the internal synchronization parameters (P-0-0142, P-0-0143, P-0-0154, P-0-0151), a smooth transition of the internal position command value from the current actual position to the new command value characteristic input by the NC. After the synchronization process has been completed, the drive follows the position command values input by the master in the NC cycle.

☞ The command value cyclically transmitted by the control unit is displayed in parameter "P-0-0047, Position command value control".

The internal position command value at the position controller is displayed in parameter "P-0-0434, Position command value of controller". If required, it can also be read via parameter "S-0-0047, Position command value".

Command Value Filtering (Jerk Limitation)

The position command values preset by the control unit can be smoothed via an average value filter that can be set ("P-0-0041, Position command average value filter time constant", moving average filter for a maximum of 64 values). The resulting filter degree is displayed via "P-0-0042, Current position command average value filter order". This filter can be used for jerk limitation.

In the case of drive-controlled position control, a jump of the position command value is traveled by a change of the position command average value filter with synchronization motion in control.

☞ The PT1 filter for jerk limitation that can be parameterized via "P-0-0099, Position command smoothing time constant" only takes effect for linear fine interpolation.

Fine Interpolation of the Position Command Value

The position command value cyclically transmitted in the NC cycle time by the control unit can be fine interpolated in the drive, if necessary.

Via "P-0-0187, Position command processing mode", it is possible to switch between:

- Linear fine interpolator
- Cubic approximator (default setting) or
- Cubic fine interpolator (according to contour)

The default value is the cubic approximation; cubic fine interpolation (according to contour) cannot be selected with the firmware variant MPE.

ℹ See also Parameter Description "P-0-0187, Position command processing mode"

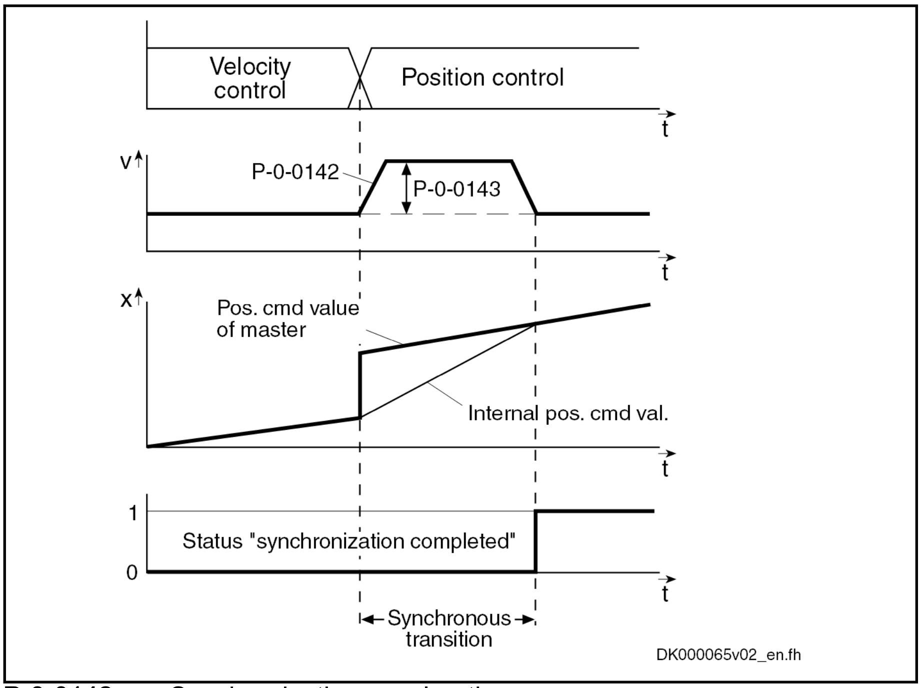
☞ It is recommended to use the cubic fine interpolator (according to contour), because it provides clearly higher quality of velocity and acceleration feedforward, particularly with lagless position control.

Position Command Value Deceleration

The position command value can be delayed by a maximum of 32 position clocks after the fine interpolator, before it is transmitted to the position controller. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position clocks is set with the position command value delay (P-0-0456). The position command value generator without delay (P-0-0457) is entered in a ring buffer and then the position command value with delay is applied to the position command value of controller (P-0-0434).

Drive-Controlled Change of Operation Mode

During drive-controlled change of operation mode, the drive makes sure internally that when the operation mode is changed, the transition is carried out in a synchronized way, even if the command value changes abruptly.



P-0-0142 Synchronization acceleration
P-0-0143 Synchronization velocity

Fig. 7-14: Time Diagram "Drive-Controlled Change of Operation Mode"

See also "Changing the Operation Mode"

Acceleration Feedforward External

The additive torque/force command value (S-0-0081), cyclically transmitted in the NC cycle time by the control unit, can be adjusted in such a way that it takes effect in the controller at the same time as the position command value (S-0-0047). For this purpose, the sequence of storing of the position command value for the additive torque/force command value is simulated as follows:

- Moving **average filter** in the NC clock with filter order from "P-0-0041, Position command average value filter time constant"
- **Linear fine interpolator** in the position clock for division of the additive torque/force command value to the position clock
- **Delay element** in the position clock with a delay of a maximum of 64 clocks to be set in "P-0-0458, Delay of add. command values"

The output value of this command value adjustment is added to the output of the velocity controller and is output in the parameter "P-0-0070, Effective additive torque/force command value". With a value greater than zero in "P-0-0458, Delay of add. command values", the "external acceleration feedforward" function is activated.

To make "P-0-0434, Position command value of controller" and P-0-0070 take effect at the same time, parameterize the delay element (P-0-0458) in dependence of "P-0-0187, Position command processing mode":

P-0-0187	Type of interpolation	P-0-0458
0	Linear interpolation	P-0-0456 + 1
1	Cubic approximation	P-0-0456 + (NC clock / position clock - 1) + 1
2	Cubic fine interpolation	P-0-0456 + (NC clock / position clock) + 1

Tab. 7-1: Calculating the Number of Delay Cycles of External Acceleration Feedforward

If the NC cycle time is identical to the position clock, the term "NC clock / position clock" or "NC clock / position clock - 1" is not required when calculating P-0-0458.

☞ The function is also activated with P-0-0458 = "-1". In this case, the delay element is calculated internally, according to the above formula and depending on P-0-0187.

The PT1 filter that can be parameterized via P-0-0099 is not taken into account by the external acceleration feedforward and therefore should be deactivated when the linear interpolation is used.

Block Diagram

The figure below illustrates command value adjustment in the "position control" mode as a block diagram.

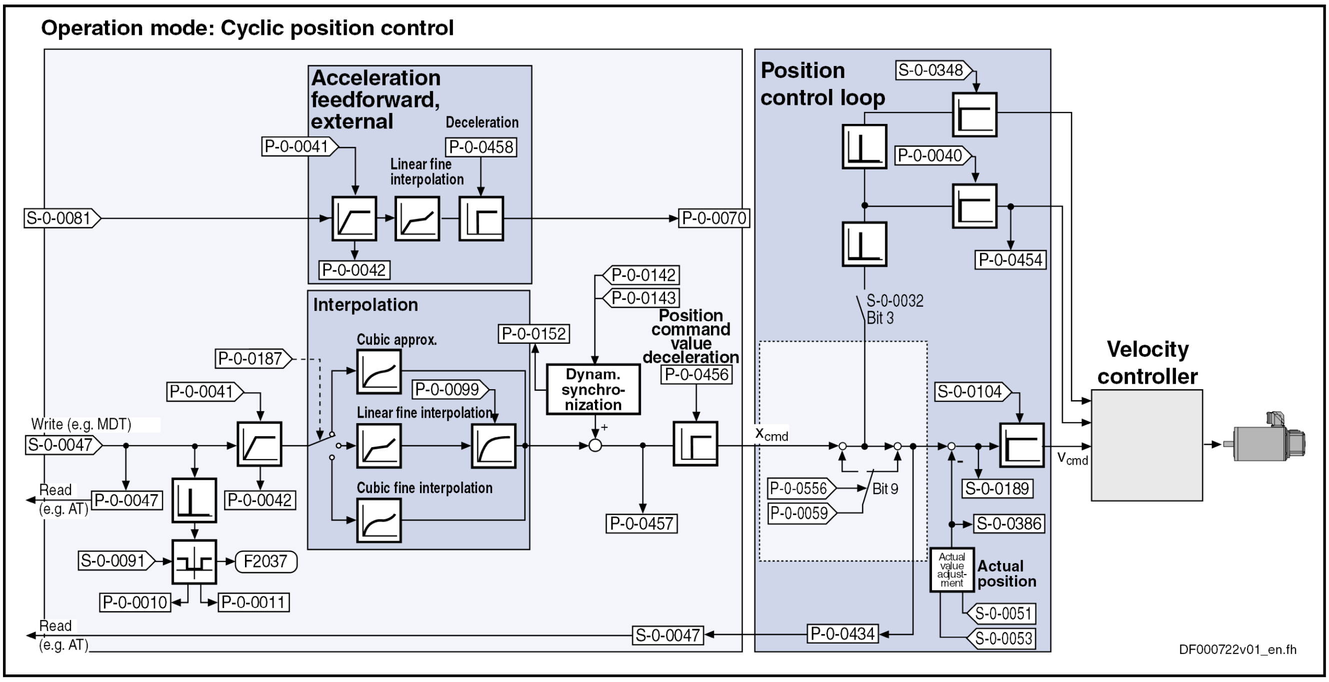


Fig. 7-15: Command Value Adjustment in Position Control

See also "Position Controller" in the same section

See also "Velocity Controller" in the "Velocity Control" section

See also "Current Controller" in the "Torque/Force Control" section

7.5.3 Position controller

The position controller is a simple P-controller, its proportional gain can be set with the value of "S-0-0104, Position loop Kv-factor".

See also "Control Loop Structure"

Operation modes

Controller Performance and Cycle Times

The position control loop is closed according to the available performance design (see "Performance Data").

Velocity Feedforward

The type of position control with regard to velocity feedforward can be set via "S-0-0520, Axis control word", but for operation modes with a definitely assigned encoder (e.g., position control, encoder 1 or ...., encoder 2 etc.) this property is exclusively controlled via a bit of the operation mode parameter.

- Lagless operation (**with** velocity feedforward)
- Operation with lag error (**without** velocity feedforward)

The lag error is the difference between position command value and actual position value. The current value is stored in "S-0-0189, Following distance".

☞ If the mechanical system and the application permit it, lagless operation should always be selected.

The velocity feedforward is variable and can be set via "P-0-0040, Velocity feedforward evaluation". This allows setting the lag error to a desired percentage value at constant velocity.

☞ In lagless operation with P-0-0040 = 100%, there is a minimum lag error of "0" at constant velocity.

Acceleration Feedforward

In lagless operation, variable acceleration feedforward can be activated in addition to variable velocity feedforward (parameter "P_0_0040, Velocity feedforward evaluation).

To do this, the acceleration-proportional feedforward component (additive torque/force command value) is set via "S-0-0348, Acceleration feedforward gain".

☞ In addition, it is possible to realize feedforward via "P-0-1126, Velocity control loop: Acceleration feedforward", but this feedforward is derived from the velocity command value. Therefore, you have to make sure that you did not activate both feedforward values by mistake!

See also "Axis Control: Position Controller (with Respective Feedforward Functions and Actual Value Adjustment)"

7.5.4 Diagnostic Messages and Monitoring Functions

Diagnostic Status Messages

The activated "position control with cyclic command value input" mode is displayed by one of the following diagnostic messages:

- A0102 Position mode, encoder 1
- A0103 Position mode, encoder 2
- A0104 Position mode lagless, encoder 1
- A0105 Position mode lagless, encoder 2
- A0154 Position mode drive controlled, encoder 1
- A0155 Position mode drive controlled, encoder 2
- A0156 Position mode lagless, encoder 1 drive controlled
- A0157 Position mode lagless, encoder 2 drive controlled

Monitoring Functions/Diagnostic Messages Specific to Operation Mode

Monitoring for Single Position Command Value Failure

Position Command Value Extrapolation

In the "position control with cyclic command value input" mode, new position command values are transmitted to the drive in every NC cycle. The difference between the current and the last position command value is determined and a validation check is carried out for this difference.

Reasons why the monitoring function triggers:

- Incorrect command value input by control unit
- Command value transmission error

> ☞ In the case of single command value failure, the position command value is extrapolated.

Excessive Position Command Difference

When the "position control" mode was activated, the calculated velocity required for reaching the preset position command value (S-0-0047) is compared to "S-0-0091, Bipolar velocity limit value". The NC cycle time (TNcyc in S-0-0001) is used as the time base for converting the position command value differences into a velocity.

If the command velocity corresponding to the preset position command value exceeds the value in S-0-0091, the error message "F2037 Excessive position command difference" is generated. In addition, the two involved command values are written to the following parameters:

- P-0-0010, Excessive position command value
- P-0-0011, Last valid position command value

The velocity resulting from the difference of these two values generated the error message.

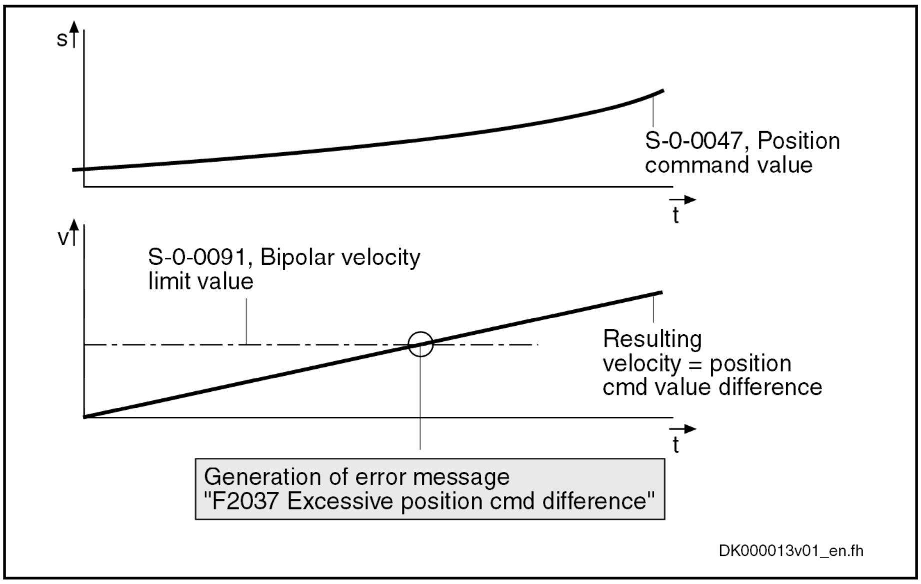


Fig. 7-16: Monitoring for Error "F2037 Excessive Position Command Difference"

> ☞ The value entered in parameter "S-0-0091, Bipolar velocity limit value" should be approximately 5 to 10% above the intended maximum velocity of the axis.

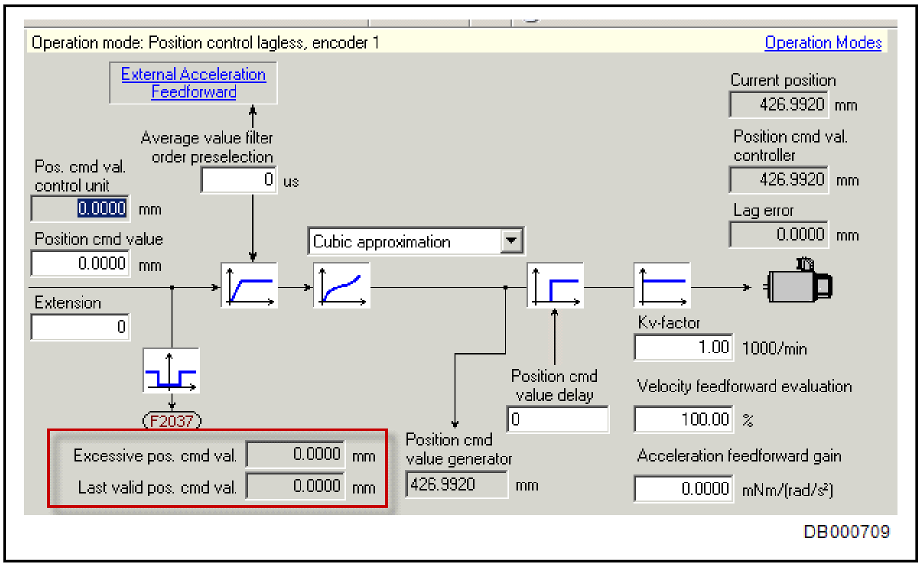


Fig. 7-17: IndraWorks Dialog for Diagnosing the Excessive Position Command Value Difference F2037

The error message F2037 can be deactivated by reconfiguring it into a warning (E2037). This is done in "P-0-0173, List of configurable axis-specific monitoring functions". In this case, there is no drive-side error reaction. The user is then responsible for initiating an appropriate reaction via the control master.

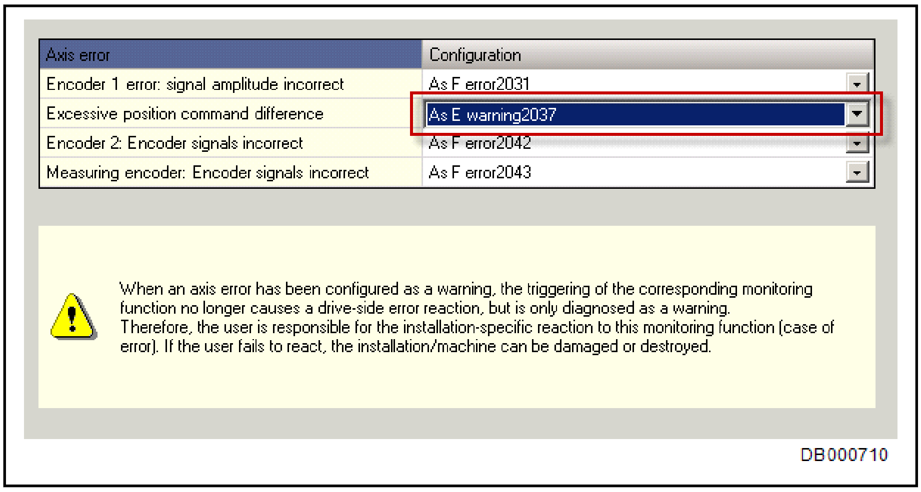


Fig. 7-18: IndraWorks Dialog for Reconfiguring the Error Messages F2037 into a Warning

7.6 Drive-internal interpolation

7.6.1 Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

The two operation modes "drive-internal interpolation" and "drive-controlled positioning" allow time-optimized positioning of a single axis. The "drive-internal interpolation" mode is the basis for the more comprehensive functionality of the "drive-controlled positioning" mode.

In the "drive-internal interpolation" mode, a target position is directly preset for the drive. In the internal positioning generator, a position command value characteristic is generated (interpolated), from the preset value for the target position considering preset positioning data (velocity, acceleration and jerk), as the input value for the position controller.

There are different forms of the "drive-internal interpolation" mode which result in the corresponding diagnostic messages when the operation mode was activated (see below "Pertinent Diagnostic Messages").

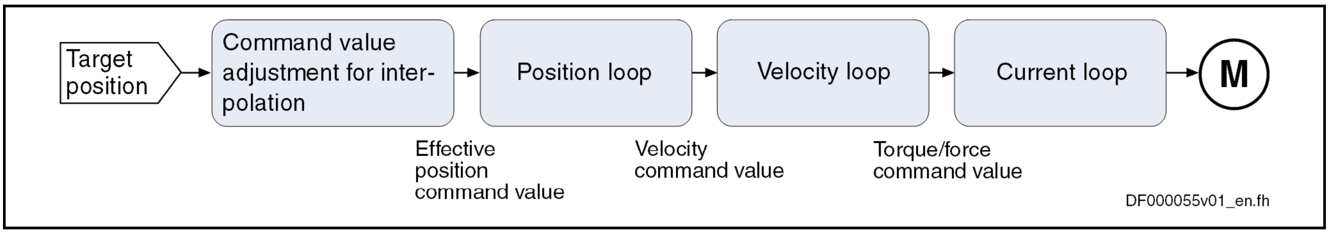


Fig. 7-19: Block Diagram, "Drive-Internal Interpolation"

Features

- Drive-internal generation of a position command value profile to travel to a preset target position (S-0-0258) while maintaining the positioning velocity (S-0-0259) and positioning acceleration (S-0-0260) or positioning deceleration (S-0-0359) that can be set; can be set separately
- Command value generation runs in the NC cycle "S-0-0001, NC cycle time (TNcyc)". The transition to the position controller cycle is made by cubic fine interpolation.
- Jerk limitation of the generated position command value via "S-0-0193, Positioning jerk"
- Setting of the average value filter (jerk limitation) to a fixed filter time with interpolation command value average value filter time constant (P-0-0641)
- Adjustable position command value delay in position cycle times (P-0-0456), maximum of 32 cycles.
- Evaluation of the positioning velocity with "S-0-0108, Feedrate override"
- Monitoring of the positioning velocity for exceeding "S-0-0091, Bipolar velocity limit value"

☞ The positioning velocity can be limited with the use of the safety technology by "P-0-3238, SMO: Active velocity threshold" see also "Rexroth IndraDrive, Integrated Safety Technology "Safe Motion" (as of MPx-18)" (DOK-INDRV*-SI3*SMO-VRS-AP**-EN-P; Mat. No. R911338920).

☞ The initial speed of the operation mode can be limited, for one axis with safety technology, to an additional speed value [product from "SMO: active speed threshold" (P-0-3238) and "SMO: evaluation factor speed limit "(P-0-3218)] when activated in the parameter "SMO: Configuration support functions" (P-0-3219), see also the separate documentation "Rexroth IndraDrive, Integrated Safety Technology "Safe Motion" (as of MPx-18)" (DOK-INDRV*-SI3*SMO-VRS-AP**-EN-P; Mat. No. R911338920), chapter "Additional and auxiliary functions".

- Monitoring of the target position for compliance with the position limit values

- Command value mode can be set (S-0-0393) in modulo format (shortest distance, only positive or only negative direction)
- Position control with regard to "S-0-0051, Position feedback value 1" (motor encoder) or "S-0-0053, Position feedback value 2" [external (load-side) encoder]
- Acceleration and deceleration ramps, can be set separately
- No change in direction of motion when

  "command value mode in modulo format" equals "shortest distance", if v_{act} > S-0-0417
- "Shortest distance" mode when "command value mode in modulo format" equals "only positive/negative direction of motion" and target position within "S-0-0418, Target position window in modulo mode"

☞ In this operation mode, it is possible to separately parameterize the acceleration and deceleration processes. This allows optimum adjustment to the respective application-specific requirements.

Pertinent Parameters

- S-0-0108, Feedrate override
- S-0-0138, Bipolar acceleration limit value
- S-0-0193, Positioning jerk
- S-0-0258, Target position
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0359, Positioning deceleration
- S-0-0393, Command value mode
- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode
- S-0-0430, Effective target position
- S-0-0437, Positioning status
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant

Pertinent Diagnostic Messages

- A0106 Drive-internal interpolation, encoder 1
- A0107 Drive-internal interpolation, encoder 2
- A0108 Drive controlled interpolation, lagless, encoder 1
- A0109 Drive controlled interpolation, lagless, encoder 2
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2055 Feedrate override S-0-0108 = 0
- F2057 Target position out of travel range

7.6.2 Command Value Adjustment With Drive-Internal Interpolation

The target position can be cyclically preset via parameter "S-0-0258, Target position".

The drive generates the position command value profile necessary to move to the target position, considering the requirements defined in the following parameters:

- S-0-0108, Feedrate override
- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0359, Positioning deceleration

☞ The target position preset by the control master is displayed in parameter S-0-0430.

The figure below illustrates the command value adjustment in the "drive-internal interpolation" mode as a block diagram.

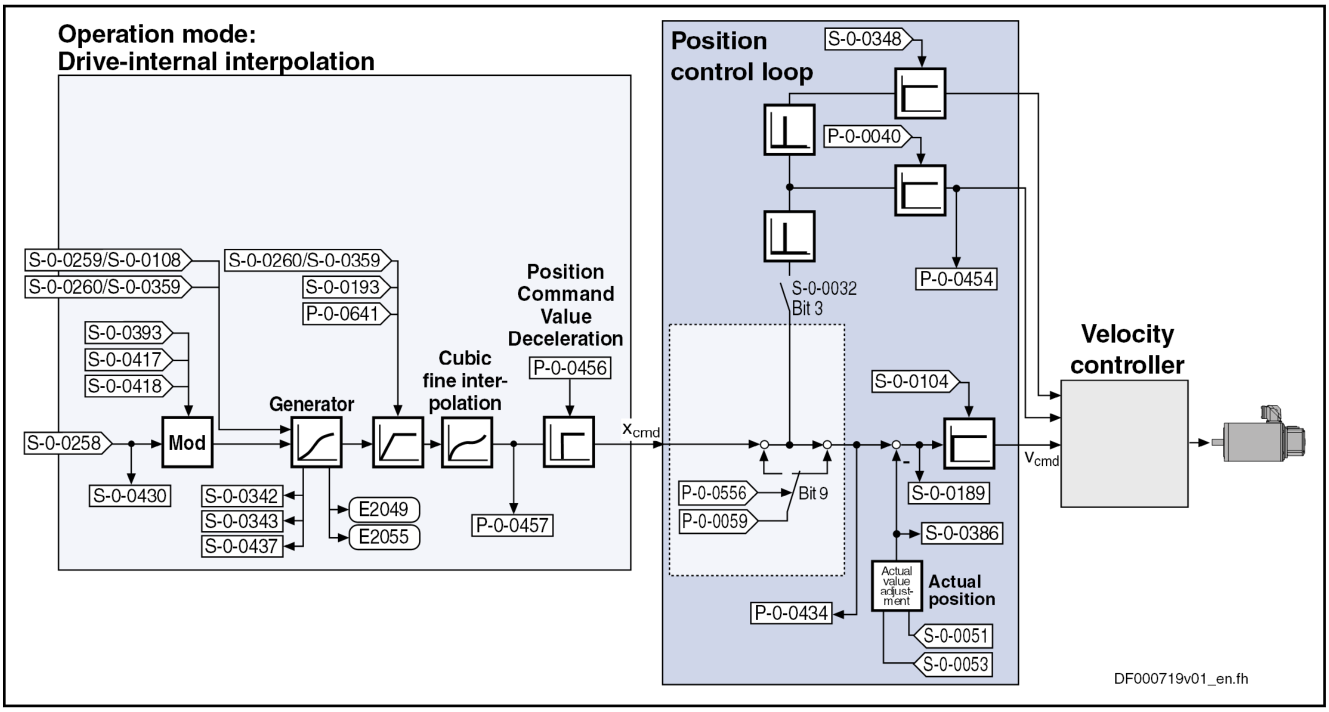


Fig. 7-20: Command Value Adjustment with "Drive-Internal Interpolation"

7.6.3 Position Controller with Drive-Internal Interpolation

The position command value generated at the output of the command value generator is displayed in parameter "P-0-0434, Position command value of controller" and can be output at the analog output.

In this operation mode, the same information as relevant in the "position control with cyclic command value input" mode applies to the position control loop.

See also "Control Loop Structure"

See also "Position Controller" in section "Position Control with Cyclic Command Value Input"

7.6.4 Notes on Commissioning

Effective Positioning Velocity

The drive reaches its maximum velocity after an acceleration phase with the value set in parameter "S-0-0260, Positioning acceleration".

The maximum velocity during a positioning process is the result of:

$$v_{max} = \text{S-0-0259} \times \frac{\text{S-0-0108}}{100\ \%}$$

S-0-0259 Positioning velocity
S-0-0108 Feedrate override

Fig. 7-21: Determining the Maximum Velocity during the Positioning Process

Effective Acceleration and Deceleration

The maximum deceleration is defined in parameter "S-0-0359, Positioning deceleration".

If the value in parameter S-0-0359 equals zero, the drive uses the parameter value of "S-0-0260, Positioning acceleration" for deceleration, too.

If the value in parameter S-0-0260 equals zero, too, the parameter value of "S-0-0138, Bipolar acceleration limit value" is used. If this value has likewise been set to zero, acceleration is not limited. If possible, the drive sets the positioning velocity immediately.

Smoothing Filter (Jerk Filter)

In the "drive-internal interpolation" mode, the position command value can be filtered at the output of the positioning generator. We distinguish two cases for setting the filter order.

Case 1: Filter order calculated from A / R

The filter order of the (moving) average filter available to do this (cf. P-0-0042) is calculated on the basis of the preset positioning acceleration or the positioning jerk.

This means that the parameterized acceleration or deceleration only becomes effective after t = P-0-0042 × T_{NCYC}.

☞ T_{NCYC} is the generator cycle time (S-0-0001).

$$\text{P-0-0042} = \frac{\text{S-0-0260}}{\text{S-0-0193}}[s]\frac{10^6}{T_{NCYC}}$$

-or-

$$\text{P-0-0042} = \frac{\text{S-0-0359}}{\text{S-0-0193}}[s]\frac{10^6}{T_{NCYC}}$$

P-0-0042 Current position command average value filter order
S-0-0260 Positioning acceleration
S-0-0193 Positioning jerk
S-0-0359 Positioning deceleration

Fig. 7-22: Internally Determining the Value of P-0-0042 for Operation Modes with Drive-Internal Interpolation

☞ The setting S-0-0193 = 0 switches the smoothing filter off; i.e. the desired acceleration or deceleration is immediately reached.

Case 2: Constant filter order

The filter order can be set to a constant value via the parameter interpolation command value average value filter time constant (P-0-0641). The filter order is calculated from the time constant related to the generator cycle time T_{NCYC}; with an order > 0, the "constant filter order" function is active and the calculation A / R is not effective. In this context, a new filter order may only take effect upon initialization of the operation mode, as well as upon block change. The current filter order is still displayed in P-0-0042.

Position Command Value Deceleration

The position command value can be delayed by a maximum of 32 position clocks after the fine interpolator, before it is transmitted to the position controller. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position clocks is set with the position command value delay (P-0-0456). The position command value generator without delay (P-0-0457) is entered in a ring buffer and then the position command value with delay is applied to the position command value of controller (P-0-0434).

Modulo Processing

The parameter "S-0-0393, Command value mode" controls the drive behavior in the case of **position processing in modulo format**.

The following definition applies to S-0-0393:

- Bit 1/0 = 00 → Positive direction of rotation
- Bit 1/0 = 01 → Negative direction of rotation
- Bit 1/0 = 10 → Shortest distance

ⓘ See also Parameter Description "S-0-0393, Command value mode"

Special Cases

The following special cases apply to the evaluation of the settings for S-0-0393:

- If the absolute value of the current actual velocity is greater than the velocity threshold for positioning (parameter "S-0-0417, Positioning velocity threshold in modulo mode"), the drive always moves in the last active direction of rotation.
- If the target position is within the target position window (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

NOTICE	If the velocity threshold for positioning behavior was parameterized with very low values that are within the noise level of the actual velocity value, this can cause unpredictable behavior.

ⓘ See also Parameter Description "S-0-0417, Positioning velocity threshold in modulo mode", "S-0-0418, Target position window in modulo mode" and "S-0-0430, Effective target position"

7.6.5 Diagnostic Messages and Monitoring Functions

Diagnostic Status Messages

The activated "drive-internal interpolation" mode is displayed by one of the following diagnostic messages:

- A0106 Drive-internal interpolation, encoder 1
- A0107 Drive-internal interpolation, encoder 2
- A0108 Drive controlled interpolation, lagless, encoder 1
- A0109 Drive controlled interpolation, lagless, encoder 2

Monitoring Functions

Monitoring functions specific to the operation mode:

Target Position outside of Travel Range

- If position limit value monitoring is activated (bit 4 of parameter "S-0-0055, Position polarities" has been set) and the measuring system used for the operation mode has been homed, the parameter "S-0-0258, Target position" is monitored for compliance with the position limit values (S-0-0049 or S-0-0050). If these values are exceeded, depending on the definition in "P-0-0090, Travel range limit parameter", either the error message "F2057 Target position out of travel range" or the warning "E2053 Target position out of travel range" is generated. If the warning has been parameterized, positioning to the limit switches takes place.

  The preset target position will not be accepted.

Positioning Velocity >= Limit Value

- If the preset positioning velocity ("S-0-0259, Positioning velocity") exceeds the maximum allowed limit value ("S-0-0091, Bipolar velocity limit value"), the warning "E2049 Positioning velocity >= limit value" is generated.

  The drive moves to the new target position with the velocity from parameter "S-0-0091, Bipolar velocity limit value".

Feedrate Override (S-0-0108) = 0

- If the positioning velocity factor "S-0-0108, Feedrate override" equals zero, the warning "E2055 Feedrate override S-0-0108 = 0" is generated.

Status Messages

The parameter "S-0-0437, Positioning status" contains all important status information for the operation mode "drive-internal interpolation".

See Parameter Description "S-0-0437, Positioning status"

The figures below illustrate the operating principle of the status messages:

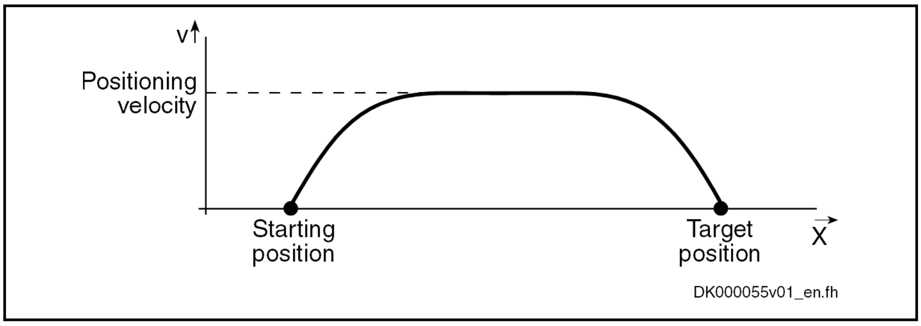


Fig. 7-23: Travel Profile to Explain How the Interpolation Status Messages Work

In this example, the drive is at the starting position when the new target position is preset.

The result is the following time diagram:

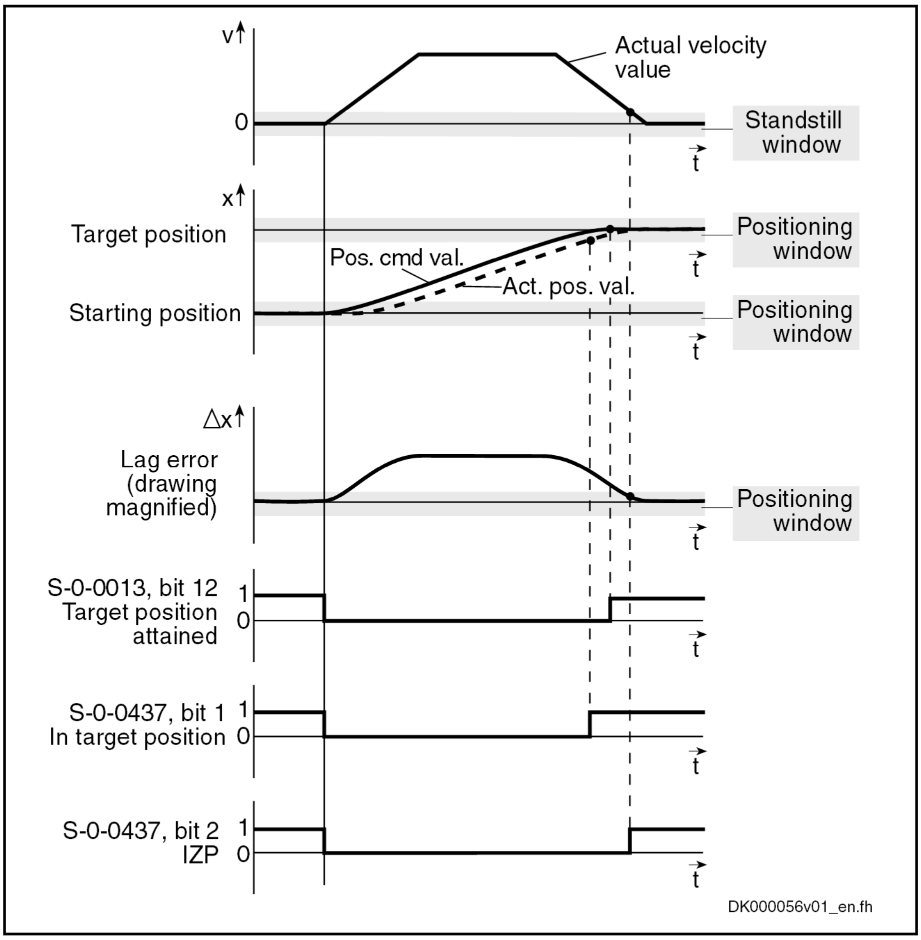


Fig. 7-24: Generating the Status Bits of the Operation Modes with Drive-Internal Interpolation

7.7 Drive-controlled positioning

7.7.1 Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

The operation modes "drive-internal interpolation" and "drive-controlled positioning" allow time-optimized positioning of a single axis. The "drive-internal interpolation" mode is the basis for the more comprehensive functionality of the "drive-controlled positioning" mode.

In the "drive-controlled positioning" mode, a positioning command value is preset for the drive. The drive can continue processing this value internally in absolute (position target) or relative (travel distance) form. In the internal interpolator, a position command value characteristic is generated as the input value for the position controller from the preset positioning data (effective target position, velocity, acceleration and jerk).

There are different forms of the "drive-internal positioning" mode which result in the corresponding diagnostic messages when the operation mode was activated (see below "Pertinent Diagnostic Messages").

Operation modes

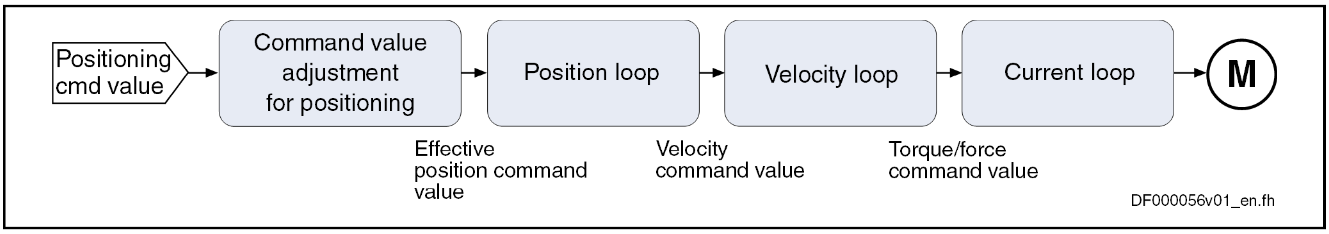


Fig. 7-25: Block Diagram, Drive-Controlled Positioning

Features

- Processing of an absolute target position or a relative travel distance
- Drive-internal generation of a position command value profile to travel to the positioning command value (S-0-0282) while maintaining the positioning velocity (S-0-0259) and positioning acceleration (S-0-0260) or positioning deceleration (S-0-0359) that can be set; can be set separately
- Command value generation runs in the NC cycle "S-0-0001, NC cycle time (TNcyc)". The transition to the position controller cycle is made by cubic fine interpolation.
- Acceptance of the positioning command value via toggle bit (S-0-0346, bit 0)
- Jerk limitation of the generated position command value with parameter "S-0-0193, Positioning jerk"
- Setting of the average value filter (jerk limitation) to a fixed filter time with interpolation command value average value filter time constant (P-0-0641)
- Adjustable position command value delay in position cycle times (P-0-0456), maximum of 32 cycles.
- Evaluation of the positioning velocity with parameter "S-0-0108, Feedrate override"
- Monitoring of the positioning velocity for exceeding the value in parameter "S-0-0091, Bipolar velocity limit value"

☞ The positioning velocity can be limited with the use of the safety technology by "P-0-3238, SMO: Active velocity threshold" see also "Rexroth IndraDrive, Integrated Safety Technology "Safe Motion" (as of MPx-18)" (DOK-INDRV*-SI3*SMO-VRS-AP**-EN-P; Mat. No. R911338920).

☞ The initial speed of the operation mode can be limited, for one axis with safety technology, to an additional speed value [product from "SMO: active speed threshold" (P-0-3238) and "SMO: evaluation factor speed limit "(P-0-3218)] when activated in the parameter "SMO: Configuration support functions" (P-0-3219), see also the separate documentation "Rexroth IndraDrive, Integrated Safety Technology "Safe Motion" (as of MPx-18)" (DOK-INDRV*-SI3*SMO-VRS-AP**-EN-P; Mat. No. R911338920), chapter "Additional and auxiliary functions".

- Monitoring of the target position for compliance with the position limit values (see "S-0-0049, Positive position limit value", "S-0-0050, Negative position limit value")

- Command value mode can be set in modulo format in parameter "S-0-0393, Command value mode" (shortest distance, positive only or negative only direction, no reversal of direction of rotation)
- Position control with regard to "S-0-0051, Position feedback value 1" (motor encoder) or "S-0-0053, Position feedback value 2" [external (load-side) encoder]
- Acceleration and deceleration ramps can be set separately ("S-0-0260, Positioning acceleration" or "S-0-0359, Positioning deceleration")
- Position limit values taken into account when accepting target position, positioning velocity and positioning acceleration
- Jog mode ("infinite travel" positive/negative; S-0-0346, bits 1 and 2)
- Residual path processing can be activated
- "On-the-fly acceptance" of the new target position or intermediate stop

☞ In this operation mode, it is possible to separately parameterize the acceleration and deceleration processes in order to achieve optimum adjustment to the respective application-specific requirements.

Pertinent Parameters

- S-0-0057, Position window
- S-0-0108, Feedrate override
- S-0-0138, Bipolar acceleration limit value
- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0282, Positioning command value
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0346, Positioning control word
- S-0-0359, Positioning deceleration
- S-0-0393, Command value mode
- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode
- S-0-0419, Positioning command acknowledge
- S-0-0430, Effective target position
- S-0-0437, Positioning status
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant

Pertinent Diagnostic Messages

- A0150 Drive-controlled positioning, encoder 1
- A0151 Drive-controlled positioning, encoder 1, lagless
- A0152 Drive-controlled positioning, encoder 2

- A0153 Drive-controlled positioning, encoder 2, lagless
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2055 Feedrate override S-0-0108 = 0
- F2050 Overflow of target position preset memory
- F2057 Target position out of travel range

7.7.2 Command Value Adjustment with Drive-Controlled Positioning

Overview

The figure below illustrates command value adjustment in the "drive-controlled positioning" mode as a block diagram.

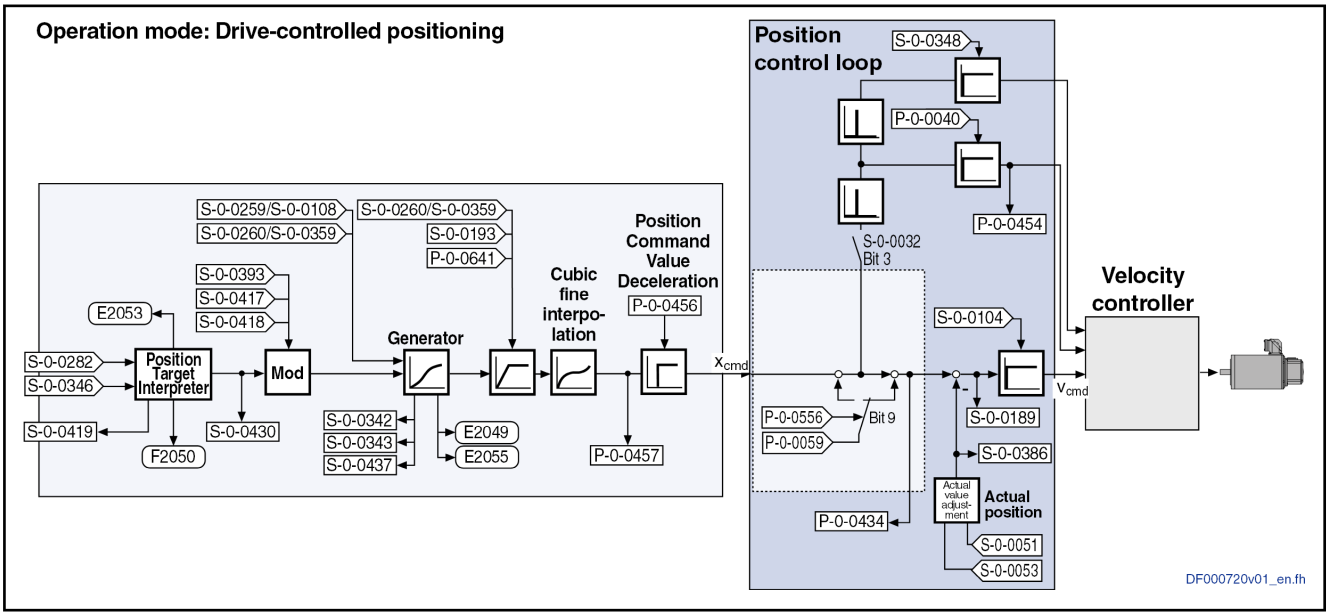


Fig. 7-26: Command Value Adjustment with Drive-Controlled Positioning

Position Target Interpreter

Accepting and Acknowledging the Command Value

The acceptance and internal processing of "S-0-0282, Positioning command value" to a value entered in parameter "S-0-0430, Effective target position" is controlled via "S-0-0346, Positioning control word".

At every edge of bit 0 (toggle bit) of S-0-0346, the content of "S-0-0282, Positioning command value", depending on bit 3 of S-0-0346, is

- **copied** to parameter S-0-0430

  (when bit 3 = 0 → absolute **target position**)

- or -

- **added** to the value of parameter S-0-0430

  (when bit 3 = 1 → **travel distance**).

☞ If a positioning process is aborted by switching bits 1 and 2 of S-0-0346 from status "00" to "01", "10" or "11", repeated edge reversal has to take place in bit 0 in order to start a new positioning process! A residual path possibly present is cleared, i.e. the status of bit 4 of S-0-0346 is automatically interpreted as "1" during the next positioning process.

Via "S-0-0419, Positioning command acknowledge" (bit 0), the drive acknowledges that it has applied the positioning command value. This allows realizing a data handshake for monitoring the command value acceptance between master and drive.

☞ The active target position is displayed in parameter "S-0-0430, Effective target position".

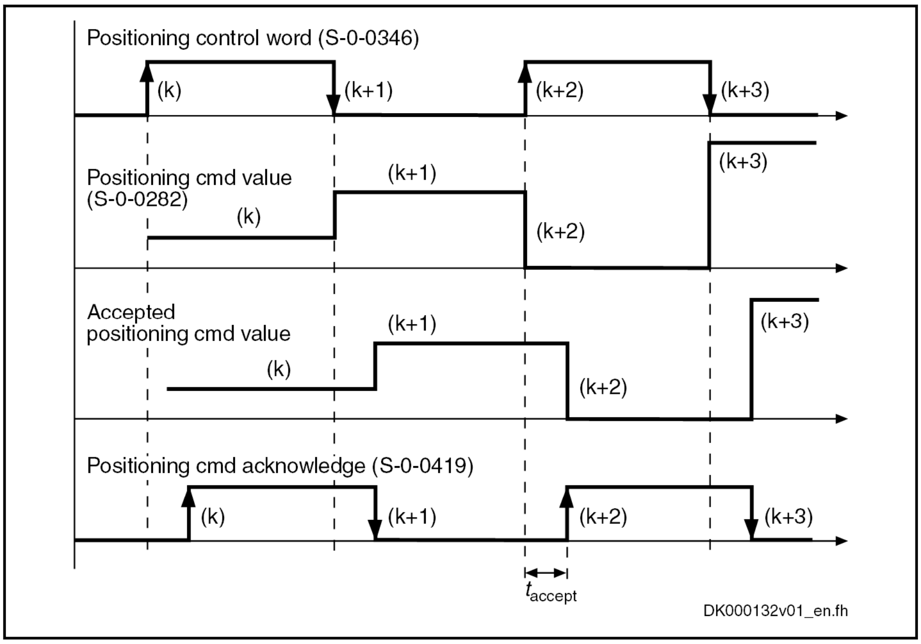


Fig. 7-27: Positioning Command Value Acceptance and Acknowledgment

Time t_{accept} (see illustration above) defines the time that passes between status change of the acceptance bit by the control unit and the reception of acknowledgment in the master. The time is made up of the effective transmission time of the command values and actual values and thus depends on the configuration of the interface to the master (e.g. sercos/field bus timing parameter).

☞ If the "drive-controlled positioning" mode is not yet active, the acceptance of the new positioning command value is not acknowledged.

If bit 0 of S-0-0346 is unequal bit 0 of S-0-0419 while the operation mode is active, the positioning command value from S-0-0282 is immediately accepted and the drive immediately moves to this command value.

The acknowledgment of acceptance takes place when the new positioning command value is accepted from the intermediate memory to parameter "S-0-0430, Effective target position" and thus to the position command value generator.

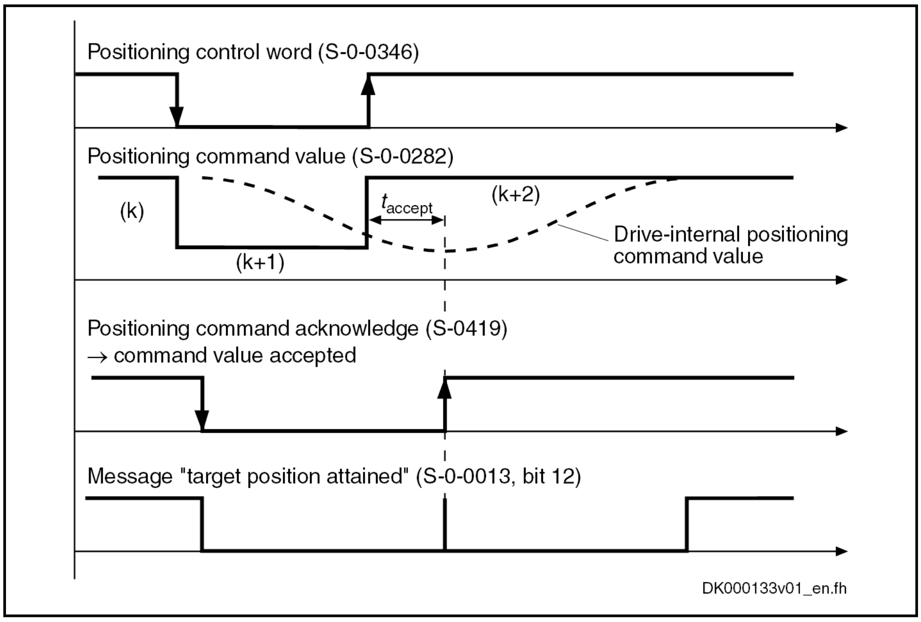


Fig. 7-28: Acknowledgment of Positioning Command Value Acceptance in "Complete Move to Positioning Command Value (k+2)" Mode

Acknowledgment with Error "Overflow of Target Position Preset Memory"

When trying, in the "complete move to positioning command value" mode, to preset a new positioning command value by toggling parameter "S-0-0346, Positioning control word", although the previous positioning command value (k+1) was not accepted [because the drive had not yet moved to the previous positioning command value (k)], the error message "F2050 Overflow of target position preset memory" is generated.

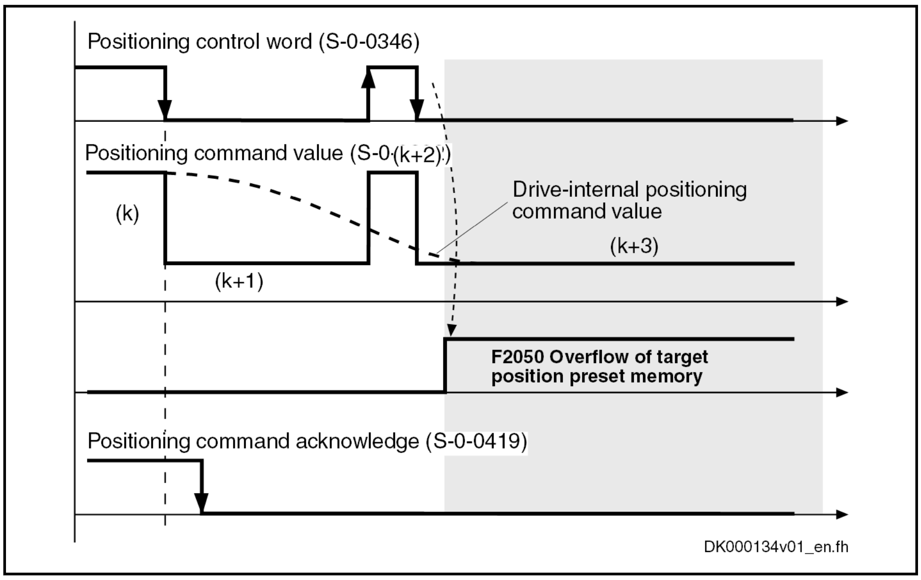


Fig. 7-29: Acknowledgment with Error "Overflow of Target Position Preset Memory"

In addition to bit 0 for mere block acceptance, the parameter "S-0-0346, Positioning control word" contains further control bits which are explained below.

Positioning Modes to be Selected

Via bit 1 and bit 2 of S-0-0346, you can determine different positioning modes:

- **"Infinite travel"** (jog positive or negative → **Jog mode**) when:
  - Bit 2/1 = 01 → "Infinite travel" positive

- Bit 2/1 = 10 → "Infinite travel" negative
- **"Stopping"** (with "S-0-0359, Positioning Deceleration") when:
  - Bit 2/1 = 11

Reference of Active Target Position

Via bit 4 of S-0-0346, it is possible to determine the reference of the active target position.

- **Bit 4 = 0** → Reference for positioning is the "old target position", i.e. a residual path that possibly has not been traveled yet is traveled before the drive moves to the new target

  → Incremental dimension is maintained in the case of successive positioning procedures
- **Bit 4 = 1** → Reference for positioning is the current actual position value, a possibly existing residual path is not traveled

  → Incremental dimension reference is maintained

> Bit 4 takes effect with every new travel job (edge on bit 0). Residual path processing is only carried out, during the first positioning process after the operation mode was activated, when the position status has been set and bit 2 = 1 in parameter S-0-0393. In this case the residual path, after the operation mode was activated, is traveled without start edge.

Reaction to New Target Position Input

Via bit 5 of S-0-0346, it is possible to determine the time of the reaction to a new target position input:

- **Bit 5= 0** → The drive travels to the last preset target before positioning at the new target. The target is considered to have been reached when the following applies:

  Target position –actual position value < positioning window
- **Bit 5 =1** → The previous target is rejected and the drive immediately travels to the new target.

  → Immediate block change

See also Parameter Description "S-0-0346, Positioning control word"

Processing in Modulo Format

The parameter "S-0-0393, Command value mode" controls the drive behavior in the case of **position processing in modulo format**. The following definition applies to S-0-0393:

- Bit 1/0 = 00 → Positive direction of rotation
- Bit 1/0 = 01 → Negative direction of rotation
- Bit 1/0 = 10 → Shortest distance

See also Parameter Description "S-0-0393, Command value mode"

Special Cases

The following special cases apply to the evaluation of the settings for "S-0-0393, Command value mode":

- If the absolute value of the current actual velocity is greater than the velocity threshold for positioning (S-0-0417, Positioning velocity threshold in modulo mode), the drive always moves in the last active direction of rotation.
- If the target position is within the target position window (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

NOTICE

If the velocity threshold for positioning behavior was parameterized with very low values that are within the noise level of the actual velocity value, this can cause unpredictable behavior.

See also Parameter Description "S-0-0417, Positioning velocity threshold in modulo mode", "S-0-0418, Target position window in modulo mode" and "S-0-0430, Effective target position"

Positioning Generator

The drive generates the position command value profile necessary to move to the target position, considering the conditions defined in the following parameters:

- S-0-0108, Feedrate override
- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0359, Positioning deceleration

7.7.3 Position Controller with Drive-Controlled Positioning

The position command value generated at the output of the command value generator is displayed in parameter "P-0-0434, Position command value of controller" and can be output at the analog output.

In this operation mode, the same information as relevant in the "position control with cyclic command value input" mode applies to the position control loop.

See also "Control Loop Structure"

See also "Position Controller" in section "Position Control with Cyclic Command Value Input"

7.7.4 Jog Mode with Drive-Controlled Positioning ("Jog Mode")

The jog mode is part of the positioning mode and not an individual operation mode! This means that there aren't any separate parameters for the jog mode, but you have to use the parameters of the "drive-controlled positioning" mode.

Activating the Jog Mode

To use the jog mode, make the following settings:

- Activate the "drive-controlled positioning" mode

  - and -
- Select the positioning mode "infinite travel" (jog positive or negative → jog mode) via bits 1 and 2 of parameter "S-0-0346, Positioning control word"

Parameterizing the Jog Mode

When jogging, the following parameters are relevant for operation:

- S-0-0108, Feedrate override

  → To achieve online, if necessary, the reduction of the jog velocity by means of a "potentiometer"

- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity

  When the jog mode is active, the positioning velocity also takes immediate effect.
- S-0-0260, Positioning acceleration
- S-0-0282, Positioning command value
- S-0-0346, Positioning control word

  → To select the jog direction ("Jog+", "Jog-" and "stopping")
- S-0-0359, Positioning deceleration

The parameters for acceleration, deceleration and jerk are applied at the start and stop of a jog movement.

During the jog mode, changes in the parameters can only take effect when the acceleration bit in the positioning control word (bit 0) is toggled.

☞ Bits 1 and 2 of parameter S-0-0346 are parts of the field bus control word and, if required, can be assigned to the digital inputs.

See "Profile Types (with Field Bus Interfaces)"

See "Digital Inputs/Outputs"

7.7.5 Notes on Commissioning

Effective Positioning Velocity

The drive reaches its maximum velocity after an acceleration phase with the value set in parameter "S-0-0260, Positioning acceleration".

The maximum velocity during a positioning process is the result of:

$$v_{max} = S\text{-}0\text{-}0259 \times \frac{S\text{-}0\text{-}0108}{100\ \%}$$

S-0-0259 Positioning Velocity
S-0-0108 Feedrate override

Fig. 7-30: Determining the Maximum Velocity during the Positioning Process

Effective Acceleration and Deceleration

The maximum deceleration is defined in parameter "S-0-0359, Positioning deceleration".

If the value in parameter S-0-0359 equals zero, the drive uses the parameter value of "S-0-0260, Positioning acceleration" for deceleration, too.

If the value in parameter S-0-0260 equals zero, too, the parameter value of "S-0-0138, Bipolar acceleration limit value" is used. If this value has likewise been set to zero, acceleration is not limited. If possible, the drive sets the positioning velocity immediately.

Smoothing Filter (Jerk Filter)

In the "drive-controlled interpolation" mode, the position command value can be filtered at the output of the positioning generator. We distinguish two cases for setting the filter order.

Case 1: Filter order calculated from A / R

The filter order of the (moving) average filter available to do this (cf. P-0-0042) is calculated on the basis of the preset positioning acceleration or the positioning jerk.

This means that the parameterized acceleration or deceleration only becomes effective after t = P-0-0042 × T_{NCYC}.

☞ T_{NCYC} is the generator cycle time (S-0-0001).

$$\text{P-0-0042} = \frac{\text{S-0-0260}}{\text{S-0-0193}}[s]\frac{10^6}{T_{NCYC}}$$

-or-

$$\text{P-0-0042} = \frac{\text{S-0-0359}}{\text{S-0-0193}}[s]\frac{10^6}{T_{NCYC}}$$

P-0-0042	Current position command average value filter order
S-0-0260	Positioning acceleration
S-0-0193	Positioning jerk
S-0-0359	Positioning deceleration

Fig. 7-31: Internally Determining the Value of P-0-0042 for Operation Modes with Drive-Internal Interpolation

☞ The setting S-0-0193 = 0 switches the smoothing filter off; i.e. the desired acceleration or deceleration is immediately reached.

Case 2: Constant filter order

The filter order can also be set to a constant value; this is done by means of the parameter " Interpolation cmd value average value filter time constant" (P-0-0641). The filter order is calculated from the time constant related to the generator cycle time T_{NCYC}; with an order > 0, the const. filter order function is active and the calculation A / R is not effective. In this context, a new filter order may only take effect upon initialization of the operation mode, as well as upon block change. The current filter order is still displayed in P-0-0042.

Position Command Value Deceleration

The position command value can be delayed by a maximum of 32 position clocks after the fine interpolator, before it is transmitted to the position controller. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position clocks is set with the position command value delay (P-0-0456). The position command value generator without delay (P-0-0457) is entered in a ring buffer and then the position command value with delay is applied to the position command value of controller (P-0-0434).

Command Value Mode in Modulo Format

Positive/Negative Direction of Motion

If modulo format was selected for displaying position data (infinitely turning axes) and positive or negative direction of motion was set in parameter "S-0-0393, Command value mode", the drive moves to the preset target position in the programmed direction.

Via parameter "S-0-0418, Target position window in modulo mode", it is possible to set the distance between actual position value and target position from which on it is the "shortest distance" that is traveled.

"Positive Direction" and Position Target Outside of Target Position Window

The examples below show the behavior of the drive for 3 different start velocities in the "positive direction" mode and target position outside of the target position window (S-0-0418).

- **Case 1:**

  Current velocity positive and braking distance greater than the distance between starting point and next target point

  → Drive moves to next possible target position
- **Case 2:**

  Current velocity positive and braking distance smaller than the distance between starting position and next target position

  → Drive moves to next possible target position
- **Case 3:**

  Current velocity negative (< S-0-0417)

  → Drive brakes to velocity = 0 and positions at next target in positive direction

"Positive Direction" and Position Target Inside of Target Position Window

The examples below show the behavior of the drive for 4 different start velocities in the "positive direction" mode and target position inside of the target position window (S-0-0418).

- **Case 4:**

  Current velocity positive and braking distance greater than the distance between starting point and next target point

  → Drive moves to next possible target position in positive direction

  Braking and moving back would lead to a movement in negative direction greater than the programmed target position window!

  The following applies to the braking procedure:

  Starting position + braking distance – target position **> S-0-0418**

  → Positioning in negative direction not allowed; i.e. drive must move to target in positive direction
- **Case 5:**

  Current velocity = 0

  → Drive moves to target position in negative direction

  The following applies to the braking procedure:

  Starting position + braking distance – target position **< S-0-0418**

  → Positioning in negative direction allowed; i.e. drive must move to target in negative direction
- **Case 6:**

  Current velocity negative and braking distance smaller than the difference between starting position and next target position

  → Drive directly moves to target position in negative direction

  The following applies to the braking procedure:

  Starting position + braking distance (negative) – target position **< S-0-0418**

  → Positioning in negative direction directly at target position
- **Case 7:**

  Current velocity negative (< S-0-0417) and braking distance greater than the difference between starting position and next target position

  → Drive brakes to zero and positions at next target position in positive direction

The following applies to the braking procedure:

Starting position + braking distance (negative) – target position **> S-0-0418**

→ Drive brakes to zero and positions positively at next target position

☞ As a matter of principle, the braking distance is calculated before starting the positioning movement; the result of the calculation influences the subsequent positioning procedure.

Shortest distance

In the "shortest distance" mode, the drive positions at the effective target position (cf. S-0-0430) over the shortest possible distance.

☞ Depending on "S-0-0417, Positioning velocity threshold in modulo mode", the drive moves with or without change in direction.

"Shortest Distance" with Different Velocities

The following examples show the behavior of the drive in the "shortest distance" mode with different velocities.

- Case 8:

  Current velocity positive and **> S-0-0417**; braking distance greater than the distance between starting position and next target position

  → Drive moves to target position that can be reached without reversal of direction, in positive direction

  The following applies to the braking procedure:

  Starting position + braking distance – target position **> S-0-0418**

  → Positioning in negative direction not allowed; i.e. drive must move to target in positive direction

- Case 9:

  Current velocity (positive) **< S-0-0417**; braking distance smaller than distance between starting position and next target position

  → Drive moves to next target position

  The following applies to the braking procedure:

  Starting position + braking distance – target position **< S-0-0418**

  → Positioning in negative direction allowed; i.e. drive must move to target in negative direction

- Case 10:

  Current velocity (negative) **< S-0-0417**

  Braking distance smaller than distance between starting position and next target position

  → Drive moves to next target position

  The following applies to the braking procedure:

  Starting position + braking distance (negative!) – target position **< S-0-0418**

  → Positioning in negative direction directly at target position

- Case 11:

  Current velocity negative and braking distance greater than the difference between starting position and next target position

  → Drive positions at next target position in negative direction

The following applies to the braking procedure:

Starting position + braking distance (now negative) – target position **> S-0-0418**

→ Drive positions negatively at next target position

☞ As a matter of principle, the braking distance is calculated before starting the positioning movement; the result of the calculation influences the subsequent positioning procedure.

- **Case 12:**

  Current velocity (positive) **< S-0-0417**; braking distance greater than distance between starting position and next target position

  → Drive brakes to zero and changes direction in order to move to the next target position

- **Case 13:**

  Current velocity (negative) **< S-0-0417**; braking distance greater than distance between starting position and next target position

  → Drive brakes to zero and changes direction in order to move to the next target position

7.7.6 Diagnostic Messages and Monitoring Functions

Diagnostic Status Messages

The activated "drive-controlled positioning" mode is displayed by one of the following diagnostic messages:

- A0150 Drive-controlled positioning, encoder 1
- A0151 Drive-controlled positioning, encoder 1, lagless
- A0152 Drive-controlled positioning, encoder 2
- A0153 Drive-controlled positioning, encoder 2, lagless

Monitoring Functions

Monitoring functions specific to the operation mode:

Target Position outside of Travel Range

- If position limit value monitoring is activated (bit 4 of parameter "S-0-0055, Position polarities" has been set) and the measuring system used for the operation mode has been homed, the parameter "S-0-0258, Target position" is monitored for compliance with the position limit values (S-0-0049 or S-0-0050). If these values are exceeded, depending on the definition in "P-0-0090, Travel range limit parameter", either the error message "F2057 Target position out of travel range" or the warning "E2053 Target position out of travel range" is generated. If the warning has been parameterized, positioning to the limit switches takes place.

  The preset target position will not be accepted.

Positioning Velocity >= Limit Value

- If the preset positioning velocity (("S-0-0259, Positioning velocity") exceeds the maximum allowed limit value ("S-0-0091, Bipolar velocity limit value"), the warning "E2049 Positioning velocity >= limit value" is generated.

  The drive moves to the new target position with the velocity from parameter "S-0-0091, Bipolar velocity limit value".

Feedrate Override (S-0-0108) = 0

- If the positioning velocity factor "S-0-0108, Feedrate override" equals zero, the warning "E2055 Feedrate override S-0-0108 = 0" is generated.

Status Messages

The parameter "S-0-0437, Positioning status" contains all important status information for the operation mode "drive-internal interpolation".

See Parameter Description "S-0-0437, Positioning status"

The figures below illustrate the operating principle of the status messages:

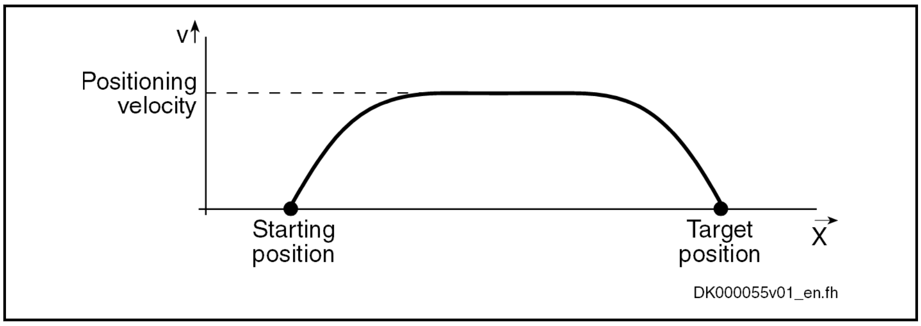


Fig. 7-32: Travel Profile to Explain How the Interpolation Status Messages Work

In this example, the drive is at the starting position when the new target position is preset.

The result is the following time diagram:

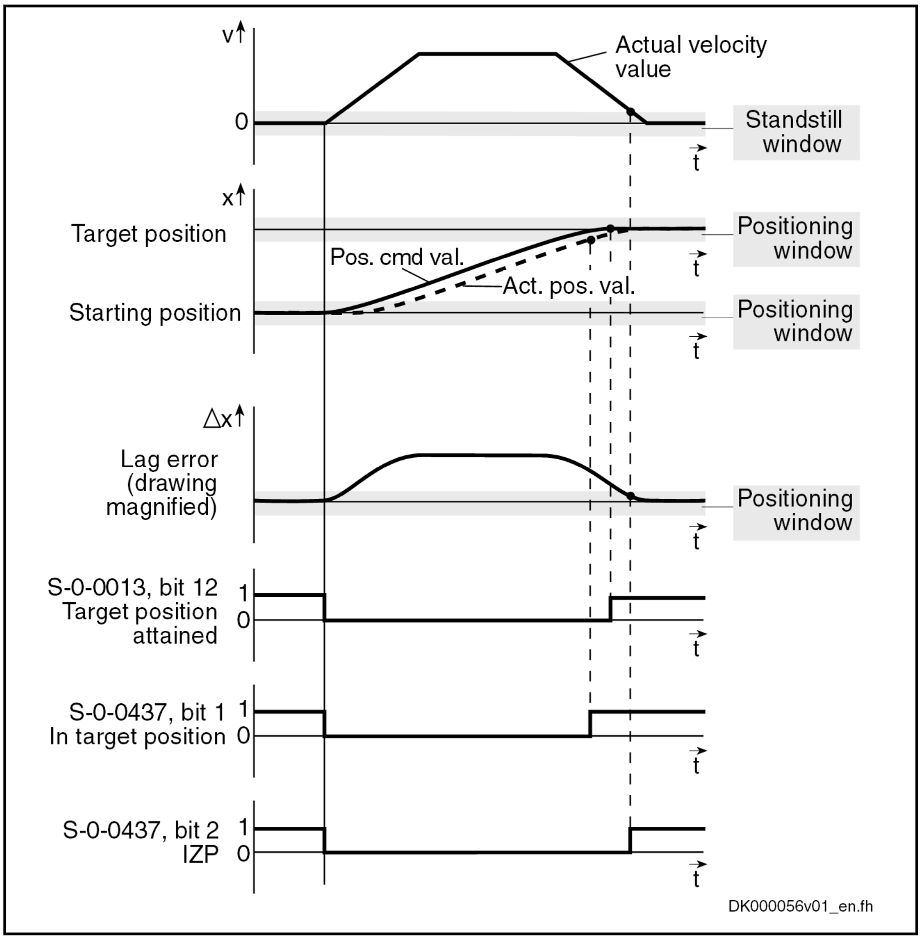


Fig. 7-33: Generating the Status Bits of the Operation Modes with Drive-Internal Interpolation

7.8 Positioning block mode

7.8.1 Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the operation mode, it is possible to run up to 64 programmed positioning blocks. The drive moves to the target position in position control, while maintaining velocity, acceleration, deceleration and jerk limits as defined in the respective positioning block.

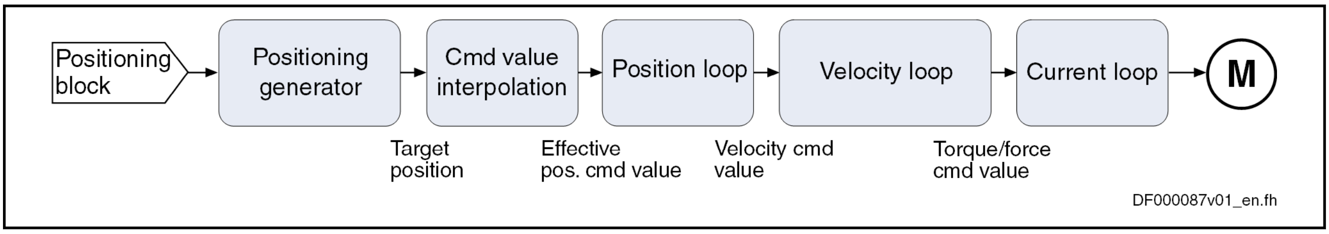


Fig. 7-34: Block Diagram "Positioning Block Mode"

Features

- Parameterization of up to 64 positioning blocks; each with target position/travel distance, velocity, acceleration, deceleration and jerk
- Command value generation runs in the NC cycle "S-0-0001, NC cycle time (TNcyc)". The transition to the position controller cycle is made by cubic fine interpolation.
- Jerk limitation of the generated position command value via "P-0-4009, Positioning block jerk"
- Setting of the average value filter (jerk limitation) to a fixed filter time with interpolation command value average value filter time constant (P-0-0641)
- Adjustable position command value delay in position cycle times (P-0-0456), maximum of 32 cycles.
- Defined block acceptance by toggling bit 0 in S-0-0346 with reaction time $t_{R\_strobe} = t_{position}$

  Note: With field bus drives, the I/O mode is an exception. In these cases, acceptance takes place by a positive edge of bit 0 in P-0-4060.

  → Block selection and acknowledgment via separate parameters (handshake principle)
- Positioning modes to be freely parameterized:
  – Relative positioning
  – Absolute positioning
  – Infinite travel (positive or negative)
- Single-block or sequential block mode with different conditions for advancing:
  – Block advance with switch cams
  – Block advance at defined position value
  – Block transition with "old" or "new" positioning velocity
- Positioning block transition with freely definable delay time (P-0-4018)
- Positioning while taking command value mode into account (shortest distance, positive direction, …)

- Residual path processing can be activated (→ no loss of incremental dimension)
- "Slow travel" mode can be activated
- Velocity override to be set

☞ The positioning velocity can be limited with the use of the safety technology by "P-0-3238, SMO: Active velocity threshold" see also "Rexroth IndraDrive, Integrated Safety Technology "Safe Motion" (as of MPx-18)" (DOK-INDRV*-SI3*SMO-VRS-AP**-EN-P; Mat. No. R911338920).

☞ The initial speed of the operation mode can be limited, for one axis with safety technology, to an additional speed value [product from "SMO: active speed threshold" (P-0-3238) and "SMO: evaluation factor speed limit "(P-0-3218)] when activated in the parameter "SMO: Configuration support functions" (P-0-3219), see also the separate documentation "Rexroth IndraDrive, Integrated Safety Technology "Safe Motion" (as of MPx-18)" (DOK-INDRV*-SI3*SMO-VRS-AP**-EN-P; Mat. No. R911338920), chapter "Additional and auxiliary functions".

Fields of Application

Sequential block processing allows executing several positioning blocks in direct sequence without having to give a new start signal each time. Typical fields of application are:

- There is none or only a very simple higher-level control unit available and control is realized via digital I/Os only or a field bus control word (I/O mode with field bus interface).
- There are quick reaction times or block advances required. The required motion profiles can be represented in the drive by the maximum possible 64 positioning blocks.
- There are positioning processes required which cover long distances at high speeds (rapid traverse) and then position at the end position at low speed without any intermediate stops; for example:
  - Taking up or putting down transport goods in handling robots
  - Executing joining processes in assembly facilities

Pertinent Parameters

- S-0-0138, Bipolar acceleration limit value
- S-0-0259, Positioning velocity
- S-0-0346, Positioning control word
- S-0-0393, Command value mode
- S-0-0419, Positioning command acknowledge
- S-0-0430, Effective target position
- S-0-0437, Positioning status
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant

- P-0-4006, Positioning block target position
- P-0-4007, Positioning block velocity
- P-0-4008, Positioning block acceleration
- P-0-4009, Positioning block jerk
- P-0-4018, Positioning block delay time
- P-0-4019, Positioning block mode
- P-0-4026, Positioning block selection
- P-0-4051, Positioning block acknowledgment
- P-0-4052, Positioning block, last accepted
- P-0-4053, Positioning block, last active
- P-0-4057, Positioning block, input linked blocks
- P-0-4060, Positioning block control word
- P-0-4061, Positioning block status word
- P-0-4063, Positioning block deceleration

☞ Parameter S-0-0259 is used in positioning block mode to reduce positioning velocity (see also "P-0-4060, Positioning block control word").

Pertinent Diagnostic Messages

- A0162 Positioning block mode
- A0206 Positioning block mode, encoder 1
- A0207 Positioning block mode lagless, encoder 1
- A0210 Positioning block mode, encoder 2
- A0211 Positioning block mode lagless, encoder 2
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2054 Not homed
- E2055 Feedrate override S-0-0108 = 0
- E2058 Selected positioning block has not been programmed
- F2028 Excessive deviation

7.8.2 Command Value Adjustment with Positioning Block Mode

The figure below illustrates command value adjustment in the "positioning block mode" as a block diagram.

Operation modes

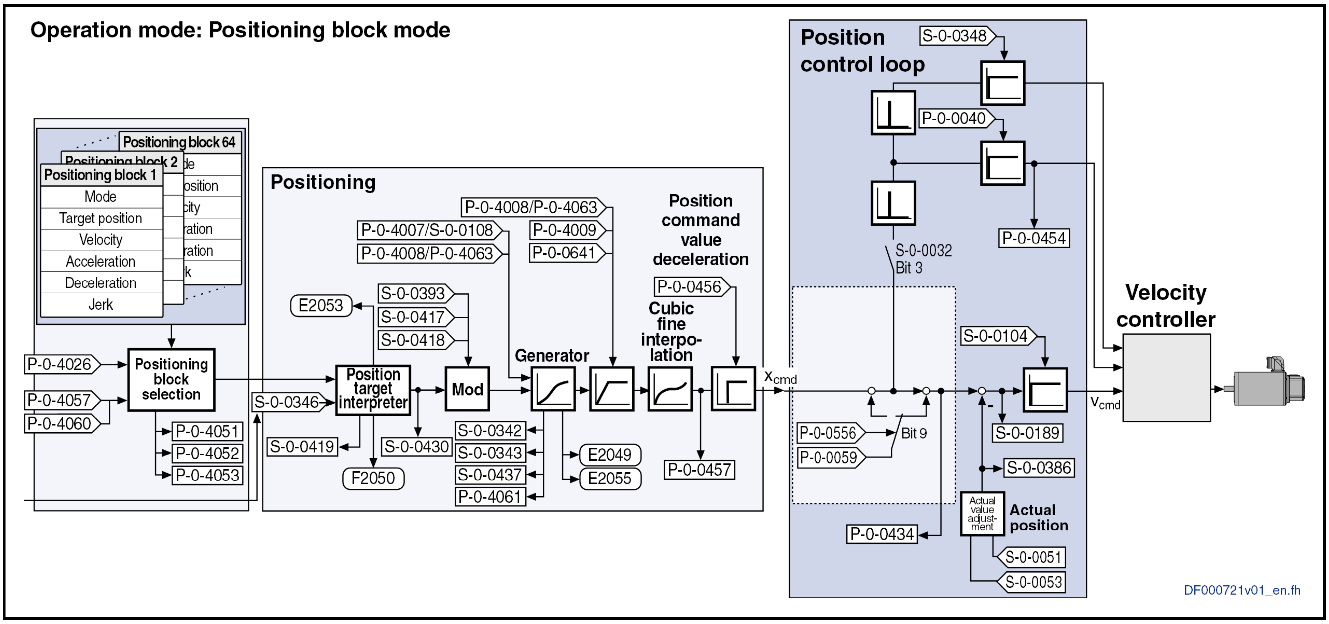


Fig. 7-35: Command Value Adjustment with Positioning Block Mode

7.8.3 single-block processing

Description of Basic Function

General Information

Positioning Block Elements

A positioning block is defined by the values of the following list parameters:

- P-0-4006, Positioning block target position
- P-0-4007, Positioning block velocity
- P-0-4008, Positioning block acceleration
- P-0-4009, Positioning block jerk
- P-0-4018, Positioning block delay time
- P-0-4019, Positioning block mode
- P-0-4063, Positioning block deceleration

☞ Each list parameter contains 64 elements, elements of the same number generate the travel profile of the respective positioning block.

The drive reaches the relevant positioning block velocity after an acceleration phase with the corresponding positioning block acceleration (P-0-4008).

Effective Positioning Velocity

The effective velocity during a positioning process is calculated as follows:

$$v_{max} = P\text{-}0\text{-}4007 \times \frac{S\text{-}0\text{-}0108}{100\ \%}$$

v_{max}	Velocity
P-0-4007	Positioning block velocity
S-0-0108	Feedrate override

Fig. 7-36: Effective Velocity during a Positioning Process

Effective Acceleration and Deceleration

The maximum deceleration is specified by parameter "P-0-4063, Positioning block deceleration".

NOTICE

The specified target is never reached or overrun, when the acceleration or deceleration value equals zero, because the drive can no longer brake!

⇒ Set acceleration value > 0!

☞ Further limitation takes place by the value of parameter "S-0-0138, Bipolar acceleration limit value" because this limit value takes effect in all operation modes with position control.

Jerk Limitation by Jerk Filter

In the "positioning block mode", the position command value can be filtered at the output of the positioning generator. We distinguish two cases for setting the filter order.

Case 1: Filter order calculated from A / R

The filter order of the (moving) average filter available to do this (cf. P-0-0042) is calculated on the basis of the preset positioning block acceleration or the positioning block jerk.

This means that the parameterized acceleration or deceleration only becomes effective after t = P-0-0042 × T_{NCYC}.

☞ T_{NCYC} is the generator cycle time (S-0-0001).

$$\text{P-0-0042} = \frac{\text{P-0-4008}}{\text{P-0-4009}}$$

– or –

$$\text{P-0-0042} = \frac{\text{P-0-4063}}{\text{P-0-4009}}$$

P-0-0042 Current position command average value filter order
P-0-4008 Positioning block acceleration
P-0-4063 Positioning block deceleration
P-0-4009 Positioning block jerk

Fig. 7-37: Internally Determining the Value of P-0-0042 for Positioning Block Mode

☞ With value equal zero in parameter P-0-4009, the smoothing filter is switched off, i.e. the desired acceleration or deceleration is immediately reached.

Case 2: Constant filter order

The filter order can also be set to a constant value. This is made via parameter "P-0-0641, Interpolation cmd value average value filter time constant". The filter order is calculated from the time constant related to the generator cycle time T_{NCYC}; with an order > 0, the constant filter order function is active and the calculation A / R is not effective. In this context, a new filter order may only take effect upon initialization of the operation mode, as well as upon block change. The current filter order is still displayed in P-0-0042.

Position Command Value Deceleration

The position command value can be delayed by a maximum of 32 position clocks after the fine interpolator, before it is transmitted to the position controller. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position clocks is set with the position command value delay (P-0-0456). The position command value generator without delay (P-0-0457) is entered in a ring buffer and then the position command value with delay is applied to the position command value of controller (P-0-0434).

Positioning Block Control Word

With parameter "P-0-4060, Positioning block control word" (bit 1), the positioning velocity can be limited to the value defined in parameter "S-0-0259, Positioning velocity".

Position Feedback

When a positioning block has been completed, bit 4 (end position reached) is set in parameter "P-0-4061, Positioning block status word".

→ |S-0-0430 – S-0-0051/53| < S-0-0057 && no sequential block

Interrupting a Positioning Block

The positioning block mode can be interrupted by:

- Removing drive enable
- Activating "Drive Halt"
- Changing the operation mode
- Jogging
- Positioning stop or operational stop (S-0-0346, bit 1 and bit 2 = 1)
- A drive error occurring

Positioning Block Modes

Parameter "P-0-4019, Positioning block mode" is used to define the way in which the target position is processed in parameter "P-0-4006, Positioning block target position". There are the following options:

- Absolute positioning
- Relative positioning
- Relative positioning with residual path storage
- Infinite Travel in Positive/Negative Direction
- Sequential block processing

See Parameter Description "P-0-4019, Positioning block mode"

☞ It is possible to define an individual positioning mode for each positioning block.

Command Value Mode (S-0-0393)

The parameter "S-0-0393, Command value mode" controls the drive behavior in case "modulo format" was set as processing format of the position data.

See also Parameter Description "S-0-0393, Command value mode"

The following modes are distinguished:

- Shortest distance
- Positive direction
- Negative direction

The following limiting conditions have to be taken into account:

- If the absolute value of the current actual velocity is greater than the velocity threshold for positioning in modulo format (S-0-0417), the drive always moves in the last active direction of rotation.
- If the target position is within the target position window in modulo format (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

NOTICE	If the velocity threshold for positioning in modulo format was parameterized with very low values that are within the noise level of the actual velocity value, this can cause unpredictable behavior.

See also Parameter Description "S-0-0417, Positioning velocity threshold in modulo mode"

See also Parameter Description "S-0-0418, Target position window in modulo mode"

Activating Positioning Blocks

Requirements

"Positioning block mode" must have been entered as the primary mode of operation.

> This is done by the respective selection of the active operation mode in the status word, by activating drive enable and by setting "Drive Halt" = 1.

Command value acceptance

Depending on the master communication, a positioning block is started by:

- Toggling bit 0 in parameter "S-0-0346, Positioning control word"

- or -

- with **field bus interface in I/O mode**, positive edge of bit 0 in parameter "P-0-4060, Positioning block control word"

The positioning command value is thereby copied to the effective target position S-0-0430 (absolute target position) or added (relative position target, travel distance).

> The block acceptance is confirmed by updating "P-0-4051, Positioning block acknowledgment" and "S-0-0419, Positioning command acknowledge". In addition, bit 0 of parameter S-0-0346 is toggled internally, too, in the case of a positive edge of bit 0 of parameter P-0-4060.

According to master communication and profile type, the block acceptance requires different configurations in the cyclic command value channel:

- **sercos interface**
  - "S-0-0346, Positioning control word" has to be configured in the cyclic data channel (MDT)
- **Field bus interface**
  - In the freely configurable mode (profile type P-0-4084 = 0xFFFE), bit 0 of P-0-4077 is mapped to bit 0 of S-0-0346.
  - In the "I/O mode positioning" (profile type P-0-4084 = 0xFF82), bit 3 of P-0-4068 is mapped to bit 0 of "P-0-4060, Positioning block control word".

    As an alternative, the start in the I/O mode can also take place by setting the start signal (P-0-4068, bit 1).

See also "Command Value Acceptance and Acknowledgment" in section "General Information on the Operation Modes"

☞ If bit 0 is different in S-0-0346 and in S-0-0419 when the operation mode is activated, the selected positioning block is immediately accepted and executed.

Block Selection

In the positioning block mode, block selection is always carried out via the content of parameter "P-0-4026, Positioning block selection".

Depending on the master communication, the parameter P-0-4026 can be written in different ways:

Configuration of P-0-4026	Master Communication	
	sercos interface	Field bus interface
Via cyclic data channel	■	■
Via digital inputs	■	■
Via Engineering Port	■	■
Via field bus control word	--	■

Tab. 7-2: Possibilities of Writing Parameter P-0-4026 Depending on the Master Communication

☞ The assignment of P-0-4026 to digital inputs requires, among other things, the parameters "S-0-0144, Signal status word" and "S-0-0145, Signal control word".

Absolute positioning

Parameter Setting

"P-0-4019, Positioning block mode" = 0000 0000 0000 000X

Function

In an absolute positioning block, the target position is a fixed (absolute) position within the machine coordinate system.

For absolute positioning the drive must have been homed.

Requirements

Requirements for executing absolute positioning blocks are:

- The drive must have been homed.
- The travel range can be limited with position limit values. Absolute positioning blocks are only executed, if the target position is within the allowed travel range.

Example:

Absolute positioning with target position = 700 (current position = 200)

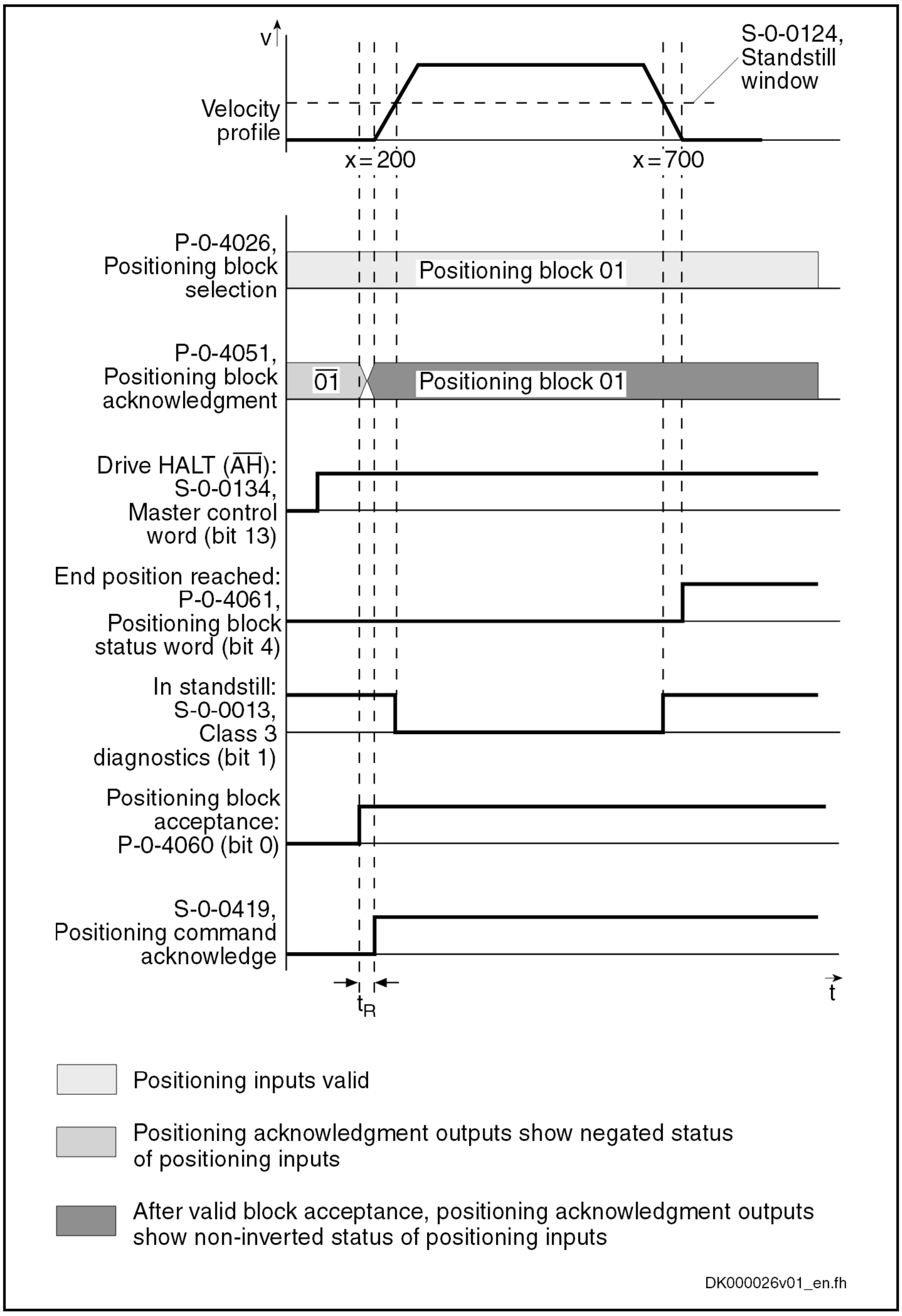


Fig. 7-38: Absolute Positioning Block

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Relative Positioning without Residual Path Storage

Parameter Setting "P-0-4019, Positioning block mode" = 0000 0000 0000 001X

Dedicated Position In the case of relative positioning blocks without residual path storage, the target position contained in the positioning block is added to the current position.

Relative positioning blocks are also executed, if the drive has not been homed.

Incremental Dimension Reference

By sequencing relative positioning blocks it is possible to position with incremental dimension. If a relative positioning block without residual path storage is interrupted, the incremental dimension reference gets lost.

If the positioning block is completed (i.e. the drive reaches target position and message "end position reached" is active), positioning is possible without losing the incremental dimension reference.

☞ If infinite positioning in either a forward or backward direction is achieved by sequencing relative positioning blocks (transport belt), the position data must be scaled in modulo format (modulo value = length of transport belt or modulo value = 2 × maximum travel distance).

Example:

Relative positioning without residual path storage with travel distance = 700 (current position = 200; target position = 900)

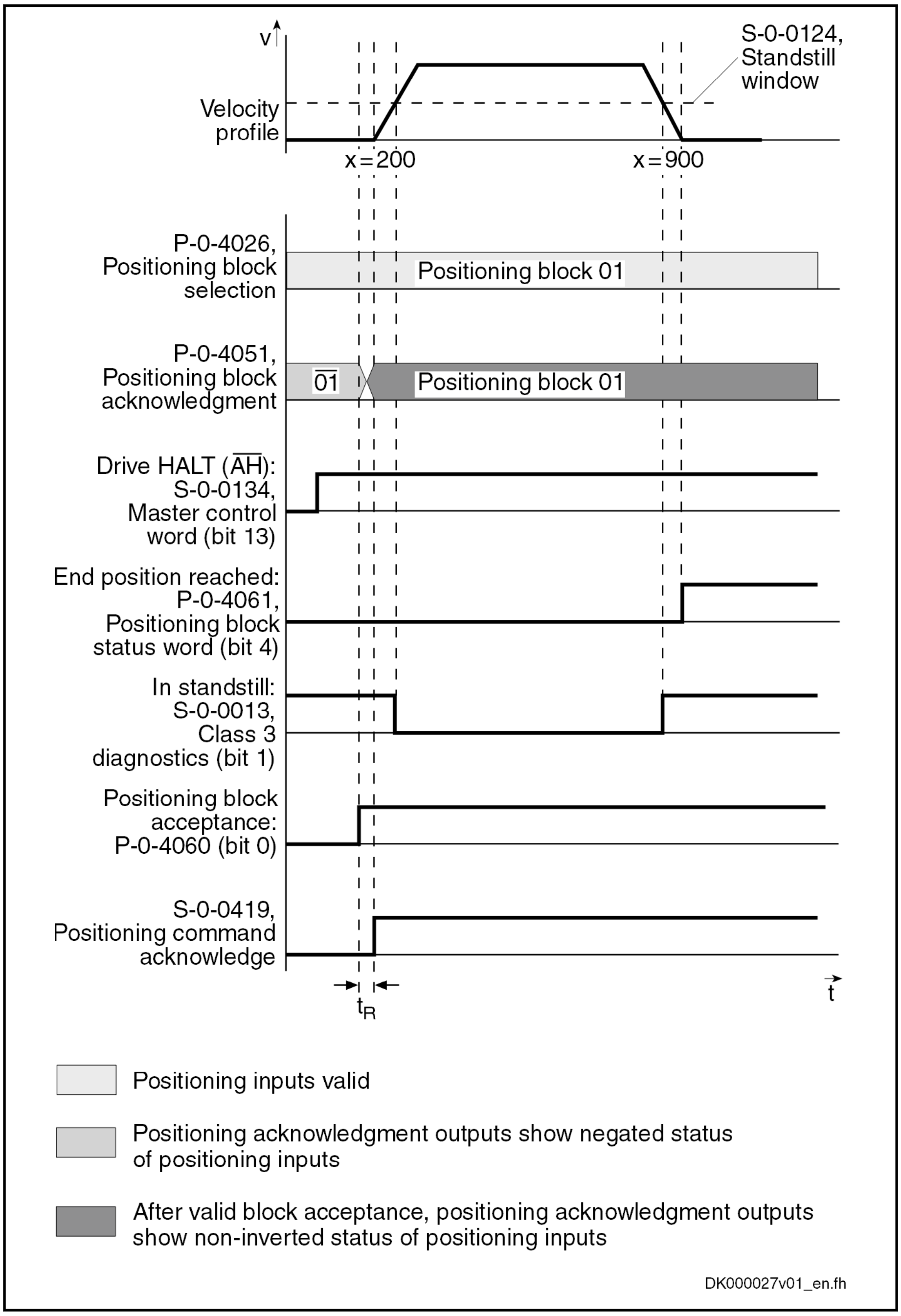


Fig. 7-39: Relative Positioning Block without Residual Path Storage

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Example:

Relative positioning without residual path storage with target position = 700 (current position = 200); interrupting and restarting a relative positioning block without residual path storage

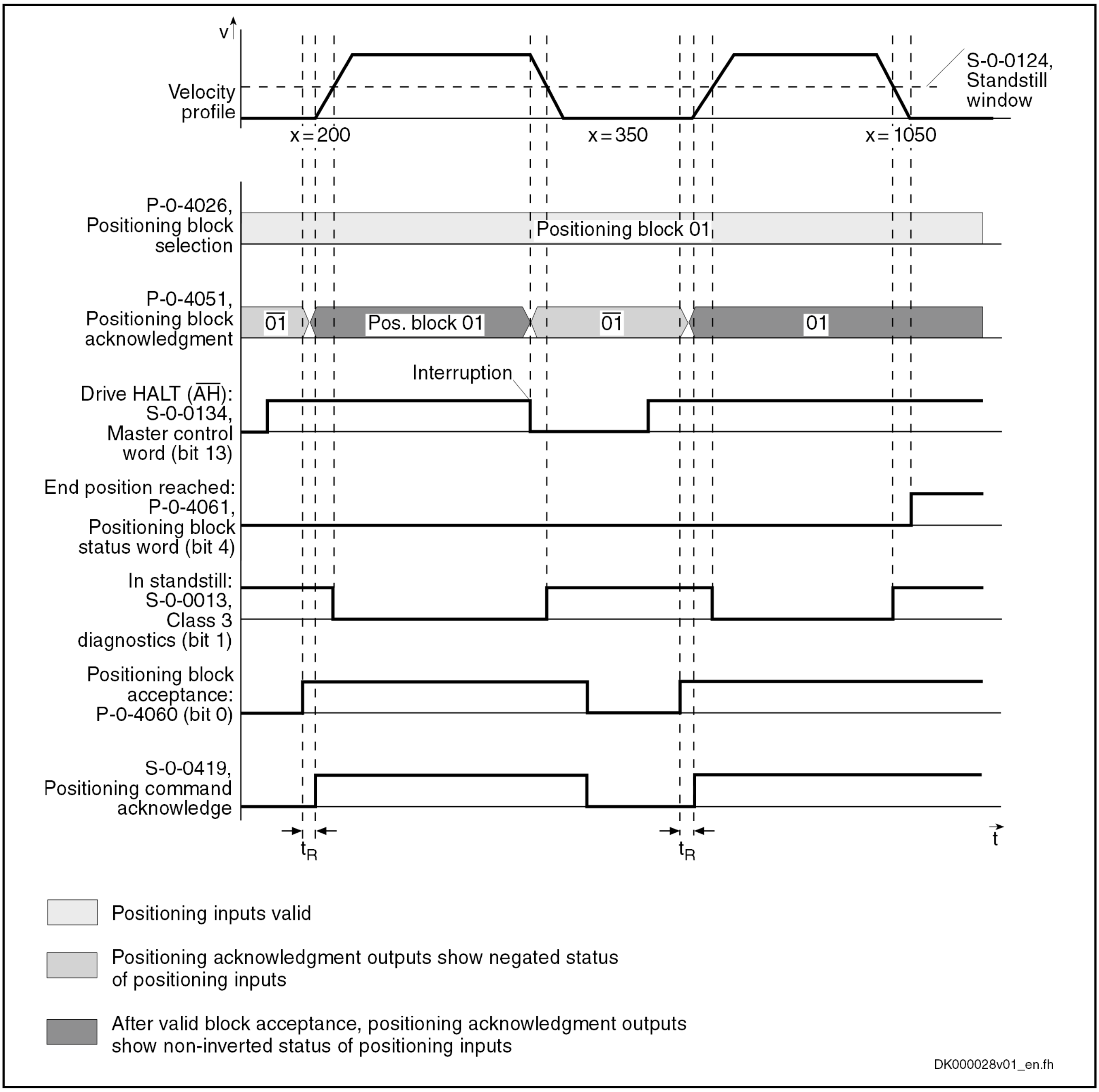


Fig. 7-40: Interrupting a Relative Positioning Bock without Residual Path Storage

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Relative positioning with residual path storage

Basic Function

Parameter Setting "P-0-4019, Positioning block mode" = 0000 0001 0000 001X

Residual Path If positioning blocks are interrupted, a distance still to be traveled up to the target position remains. This remaining distance is the residual path.

In a relative positioning block with residual path storage, the target position is a relative distance that relates to the target position at which the message "end position reached" was last active.

Relative positioning blocks with residual path storage are also executed, if the drive has not been homed.

Incremental Dimension Reference

By sequencing relative positioning blocks it is possible to position with incremental dimension. If a relative positioning block with residual path storage is interrupted, the incremental dimension reference is retained.

☞ If another positioning block is started while such a positioning block is being executed, the residual path is rejected. If this new block is also a relative positioning block with residual path storage, the target position is related to the current actual position as a relative distance.

Example:

- Relative positioning with residual path storage with travel distance = 700 (plus residual path = 20 of positioning block n-1)
- Without interruption
- Current position = 180; new target position = 900

Dedicated Position

The last valid target position is used as dedicated position (in the example, position = 200 of positioning block n-1).

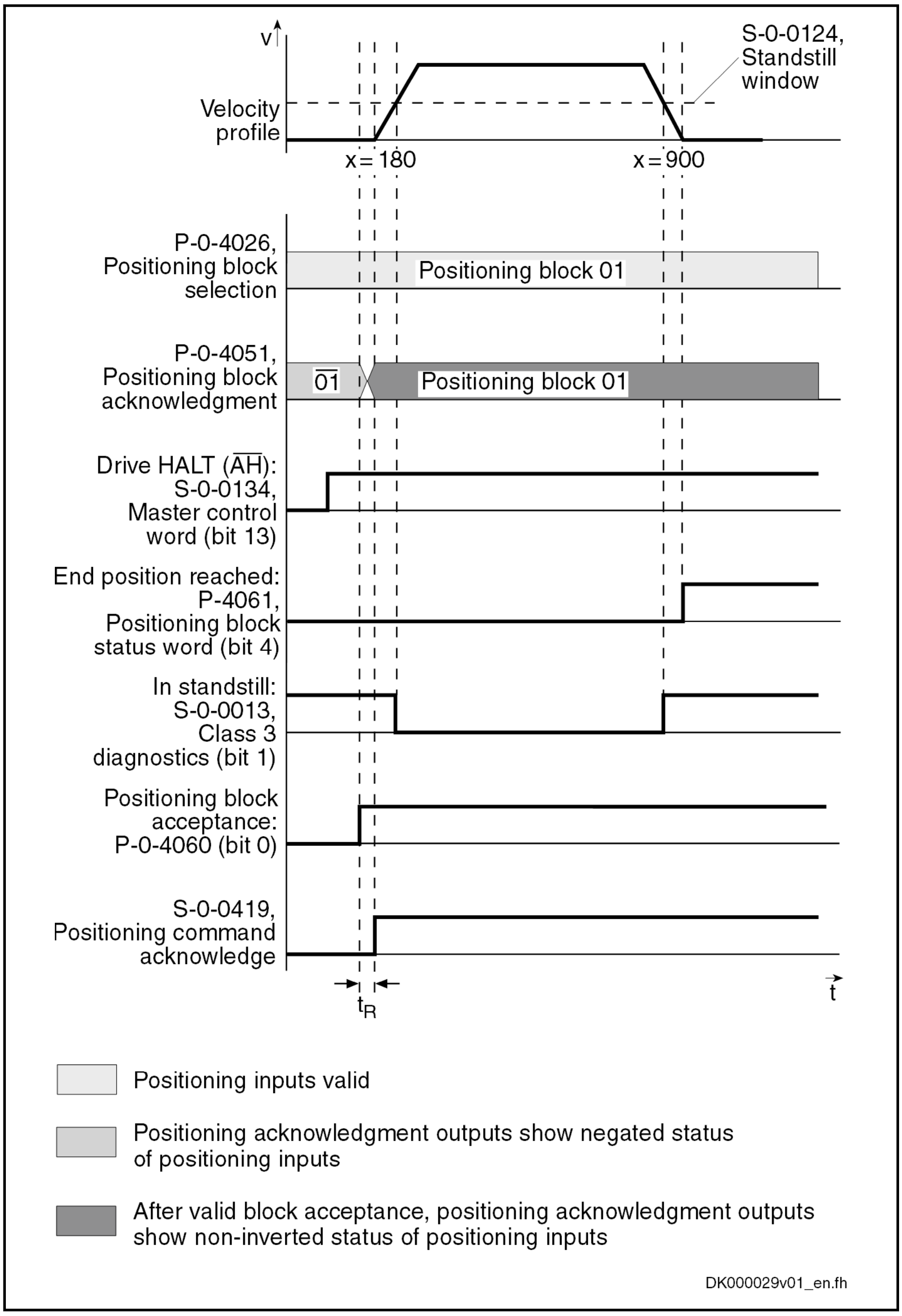


Fig. 7-41: Relative Positioning Block with Residual Path Storage

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Relative Positioning Block with Residual Path Storage after Activating Drive Enable

Example:

Interrupted relative positioning block with residual path storage after activation of drive enable with travel distance = 400 (current position = 200; target position = 800).

Dedicated Position

The position command value at the last "end position reached" (position = 200) message is used as the dedicated position.

☞ The incremental dimension reference is ensured.

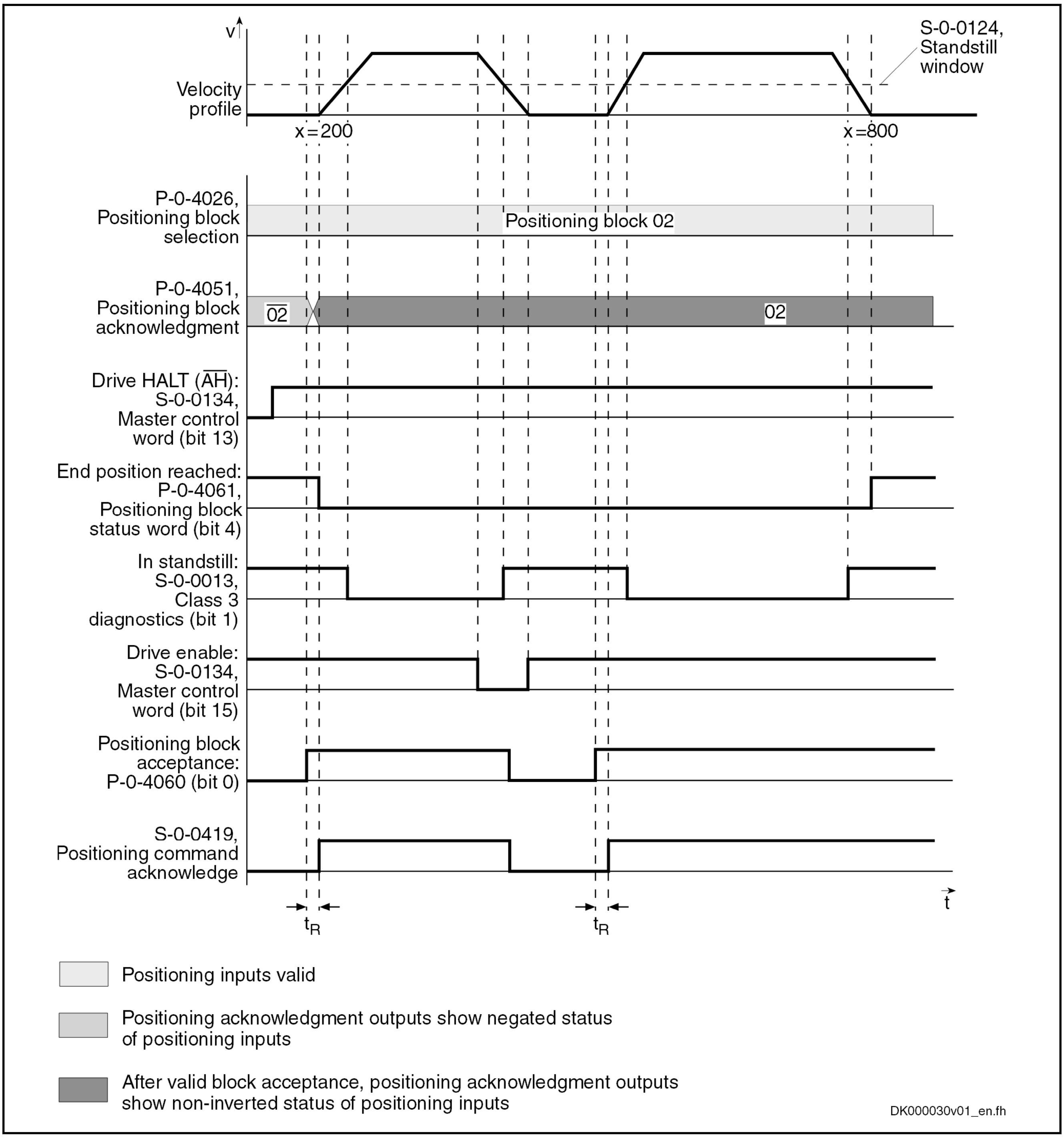


Fig. 7-42: Relative Positioning Block with Residual Path Storage after Activating Drive Enable

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Relative Positioning Block with Residual Path Storage after Interruption with Jog Mode

Example

Interrupted relative positioning block **with residual path storage** after jog mode with target position = 600 **without overrunning the target position** while jogging

Dedicated Position Behavior

Positioning is always continued at the current actual position value.

An interruption by means of jogging or positioning stop clears the residual path memory.

NOTICE	When an interruption by means of jogging or positioning stop takes place, the residual path is not traveled when the positioning block is restarted, but the positioning block is restarted (complete relative positioning block). The incremental dimension reference is no longer ensured!

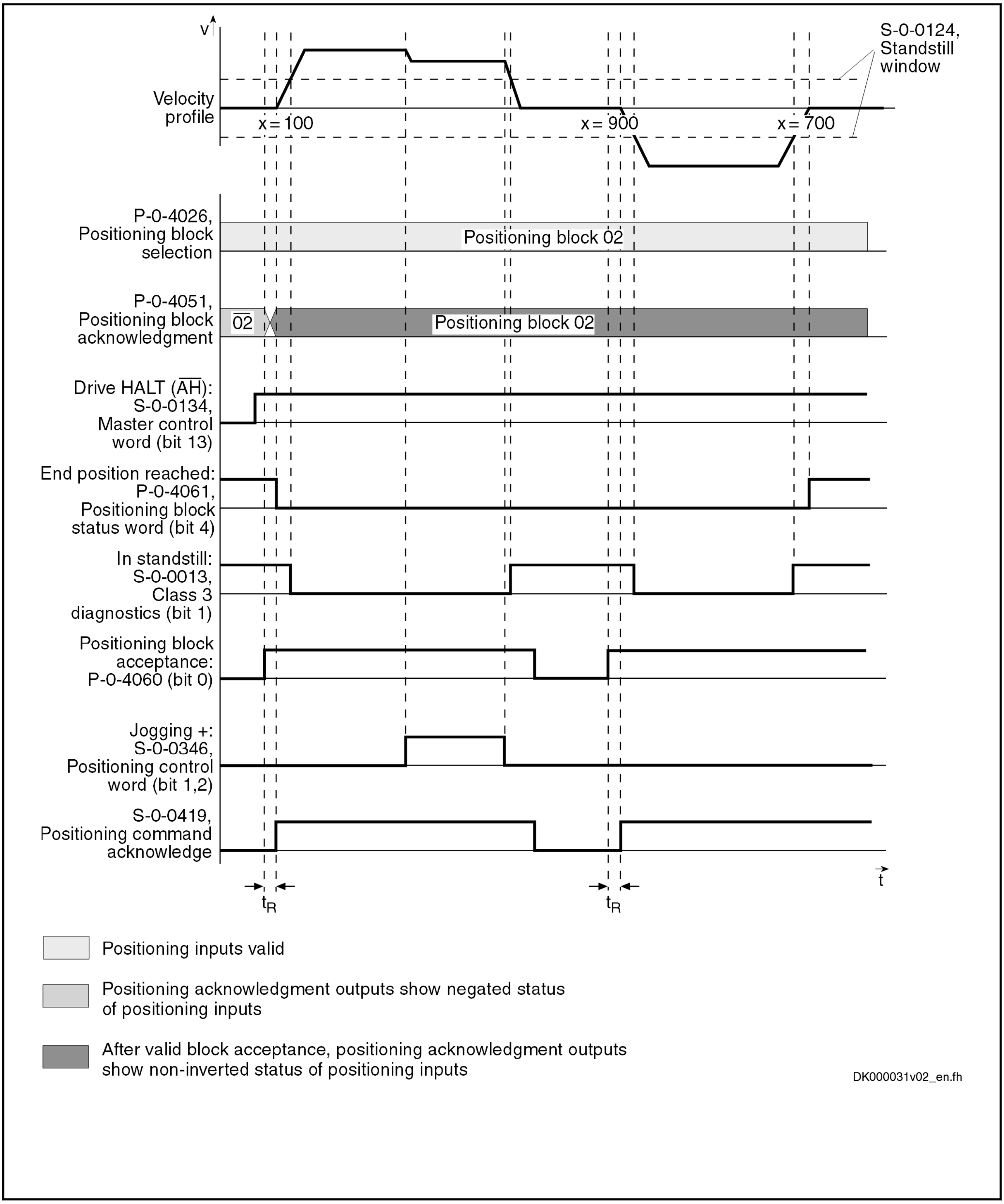


Fig. 7-43: Relative Positioning Block with Residual Path Storage after Jog Mode

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Relative Positioning Block with Residual Path Storage after Switching Drive Controller Control Voltage Off and On

If an absolute encoder is used, the incremental dimension reference can be retained after switching control voltage off and on. The previously calculated target position is stored at power shutdown. The rest of the distance is traveled after the interrupted relative positioning block with residual path storage is activated.

If a single-turn encoder is used, the residual path is rejected and positioning continues at the actual position.

Dedicated Position

The position command value at the last "end position reached" (position = 100) message is used as the dedicated position.

☞ If a positioning block is not accepted, the drive behaves as if the positioning block had not been started.

Infinite Travel in Positive/Negative Direction

If an axis is to be moved with defined velocity, acceleration and jerk without a specific target position, the travel block mode "traveling in positive direction" or "traveling in negative direction" must be specified. The drive moves in the indicated direction until the start signal is reset or one of the position limit values or the travel range limit switch is reached.

The target position which was set is irrelevant in this positioning mode.

Parameter Setting

- P-0-4019, Positioning block mode = 0000 0000 0000 010X
  → Travel in positive direction
- "P-0-4019, Positioning block mode" = 0000 0000 0000 100X
  → Travel in negative direction

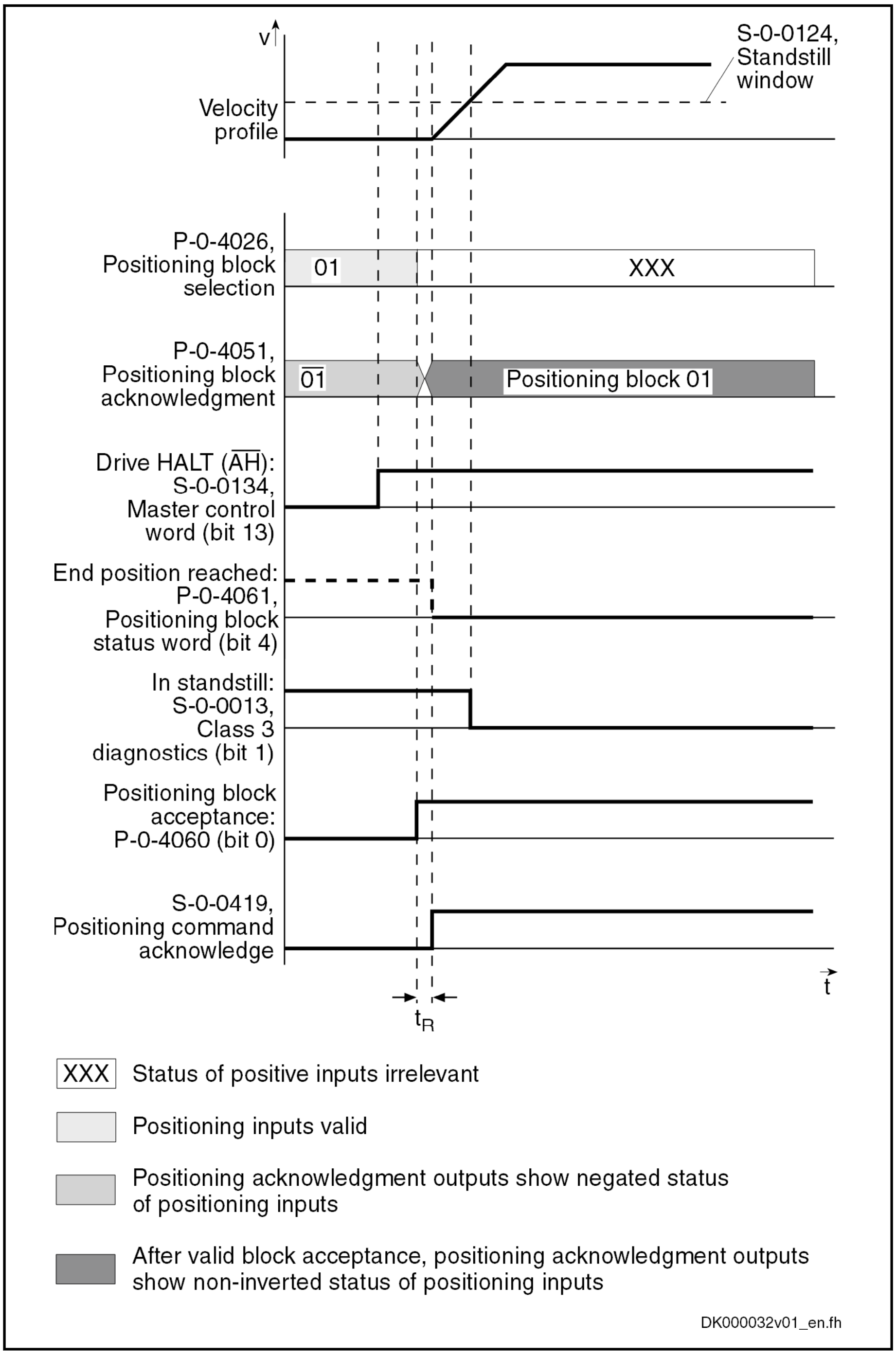


Fig. 7-44: Example: Infinite Travel in Positive/Negative Direction

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

7.8.4 Sequential block processing

Basic Function

> ☞ For sequential block processing, first of all the same basic rules apply as for single-block processing (see description of single-block processing). In addition to mere positioning block functions with defined positioning blocks and block acceptance, there also is a defined block transition to be parameterized.

Selecting and Activating a Sequential Block

A positioning block with sequential block is selected and activated in the usual way, only the first block of the sequential block chain being selected. The sequential block is the block with the next higher block number. A sequential block can also have a sequential block so that after a start block up to 63 sequential blocks can be set.

> ☞ The potential sequential block of the last valid block is block 0.

Conditions to Advance in Sequential Block Mode

There are two basically different modes for block advance; these modes can be subdivided:

- Position-Dependent Block Advance
  - Block transition with old positioning velocity
  - Block transition with new positioning velocity
  - Block transition with intermediate stop and defined delay time (see P-0-4018)
- Switch-Signal-Dependent Block Advance

Position-Dependent Block Advance

General Information

With position-dependent block advance, switching to the sequential block is carried out at the target position of the start block.

There are three different types of block transition:

- Block Transition with Old Positioning Velocity (Mode 1)
- Block Transition with New Positioning Velocity (Mode 2)
- Block Transition with Intermediate Stop and Defined Delay Time

Block Transition with Old Positioning Velocity (Mode 1)

Parameter Setting

- "P-0-4019, Positioning block mode" = 0000 0000 0001 000X

  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0001 001X

  → Relative block with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0001 010X

  → Infinite block in positive direction with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0001 100X

  → Infinite block in negative direction with sequential block

Function

In this mode, the target position of the start block is run through at the velocity of the start block. Then the positioning velocity is switched to that of the sequential block.

With relative and absolute positioning blocks with block advance, the drive moves in the direction of the target position. As soon as the target position is passed, the drive switches to the next travel block n+1.

With infinite positioning blocks, the drive moves in positive or negative direction. As soon as the target position is passed, the drive switches to next positioning block n+1, the block n representing the positioning block currently in process.

☞ If the target position is not in the selected travel direction, the drive moves in the direction of the target position. Thus, the drive always reaches the switching position.

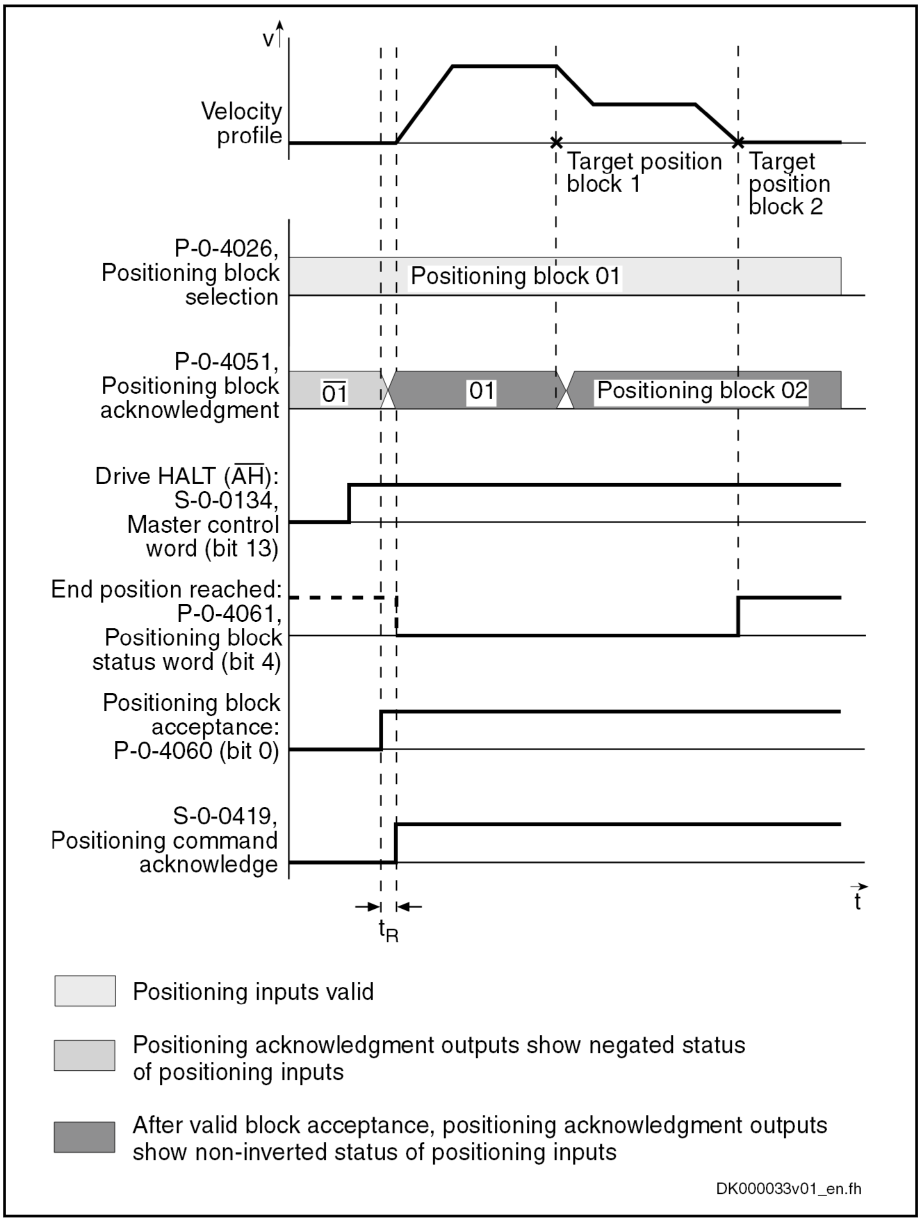


Fig. 7-45: Example: Position-Dependent Block Advance (Mode 1)

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Block Transition with New Positioning Velocity (Mode 2)

Parameter Setting

- "P-0-4019, Positioning block mode" = 0000 0000 0010 000X
  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0010 001X
  → Relative block with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0010 010X
  → Infinite block in positive direction with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0010 100X
  → Infinite block in negative direction with sequential block

Function

In this mode, the target position of the start block is run through at the positioning velocity of the sequential block. The deceleration or acceleration processes required to adjust the velocity are already carried out in the start block.

The drive moves in the direction of the target position x_n (with infinite blocks in the preset direction) set in current positioning block n. In due time before that, the acceleration is used to accelerate or decelerate to the next positioning velocity v_{n+1} so that the velocity v_{n+1} is reached at the target position x_n.

But switching to the next positioning block does not occur until the target position is overrun.

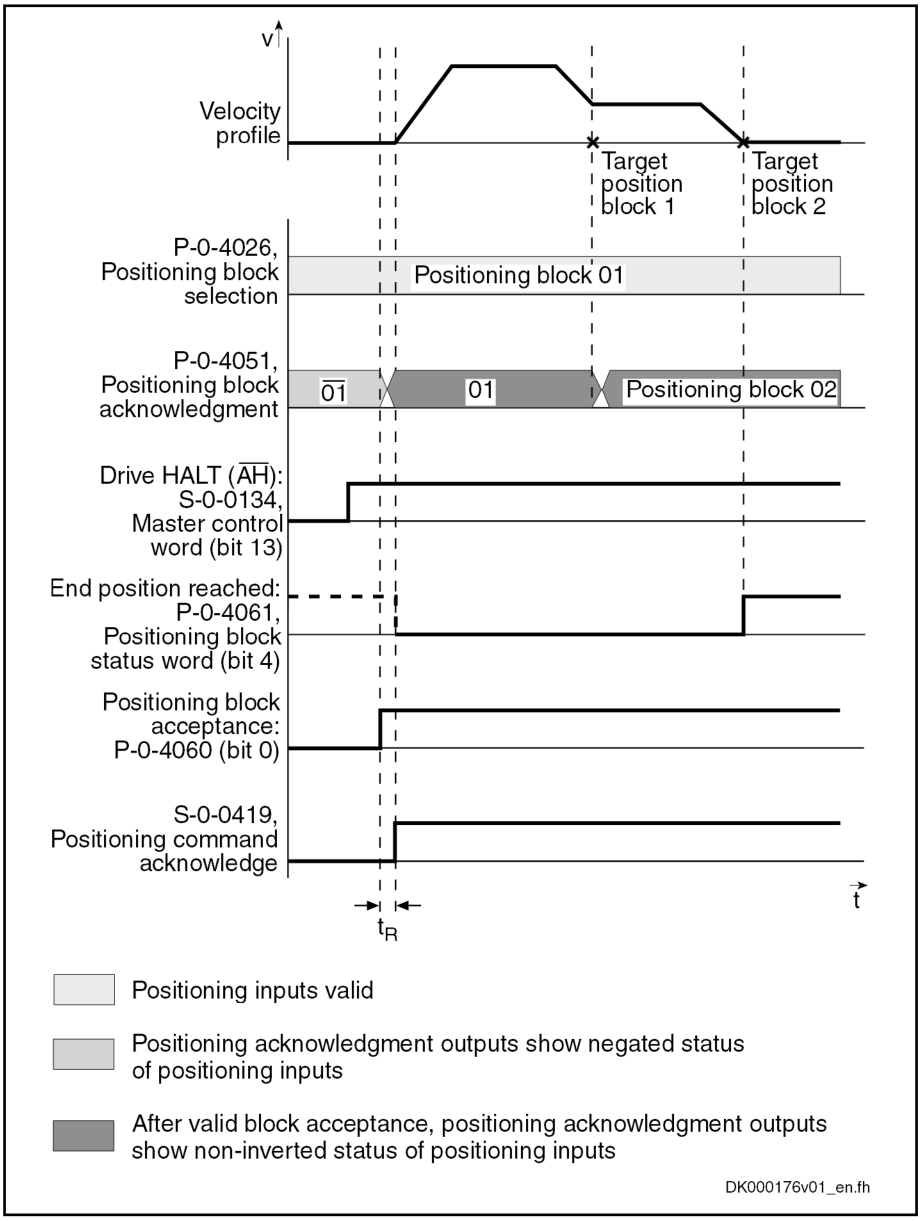


Fig. 7-46: Example: Position-Dependent Block Advance (Mode 2)

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Block Transition with Intermediate Stop and Defined Delay Time

Parameter Setting

- "P-0-4019, Positioning block mode" = 0000 0000 0100 000X
  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0100 001X
  → Relative block with sequential block

Function

In this mode, the drive positions at the target position of the start block. Once the position command value is at the target position, the sequential block is automatically started without a new start signal having been given externally.

If a delay time (P-0-4018) was parameterized for the positioning block, the sequential block is only started when the delay time is over.

Another operating mode is the switching when overrunning the target position with intermediate stop.

In this case, the drive is decelerated to speed "0" at the target position and then accelerated to the new positioning velocity.

☞ Advancing takes place when the internal command value generator has reached the target position and a possibly parameterized delay time (P-0-4018) has passed. With very low jerk values, the resulting dwell time is relatively long.

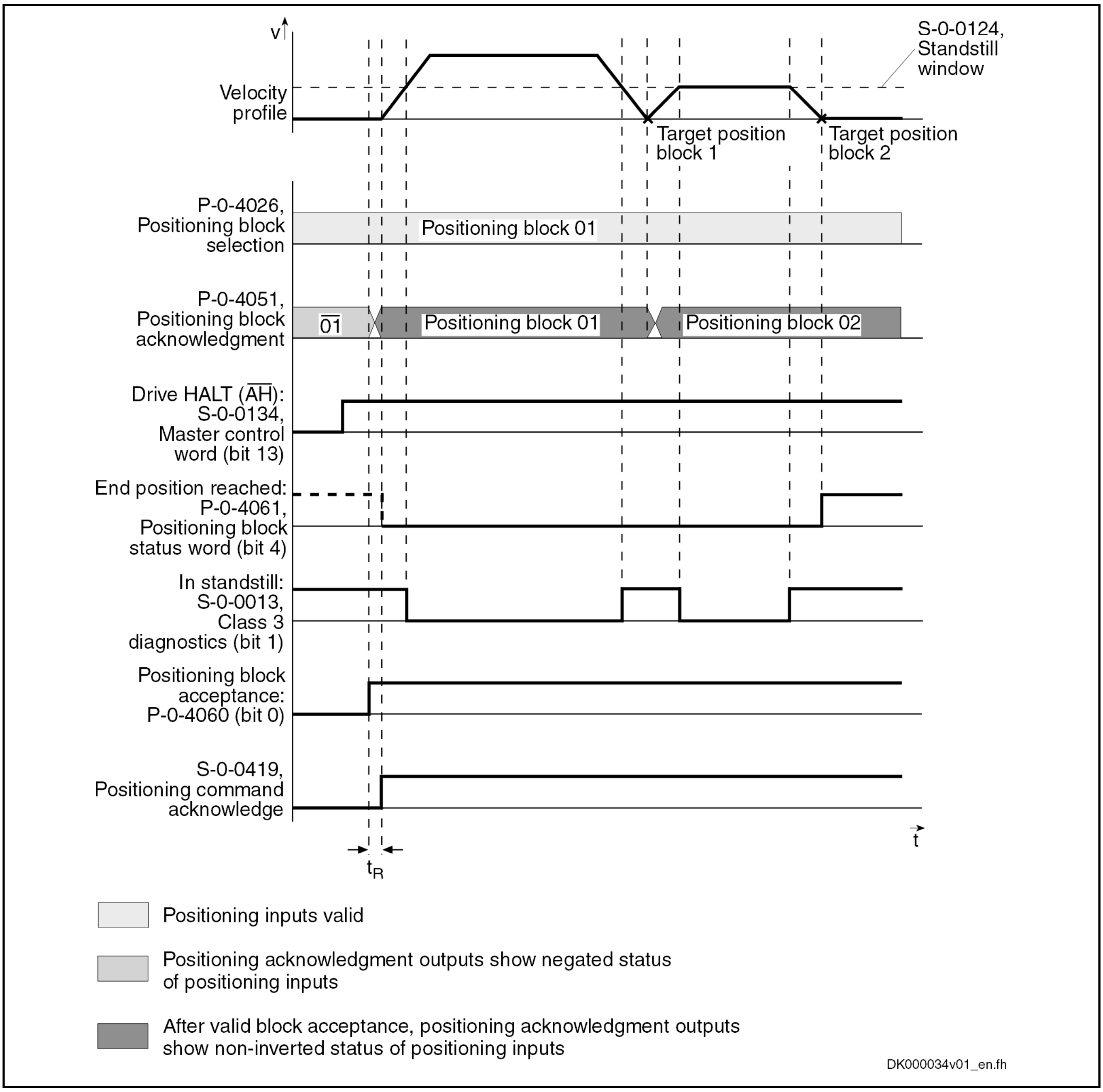


Fig. 7-47: Example: Sequential Block Advance for Target Position with Intermediate Stop

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

☞ This mode should be used if there is a change in direction in the case of two consecutive sequential blocks within one sequential block chain. Otherwise, the position at which the direction is changed will be inevitably overrun.

Switch-Signal-Dependent Block Advance

For switch-signal-dependent block advance, there are the following positioning modes:

- "P-0-4019, Positioning block mode" = **0000 0000 1000 000X**

  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 1000 001X**

  → Relative block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 1000 010X**

  → Infinite block in positive direction with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 1000 100X**

  → Infinite block in negative direction with sequential block

☞ Advance to the block with the next higher block number is triggered by an externally applied switch signal.

Switching with Cams

The switch-signal-dependent block advance allows transition to a sequential block, triggered by an external switch signal. As input for this switch signal, there are two sequential block inputs/probe inputs available.

The state of the hardware signals is displayed in parameter "P-0-4057, Positioning block, input linked blocks".

Function

The drive switches to the **next travel block n+1**, as soon as the input for the **sequential block cam 1** changes from "0" to "1". If the target position is not reached, switching to the new positioning block is carried out while traveling.

The drive switches to the **next travel block n+1**, as soon as the input for the **sequential block cam 2** changes from "0" to "1". If a sequential block cam is activated during this travel, the drive switches to the positioning block after the next.

Dedicated Position

A following relative positioning block refers to the position at which the sequential block cam was switched.

☞ The sequential block cams are sampled in the position controller clock (see "Performance Data"). The precision of position detection therefore strongly depends on the velocity during overrun.

Assignment Table for Cams

Cam 2	Cam 1	Drive reaction
0	0	Drive moves to target position of block n
x	0 → 1	Block n+1 is started
0 → 1	x	Block n+2 is started

n Positioning block preselected via the parallel inputs or parameter "P-0-4026, Positioning block selection"

x Not relevant

Tab. 7-3: Drive Reaction with Different Switch Signal Sequences

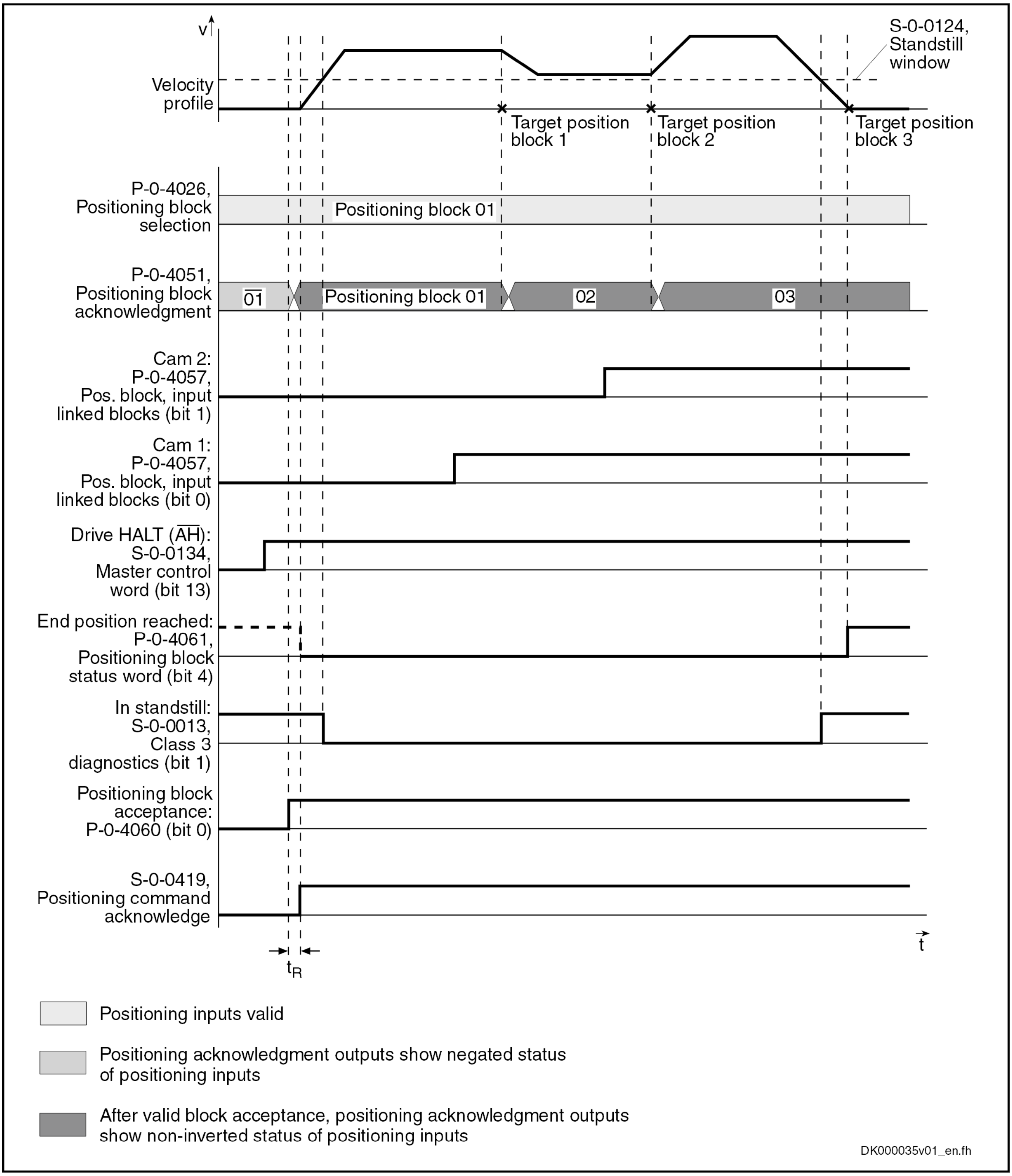


Fig. 7-48: Example: Switch-Signal-Dependent Block Advance

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Operation modes

Failure of Switch Signal for Block Advance

If the start block of a switch-signal-dependent sequential block is an absolute or relative positioning block, the drive positions at target position, if the switch signal for block advance is not received. The drive thus only generates the message "end position reached" after the sequential block chain is completed. If a switch signal is then applied, the drive will carry out the sequential block.

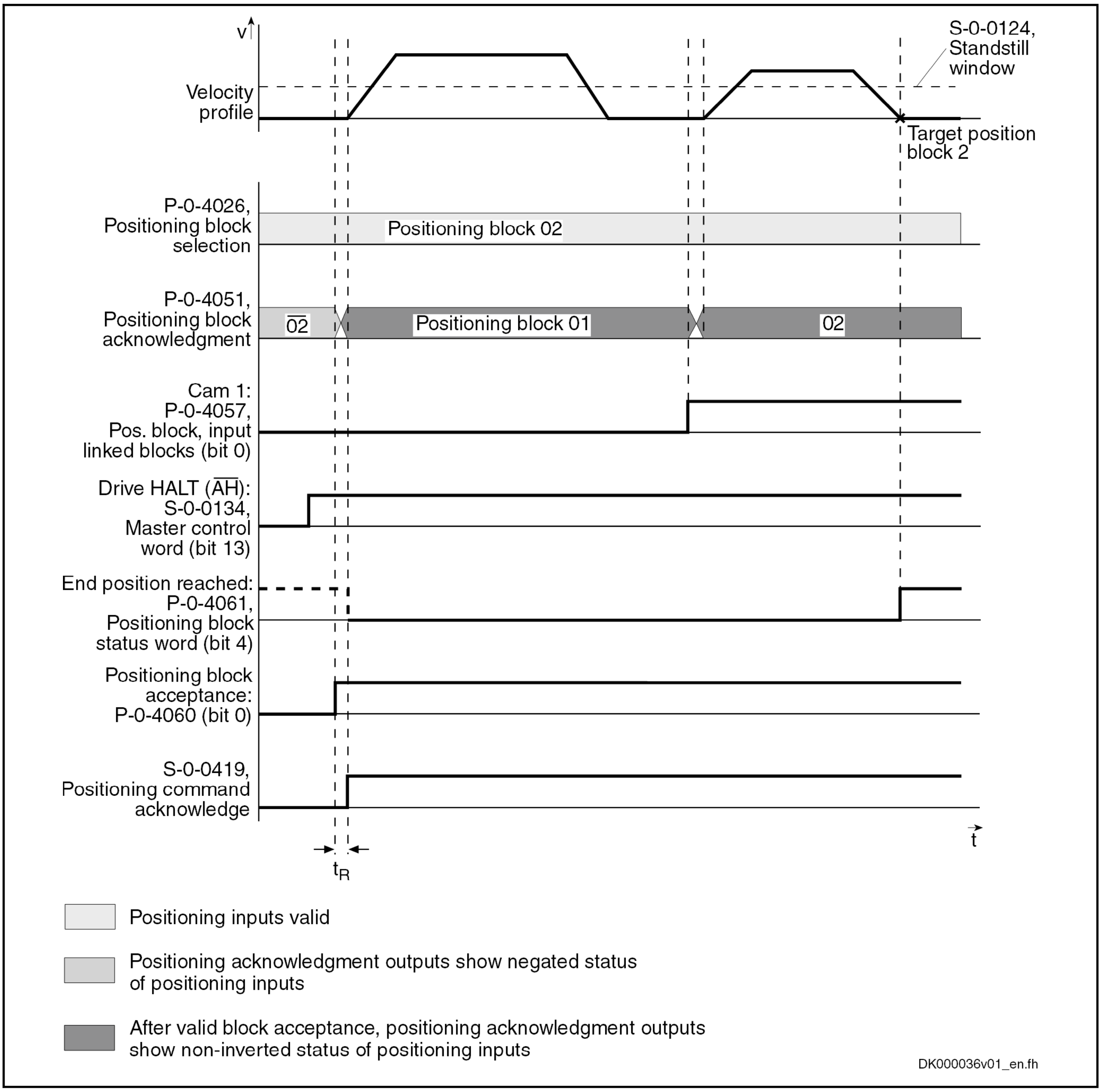


Fig. 7-49: Example: Switch-Signal-Dependent Block Advance (Behavior with Failure of Switch Signal)

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

All conditions for advancing are constantly queried and evaluated to be able to switch to the correct sequential block, even after the sequential block chain was interrupted. Only the first condition for advancing occurring during an interruption is recognized, however. All other conditions are not taken into account!

Interrupting a Sequential Block Chain

There are two basically different behaviors when a sequential block chain is interrupted:

- **Residual path is rejected** when interruption by:
  - Positioning stop (S-0-0346, bit 1 and bit 2 = 1)
  - Jogging +/-
  - Control voltage "Off"

  After interruption with "positioning stop" and "jogging +/-" positioning always continues at the current actual position. The sequential block chain interrupted before is not completed, but the currently selected block is executed. Thereby the incremental dimension reference gets lost!
- **Residual path is maintained** when interruption by:
  - Removing drive enable
  - Removing the "drive start" signal
  - Changing the operation mode

Depending on the block type of the sequential block chain that was interrupted and the events occurring during this interruption, the sequential block chain is processed differently after a restart.

In sequential block mode, relative positioning blocks **without residual path storage** are **not allowed**, as otherwise the incremental dimension reference would get lost in the case of interruption.

Given an interruption, a restart will end the sequential block chain.

Dedicated Position

The dedicated position is the original start position of the sequential block chain.

The incremental dimension reference is retained, as only absolute and relative positioning blocks with residual path storage are used in sequential block mode!

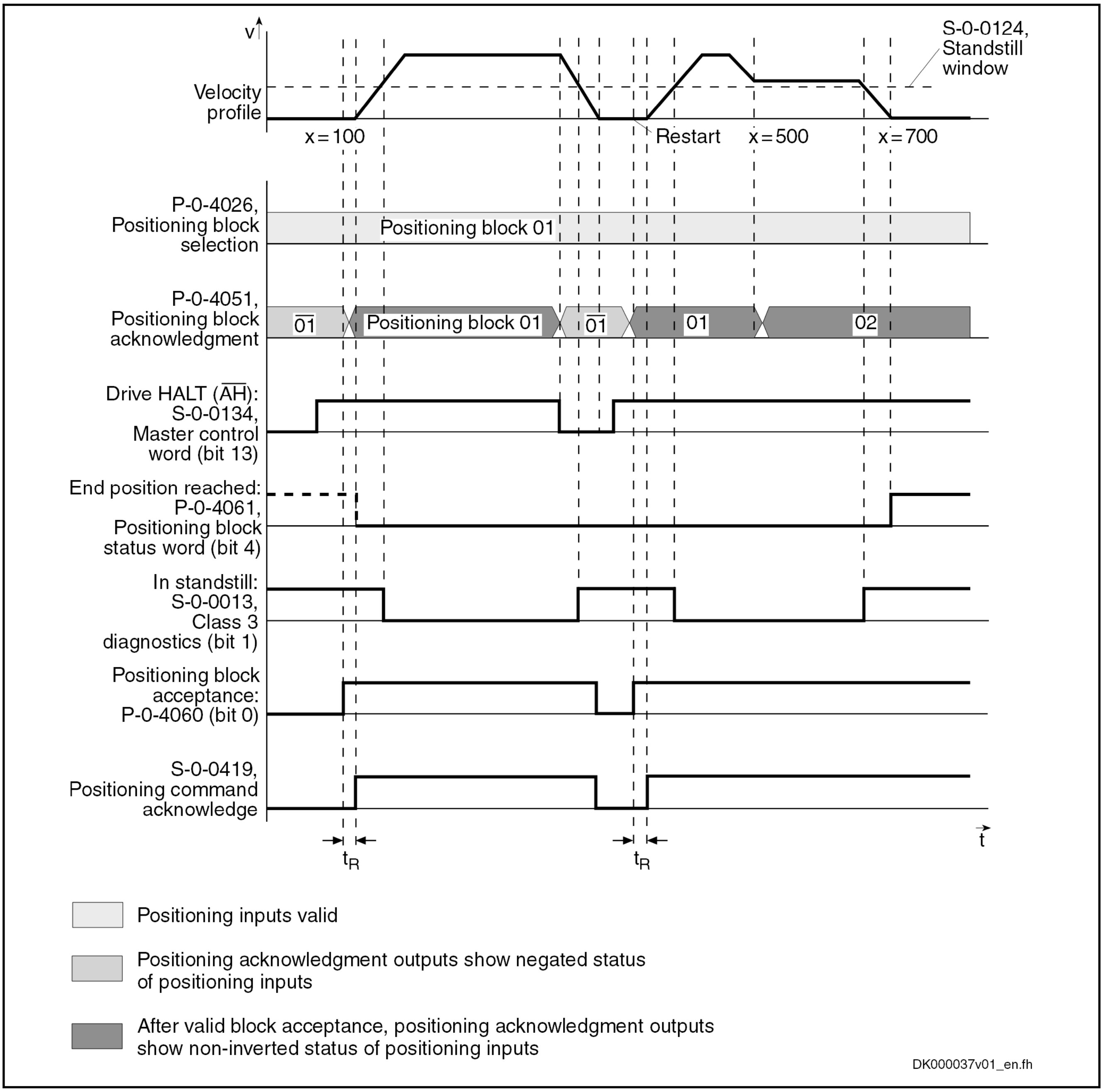


Fig. 7-50: Example: Sequential Block Interruption with Same Block Selected

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Changing to Different Operation Mode

When changing the operation mode during an interruption, the sequential block chain interrupted before is completed at the restart, if there hadn't been any new block selected.

Given a sequential block with advancing due to target position, only the overrun of the target position of the current positioning block will be detected. The processing of the sequential block is completed from this position.

> The condition for advancing due to switch signals is always detected.

Interrupting a Sequential Block Chain with Selection of New Positioning Block

If a new positioning block is selected during an interruption (e.g. with "Drive Halt"), the previously interrupted sequential block chain is not completed after a restart, but the currently selected block is executed.

Dedicated Position

The dedicated position is the current actual position value.

NOTICE

In case the sequential block is interrupted, the incremental dimension reference gets lost; therefore, the residual path is not traveled when the positioning block is restarted, but the positioning block is restarted (complete relative positioning block). The incremental dimension reference is no longer ensured!

The conditions for the interruption of sequential blocks also apply after the control voltage is switched off, if an absolute encoder is used.

Interrupting a Sequential Block Chain with Absolute Sequential Blocks

An interruption with absolute positioning blocks does not represent any problem, as the position data reference is always guaranteed.

When a **new block number** is selected in the case of an interruption, the sequential block interrupted before is not completed when toggling bit 0 in "S-0-0346, Positioning control word" or with a positive edge of bit 0 in "P-0-4060, Positioning block control word", but the currently selected block is executed.

When **no new block number** is selected in the case of an interruption, the sequential block interrupted before is completed when toggling bit 0 in "S-0-0346, Positioning control word" or with a positive edge of bit 0 in "P-0-4060, Positioning block control word".

7.8.5 Notes on Commissioning and Parameterization

Limit Values of the Drive

When parameterizing sequential blocks, the maximum values of the drive must be taken into account. These data are:

- Maximum acceleration capability
- Maximum speed (independent of mains voltage)

If blocks are parameterized for which the drive would have to generate values greater than the maximum values, this will cause an excessive lag error. With the error message "F2028 Excessive deviation" the drive will then signal that it cannot follow the position command value.

Minimum Values for Acceleration and Jerk

Acceleration values parameterized too low can lead to problems. Therefore, guide values according to the formula below are to be preferred when determining positioning blocks:

$$\text{Acceleration} > \frac{\text{Velocity difference}^2}{2 \times \text{Target position difference}} \times \frac{(v_{n+1} - v_n)^2}{2 \times (x_{n+1} - x_n)}$$

v_n	Velocity of block n
v_{n+1}	Velocity of block n+1
x_n	Target position of block n
x_{n+1}	Target position of block n+1

Fig. 7-51: Minimum Acceleration Value with Sequential Block Mode (Linear)

☞ The above relationship applies to an infinitely large jerk which corresponds to a jerk filter that has been switched off (= 0). If a jerk filter is used, the calculated values have to be doubled in first approximation. The distance to be run with a block and the respective velocity are generally fixed by the process. If the minimum acceleration value calculated with the above guide value formula already causes the maximum value, mentioned in the previous section, to be exceeded, a lower positioning block velocity must be selected.

Minimum Jerk Value

If the acceleration values parameterized are too low, this can cause the parameterized velocity not to be reached. In this case, the so-called "triangular mode" is used.

Directional Change within a Sequential Block Chain

☞ If a directional change takes place when changing from block n to block n+1 of a sequential block, the "switching at target position with halt" mode should be used for block n to reverse the direction without overshoot.

Explanation of the Figure Below

Block n with intermediate stop follows block n-1 with mode 1 (block transition with old positioning velocity), because a change in direction occurs when changing from block n to block n+1. At change in direction there is a change of sign of the velocity at target position n. If the acceleration parameterized in block n is too low to decelerate within the path difference x_n-x_{n-1} from velocity v_{n-1} to the value "0", the parameterized target position x_n will be overrun.

This may cause software or hardware limit switches to trigger.

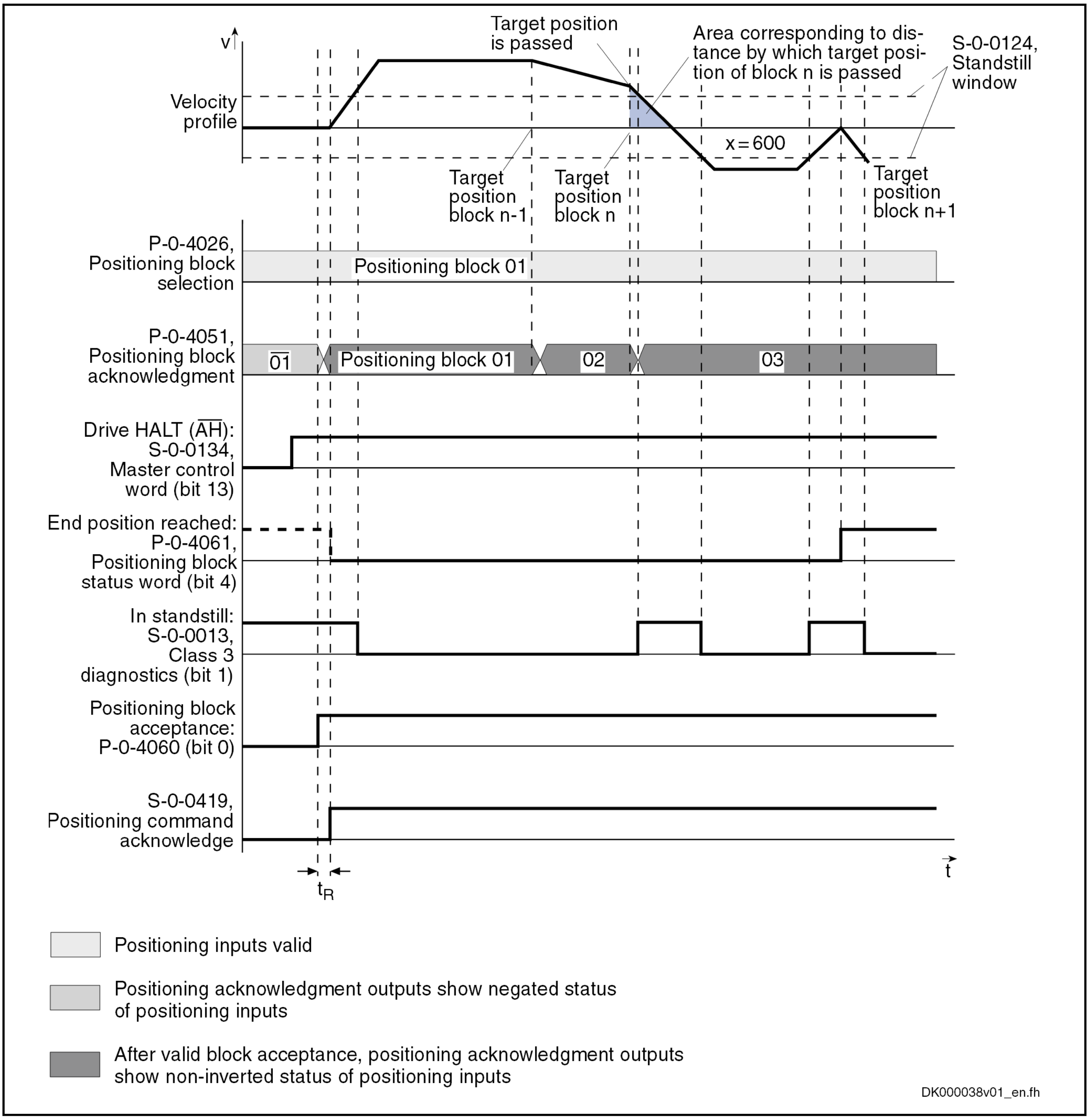


Fig. 7-52: Parameterizing a Sequential Block with Directional Change

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

☞ In the case of a sequential block with directional change, it is necessary to take values according to the above formula for the minimum acceleration value into account in order to avoid overshooting of position!

7.8.6 Diagnostic and Status Messages, Acknowledgment

Positioning Block Acknowledgment

The positioning block acknowledgment is used for feedback of the execution of the active positioning block.

Acknowledgment with Active Operation Mode

After the positioning block mode has been activated, the complement of the block number of the selected positioning block is acknowledged, until a start signal (toggling of bit 0 in "S-0-0346, Positioning control word" or positive edge of bit 0 in "P-0-4060, Positioning block control word") is set. As of the first start signal and if operation is trouble-free, the block number of the positioning block that was started is output. If an error is detected at the start of a positioning block, the faulty positioning block is acknowledged with the complement of the block number. The drive generates a warning and stops.

Acknowledgement with "Drive Halt"

If "Drive Halt" is active, the complement of the block number of the selected positioning block is output in parameter "P-0-4051, Positioning block acknowledgment".

Acknowledgment with Secondary Operation Modes

The acknowledgment is not affected by secondary operation modes, error reaction and command inputs, i.e. parameter "P-0-4051, Positioning block acknowledgment" retains the value.

Acknowledgment with Drive Enable Switched Off

After switching off drive enable, the last accepted positioning block is output at the acknowledge outputs. If the drive is at the target position of the last accepted positioning block, the message "end position reached" is additionally output.

The example below shows the same absolute positioning block being started once again.

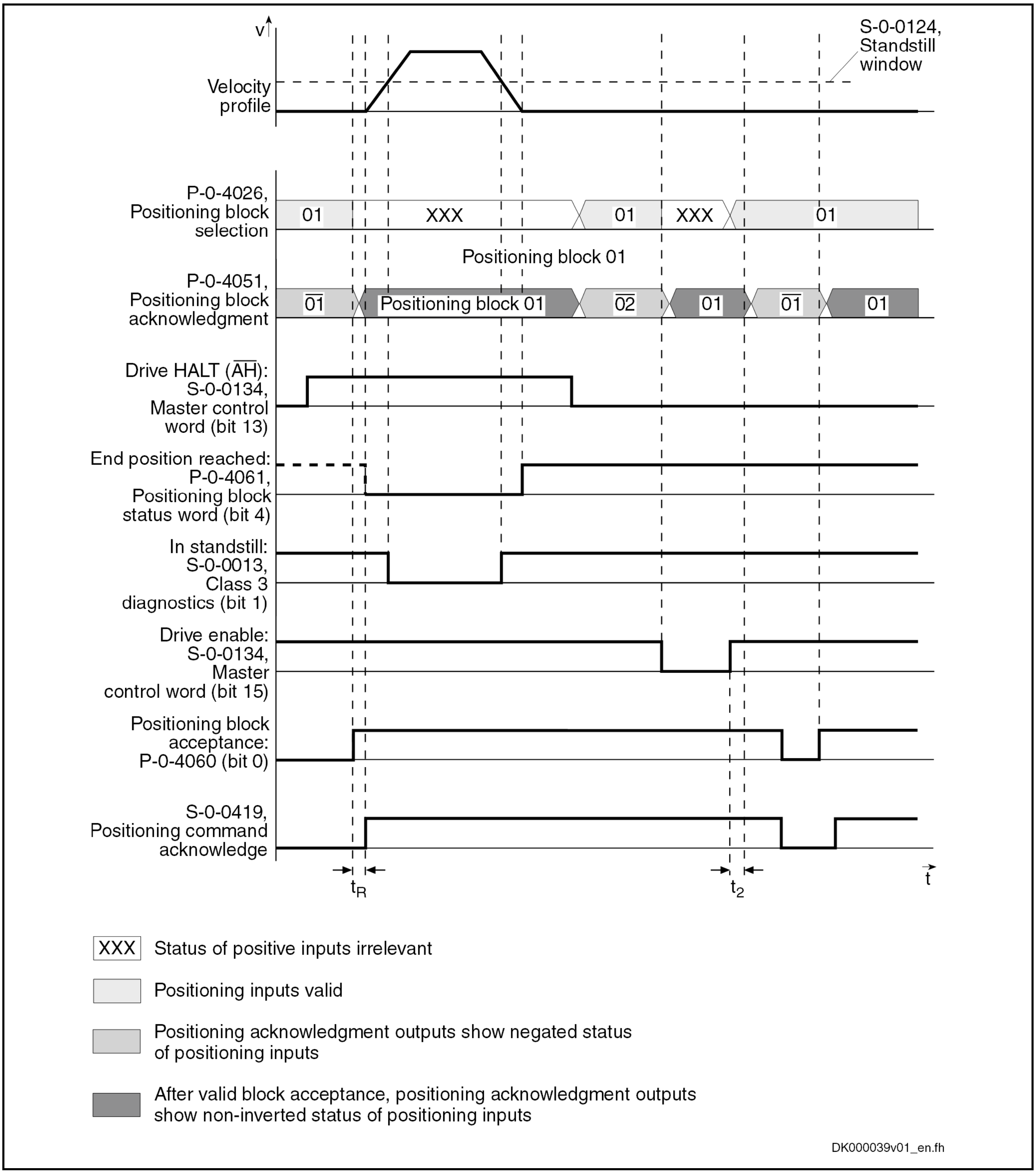


Fig. 7-53: Acknowledgment and Message "End Position Reached" after Drive Enable Switched Off

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a positive edge of bit 0 in P-0-4060.

Acknowledgment with Control Voltage Interrupted

If the control voltage is switched off, the last accepted positioning block is stored in parameter "P-0-4052, Positioning block, last accepted" so that after switching control voltage on, it is always the last accepted positioning block that is output.

With Absolute Value Encoder

If an **absolute value encoder** is used, it is possible to decide, after the control voltage is switched off and on, whether the drive still is at the target position of the last accepted positioning block (end position reached).

The "end position reached" message is generated as soon as the drive is ready for operation again (bb contact closed).

With Single-Turn Encoder

If a **single-turn encoder** is used, the"end position reached" message is not clearly defined after a voltage interrupt until the first target position has been run to or homed.

☞ The "end position reached" message is only retained if the axis has not been moved during the interruption. If the axis is moved into the positioning window during the interruption, the "end position reached" message will also be generated! After activating drive enable, positioning block acknowledge changes as described under "Acknowledgment with Drive Enable Switched Off".

Status Messages

Status Bits

In addition to the status messages during the "drive-internal interpolation" mode, the "end position reached" status message is generated in the "positioning block mode" (bit 4 = 1 in parameter "P-0-4061, Positioning block status word"), if the following applies:

- |S-0-0430 – S-0-0051/S-0-0053| < S-0-0057 (In Position)

  - and -

- No sequential block has been selected.

See also section "Status Messages" of the operation mode "Drive-Internal Interpolation"

ⓘ See also Parameter Description "P-0-4061, Positioning block status word"

Status Parameters

The following parameters provide further diagnostic possibilities:

- P-0-4051, Positioning block acknowledgment

  → Acknowledgment of the currently accepted and active positioning block

  Note: At "Drive Halt", the selected positioning block is returned in negated form (complementary to positioning block selection).

- P-0-4052, Positioning block, last accepted

  → Contains the last accepted positioning block (stored in non-volatile form)

  Note: For sequential block chains, this is always the first block of the sequential block chain!

- P-0-4053, Positioning block, last active

  → Contains the last active positioning block (stored in non-volatile form)

  Note: For sequential block chains, this is the last active block of the sequential block chain. For single blocks (no sequential block processing), the contents of parameters P-0-4052 and P-0-4053 are always equal!

- P-0-4057, Positioning block, input linked blocks

  → Contains an image of the digital sequential block inputs (switch cam inputs)

Diagnostic Messages

Diagnostic status messages:

- A0162 Positioning block mode
- A0206 Positioning block mode, encoder 1
- A0207 Positioning block mode lagless, encoder 1
- A0210 Positioning block mode, encoder 2
- A0211 Positioning block mode lagless, encoder 2

Warnings:

- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2054 Not homed
- E2055 Feedrate override S-0-0108 = 0
- E2058 Selected positioning block has not been programmed

Error messages:

- F2028 Excessive deviation

7.9 Synchronization modes

7.9.1 Basic Functions of the Synchronization Modes

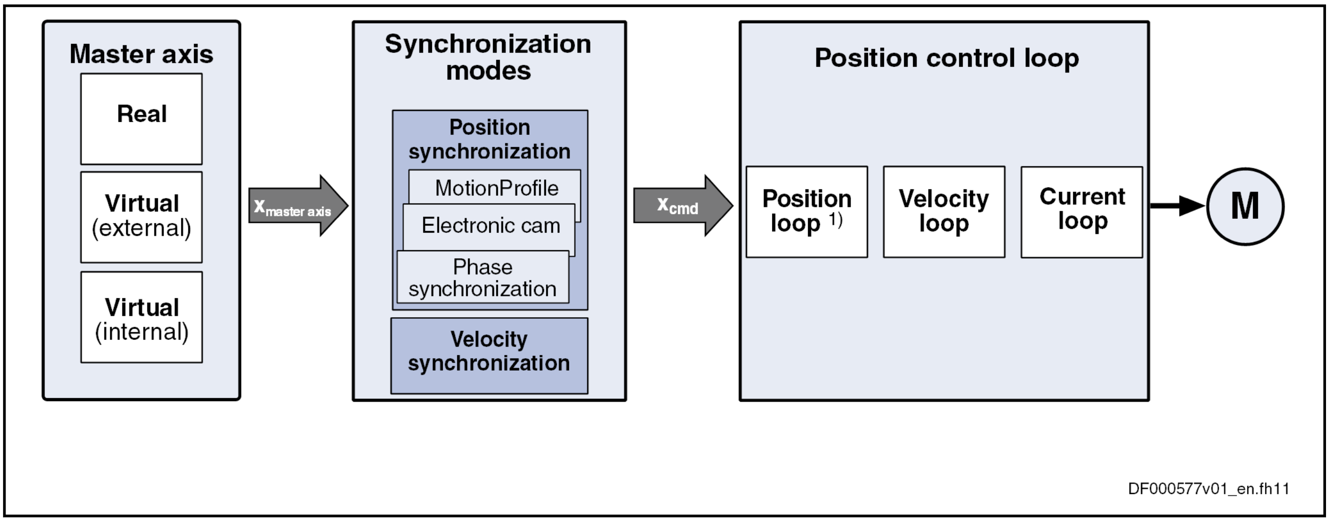
Overview

General Information on Synchronization Modes

The synchronization modes allow the drive to run synchronously with regard to a real or virtual master axis. The synchronization modes are basically divided into the following groups:

- Velocity synchronization
- Position synchronization with the operation modes
  - Phase synchronization
  - Electronic cam
  - MotionProfile

The figure below illustrates how the synchronization modes are integrated in the control loop structure.



1) No position controller with "velocity synchronization" mode

Fig. 7-54: General Block Diagram of the Synchronization Modes

All synchronization modes have the following identical or similar basic functions which are comprehensively described in this section:

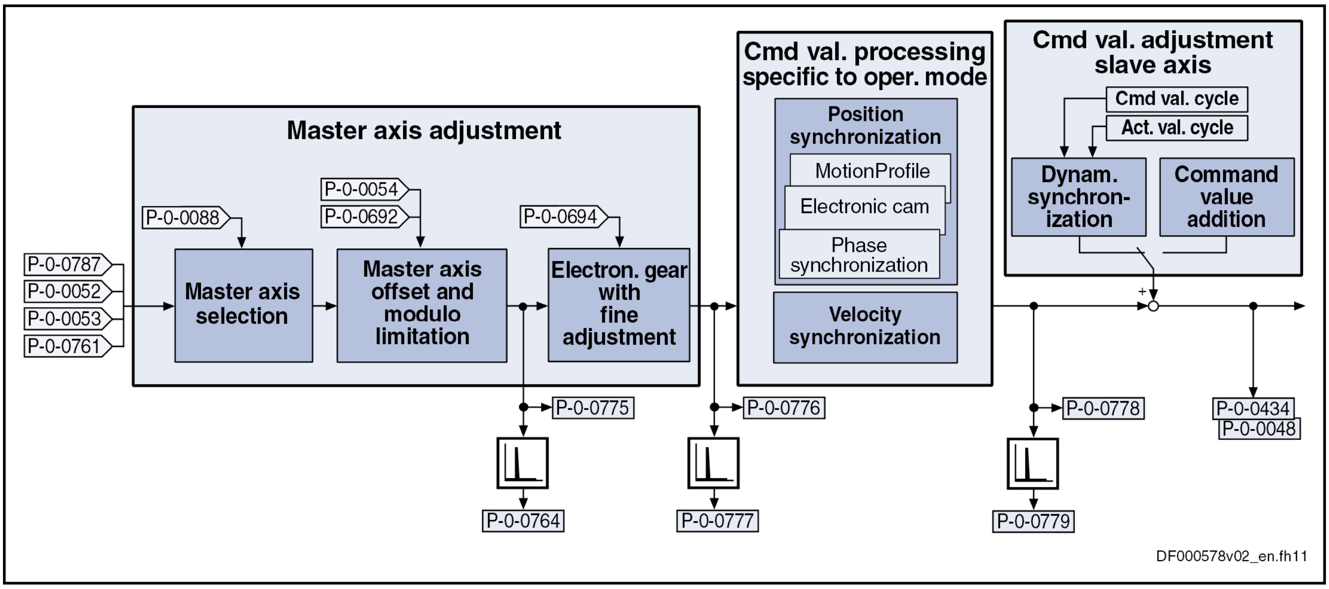
- Adjustment of master axis, consisting of
  - Generation of master axis
  - Master axis offset and modulo limitation
  - Electronic gear with fine adjustment
- Drive-controlled dynamic synchronization

☞ The individual synchronization modes basically differ in the following function blocks:

- Command value processing specific to operation mode
- Command value addition for slave axis

These function blocks are described specific to operation mode in the individual sections on the respective synchronization modes.

The figure below illustrates the interaction of the individual basic functions (function blocks) of the synchronization modes.



P-0-0048	Effective velocity command value
P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0054	Additive master axis position
P-0-0088	Control word synchronization modes
P-0-0434	Position command value of controller
P-0-0692	Additive position command value, process loop
P-0-0694	Gear ratio fine adjustment, process loop
P-0-0761	Master axis position for slave axes
P-0-0764	Master axis speed
P-0-0775	Resulting master axis position
P-0-0776	Effective master axis position
P-0-0777	Effective master axis velocity
P-0-0778	Synchronous position command value
P-0-0779	Synchronous velocity
P-0-0787	Group axis position

Fig. 7-55: Function Blocks of the Synchronization Modes

Explanation of Terms

Master axis:

The virtual or real axis that provides the master axis position for generating the synchronous position command value for the slave axis is called master axis.

Master axis cycle:

The master axis cycle specifies the range in which the master axis values move. It corresponds to one master axis revolution or a multiple of that. So that the master axis positions can be processed correctly (e.g. in the case of modulo overflow), the size of the master axis cycle must be known to the drive. The control unit communicates the size of the master axis cycle to the drive in the configuration of parameter **"P-0-0750, Master axis revolutions per master axis cycle"**.

Slave axis:

The drive that follows the command values derived from the master axis is called the slave axis.

Command value cycle:

In processes with different machining cycles, the slave axis must be able to synchronize over several master axis revolutions or divisions of a master axis revolution. The so-called command value cycle provides this option. The modulo value of the command value cycle is calculated internally depending on the electronic gear (P-0-0156, Master drive gear input revolutions; P-0-0157, Master drive gear output revolutions) and the values "P-0-0750, Master axis revolutions per master axis cycle" and "S-0-0103, Modulo value".

See also parameter description "P-0-0754, Command value cycle".

Actual value cycle (actual position value in the actual value cycle):

The actual value cycle ("P-0-0786, Modulo value actual value cycle") is the modulo range within which the actual position values of the slave axis are to be found when the position synchronization mode is active (P-0-0753, Position actual value in actual value cycle). The user can specify the modulo value of the actual value cycle.

☞ **The operation modes of the position synchronization (phase synchronization, cam and MotionProfile) use the "actual position value in the actual value cycle" (P-0-0753) to close their position control loop.**

The travel distance for synchronization is determined using the "actual position value in the actual value cycle" and the set synchronization range (see parameter description "P-0-0155, Synchronization mode") when one of the operation modes of the position synchronization is activated. The travel distance is limited by the synchronization range, i.e. the command value cycle, division of the command value cycle or modulo range (S-0-0103, Modulo value).

See parameter description "P-0-0753, Position actual value in actual value cycle".

See parameter description "P-0-0786, Modulo value actual value cycle"

The modulo value of the actual value cycle must be specified such that it corresponds with a whole number multiple of the command value cycle or the modulo range (S-0-0103, Modulo value).

Configuring and Controlling the Synchronization Modes

The synchronization modes velocity synchronization and position synchronization are configured and controlled by means of the following synchronization parameters:

Pertinent Parameters (Synchronization Parameters)

- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes

The following specifications can be made for the position-controlled operation modes using parameter S-0-0520:

- Position control with lag error or lagless
- Use of encoder 1 or encoder 2

See also "Operation Mode Handling"

Command Value Addition

This section contains an overview of the basic possibilities of adding command values. The characteristics and details specific to operation mode are described in the section of the respective synchronization mode.

Pertinent Parameters

- S-0-0037, Additive velocity command value
- S-0-0048, Additive position command value
- P-0-0048, Effective velocity command value
- P-0-0054, Additive master axis position
- P-0-0060, Filter time constant additive position cmd value
- P-0-0434, Position command value of controller
- P-0-0686, Additive position command value, positioning velocity
- P-0-0687, Additive position command value, positioning acceleration
- P-0-0688, Additive master axis position, positioning velocity
- P-0-0689, Additive master axis position, positioning acceleration
- P-0-0690, Additive velocity command value, process loop
- P-0-0691, Additive position command value, process loop
- P-0-0692,
- P-0-0693, Filter time constant, add. master axis pos., process loop

The figure below contains a rough overview of the command values which can act on the master and slave axis and of how they can be influenced.

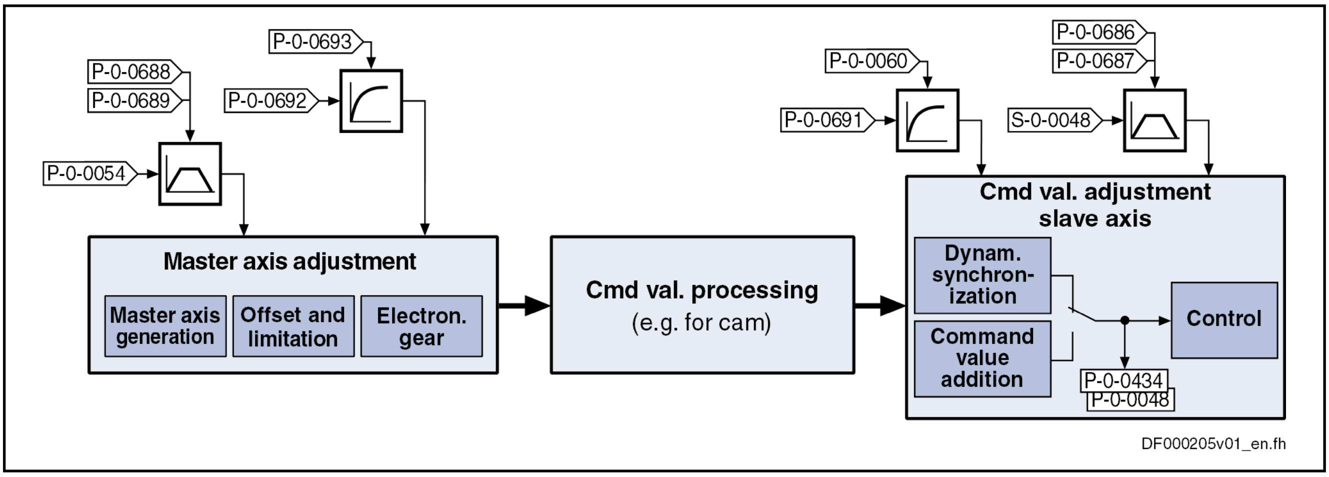


Fig. 7-56: Possibilities of Command Value Addition for Master and Slave Axis

Master Axis Adjustment

Brief Description

Master Axis Generation

The following are possible as signal sources for the resulting master axis position **(P-0-0775)**:

- **Real master axis** (P-0-0052, Actual position value of measuring encoder)
- **Virtual master axis, external** (P-0-0053, Master axis position)
- **Virtual master axis, internal** (P-0-0761, Master axis position for slave axis)
- **Virtual master axis 2, external / group master axis** (P-0-0787, Group axis 1 position)

> ☞ Selection of the group master axis is not available in firmware variant MPE.

Master axis offset and modulo limitation

For internal adjustment or processing of the master axis information, there are the following options:

- Addition of components (= offset) to the incoming master axis angle:
  - Via parameter "P-0-0054, Additive master axis position"
  - Via parameter "P-0-0692, "
- Limitation to modulo range of master axis

Electronic Gearbox Function

By means of factors to be set (e.g. input revolutions, output revolutions, polarity), the electronic gearbox function can influence the master axis position relevant for the operation mode as compared to the master axis position preset by master axis evaluation.

Pertinent Parameters

The following parameters are used in conjunction with master axis adjustment:

- P-0-0052, Actual position value of measuring encoder
- P-0-0053, Master axis position
- P-0-0054, Additive master axis position
- P-0-0084, Number of bits per master axis revolution
- P-0-0688, Additive master axis position, positioning velocity
- P-0-0689, Additive master axis position, positioning acceleration
- P-0-0692,
- P-0-0693, Filter time constant, add. master axis pos., process loop
- P-0-0750, Master axis revolutions per master axis cycle
- P-0-0761, Master axis position for slave axis
- P-0-0764, Master axis speed
- P-0-0765, Modulo factor measuring encoder
- P-0-0775, Resulting master axis position
- P-0-0787, Group axis 1 position

The following parameters are used in conjunction with the electronic gearbox with fine adjustment:

- P-0-0083, Gear ratio fine adjustment
- P-0-0108, Master drive polarity
- P-0-0156, Master drive gear input revolutions
- P-0-0157, Master drive gear output revolutions
- P-0-0694, Gear ratio fine adjustment, process loop
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity

Master Axis Generation

The synchronization modes allow the drive to run synchronously with regard to a real or virtual master axis. Command value input in the synchronization modes takes place depending on the type of master axis.

The firmware supports the following possibilities of input of the master axis position:

- Real master axis

For real master axes, the master axis position is input by evaluating the signals of a master axis encoder (measuring encoder) via parameter "P-0-0052, Actual position value of measuring encoder".

☞ The scaling of the position data generated with a measuring encoder is rotary and axis- or shaft-related. Due to the infinite motion range of the measuring encoder and the limited value range of the position data, modulo scaling is set automatically. The modulo range can be selected as an integral multiple of an axis- or shaft-side revolution. The parameter "P-0-0765, Modulo factor measuring encoder" is used to set the modulo range of the measuring encoder. This parameter must be set to the same value as "P-0-0750, Master axis revolutions per master axis cycle".

See also "Measuring Encoder"

- **Virtual master axis, external**

  For external virtual master axes, the master (e.g. MLD) cyclically inputs command values in the NC clock via the master communication in parameter "P-0-0053, Master axis position".

- **Virtual master axis, internal**

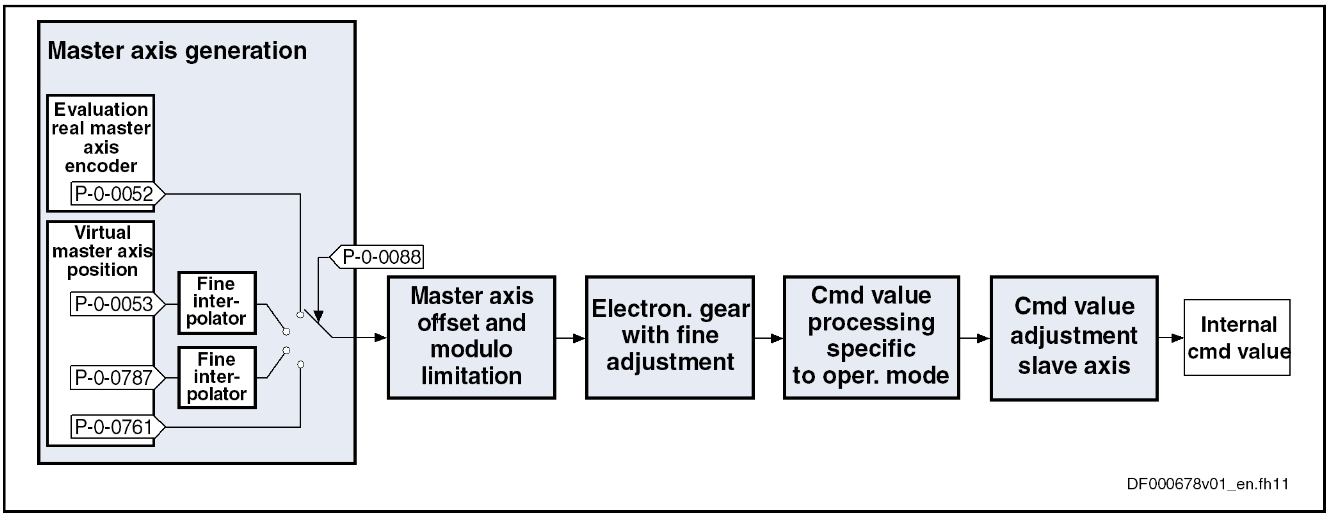
  For internal virtual master axes, the master axis position is generated by the master axis generator contained in the drive and is input in the position loop clock via "P-0-0761, Master axis position for slave axis".

  See also "Virtual Master Axis Generator"

- **Virtual master axis 2, external / group axis 1 position**

  For the external virtual master axis 2, the master (e.g. MLD) cyclically inputs command values in the NC clock via the master communication in parameter "P-0-0787, Group axis 1 position". The parameter "P-0-0788, Group axis 1 position, fine-interpolated" contains the group axis 1 position (P-0-0787) fine interpolated in linear form with regard to the position loop clock.

☞ The selection which master axis is used by the position synchronization modes (phase synchronization, cam or MotionProfile) or the velocity synchronization mode is made via bits 6 and 7 of parameter "P-0-0088, Control word synchronization modes".



P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0088	Control word synchronization modes
P-0-0787	Group axis 1 position
P-0-0761	Master axis position for slave axis

Fig. 7-57: Function Block "Master Axis Generation" for Real/Virtual Master Axis

For the generation of the master axis (real or virtual) the following requirements must be taken into consideration (with N = value from "P-0-0084, Number of bits per master axis revolution"):

- The master axis position can only be processed in a binary format (1 master axis revolution = 2^N increments).
- The minimum/maximum value of "P-0-0054, Additive master axis position" at maximum corresponds to the master axis cycle (P-0-0750 × 2^N).

  Note: When "P-0-0750, Master axis revolutions per master axis cycle" equals zero, the resulting maximum value for parameter P-0-0054 is (2^{31} – 1) increments and the minimum value is -2^{31} increments.

Master axis offset and modulo limitation

In conjunction with master axis adjustment, it is possible to add an offset and limit the preset master axis values.

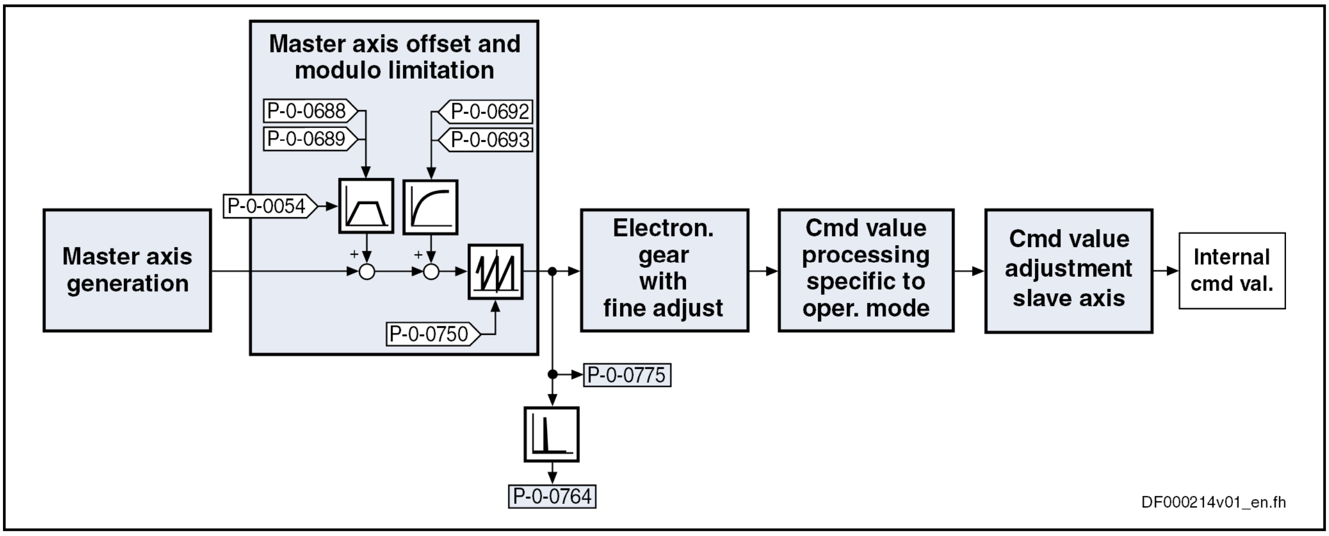


Fig. 7-58: Function Block "Master Axis Offset and Modulo Limitation" for Real/Virtual Master Axis

Additive Master Axis Position

If required, the preset master axis can be influenced via additive master axis values (offset):

- For all master axes (real or virtual), the master axis position can be changed by an additive component (= offset) via parameter "P-0-0054, Additive master axis position".

  Any change in the value of P-0-0054 is traveled with a 2nd order interpolator, taking the parameters "P-0-0688, Additive master axis position, positioning velocity" and "P-0-0689, Additive master axis position, positioning acceleration" into account.

- Another master axis offset can be set via parameter "P-0-0692, ". Parameter "P-0-0693, Filter time constant, add. master axis pos., process loop" determines the time constant of a 1st order filter by means of which the value of P-0-0692 is smoothed.

Generating the Resulting Master Axis Position

The "P-0-0775, Resulting master axis position" is the master axis position which takes effect at the input of the electronic gearbox in the synchronous operation modes. Depending on the parameterization, the resulting master axis position consists of several different master axis positions and is generated in the drive in the position controller clock, see also Parameter Description "P-0-0775, Resulting master axis position".

Limiting the Master Axis Position

The resulting master axis position is limited to the master axis cycle ("P-0-0750, Master axis revolutions per master axis cycle").

With N = value from "P-0-0084, Number of bits per master axis revolution" the following applies:

→ Modulo value master axis cycle = P-0-0750 × 2^N

Observe the following aspects:

- The master axis cycle is set by means of the parameter

  "P-0-0750, Master axis revolutions per master axis cycle" as an integer multiple of a master axis revolution (= 2^N increments).

- The total of the master axis values (master axis generation including additive master axis positions) for generating the resulting master axis position (see Parameter Description "P-0-0775, Resulting master axis position") must not exceed twice the master axis range (P-0-0750 × 2^N)!

When a real master axis is used, the parameter "P-0-0765, Modulo factor measuring encoder" must be set to the same value as the parameter "P-0-0750, Master axis revolutions per master axis cycle".

Master axis speed

The master axis speed is generated by differentiating the resulting master axis position (P-0-0775) and displayed in parameter "P-0-0764, Master axis speed".

Electronic Gearbox Function With fine adjustment

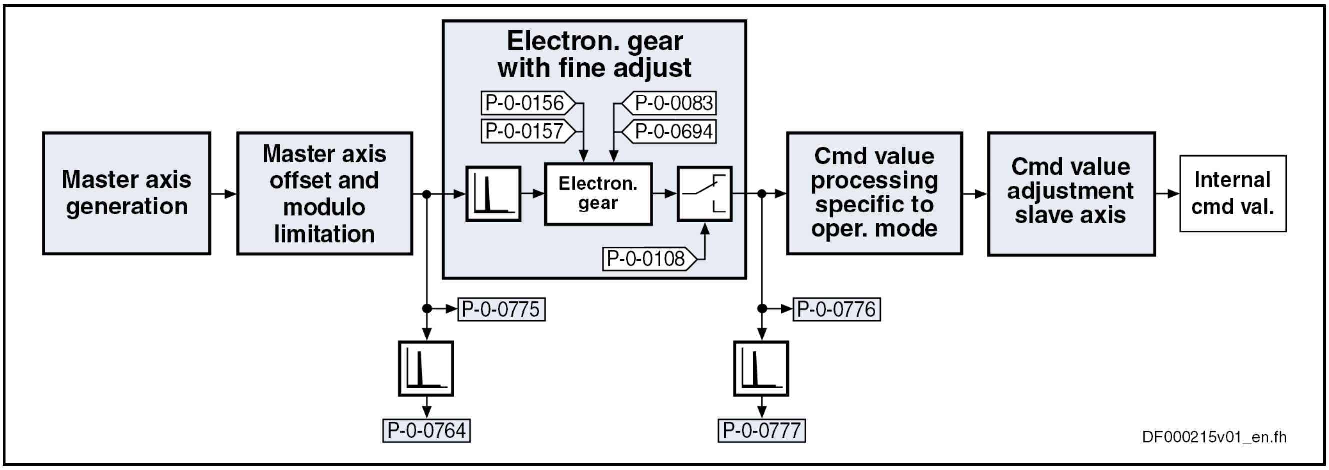


Fig. 7-59: Function Block "Electronic Gearbox with Fine Adjustment"

Functional Principle

The function block "electronic gearbox with fine adjustment" is divided into the following subfunctions:

- Electronic master axis gearbox with fine adjustment
- Polarity reversal of master axis position

The input value for the function block "electronic gearbox with fine adjustment" is either

- "P-0-0775, Resulting master axis position" in the position synchronization mode

or

- "P-0-0764, Master axis speed" in the velocity synchronization mode.

The input values are processed in the position controller clock, see also "Performance Data"

The output value(s) for the function block "electronic gearbox with fine adjustment" are:

- "P-0-0776, Effective master axis position" only in the position synchronization mode
- "P-0-0777, Effective master axis velocity"

The effective master axis position is **only** generated if one of the position synchronization modes is active. With modulo scaling, the effective master axis position is limited to $2^{P\text{-}0\text{-}0084}$ increments (one master axis revolution).

Calculating the Output Values

Calculating the factor of the electronic master axis gearbox with fine adjustment

$$f_{Gear} = \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times (1 + \frac{P\text{-}0\text{-}0083}{100\%}) \times (1 + \frac{P\text{-}0\text{-}0694}{100\%}) \times f_{pol}$$

P-0-0156	Master drive gear input revolutions
P-0-0157	Master drive gear output revolutions
P-0-0083	Gear ratio fine adjustment
P-0-0694	Gear ratio fine adjustment, process controller
f_{pol}, P-0-0108	Master drive polarity

Fig. 7-60: Factor of the electronic master axis gearbox with fine adjustment

Calculating the effective master axis position when activating the "position synchronization" mode

$$P\text{-}0\text{-}0776 = (P\text{-}0\text{-}0775 \times f_{Gear})\%2^{P\text{-}0\text{-}0084}$$

P-0-0776	Effective master axis position
P-0-0775	Resulting master axis position
f_{Gear}	Factor of the electronic master axis gearbox with fine adjustment
%	Modulo operand
P-0-0084	Number of bits per master axis revolution

Fig. 7-61: Effective Master Axis Position when Activating the "Position Synchronization" Mode

☞ When the "position synchronization" mode is activated, the absolute value of the result not yet limited to $2^{P\text{-}0\text{-}0084}$ increments must not exceed the value 2^{31}-1 increments. Otherwise, "P-0-0776, Effective master axis position" is incorrectly initialized.

Calculating the effective master axis position with active "position synchronization" mode

After the effective master axis position was initialized in absolute form upon activation of the operation mode, the subsequent processing will only be differential.

$$P\text{-}0\text{-}0776 = (P\text{-}0\text{-}0776 + \Delta P\text{-}0\text{-}0775 \times f_{Gear})\%2^{P\text{-}0\text{-}0084}$$

P-0-0776	Effective master axis position
ΔP-0-0775	Difference of the resulting master axis position per position controller clock
f_{Gear}	Factor of the electronic master axis gearbox with fine adjustment
%	Modulo operand
P-0-0084	Number of bits per master axis revolution

Fig. 7-62: Effective Master Axis Position with Active "Position Synchronization" Mode

Calculating the effective master axis position with active "position synchronization" and "velocity synchronization" modes

$$P\text{-}0\text{-}0777 = P\text{-}0\text{-}0764 \times f_{Gear}$$

P-0-0777 Effective master axis velocity
P-0-0764 Master axis speed
f_{Gear} Factor of the electronic master axis gearbox with fine adjustment

Fig. 7-63: Effective Master Axis Position with Active "Position Synchronization" and "Velocity Synchronization" Modes

"P-0-0777, Effective master axis velocity" must not fall below the following values:

- Advanced performance: 240000 rpm
- Standard performance: 120000 rpm
- Economy performance: 60000 rpm

Command Value Processing for Slave Axis Depending on Operation Mode

When the output value of the electronic gearbox is processed, there are different operations carried out, according to the synchronization mode, for generating the position or velocity command value for the subsequent control loop (slave axis). This "command value processing depending on operation mode" is described in the sections on the respective operation mode:

- See "Velocity Synchronization"
- See "Position Synchronization: Phase Synchronization"
- See "Position Synchronization: Electronic Cam"
- See "Position Synchronization: MotionProfile"

Master Axis Cycle, Command Value Cycle, Actual Value Cycle and Synchronization Ranges

Applications

The extended functions of synchronization (master axis cycle, command value and actual value cycle) are required in conjunction with the following applications:

- Change of format, i.e. variable master axis gearbox settings in operation
- Necessity of mechanical relation of slave axis to master axis

Command value and actual value cycle are only relevant for the position synchronization modes ("phase synchronization", "cam" and "MotionProfile").

The figure below illustrates the interaction of the pertinent parameters for the command value cycle and the actual value cycle:

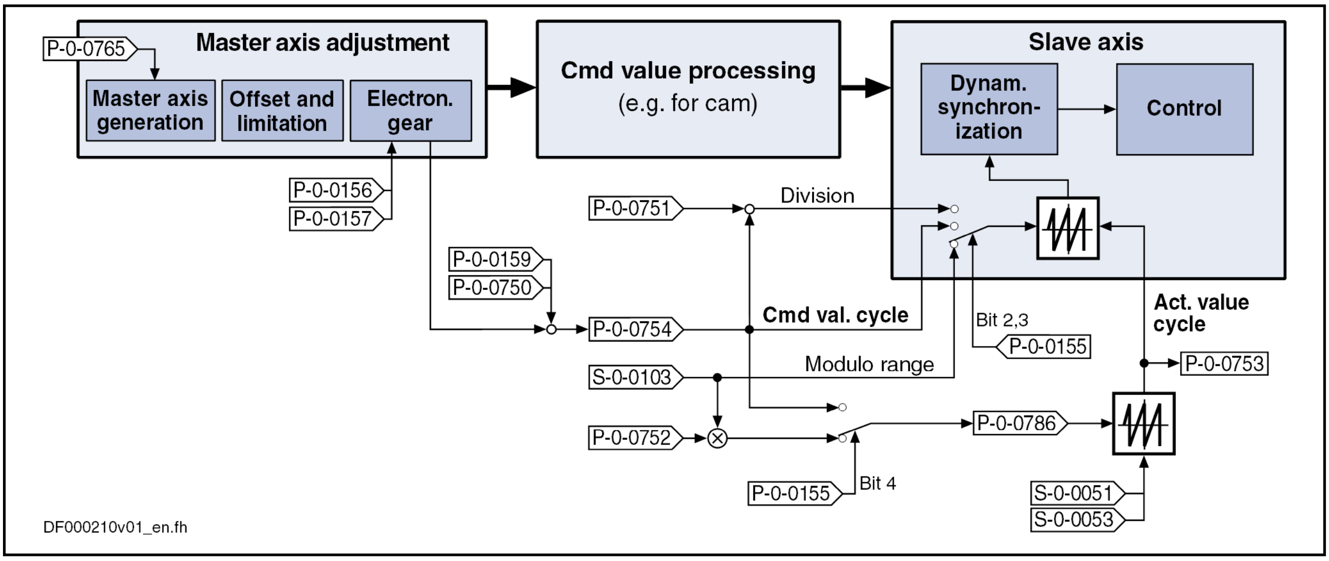


Fig. 7-64: Generation and Operating Principle of Command Value Cycle and Actual Value Cycle

Master Axis Cycle

The master axis cycle specifies the range in which the master axis values move. It corresponds to one master axis revolution or a multiple of that. The drive must be notified of the master axis cycle by the control unit in order to allow for the correct processing of the master axis positions (e.g. modulo overflows).

The master axis cycle is configured via parameter **"P-0-0750, Master axis revolutions per master axis cycle"**. See Parameter Description "P-0-0750, Master axis revolutions per master axis cycle"

In printing machines, for example, the master axis cycle specifies how many master axis revolutions are required for producing a (partial) product. After each master axis cycle, the mechanical alignment of all slave axes to each other corresponds to the initial position in the machining process.

In more complex systems, the duration of the partial processes required for producing a product is different. The end product consists of several partial products running through different processing cycles.

In the following example, brochures consisting of two double pages A, B are produced. Within one revolution of the impression cylinder, the two double pages A, B are printed onto one path. A cross cutter divides the imprinted path into the partial formats A and B. The partial products A, B are taken over by a collective cylinder. One part B is in each case put onto one part A. After 2 revolutions of the collective cylinder, 6 subsequent partial products A, B are processed. In order to allow for a clear alignment of all drives also after one master axis revolution, the multi-turn capability of the master axis (P-0-0750) is used. In the drives, different synchronization ranges for the individual partial processes are set.

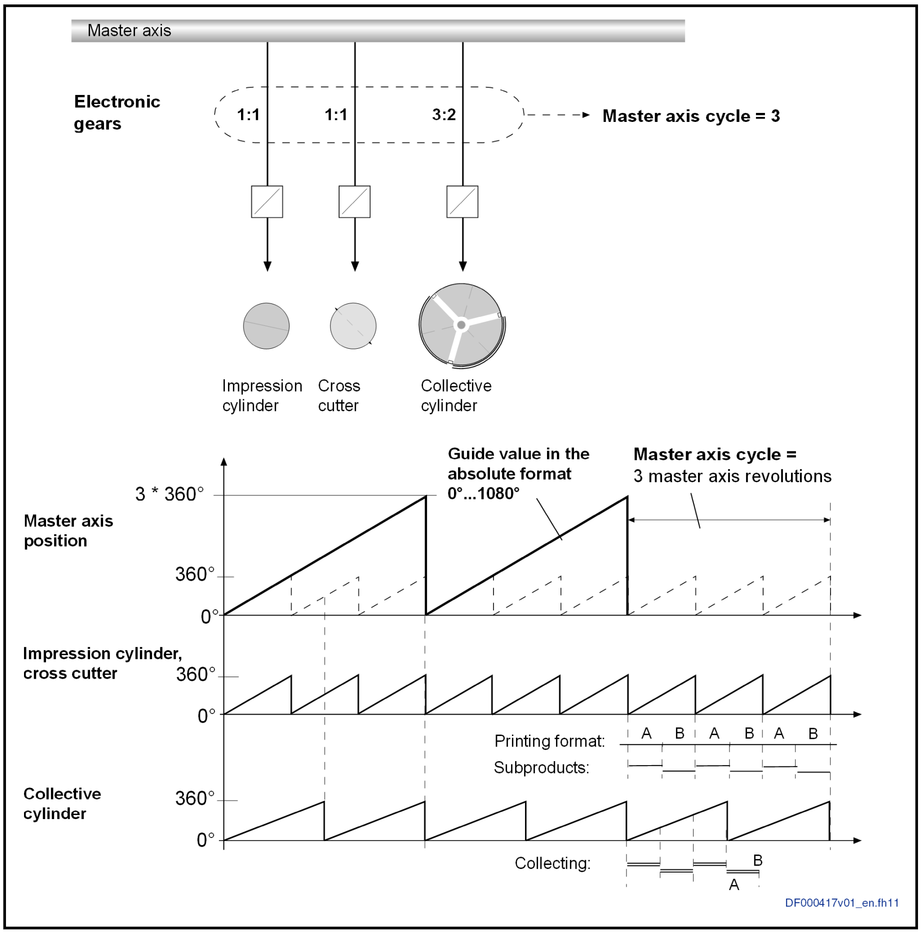


Fig. 7-65:

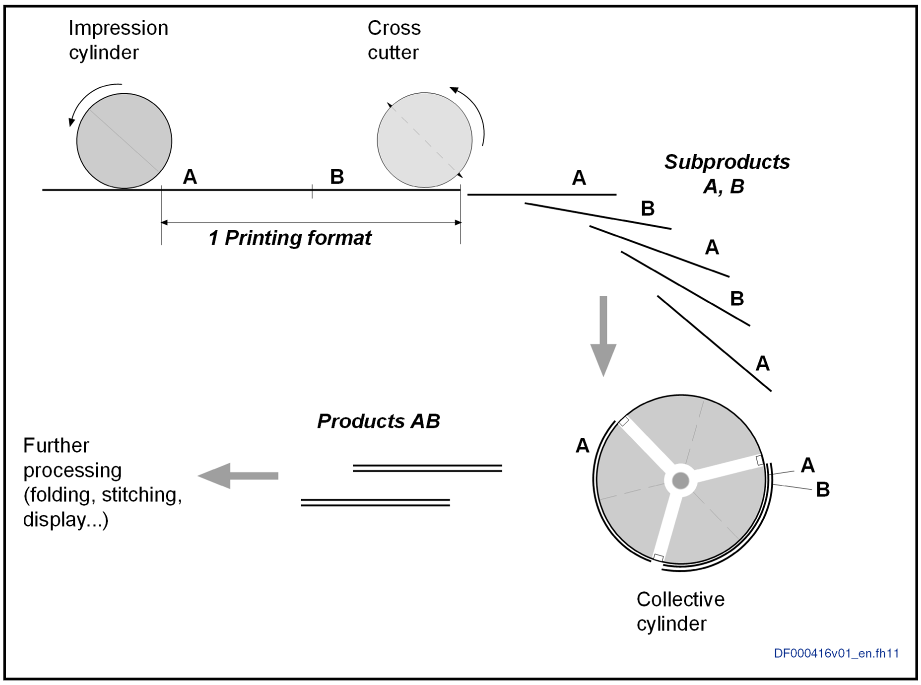


Fig. 7-66:

During commissioning, the master axis cycle is once set according to the following rule:

$$\text{Master axis cycle} = \text{LCM of the P-0-0156}$$

LCM: Least common multiple
P-0-0156: Master drive gear input revolutions

Fig. 7-67: Master Axis Cycle

In format-variable processes, the electronic gearboxes of individual slave axes are changed in case of a product change: The partial processes may vary, depending on the product. In these applications, all admissible gearbox settings must be considered when determining the master axis cycle.

Command Value Cycle

In processes with different machining cycles, the slave axis must be able to synchronize either over several master axis revolutions or divisions of a master axis revolution. This property is defined via the so-called command value cycle.

See also parameter description "P-0-0754, Command value cycle".

The command value cycle results from the settings for the master axis cycle, the electronic gearbox and the modulo range. It specifies the range in which its master-axis-synchronous position command values are to be found. This absolute position range is the command value cycle; i.e. the position range of the slave axis within a master axis cycle.

☞ The command value cycle is calculated internally by the drive and displayed in parameter "P-0-0754, Command value cycle". The command value cycle for synchronization is only required in the case of modulo scaling of the slave axis.

The range for the command value cycle at the slave axis is defined by the master axis cycle and the electronic gearbox.

With "Phase synchronization",
with "Cam without gear reduction" and (P-0-0755 = 0) and
with "MotionProfile without gear reduction" (P-0-0755 = 0):

$$\text{Command value cycle} = \text{P-0-0750} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times \text{S-0-0103}$$

With "Cam with gear reduction" (P-0-0755 ≠ 0) and
with "MotionProfile with gear reduction" (P-0-0755 ≠ 0):

$$\text{Command value cycle} = \text{P-0-0750} \times \frac{\text{P-0-0157} \times \text{S-0-0103}}{\text{P-0-0156} \times \text{P-0-0755}}$$

Fig. 7-68: Command Value Cycle with Modulo Scaling

☞ The master-axis-synchronous position command values are an absolute position range related to the master axis cycle; they are not the range of the effective position command values of the axis generated in dependance of the operation mode.

Actual Value Cycle / Position Actual Value in the Actual Value Cycle

The modulo range within which the actual position values (P-0-0753, Position actual value in actual value cycle) of the slave axis are to be found in case of active position synchronization mode is called actual value cycle.

> **The position synchronization modes (phase synchronization, cam and MotionProfile) use the "position actual value in actual value cycle" (P-0-0753) in order to close their position control loop.**

By means of the "position actual value in actual value cycle" and the synchronization range that has been set (see Parameter Description for "P-0-0155, Synchronization mode"), the travel distance for synchronization is determined when one of the position synchronization modes is activated. In this connection, the travel distance is limited to the synchronization range (command value cycle, division of the command value cycle or modulo range, "S-0-0103, Modulo value").

See parameter description "P-0-0753, Position actual value in actual value cycle".

See Parameter Description "P-0-0786, Modulo value actual value cycle"

The modulo value of the actual value cycle must be set in such a way that it corresponds to an integer multiple of the command value cycle or the modulo range (S-0-0103, Modulo value).

> The drive displays the value range of the actual value cycle in parameter "P-0-0786, Modulo value actual value cycle".

For the setting of bit 4 in parameter "P-0-0155, Synchronization mode", we distinguish the following cases:

- Bit 4 = 1

  → The actual value cycle (P-0-0786) equals the command value cycle (P-0-0754).

- Bit 4 = 0

  → The actual value cycle is determined by the parameters "P-0-0752, Load revolutions per actual value cycle slave axis" and "S-0-0103, Modulo value".

$$P\text{-}0\text{-}0786 = S\text{-}0\text{-}0103 \times P\text{-}0\text{-}0752$$

Fig. 7-69: Internal Calculation Formula of the Value for P-0-0786

The actual value cycle (P-0-0786) is calculated

- automatically when progressing from parameter mode to operating mode

- or -

- manually by starting the command "P-0-0071, C3100 Command Recalculate actual value cycle" for recalculating the actual value cycle in the operating mode when a parameter, that is used for calculating the actual value cycle, was changed in the operating mode.

> At the start of command C3100, the status bits in "S-0-0403, Position feedback value status" and the status bit in "P-0-0089, Status word synchronization modes" (bit 4) are cleared. After the position data reference has been successfully established, the bits are set again.

Synchronization Range

In the case of modulo scaling, the range for synchronization can be set in parameter "P-0-0155, Synchronization mode", i.e. the distance to be traveled is limited to this range:

- Modulo value (S-0-0103)
- Command value cycle (P-0-0754)
- Division of the command value cycle

☞ The actual position value used for calculating the distance must be unequivocal in the range in which synchronization is to take place. The actual value cycle must therefore be determined in such a way that is a multiple of the synchronization range, i.e. a multiple of the command value cycle (P-0-0754) or the modulo value (S-0-0103).

Synchronization in the Command Value Cycle

The distance traveled during synchronization is the result of the difference between synchronous position command value ("S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and the position actual value in actual value cycle (P-0-0753). The synchronization distance is limited to the modulo command value cycle.

$$\text{Distance} = \%\ \text{cmd value cycle}\left[x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - \text{actual position value}\right]$$

Fig. 7-70: Synchronization Distance during Synchronization in Command Value Cycle

Within the actual value cycle, there may be several synchronization ranges with the value of a command value cycle.

Example of the calculation of the synchronization distance with a master axis that has stopped:

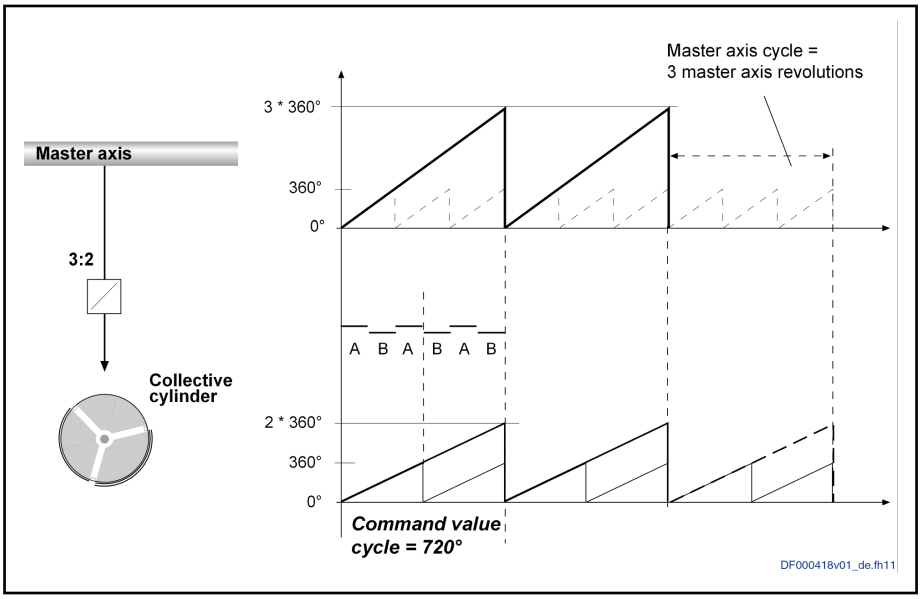


Fig. 7-71:

- Phase synchronization mode
- Modulo value (S-0-0103) = 360°
- Master axis cycle (P-0-0750) = 3
- Master drive gear input revolutions (P-0-0156) = 3
- Master drive gear output revolutions (P-0-0157) = 2

- Command value cycle (P-0-0754) = 720°
- Actual value cycle (P-0-0786) = 720°
- Additive command values (S-0-0048 / P-0-0691) = 0°
- Number of bits per master axis revolution (P-0-0084) = 20 bits
- Resulting master axis position (P-0-0775) = 2228224 incr
- Current position actual value in actual value cycle (P-0-0753) = 210°
- Master axis has stopped

When the operation mode is activated, the following synchronous position command value results:

X_{SYNC} = %P-0-0786 [P-0-0775 * P-0-0157 * S-0-0103 / ($2^{P\text{-}0\text{-}0084}$* P-0-0156)] = 510°.

According to the preceding formula, the following synchronization distance results:

Distance = %720° [510°- 210°] = 300°

Depending of the configuration of the parameter "P-0-0154, Synchronization direction", the slave axis travels the following distance in order to reach the synchronous position.

- Shortest distance: Synchronization distance = +300° as 300° < (P-0-0754 / 2)
- Positive direction: Synchronization distance = + 300°
- Negative direction: Synchronization position = 300° - P-0-0754 = - 420°

> If, however, the shortest distance to the absolute synchronization is smaller than "P-0-0151, Synchronization window for modulo format", the shortest distance will be traveled and the specified synchronization direction will be ignored.

Synchronization in a Division of the Command Value Cycle

The number of divisions per command value cycle and thus the division itself are determined via parameter "P-0-0751, Synchronization divisions per command cycle slave axis". This value must be integer.

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ "S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and the position actual value in actual value cycle. The synchronization distance is limited to a division of the modulo command value cycle.

$$\text{Distance} = \%\ \text{division of cmd value cycle} \left[x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - \text{actual position value} \right]$$

Fig. 7-72: Synchronization Distance for Synchronization in a Division of the Command Value Cycle

Example 1

- A collective cylinder is to only synchronize within one of several collection areas.

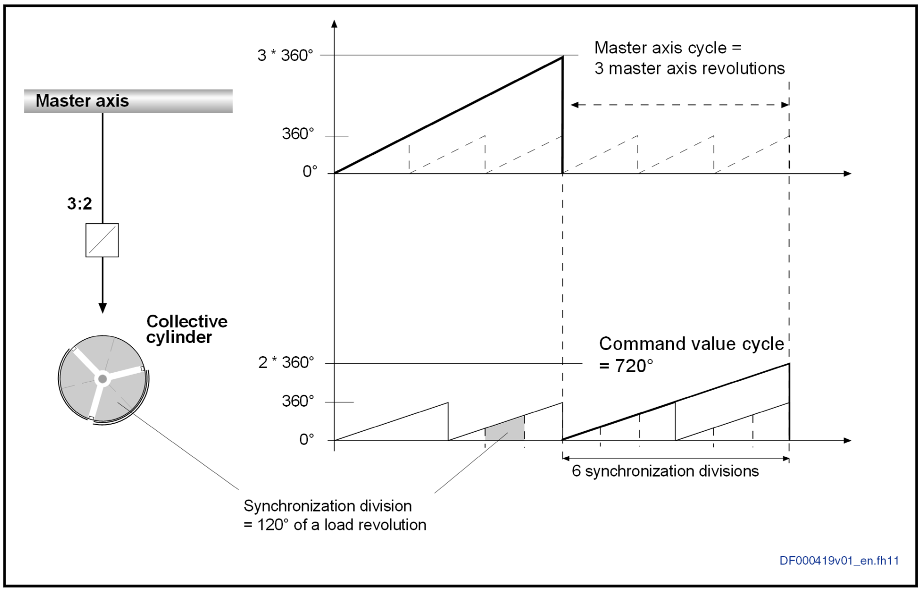


Fig. 7-73:

- Phase synchronization mode
- Modulo value (S-0-0103) = 360°
- Master axis cycle (P-0-0750) = 3
- Master drive gear input revolutions (P-0-0156) = 3
- Master drive gear output revolutions (P-0-0157) = 2
- Command value cycle (P-0-0754) = 720°
- Synchronization divisions (P-0-0751) = 6
- Actual value cycle (P-0-0786) = 720°
- Additive command values (S-0-0048 / P-0-0691) = 0°
- Number of bits per master axis revolution (P-0-0084) = 20 bits
- Resulting master axis position (P-0-0775) = 2228224 Incr
- Current position actual value in actual value cycle (P-0-0753) = 210°
- Master axis has stopped

When the operation mode is activated, the following synchronous position command value results:

X_{SYNC} = %P-0-0786 [P-0-0775 * P-0-0157 * S-0-0103 / ($2^{P-0-0084}$* P-0-0156)] = 510°.

According to the preceding formula, the following synchronization distance results:

Distance = %(P-0-0754 / P-0-0751) [510°- 210°] = 60°

Depending of the configuration of the parameter "P-0-0154, Synchronization direction", the slave axis travels the following distance in order to reach the synchronous position.

- Shortest distance: Synchronization distance = +60° as 60° == (P-0-0754 / (P-0-0751 * 2))

  Synchronization position = P-0-0753° + 60° = 270°
- Positive direction: Synchronization distance = +60°

  Synchronization position = P-0-0753° + 60° = 270°

- Negative direction: Synchronization distance = 60° - (P-0-0754/ P-0-0751) = - 60°

  Synchronization position = P-0-0753° - 60° = 150°

> If, however, the shortest distance to the absolute synchronization is smaller than "P-0-0151, Synchronization window for modulo format", the shortest distance will be traveled and the specified synchronization direction will be ignored.

Example 2

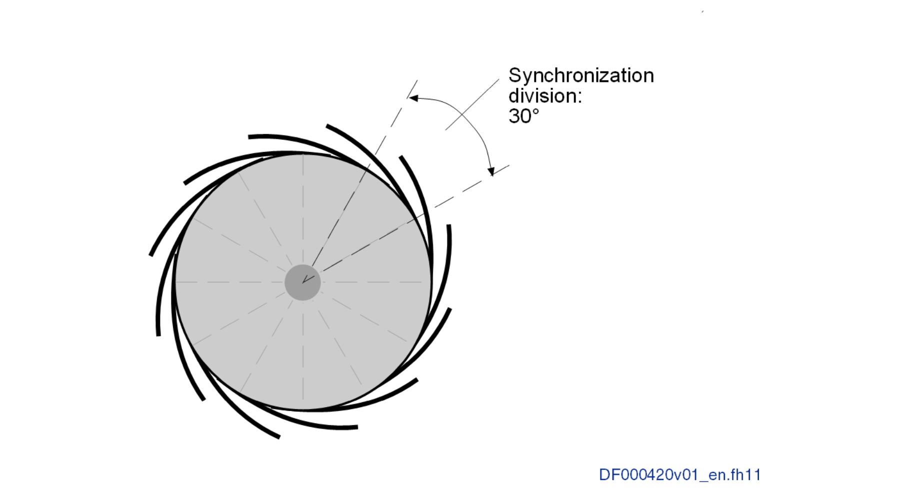


Fig. 7-74: Synchronization Division

In the ongoing process, each paddle takes up a product; e.g. a printed magazine. Upon switch-on, the paddle wheel only synchronizes in the area of one paddle in order to ensure that collected copies do not fall out.

Synchronization in the Modulo Range

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ "S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and the position actual value in actual value cycle. The synchronization distance is limited to the modulo value (S-0-0103).

$$\text{Distance} = \%\ \text{modulo value} \left[x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - \text{actual position value} \right]$$

Fig. 7-75: Synchronization Distance for Synchronization in Modulo Range

Notes on Usage and Parameterization

Selecting the Actual Value Cycle and Master Axis Cycle

When using the command value cycle or actual value cycle, observe the following aspects:

- Master axis cycle:

  P-0-0750 = LCM (least common multiple) of "P-0-0156, Master drive gear input revolutions" when using several electronic gear ratios.

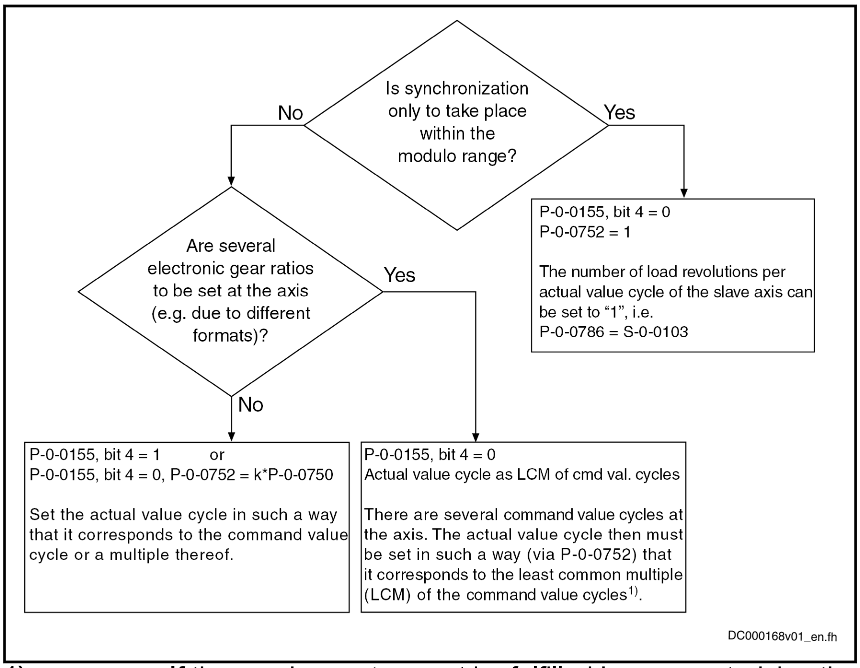
  The least common multiple (LCM) of all P-0-0156 is to be preset, of the axes in the system that clearly have to synchronize in the master axis cycle.

  This ensures that one position before the electric gearbox can be unequivocally assigned to each position after the electric gearbox.
- Actual value cycle:

The setting of the actual value cycle depends on the following questions:

– In which range(s) is synchronization to take place later on?
– Are several electronic gear ratios to be set at the axis?

When these two questions have been clarified, you can proceed according to the following decision matrix to set the actual value cycle:



1) If the requirement cannot be fulfilled by parameterizing the actual value cycle, it is possible to have the range of the actual value cycle calculated by the drive by analogy to the command value cycle by setting bit 4 = "1" in parameter "P-0-0155, Synchronization mode".

Fig. 7-76: Commissioning

Calculating the Actual Value Cycle (P-0-0786)

The actual value cycle (P-0-0786) is calculated

- automatically when progressing from parameter mode to operating mode

- or -

- manually by starting the command "P-0-0071, C3100 Command Recalculate actual value cycle" for recalculating the actual value cycle in the operating mode when a parameter, that is used for calculating the actual value cycle, was changed in the operating mode.

☞ At the start of command C3100, the status bits in "S-0-0403, Position feedback value status" and the status bit in "P-0-0089, Status word synchronization modes" (bit 4) are cleared. After the position data reference has been successfully established, the bits are set again.

The actual value cycle is calculated in dependence of bit 4 of parameter "P-0-0155, Synchronization mode".

- With **bit 4 = 0** in P-0-0155, the actual value cycle is determined in dependence of "P-0-0752, Load revolutions per actual value cycle slave axis":

$$P\text{-}0\text{-}0786 = S\text{-}0\text{-}0103 \times P\text{-}0\text{-}0752$$

Fig. 7-77: "Modulo Value Actual Value Cycle" (P-0-0786) with Rotary and Linear Modulo Scaling and P-0-0155, Bit 4 = 0

- With **bit 4 = 1** in P-0-0155 (actual value cycle = command value cycle), the actual value cycle is determined according to the formulas below:

With "Phase synchronization",

with "Cam without gear reduction" (P-0-0755 = 0) and

with "MotionProfile without gear reduction" (P-0-0755 = 0):

$$\text{Actual value cycle (P-0-0786)} = \text{P-0-0750} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times \text{S-0-0103}$$

With "Cam with gear reduction" (P-0-0755 ≠ 0) and

with "MotionProfile with gear reduction" (P-0-0755 ≠ 0):

$$\text{Actual value cycle (P-0-0786)} = \text{P-0-0750} \times \frac{\text{P-0-0157} \times \text{S-0-0103}}{\text{P-0-0156} \times \text{P-0-0755}}$$

Fig. 7-78: "Modulo Value Actual Value Cycle" with Modulo Scaling and P-0-0155, Bit 4 = 1

Establish the position data reference

"P-0-0753, Position actual value in actual value cycle" is set by

- The "set absolute position procedure" command
- "Drive-controlled homing procedure"

  For the actual position value that is selected by means of parameter "S-0-0520, Axis control word", in the parameter mode (PM)

If, for example, encoder 1 is selected in parameter mode (PM) in parameter S-0-0520, the actual position value in actual value cycle (P-0-0753) will change by analogy with the actual position value 1 (S-0-0051).

> ☞ In contrast to the actual position value in actual value cycle (P-0-0753), the actual position value 1 (S-0-0051) is limited to the modulo value (S-0-0103)!

Homing of the actual position value 1 then causes the actual position value in actual value cycle (P-0-0753) to be set to the same value as actual position value 1.

> ☞ The position status of the position actual value in actual value cycle is displayed in bit 4 of parameter "P-0-0089, Status word synchronization modes".

Synchronization Direction

In the case of absolute position scaling, the calculated synchronization distance is always traveled. The settings in parameters "P-0-0154, Synchronization direction" and "P-0-0151, Synchronization window for modulo format" are **not** taken into account.

For modulo axes, the distance is limited to +/-0.5 × synchronization range. In addition, the settings in parameters "P-0-0154, Synchronization direction" and "P-0-0151, Synchronization window for modulo format" are taken into account.

☞ The setting in parameter "P-0-0154, Synchronization direction" will only take effect, if the shortest distance (absolute value ≤ 0.5 × synchronization range) is greater than the synchronization window. In this case, the synchronization direction according to parameter P-0-0154 is used (positive or negative or shortest distance). If the shortest distance is smaller than the synchronization window, the shortest distance will always be traveled.

Synchronization with Absolute Scaling

The position command value is generated in absolute form. There is no command value cycle and no actual value cycle calculated.

Synchronization may take place up to ± $2^{31\text{ - P-0-0084}}$ revolutions absolute as the max. master axis encoder range ranges from -2^{31} to 2^{31}-1 increments.

☞ Make sure that the motion of the slave axis does not exceed the range defined in parameter "S-0-0278, Maximum travel range".

In order to be able to travel in absolutely synchronous form within the max. travel range (S-0-0278), the parameter "P-0-0750, Master axis revolutions per master axis cycle" has to be initialized with zero.

☞ Incorrect parameterization can cause unwanted jumps in position.

Recommendation: Activate position limit value monitor!

See "Position Limitation/Travel Range Limit Switches"

The synchronization distance is calculated according to the following formula:

$$\text{Distance} = x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - \text{actual position value}$$

Fig. 7-79: Synchronization Distance with Absolute Scaling

☞ The synchronization range corresponds to the maximum travel range.

Dynamic Synchronization of the Slave Axis

Brief Description

The synchronization process is a drive-controlled motion with the objective of achieving absolute or relative synchronization between master axis and slave axis. Depending on the synchronization mode, we distinguish the following characteristics of dynamic synchronization:

Synchronization with Velocity Synchronization

Features of synchronization in the "velocity synchronization" mode:

- Synchronization takes place as velocity adjustment
- Option: Synchronization only in case of activation of the operation mode or always
- Generation of status message "synchronization completed" (P-0-0152; bit 0)
- Generation of status message "synchronous mode in synchronization" (P-0-0089, bit 8)

Synchronization with the Position Synchronization Modes

Features of the synchronization with the position synchronization modes:

- Selection sequence of synchronization is **single-step, double-step or double-step optimized**

- Synchronization **absolute** (position and velocity adjustment) or **relative** (only velocity adjustment)
- **Modulo ranges** to be set for synchronization:
  - Modulo value (S-0-0103)
  - Command value cycle slave axis (P-0-0754)
  - Division for command value cycle (setting in P-0-0751)
- Possibility of repeated synchronization with active operation mode (P-0-0088, bit8)
- Direction for synchronization to be set for position adjustment of modulo axes, shortest distance, positive or negative direction in parameter "P-0-0154, Synchronization direction"; setting the tolerance window with only positive or negative direction via "P-0-0151, Synchronization window for modulo format"
- Display of the difference between position actual value in actual value cycle and the synchronous position command value generated from the master axis position in parameter "P-0-0034, Position command additional actual value"
- Generation of status message "synchronization completed" (P-0-0152; bit 0)
- Command value addition for slave axis possible
- Generation of status message "synchronous mode in synchronization" ("P-0-0089, Status word synchronization modes", bit 8)

See Parameter Description "P-0-0115, Synchronization mode"

The figure below contains an overview of the different possible settings for carrying out synchronization and for adding command values in the synchronization modes:

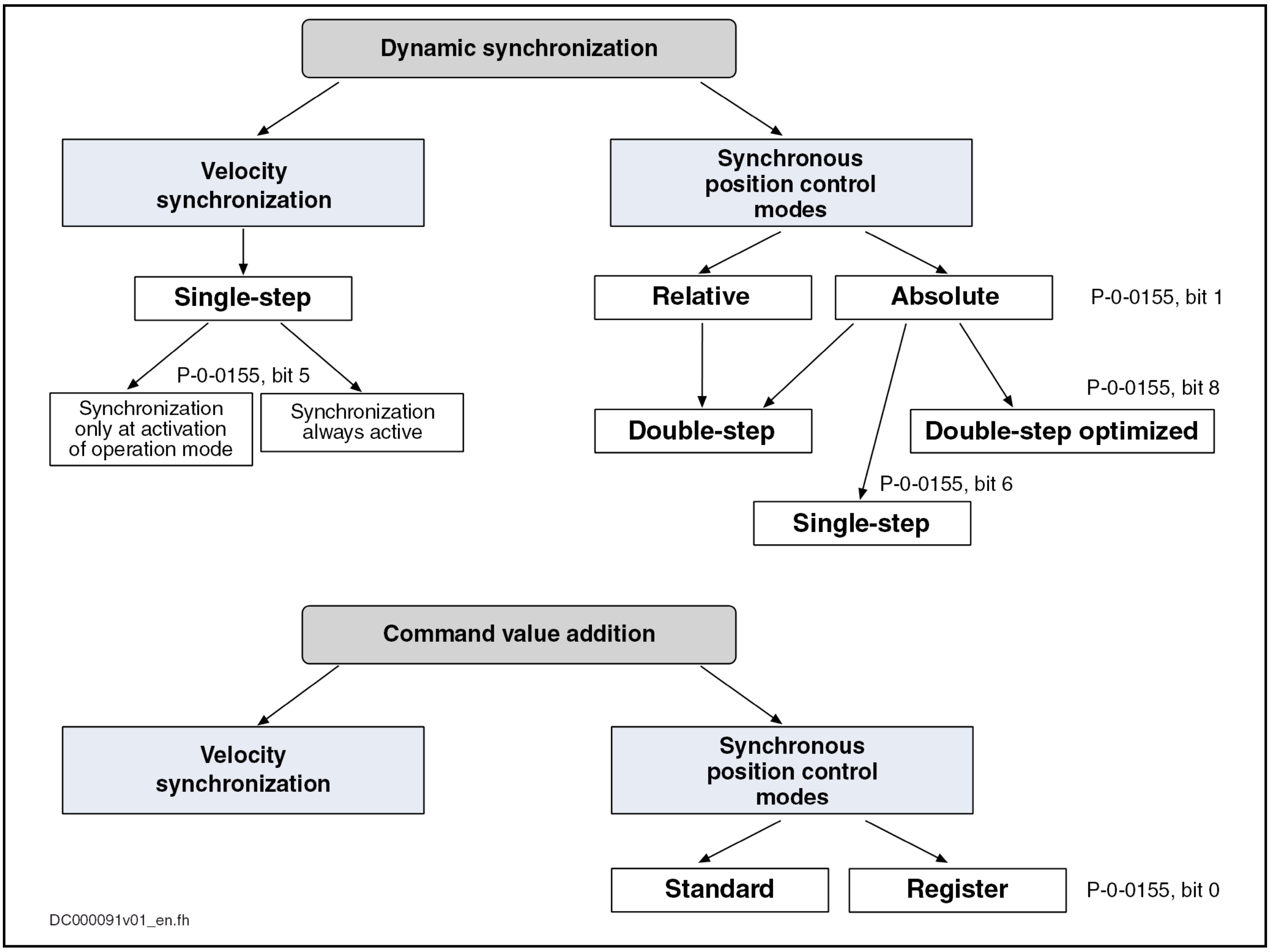


Fig. 7-80: Overview of Methods to be Selected for Synchronization and for Command Value Addition

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☞ In the default setting of parameter P-0-0155, all bits are at value "0"!

Pertinent Parameters

The following parameters are used in conjunction with dynamic synchronization:

- S-0-0048, Additive position command value
- S-0-0183, Velocity synchronization window
- S-0-0228, Position synchronization window
- P-0-0034, Position command additional actual value
- P-0-0060, Filter time constant additive position cmd value
- P-0-0071, C3100 Command Recalculate actual value cycle
- P-0-0142, Synchronization acceleration
- P-0-0143, Synchronization velocity
- P-0-0151, Synchronization window for modulo format
- P-0-0152, Synchronization completed
- P-0-0154, Synchronization direction
- P-0-0155, Synchronization mode

- P-0-0686, Additive position command value, positioning velocity
- P-0-0687, Additive position command value, positioning acceleration
- P-0-0691, Additive position command value, process loop
- P-0-0697, Synchronization, master axis synchronous position
- P-0-0698, Synchronization, master axis synchronization range
- P-0-0751, Synchronization divisions per command cycle slave axis
- P-0-0752, Load revolutions per actual value cycle slave axis
- P-0-0753, Position actual value in actual value cycle
- P-0-0754, Command value cycle
- P-0-0786, Modulo value actual value cycle

Synchronization with the Velocity Synchronization Mode

Drive-controlled dynamic synchronization in the "velocity synchronization" mode is carried out depending on bit 5 of parameter "P-0-0155, Synchronization mode".

- Bit 5 = 0 → Synchronization only when operation mode is activated

  After the first synchronization and with the operation mode active, the changes of velocity are made at maximum acceleration (S-0-0138, Bipolar acceleration limit value)
- Bit 5 = 1 → Synchronization is always active

By generating velocity command values, the drive accelerates or decelerates during synchronization until the synchronous velocity has been reached. The velocity command values are generated taking the preset synchronization acceleration (P-0-0142) into account.

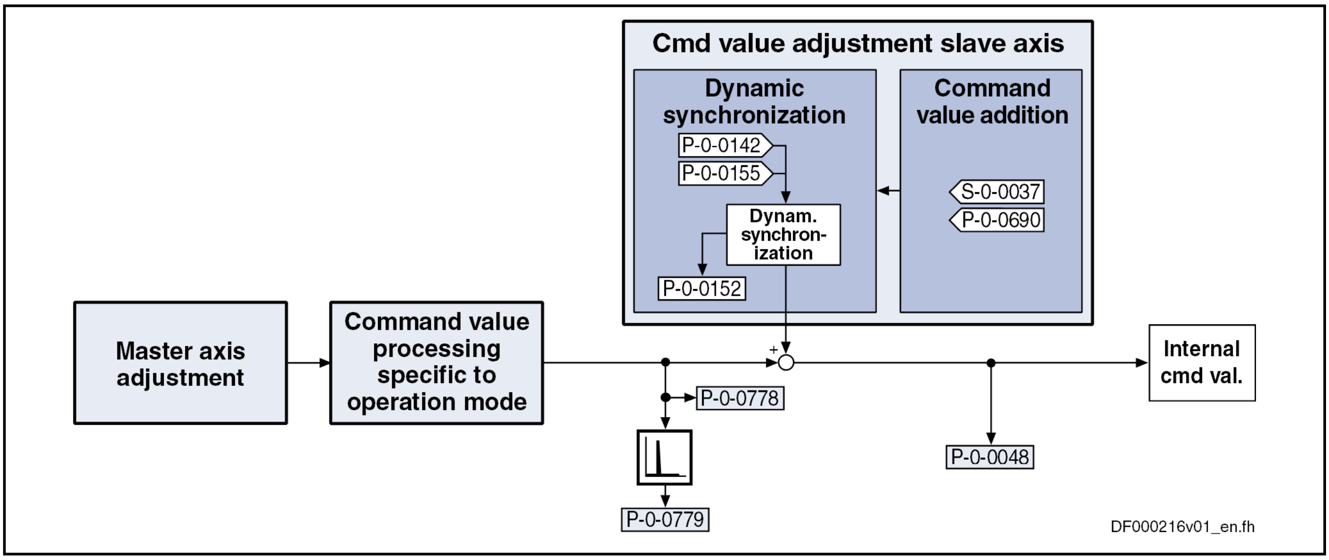


Fig. 7-81: Function Block "Dynamic Synchronization" with Velocity Synchronization

Synchronization with the Position Synchronization Modes

In the position synchronization modes, you can select between single-step, double-step, optimized double-step, and relative synchronization.

☞ All settings relevant for synchronization have to be made in parameter "P-0-0155, Synchronization mode".

The figure below contains an overview of the parameters used for synchronization.

Not all listed parameters are required for each synchronization process!

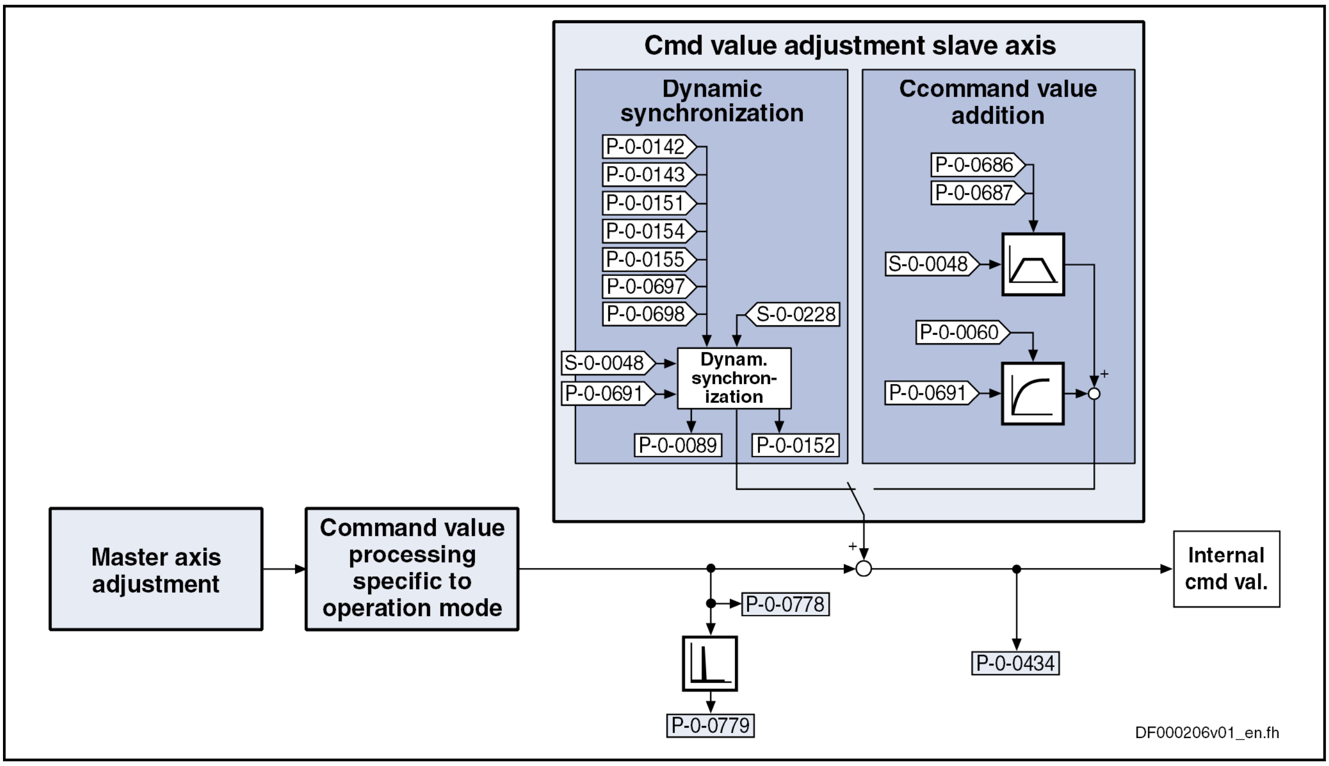


Fig. 7-82: Function Block "Dynamic Synchronization" with Synchronous Position Control Modes

Single-Step Synchronization

Single-step synchronization is a master-axis-synchronous synchronization that is added to the synchronous movement. The processing of the slave axis synchronization distance is carried out while the master axis is going through the master axis synchronization range.

As a slave axis synchronization distance can only be calculated with absolute synchronization (bit 1 = 0 in parameter "P-0-0155, Synchronization mode", single-step synchronization is only possible with absolute synchronization.

Selection takes place via bit 6 of the parameter P-0-0155.

In this case, the corresponding parameters take effect:

- P-0-0697, Synchronization, master axis synchronous position
- P-0-0698, Synchronization, master axis synchronization range

The parameters P-0-0697 and P-0-0698 refer to the output of the electronic gearbox.

By means of bit 7 = 1 in parameter P-0-0155 a relative master-axis-synchronous synchronization is set. As a consequence, synchronizing is immediately started at activation of the synchronization mode. The parameter for the master axis synchronous position (P-0-0697) does not take effect. Starting the synchronization for a master axis that has stopped will produce a velocity command value of zero. This must be prevented for a moving slave axis.

With bit 7 = 0, you can set that the master-axis-synchronous synchronization motion only starts when the master axis start position is passed (absolutely master-axis-synchronous). This position results from subtraction of master axis synchronous position and master axis synchronization range. Until the master axis start position is passed, the axis decelerates or accelerates, based on the current actual velocity, with the parameterized synchronization acceleration (P-0-0142) in the direction of the synchronous velocity.

Single-Step Synchronization with Modulo Position Scaling

For modulo axes, the slave axis synchronization distance is not unequivocal. It can be increased or reduced by one or several synchronization ranges. By setting bit 9 in the parameter "P-0-0155, Synchronization mode", you can select the optimization of the slave axis synchronization distance by the drive. As an alternative, the slave axis synchronization distance can be influenced by the parameters "P-0-0154, Synchronization direction" and "P-0-0151, Synchronization window for modulo format".

- **Distance optimization** (P-0-0155, bit 9 = 1): An ideal value for the slave axis synchronization distance is firstly calculated from the values available for master axis velocity, master axis synchronization distance and slave axis velocity, and the ideal value of the standardized velocity (2.08333) for the motion profile "velocity in rest" which is used. The required slave axis synchronization distance (difference between synchronous position command value and actual position value of the slave axis) is then approximated as near as possible to the ideal value by adding or subtracting synchronization ranges. The optimization aims at not having any reversal point in the position curve in the added synchronization profile. In this case, there won't be any maximum in the velocity curve (overshooting) and no change of the acceleration sign. When the user significantly increases the master axis synchronization distance, this also increases the slave axis synchronization distance. The occurring acceleration values can thus be reduced.
- **No distance optimization** (P-0-0155, bit 9 = 0): The polarity of the added slave axis synchronization distance ist set in the parameter "P-0-0154, Synchronization direction". However, this only applies if the absolute value of the shortest synchronization distance is greater than the value of "P-0-0151, Synchronization window for modulo format". The maximum value (absolute value) of the added synchronization distance corresponds to one synchronization range.

For single-step synchronization, observe the following notes on utilization:

- Single-step synchronization is only active when the operation mode is activated. This means that, after the synchronous operation mode was activated, synchronization starts the next time the master axis start position is passed.

  The master axis position used for the comparison with the master axis start position is defined:

  - **In phase synchronization** by parameter "P-0-0776, Effective master axis position"
  - **In cam and MotionProfile mode** by parameter "P-0-0227, Cam table, access angle"
- The profile for synchronization is determined by a 5th order polynomial.
- The synchronous position command values, generated from the master axis positions, take immediate effect when the master axis start position is passed or at the beginning of the master axis synchronization range.
- The velocity of the master axis should be constant when passing through the master axis synchronization range.

- The values set in the parameters "P-0-0142, Synchronization acceleration" and "P-0-0143, Synchronization velocity" are not taken into account for the synchronization process.
- Apart from by the other conditions of the synchronization mode, the resulting characteristics of velocity and acceleration can only be influenced by the master axis synchronization range.
- For modulo axes, the polarity of the slave axis synchronization distance can be set by parameter "P-0-0154, Synchronization direction". However, this only applies if the absolute value of the shortest synchronization distance is greater than the value of parameter "P-0-0151, Synchronization window for modulo format".
- Synchronization is completed when the master axis position has gone through the master axis synchronization range. Bit 0 of "P-0-0155, Synchronization mode" then defines how subsequent changes of "S-0-0048, Additive position command value" are processed (see section "Command Value Addition for Slave Axis" below).

To be noticed for single-step synchronization

With single-step synchronization, a profile "velocity in rest" (standard profile "G-R" according to VDI 2143) is added to the synchronous position command values:

- The distance traveled with the added profile is determined by the difference of synchronous position command value (+ "S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and actual position value at the starting point of time.
- When modulo scaling has been set, the distance is limited to the synchronization range set in parameter "P-0-0155, Synchronization mode".
- The parameter "P-0-0154, Synchronization direction" is not evaluated with modulo scaling. The preferred direction that has been set is taken into account, if the determined synchronization distance is greater than the "P-0-0151, Synchronization window for modulo format".
- The initial velocity of the profile is determined by the difference of actual velocity and synchronous velocity at the starting point of time.
- We assume that the acceleration of the slave axis at the starting point of time equals zero.

☞ More details regarding the "velocity in rest" profile used are described in section "MotionProfile"!

Double-Step Synchronization

The double-step synchronization process consists of velocity adjustment and subsequent position adjustment.

Step 1 –Velocity adjustment:

- The drive either accelerates or decelerates from the current actual velocity at the time of activation to the synchronous velocity.
- The synchronous velocity is generated by differentiating the synchronous position command value. The synchronous position command value x_{sync} is determined from the master axis position ("P-0-0052, Actual position value of measuring encoder" or "P-0-0053, Master axis position") according to the operation mode.
- Velocity adjustment already takes place in position control. When accelerating or decelerating, the drive takes the value in parameter "P-0-0142, Synchronization acceleration" into account.

Step 2 –Position adjustment:

After velocity adjustment, there is a difference between the active position command value and the sum of the synchronous position command value (x_{sync}), additive position command value (S-0-0048) and additive position command value of the process controller (P-0-0691).

The difference is calculated according to the following equation:

$$\Delta x = x_{synch} + (S\text{-}0\text{-}0048) + (P\text{-}0\text{-}0691) - (P\text{-}0\text{-}0434)$$

Δx	Difference (distance)
x_{synch}	Synchronous position command value
S-0-0048	Additive position command value
P-0-0691	Additive position command value, process controller
P-0-0434	Position command value of controller

Fig. 7-83: Difference with Absolute Synchronization (Travel Distance)

In the second step of synchronization, the difference generated during velocity adjustment is compensated by a travel motion taking"P-0-0142, Synchronization acceleration" and "P-0-0143, Synchronization velocity" into account. This position adjustment is added to the synchronous movement.

The figure below illustrates the absolute synchronization to a virtual master axis, the master axis being in standstill when the operation mode is activated.

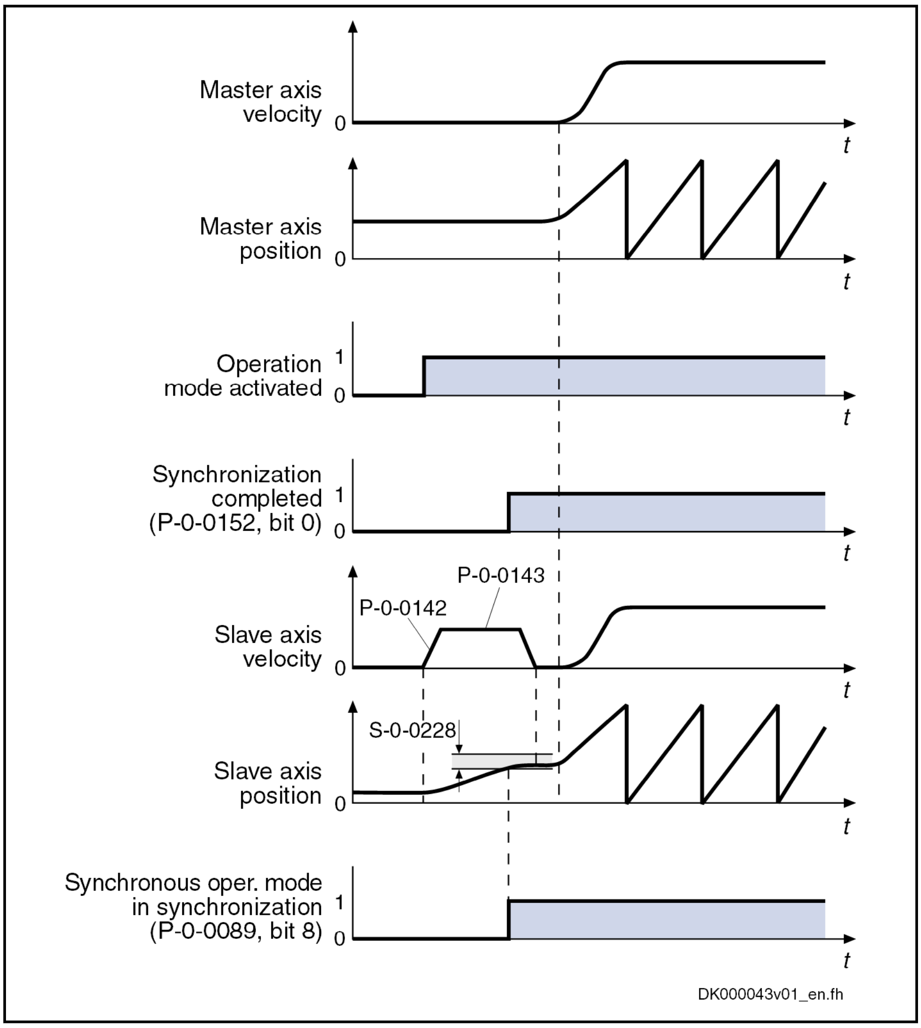


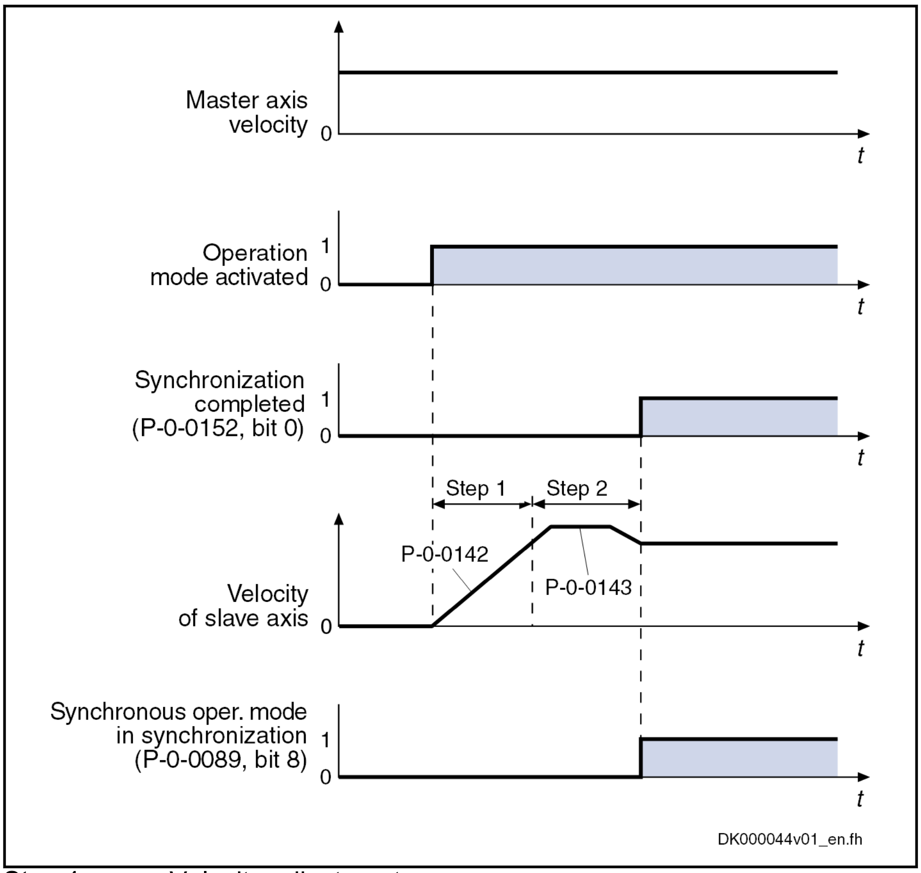
Fig. 7-84: Example: Absolute Synchronization out of Standstill

Explanation of the example

- When the operation mode is activated, the synchronous velocity = 0. The current master axis position differs from the synchronous position.
- The synchronization status signals "synchronization running" (P-0-0152, bit 0 = 0).
- The absolute angle reference between slave axis and master axis position is established. The slave axis is turning with the parameterized synchronization velocity (P-0-0143). During acceleration and deceleration, the synchronization acceleration (P-0-0142) is effective.
- As soon as the position difference between master axis and slave axis is smaller than the "position synchronization window" (S-0-0228), the status bit "slave axis has been synchronized" (P-0-0089, bit 8 = 1) is output.

  Bit 0 is set in parameter P-0-0152 when synchronization has been completed.

The figure below illustrates the absolute synchronization to a virtual master axis, the master axis having a velocity ≠ 0 when the operation mode is activated.



Step 1 Velocity adjustment
Step 2 Position adjustment
Fig. 7-85: Example: Absolute Synchronization in Running Operation

Explanation of the example

- When the operation mode is activated, the master axis moves at constant velocity.
- The synchronization status signals "synchronization running" (P-0-0152, bit 0 = 0).

- Based on its current position, the slave axis accelerates to the synchronous velocity. While this is done, the synchronization acceleration (P-0-0142) is effective.
- After velocity adjustment, the absolute position reference is established. Position adjustment takes place with parameterized synchronization acceleration (P-0-0142) and synchronization velocity (P-0-0143).
- As soon as the position difference between master axis and slave axis is smaller than the "position synchronization window" (S-0-0228), the status bit "slave axis has been synchronized" (P-0-0089, bit 8 = 1) is output.

  Bit 0 is set in parameter P-0-0152 when synchronization has been completed.

Optimized Double-Step Synchronization

The third synchronization method available for selection is a mixture between one-step and double-step synchronization. This method has the following characteristics:

- Not master-axis-synchronous
- Immediate start upon activation of the synchronous operation mode
- No separation between velocity and position adjustment
- Superimposed synchronization motion with 2nd order interpolator
- Limitation of synchronization motion by "P-0-0142, Synchronization acceleration" and "P-0-0143, Synchronization velocity"
- Reduced braking acceleration (deceleration) during positioning in order to reduce the number of acceleration jumps

Specific features with modulo position scaling

We distinguish two cases depending on whether upon start of the synchronization process, the braking distance is smaller or larger than a synchronization range.

In the 1st case, the initial velocity of the synchronization motion (difference between synchronous velocity and current actual velocity) is so small that positioning can take place immediately. When determining the synchronization distance, you than analyze parameter "P-0-0154, Synchronization direction", in connection with "P-0-0151, Synchronization window for modulo format".

In the 2nd case, you firstly reduce the velocity of the synchronization motion until the braking distance is smaller than a synchronization range. In this case, a parameterized synchronization direction is ignored, so that the velocity of the synchronization motion has no change of sign.

Relative Synchronization

If no absolute position reference between master axis and slave axis is necessary, relative synchronization is used. With relative synchronization, the slave axis velocity is only adjusted to the synchronous velocities derived form the master axis positions. After synchronization, the slave axis is moved synchronously to the master axis.

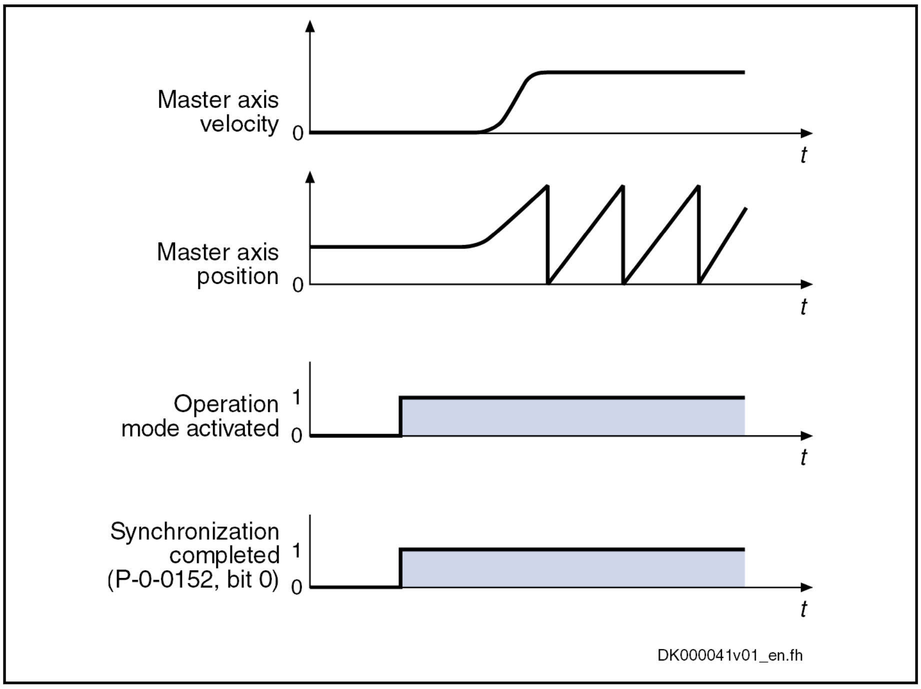


Fig. 7-86: Example: Relative Synchronization out of Standstill

Explanation of the example

- When the operation mode is activated, the synchronous velocity = 0.
- When the operation mode is activated, the bits for "synchronization completed" (P-0-0152; bit 0 = 1) and "slave axis has been synchronized" (P-0-0089, bit 8 = 1) are output.
- When the machine starts, the axis, based on its current position, follows the master axis position with relatively synchronous position.

The figure below illustrates the relative synchronization to a virtual master axis, the master axis having a velocity ≠ 0 when the operation mode is activated.

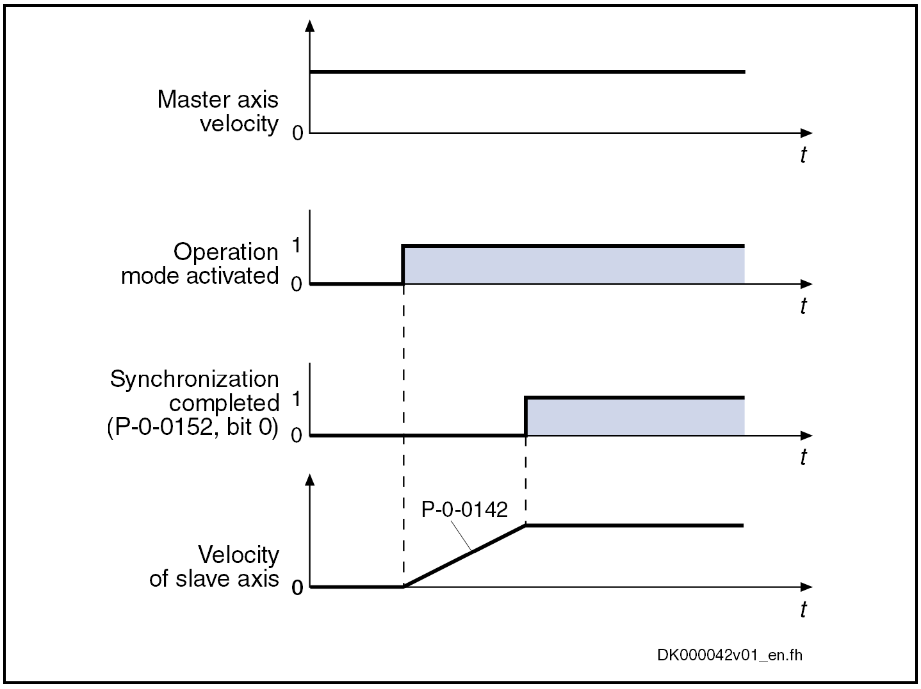


Fig. 7-87: Example: Relative Synchronization in Running Operation

Explanation of the example

- When the operation mode is activated, the master axis moves at constant velocity.
- Based on its current position, the slave axis accelerates to the synchronous velocity. While this is done, the synchronization acceleration (P-0-0142) is effective.
- Upon reaching the synchronous velocity, the bits for "synchronization completed" (P-0-0152, Bit 0 = 1) and "slave axis has been synchronized" (P-0-0089, bit 8 = 1) are output.

Absolutely Synchronized Slave Axis

The drive is absolutely synchronous to the master axis when the following condition has been fulfilled:

$$S\text{-}0\text{-}0228 \geq \left| \%modulo\left[(P\text{-}0\text{-}0753) - \langle (S\text{-}0\text{-}0048) + (P\text{-}0\text{-}0691) + P\text{-}0\text{-}0778) \rangle \right] \right|$$

S-0-0228	Position synchronization window
P-0-0753	Position actual value in actual value cycle
S-0-0048	Additive position command value
P-0-0691	Additive position command value, process controller
P-0-0778	Synchronous position command value

Fig. 7-88: Condition of Synchronism for Synchronous Position Control Modes

The **modulo range** can be set depending on the mode of synchronization and the command value addition:

- Modulo value (S-0-0103)
- Command value cycle slave axis (P-0-0754)
- Division for command value cycle (setting in P-0-0751)

☞ In the case of absolute scaling, there is no modulo limitation!

Command Value Addition for Slave Axis

Brief Description

In the "velocity synchronization" mode, the addition of command values for the slave axis is directly associated with the synchronization process.

In synchronous position control modes, the addition of command values for the slave axis is an independent functional sequence for which you can choose between the following modes as regards command value addition:

- "Standard" mode

  → Changes are processed with the values from the parameters P-0-0686 and P-0-0687
- "Register controller" mode

  → Changes are smoothed by a 1st order filter (time constant in parameter P-0-0060)

The mode is selected via bit 0 of parameter "P-0-0155, Synchronization mode". By default setting, the "standard" mode is active.

"Standard" Mode

In the "standard" mode, all further changes in the value of parameter "S-0-0048, Additive position command value" are - after synchronization of the operation mode is completed - processed with the values set in the following parameters:

- P-0-0686, Additive position command value, positioning velocity
- P-0-0687, Additive position command value, positioning acceleration
- P-0-0151, Synchronization window for modulo format
- P-0-0154, Synchronization direction

The changes made in parameter "P-0-0691, Additive position command value, process loop" are smoothed via a 1st order filter. The time constant of the filter is set in parameter "P-0-0060, Filter time constant additive position cmd value".

☞ The status bit "synchronization completed" is only set when the condition P-0-0434 = S-0-0048 + x_{sync} has been fulfilled.

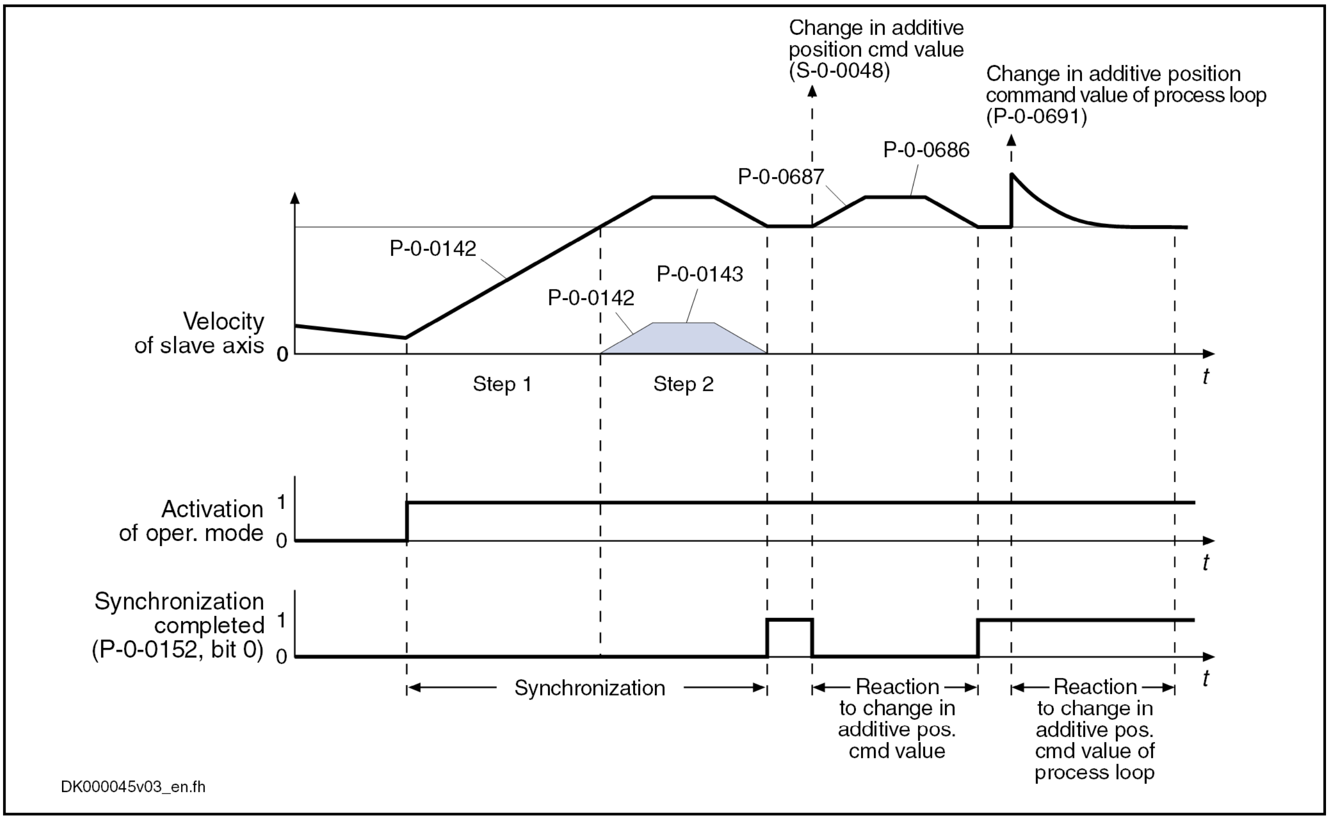


Fig. 7-89: "Standard" Mode

In the "standard" mode, the command values are limited with regard to "S-0-0091, Bipolar velocity limit value" and "S-0-0138, Bipolar acceleration limit value".

"Register Controller" Mode

In the "register controller" mode, all further changes in the parameter "S-0-0048, Additive position command value" are, after synchronization, smoothed by a 1st order filter. The time constant of the filter is set in parameter "P-0-0060, Filter time constant additive position cmd value". The value of "P-0-0691, Additive position command value, process loop" is processed in differential form and the difference between old and new value of P-0-0691 is added to the position command value.

The status bit "synchronization completed" is set when the absolute synchronization has been reached and will not be cleared, even with further changes in "S-0-0048, Additive position command value" and "P-0-0691, Additive position command value, process loop".

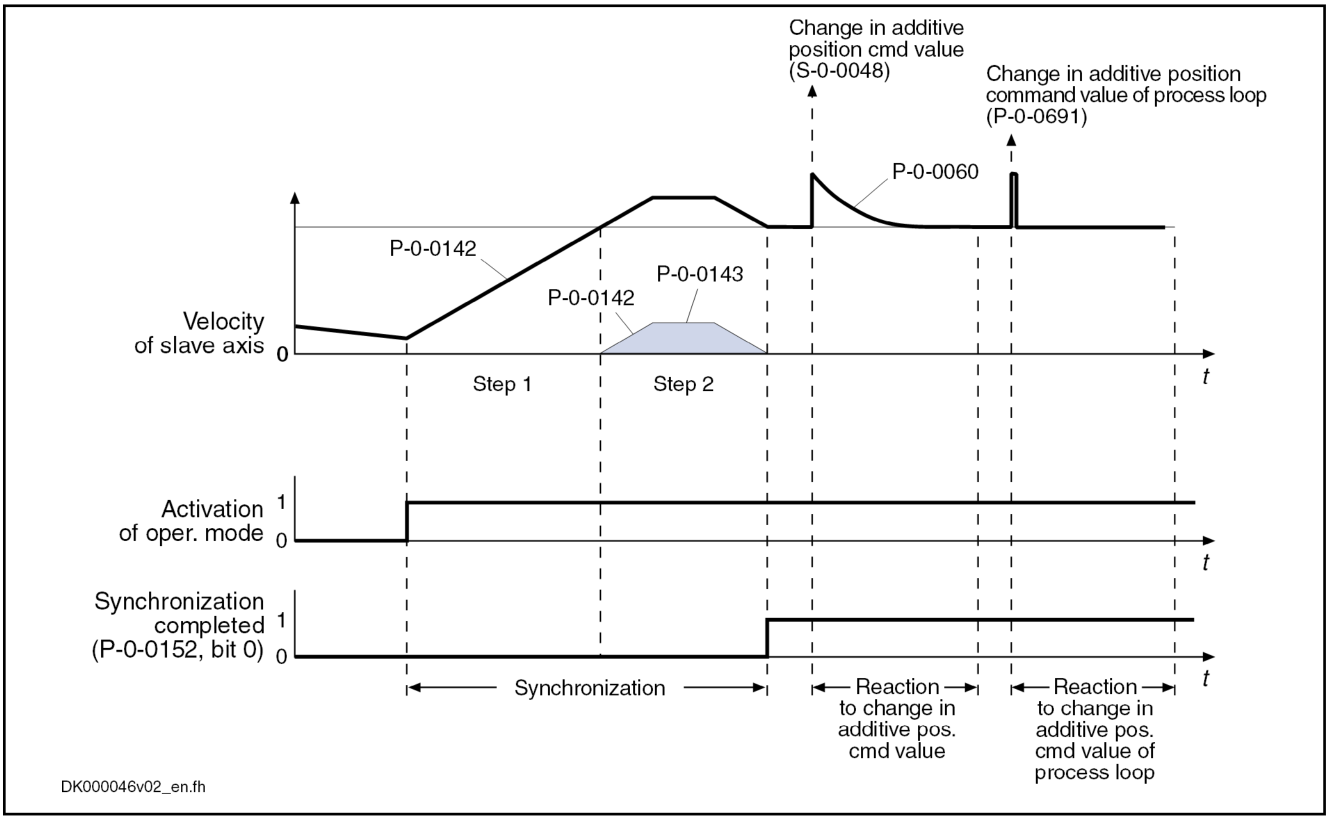


Fig. 7-90: "Register Controller" Mode

In the "register controller" mode, the command values are monitored with regard to "S-0-0091, Bipolar velocity limit value" and "S-0-0138, Bipolar acceleration limit value".

If the command values exceed the limit values, the error message "F2037 Excessive position command difference" is generated.

Possible countermeasures:

- Increasing the filter time constant
- Reducing the changes in the additive position command value
- Increasing the limit values for velocity and acceleration

Diagnostic and Status Messages

Status Messages

In addition to some status and display parameters that are valid for all operation modes, the parameters "P-0-0089, Status word synchronization modes" and "P-0-0152, Synchronization completed" are available for diagnosing the synchronization modes.

Synchronous Mode in Synchronization

The feedback signaling that the slave axis has been synchronized takes place in bit 8 of parameter "P-0-0089, Status word synchronization modes".

- Bit 8 = 0 → Slave axis has not been synchronized
- Bit 8 = 1 → Slave axis has been synchronized

Depending on the synchronization mode, the drive sets bit 8 in parameter P-0-0089.

In the case of velocity synchronization:

$$\left| dx_{sync} + (S\text{-}0\text{-}0037) + (P\text{-}0\text{-}0690) - (S\text{-}0\text{-}0040) \right| < S\text{-}0\text{-}0183$$

Fig. 7-91: Condition for "Slave Axis has Been Synchronized" in the Case of Velocity Synchronization

In the case of synchronous position control modes:

$$\left| x_{sync} + (S\text{-}0\text{-}0048) + (P\text{-}0\text{-}0691) - (P\text{-}0\text{-}0753) \right| < S\text{-}0\text{-}0228$$

Fig. 7-92: Condition for "Slave Axis has Been Synchronized" in the Case of Synchronous Position Control Modes

Synchronization Status

The information on whether a synchronization process is active or has been completed is mapped to bit 0 of parameter "P-0-0152, Synchronization completed":

- Bit 0 = 0 → Synchronization running
- Bit 0 = 1 → Synchronization completed

As regards the generation of bit 0 in parameter P-0-0152, the following cases have to be distinguished for the operating modes "phase synchronization" and "electronic cam":

- First synchronization process

  → Bit 0 is set when the distance up to the absolute or relative position has been traveled.
- Cyclic normal operation

  → When bit 0 has been set, the fact of whether bit 0 is cleared for the duration of the following travel reaction when the additive position command value (S-0-0048) is changed, depends on the setting of bit 0 in parameter "P-0-0155, Synchronization mode". If bit 0 = 1 in parameter P-0-0155 ("register controller" mode), bit 0 remains set in parameter P-0-0152.

Diagnostic Messages

In conjunction with the synchronization modes, there is a number of diagnostic messages specific to operation mode.

Diagnostic command messages:

- C0244 Act. modulo value cycle greater than max. travel range
- C3100 Recalculate actual value cycle
- C3101 Act. modulo value cycle greater than max. travel range
- C3102 Drive is still in drive enable

Warnings:

- E2049 Positioning velocity >= limit value
- E2063 Velocity command value > limit value

Diagnostic error messages:

- F2002 Assignment of encoder for synchronization is not allowed
- F2003 Motion step skipped
- F2004 Error in MotionProfile
- F2005 Cam table invalid
- F2037 Excessive position command difference

7.9.2 Velocity Synchronization with Real/Virtual Master Axis

Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the operation mode "velocity synchronization with real/virtual master axis", the drive follows a preset master axis velocity at a synchronous velocity.

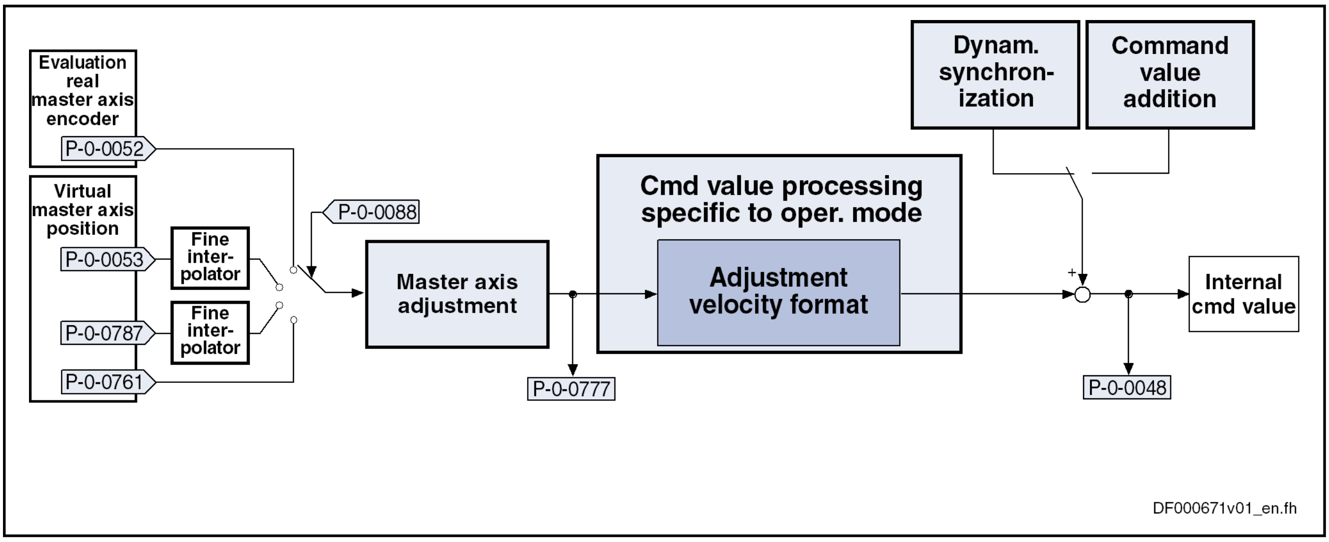
The real master axis velocity is generated by a measuring encoder; in contrast, the virtual master axis velocity is preset by the master.

See also "Dynamic Synchronization of the Slave Axis" in the section "Basic Functions of the Synchronization Modes"

Features

- Determination of the effective velocity command value (P-0-0048) from the differentiated and fine interpolated sum of master axis position (P-0-0053) or measuring encoder position (P-0-0052) and additive components of "P-0-0054, Additive master axis position" and "P-0-0692, ", multiplied by master axis gear and fine adjustment
- Adjustable master axis polarity
- Synchronization takes place in single-step form
- Synchronization mode to be selected
  - Velocity adjustment always uses synchronization acceleration (P-0-0142)
  - Velocity adjustment using synchronization acceleration (P-0-0142) only in the first synchronization

The figure below illustrates the interaction of the individual subfunctions (function blocks) of the "velocity synchronization" mode:



P-0-0048 Effective velocity command value
P-0-0052 Actual position value of measuring encoder
P-0-0053 Master axis position
P-0-0088 Control word synchronization modes
P-0-0761 Master axis position for slave axis
P-0-0777 Effective master axis velocity
P-0-0787 Group axis 1 position

Fig. 7-93: Function Blocks of the Operation Mode "Velocity Synchronization with Real/Virtual Master Axis"

Variants of the Operation Mode

The following variants can be configured:

- Velocity synchronization with real master axis
- Velocity synchronization with virtual master axis

How to Use the Operation Mode

Velocity synchronization is used, for example, for simple transport rolls of printing machines. The drive runs with a velocity synchronous to the master axis. The track speed at the circumference of the transport roll or the winder is preset by the electric gear. A defined tension can be set by the fine adjustment of the gear.

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in velocity synchronization:

- S-0-0037, Additive velocity command value
- S-0-0183, Velocity synchronization window
- P-0-0159, Slave drive feed travel
- P-0-0690, Additive velocity command value, process loop
- P-0-0777, Effective master axis velocity

See also "Pertinent Parameters" in the subsections of "Basic Functions of the Synchronization Modes"

Pertinent Diagnostic Messages

In addition to the general diagnostic messages of all synchronization modes, there are other diagnostic messages involved in velocity synchronization:

- A0110 Velocity synchronization, virtual master axis
- A0111 Velocity synchronization, real master axis
- A0164 Velocity synchronization
- E2063 Velocity command value > limit value

See also "Pertinent Diagnostic Messages" in the subsections of "Basic Functions of the Synchronization Modes"

Overview of the Operation Mode

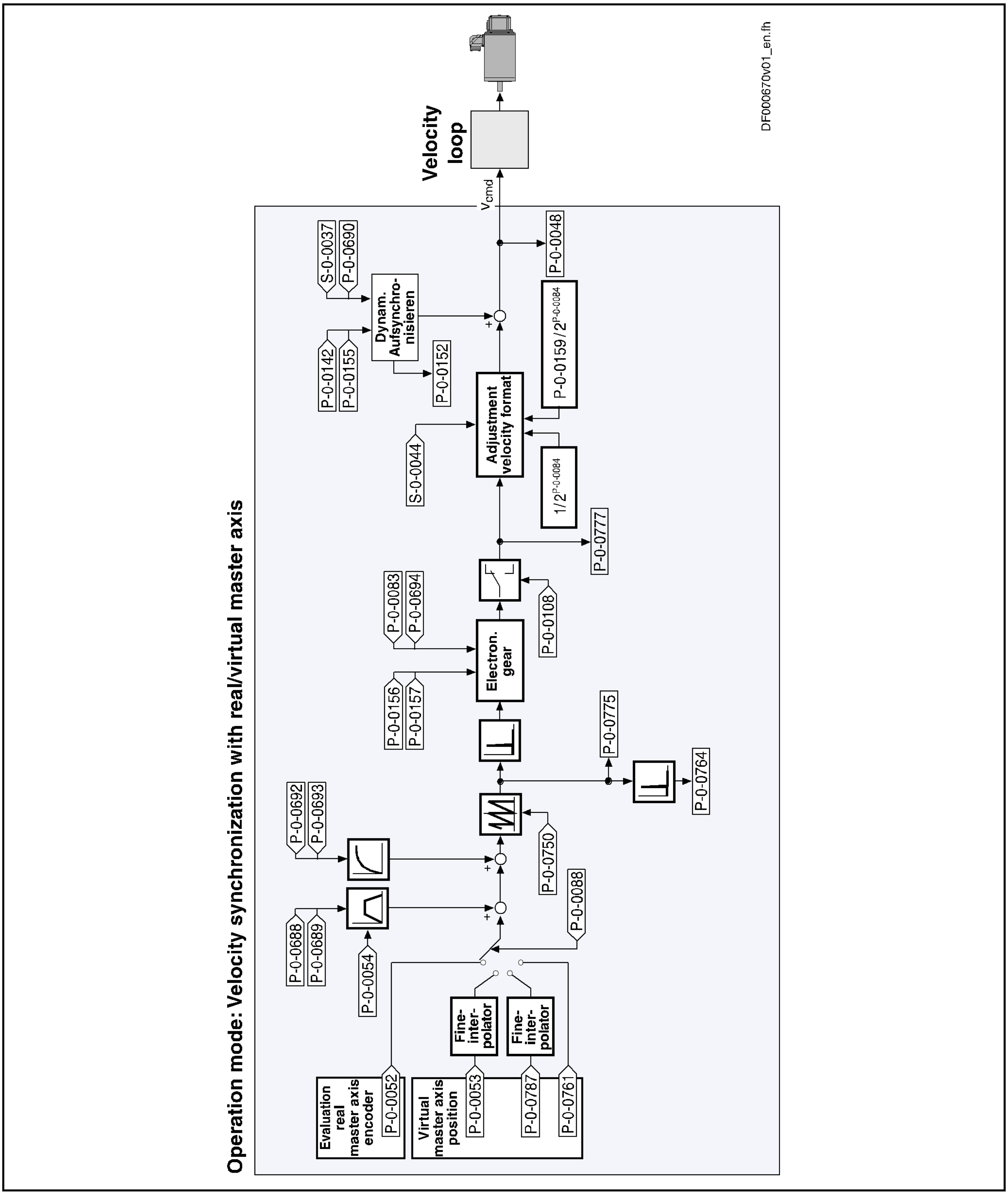


Fig. 7-94: Block Diagram: Velocity Synchronization with Real/Virtual Master Axis

Master Axis Adjustment

Master axis adjustment is realized by means of the following subfunctions:

- Generation of master axis

- Master axis offset and modulo limitation
- Electronic gearbox with fine adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview Command value adjustment in the "velocity synchronization" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operation mode
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

Only the function block "command value processing" specific to velocity synchronization is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

See "Basic Functions of the Synchronization Modes"

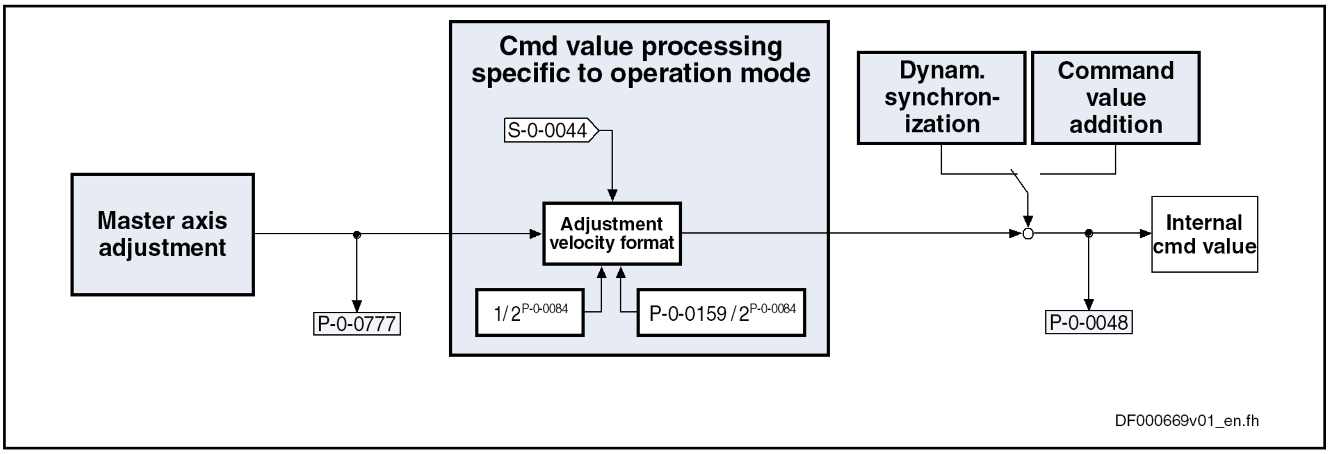


Fig. 7-95: Command Value Processing Specific to Operation Mode for Velocity Synchronization

Generating the Synchronous Velocity Command Value The synchronous velocity command value (dx_{sync}) is generated in terms of the selected master axis polarity (P-0-0108) and the scaling type (S-0-0044) that was set, using one of the following equations:

$$dx_{sync} = \pm\Delta\ [(P\text{-}0\text{-}0053) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)] \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times [1 + (P\text{-}0\text{-}0083)] \times [1 + (P\text{-}0\text{-}0694)] \times \frac{1}{2^{P\text{-}0\text{-}0084}}$$

dx_{sync} Synchronous velocity command value

Fig. 7-96: Generating the Synchronous Velocity Command Value with Rotary Scaling

$$dx_{sync} = \pm\Delta\ [(P\text{-}0\text{-}0053) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)] \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times [1 + (P\text{-}0\text{-}0083)] \times [1 + (P\text{-}0\text{-}0694)] \times \frac{P\text{-}0\text{-}0159}{2^{P\text{-}0\text{-}0084}}$$

dx_{sync} Synchronous velocity command value

Fig. 7-97: Generating the Synchronous Velocity Command Value with Linear Scaling

☞ One master axis revolution is standardized to 2^{N} increments (with N = value from "P-0-0084, Number of bits per master axis revolution"). This means that the LSB of the master axis position corresponds to 2^{-N} master axis revolutions.

Synchronization with Velocity Synchronization

The synchronization process is a drive-controlled motion with the aim of synchronizing the axis to the master axis velocity. The slave axis is velocity-synchronous when the following condition has been fulfilled:

$$dx_{sync} + (S\text{-}0\text{-}0037) + (P\text{-}0\text{-}0690) = S\text{-}0\text{-}0040$$

dx_{sync} Synchronous velocity command value

S-0-0040 Velocity feedback value

Fig. 7-98: Condition for Velocity Synchronism of the Slave Axis

Synchronization Process

Upon activation of the operation mode, a **velocity adjustment** is executed.

This means that the drive either accelerates or decelerates from the current actual velocity at the time of activation to the synchronous velocity.

After the synchronous velocity has been reached, another change of the synchronous velocity is processed depending on "P-0-0155, Synchronization mode".

The following variants are available to do this:

- **P-0-0155, bit 5 = 0**

  → Velocity adjustment only carried out once, all following changes of velocity are carried out with maximum acceleration

- **P-0-0155, bit 5 = 1**

  → Every change of velocity is limited by the value of "P-0-0142, Synchronization acceleration"

ℹ See also Parameter Description "P-0-0155, Synchronization mode"

Notes on Commissioning and Parameterization

General Parameterization

For general parameterization, it is necessary to make machine-specific presettings:

- Scaling of parameter data (linear or rotary)
  - S-0-0076, S-0-0077, S-0-0078 and S-0-0079 for position data
  - S-0-0044, S-0-0045 and S-0-0046 for velocity data
  - S-0-0160, S-0-0161 and S-0-0162 for acceleration data

  See "Scaling of Physical Data"
- For linear scaling with rotary motor, parameterizing the feed constant per slave axis revolution (S-0-0123)
- Parameterizing the load gear of the slave axis (S-0-0121 and S-0-0122)

Parameterizing the Operation Mode

Sequence of parameterization specific to operation mode:

1. Depending on parameter "P-0-0750, Master axis revolutions per master axis cycle", the range of values for the master axis can be between 0 and P-0-0750 × $2^{P\text{-}0\text{-}0084}$ increments. In the special case P-0-0750 = 0, the master axis range is from $-(2^{31})$ to $(2^{31})-1$.

2. With linear scaling, the slave axis moves by the feed travel, per output revolution of the master drive gear (including fine adjust), parameterized in "P-0-0159, Slave drive feed travel".
3. Settings for the electronic gearbox are made in the following parameters:
   - P-0-0083, Gear ratio fine adjustment
   - P-0-0108, Master drive polarity
   - P-0-0156, Master drive gear input revolutions
   - P-0-0157, Master drive gear output revolutions
   - P-0-0694, Gear ratio fine adjustment, process loop
4. The following settings have to be made for synchronization:
   - P-0-0142, Synchronization acceleration
   - Time of activation for synchronization (P-0-0155, bit 5)

Diagnostic and Status Messages

Diagnostic Status Messages

The following diagnostic status messages are displayed in normal operation of the operation mode (drive enabled, "AF"):

- A0110 Velocity synchronization, virtual master axis
- A0111 Velocity synchronization, real master axis
- A0164 Velocity synchronization

Error Messages and Warnings

Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operation mode:

- E2063 Velocity command value > limit value

There are also several status messages specific to operation mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word synchronization modes" and "P-0-0152, Synchronization completed").

7.9.3 Position Synchronization: Phase synchronization

Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the operation mode "phase synchronization with real/virtual master axis", the drive follows a preset master axis position in an absolute or relative phase synchronous way.

The real master axis velocity is generated by a measuring encoder; in contrast, the virtual master axis velocity is preset by the master.

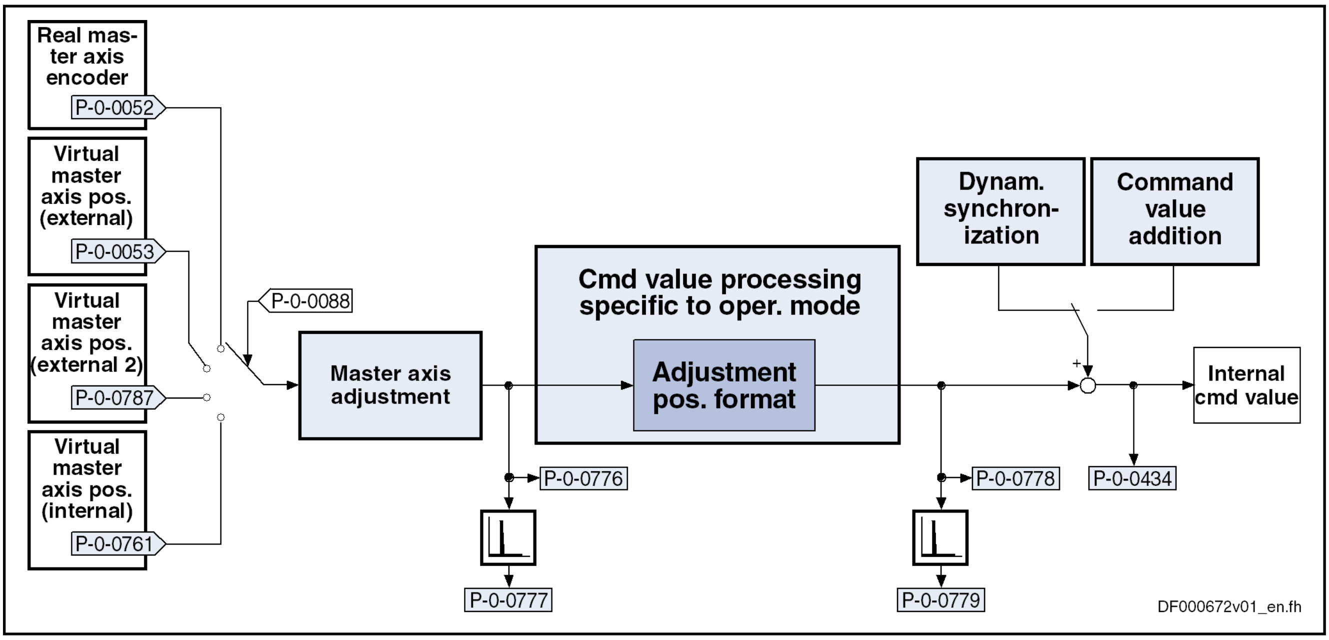
See also "Dynamic Synchronization of the Slave Axis" in the section "Basic Functions of the Synchronization Modes"

Features

- Determination of the position command value from the master axis position using the electronic gear with fine adjustment, adjustable master axis polarity
- Synchronization mode to be selected
- Single-step, double-step or optimized double-step synchronization
- Absolute or relative phase synchronization

- Synchronization range to be selected

The figure below illustrates the interaction of the individual subfunctions (function blocks) of the "phase synchronization" mode:



P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0088	Control word synchronization modes
P-0-0434	Position command value of controller
P-0-0776	Effective master axis position
P-0-0777	Effective master axis velocity
P-0-0778	Synchronous position command value
P-0-0779	Synchronous velocity
P-0-0787	Group axis 1 position

Fig. 7-99: Function Blocks of the Operation Mode "Phase Synchronization with Real/Virtual Master Axis"

Variants of the Operation Mode

The following variants can be configured:

- Position Synchronization: Phase synchronization
  - Phase synchronization with real master axis, encoder 1
  - Phase synchronization with real master axis, encoder 2
  - Phase synchronization with real master axis, encoder 1, lagless
  - Phase synchronization with real master axis, encoder 2, lagless
  - Phase synchronization with virtual master axis, encoder 1
  - Phase synchronization with virtual master axis, encoder 2
  - Phase synchronization with virtual master axis, encoder 1, lagless
  - Phase synchronization with virtual master axis, encoder 2, lagless

☞ The position synchronization mode "phase synchronization", "cam" or "MotionProfile" and the active master axis are selected in parameter "P-0-0088, Control word synchronization modes". Encoder selection and specification of lagless position control or position control with lag error are made in parameter "S-0-0520, Axis control word".

Operation modes

Application "Absolute Phase Synchronization"

In machining processes that require absolute phase synchronization, e.g. printing, punching or perforating in printing machines, the absolute position reference to the master axis is established in the "phase synchronization" mode. The drive synchronizes with a position command value that is generated from master axis position and additive position command value.

Application "Relative Phase Synchronization"

For machining processes that only require relative phase synchronization, e.g. synchronization of belts or feed rollers without defined starting point, a relative position reference to the master axis is established. During the first synchronization, there is only an adjustment to the synchronous velocity but no position adjustment carried out.

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in phase synchronization:

- S-0-0103, Modulo value
- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes
- P-0-0159, Slave drive feed travel
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity
- P-0-0778, Synchronous position command value
- P-0-0779, Synchronous velocity

See also "Pertinent Parameters" in the subsections of "Basic Functions of the Synchronization Modes"

Overview of the Operation Mode

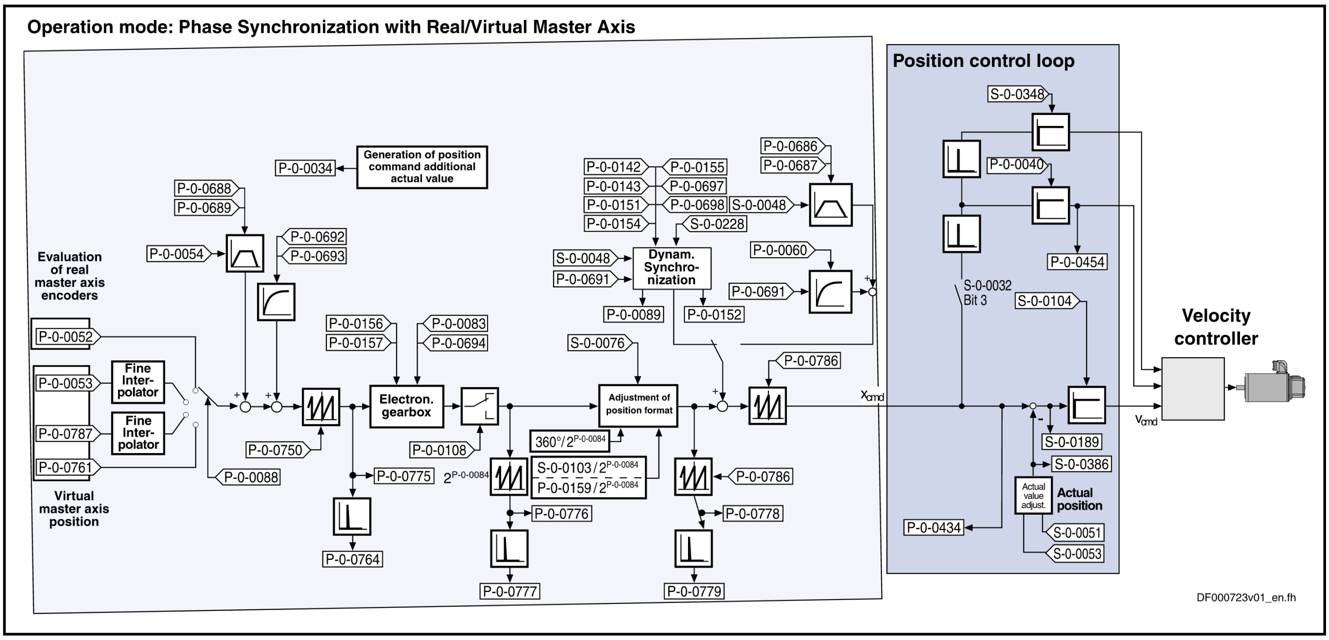


Fig. 7-100: Block Diagram: Phase Synchronization with Real/Virtual Master Axis

Master Axis Adjustment

Master axis adjustment is realized by means of the following subfunctions:

- Generation of master axis
- Master axis offset and modulo limitation
- Electronic gearbox with fine adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "phase synchronization" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operation mode
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

Only the function block "command value processing" specific to phase synchronization is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

See "Basic Functions of the Synchronization Modes"

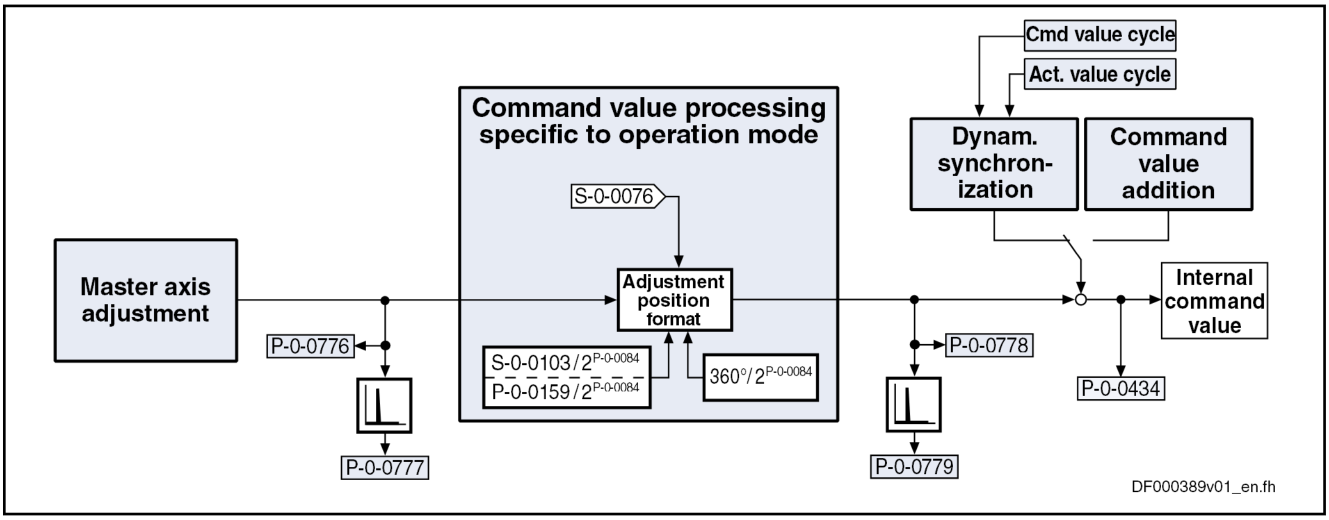


Fig. 7-101: Command Value Processing Specific to Operation Mode for Phase Synchronization

Generating the Internal Position Command Value

In the operation mode "phase synchronization with real/virtual master axis", the internal position command value (P-0-0434) is generated by addition of the synchronous position command value (x_{sync}) with the components of the additive position command value (S-0-0048) and the additive position command value of process controller (P-0-0691).

$$\text{P-0-0434} = x_{sync} + x_{add} + x_{add\_PR}$$

P-0-0434 Position command value of controller
x_{sync} Synchronous position command value
x_{add} Filter output of "S-0-0048, Additive position command value"
x_{add_PR} Filter output of "P-0-0691, Additive position command value, process loop"

Fig. 7-102: Generating the Internal Position Command Value

Note: In the synchronized state (P-0-0089; bit 8 = 1), the following applies:

$$\text{P-0-0434} = x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691})$$

Fig. 7-103: Generating the Internal Position Command Value in the Synchronized State

Generating the Synchronous Position Command Value

The synchronous position command value (x_{sync}) is generated in terms of the selected master axis polarity (P-0-0108) and the scaling type (S-0-0076) that was set, using the following equation:

$$x_{sync} = \left\langle \text{P-0-0775} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times [1 + (\text{P-0-0083})] \times [1 + (\text{P-0-0694})] \times \frac{\text{S-0-0103}}{2^{\text{P-0-0084}}} \right\rangle \% \text{ P-0-0786}$$

Fig. 7-104: Generating the Synchronous Position Command Value with Modulo Scaling

$$x_{sync} = \left\langle \text{P-0-0775} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times [1 + (\text{P-0-0083})] \times [1 + (\text{P-0-0694})] \times \frac{360\,°}{2^{\text{P-0-0084}}} \right\rangle \% \text{ P-0-0786}$$

Fig. 7-105: Generating the Synchronous Position Command Value with Rotary Absolute Scaling

$$x_{sync} = \left\langle \text{P-0-0775} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times [1 + (\text{P-0-0083})] \times [1 + (\text{P-0-0694})] \times \frac{\text{P-0-0159}}{2^{\text{P-0-0084}}} \right\rangle \% \text{ P-0-0786}$$

Fig. 7-106: Generating the Synchronous Position Command Value with Linear Absolute Scaling

☞ One master axis revolution is standardized to 2^N increments (with N = value from "P-0-0084, Number of bits per master axis revolution"). This means that the LSB of the master axis position corresponds to 2^{-N} master axis revolutions.

Synchronization

See "Basic Functions of the Synchronization Modes"

Notes on Commissioning and Parameterization

General Parameterization

For general parameterization, it is necessary to make machine-specific presettings:

Scaling of Data

- Scaling of parameter data (linear or rotary)
  - S-0-0076, S-0-0077, S-0-0078 and S-0-0079 for position data
  - S-0-0044, S-0-0045 and S-0-0046 for velocity data
  - S-0-0160, S-0-0161 and S-0-0162 for acceleration data

  See "Scaling of Physical Data"
- For linear scaling with rotary motor, parameterizing the feed constant per slave axis revolution (S-0-0123)
- Parameterizing the load gear of the slave axis (S-0-0121 and S-0-0122)
- Determining the synchronization velocity (P-0-0143) and the synchronization acceleration (P-0-0142)

"Modulo Scaling" Parameterization

For "modulo" parameterization, make the following settings:

1. Modulo Range

   In parameter "S-0-0103, Modulo value", set the modulo range to that value at which the overflow of the position data (from modulo value to "0") is to take place with infinitely turning axis.

2. Maximum travel range

   Select the maximum travel range (S-0-0278) at least as large as the actual value cycle.

3. "Modulo" Master Axis

   The "modulo" master axis is a master axis the master axis positions of which are within the master axis cycle determined by parameter "P-0-0750, Master axis revolutions per master axis cycle". The master axis positions may overflow or underflow (infinitely turning master axis).

4. Electronic Gearbox

   Settings for the electronic gearbox are made in the following parameters:

   - P-0-0083, Gear ratio fine adjustment
   - P-0-0694, Gear ratio fine adjustment, process loop
   - P-0-0108, Master drive polarity
   - P-0-0156, Master drive gear input revolutions
   - P-0-0157, Master drive gear output revolutions

5. Synchronization

   The following settings have to be made for synchronization:

   - Mode for reaction to changes in parameter S-0-0048 after first synchronization (P-0-0155, bit 0)
   - Single-step or double-step synchronization (P-0-0155, bit 6)
   - Mode for single-step synchronization (P-0-0155, bit 7)
   - Optimized double-step synchronization (P-0-0155, bit 8)
   - Relative or absolute synchronization (P-0-0155, bit 1)
   - Synchronization range (P-0-0155, bits 2 and 3)
   - Generation of actual value cycle (P-0-0155, bit 4)

☞ The actual value cycle has to be an integral multiple of the synchronization range.

"Absolute Scaling" Parameterization

For "absolute" parameterization, make the following settings:

1. Maximum travel range

   In the case of absolute scaling, the maximum travel range in parameter S-0-0278 has to be selected at least as large as the range in which the synchronous position data are to be contained.

2. "Absolute" Master Axis

   The "absolute" master axis is a master axis the master axis positions of which are within the master axis cycle determined by parameter "P-0-0750, Master axis revolutions per master axis cycle". The master axis positions **mustn't** overflow nor underflow. If the master axis does overflow, this causes an unwanted jump in position.

NOTICE	Incorrect parameterization can cause unwanted jumps in position.)!

It is recommended that you activate the position limit value monitor (see "Position Limitation/Travel Range Limit Switches")

3. Slave Drive Feed Travel with Linear Absolute Scaling

   The distance that the slave axis covers per master axis revolution is determined in parameter "P-0-0159, Slave drive feed travel".

4. Electronic Gearbox

   Settings for the electronic gearbox are made in the following parameters:

   - P-0-0083, Gear ratio fine adjustment
   - P-0-0694, Gear ratio fine adjustment, process loop
   - P-0-0108, Master drive polarity
   - P-0-0156, Master drive gear input revolutions
   - P-0-0157, Master drive gear output revolutions

5. Synchronization

   The following settings have to be made for synchronization:

   - Mode for reaction to changes in parameter S-0-0048 after first synchronization (P-0-0155, bit 0)
   - Relative or absolute synchronization (P-0-0155, bit 1)
   - Single-step or double-step synchronization (P-0-0155, bit 6)
   - Mode for single-step synchronization (P-0-0155, bit 7)
   - Optimized double-step synchronization (P-0-0155, bit 8)

Commissioning Summary

The figure below illustrates the basic sequence of commissioning.

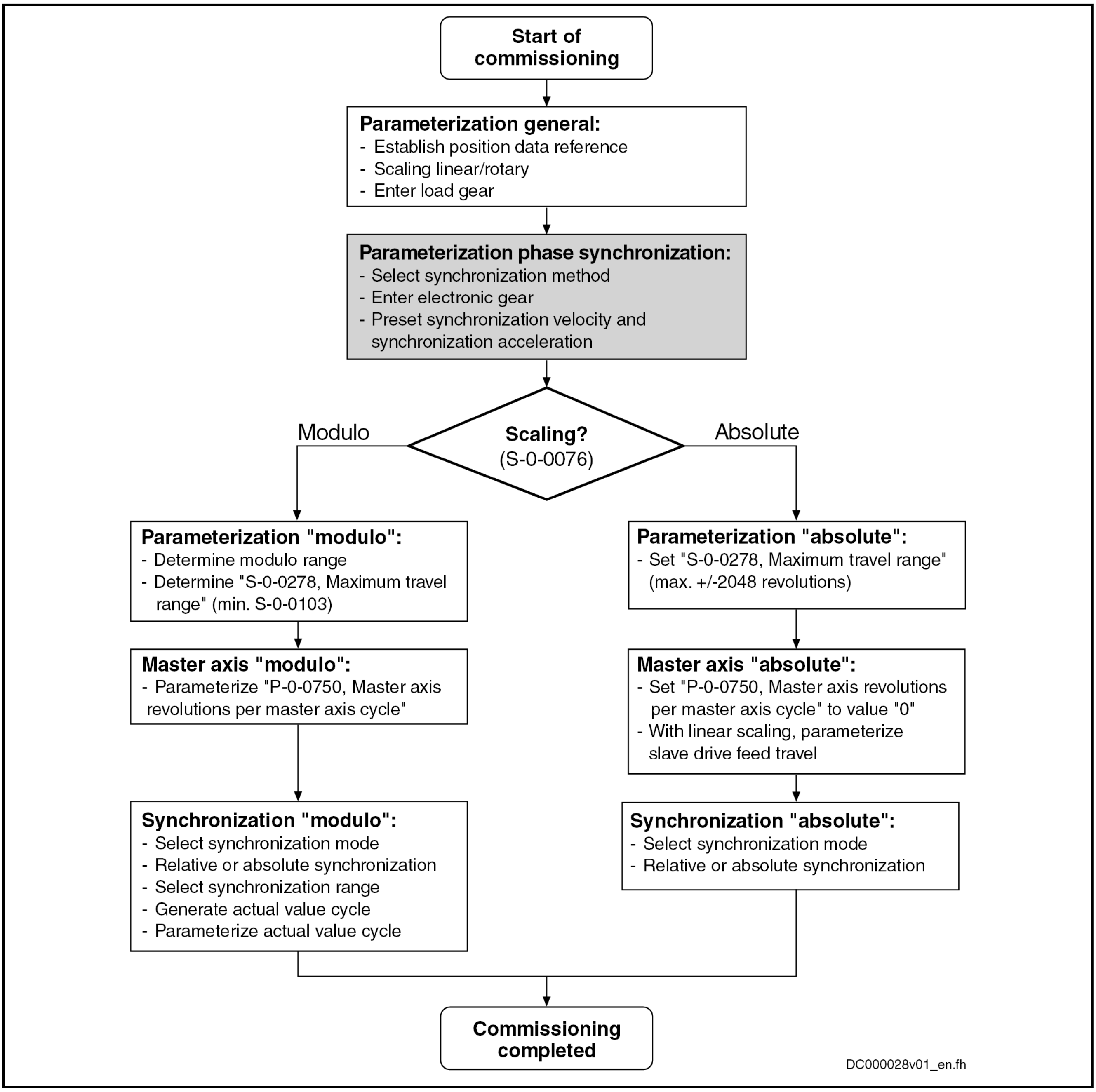


Fig. 7-107: Overview of Commissioning Steps for Phase Synchronization

Diagnostic and Status Messages

Diagnostic Status Messages

The following diagnostic status messages are displayed in normal operation of the operation mode (drive enabled, "AF"):

- A0112 Phase synchronization, encoder 1, virtual master axis
- A0113 Phase synchronization, encoder 2, virtual master axis
- A0114 Phase synchronization, encoder 1, real master axis
- A0115 Phase synchronization, encoder 2, real master axis
- A0116 Phase synchr. lagless, encoder 1, virtual master axis
- A0117 Phase synchr. lagless, encoder 2, virtual master axis

- A0118 Phase synchr. lagless, encoder 1, real master axis
- A0119 Phase synchr. lagless, encoder 2, real master axis
- A0163 Position synchronization

Error Messages and Warnings

Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operation mode:

- F2002 Assignment of encoder for synchronization is not allowed

  → When activating a synchronous operation mode with outer position control loop ("MotionProfile", "cam" or "phase synchronization"), a check is run to find out whether "P-0-0753, Position actual value in actual value cycle" has been initialized to the currently effective control encoder. If this is not the case, an error is triggered.

Status Bits

There are also several status messages specific to operation mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word synchronization modes" and "P-0-0152, Synchronization completed").

Position Controller Status

The status display via the control encoder and for lagless operation or operation with lag error takes place in parameter "S-0-0521, Axis status word".

7.9.4 Position Synchronization: Electronic cam

Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the operation mode "electronic cam with real/virtual master axis", there is a fixed relationship between the master axis position and the slave axis.

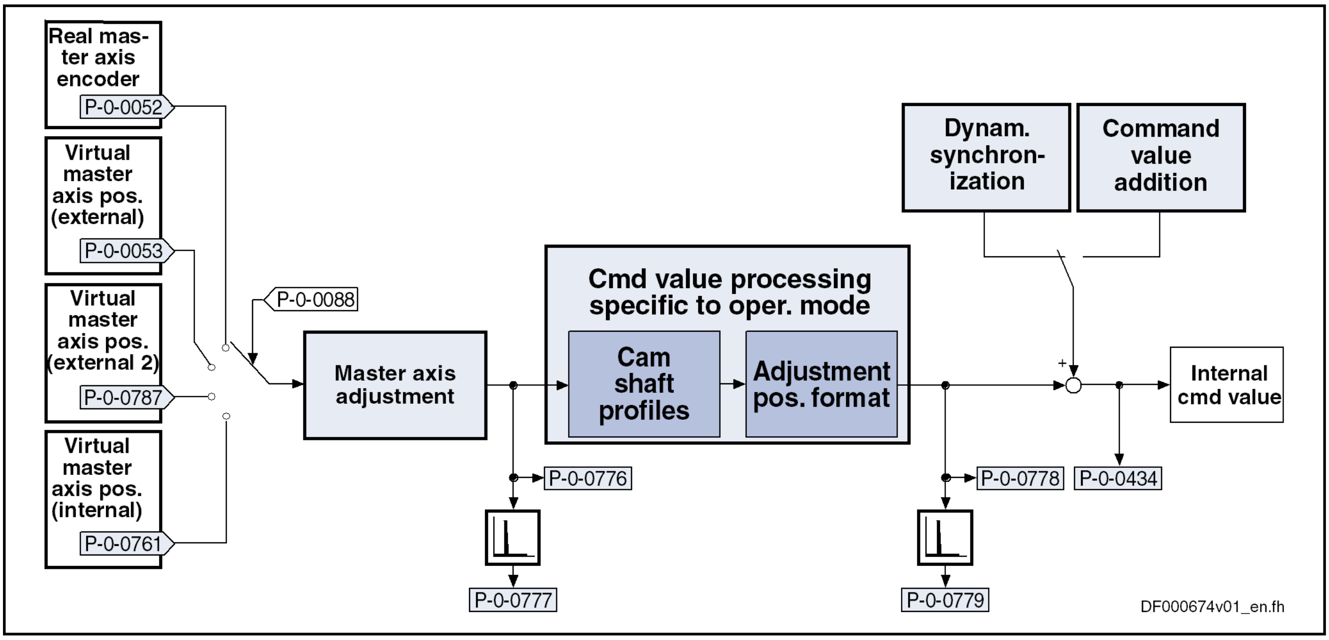
The real master axis velocity is generated by a measuring encoder; in contrast, the virtual master axis velocity is preset by the master.

See also "Dynamic Synchronization of the Slave Axis" in the section "Basic Functions of the Synchronization Modes"

Features

- 4 cam tables with a max. of 1024 data points (P-0-0072, P-0-0092, P-0-0780, P-0-0781)
- 4 cam tables with a max. of 128 data points (P-0-0783, P-0-0784, P-0-0785, P-0-0786)
- Cubic spline interpolation of the cam data points
- Dynamic angle offset and angle offset at begin of profile
- Freely definable switch angle for cam and cam distance
- Synchronization mode to be selected
- Single-step, double-step or optimized double-step synchronization
- Absolute or relative phase synchronization
- Synchronization range to be selected
- Change of format "on the fly"
- Cross cutter function
- Clocked pull roll

The figure below illustrates the interaction of the individual subfunctions (function blocks) of the "electronic cam" mode:



P-0-0052 Actual position value of measuring encoder
P-0-0053 Master axis position
P-0-0088 Control word synchronization modes
P-0-0434 Position command value of controller
P-0-0776 Effective master axis position
P-0-0777 Effective master axis velocity
P-0-0778 Synchronous position command value
P-0-0779 Synchronous velocity
P-0-0787 Group axis 1 position

Fig. 7-108: Function Blocks of the Operation Mode "Electronic Cam"

Variants of the Operation Mode

The following variants can be configured:

- Position Synchronization: Cam with real master axis, encoder 1
- Position Synchronization: Cam with real master axis, encoder 2
- Position Synchronization: Cam with real master axis, encoder 1, lagless
- Position Synchronization: Cam with real master axis, encoder 2, lagless
- Position Synchronization: Cam with virtual master axis, encoder 1
- Position Synchronization: Cam with virtual master axis, encoder 2
- Position Synchronization: Cam with virtual master axis, encoder 1, lagless
- Position Synchronization: Cam with virtual master axis, encoder 2, lagless

☞ The position synchronization mode "phase synchronization", "cam" or "MotionProfile" and the active master axis are selected in parameter "P-0-0088, Control word synchronization modes". Encoder selection and specification of lagless position control or position control with lag error are made in parameter "S-0-0520, Axis control word".

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in this operation mode:

- S-0-0103, Modulo value

- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0061, Angle offset begin of table
- P-0-0072, Cam table 1
- P-0-0073, Cam distance 2
- P-0-0085, Dynamic angle offset
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes
- P-0-0092, Cam table 2
- P-0-0093, Cam distance
- P-0-0094, Cam switch angle
- P-0-0144, Cam distance switch angle
- P-0-0158, Angle offset change rate
- P-0-0159, Slave drive feed travel
- P-0-0227, Cam table, access angle
- P-0-0695, Angle offset begin of table, process loop
- P-0-0696, Filter time constant, angle offset profile, process loop
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity
- P-0-0778, Synchronous position command value
- P-0-0779, Synchronous velocity
- P-0-0780, Cam table 3
- P-0-0781, Cam table 4
- P-0-0782, Cam table 5
- P-0-0783, Cam table 6
- P-0-0784, Cam table 7
- P-0-0785, Cam table 8

See also "Pertinent Parameters" in the subsections of "Basic Functions of the Synchronization Modes"

Pertinent Diagnostic Messages

In addition to the general diagnostic messages of all synchronization modes, there are other diagnostic messages involved in this operation mode:

- A0128 Cam, encoder 1, virtual master axis
- A0129 Cam, encoder 2, virtual master axis
- A0130 Cam, encoder 1, real master axis
- A0131 Cam, encoder 2, real master axis
- A0132 Cam, lagless, encoder 1, virt. master axis
- A0133 Cam, lagless, encoder 2, virt. master axis
- A0134 Cam, lagless, encoder 1, real master axis
- A0135 Cam, lagless, encoder 2, real master axis
- A0163 Position synchronization
- F2002 Assignment of encoder for synchronization is not allowed
- F2005 Cam table invalid

See also "Pertinent Diagnostic Messages" in the subsections of "Basic Functions of the Synchronization Modes"

Overview of the Operation Mode

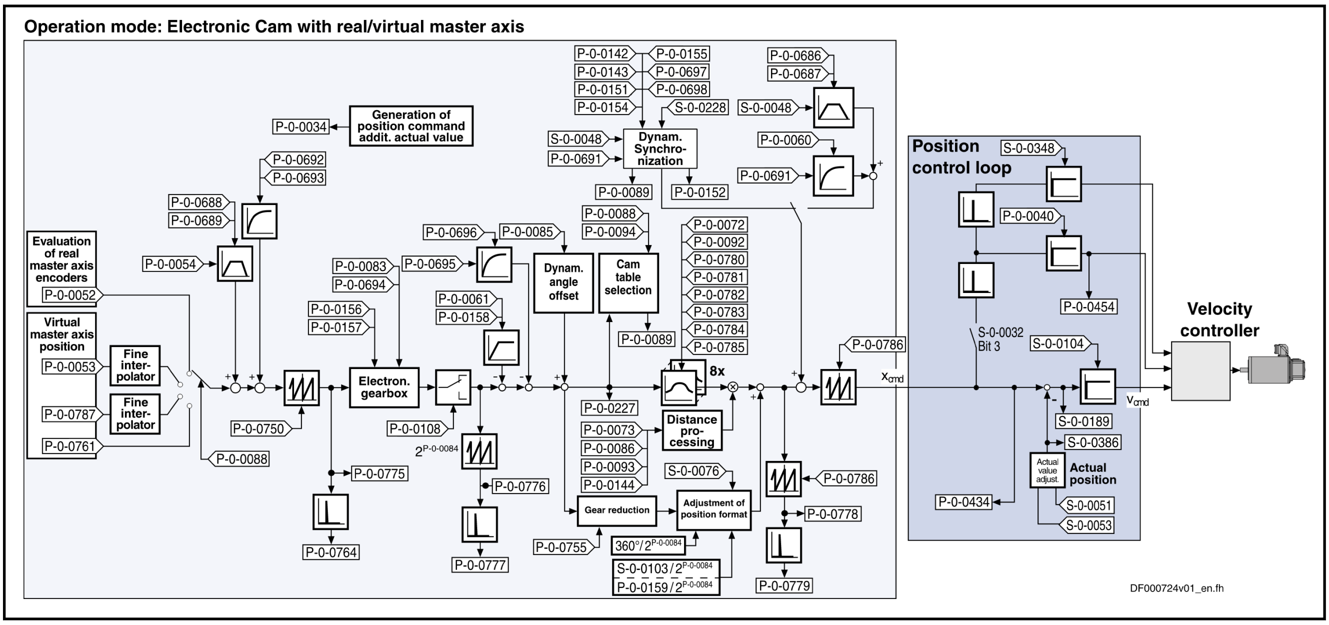


Fig. 7-109: Block Diagram: Electronic Cam with Real/Virtual Master Axis

Master Axis Adjustment

Master axis adjustment is realized by means of the following subfunctions:

- Generation of master axis
- Master axis offset and modulo limitation
- Electronic gearbox with fine adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "electronic cam" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operation mode, consisting of
  - Cam tables (incl. access)
  - Adjustment of position format
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

☞ Only the function block "command value processing" specific to the cam mode is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

See "Basic Functions of the Synchronization Modes"

Operation modes

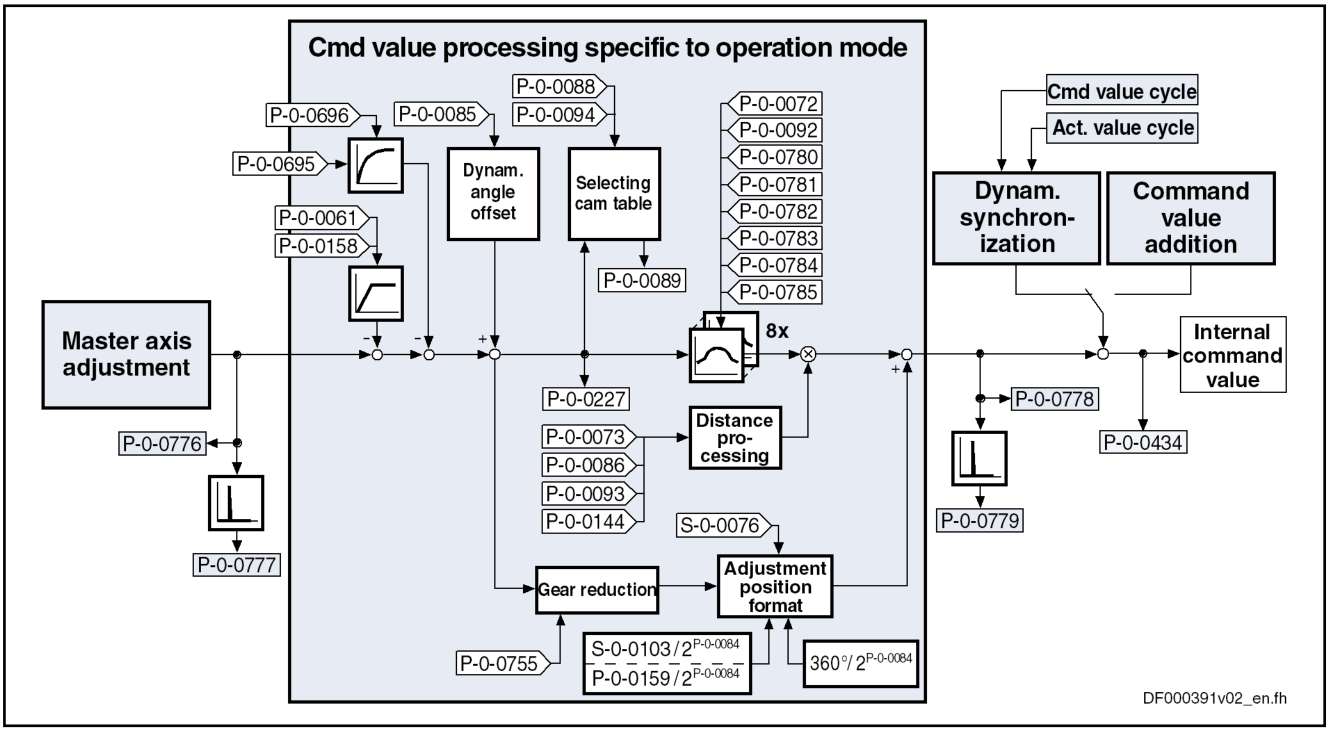


Fig. 7-110: Command Value Processing Specific to Operation Mode for Cam Mode

Generating the Internal Position Command Value

In the operation mode "electronic cam with real/virtual master axis", the internal position command value (P-0-0434) is generated by addition of the synchronous position command value (x_{sync}) with the components of the additive position command value (S-0-0048) and the additive position command value of process loop (P-0-0691).

$$\text{P-0-0434} = x_{sync} + x_{add} + x_{add\_PR}$$

P-0-0434	Position command value of controller
x_{sync}	Synchronous position command value
x_{add}	Filter output of "S-0-0048, Additive position command value"
x_{add_PR}	Filter output of "P-0-0691, Additive position command value, process loop"

Fig. 7-111: Generating the Internal Position Command Value

Note: In the synchronized state (P-0-0089; bit 8 = 1), the following applies:

$$\text{P-0-0434} = x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691})$$

Fig. 7-112: Generating the Internal Position Command Value in the Synchronized State

In the function block "command value processing specific to operation mode" the calculations specific to the cam mode are carried out for generating the synchronous position command value.

Depending on "P-0-0061, Angle offset begin of table" and "P-0-0695, Angle offset begin of table, process loop", an interpolated table value is taken from the cam tables in every control cycle and the difference to the last interpolated table value is multiplied by the distance. The result is added to the position command value.

If the phase-synchronous gear reduction path has been activated by bit 4 of parameter "P-0-0086, Configuration word synchronous operation modes", the master axis position at the output of the electronic gearbox is additionally divided by the gear reduction (P-0-0755) and multiplied with a scaling-dependent factor. The result is differentiated and added to the position command value.

☞ If the table limit is exceeded in positive direction, the table continues with its first value, the same happens if the limit is exceeded in negative direction.

Calculating the Internal Position Command Value (Initialization)

Upon activation of the operation mode "electronic cam with real/virtual master axis", the position command value of the drive is first initialized in terms of the following relation:

$$x_F = \left[h \times tab(\varphi_{ZGW}) + \frac{\varphi_{ZGW}}{U} + x_V + x_{VPR} \right] \% \, IWZ$$

x_F	Position command value of slave drive (P-0-0434)
h	Cam distance (P-0-0093 or P-0-0073)
tab(φ)	Cam table value (P-0-0072, P-0-0092, P-0-0780, P-0-0781)
φ_{ZGW}	Table access angle (P-0-0227)
U	Gear reduction (P-0-0755)
x_V	Additive position command value (S-0-0048)
x_{VPR}	Additive position command value, process controller (P-0-0691)
IWZ	Modulo actual value cycle (P-0-0786)

Fig. 7-113: Initializing the Position Command Value

$$\varphi_{ZGW} = \pm \varphi_L \times \frac{G_a}{G_e} \times (1 + F) \times (1 + F_{PR}) - \varphi_V - \varphi_{VPR} + \varphi_D$$

φ_{ZGW}	Table access angle (P-0-0227)
+/-	Master drive polarity (P-0-0108)
φ_L	Resulting master axis position (P-0-0775)
G_a	Master drive gear output revolutions (P-0-0157)
G_e	Master drive gear input revolutions (P-0-0156)
F	Gear ratio fine adjustment (P-0-0083)
F_{PR}	Gear ratio fine adjustment, process controller (P-0-0694)
φ_V	Angle offset begin of table (P-0-0061)
φ_{VPR}	Angle offset begin of table, process controller (P-0-0695)
φ_D	Dynamic angle offset (P-0-0085)

Fig. 7-114: Determining the Table Access Angle

NOTICE

With the operation mode activated, differences, that later on will be added again, are processed in the electronic gearbox and the cam tables. Therefore, changes in the electronic gearbox and the cam distance do not cause position command value jumps. Velocity jumps, however, can occur and the absolute position reference, established when activating the operation mode, is lost.

Operation modes

Accessing the Cam Table

From the activated cam table, an interpolated table value is taken in each position control cycle, the difference to the last interpolated table value is generated and a multiplication with the cam distance is carried out. The result is added to the position command value.

Cubic spline interpolation takes place between the table values.

> With an infinite cam, the difference between initial value and final value of the cam table is 100%.

Calculating the Internal Position Command Value (in Cyclic Operation)

The position command value is generated as per the following relation:

$$x_{F,n}(\varphi_{ZGW}) = \left[x_{F,n-1}(\varphi_{ZGW}) + h \times \Delta tab(\varphi_{ZGW}) + \frac{\varphi_{ZGW}}{U} + x_V + x_{VPR} \right] \% \, IWZ$$

x_F	Position command value of slave drive (P-0-0434)
φ_{ZGW}	Table access angle (P-0-0227)
h	Cam distance (P-0-0093 or P-0-0073)
tab(φ)	Cam table value (P-0-0072, P-0-0092, P-0-0780, P-0-0781)
U	Gear reduction (P-0-0755)
x_V	Additive position command value (S-0-0048 + P-0-0691)
IWZ	Modulo actual value cycle (P-0-0786)

Fig. 7-115: Cyclically Generating the Position Command Value for the Slave Drive

Synchronization

See "Basic Functions of the Synchronization Modes"

Notes on Commissioning and Parameterization

General Parameterization

For general parameterization, it is necessary to make machine-specific presettings:

Scaling of Data

- Scaling of parameter data (linear or rotary)
  - S-0-0076, S-0-0077, S-0-0078 and S-0-0079 for position data
  - S-0-0044, S-0-0045 and S-0-0046 for velocity data
  - S-0-0160, S-0-0161 and S-0-0162 for acceleration data

  See "Scaling of Physical Data"
- For linear scaling with rotary motor, parameterizing the feed constant per slave axis revolution (S-0-0123)
- Parameterizing the load gear of the slave axis (S-0-0121 and S-0-0122); if available
- Determining the synchronization velocity (P-0-0143) and the synchronization acceleration (P-0-0142)

Selecting and Acknowledging the Active Cam

Select and acknowledge the active cam table:

- The active cam table (P-0-0072, P-0-0092, P-0-0780 to P-0-0785) is selected with parameters "P-0-0088, Control word synchronization modes" and "P-0-0094, Cam switch angle".
- The active cam is included in parameter "P-0-0089, Status word synchronization modes". Switching of the cam is started by changing the control word. It is carried out by the drive and acknowledged in the

status word, when the master axis position exceeds the angle set in parameter "P-0-0094, Cam switch angle".

☞ For constantly fault-free processing of the position data with infinitely turning axes, the values resulting from gear reduction (P-0-0086, bit 4 = 1) must be used for forward motion. A finite cam table can be superimposed. When using an infinite cam table (difference between first and last table value > 50%), a small error can occur with each table sequence. Exception: Cam distance corresponds to modulo value (S-0-0103).

☞ When cam tables are used with a difference between the table values of two cam elements > 50%, the "linear cam interpolation" must be activated (P-0-0086, bit 7 = 1). An exception is a difference of > 50% between the first and the last table value of one cam table.

Parameterizing the Cam Distance

Parameterize the cam distance:

- Parameter "P-0-0144, Cam distance switch angle" defines at which table access angle and thus table element a change in value becomes effective for "P-0-0093, Cam distance". If the table values in the switch range = 0, an absolute position reference is maintained in the case of a change.
- In parameter "P-0-0086, Configuration word synchronous operation modes", select with bits 0 and 1 whether new values for cam distance (P-0-0093) and for the electronic gearbox (P-0-0156/P-0-0157) take effect immediately or only when the cam distance switch angle is passed or when the cam table is switched.

  In bit 3 you can determine which reference is to be valid for delayed acceptance of changes (cam distance switch angle or cam table switching).

ⓘ See also Parameter Description "P-0-0086, Configuration word synchronous operation modes"

Parameterizing the Angle Offset

To avoid great position jumps when changing the table access angle, a new value for the parameter "P-0-0061, Angle offset begin of table" does not immediately become effective. Starting with the current value, a ramp-like approximation to the new value is carried out. The approximation is carried out over the shortest possible distance. The gradient of the ramp is set in parameter "P-0-0158, Angle offset change rate".

Approximation to a new value always takes place over the shortest distance.

☞ With "P-0-0158, Angle offset change rate" equal zero, the angle offset is carried out in one step (immediately effective).

Process controllers can additionally write data to parameter "P-0-0695 Angle offset begin of table, process loop". After the electronic gearbox, the master axis position is reduced via a 1st order filter by the angle determined in parameter P-0-0695. The filter time constant is determined in parameter "P-0-0696, Filter time constant, angle offset profile, process loop".

Dynamic Angle Offset

Parameter "P-0-0085, Dynamic angle offset" can be used for compensating a lag error in operation with lag distance, if the mechanical system does not allow lagless operation.

With dynamic angle offset, the table access angle is offset depending on the velocity so that the internal master axis position can be calculated according to the formula below:

$$\varphi_{\text{effective internal master axis pos.}} = \varphi_{\text{internal master axis pos.}} + \frac{v_{\text{internal master axis velocity}}}{\text{Kv-factor}} \times \text{dynam. angle offset}$$

Internal After electronic gearbox (P-0-0156/P-0-0157) and fine adjustment (P-0-0083)

Fig. 7-116: Effective Internal Master Axis Position Taking the Dynamic Angle Offset Into Account

☞ The master axis velocity used is generated on the timebase T_A = communication cycle time so that a moving average filter results with $T_A = N \times T_{position}$.

Clocked pull roll

For the special case "clocked pull roll", it is possible, with bit 2 = 1 of parameter "P-0-0086, Configuration word synchronous operation modes", to change between "P-0-0093, Cam distance" and "P-0-0073, Cam distance 2", depending on the gradient of the cam.

Positive gradient means that "P-0-0093, Cam distance" is active, negative gradient means that "P-0-0073, Cam distance 2" is active.

Cross cutter function

By means of the command values of "P-0-0755, Gear reduction", a cross cutter axis can be operated. A cross cutter (rotating knife) is used to cut a defined piece (format) off some material that is transported at constant velocity. The format is set by the electronic gearbox. With an electronic gearbox 1:1, the format corresponds to the circumference of the cutting cylinder (with number of knives = 1). Smaller formats are realized by an electronic gearbox [(output/input) > 1]. The slave axis (cutting cylinder) then turns faster than the master axis. In this case, the cutting cylinder, in the cutting range, has to be decelerated to the transport velocity of the material. After the cutting range, the cylinder is accelerated again. This is achieved by superimposing a more or less sinusoidal cam to the constant speed of the axis that is caused by the linear component of the gear reduction. With a constant cam table, it is then possible to define, by means of the cam distance, whether the axis decelerates (distance > 0) or accelerates (distance < 0) within the cutting range.

- The number of knives that are distributed at the circumference of the cutting cylinder is entered in parameter "P-0-0755, Gear reduction". Per cam table sequence, the cutting cylinder will move by the distance of two knives at the circumference.
- To change the format "on the fly", it is necessary to simultaneously change electronic gearbox and cam distance in the cutting range. This function is switched on by setting bit 1 in "P-0-0086, Configuration word synchronous operation modes". A change in the electronic gearbox will only take effect, when the new value, after having changed the distance, is accepted when passing the angle of "P-0-0144, Cam distance switch angle".

"Modulo Scaling" Parameterization

For "modulo" parameterization, make the following settings:

1. Modulo Range

   In parameter "S-0-0103, Modulo value", set the modulo range to that value at which the overflow of the position data (from modulo value to "0") is to take place with infinitely turning axis.

2. Maximum travel range

   Select the maximum travel range (S-0-0278) at least as large as the actual value cycle.
3. Master Axis Position Range/
   Master Axis Cycle

   Depending on parameter "P-0-0750, Master axis revolutions per master axis cycle", the range of values for the master axis can be between 0 and P-0-0750 × $2^{P\text{-}0\text{-}0084}$ increments. In the special case P-0-0750 = 0, the master axis range is from $-(2^{31})$ to (2^{31})-1.
4. "Modulo" Master Axis

   The "modulo" master axis is a master axis the master axis positions of which are within the master axis cycle determined by parameter "P-0-0750, Master axis revolutions per master axis cycle". The master axis positions may overflow or underflow (infinitely turning master axis).
5. Electronic Gearbox

   Settings for the electronic gearbox are made in the following parameters:
   - P-0-0083, Gear ratio fine adjustment
   - P-0-0694, Gear ratio fine adjustment, process loop
   - P-0-0108, Master drive polarity
   - P-0-0156, Master drive gear input revolutions
   - P-0-0157, Master drive gear output revolutions
6. Synchronization

   The following settings have to be made for synchronization:
   - Mode for reaction to changes in parameter S-0-0048 after first synchronization (P-0-0155, bit 0)
   - Relative or absolute synchronization (P-0-0155, bit 1)
   - Single-step or double-step synchronization (P-0-0155, bit 6)
   - Mode for single-step synchronization (P-0-0155, bit 7)
   - Optimized double-step synchronization (P-0-0155, bit 8)
   - Synchronization range (P-0-0155, bits 2 and 3)
   - Generation of actual value cycle (P-0-0155, bit 4)
   - Synchronization range determination (P-0-0155, bit 2/3)
7. Gear Reduction with Linear Absolute Scaling

   With linear absolute scaling, parameter "P-0-0159, Slave drive feed travel" takes effect with activated gear reduction in the gear reduction component.

"Absolute Scaling" Parameterization

For "absolute" parameterization, make the following settings:

1. Maximum travel range

   In the case of absolute scaling, the maximum travel range in parameter S-0-0278 has to be selected at least as large as the range in which the synchronous position data are to be contained.
2. Master Axis Position Range/
   Master Axis Cycle

   Depending on parameter "P-0-0750, Master axis revolutions per master axis cycle", the range of values for the master axis can be between 0 and P-0-0750 × $2^{P\text{-}0\text{-}0084}$ increments. In the special case P-0-0750 = 0, the master axis range is from $-(2^{31})$ to $(2^{31})-1$.

3. "Absolute" or "Modulo" Master Axis

   The "absolute" master axis is a master axis the master axis positions of which are within the master axis cycle determined by parameter "P-0-0750, Master axis revolutions per master axis cycle". The master axis positions in this case do neither overflow nor underflow.

   This possibility is not used for practical application. Theoretically, the absolute master axis could be used for infinite cams (e.g. linear cams) and/or when a gear reduction (P-0-0755) unequal zero is selected.

   NOTICE **When a gear reduction (bit 4, P-0-0086 = 1) has been parameterized, the modulo overflow of the master axis mustn't take place with absolute position scaling! Otherwise, this would cause unwanted jumps in position.**

   The "modulo" master axis is a master axis the master axis positions of which are within the master axis cycle determined by parameter "P-0-0750, Master axis revolutions per master axis cycle". The master axis positions may overflow or underflow (infinitely turning master axis).

   This master axis is used in conjunction with a finite cam (initial value = final value) and when there is no gear reduction (bit 4, P-0-0086 = 0). If you select a gear reduction, the drive, with infinitely turning master axis, will leave the maximum travel range at some time.

   NOTICE **Incorrect parameterization can cause unwanted jumps in position.**

   It is recommended that you activate the position limit value monitor (see "Position Limitation/Travel Range Limit Switches")!

4. Gear Reduction with Linear Absolute Scaling

   With linear absolute scaling, parameter "P-0-0159, Slave drive feed travel" takes effect with activated gear reduction in the gear reduction component.

5. Electronic Gearbox

   Settings for the electronic gearbox are made in the following parameters:

   - P-0-0083, Gear ratio fine adjustment
   - P-0-0694, Gear ratio fine adjustment, process loop
   - P-0-0108, Master drive polarity
   - P-0-0156, Master drive gear input revolutions
   - P-0-0157, Master drive gear output revolutions

6. Synchronization

   The following settings have to be made for synchronization:

   - Mode for reaction to changes in parameters S-0-0048 and P-0-0691 after first synchronization (P-0-0155, bit 0)
   - Single-step or double-step synchronization (P-0-0155, bit 6)

- Mode for single-step synchronization (P-0-0155, bit 7)
- Optimized double-step synchronization (P-0-0155, bit 8)
- Relative or absolute synchronization (P-0-0155, bit 1)

Commissioning Summary

The figure below illustrates the basic sequence of commissioning.

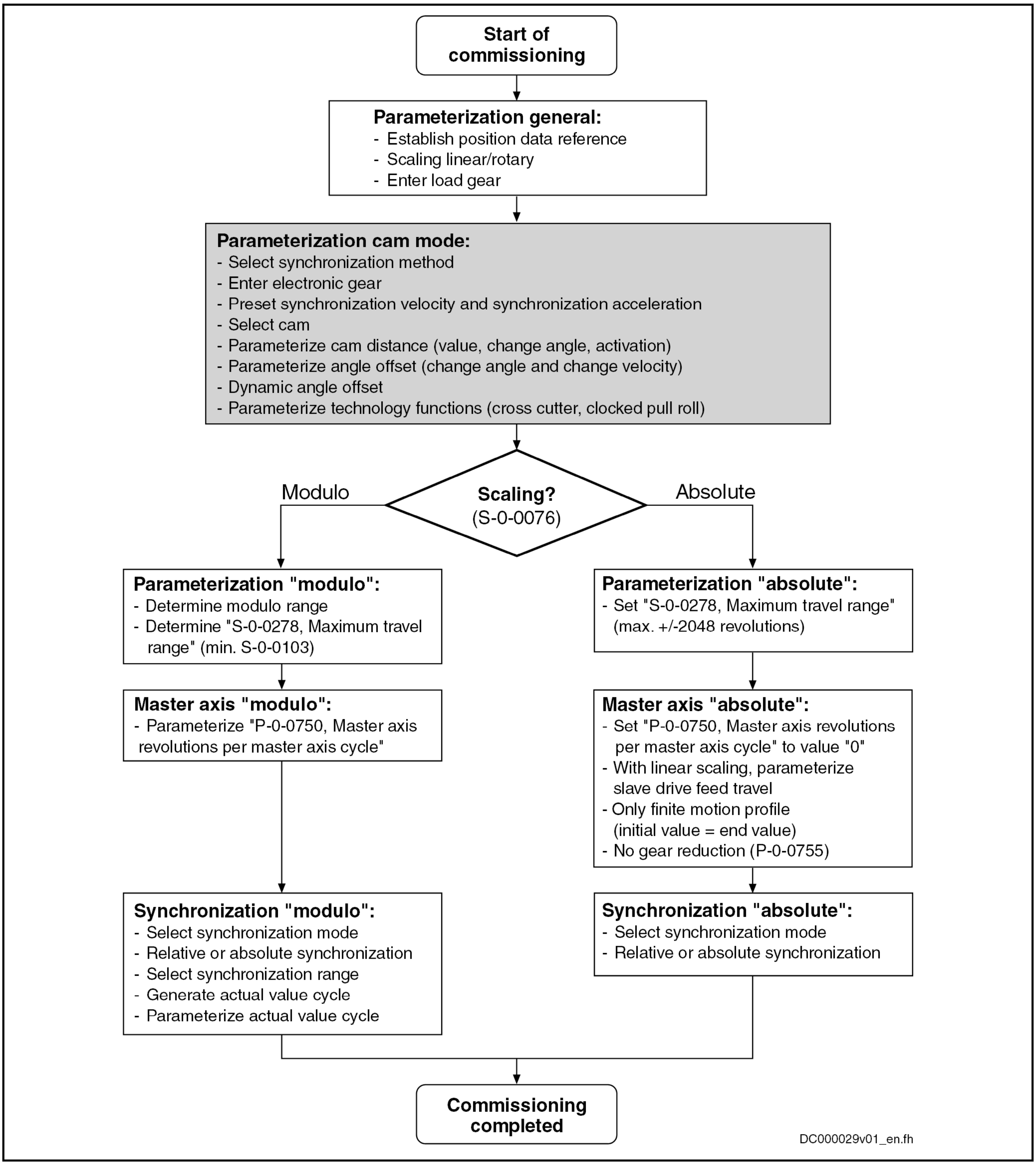


Fig. 7-117: Overview of Commissioning Steps for Cam Mode

Diagnostic and Status Messages

Diagnostic Status Messages

The following diagnostic status messages are displayed in normal operation of the operation mode (drive enabled, "AF"):

- A0128 Cam, encoder 1, virtual master axis
- A0129 Cam, encoder 2, virtual master axis
- A0130 Cam, encoder 1, real master axis
- A0131 Cam, encoder 2, real master axis
- A0132 Cam, lagless, encoder 1, virt. master axis
- A0133 Cam, lagless, encoder 2, virt. master axis
- A0134 Cam, lagless, encoder 1, real master axis
- A0135 Cam, lagless, encoder 2, real master axis
- A0163 Position synchronization

Error Messages and Warnings

Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operation mode:

- F2002 Assignment of encoder for synchronization is not allowed

  → When activating a synchronous operation mode with outer position control loop ("MotionProfile", "cam" or "phase synchronization"), a check is run to find out whether "P-0-0753, Position actual value in actual value cycle" has been initialized to the currently effective control encoder. If this is not the case, an error is triggered.
- F2005 Cam table invalid

  → This message is generated when there is, with the drive having been enabled, an access to a cam table (P-0-0072, P-0-0092, P-0-0780, P-0-0781) that hasn't been written with at least 4 values.

Status Bits

There are also several status messages specific to operation mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word synchronization modes").

Position Controller Status

The status display via the control encoder and for lagless operation or operation with lag error takes place in parameter "S-0-0521, Axis status word".

7.9.5 Position Synchronization: MotionProfile

Brief Description

Expansion package **Synchronization** (order code **SNC**) for the variants **MPB and MPD** in **closed-loop** characteristic

In the operation mode "MotionProfile with real/virtual master axis", there is a fixed relationship between the master axis position and the slave axis.

The real master axis velocity is generated by a measuring encoder; in contrast, the virtual master axis velocity is preset by the master.

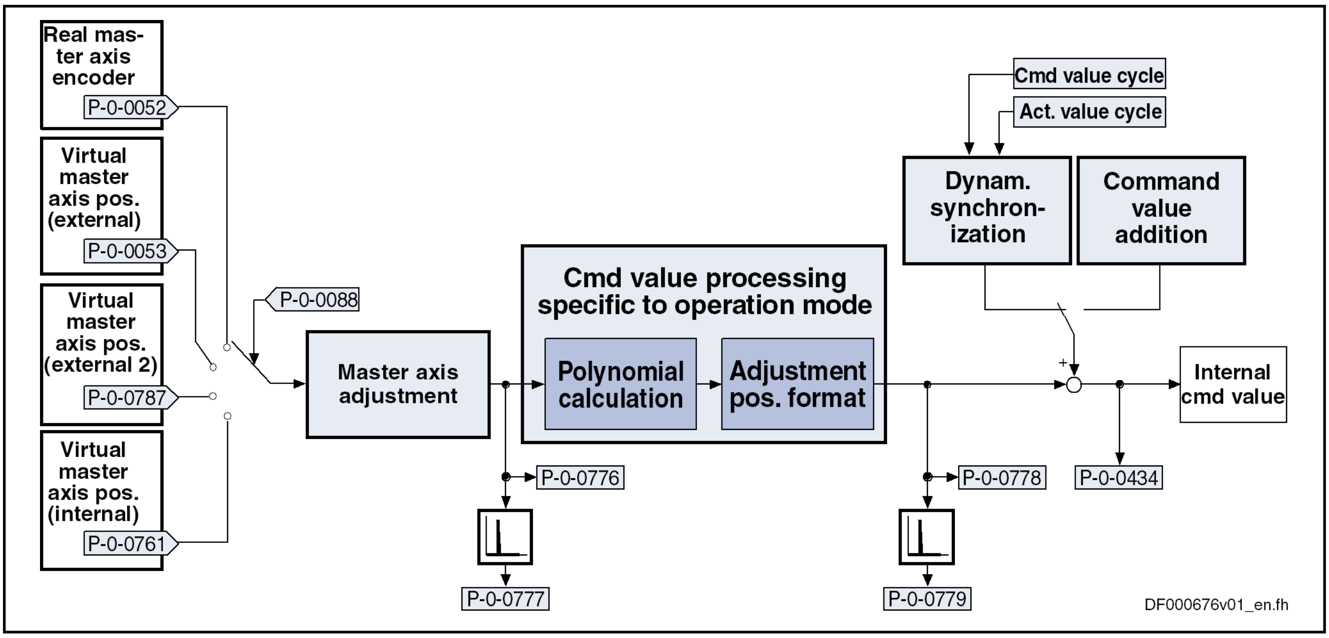
See also "Dynamic Synchronization of the Slave Axis" in the section "Basic Functions of the Synchronization Modes"

Features

- 2 sequences of motion with up to 8 motion steps per master axis revolution
- Definition of a motion step by standardized profile or cam table
- Motion laws can be selected (rest in rest, rest in velocity, velocity in rest, velocity in velocity, constant velocity)

- Motion laws realized by 5th order polynomial or, in the case of rest in rest, alternatively by inclined sine curve
- Individual distance for each motion step
- Dynamic angle offset and angle offset at begin of profile
- Absolute synchronization can be switched off
- Synchronization mode to be selected
- Absolute or relative processing of the motion steps to be selected
- Synchronization range to be selected
- Cross cutter function

The figure below illustrates the interaction of the individual subfunctions (function blocks) of the "MotionProfile" mode:



P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0088	Control word synchronization modes
P-0-0434	Position command value of controller
P-0-0776	Effective master axis position
P-0-0777	Effective master axis velocity
P-0-0778	Synchronous position command value
P-0-0779	Synchronous velocity

Fig. 7-118: Function Blocks of the "MotionProfile" Mode

Variants of the Operation Mode

The following variants can be configured:

- Position Synchronization: MotionProfile
  - MotionProfile with real master axis, encoder 1
  - MotionProfile with real master axis, encoder 2
  - MotionProfile with real master axis, encoder 1, lagless
  - MotionProfile with real master axis, encoder 2, lagless
  - MotionProfile with virtual master axis, encoder 1
  - MotionProfile with virtual master axis, encoder 2
  - MotionProfile with virtual master axis, encoder 1, lagless
  - MotionProfile with virtual master axis, encoder 2, lagless

☞ The position synchronization mode "phase synchronization", "cam" or "MotionProfile" and the active master axis are selected in parameter "P-0-0088, Control word synchronization modes". Encoder selection and specification of lagless position control or position control with lag error are made in parameter "S-0-0520, Axis control word".

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in this operation mode:

- S-0-0103, Modulo value
- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0061, Angle offset begin of table
- P-0-0085, Dynamic angle offset
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes
- P-0-0158, Angle offset change rate
- P-0-0159, Slave drive feed travel
- P-0-0227, Cam table, access angle
- P-0-0695, Angle offset begin of table, process loop
- P-0-0696, Filter time constant, angle offset profile, process loop
- P-0-0700, MotionProfile, master axis switching position
- P-0-0701, Motion step 1, slave axis initial position
- P-0-0702, MotionProfile, diagnosis, set 0
- P-0-0703,
- P-0-0704, Master axis velocity, set 0
- P-0-0705, List of master axis initial positions, set 0
- P-0-0706, List of motion laws, set 0
- P-0-0707, List of distances, set 0
- P-0-0708, List of slave axis velocities, set 0
- P-0-0709, MotionProfile, diagnosis, set 1
- P-0-0710,
- P-0-0711, Master axis velocity, set 1
- P-0-0712, List of master axis initial positions, set 1
- P-0-0713, List of motion laws, set 1
- P-0-0714, List of distances, set 1
- P-0-0715, List of slave axis velocities, set 1
- P-0-0755, Gear reduction
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity
- P-0-0778, Synchronous position command value
- P-0-0779, Synchronous velocity

See also "Pertinent Parameters" in the subsections of "Basic Functions of the Synchronization Modes"

Pertinent Diagnostic Messages

In addition to the general diagnostic messages of all synchronization modes, there are other diagnostic messages involved in this operation mode:

- A0136 MotionProfile, encoder 1, virtual master axis
- A0137 MotionProfile, encoder 2, virtual master axis
- A0138 MotionProfile, encoder 2, real master axis
- A0139 MotionProfile, encoder 1, real master axis
- A0140 MotionProfile lagless, encoder 1, virtual master axis
- A0141 MotionProfile lagless, encoder 2, virtual master axis
- A0142 MotionProfile lagless, encoder 1, real master axis
- A0143 MotionProfile lagless, encoder 2, real master axis
- A0163 Position synchronization
- F2002 Assignment of encoder for synchronization is not allowed
- F2003 Motion step skipped
- F2004 Error in MotionProfile

See also "Pertinent Diagnostic Messages" in the subsections of "Basic Functions of the Synchronization Modes"

Overview of the Operation Mode

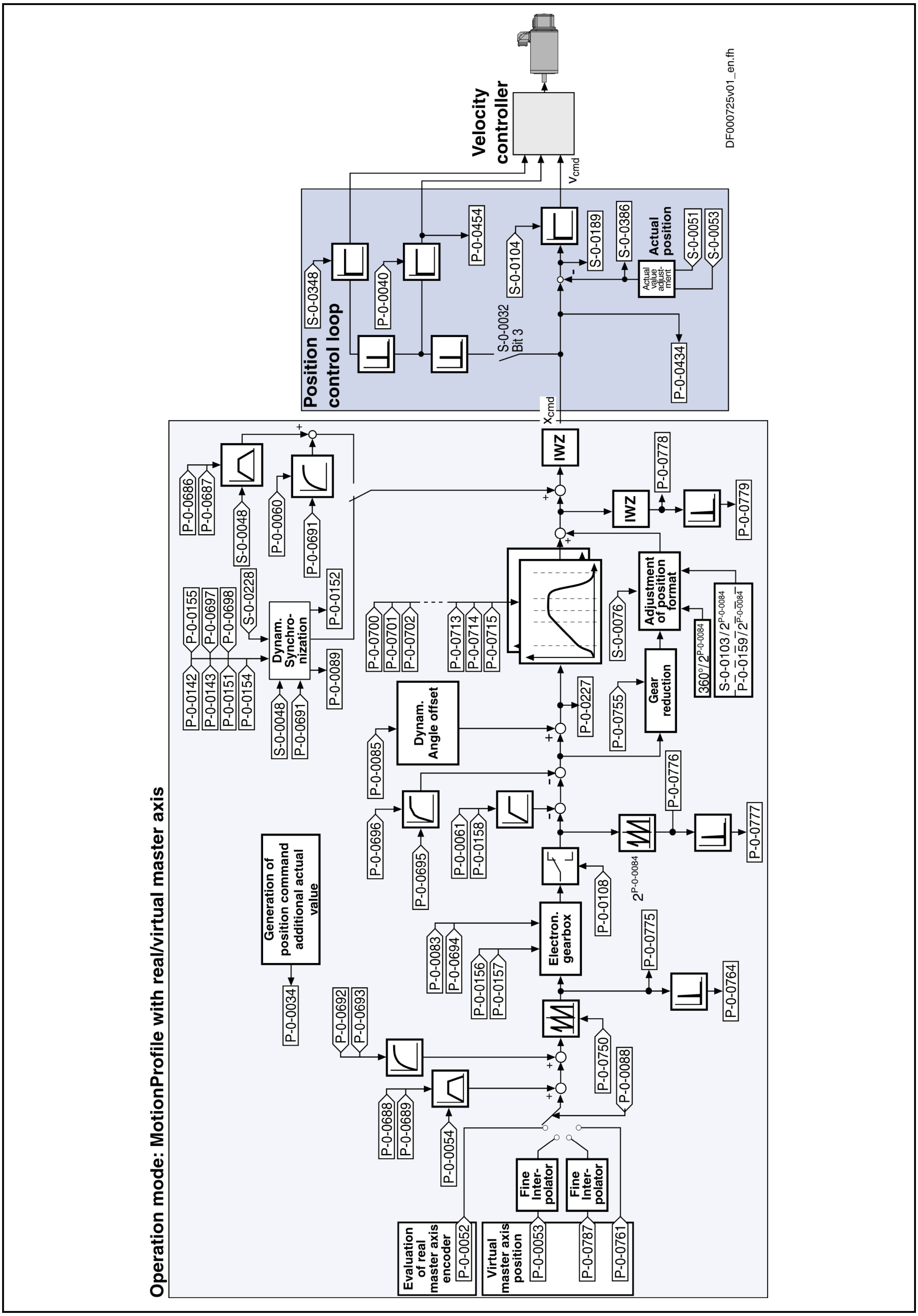


Fig. 7-119: Block Diagram: MotionProfile with Real Master Axis

Master Axis Adjustment

Master axis adjustment is realized by means of the following subfunctions:

- Generation of master axis
- Master axis offset and modulo limitation
- Electronic gearbox with fine adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "MotionProfile" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operation mode, consisting of
  - Cam tables (incl. access)
  - Adjustment of position format
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

In the following only the function block "command value processing" specific to operation mode for the MotionProfile will be described in detail. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

See "Basic Functions of the Synchronization Modes"

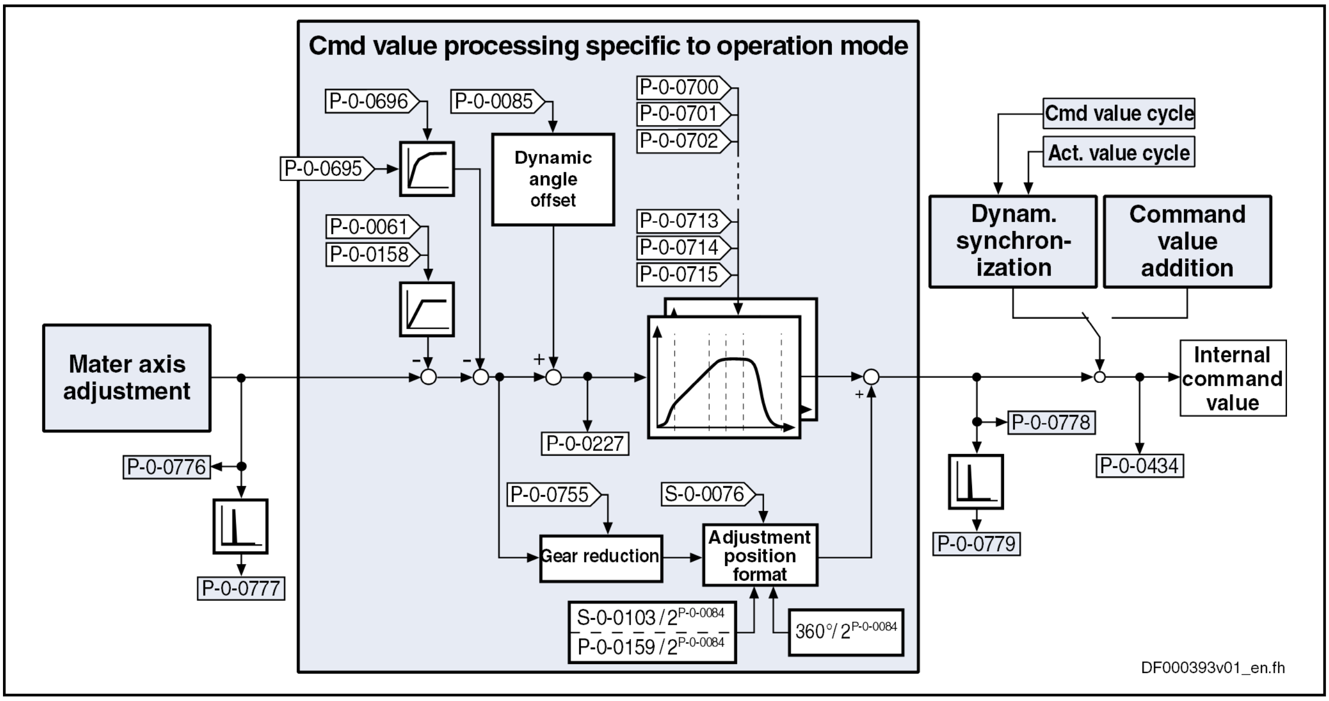


Fig. 7-120: Command Value Processing Specific to Operation Mode with MotionProfile

Generating the Internal Position Command Value

In the operation mode "MotionProfile with real/virtual master axis", the internal position command value (P-0-0434) is generated by addition of the synchronous position command value (x_{sync}) with the components of the additive position command value (S-0-0048) and the additive position command value of process loop (P-0-0691).

$$\text{P-0-0434} = x_{sync} + x_{add} + x_{add\_PR}$$

P-0-0434	Position command value of controller
x_{sync}	Synchronous position command value
x_{add}	Filter output of "S-0-0048, Additive position command value"
x_{add_PR}	Filter output of "P-0-0691, Additive position command value, process loop"

Fig. 7-121: Generating the Internal Position Command Value

Note: In the synchronized state (P-0-0089; bit 8 = 1), the following applies:

$$\text{P-0-0434} = x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691})$$

Fig. 7-122: Generating the Internal Position Command Value in the Synchronized State

In the function block "command value processing specific to operation mode", the calculations specific to the MotionProfile are carried out for generating the synchronous position command value.

"P-0-0227, Cam table, access angle" is generated first. The current motion step is determined from this value and the master axis initial positions of the individual motion steps. Depending on the motion law of this motion step, the decision is taken as to whether the current step is determined by a cam table or a standard profile. With the table access angle, table access or a polynomial calculation takes place accordingly to calculate the standardization value (factor) for the distance of this step. The standardization value for a cam table is between +799,999999 % and -799,999999 %, for a standard profile it is between 0 and 1. The multiplication of standardization value and distance of the current step results in a position command value which is added to the final position value of the previous motion step. Depending on the setting in the motion law of this step, the sum is processed in absolute or relative form.

If the phase-synchronous path has been activated by bit 4 of parameter "P-0-0086, Configuration word synchronous operation modes", the master axis position at the output of the electronic gearbox is additionally divided by the gear reduction (P-0-0755) and multiplied with a scaling-dependent factor. The result is differentiated and added to the position command value.

Calculating the Internal Position Command Value (Initialization)

Upon activation of the operation mode "MotionProfile with real/virtual master axis", the position command value of the drive is first initialized in terms of the following relation:

$$x_{F(\varphi L)} = \left[x_{start\_n} + H_n \times f_n(\varphi_{ZGW}) + \left(\frac{\varphi_{ZGW}}{U}\right) \times \left(\frac{MW}{2^{20}}\right) + x_V + x_{VPR} \right] \% \, IWZ$$

x_F	Position command value of slave drive (P-0-0434)
x_{start_n}	Slave axis initial position of the current motion step
H_n	Distance of the current motion step
$f_{n\ (\varphi ZGW)}$	Standardized function value of the current motion step from table access or polynomial calculation
φ_{ZGW}	Table access angle
U	Gear reduction (P-0-0755)
MW	Modulo value
x_V	Additive position command value (S-0-0048)
x_{VPR}	Additive position command value, process controller (P-0-0691)
IWZ	Modulo actual value cycle

Fig. 7-123: Initializing the Position Command Value

$$\varphi_{ZGW} = \pm \varphi_L \times \frac{G_a}{G_e} \times (1 + F) \times (1 + F_{PR}) - \varphi_V - \varphi_{VPR} + \varphi_D$$

φ_{ZGW}	Table access angle
+/-	Master drive polarity (P-0-0108)
φ_L	Resulting master axis position (P-0-0775)
G_a	Master drive gear output revolutions (P-0-0157)
G_e	Master drive gear input revolutions (P-0-0156)
F	Gear ratio fine adjustment (P-0-0083)
F_{PR}	Gear ratio fine adjustment, process controller (P-0-0694)
φ_V	Angle offset begin of table (P-0-0061)
φ_{VPR}	Angle offset begin of table, process controller (P-0-0695)

Fig. 7-124: Determining the Table Access Angle

The slave axis initial position of the current motion step is supposed to be zero, when relative processing of the position data (bit 10 = 1) has been set in the control word for synchronization modes (P-0-0088). Otherwise, the slave axis initial position of the current motion step is the sum of the slave axis initial position (P-0-0701) and the distances up to the current step.

The cyclic calculation of the position command value takes place according to the above formula, too. The slave axis initial position of the respective current step is determined by the end position of the previous step.

NOTICE

With the operation mode activated, differences, that later on will be added again, are processed in the electronic gearbox. Therefore, changes in the electronic gearbox do not cause position command value jumps. Velocity jumps, however, can occur and the absolute position reference, established when activating the operation mode, is lost.

Synchronization

See "Basic Functions of the Synchronization Modes"

Notes on Commissioning and Parameterization

General Parameterization

Parameterizing the Angle Offset

The parameter "P-0-0061, Angle offset begin of table" allows shifting the table access angle. To avoid great position jumps when changing the table access angle, a new value for the parameter P-0-0061 does not immediately become effective. Starting with the current value, a ramp-like approximation to the new value is carried out. The approximation is carried out over the shortest possible distance. The gradient of the ramp is set in parameter "P-0-0158, Angle offset change rate".

> ☞ With "P-0-0158, Angle offset change rate" equal zero, the angle offset is carried out in one step (immediately effective).

Dynamic Angle Offset

Parameter "P-0-0085, Dynamic angle offset" can be used for compensating a lag error in operation with lag distance, if the mechanical system does not allow lagless operation.

With dynamic angle offset, the table access angle is offset depending on the velocity so that the internal master axis position can be calculated according to the formula below:

$$\varphi_{\text{effective internal master axis pos.}} = \varphi_{\text{internal master axis pos.}} + \frac{v_{\text{internal master axis velocity}}}{\text{Kv-factor}} \times \text{dynam. angle offset}$$

Internal	After electronic gearbox (P-0-0156/P-0-0157) and fine adjustment (P-0-0083)

Fig. 7-125: Effective Internal Master Axis Position Taking the Dynamic Angle Offset Into Account

> ☞ The master axis velocity used is generated on the timebase T_A = communication cycle time so that a moving average filter results with $T_A = N \times T_{position}$.

Switching the Electronic Gearbox

When bit 1 (gear switching) has been set in parameter "P-0-0086, Configuration word synchronous operation modes", any change, with active operation mode, in the electronic gearbox (P-0-0156 and P-0-0157) will only take effect when a set is switched.

Gear Reduction (Cross Cutter Function)

By activating the phase-synchronous path (P-0-0086, bit 4 = 1), the master axis position at the output of the electronic gearbox is additionally divided by the gear reduction (P-0-0755) and multiplied with a scaling-dependent factor. The result is differentiated and added to the position command value.

Parameterizing the MotionProfile

Number of Motion Steps

In the parameters "P-0-0703, " and "P-0-0710, ", set the number of motion steps of which the sequence of motion consists. A maximum of 8 motion steps can be set per motion profile.

Absolute or Relative Motion Step

In the control word for synchronization modes (P-0-0088, bit 10), set whether the motion is to have absolute or relative position reference. Only with absolute position reference is the value in "P-0-0701, Motion step 1, slave axis initial position" taken into account to establish the position reference of the motion profile during synchronization.

Master axis velocity

Via the parameters "P-0-0704, Master axis velocity, set 0" or "P-0-0711, Master axis velocity, set 1", preset the master axis velocity required for calculating specific motion steps.

☞ Set the master axis velocity after the electronic gearbox.

Defining a Step

To specify the individual steps, there are 4 list parameters available for each of the two sets:

- P-0-0705, List of master axis initial positions, set 0
- P-0-0706, List of motion laws, set 0
- P-0-0707, List of distances, set 0
- P-0-0708, List of slave axis velocities, set 0
- P-0-0712, List of master axis initial positions, set 1
- P-0-0713, List of motion laws, set 1
- P-0-0714, List of distances, set 1
- P-0-0715, List of slave axis velocities, set 1

A motion step is limited by a master axis initial position and a master axis end position. The master axis end position is determined by the master axis initial position of the following motion step or by 360 degrees.

The slave axis velocity can be preset in the case of certain standard profiles or is preset by the distance and the profile.

☞ The positions of the data in the lists define to which step the values belong. For example, the data at the second position of the lists for master axis initial position, mode, distance and slave axis velocity define the second motion step.

This means that the number of elements defined in the lists as must be at least the number of motion steps.

Standard Profiles

Different standard profiles or a cam table can be defined as the motion law of a step.

The following motion laws are available:

- Rest in rest (R-R)
- Rest in velocity (R-V)
- Velocity in rest (V-R)
- Constant velocity (V)
- Velocity in velocity (V-V)
- Cam Table

Rest in Rest

For the profile "rest in rest", there are three profiles available. These profiles are characterized by the fact that velocity and acceleration are zero at the start and at the end of the motion. You can choose between the standardized motion laws "5th order polynomial" and "inclined sine curve". The third profile "rest in rest with limited velocity" is realized in a 5th order polynomial. For this profile the indication of a maximum velocity of the slave axis is required.

In addition, these profiles are defined by the distance and the master axis range.

The following relation applies to the profile "5th order polynomial":

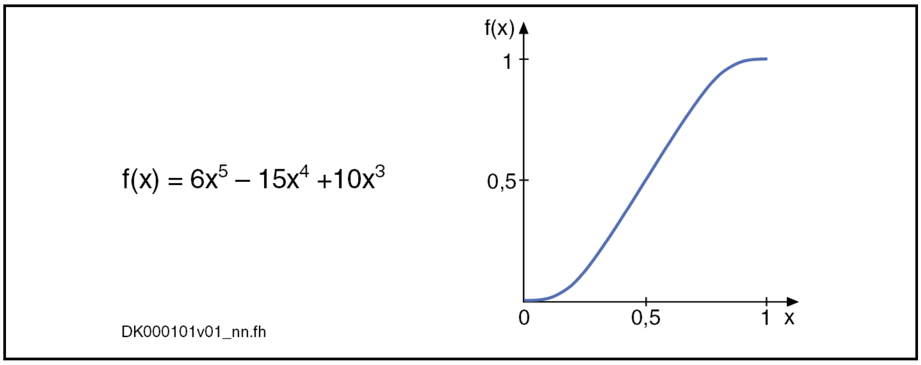


Fig. 7-126: Profile "5th Order Polynomial"

The following relation applies to the profile "inclined sine curve":

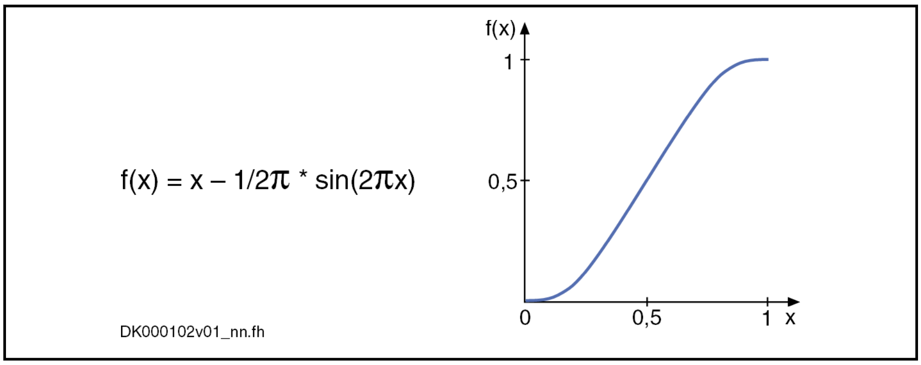


Fig. 7-127: Profile "Inclined Sine Curve"

> You should prefer the profile with inclined sine curve for mechanical systems susceptible to oscillation, as the jerk curve is better. The occurring maximum values for velocity and acceleration, however, are higher.

For the profile "rest in rest with limited velocity" the maximum occurring slave axis velocity is calculated from the indicated values of master axis velocity, master axis distance and master axis range. If this velocity is lower than the indicated maximum slave axis velocity, the above-mentioned 5th order polynomial is used. The maximum velocity is parameterized in the list of the slave axis velocity. If the maximum slave axis velocity would be exceeded, this step would be divided into three individual steps "rest in velocity", "constant velocity" and "velocity in rest". During the middle range the axis moves with the maximum slave axis velocity.

The figure below illustrates the velocity curves of a simple 5th order polynomial (black) and of the profile "rest in rest with limited velocity" (blue) for identical values of axis distance, master axis range and master axis velocity.

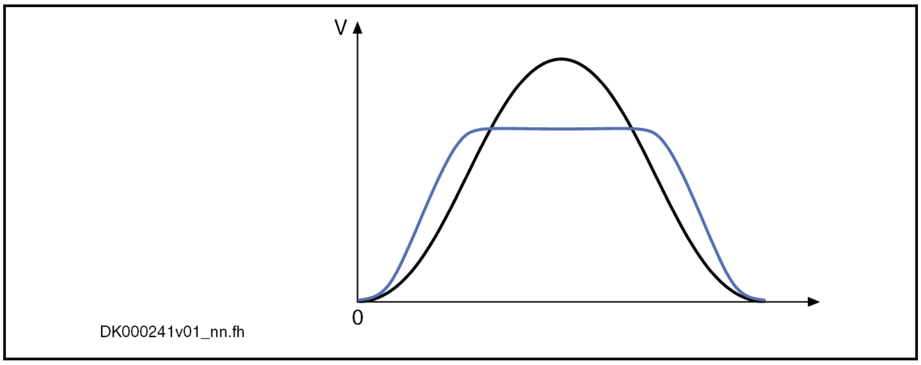


Fig. 7-128: Profile "Rest in Rest with Limited Velocity" → Curve of the Slave Axis Velocity

In case it is not possible to divide this step into three individual steps, maybe due to the distance being to large, on examination of this profile, the respective error number (81 … 88, for significance, please see description of diagnostic message F2004) is indicated in the diagnostic parameter of the MotionProfile set in question.

If the profile "rest in rest" is divided into the three steps "rest in velocity", "constant velocity" and "velocity in rest", acceleration values will occur in the first and the last partial range which are significantly higher than for the profile with the simple 5th order polynomial. The acceleration values are not monitored!

Rest in Velocity

The profile "rest in velocity" is used for transition from standstill to a certain velocity. The velocity and the acceleration at the beginning of the profile are zero. At the end of the profile, the slave axis velocity preset by the corresponding parameter has been reached. The acceleration at the end of the profile is zero.

The drive calculates the coefficients of this polynomial from the following values preset for this motion step:

- Master axis range
- Distance
- Slave axis velocity
- Master axis velocity

The profile is calculated with a 5th order polynomial:

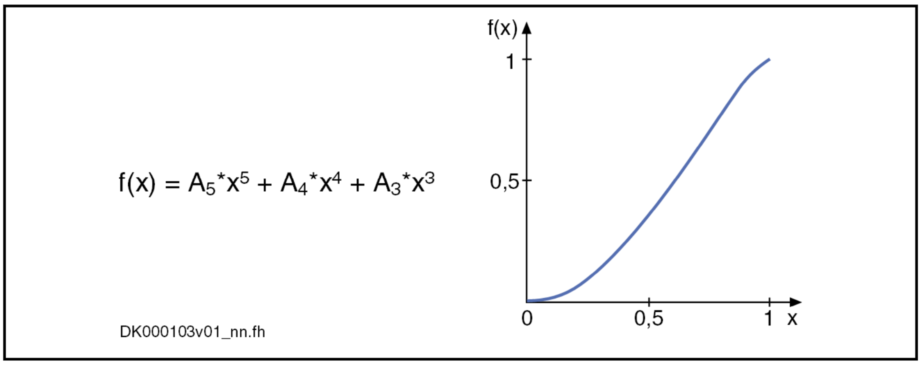


Fig. 7-129: Profile "Rest in Velocity"

> The function curve contains a reversal point, when the standardized velocity $v_{standard}$ is not between the values 1.66 and 2.5.

The standardized velocity can be calculated with the following formula, the master axis range being the difference of two master axis initial positions:

$$v_{Standard} = \frac{v_{Slave\ axis} \times \text{Master axis range}}{v_{Master\ axis} \times \text{Distance}}$$

Fig. 7-130: Calculating the Standardized Velocity

☞ The distance belonging to this motion step mustn't be zero!

Velocity in Rest

The profile "velocity in rest" is used for transition from a defined velocity to standstill. The velocity at the beginning of the profile must correspond to the slave axis velocity set in the parameter. At the end of the profile the velocity is zero. The acceleration at the beginning and at the end of the profile is zero.

The path traveled with this motion profile is defined by the distance for this motion step.

The drive calculates the coefficients of this polynomial from the following values preset for this motion step:

- Master axis range
- Distance
- Slave axis velocity
- Master axis velocity

The profile is calculated with a 5th order polynomial:

$$f(x) = A_5{*}x^5 + A_4{*}x^4 + A_3{*}x^3 + A_1{*}x$$

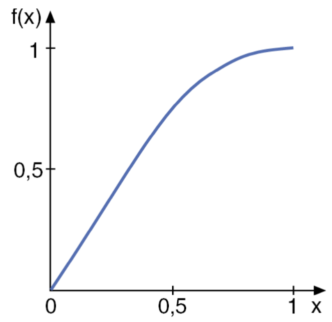


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Fig. 7-131: Profile "Velocity in Rest"

☞ The function curve contains a reversal point, when the standardized velocity $v_{standard}$ is not between the values 1.66 and 2.5.

The standardized velocity can be calculated with the following formula, the master axis range being the difference of two master axis initial positions:

$$v_{Standard} = \frac{v_{Slave\ axis} \times \text{Master axis range}}{v_{Master\ axis} \times \text{Distance}}$$

Fig. 7-132: Calculating the Standardized Velocity

☞ The distance belonging to this motion step mustn't be zero!

Constant Velocity

The profile "constant velocity" of this motion step is a straight line. The velocity within this step is constant. The path traveled is defined by the distance for this motion step.

The profile results from the following formula (in standardized form):

$$f(x) = x$$

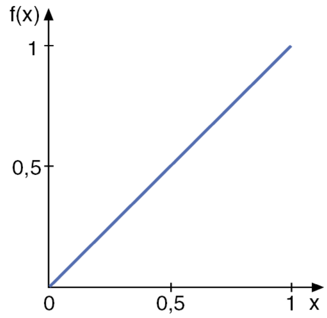

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Fig. 7-133: Profile "Constant Velocity"

The slave axis velocity is determined from the following values preset for this motion step:

- Master axis range
- Distance
- Master axis velocity

$$v_{\text{Slave axis}} = \frac{\text{Distance} \times v_{\text{Master axis}}}{\text{Master axis range}}$$

Fig. 7-134: Calculating the Slave Axis Velocity

It is not necessary to enter a value for the slave axis velocity. For the validation check, a value is calculated in the drive according to the above formula. The calculated value can be read from the list parameter for the slave axis velocities.

Velocity in Velocity (2 Velocities)

The profile "velocity in velocity" is used for transition from one slave axis velocity to a different slave axis velocity. The velocity at the beginning of the profile must correspond to the indicated slave axis velocity. The velocity at the end of the profile is determined by the velocity parameter of the subsequent motion step. The acceleration at the beginning and at the end of the profile is zero.

The profile is calculated with a 5th order polynomial:

$$f(x) = A_5{*}x^5 + A_4{*}x^4 + A_3{*}x^3 + A_1{*}x$$

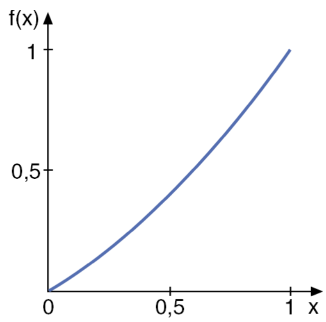

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Fig. 7-135: Profile "Velocity in Velocity"

The drive calculates the coefficients of this polynomial from the following values preset for this motion step:

- Master axis range
- Distance
- Master axis velocity

- 2 slave axis velocities

> The function curve contains a reversal point, when the pair of values $v_{standard0}$ and $v_{standard1}$ is not in the range that is defined by the functions f1(x) = (5 – 2x)/3 and f2(x) = (5 – 3x)/2. The range is marked in the figure below.

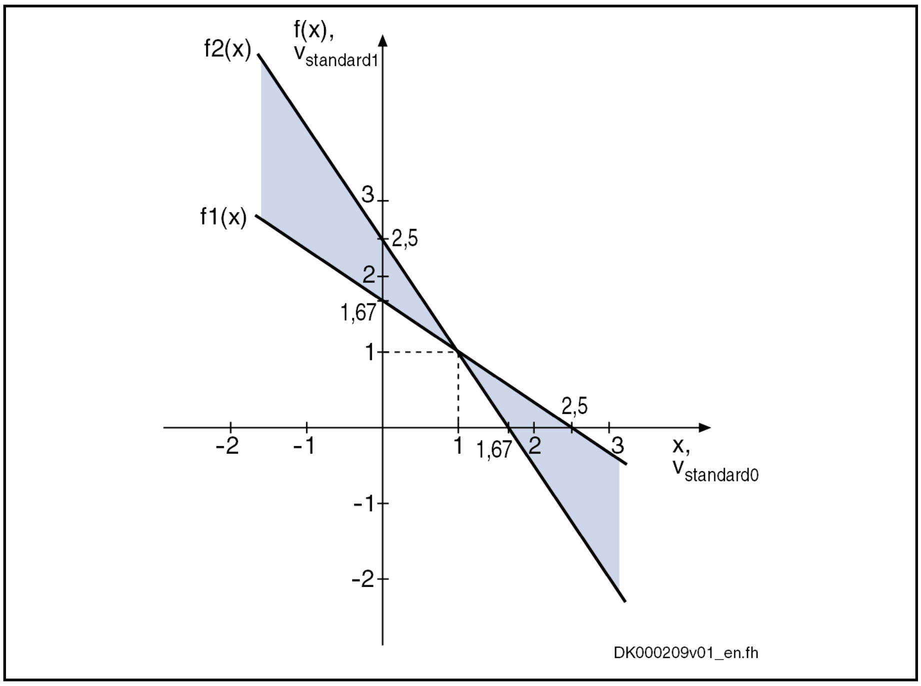


Fig. 7-136: Advantageous Range for the Pair of Values v_standard0 and v_standard1

$$v_{Standard0} = \frac{v_{BS0} \times \text{Master axis range}}{v_{\text{Master axis}} \times \text{Distance}}$$

$$v_{Standard1} = \frac{v_{BS1} \times \text{Master axis range}}{v_{\text{Master axis}} \times \text{Distance}}$$

v_{BS0}	Slave axis velocity i
v_{BS1}	Slave axis velocity i+1
Master axis range	Difference of two master axis initial positions

Fig. 7-137: Calculating the Standardized Velocities v_standard0 and v_standard1

> The distance belonging to this motion step mustn't be zero!

Cam Table

When you select a cam table via "P-0-0706, List of motion laws, set 0" or "P-0-0713, List of motion laws, set 1", the selected cam table is used instead of a motion profile.

The value selected from "P-0-0705, List of master axis initial positions, set 0" or "P-0-0712, List of master axis initial positions, set 1" determines as of which master axis position a profile is processed. This master axis initial position determines the position of the 1st table element, the master axis end position determines the position of the last table element. The master axis end position is determined by the master axis initial position of the following motion step or by 360 degrees for the last motion step.

The number of data points of a table is variable. The table length results from the parameterized actual length.

The data point distance is calculated according to the formula below:

$$\text{Data point distance} = (\text{master axis end position} - \text{master axis initial position}) \times 2^{P\text{-}0\text{-}0084} / 360 / (n-1)$$

P-0-0084 Number of bits per master axis revolution
n Number of table elements

Fig. 7-138: Calculating the Data Point Distance (in Increments)

The table values can be between –799.999999 % and +799.999999 %.

The first table value has to be zero. The value of the last table element is arbitrary.

For one table sequence the traveled path results from the product of the distance and the last table element.

Cubic spline interpolation is carried out between the data points.

> The format of the cam table in the MotionProfile must be the "new" cam table format for which the last table value corresponds to the value at 360 degrees (corresponding bit in parameter P-0-0086, bit 8...15 = 1).

See also operation mode "Electronic Cam with Real/Virtual Master Axis"

Changing the MotionProfile

A change in the data of a motion step normally requires changes in other motion steps. An individual change therefore mustn't be immediately applied. When the operation mode is active, position command value jumps might occur.

When the master axis velocity is changed, it is also necessary, for motion steps with contained velocity, to recalculate the polynomial coefficients.

To allow changes while the operation mode is active, there are two sets with a maximum of 8 motion steps. The use of the second data set is selected by bit 9 of parameter "P-0-0088, Control word synchronization modes".

In the control word, make the setting to determine which one of the two sets is to be active. For switching, you have to change bit 9; switching takes place when the position set in parameter "P-0-0700, MotionProfile, master axis switching position" is passed.

The active set is displayed in bit 3 of "P-0-0089, Status word synchronization modes".

> In case a profile is processed in relative form, the switch angle must comply with the master axis initial position of a motion step.

MotionProfile Check

To check a MotionProfile you can query information on both sets from the status word (P-0-0089). After a set has been changed, the complete set is checked. The check was carried out when the "profile check carried out" bit has been set for the selected set. The status word also shows whether the check was successful.

When switching to a set, for which the profile check has not been carried out successfully, takes place with active operation mode, the message "F2004 Error in MotionProfile" (class 1 diagnostics error) is generated. This error message is also generated when the active set, with active operation mode, is changed in such a way that the profile check is unsuccessful.

There are the following validation checks for the sequence of motion:

- The master axis initial positions of the motion steps used must increase and be smaller than 360 degrees.
- "Constant velocity" motion law

  → The motion profile is defined by master axis range and distance. The velocity is calculated and possibly compared to preset velocities of previous and following step.
- "Rest in velocity" motion law

  → The following step mustn't start with a rest position. If the following motion step is "velocity in rest", "constant velocity" or "velocity in velocity", the velocity values have to match. The distance must not be zero.
- "Velocity in rest" motion law

  → The previous step mustn't end with a rest position. If the previous motion step is "rest in velocity" or "constant velocity", the velocity values have to match. The distance must not be zero.
- "Velocity in velocity" motion law

  → The previous step mustn't end with a rest position. If the previous motion step is "rest in velocity" or "constant velocity", the velocity values have to match. The distance must not be zero.
- The first value of a cam table must be zero.
- In the case of absolute position scaling and absolute MotionProfile, the sum of travel distances must be zero. The travel distances are to be taken from the distance values or, for a motion step with table, from the product of final table value and distance.
- In the case of modulo position scaling and absolute MotionProfile, the sum of travel distances must be zero or a multiple of the modulo value (S-0-0103). The travel distances of the individual steps are determined like in the case of absolute position scaling.

The profile is checked after every change. When the "profile check carried out" bit has been set for a set and the "without error" bit has not been set, an extended diagnosis can be read in the respective diagnostic parameter (P-0-0702 or P-0-0709).

☞ When switching between relative and absolute processing of the motion step takes place (P-0-0088, bit 10), there is no profile check carried out.

This can cause problems when switching from relative to absolute processing takes place after the definition of the motion step.

Example of a Motion Profile

The figure below illustrates a sequence of motion consisting of 5 steps.

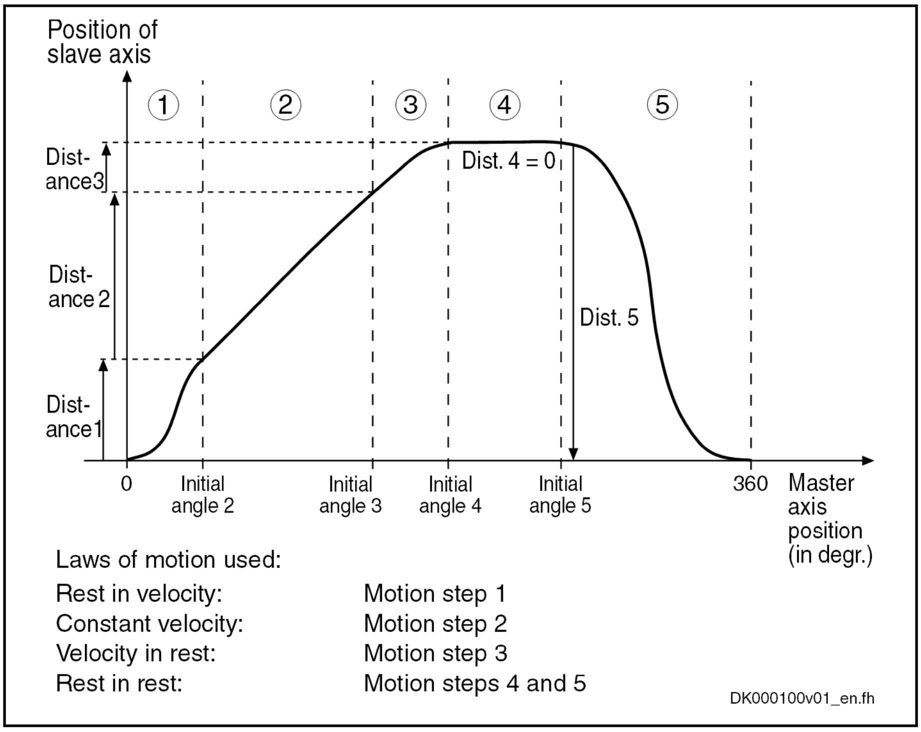


Fig. 7-139: Example of a MotionProfile with 5 Motion Steps

Commissioning Summary

The figure below illustrates the basic sequence of commissioning.

Operation modes

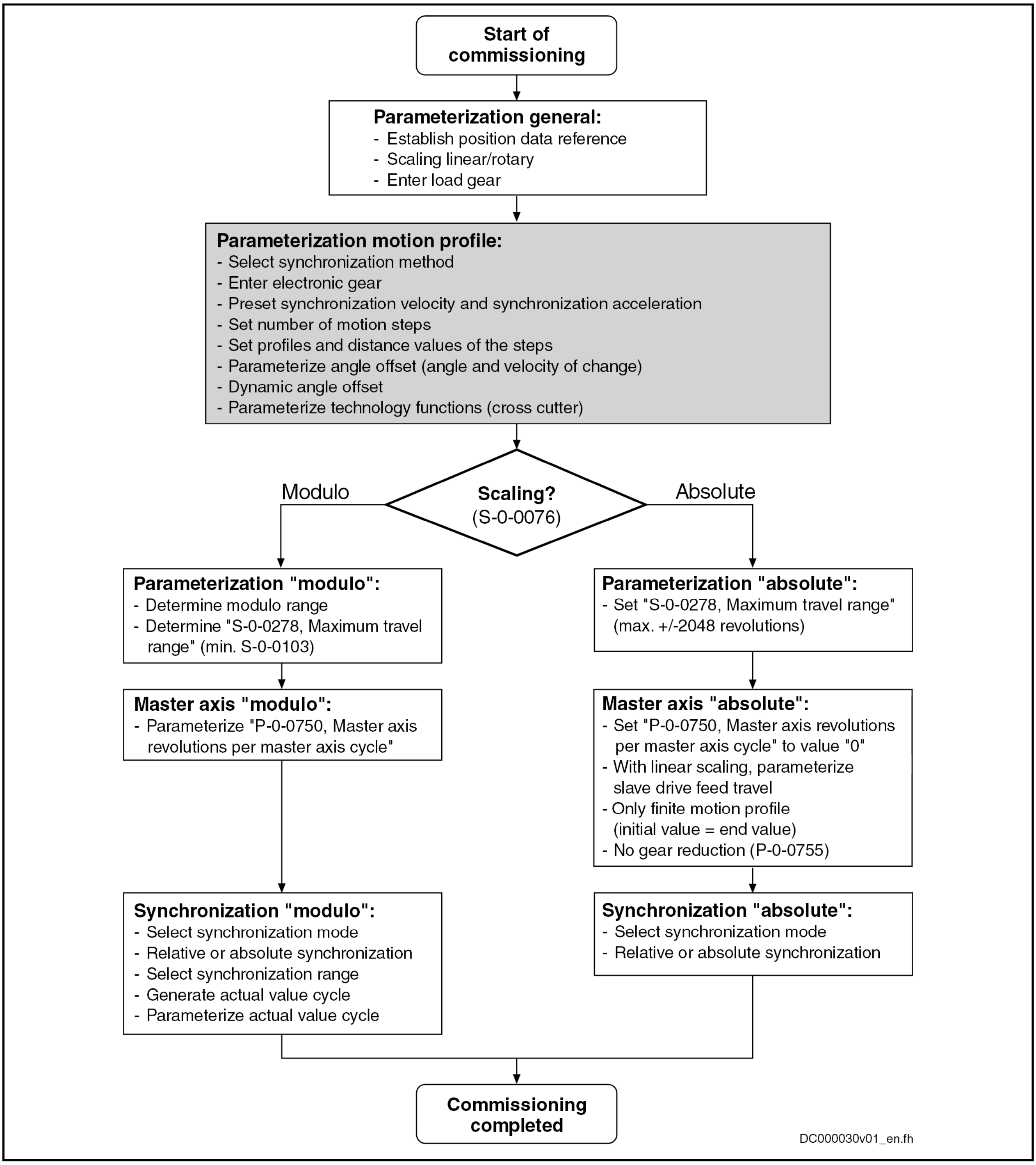


Fig. 7-140: Overview of Commissioning Steps for Motion Profile

Diagnostic and Status Messages

Diagnostic Status Messages

The following diagnostic status messages are displayed in normal operation of the operation mode (drive enabled, "AF"):

- A0136 MotionProfile, encoder 1, virtual master axis
- A0137 MotionProfile, encoder 2, virtual master axis

- A0138 MotionProfile, encoder 2, real master axis
- A0139 MotionProfile, encoder 1, real master axis
- A0140 MotionProfile lagless, encoder 1, virtual master axis
- A0141 MotionProfile lagless, encoder 2, virtual master axis
- A0142 MotionProfile lagless, encoder 1, real master axis
- A0143 MotionProfile lagless, encoder 2, real master axis
- A0163 Position synchronization

Error Messages and Warnings

Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operation mode:

- F2002 Assignment of encoder for synchronization is not allowed

  → When activating a synchronous operation mode with outer position control loop ("MotionProfile", "cam" or "phase synchronization"), a check is run to find out whether "P-0-0753, Position actual value in actual value cycle" has been initialized to the currently effective control encoder. If this is not the case, an error is triggered.
- F2003 Motion step skipped

  → This error message is displayed in the event that the master axis velocity is so high that a motion step is skipped during processing of the profile. This is the case when the product from master axis velocity and position controller cycle time (see Parameter Description "P-0-0556, Config word of axis controller") becomes larger than the master axis range of a step.
- F2004 Error in MotionProfile

  → This message is generated, if a profile that has not passed the validation checks is activated with the drive having been enabled.

If a discrepancy is detected during the validation check, its possible cause is encoded by means of an error number (for its significance, see description of diagnostic message F2004) in one of the following diagnostic parameters:

- P-0-0702, MotionProfile, diagnosis, set 0
- P-0-0709, MotionProfile, diagnosis, set 1

Status Bits

There are also several status messages specific to operation mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word synchronization modes").

Position Controller Status

The status display via the control encoder and for lagless operation or operation with lag error takes place in parameter "S-0-0521, Axis status word".

8 Extended Axis Functions

8.1 Safety Instructions

⚠ WARNING **Dangerous movements! Danger to life, risk of injury, serious injury or property damage!**

- Keep free and clear of the ranges of motion of machines and moving machine parts.
- Prevent personnel from accidentally entering the machine’s range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

8.2 Availability of the Extended Axis Functions

For an overview that illustrates in which base or functional packages the respective extended axis function is available, see chapter "Overview of Functions/Functional Packages, Availability of the Extended Axis Functions".

8.3 Drive Halt

8.3.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The "Drive Halt" function is used to shut down an axis with defined acceleration and defined jerk.

In the default case, Drive Halt is executed as a quick stop in position control or velocity control. Position control is activated when one of the operation modes (S-0-0032 ...) with position control is defined (including internal PLC operation modes). Otherwise, velocity control is active.

With the Drive Halt configuration (P-0-0558, bit 1, bit 2), the type of control can also be freely selected.

- Bit 1 = 1, bit 2 = 1: Position Control
- Bit 1 = 1, bit 2 = 0: Velocity Control

With the "Drive Halt" configuration (P-0-0558, bit 0 = 1), it is possible to switch to the "operational stop" function. Then the operation modes "velocity control", "drive-internal interpolation", "drive-controlled positioning" and "positioning block" are stopped internally with Vcmd = 0. After "Drive Halt" has been removed, motion is active again.

The adjustable position command value delay in position cycle times (P-0-0456) is a maximum of 32 cycles.

☞ In addition to the "Drive Halt" function, there is an operational stop for the operation modes "drive-controlled positioning" and "drive-internal interpolation". This function, however, has its own control signal.

Features

- Activation using the "halt bit" of the master communication (see "Device Control and State Machines")
- Active operation mode interrupted; drive remains in control (after setting the "halt bit" the interrupted operation mode is continued)
- Quick stop in position control

  → Shutdown with acceleration (S-0-0372) and jerk limit values (S-0-0349) in position control
- Quick stop in velocity control

  → Shutdown with acceleration (S-0-0372) and jerk limit values (S-0-0349) in velocity control
- If the Drive Halt acceleration bipolar (S-0-0372) is set to "0", "S-0-0138, Bipolar acceleration limit value" is effective at shutdown.
- Acknowledgement of "Drive Halt" in P-0-0115

Pertinent Parameters

- S-0-0124, Standstill window
- S-0-0349, Bipolar jerk limit
- S-0-0372, Drive Halt acceleration bipolar
- S-0-0138, Bipolar acceleration limit value
- P-0-0115, Device control: Status word
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0558, Drive Halt configuration

8.3.2 Functional Description

Quick stop

When the "Drive Halt" function is activated, the drive no longer follows the command values of the active operation mode, but automatically shuts down while maintaining a parameterized acceleration.

Activating the "Drive Halt" Function

The "Drive halt" function is activated by:

- Disabling the Drive Halt bit in control word of master communication (e.g. with servos Bit 13 in "S-0-0134, Master control word"; see "Device Control and State Machines")
- Interrupting a drive control command (e.g. "drive-controlled homing procedure")

Returning to the Previously Active Operation Mode

The operation mode active before and still selected becomes active again, when the Drive Halt bit is set again in the control word of the master communication.

The kind of shutdown, in the case of "Drive Halt", depends on the operation mode active before.

Quick stop in position control

In position control, shutdown is carried out using the the deceleration in "S-0-0372, Drive Halt acceleration bipolar" and the jerk in "S-0-0349, Bipolar jerk limit".

☞ If the content of "S-0-0372, Drive Halt acceleration bipolar" equals "0", deceleration is carried out by means of the value in "S-0-0138, Bipolar acceleration limit value".

☞ The value from parameter "P-0-0109, Torque/force peak limit" is used for torque/force limitation.

When Drive Halt is started from an operation mode with position command value delay, the delay is activated with Drive Halt, too.

The position command value can be delayed by a maximum of 32 position clocks after the fine interpolator, before it is transmitted to the position controller. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position clocks is set with the position command value delay (P-0-0456). The position command value generator without delay (P-0-0457) is entered in a ring buffer and then the position command value with delay is applied to the position command value of controller (P-0-0434).

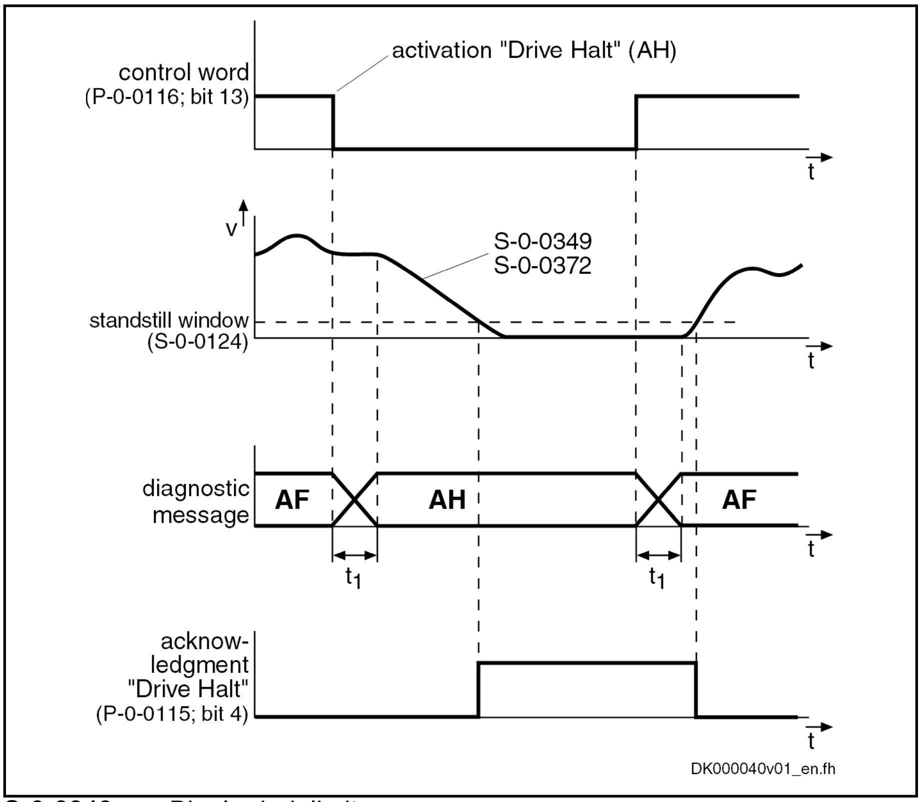
Position-controlled shutdown is carried out with position control with lag error, if an operation mode that also contained position control with lag error was active before. If not, the function is carried out with lagless position control.

Quick Stop in Velocity Control

When the control mode velocity has been set, shutdown in velocity control takes place using the value in parameter "S-0-0372, Drive Halt acceleration bipolar" and the jerk in "S-0-0349, Bipolar jerk limit".

☞ If the content of "S-0-0372, Drive Halt acceleration bipolar" equals "0", deceleration is carried out by means of the value in "S-0-0138, Bipolar acceleration limit value".

☞ The value from parameter "P-0-0109, Torque/force peak limit" is used for torque/force limitation.



S-0-0349	Bipolar jerk limit
S-0-0372	Drive Halt acceleration bipolar

Fig. 8-1: "Drive Halt" Principle with Quick Stop

Operational Stop

The "Drive Halt" function as an operational stop is activated by disabling the Drive Halt bit in control word of the control communication (e.g. with servos bit 13 in "S-0-0134, Master control word")

If in the Drive Halt configuration the operational stop is selected, "P-0-0558, Drive Halt configuration, bit 0 = 1", the active operation mode is maintained. It is shut down with command velocity = "0". For shutdown, the parameters of the active operation mode are used. After Drive Halt has been removed, the operation mode and the axis motion, if applicable, continue.

This only applies to the operation modes "velocity control", "drive-internal interpolation", "drive-controlled positioning" and "positioning block mode".

8.3.3 Notes on Commissioning

Diagnostic and Status Messages

The activated "Drive Halt" function is displayed as described below:

- "AH" appears on the control panel display at the front of the device
- Entry of "C00A0010" in the parameter "S-0-0390, Diagnostic message number"
- "A0010 Drive HALT" is entered in parameter "S-0-0095, Diagnostic message"
- In the bit "status of command value processing" in the status word of the master communication (e.g. with servos: bit 3 = 0 in "S-0-0135, Drive status word")

☞ To receive, in the firmware MPx-18, the contents of the S-0-0390 compatible with the firmware MPx-17 / MPx-16, the diagnosis output can be switched with the parameter P-0-0006.

Acknowledging "Drive Halt" The acknowledgment is carried out when the actual velocity falls below the threshold defined in the parameter "S-0-0124, Standstill window". Bit 4 (Drive Halt acknowledgment) is then set in the drive in parameter "P-0-0115, Device control: Status word".

8.4 Error reactions

8.4.1 Overview of Error Reactions

Depending on the operation mode that is used and some parameter settings, the drive controller carries out monitoring functions. An error message is generated by the drive controller, if a state is detected that no longer allows correct operation.

Errors are classified in error classes. The error class is represented by the first two digits of the diagnostic message number.

See also "Terms, Basic Principles"

See also "Diagnostic System"

If the drive controller is in control (drive enable was set) and an error occurs, the drive controller automatically starts a drive error reaction.

This drive error reaction depends on:

- The error class of the error occurred and
- The settings of the following parameters:
  - P-0-0117, Activation of control unit reaction on error
  - P-0-0118, Power supply, configuration
  - P-0-0119, Best possible deceleration

☞ At the end of each error reaction, the drive goes torque-free. Power off depends on the setting in P-0-0118!

Error Classes There are different error classes with increasing priority:

Diagnostics Number and Error class	Control unit reaction according to "P-0-0117, Activation of control unit reaction on error"	Power supply switched off according to "P-0-0118, Power supply, configuration"	Drive-side error reaction according to "P-0-0119, Best possible deceleration"
F2xxx Non-fatal error	■	■	■
F28xx Non-fatal error	■	General shutdown of power supply, because this concerns errors of the supply unit of the converter	■
F3xxx Non-fatal Safety technology error	-	■	■
F4xxx Error of master communication	-	■	■

Diagnostics Number and Error class	Control unit reaction according to "P-0-0117, Activation of control unit reaction on error"	Power supply switched off according to "P-0-0118, Power supply, configuration"	Drive-side error reaction according to "P-0-0119, Best possible deceleration"
F6xxx Emergency stop error	-	■	■
F7xxx Safety technology error	-	■	■ At the end of each F7 error reaction, the drive goes torque-free.
F8xxx Fatal error	-	■	■
F83xx Fatal error of safety technolo-gy	-	■	■
F9xxx Fatal system error	-	■	Always torque disable

Tab. 8-1: Error Classes and Drive Reaction

☞ The error class defines the drive behavior in the case of error. The "fatal system error" (E-xxxx) has the highest priority.

8.4.2 Best possible deceleration

Brief Description

The error reaction "best possible deceleration", which can be set in "P-0-0119, Best possible deceleration", is carried out automatically in the case of the following states:

- Non-fatal errors (F2xxx)
- Non-fatal safety technology errors (F3xxx)
- Interface errors (F4xxx)
- Drive enable is removed
- Drive-controlled transition to the special mode standstill SS1ES/SS1
- Travel range errors (F6xxx)
- Errors of safety technology (F7xxx)
- Fatal errors (F8xxx), if possible
- Fatal warnings (E8xxx)

One of the following reactions for "best possible deceleration" can be set in P-0-0119:

- Velocity command value reset (emergency stop)
- Velocity command value reset with ramp and filter (emergency stop)
- Velocity command value reset with ramp and filter (quick stop)
- Return motion
- Emergency stop by means of motor winding short circuit
- Torque disable

See also parameter description "P-0-0119, Best possible deceleration"

In the case of fatal system errors (F9xxx), the setting in P-0-0119 is without effect; the drive immediately goes torque-free. Shut-down on the drive side is no longer possible!

Pertinent Parameters

- S-0-0138, Bipolar acceleration limit value
- S-0-0273, Maximum drive off delay time
- S-0-0349, Bipolar jerk limit
- S-0-0372, Drive Halt acceleration bipolar
- S-0-0429, Emergency halt deceleration

- P-0-0045, Control word of current controller
- P-0-0055, Return distance
- P-0-0056, Return velocity
- P-0-0057, Return acceleration
- P-0-0058, Return jerk
- P-0-0109, Torque/force peak limit
- P-0-0119, Best possible deceleration
- P-0-0525, Holding brake control word
- P-0-0569, Maximum stator frequency slope

Intended Use and Parameterization Options

Parameterization options and intended use of best possible deceleration.

Extended Axis Functions

Deceleration type	Purpose	Parameterizable deceleration in reaction to		
		- Non-fatal errors F2xxx - Non-fatal safety technology errors F3xxx - Interface errors (F4xxx) - Fatal warnings E83xx, E8034, E8058*4) - Removal of drive enable*5) - Drive-contr. transition to special mode standstill SS1ES/SS1	- Travel range errors F6xxx, - Safety technology errors F7xxx (as of MPx-18VRS)	- Fatal errors F8xxx *3)
Emergency stop Velocity command value reset	Fastest possible deceleration	□□□0$_{hex}$	□□0□$_{hex}$	Not possible
Emergency stop Velocity command value reset with ramp and filter	Deceleration preventing damage to mechanical system while maintaining emergency stop properties	□□□4$_{hex}$	□□4□$_{hex}$	Not possible
Quick stop Velocity command value reset with ramp and filter	Deceleration preventing damage to mechanical system while maintaining quick stop properties	□□□2$_{hex}$	Not possible	Not possible
The **return motion** as of MPx-18VRS is available in connection with expansion package "SRV"	For targeted return motion in case of an error	□□□3$_{hex}$	Not possible	Not possible
Emergency stop by means of motor winding short-circuit*1)	Deceleration of the axis in case of fatal errors where control is not possible	Not possible	Not possible	□1□□$_{hex}$ *2)
Torque disable	For slave axes provided they are bonded to the master axis	□□□1$_{hex}$	□□1□$_{hex}$	Torque disable even if □1□□$_{hex}$ has been set

1) The braking effect cannot be controlled and, where appropriate, is lower in case of non-fatal errors.
2) □0□□$_{hex}$ leads to torque disable
3) In case of F8000, F8060, F8067 and F83xx, deceleration by means of motor winding short-circuit is **not** possible.
4) Only possible with return motion
5) Not possible with return motion

Tab. 8-2: Options for parameterization

☞ In the case of the fatal warnings E8029, E8030, E8042, E8044 and in the case of quick stop with probe detection (AR), the drive is decelerated with the ramp "S-0-0138, Bipolar acceleration limit value", when □□4□ $_{hex}$ has been parameterized in the parameter **P-0-0119**.

With the parameterization **P-0-0119** □□■□ $_{hex}$ ≠ 4_{hex}, the drive reacts with velocity command value reset (vCmd = 0) without taking an acceleration limitation into account. The available torque is determined by the parameter "P-0-0109, Torque/force peak limit".

Effective Limitation Parameters

Depending on the configured best possible deceleration, different limitation parameters take effect in the case of error.

Deceleration type	Torque/ force limit	Acceleration limit values				Jerk limit values	
	P-0-0109	S-0-0138	S-0-0429	S-0-0372	P-0-0057	S-0-0349	P-0-0058
Emergency stop Velocity command value reset	■	no acceleration limitation active				no jerk limitation active	
Emergency stop Velocity command value reset with ramp and filter	■	■	■	-	-	■[1]	-
Quick stop Velocity command value reset with ramp and filter	■	■	-	■	-	■[2]	-
Return motion as of MPx-18VRS	■	-			■	-	■[3)]

Emergency stop by means of motor winding short circuit	no limitations active		-
Torque enable	**Servo brake:** Friction torque of holding brake **Main spindle brake:** Not defined **without motor holding brake:** Not defined	no acceleration limitation active	no jerk limitation active

1) Calculation of the filter time constants from S-0-0349 and S-0-0429; if S-0-0429 = 0, S-0-0138 is used.
2) Calculation of the filter time constants from S-0-0349 and S-0-0372; if S-0-0372 = 0, S-0-0138 is used.
3) Calculation of the filter time constants from P-0-0057 and P-0-0058.

S-0-0138 Bipolar acceleration limit value
S-0-0349 Bipolar jerk limit value
S-0-0372 Emergency stop deceleration
S-0-0429 Emergency halt deceleration
P-0-0057 Return acceleration
P-0-0058 Return jerk
P-0-0109 Peak torque/force limit

Time Flow of the Error Reaction

Time Flow with Motor Holding Brake Available

The time flow of the error reaction and of the output stage release in the case of velocity command value reset and with a motor holding brake available is described in the section "Functional Description: Error Situation 1" under "Operating Behavior of the Motor Holding Brake".

The activation and function of the motor holding brake depends on the setting in parameter "P-0-0525, Holding brake control word".

See also "Motor Holding Brake"

Deceleration in V/Hz [U/f] Operation

In open-loop-controlled U/f operation, deceleration by means of "P-0-0109, Torque/force peak limit" only takes place, when the stall protection controller has been activated (see "P-0-0045, Control word of current controller").

> ☞ Deceleration takes place taking the delay entered in "P-0-0569, Maximum stator frequency slope" into account.

Velocity command value reset (emergency stop)

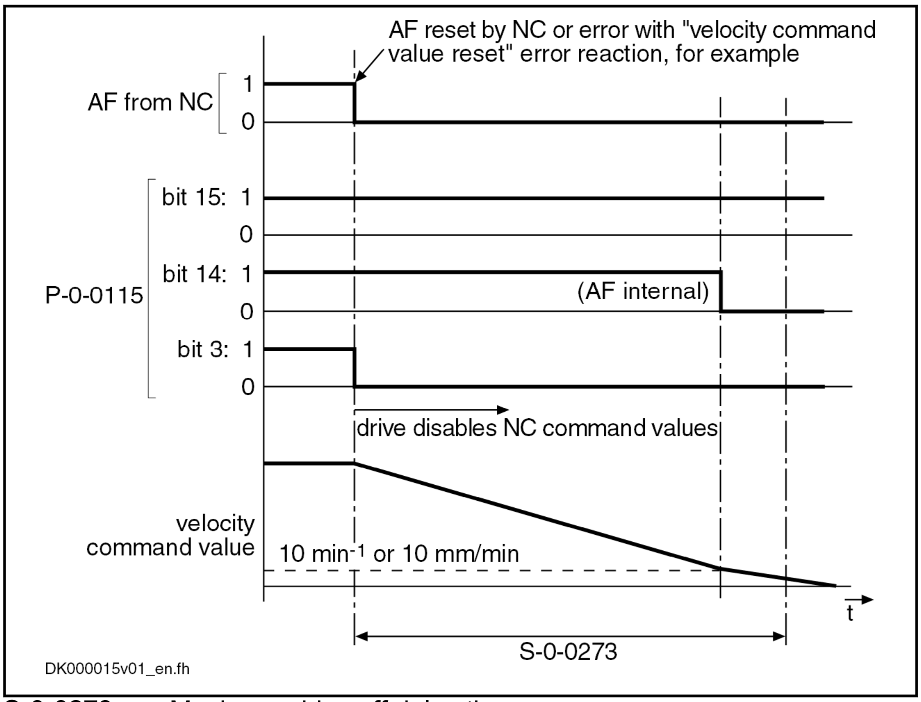
Intended Use

Velocity command value reset (emergency stop) is used, when the fastest possible deceleration without acceleration limitation is desired in the case of error.

In the case of error, the closed-loop-controlled servo drive in velocity control is shut down with command value = "0". The drive then brakes with its maximum allowed torque from parameter "P-0-0109 Torque/force peak limit", without acceleration limitation (see also "Limitations: Current and Torque/Force Limitation").

For deceleration properties in U/f operation, see chapter "Time Flow of the Error Reaction" on page 730.

If the drive has been equipped with a holding brake, the brake behaves according to the configuration of P-0-0525, see chapter "Time Flow of the Error Reaction" on page 730.



S-0-0273 Maximum drive off delay time
P-0-0115 Device control: Status Word
Fig. 8-2: Time Flow of Velocity Command Value Reset

NOTICE

If the value entered for "S-0-0273, Maximum drive off delay time" is too small, the error reaction is sometimes aborted without axis standstill!

Pertinent Parameters

- S-0-0138, Bipolar acceleration limit value
- S-0-0273, Maximum drive off delay time
- P-0-0045, Control word of current controller
- P-0-0109, Torque/force peak limit
- P-0-0569, Maximum stator frequency slope

Velocity command value reset with ramp and filter (emergency stop)

Intended Use

Velocity command value reset with ramp and filter ("emergency stop") is used, when it is desired to have deceleration preventing the mechanical system from damage while maintaining the emergency stop properties.

In the case of error

- the closed-loop-controlled servo drive in velocity control

- or -

- the open-loop-controlled drive in V/Hz [U/f] operation is shut down with a command value ramp, determined by "S-0-0429, Emergency halt deceleration" and the jerk limit value "S-0-0349, Bipolar jerk limit". If the value in S-0-0429 = "0", "S-0-0138, Bipolar acceleration limit value" is used to calculate the filter time constant. The torque/force limitation is derived from the parameter "P-0-0109, Torque/force peak limit".

Pertinent Parameters

- S-0-0138, Bipolar acceleration limit value
- S-0-0349, Bipolar jerk limit
- S-0-0429, Emergency halt deceleration
- P-0-0055, Return distance
- P-0-0056, Return velocity
- P-0-0057, Return acceleration
- P-0-0058, Return jerk
- P-0-0109, Torque/force peak limit
- P-0-0569, Maximum stator frequency slope

Velocity command value reset with ramp and filter (quick stop)

Intended Use

Velocity command value reset with filter and ramp ("quick stop") is used, when it is desired to have deceleration preventing the mechanical system from damage while maintaining the quick stop properties.

In the case of error

- the closed-loop-controlled servo drive in velocity control

- or -

- the open-loop-controlled drive in V/Hz [U/f] operation

is shut down with a command value ramp, determined by "S-0-0372, Drive Halt acceleration bipolar" and the jerk limit value "S-0-0349, Bipolar jerk limit". If the value in S-0-0372 = "0", "S-0-0138, Bipolar acceleration limit value" is used to calculate the filter time constant. The torque/force limitation is derived from the parameter P-0-0109.

Pertinent Parameters

- S-0-0138, Bipolar acceleration limit value
- S-0-0349, Bipolar jerk limit
- S-0-0372, Drive Halt acceleration bipolar
- P-0-0569, Maximum stator frequency slope
- P-0-0109, Torque/force peak limit

The parameters take effect as described in the "Drive Halt" function.

Emergency Stop by means of Motor Winding Short Circuit

Intended Use

Deceleration of the axis in the case of fatal errors, when motor control is no longer possible.

In the case of fatal F8xxx errors, the axis can be decelerated by means of motor winding short circuit, if this has been set in the parameter P-0-0119.

☞ The braking effect might possibly be less than in the case of non-fatal errors.

If torque disable has been parameterized as the error reaction for F2xxx, F3xxx, F4xxx or F6xxx errors, the torque is disabled for F8xxx errors, too. When the error F8 occurs, a holding brake controlled by the controller behaves according to the functional principle defined in "P-0-0525, Holding brake control word", see chapter "Time Flow of the Error Reaction" on page 730.

> For exceptions, see [External link could not be resolved.]

Torque disable

Intended Use

Torque disable is used for a slave axis, if it has been connected to the master axis in friction-locked form.

In the case of error, the drive torque is disabled. The drive in this case is only braked by the friction torque; it "coasts to stop". The time until standstill can be considerable, especially with spindles.

For the use of a motor holding brake, see chapter "Time Flow of the Error Reaction" on page 730.

> The "torque disable" error reaction is used for fatal errors (F8xxx), if motor winding short circuit is impossible.

NOTICE

Drive continues to move unbraked in the case of error!

Danger to life from parts in motion when the safety door at the machining cell is opened!

Check drive for motion (e.g. if possible using "S-0-0040, Velocity feedback value") and wait for standstill!

8.4.3 Package reaction on error

Brief Description

> Assignment to functional firmware package, see chapter "Availa-bility of the Extended Axis Functions".

"Package reaction" is the simultaneous error reaction of all axis drives sup-plied by a common power bus (DC bus). Drive errors of a drive can be sig-naled to all other axis drives via the module bus (signal bus) which allows the simultaneous error reaction (according to setting in parameter "P-0-0119, Best possible deceleration") of all axis drives.

The settings for signaling drive errors and package reaction are made individ-ually for each drive in "P-0-0118, Power supply, configuration". This allows activating the package reaction only for individual axes. The behavior of the axes for which the package reaction has not been activated has to be taken into account for the case of error and must be controlled on the master side, if necessary!

> The supply unit switches off power supply only in the case of its own errors and in the case of fatal drive errors (F8xxx), if the drive signaling errors signals F8 errors to the supply.

Fields of Application

Examples of applications with interactive (interpolating, synchronized) use of drives that are supplied by a common power bus ("drive system"):

- Machine tools (e.g. milling, turning, grinding machines)
- Gear cutting machines (gear wheel machining)

- Printing mechanisms of printing machines, etc.

By setting the error reaction of the drive system devices according to the application, the following damages can be minimized:

- Machine damages
- Tool/workpiece/material damages

⚠ WARNING **The package reaction is not suitable for avoiding personal injury!**

Reaction to drive errors	Priority of appropriate error reactions for typical drive applications	Setting in P-0-0117	Setting in P-0-0118	General conditions
NC master-side reaction	NC master-side priority of shutdown and power off	NC reaction active	No package reaction, no signaling of drive errors	Drive with F8 error does not decelerate!
Drive reaction	Shutdown spindle drive (asynchronous motors) Shutdown servo drives (synchronous motors) Power off	NC reaction not active	Package reaction, signaling of drive errors	Drive with F8 error does not decelerate! , No DC bus short circuit Power off via NC master
	Shutdown servo drives (synchronous motors) Power off Shutdown spindle drive (asynchronous motors) irrelevant	NC reaction not active	Package reaction, signaling of drive errors, signaling of F8 errors to supply	Power off only with F8 error, otherwise via NC master with DC bus short circuit
	Power off Shutdown spindle drive (asynchronous motors) Shutdown servo drives (synchronous motors)	NC reaction not active	Package reaction, signaling of drive errors, signaling of F8 errors to supply	Power off only with F8 error, otherwise via NC master; no DC bus short circuit, drive with F8 error does not decelerate!
	Power off Shutdown servo drives (synchronous motors) Shutdown spindle drive (asynchronous motors)	NC reaction not active	Package reaction, signaling of drive errors, signaling of F8 errors to supply	Power off only with F8 error, otherwise via NC master with DC bus short circuit

Tab. 8-3: Examples of Settings in P-0-0117 and P-0-0118, Depending on the Priority of Appropriate Error Reactions (with General Conditions)

☞ The above examples are not binding and provide basic information on the settings that have to be made according to the axis-specific and application-dependent requirements.

Pertinent Parameters

- P-0-0118, Power supply, configuration
- P-0-0119, Best possible deceleration

Notes on Commissioning

Basic settings with regard to error handling have to be made in parameter "P-0-0118, Power supply, configuration":

- Reaction to signaled errors of other drives in the drive system ("package reaction")
- Signaling of own drive errors in drive system via module bus
- Handling of "undervoltage" message for inverters (HMS or HMD type) and converters (HCS type)
- Automatic clearing of the error "F2026 Undervoltage in power section" by switching off drive enable
- Signaling of own, fatal drive errors (F8xxx) to the supply via module bus

8.4.4 Control Reaction on Error

NC reaction on error

Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

To avoid damage to the machine, some applications require that the master (e.g. NC) retains control of the travel profile of the axes even in case of error and shuts down the machine axes in a coordinated way. For this case, the "NC reaction on error" option was implemented; it can be activated via parameter P-0-0117.

The master is informed of an error in the drive controller via the drive status word (see S-0-0135) so that the master can shut down the machine axes in a coordinated way and therefore avoid possible damage.

NC reaction on error is only possible with non-fatal errors (diagnostic message F2xxx), otherwise the drive always reacts with an immediate drive-side error reaction.

Pertinent Parameters

- S-0-0135, Drive status word
- P-0-0117, Activation of control unit reaction on error
- P-0-0119, Best possible deceleration

Functional Description

In the case of NC reaction on error, the axis signaling the error still is provided with the command values preset by the master and follows them, even in the case of error, for another 30 s. To achieve this, the function has to be activated so that the defined time delay of 30 s becomes effective between the detection of the error and the drive-side reaction.

Activating the NC reaction

The NC reaction on error is activated in "P-0-0117, Activation of control unit reaction on error".

P-0-0117, bit 0:

- Bit 0 = "0" → The drive carries out its error reaction **without delay** after recognizing the error according to the setting in "P-0-0119, Best possible deceleration".

- Bit 0 = "1" → The drive carries out its error reaction according to the setting in P-0-0119 **only 30 s after recognizing the error**. The drive, for the duration of 30 s after detection of the error, continues following the command values of the master and therefore allows an **NC error reaction**.

  Note: If the error message is deleted within this waiting period after detection of the error, **no** drive reaction set in P-0-0119 is executed.

The activation of "NC reaction on error" (P-0-0117, bit 0 = "1") only makes sense for masters that have the respective procedure for the case of error.

MLD reaction on error

Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

As an alternative to the NC reaction, the IndraMotion MLD reaction on error can also be realized for the (local) axis. In this, the MLD reaction and the NC reaction are differentiated functionally insofar as by means of IndraMotion MLD, even for an interface error (F4xxx) an error reaction to be defined by the user can be executed for the (local) axis.

Prerequisite for using the MLD error reaction is the enabling of the PLC function in the drive (see "Enabling of Functional Packages").

Pertinent Parameters

- S-0-0135, Drive status word
- P-0-0117, Activation of control unit reaction on error
- P-0-0119, Best possible deceleration
- P-0-2003, Selection of functional packages

Functional Description

By means of the MLD reaction on error, the (local) axis is commanded by the IndraMotion MLD for another 30 s in the case of an error. In case the MLD already had control over the axis before the occurrence of an error, it will maintain it or it will take over control over the axis, which results in control by an external control unit to be inhibited.

Activating the NC reaction

The MLD reaction on error is activated in "P-0-0117, Activation of control unit reaction on error".

P-0-0117, bit 1 (bit 0 must be Zero):

- Bit 1 = 0 → The drive carries out its error reaction **without delay** according to the setting in "P-0-0119, Best possible deceleration", after recognizing the error.
- Bit 1 = 1 → The drive carries out its error reaction according to the setting in P-0-0119 **only 30 s after recognizing the error**. For a period of 30 s as of the time of error recognition, the IndraMotion MLD will receive control over the axis and therefore it can carry out an **MLD error reaction**.

> If the error message is deleted within this waiting period after detection of the error, **no** drive reaction set in P-0-0119 is executed.

Notes on utilization

When using the function, observe the following aspects:

- The MLD reaction on error, is also carried out if the IndraMotion MLD is not running. Therefore, the activation of "MLD reaction on error" (P-0-0117, Bit 1 = 1) can only be carried out, if a respective reaction is programmed via IndraMotion MLD.
- MLD reaction on error is only possible with non-fatal errors (F2xxx) and with interface errors (F4xxx), otherwise the drive always reacts with an immediate drive-side error reaction.
- The MLD reaction on error facilitates a very fast and - above all - flexible reaction on the occurrence of an error.

8.5 E-stop function

8.5.1 Brief Description

> Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The E-Stop function is used to shut down the drive with a selectable drive reaction (see Parameter Description "P-0-0008, Activation E-Stop function") via a digital input of the drive controller.

To use the E-Stop function, you have the following options:

- E-Stop with reaction to interface error (F4034 Emergency-Stop activated)

  → **Reaction:** Best possible deceleration (as set in P-0-0119)
- E-Stop with reaction to travel range error (F6034 Emergency-Stop activated)

  → **Reaction:** Velocity command value reset
- E-Stop as fatal warning "E8034 Emergency-Stop activated"

  → **Reaction:** Best possible deceleration (as set in P-0-0119)

> If "E-Stop" was parameterized as a warning, the diagnostic message does not have to be cleared!

Pertinent Parameters

- P-0-0008, Activation E-Stop function
- P-0-0119, Best possible deceleration
- P-0-0223, E-Stop input
- P-0-0249, E-Stop and safety zones

Pertinent Diagnostic Messages

- E8034 Emergency-Stop activated
- F4034 Emergency-Stop activated
- F6034 Emergency-Stop activated

8.5.2 Functional Description

By activating the E-Stop input (P-0-0008, bit 0 = 1) and assigning bit 0 of P-0-0223 to a digital input, the drive is caused to carry out, with 0 V at the E-Stop input, the reaction defined via P-0-0008 for shutting the drive down.

E-Stop Reaction according to P-0-0008, Bit 2

The reaction is initially depending on the setting of bit 2 in P-0-0008.

If the interpretation "fatal warning" was parameterized in P-0-0008 (bit 2 = 1), the drive reacts, as in the case when the external drive enable is switched off, with the reaction set in "P-0-0119, Best possible deceleration".

- The warning "E8034 Emergency-Stop activated" appears. Bit 15 (manufacturer-specific warning) is set in "S-0-0012, Class 2 diagnostics".
- Simultaneously, the bit "change bit class 2 diagnostics" is set in the drive status word.

> ☞ This change bit is cleared by reading "S-0-0012, Class 2 diagnostics". Using "S-0-0097, Mask class 2 diagnostics", warnings can be adjusted in terms of their effect on the change bit.

> ☞ To reactivate the drive, the E-Stop input has to be deactivated and **another positive edge has to be applied to the external drive enable**.

If the interpretation as an error has been set in P-0-0008 (bit 2 = 0), the reaction selected in bit 1 is carried out:

- The error diagnosis "F4034 Emergency-Stop activated" (or "F6034 Emergency-Stop activated") appears
- Bit 15 is set in parameter "S-0-0011, Class 1 diagnostics".
- Bit 13 (drive lock-out, error in class 1 diagnostics) is set in the drive status word of the drive telegram. The error message can be cleared via command "S-0-0099, C0500 Reset class 1 diagnostics", or the "Esc" key of the control, if the E-Stop is no longer active.

> ☞ The error reaction is carried out without delay, independent of "P-0-0117, Activation of control unit reaction on error".

E-Stop Reaction according to P-0-0008, Bit 1

If bit 1 = 0 was set in parameter P-0-0008, the drive is shut down according to the error reaction parameterized via "P-0-0119, Best possible deceleration".

The diagnostic message upon activating the E-Stop input then is "F4034 Emergency-Stop activated".

If bit 1 = 1 was set in parameter P-0-0008, the drive, when the E-Stop triggers, is braked with maximum torque to speed = 0, independent of the error reaction set in P-0-0119. This setting corresponds to the best possible deceleration "velocity command value reset".

The diagnostic message upon activating the E-Stop input then is "F6034 Emergency-Stop activated".

8.5.3 Notes on Commissioning

Activation and Polarity of the E-Stop Input

Assigning the Digital Input

Prerequisite for using the function is the assignment of bit 0 of parameter P-0-0223 to a digital input (see "Digital Inputs/Outputs"). A voltage level at the digital input therefore also affects bit 0 of P-0-0223.

NOTICE

Without this assignment to the digital input, the E-Stop reaction fails to occur in spite of the input having been activated! This does not apply to IndraDrive Mi.

Special Case IndraDrive Mi

If the E-Stop input (P-0-0223) at IndraDrive Mi has not been configured in the assignment list of the digital inputs (P-0-0300), the E-Stop signal from the hybrid cable is evaluated for the E-Stop function, see also "Zone Formation" in the separate documentation "Rexroth IndraDrive Mi, Drive Systems with KCU02, KSM02, KMS02, Project Planning Manual", (DOK-INDRV*-KCU02+KSM02-PR01-EN-P; mat. No.: R911335702).

Activating the E-Stop

The activation of the E-Stop input and the selection of a reaction for shutdown of the drive is carried out via bit 0 of "P-0-0008, Activation E-Stop function" (see also Parameter Description P-0-0008).

P-0-0008, bit 0 (activation E-Stop):

- Bit 0 = 0 → Function not activated
- Bit 0 = 1 → Function activated

Selecting the Drive Reaction

Determining the Reaction

It is possible to determine whether an error message or a warning is generated when 0 V are detected at the E-Stop input. Bit 1 and bit 2 of "P-0-0008, Activation E-Stop function" are relevant for determining this.

P-0-0008, bit 1 (error class when interpreted as error):

- Bit 1 = 0 → F4034 → Best possible deceleration
- Bit 1 = 1 → F6034 → Velocity command value reset

P-0-0008, bit 2 (interpretation of the E-Stop input):

- Bit 2 = 0 → Interpreted as error (see bit 1)
- Bit 2 = 1 → Interpreted as fatal warning

☞ The error reaction can be set in "P-0-0119, Best possible deceleration".

Connecting the E-Stop Input

ⓘ See documentation "Control Sections for Drive Controllers; Project Planning Manual"

☞ The polarity of the input cannot be selected. It is always active when the signal = 0 V; this means that 0 V at the digital input causes the E-Stop to trigger.

8.5.4 Diagnostic and Status Messages

Diagnostic Warning and Error Messages

There are the following diagnostic messages for the E-Stop function:

- Warning "E8034 Emergency-Stop activated"
  → E-Stop with best possible deceleration
- Error "F4034 Emergency-Stop activated"

→ E-Stop with best possible deceleration

- Error "F6034 Emergency-Stop activated"

  → E-Stop with velocity command value reset

Status Messages

The state of the E-Stop input can be read via "P-0-0223, E-Stop input":

- Bit 0 = 0: 0 V at input

  → E-Stop triggers

- Bit 0 = 1: 24 V at input

  → E-Stop does not trigger

8.6 Compensation Functions/Corrections

8.6.1 Friction torque compensation

Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The behavior of a machine axis is negatively affected by static friction when starting or when reversing the direction. The drive-internal friction torque compensation allows compensating the static friction by adding, depending on the direction of movement, a torque/force command value.

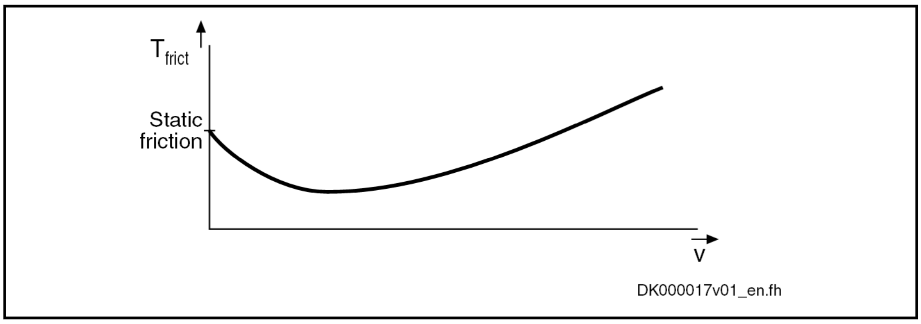


Fig. 8-3: Friction Torque Curve with Static Friction

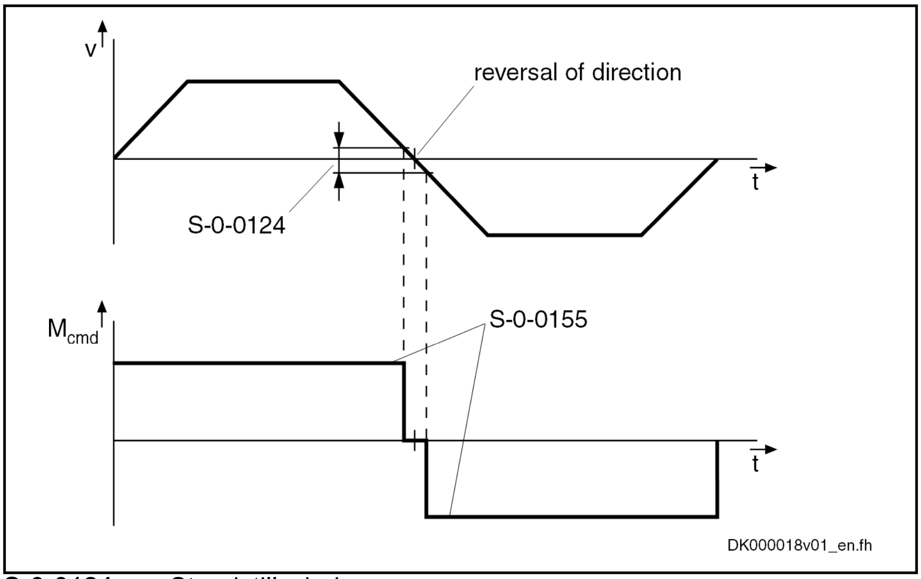
Friction torque compensation is mainly intended to be used in precision machine tools and to reduce the path errors caused by static friction. This applies particularly to circular errors at the quadrant transitions.

Pertinent Parameters

- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0155, Friction compensation

Functional Principle

The principle of friction torque compensation is that the known friction component is pre-controlled (compensated) via an added torque/force command value and does not have to be compensated by the controller. This allows the control behavior to be improved (little lag error) especially when reversing the direction of movement. Precision of drive control is thereby increased.



S-0-0124 Standstill window
S-0-0155 Friction compensation
Fig. 8-4: Functional Principle of Friction Compensation

☞ A hysteresis was implemented in the reversal point so that the compensation value is only added when the drive velocity is outside the standstill window (see S-0-0124).

Notes on Commissioning

Requirements

Effective compensation of the friction torque requires the following:

- The friction torque of the axis must have a relevant value. With a friction torque component of less than 10 % of the nominal torque of the drive used, friction torque compensation won't have any important effect.
- The friction torque to be compensated must be largely constant and independent of current processing.

Preparations

Before activating the function, make the following preparations:

- Set velocity and position control loops according to the Notes on Commissioning.

  See "Commissioning and Parameterizing the Control Loops" for the respective operation mode
- Connect the master; it must allow moving the drive (e.g. jog function).
- Set and activate the travel range limits of the axis (cf. P-0-0090, S-0-0049, S-0-0050).
- If the friction characteristic of the axis is highly temperature-dependent, bring the drive to operating temperature before determining the compensation value.
- Set the torque limit to minimum value so that the drive cannot surmount the static friction and does not move in spite of command value input.

☞ If the drive can only be moved in position control, the lag error monitor has to be switched off, as otherwise the error "F2028 Excessive deviation" can occur during determination of the compensation value!

Determining the Compensation Value

Determine the compensation value (S-0-0155) in the following steps:

1. Preset a positive command value for the axis and increase "S-0-0092, Bipolar torque/force limit value" until the axis moves. The value then contained in S-0-0092 corresponds to the static friction component for positive direction (friction value_positive).

   Repeat this procedure in the other direction of motion to determine the static friction component for negative direction (friction value_negative).

2. Derive the setting value for friction torque compensation from the determined values (friction value_positive and friction value_negative). As there is no direction-dependent correction value, the average value has to be calculated from these two values and entered in "S-0-0155, Friction compensation".

$$\text{S-0-0155} = \frac{|\text{friction value\_positive}| + |\text{friction value\_negative}|}{2}$$

Fig. 8-5: Generating the Average Value for the Entry in Parameter S-0-0155

8.6.2 Axis Error Correction

Brief Description

The actual position value provided by the measuring system can differ from the real actual position value at the axis, e.g. at the point of chip removal in the case of metal-cutting machining, due to

- inaccuracy of the measuring system,
- transmission inaccuracy in mechanical transmission elements such as gear, clutch, feed spindle etc.,
- thermal expansion of machine parts of the drive system.

For compensating the mechanically determined position error sources, IndraDrive controllers provide the following correction functions:

- Backlash on reversal correction
- Precision axis error correction
- Control-side axis error correction

The control-side axis error correction is always active. The correction value can be transmitted in the cyclic telegram or in the service channel. In addition, precision axis error correction or reversal clearance can be activated, precision axis error correction having higher priority.

Moreover, it is possible to activate the temperature error correction. IndraDrive controllers provide two possibilities of correcting temperature errors:

- Independent of axis position
- Depending on axis position

Pertinent Parameters

- S-0-0058, Reversal clearance
- S-0-0124, Standstill window
- P-0-0400, Axis correction external correction value
- P-0-0401, Axis correction active correction value
- P-0-0402, Axis correction reference temperature
- P-0-0403, Axis correction reference position for temp. corr.
- P-0-0404, Axis correction actual temperature pos.-dependent

- P-0-0405, Axis correction actual temperature pos.-independent
- P-0-0406, Axis correction temperature factor pos.-dependent
- P-0-0407, Axis correction temperature factor pos.-independent
- P-0-0408, Axis correction start position
- P-0-0409, Axis correction end position
- P-0-0410, Axis correction support point distance
- P-0-0411, Axis correction, correction table positive
- P-0-0412, Axis correction, correction table negative
- P-0-0413, Axis correction control word

Selecting the Measuring System

Measuring System to be Corrected

The actual position value system to be corrected is selected via the respective bit of "P-0-0413, Axis correction control word" It is only possible to select one of the actual position value systems!

> ☞ All position-dependent correction functions only take effect after the position data reference was established for the respective encoder (see "Establishing the Position Data Reference").

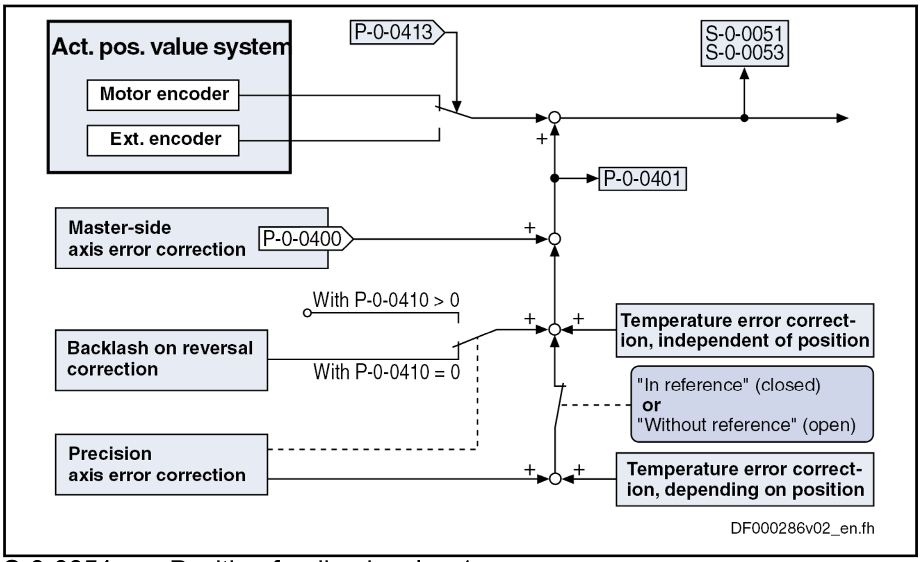
Active Correction Value

The sum of active correction values is displayed in "P-0-0401, Axis correction active correction value". The value refers to the encoder selected in P-0-0413.

Usability of the Functions of Axis Error Correction

It is possible to use several axis error corrections at the same time. The availability of the individual correction functions, however, depends on the functional package which has been activated.

The figure below illustrates the interaction of the subfunctions for axis error correction.



S-0-0051	Position feedback value 1
S-0-0053	Position feedback value 2
P-0-0400	Axis correction external correction value
P-0-0401	Axis correction active correction value
P-0-0410	Axis correction support point distance
P-0-0413	Axis correction Control word

Fig. 8-6: Overview on the Usability of the Functions of Axis Error Correction

Backlash on reversal correction

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

By means of the backlash on reversal correction, it is easily possible to correct backlash in the mechanical axis system.

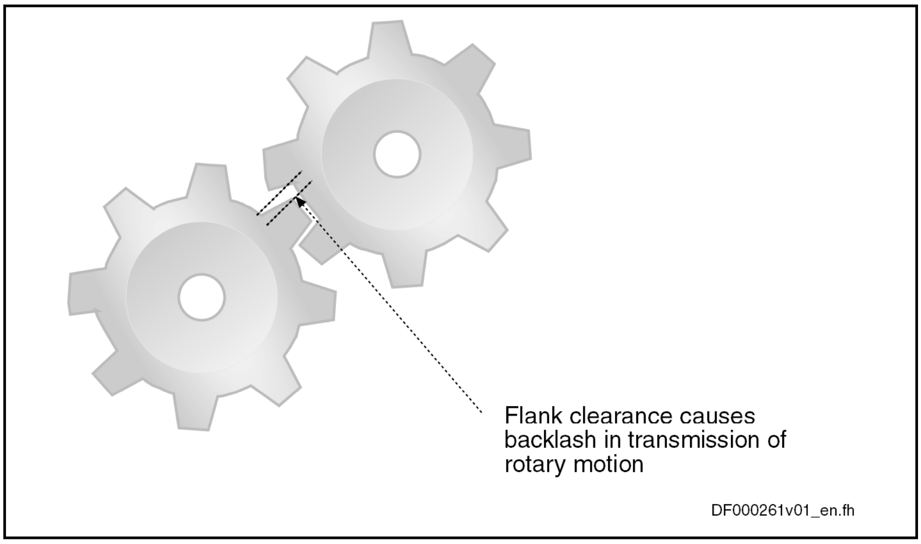


Fig. 8-7: Illustration of Backlash with Toothed Wheels

The function is activated by inputting the backlash in parameter "S-0-0058, Reversal clearance". The actual position values of the encoder selected via P-0-0413 are corrected with the value from S-0-0058 (taking the direction of motion into account).

With Position Control

In position control, the direction of motion is recognized by the sign of the value of "P-0-0434, Position command value of controller", derived with respect to time.

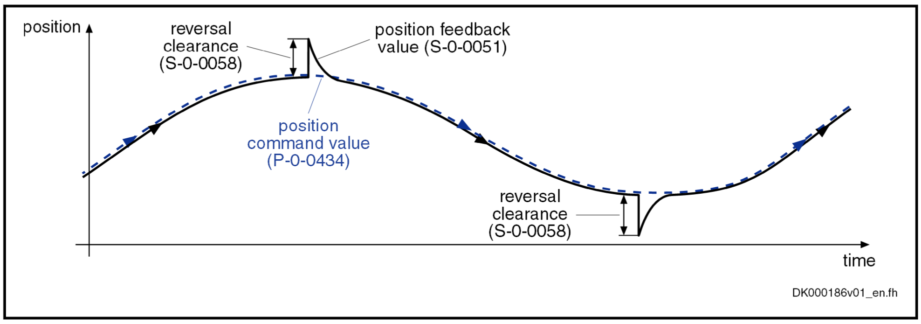


Fig. 8-8: Operating Principle of Backlash on Reversal Correction in Position Control (Reversal Clearance Added in the Case of Negative Sign of the Value of P-0-0434)

With Velocity Control

In velocity control, reversal of the direction of motion is recognized when the velocity command value (S-0-0036) has exceeded the absolute value of the standstill window (S-0-0124) in positive or negative direction. The standstill window acts as a hysteresis!

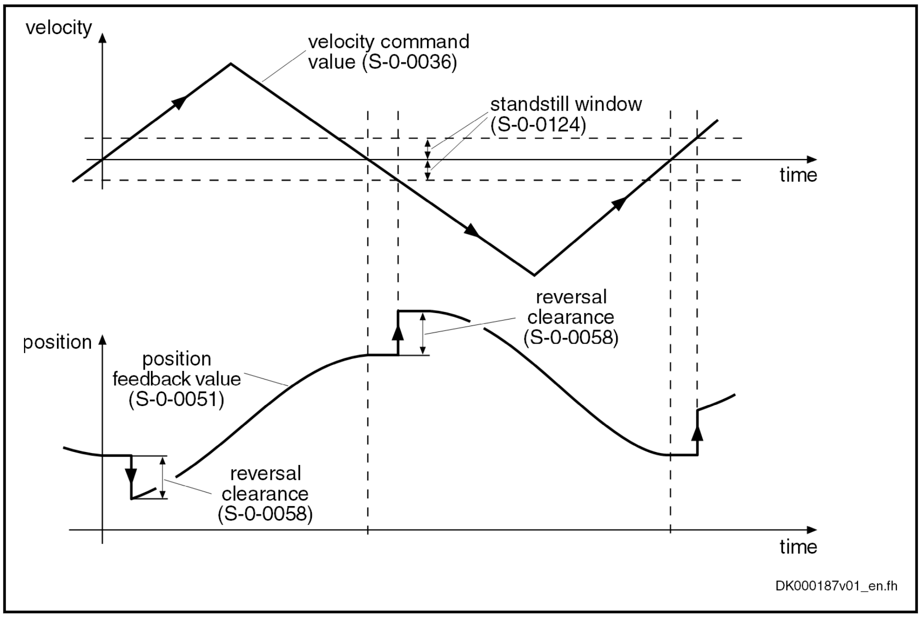


Fig. 8-9: Operating Principle of Backlash on Reversal Correction in Velocity Control (Reversal Clearance Added when Velocity Command Value Leaves Standstill Window with Negative Velocity)

$$x_{act\_corr} = x_{act}$$

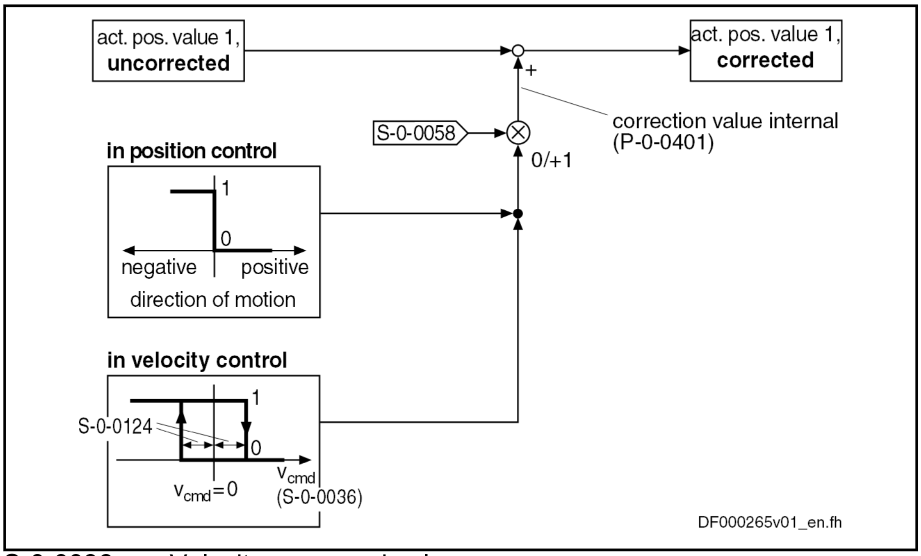
x_{act_corr} Corrected actual position value 1
x_{act} Uncorrected actual position value 1

Fig. 8-10: Corrected Actual Position Value for Positive Direction

$$x_{act\_corr} = x_{act} + \text{correction value}$$

x_{act_corr} Corrected actual position value 1
x_{act} Uncorrected actual position value 1

Fig. 8-11: Corrected Actual Position Value for Negative Direction



S-0-0036	Velocity command value
S-0-0058	Reversal clearance
S-0-0124	Standstill window
P-0-0401	Axis correction active correction value

Fig. 8-12: Block Diagram of Backlash on Reversal Correction

Determining the Reversal Clearance

The following procedure is recommended for determining the value for "S-0-0058, Reversal clearance":

- By means of jog mode, move axis in positive direction
- Place dial gauge at appropriate spot of mechanical axis system and set it to zero
- Jog axis in negative direction, until change in pointer deflection of dial gauge is visible

The reversal clearance then is determined according to the following calculation:

$$\text{Reversal clearance} = \Delta x_{\text{Control unit}} - \Delta x_{\text{Dial gauge}}$$

$\Delta x_{control}$	Distance traveled from zero position of dial gauge according to control display
$\Delta x_{dial\ gauge}$	Distance traveled according to dial gauge referring to its zero position

Fig. 8-13: Determining the Input Value for S-0-0058

Precision axis error correction

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The precision axis error correction is used for correcting non-linear encoder errors and non-linear errors of the mechanical system. The correction acts on the encoder selected by means of P-0-0413.

Pertinent Parameters

- P-0-0401, Axis correction active correction value
- P-0-0408, Axis correction start position
- P-0-0409, Axis correction end position
- P-0-0410, Axis correction support point distance

- P-0-0411, Axis correction, correction table positive
- P-0-0412, Axis correction, correction table negative

Correction Values

By means of the tables "P-0-0411, Axis correction, correction table positive" and "P-0-0412, Axis correction, correction table negative" it is possible to enter position- and direction-dependent correction values, so-called correction support points, within the correction range.

Correction Range

The correction range lies within the value range that is limited by the parameters "P-0-0408, Axis correction start position" and "P-0-0409, Axis correction end position" The start position (P-0-0408) is preset by the user, the end position (P-0-0409) is determined on the drive side from the maximum value of the correction table support points used (from P-0-0411 and P-0-0412) and the support point distance (P-0-0410).

Correction Support Points

The positions for which correction support points are entered, are determined via the parameters "P-0-0410, Axis correction support point distance" and "P-0-0408, Axis correction start position". Between the correction support points, the correction values are calculated by cubic spline interpolation.

The actual position values of the encoder selected via P-0-0413 are corrected with the interpolated values of "correction table positive" (P-0-0411) or "correction table negative" (P-0-0412), taking the direction of motion into account.

Depending on the operation mode, the direction of motion is recognized in different ways:

- **In position control**, by the sign of the value of "P-0-0434, Position command value of controller", derived with respect to time
- **In velocity control**, when the velocity command value (S-0-0036) exceeds the absolute value of the standstill window (S-0-0124) in positive/negative direction

  → The standstill window acts as a hysteresis!

Activating the Precision Axis Error Correction

The precision axis error correction is active, when a value greater than zero was entered in "P-0-0410, Axis correction support point distance" and the position data reference was established for the encoder the actual position value of which is to be corrected.

Extended Axis Functions

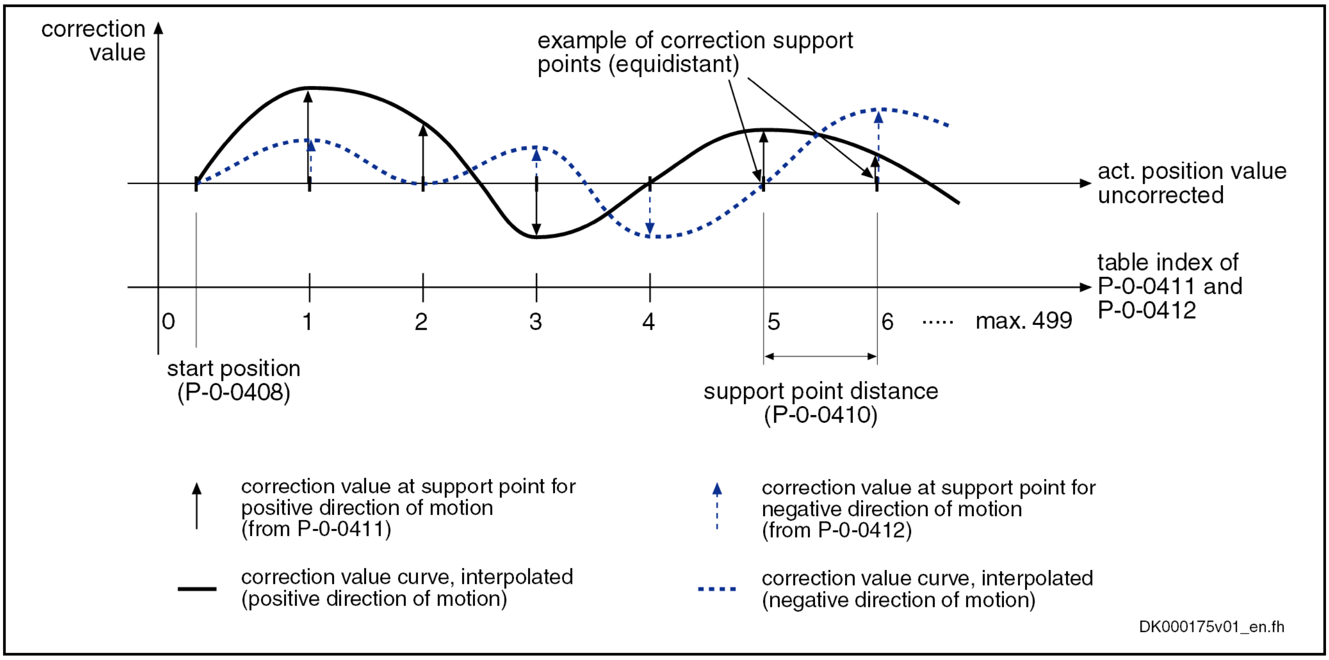


Fig. 8-14: Illustration of Correction Value Generation from the Entered Correction Support Points

Table index	P-0-0411 (positive direction)	P-0-0412 (negative direction)
0	0 (correction value at start position P-0-0408)	0 (correction value at start position P-0-0408)
1	Correction value support point 1	Correction value support point 1
2	Correction value support point 2	Correction value support point 2
3	Correction value support point 3	Correction value support point 3
....	....	....
498	Correction value support point 498	Correction value support point 498
499	0	0

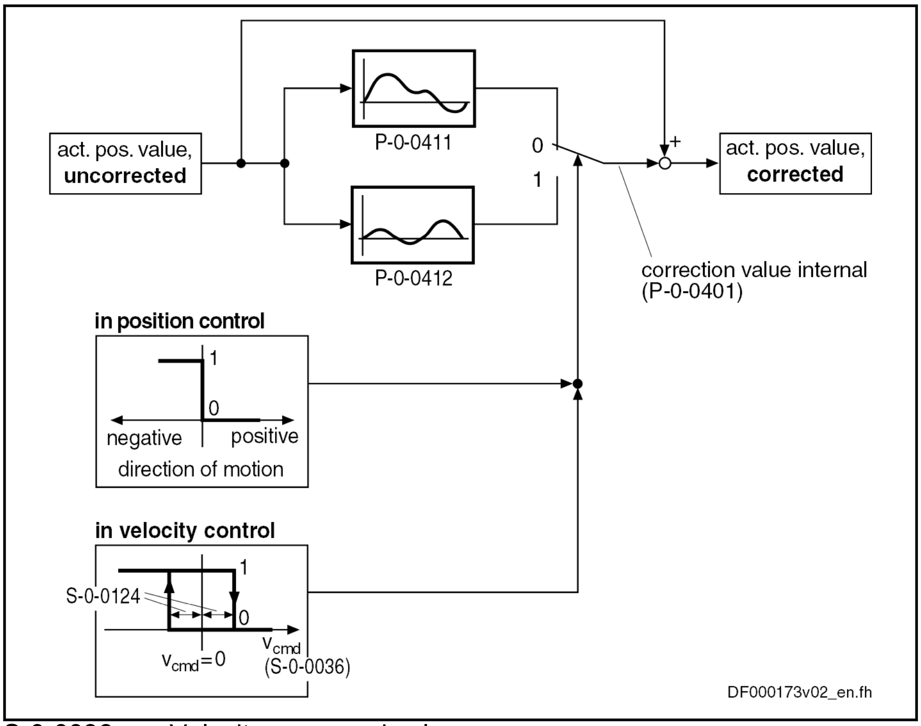
Tab. 8-4: Assigning the Support Point Correction Values to the Table Index of the Correction Tables P-0-0411 and P-0-0412

☞ At least 6, but not all of the 500 table values have to be used! It is recommended, however, to use the same number of correction support points for positive and negative directions of motion! The first and the last correction value of the table have to be zero in order to avoid discontinuity (abrupt changes) in the actual position value!

☞ Different correction values for positive and negative directions of motion at the same support point cause discontinuity in the corresponding actual position value upon a change in direction and therefore are possibly causing abrupt control with regard to the command position!

Operating Principle

The figure below illustrates the operating principle of precision axis error correction:



S-0-0036	Velocity command value
S-0-0124	Standstill window
P-0-0401	Axis correction active correction value
P-0-0411	Axis correction correction table positive
P-0-0412	Axis correction correction table negative

Fig. 8-15: Block Diagram of Precision Axis Error Correction

Determining the Required Parameter Values

The correction values are determined by means of a reference measuring system (e.g. laser interferometer). Within the desired correction range, the drive successively moves to the support points for the different directions and the corresponding position error is measured.

$$x_{Corr} = x_{Meas} - x_{Display}$$

x_{corr}	Correction value related to support point
x_{meas}	Measured position value at support point
$x_{display}$	Value of parameter S-0-0051 or S-0-0053

Fig. 8-16: Determining Correction Values for Precision Axis Error Correction

The correction values related to support point are entered in the list parameters P-0-0411 and P-0-0412.

The required length of the correction range and the maximum value of the number of support points determine the minimum support point distance. If a lower number of support points is selected, a bigger support point distance is required with a correction range of the same length. This, however, can reduce the precision of correction!

$$\text{P-0-0410} = \frac{\text{length of correction range}}{\text{max. number of support points (P-0-0411;P-0-0412)}}$$

P-0-0410	Axis correction support point distance
P-0-0411	Axis correction correction table positive
P-0-0412	Axis correction correction table negative

Fig. 8-17: Determining the Support Point Distance

When the value in parameter P-0-0410 equals zero, the precision axis error correction is deactivated!

Determining the Start Position

The start position for precision axis error correction defines the position of the first correction support point, the end position is determined by the controller and displayed in "P-0-0409, Axis correction end position".

Control-side axis error correction

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

IndraDrive controllers provide the possibility of cyclically transmitting control-side correction values for the actual position value to the drive and using them for calculating the actual position value in the position control clock.

The control-side axis error correction is activated when "P-0-0400, Axis correction external correction value" has been included in the master data telegram. The correction values act on the encoder selected in "P-0-0413, Axis correction control word" .

For control-side axis error correction, it is not necessary to establish the position data reference drive-internally for the respective encoder!

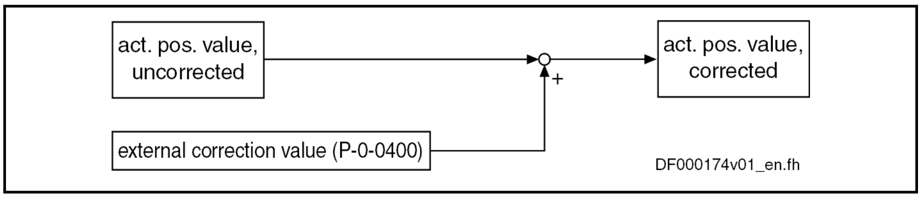


Fig. 8-18: Control-side axis error correction

Temperature error correction

General Information

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The temperature error correction is used to correct actual position value errors that can occur due to temperature-dependent linear expansion at servo axes.

Dependencies of the Actual Position Value Errors of Thermal Cause

According to the mechanical configuration of the axis and the arrangement of the workpiece or tool, the actual position value errors caused by the influence of temperature can

- only depend on temperature

- or -

- depend on the temperature and on the axis position.

IndraDrive controllers therefore provide two possibilities of temperature error correction:

- Independent of position
- Depending on position

Measured Temperature Value The measured temperature value has to be made cyclically available by the control master via the master communication. Separate measured temperature values are used for position-dependent and position-independent temperature error correction!

reference temperature The temperature-dependent correction functions are working relatively to a reference temperature at which there isn't any temperature-dependent actual position value error present. The reference temperature value has to be entered in "P-0-0402, Axis correction reference temperature".

> ☞ When actual position reference values are measured, all machine parts must have reference temperature!

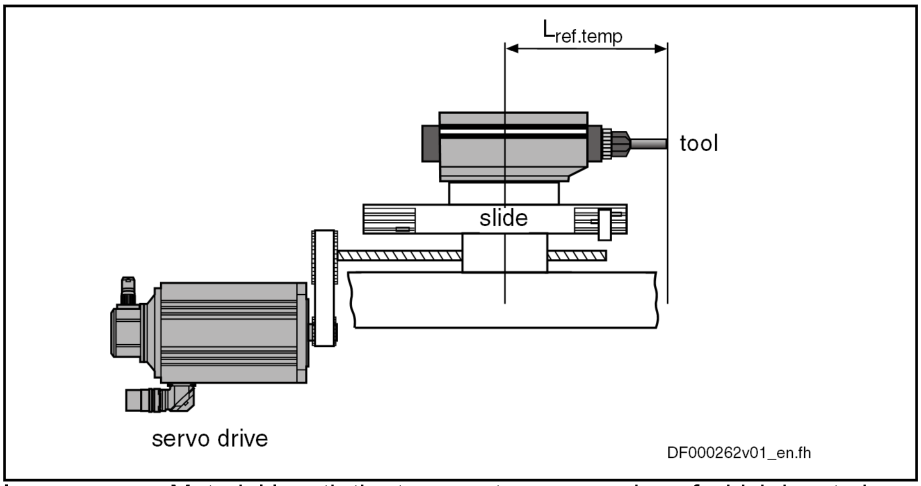
Scaling All temperature data are scaled with the temperature scaling (S-0-0208) set on the drive side. The factors for linear expansion (P-0-0406, P-0-0407) are scaled with the quotient "position data scaling/temperature scaling" (S-0-0076/S-0-0208).

Position-Independent Temperature Error Correction

Use The position-independent temperature error correction is used to compensate the temperature-dependent linear expansion of tools, workpieces and slides. The expansion of these components of a servo axis only depends on the temperature difference compared to a reference temperature, the resulting actual position value error is the same at each position of the axis.

Pertinent Parameters

- P-0-0402, Axis correction reference temperature
- P-0-0405, Axis correction actual temperature pos.-independent
- P-0-0407, Axis correction temperature factor pos.-independent



$L_{ref.temp.}$ Material length the temperature expansion of which has to be compensated (at reference temperature)

Fig. 8-19: Example of Application for Position-Independent Temperature Error Correction

> ☞ The actual position value system to be corrected is selected via the respective bit of "P-0-0413, Axis correction control word"

Operating principle of position-independent temperature error correction:

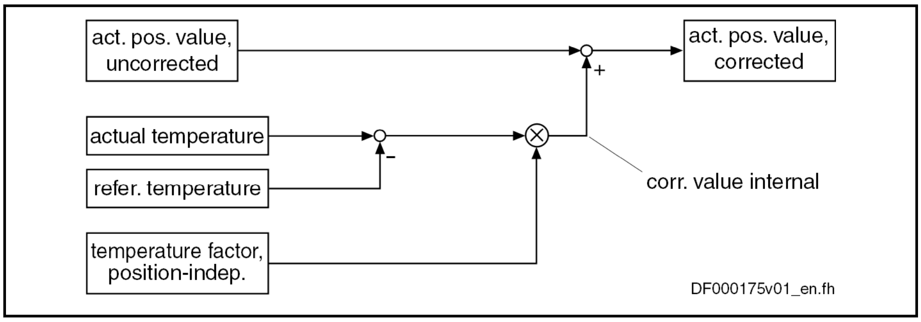


Fig. 8-20: Position-Independent Temperature Error Correction

Drive-internal determination of the correction value:

$$x_{korr} = P\text{-}0\text{-}0407 \times [(P\text{-}0\text{-}0405) - (P\text{-}0\text{-}0402)]$$

x_{corr}	Correction value, temperature-dependent
P-0-0407	Axis correction temperature factor pos.-independent
P-0-0405	Axis correction actual temperature pos.-independent
P-0-0402	Axis correction reference temperature

Fig. 8-21: Determining the Correction Value

Position-Independent Temperature Factor

The value for "P-0-0407, Axis correction temperature factor pos.-independent" can be determined by means of calculation or measurement.

Calculating the Value

If all data for the formula below can be unequivocally assigned due to the assembly of the mechanical system, the correction factor can be calculated.

$$P\text{-}0\text{-}0407 = \alpha \times L_{Ref.temp.}$$

P-0-0407	Axis correction temperature factor pos.-independent
α	Linear expansion coefficient of the material
$L_{ref.temp.}$	Material length the temperature expansion of which has to be compensated (at reference temperature)

Fig. 8-22: Calculating the Value for P-0-0407

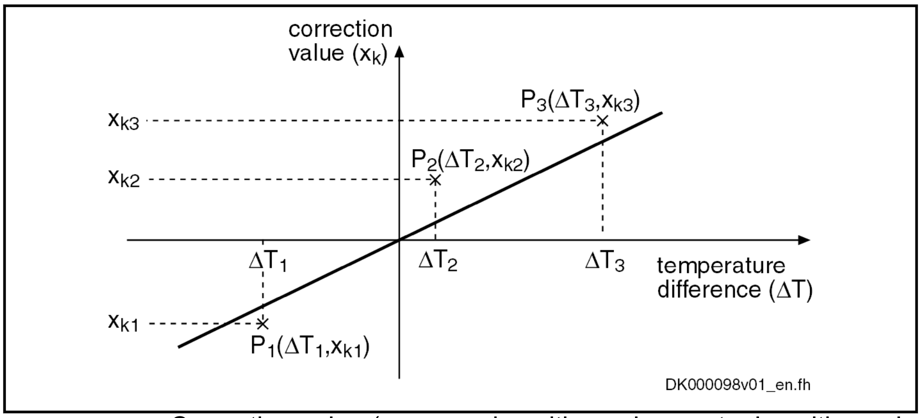
$$P\text{-}0\text{-}0407 = \alpha \times L_{Ref.temp.} = 0{,}000018\ 1/K \times 100\ mm = 0{,}00018\ mm/0{,}1\ K$$

P-0-0407	Axis correction temperature factor pos.-independent
α	For example, 0.000018 1/K, if temperature scaling °C (default scaling)
$L_{ref.temp.}$	For example, 100 mm (preferred scaling)

Fig. 8-23: Example for Calculating the Value for P-0-0407

Measuring the Value

If it is impossible to calculate the value for P-0-0407 (e.g., if the object of correction consists of different materials), it has to be measured. A series of measurements determines the actual position value error of the object of correction at different temperatures. Depending on the temperature difference, a straight correction line can be approximated by means of the measuring points.



x_{kn}	Correction value (measured position value –actual position value (S-0-0051/S-0-0053))
ΔT_n	Temperature difference (measured temperature –reference temperature (P-0-0402))

Fig. 8-24: Approximated Straight Correction Line on the Basis of Measured Correction Values at Different ΔT

Calculation by Means of the Measured Values

The gradient of the approximated straight line is the value of the position-independent temperature factor. By means of the value from the series of measurements, it is possible to calculate the position-independent temperature factor:

$$\text{P-0-0407} = \frac{n \times \sum(\Delta T_n \times x_{kn}) - \sum \Delta T_n \times \sum x_{kn}}{n \times \sum \Delta T_n^{\,2} - \left(\sum \Delta T_n\right)^2}$$

P-0-0407	Axis correction temperature factor pos.-independent
n	Number of measured values
ΔT_n	Temperature difference at which the correction value x_kn was determined
x_{kn}	Correction value at the temperature difference ΔT_n

Fig. 8-25: Calculating the Position-Independent Temperature Factor from the Values of the Series of Measurements

Activating the Function

The position-independent temperature error correction is activated, when the value of "P-0-0407, Axis correction temperature factor pos.-independent" is greater than zero.

☞ When the value in parameter P-0-0407 equals zero, the function of position-independent temperature error correction is deactivated. This correction function does not require position data reference for the measuring system to the corrected!

Position-Dependent Temperature Error Correction

Use

The position-dependent temperature error correction is used to compensate for the temperature-dependent linear expansion of the mechanical transfer elements of a servo axis or the measuring system. Depending on the position of the axis slide, the temperature-dependent linear expansion causes actual position value errors of different extent over the travel range of the axis.

At a position of the axis, there is a non-temperature-dependent "dedicated point" available that is used as the dedicated position for the position-dependent temperature error correction.

Pertinent Parameters

- P-0-0402, Axis correction reference temperature

- P-0-0403, Axis correction reference position for temp. corr.
- P-0-0404, Axis correction actual temperature pos.-dependent
- P-0-0406, Axis correction temperature factor pos.-dependent

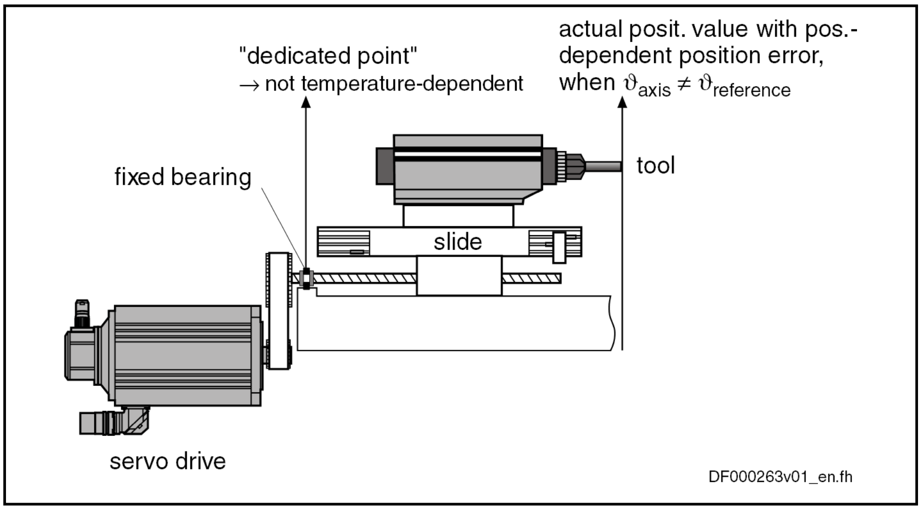


Fig. 8-26: Example of Application for Position-Dependent Temperature Error Correction

☞ The actual position value system to be corrected is selected via the respective bit of "P-0-0413, Axis correction control word"

Operating principle of position-dependent temperature error correction:

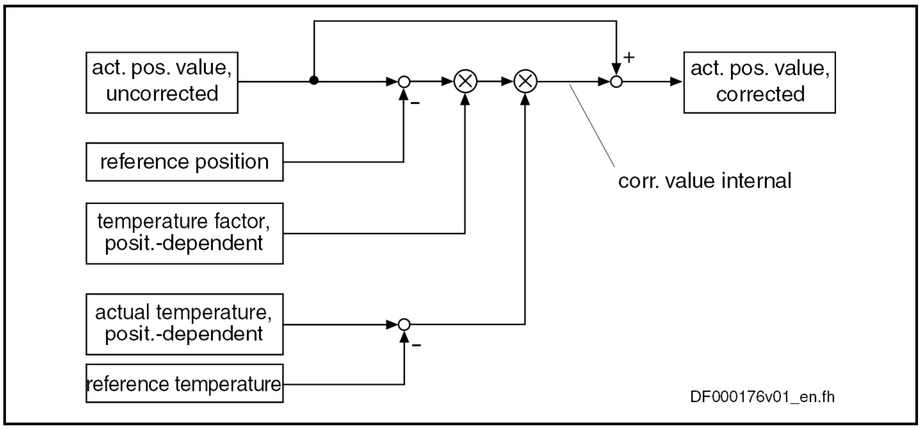


Fig. 8-27: Position-Dependent Temperature Error Correction

When the position data reference was established for the actual position value system, the correction value related to the current actual position value is drive-internally determined as follows:

$$x_{korr} = [(S\text{-}0\text{-}0051) - (P\text{-}0\text{-}0403)] \times [(S\text{-}0\text{-}0404) - (P\text{-}0\text{-}0402)] \times P\text{-}0\text{-}0406$$

X_{corr}	Correction value, temperature- and position-dependent
S-0-0051	Position feedback value 1 (or S-0-0053 for position feedback 2)
P-0-0403	Axis correction dedicated position for temp. corr.
P-0-0404	Axis correction actual temperature pos.-dependent
P-0-0402	Axis correction reference temperature
P-0-0406	Axis correction temperature factor pos.-dependent

Fig. 8-28: Determining the Correction Value, Temperature- and Position-Dependent

Determining the Dedicated Position

For position-dependent temperature error correction, there is an axis position that is not invalidated by variations of temperature. It is the dedicated position for position-dependent temperature error correction and is entered in "P-0-0403, Axis correction reference position for temp. corr.".

Determine the dedicated position by:

- Direct measurement, if the arrangement of the mechanical transmission elements allows unequivocally recognizing the dedicated position

- or -

- A series of measurements with which the actual position value error is measured at axis positions clearly different from the dedicated position (at constant temperature that is clearly different from the reference temperature (P-0-0402))

Dedicated Position by means of Series of Measurements

As in the majority of cases it is impossible to determine the dedicated point by direct measurement, determining the dedicated point by means of a series of measurements is of great importance.

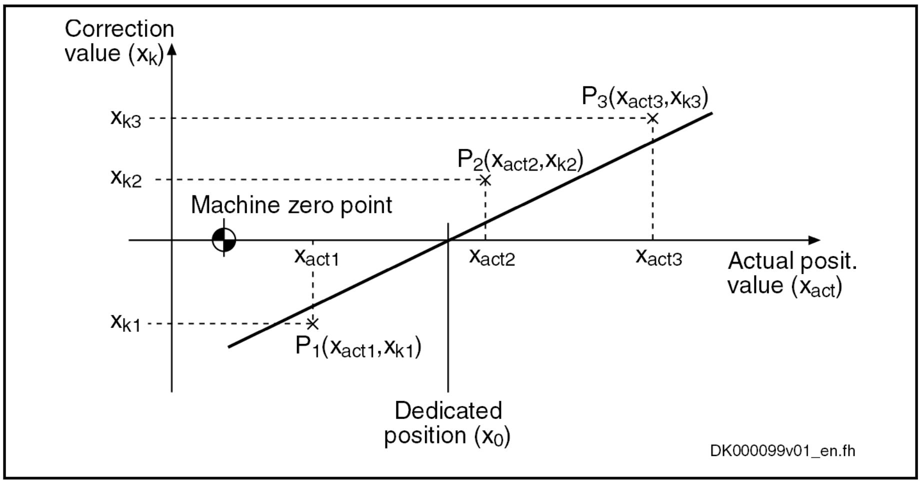


Fig. 8-29: Illustration of the Dedicated Position

By means of the measuring points (P_1, P_2, P_3), it is possible to determine the dedicated position by the equation of an approximated straight line:

$$x_0 = \frac{-b}{a}$$

x_0	Dedicated Position
b	Intersection point of straight line and correction value axis (x_k)
a	Gradient of the straight line

Fig. 8-30: Determining the Dedicated Position

Gradient of the straight line:

$$a = \frac{n \times \sum (x_{act\_n} \times x_{kn}) - \sum x_{act\_n} \times \sum x_{kn}}{n \times \sum (x_{act\_n})^2 - \left(\sum x_{act\_n}\right)^2}$$

a	Gradient of the straight line
n	Number of measured values
x_{act_n}	Actual position at which a correction value x_kn was measured
x_{kn}	Correction value at x_act_n

Fig. 8-31: Auxiliary Equation 1 for Determining the Dedicated Point

Intersection point of straight line and correction value axis (x_k):

$$b = \frac{\sum x_{kn} \times \sum (x_{act\_n})^2 - \sum x_{act\_n} \times \sum (x_{act\_n} \times x_{kn})}{n \times \sum (x_{act\_n})^2 - (\sum x_{act\_n})^2}$$

b	Intersection point of straight line and correction value axis
n	Number of measured values
x_{act_n}	Actual position at which a correction value x_kn was measured
x_{kn}	Correction value at x_act_n

Fig. 8-32: Auxiliary Equation 2 for Determining the Dedicated Point

Example

Measured errors at T_{act} = 45°C (reference temperature T_0 = 23°C):

n	X_{act_n} (actual pos. value 1) in mm	x_{kn} (error) in mm
1	+ 10.0000	- 0.0300
2	+ 70.0000	+ 0.0100
3	+ 105.0000	+ 0.0250

Tab. 8-5: Example of a Series of Measurements for Temperature Error Correction

Resulting measuring points: P = [x = x_{act_n}; x = x_{kn}]

- P1 = [+ 10.0 mm; - 0.03 mm]
- P2 = [+ 70.0 mm; + 0.01 mm]
- P3 = [+ 105.0 mm; + 0.025 mm]
- n = 3

Partial sums for auxiliary equations:

$$\sum x_{kn} = (-0{,}03 + 0{,}01 + 0{,}025)\,mm = +0{,}005\,mm$$

$$\sum x_{act\_n} = (10{,}0 + 70{,}0 + 105)\,mm = 185{,}0\,mm$$

$$\sum (x_{act\_n})^2 = (10^2 + 70^2 + 105^2)\,mm^2 = 16025\,mm^2$$

$$\sum x_{act\_n} \times x_{kn} = (-0{,}3 + 0{,}7 + 2{,}625)\,mm^2 = +3{,}025\,mm^2$$

Fig. 8-33: Example: Partial Sums for Auxiliary Equations

$$a = \frac{3 \times 3{,}025mm^2 - 185{,}0mm \times 0{,}005mm}{3 \times 16025mm^2 - (185{,}0mm)^2} = \frac{8{,}15mm^2}{13850mm^2} = 0{,}00058845$$

Fig. 8-34: Example: Auxiliary Equation 1

$$b = \frac{0{,}005 \times 16025mm^2 - 185{,}0mm \times 3{,}025mm}{3 \times 16025mm^2 - (185{,}0mm)^2} = \frac{-479{,}5mm^2}{13850mm^2} = -0{,}034621$$

Fig. 8-35: Example: Auxiliary Equation 2

$$x_0 = \frac{-(-0{,}034621)}{0{,}00058845} = 58{,}83\ \text{mm}$$

x_0 Dedicated Position

Fig. 8-36: Example: Determining the Dedicated Position

In order to be able to determine the dedicated position as exactly as possible, several series of measurements are to be recorded at different temperatures for position-dependent temperature error correction.

The resulting dedicated position is determined by the arithmetic mean of the calculated dedicated positions.

Position-Dependent Temperature Factor

The value for "P-0-0406, Axis correction temperature factor pos.-dependent" is determined

- by means of the data of the mechanical transmission elements

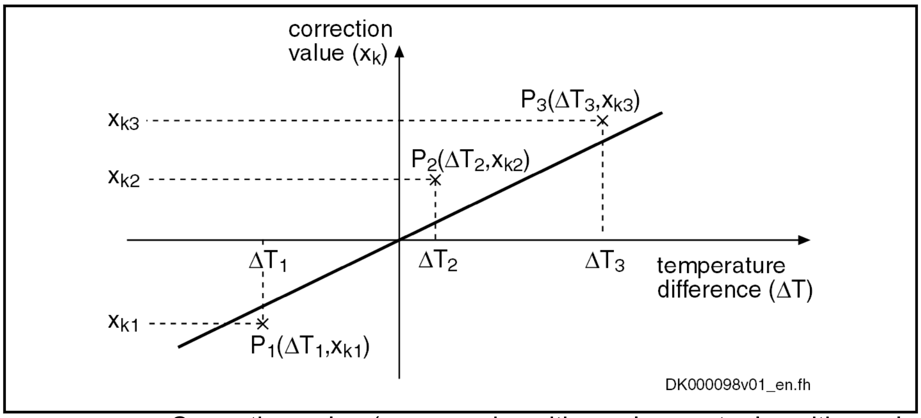
- or -

- by means of series of measurements for actual position value error at different temperatures at an identical axis position.

Temperature Factor by means of Series of Measurements

To determine the position-dependent temperature factor, it is necessary to record a series of measurements of correction values at different temperatures, at least at one position that clearly differs from the dedicated position.

Depending on the temperature difference, a straight line can be approximated through the measuring points.



x_{kn} Correction value (measured position value –actual position value (S-0-0051/S-0-0053))

ΔT_n Temperature difference (measured temperature –reference temperature (P-0-0402))

Fig. 8-37: Approximated Straight Correction Line on the Basis of Measured Correction Values at Different ΔT with Identical Actual Position

The gradient of the approximated straight line is the value of the position-dependent temperature factor. By means of the value from the series of measurements, it is possible to calculate the position-dependent temperature factor:

$$P\text{-}0\text{-}0406 = \frac{n \times \sum(\Delta T_n \times x_{kn}) - \sum \Delta T_n \times \sum x_{kn}}{n \times \sum \Delta T_n^2 - \left(\sum \Delta T_n\right)^2}$$

P-0-0406 Axis correction temperature factor pos.-dependent
n Number of measured values
ΔT_n Temperature difference at which the correction value x_kn was determined
x_{kn} Correction value at the temperature difference ΔT_n

Fig. 8-38: Calculating the Position-Dependent Temperature Factor from the Values of the Series of Measurements

In order to determine the factor as precisely as possible, it is useful to record the series of measurements at several positions.

The resulting temperature factor is determined by the arithmetic mean of the calculated temperature factors.

Activating the Function

The position-dependent temperature error correction is activated, when the value of "P-0-0406, Axis correction temperature factor pos.-dependent" is greater than zero.

When the value in parameter P-0-0406 equals zero, the function of position-dependent temperature error correction is deactivated. This correction function requires position data reference for the measuring system to the corrected!

8.6.3 Quadrant error correction

Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

In the case of axis drives that are controlled, for example, in circular interpolation, static friction at the reversal points of the direction of motion can cause distortion of the circular contour.

In order to compensate this contour error at the so-called "quadrant transitions" (velocity reversal), IndraDrive controllers provide the "quadrant error correction" function.

This correction function is useful for such cases when drives are operated in cyclic position control and in circular interpolation by the control master.

Pertinent Parameters

- P-0-0100, Position command value extension
- P-0-0435, Control word of position controller
- P-0-0436, Reference radius for quadrant error correction
- P-0-0437, Velocity time range for quadrant error correction
- P-0-0438, Table of path velocities for quadrant error correction
- P-0-0439, Table of velocity pulse for quadrant error correction

Functional Description

With quadrant error correction, static friction possibly occurring at the reversal points of the direction of motion is compensated by adding an additional, pulse-shaped command value to the velocity command value at the output of the position controller. By means of this velocity feedforward, the axis overcomes the static friction faster and with less lag error.

Sinusoidal Position Command Value Profile

To use quadrant error correction for circular interpolation, it is required that the control master operates two drives in cyclic position control. In this case, the drives are controlled in an interpolating way with sinusoidal position command value profiles with an angular difference, related to the circle, of 90 angular degrees between them. The internally generated velocity command value profiles of the two drives are also sinusoidal and have an offset of 90°.

Velocity Pulse with Reversal of Direction

When the direction of motion changes, a triangular velocity pulse with a velocity time range to be set is added to the drive-internal velocity command value.

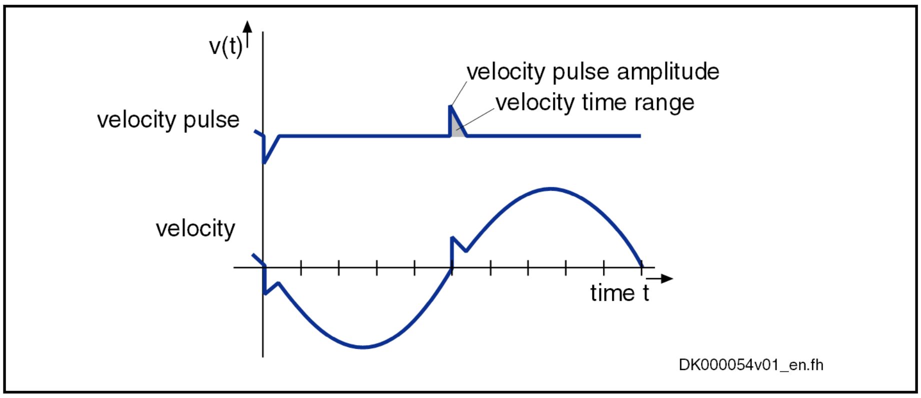


Fig. 8-39: Schematic Curves of Velocity Pulse and Velocity Command Value with Quadrant Error Correction

The controller detects changes in the direction of motion by the time flow of the cyclic position command values.

Reference Circle, Reference Radius

The settings for quadrant error correction are made when a reference circle is processed (radius of reference circle in "P-0-0436, Reference radius for quadrant error correction"), e.g. the circle that is demanded for the reference piece.

The amplitude of the velocity pulse of quadrant error correction is preset depending on the circular velocity. The pulse is added abruptly and decreases in a ramp-like way.

The higher the path velocity, the higher the pulse and the steeper it approaches zero, because the velocity time range of the pulse is independent of the velocity. It corresponds to the value entered in "P-0-0437, Velocity time range for quadrant error correction".

Estimation for the Velocity Time Range

For the dimensioning of P-0-0437, it is recommended to estimate the required pulse amplitude and the duration of the pulse. This is to be done with regard to the path velocity and the duration for processing the reference circle (P-0-0436):

$$\text{P-0-0437} = \frac{1}{2} \times \frac{a}{100\%} \times v_{path} \times \frac{b}{100\%} \times T_{circle}$$

P-0-0437	Velocity time range for quadrant error correction
a	Percentage of path velocity
v_{path}	Path velocity
b	Percentage of duration for processing of circle contour
T_{circle}	Duration for processing of circle contour

Fig. 8-40: Estimation for Value of P-0-0437

By means of list parameters, the circular velocities and velocity pulse amplitudes are assigned to one another:

- P-0-0438, Table of path velocities for quadrant error correction

- P-0-0439, Table of velocity pulse for quadrant error correction

It is possible to store 20 pairs of values for velocity and pulse amplitude in the mentioned parameters, the velocities have to be entered in ascending order.

Determining the Velocity Pulse Amplitude

The velocity pulse amplitude to be assigned to a current circular velocity is determined by means of the list parameter values:

- Between 2 pairs of values the pulse amplitude is interpolated in linear form, depending on the current path velocity.
- Below the lowest path velocity the pulse amplitude is set to zero.
- Above the highest path velocity the pulse amplitude assigned to the highest path velocity continues to take effect.

Determining the Current Circular Velocity

The controller calculates the current circular velocity by means of the current acceleration command value of the drive calculated from the position command values. The reference radius (P-0-0436) is the basis for calculating the path velocity.

If the drive-internal resolution of the calculated acceleration command value is low, quadrant error correction sometimes is without effect. For this case, it is recommended to integrate the extended position command value ("P-0-0100, Position command value extension") in the cyclic master communication. This extends the decimal places of the position command value.

☞ Experience has shown that it is absolutely necessary to integrate the extended position command value (P-0-0100) in the cyclic master communication on the control side!

Activating the Quadrant Error Correction

The quadrant error correction is activated by the control master by setting the respective bit of "P-0-0435, Control word of position controller". It is only advantageous to use the function when a circular form is to be machined in the part program.

The correction is to be activated at the earliest one clock after the start of circular interpolation so that the velocity pulse won't be added when the drive is starting. Otherwise high velocity pulses damaging the contour could be added, due to the mostly high starting accelerations, when the drive is starting.

For machining other contours, the quadrant error correction is to be deactivated. To do this, the respective bit of P-0-0435 is to be contained in the cyclic master communication and activated depending on the kind of machining.

☞ The quadrant error correction remains without effect when the value "0" is contained in "P-0-0437, Velocity time range for quadrant error correction".

Notes on Commissioning

For commissioning it is necessary to move the drive by the control master in cyclic circular interpolation. The quality of the circular form has to be determined, in the ideal case with measuring equipment for circular form testing.

Recommended Steps of Commissioning

The quadrant error correction is to be commissioned in the following steps:

1. Make the following presettings:
   - Enter value for "P-0-0436, Reference radius for quadrant error correction"
   - Set quadrant error correction inactive in "P-0-0435, Control word of position controller"

- Set "P-0-0437, Velocity time range for quadrant error correction" to "0"
- Write, for example, 50% and 70% (list lines 1 and 2) of the maximum circular velocity to "P-0-0438, Table of path velocities for quadrant error correction"
- In "P-0-0439, Table of velocity pulse for quadrant error correction", write the value "0" to first two list lines

2. Move drive on control side in circular interpolation with 50% of maximum circular velocity and check quality of circular form with measuring equipment for circular form testing.
3. Set quadrant error correction active in "P-0-0435, Control word of position controller"
4. Write approx. 1% of current path velocity to list line 2 of"P-0-0439, Table of velocity pulse for quadrant error correction".
5. Increase value in "P-0-0437, Velocity time range for quadrant error correction" starting with low values, observe quality of circular form with measuring equipment; increase values until maximum quality of circular form has been reached.

   If quality of circular form does not improve, write lower or higher value to list line 2 of P-0-0439, depending on tendency of improvement of circular form quality.
6. After optimum value was written to P-0-0437, operate drive with other, different circular velocities in order to determine optimum values for P-0-0439.

Observe interpolation data (see above) for the velocity pulse amplitude depending on the current path velocities (P-0-0438 and P-0-0439)!

8.6.4 Cogging torque compensation

Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Motors for which the magnetic excitation is realized with permanent magnets (e.g. synchronous motors) in many cases show cogging torques or cogging forces. Cogging torques/cogging forces already act on the moving component of the motor in the de-energized state and aim at moving it to a stable position.

When the motor is put into motion by control, the cogging torques/cogging forces act on the motor in a decelerating or accelerating way, according to the position. For applications in which minimum lag error or very constant velocity is important, the position-dependent cogging torques/cogging forces can have a negative effect.

To improve the synchronous operation and lag error behavior of synchronous motors, IndraDrive controllers provide cogging torque and cogging force compensation for drives with high demands on lag error and synchronous operation quality. For this purpose, the position-dependent, additive torque command values that take effect in drive control require an unequivocal position reference from the motor measuring system to the motor.

The position reference is automatically established using a search of the reference marks. If this is not possible, you can switch to the "position reference by homing" function (P-0-1131, Control word of cogging torque compensation). The position reference is then established only by the "homing"command; in this way, even encoders without a mark or with several marks can be used.

The range in which the cogging torque compensation takes effect can cover the entire travel range of an axis, but can also be restricted to a definable position range. The restricted position range can be less than one motor revolution (rotary motor) or one pole pair distance (linear motor). The drive controller determines the compensation values at axis motion with constant velocity and the values, depending on the direction of motion and referring to the position, are stored in tables.

Hardware Requirements

The compensation of the cogging torque or the cogging force is possible for the use of both measuring systems with absolute evaluation and measuring systems with relative evaluation. The following restriction applies to relative measuring systems where the reference point is automatically established:

- For rotary motors only **one** reference mark may occur per revolution or the motor encoder has distance-coded reference marks!
- For linear motors only **one** reference mark may occur over the travel distance or the motor encoder has distance-coded reference marks!

Hardware Requirements

The motor must be equipped with a motor encoder. Cogging torque compensation is not possible with sensorless motor operation!

Pertinent Parameters

- P-0-0162, C1800 Command Drive optimization / command value box
- P-0-0165, Drive optimization, control word
- P-0-0170, Drive optimization, acceleration
- P-0-0171, Drive optimization, velocity
- P-0-1129, Cogging torque compensation value
- P-0-1130, Table of cogging torque compensation values pos. direction
- P-0-1131, Control word of cogging torque compensation
- P-0-1132, Table of cogging torque compensation values neg. direction
- P-0-1133,
- P-0-1134, Velocity threshold for attenuation of cogging torque compens
- P-0-1135, Velocity threshold for switching off cogging torque compens.
- P-0-1136, Lead time cogging torque compensation
- P-0-1138, C4800 Command Determine cogging torque compensation table
- P-0-1139,
- P-0-1145, Cogging torque compensation: Lower position limit
- P-0-1146, Cogging torque compensation: Upper position limit
- P-0-1147, Cogging torque compensation: Offset positive
- P-0-1148, Cogging torque compensation: Offset negative

Pertinent Diagnostic Messages

- C1808 Drive not homed
- C4800 Command Determine cogging torque compensation table
- C4801 Cogging torque compensation: Measuring vel. too high
- C4802 Cogging torque compensation: Measuring vel. too low

- C4803 Cogging torque compensation: Inadmissible acceleration
- C4804 Cogging torque comp.: Err. when storing corr. val table
- C4805 Cogging torque comp.: Motor measuring system not homed
- C4806 Cogging torque compensation: Measuring range invalid

Functional Description

Recording the Cogging Behavior

The cogging behavior of a motor is recorded at constant velocity, once at initial commissioning. The torque/force command values currently generated by the velocity controller are recorded in a position-dependent way within a measured value detection range.

Before the measured values are recorded, the position reference is required between motor encoder and motor:

- Position reference is automatically present if a motor encoder that can be evaluated absolutely across the entire travel distance of the axis is used.
- Position reference is generated automatically when a motor with relevant motor encoder moves over its reference mark (encoders with a reference mark/motor encoder).
- Position reference is generated automatically when a motor with distance-coded motor encoder via two neighboring reference marks.

☞ With motors with relative motor encoder without a reference mark or multiple reference marks per turning, a position data reference for the axis must be established by "drive- or control-guided homing" (configuration required in "P-0-1131, Control word of cogging torque compensation")!

The range of effectiveness of the cogging torque compensation is selectable (configurable in "P-0-1131, Control word of cogging torque compensation"):

- Unrestricted across the **total travel range** of the axis
- Restricted to a **position range between definable limits**: Lower limit (P-0-1145), upper limit (P-0-1146)

In the case of cogging torque compensation over the **entire travel range**, the recording range for the cogging torque compensation table(s) is one motor revolution (rotary motor) or one pole pair distance (linear motor). The compensation values take effect "recurrently" within every motor revolution or pole pair distance.

☞ In rotary motors, the pole pairs after each rotation are again the same, which should result in good cogging torque compensation at all times. In the case of linear motors, the pole pair widths are in fact always the same, but the lined-up pole pairs of the travel distance differ from one another, which should result in differences in the effectiveness over the travel distance with cogging torque compensation merely related to the pole pair distance.

In the case of cogging torque compensation **between definable limits**, the recording range of the measured values for the cogging torque compensation table(s) is the entire **position range between the limits**. This is particularly advantageous for linear motors because the lined-up permanent magnet pole pairs are only alike within certain tolerances as regards the magnetic flux density, as well as the mechanical deviations and mounting. Thereby, individual compensation values exist for each pole pair which leads to expect good effectiveness of the cogging torque compensation over the entire, limited position range.

☞ For cogging torque compensation limited in the position range, it is necessary to establish the **position data reference between motor encoder and axis**. Position reference between motor encoder and motor only (see above) is not sufficient in this case!

Determining the Measured Values by Internal Command Value Input

The tables of values for cogging torque compensation can be recorded by activating "P-0-0162, C1800 Command Drive optimization / command value box". In this case, the command value for the motion for measured value detection is generated internally.

Determining the Measured Values by Control-Master-Side, External Command Value Input

For mechanically connected axes (e.g. Gantry axes), however, the required velocity command value can also be set by the control master.

The following requirements on the command value enable apply depending on the range of effectiveness of the cogging torque compensation:

Range of effectiveness: **Total travel range**

- Rotary motor → Motion over at least one motor revolution is required
- Linear motor → Motion over at least one pole pair distance is required

Range of effectiveness: **Limited position range** (only with axes with "modulo format")

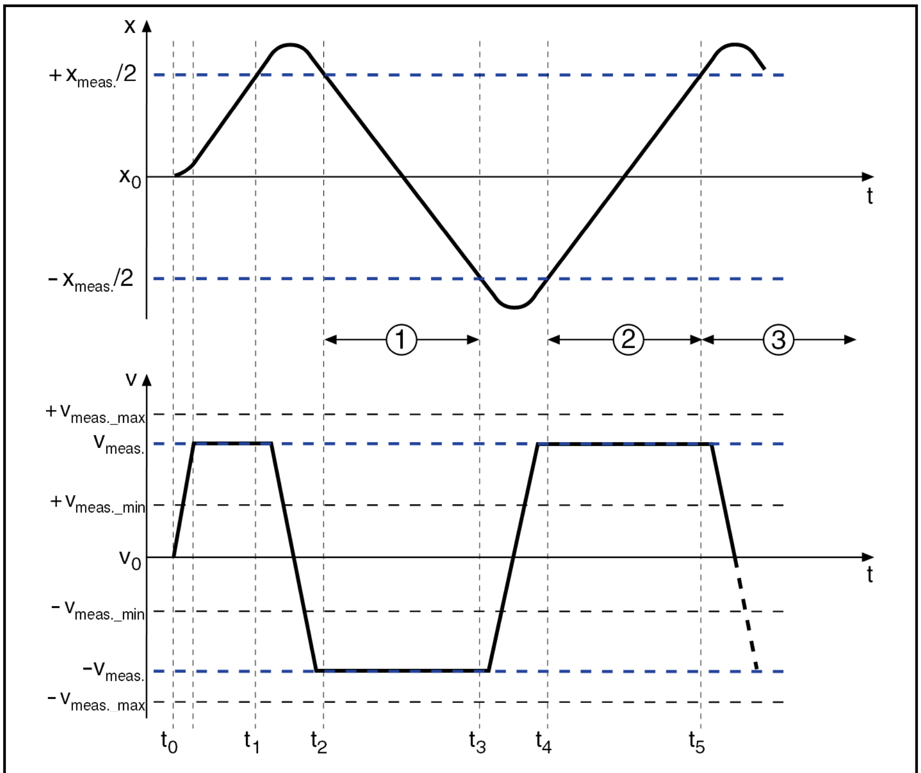
- The axis must move over the total position range between "P-0-1145, Cogging torque compensation: Lower position limit" and "P-0-1146, Cogging torque compensation: Upper position limit".

Other requirements on the command value input:

- The measured value detection is only possible for constant velocity; the measured velocity must be selected within the allowed value range, depending on the performance that has been set (see below).
- If the drive must move both in positive and negative direction, it is necessary to include measured values for positive and negative direction of motion. Otherwise, only command values for the intended direction of motion are required.
- The controller divides the range of measured value detection into a position pattern with 1024 sections. For every section of the pattern, a compensation value is stored that has been determined via 32 measured values. Depending on the selected measuring velocity, the detection range must be passed, as a maximum, 32 times or, as a minimum, once in each required direction of motion.

Command Value Curve for Bidirectional Measured Value Detection

The figure below illustrates the position command value curve, to be preset by the control master, for measured value detection for cogging torque compensation in the event that the drive has to move in both directions.



x_0 Position at starting point of time for the execution of the command

x_{meas} Measuring distance

v_{meas} Velocity during measuring value detection

Fig. 8-41: Position Command Value Curve for Bidirectional Recording of the Measured Values for Cogging Torque Compensation

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☞ The position at the time of the command start (x_0) is automatically the center of the range of measured value detection when this is a motor turn or a pole pair distance. On activation of the command "C4800 Command Determine cogging torque compensation table" the axis must be located in sufficient distance to the limits of the travel range!

☞ Measured value detection in both directions must be carried out in compliance with the following requirements:

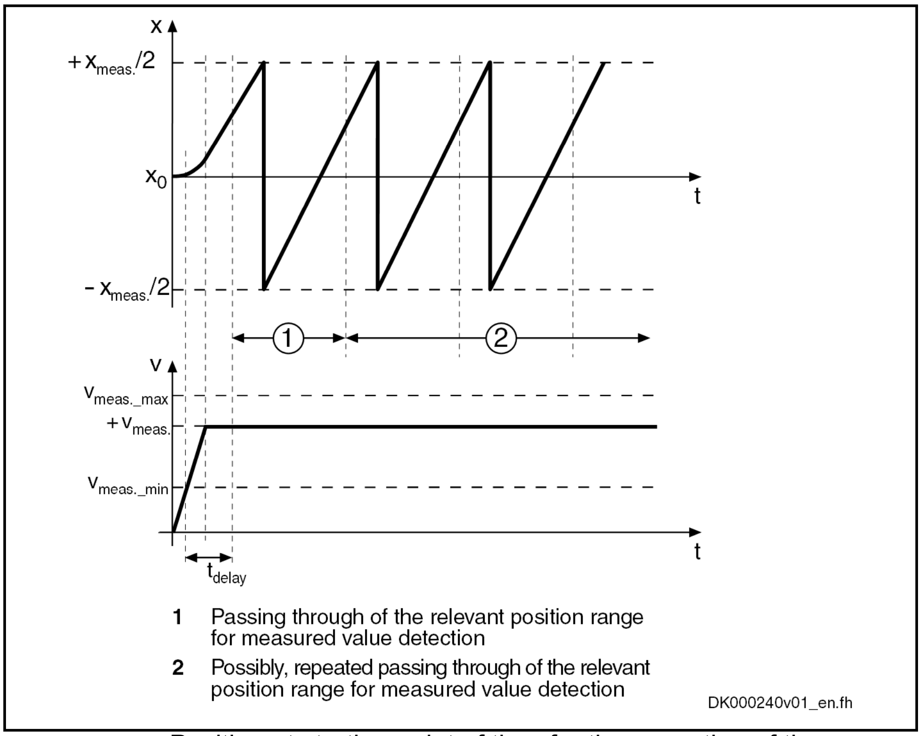
- Axis in the "absolute format"

- or -

- Axis in the "modulo format" and command value mode "Shortest distance" (see below "Notes on Commissioning")

Command Value Curve for Unidirectional Detection of the Measured Values

The figure below illustrates the position command value curve, to be preset by the control master, for measured value recording for cogging torque compensation in case the drive is to move in one direction .



x_0	Position at starting point of time for the execution of the command
x_{meas}	Measuring distance
v_{meas}	Velocity during measuring value detection
t_{delay}	Delay time of 0.5 s before detection of the measured values

Fig. 8-42: Position Command Value Curve for Unidirectional Recording of the Measured Values for Cogging Torque Compensation

☞ The unidirectional detection of the measured values for the table for cogging torque compensation is carried out in that direction which corresponds to the preceding sign of the command value, which has been recognized for the first time after activation of the command "C4800 Command Determine cogging torque compensation table".

☞ Under the following conditions, measured value detection can only be carried out in one direction:

- Axis in "modulo format" and command value mode "positive direction" or "negative direction"

Value Range of the Measuring Velocity

The measuring velocity refers to the motor output shaft or the slide of the linear motor. For load reference the command value input is to be selected such that the motor-side velocity is in the allowed value range! The value range depends on the selected control performance.

	Minimum measuring velocity v_{meas_min}		Maximum measuring velocity v_{meas_max}	
Performance	Rotary (in 1/min)	Linear 1) (in mm/min)	Rotary (in 1/min)	Linear 1) (in mm/min)
Basic	0.5	35.5	117	8789
Advanced	1.0	70.5	234	17578

1) Velocity for linear motors with a pole pair distance of 75 mm

Tab. 8-6: Value Range for the Measuring Velocity Depending on the Performance which was Set

$$v_{Meas\_limit(PPD)} = v_{Meas\_limit(75mm)} \frac{PPD}{75\ mm}$$

PPD Pole pair distance of a linear motor
$v_{meas\_limit(PPD)}$ Limit value of measuring velocity depending on the pole pair distance of a linear motor
$v_{meas\_limit(75mm)}$ Limit value of measuring velocity for linear motor with PWT = 75 mm according to above table

Fig. 8-43: Converting the Measuring Velocity Limit Values for Linear Motors

> ☞ When the maximum measuring velocity is used, the range for the measuring value detection must be passed at least 32 times, for minimum measuring velocity at least once.

Determining the Correction Values

Ideally, the cogging torque correction values of a motor are to be determined when the machine has not yet been connected.

The controller divides the range of measured value detection into a position pattern with 1024 sections. After recording the 32 required measured values within each position pattern section, a torque/force correction value for each of these position pattern is determined and stored in the cogging torque compensation tables. Every table has 1024 values, which are stored in the following parameters:

- P-0-1130, Table of cogging torque compensation values pos. direction
- P-0-1132, Table of cogging torque compensation values neg. direction

> ☞ "P-0-1133, " displays whether the required number of measurements per position pattern has been reached.

The smallest unit of the position pattern containing 1024 sections is a motor turn/pole pair distance. With **cogging torque compensation across the entire travel range**, the measuring value detection range corresponds to this smallest unit, 1024 correction values are determined for the respective direction of motion and are stored in the cogging torque compensation tables P-0-1130 and P-0-1132.

Determining the Correction Values

With **cogging torque compensation in a limited position range**, 1024 correction values are determined for the relevant direction of motion across this limited range and stored in the tables P-0-1130 and P-0-1132.

The smallest unit of the position pattern containing 1024 sections is a motor turn/pole pair distance. With **cogging torque compensation in the entire travel range**, all 1024 correction values of this measured value detection range are determined and stored in the tables of the cogging torque compensation values P-0-1130 and P-0-1132.

With **cogging torque compensation in a limited position range**, the number of the correction values stored in the tables P-0-1130 and P-0-1132 is influenced by the scope of the limited position range:

- With a selected position range for the cogging torque compensation less than one motor turn, or a pole pair distance, the number of stored correction values is reduced in the ratio of the position range scope to one motor turn or one pole pair distance.
- With a position range scope bigger than one motor turn or pole pair distance, 1024 is the maximum number of stored correction values. The maximum number is always achieved when the position range reaches or exactly meets the n-fold motor revolution or pole pair distance. When the n-fold value is exceeded, the maximum number of 1024 stored correction values is only achieved for (n+1)-fold position range (in contrast to a motor turn or pole pair distance).

Cogging Torques with Motor Axis Group

If, for example, the cogging torques for a rotary synchronous kit motor are to be compensated, the recording of the values for the tables for cogging torque compensation is only possible in the motor-axis group as the motor is only operational after it has been installed in the machine or the axis.

Range of effectiveness: **Total travel range**

If a kit motor moves a shaft, which is not rotationally symmetrical (unbalanced), and its cogging torques are to be compensated, the influence of the rotor-position-dependent inertia can be drive-internally eliminated from the measured compensation tables. The settings required for this purpose must be made in "P-0-1131, Control word of cogging torque compensation".

☞ The influence of an unbalanced mass can only be eliminated when the unbalance occurs periodically with reference to a rotor revolution!

For linear synchronous motors (kit motors) too, recording of the cogging torque compensation table values is only possible in the motor axis group, however eliminating axis-side influences only makes sense when they equally affect the entire travel range (e.g., force due to weight of a vertical axis, friction etc.).

Range of effectiveness: **Limited position range**

With limited effectively cogging torque compensation, neither an offset in the correction values nor the influence of an eccentrically-acting moment of inertia can be ruled out by computation. Only manual correction of the offset is possible via "P-0-1147, Cogging torque compensation: Offset positive" or "P-0-1148, Cogging torque compensation: Offset negative".

Activating the Cogging Torque Compensation

The cogging torque compensation must be activated via the respective bit of "P-0-1131, Control word of cogging torque compensation".

Effect of Cogging Torque Compensation

Position-dependent adding of torque/force correction values, as is required for cogging torque compensation, is carried out below the adjustable velocity threshold in "P-0-1134, Velocity threshold for attenuation of cogging torque compens") with the percentage of correction values (default: 100%) entered in "P-0-1139, ".

The compensation is completely ineffective (0%) above the adjusted switch-off velocity threshold (P-0-1135, Velocity threshold for switching off cogging torque compens.). Any gain in the cogging behavior can be suppressed by delays due to calculating time of the correction value. Between the lower and the upper velocity threshold, the effectiveness of the correction values is linearly reduced from the current value of P-0-1139 to 0%, depending on the actual velocity value.

With low speeds, intermediate values interpolated with regard to the actual position value are generated from neighboring correction values of the position raster and take effect depending on the position cycle time, in order to keep the changes of the additive torque/force command values (compensation values) as continuous as possible.

The effect of the compensation values can be intensified or attenuated stationarily or on the side of the control master (process-dependent) with "P-0-1139, ", the reference values (100%) are the table values, see Parameter Description. The currently effective, position-dependent compensation command value is displayed in parameter "P-0-1129, Cogging torque compensation value".

☞ The parameter "P-0-1129, Cogging torque compensation value" is set to the value "0" if the (drive-internal) cogging torque compensation is deactivated.

Torque/Force Limitation and Cogging Torque Compensation

The following limitations affect the total torque/force command value, including the current compensation value:

- S-0-0092, Bipolar torque/force limit value
- P-0-0109, Torque/force peak limit

The following limitations do not affect the (additive) compensation value, but merely the output of the velocity controller:

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative

External Cogging Torque Compensation

If the drive-internal cogging torque compensation is not activated, external compensation values can affect the motor control via parameter "P-0-1129, Cogging torque compensation value". It can be cyclically written by a control master (e.g. via MLD, etc.). The processing in the controller takes place in the velocity loop clock. The unchanged value is used for motor control as the additive torque/force command value.

☞ Functionalities of drive-internal cogging torque compensation, like velocity-dependent attenuation (P-0-1134, P-0-1135) or adaption by adaption factor (P-0-1139) are not available with external cogging torque compensation!

If drive-internal cogging torque compensation is activated, values written externally to P-0-1129 are ignored.

☞ Drive-internal cogging torque compensation is only available in functional packages "Servo" and "Sync"! Cogging torque compensation values can be specified externally in the base package via P-0-1129!

Diagnostic message

For the commissioning as for the operation of the drive with activated cogging torque compensation, the "status word cogging torque compensation (P-0-1133)" offers the following useful information:

Diagnoses for commissioning:

- Message bit for the display that the drive is currently in the measured value detection range

- Message bit for the required number of measured values per position pattern

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☞ In particular, the message about the completion of the measured value detection with command value input on the side of the control master!

Diagnoses for the operation:

The bit combination displays whether the cogging torque compensation is active and, where necessary, what effectiveness status it has.

Notes on Commissioning

Procedure

The compensation of cogging torque/cogging force through the IndraDrive firmware is carried out in two steps during **initial commissioning**:

1. Recording and storing of the position-dependent cogging behavior via measured value detection range and generating position-dependent torque and force correction values for the compensation of the cogging behavior.
2. Activation of the cogging torque compensation within a velocity range of the drive

The cogging torque compensation activated in the drive parameter set only takes effect **when the drive is operated** and after it has been switched on again, after the position reference has been established:

- With absolute measuring systems, the position reference is always available, i.e. compensation takes immediate effect.
- With relative measuring systems, the position reference must first be established. This takes place automatically when the motor is moved during operation or by homing the drive with a command.

Initial Commissioning

General Mechanical Conditions

The values for the cogging torque compensation table are determined during the initial commissioning of the motor. If possible, the motor should not yet have been connected to the machine for this purpose!

Kit motors are only operational when they are built on or into the axis. They must be able to move as free from load as possible!

Notes on Commutation Setting

The commutation offset (for synchronous motors) must have been optimized and, for relative motor encoders, stored with relation to the reference point! The cogging torque compensation will only lead to an improvement of the motor characteristics if the commutation offset is the same so that it can be reproduced (use "Optimum commutation with regard to reference point" for relative motor encoder!).

Notes on Velocity and Position Controller Setting

In addition, optimization of the parameters of the velocity controller for the axis is a prerequisite to ensure that the correction values for the cogging torque compensation tables are carried out with the appropriate or required control loop gains or filter settings for the axis.

When the axis is moved in position control, lagless command value input is highly recommended to ensure that the velocity command value generated for the measured value detection is as constant as possible. Keep the proportional gain of the position control loop (Kv) as low as possible.

Define Range of Effectiveness of the Cogging Torque Compensation

The range of effectiveness of cogging torque compensation is defined in "P-0-1131, Control word of cogging torque compensation".

- **Total travel range** (default): Recommended value for rotary motors
- **Limited position range**: Recommended value for linear motors

When using the **limited position range** position range limits must be defined. They must be within the allowed travel range and at a sufficient distance to the travel range limits to ensure that the reversal of motion does not lead to limit excess when recording the clogging torque compensation tables:

- P-0-1145, Cogging torque compensation: Lower position limit
- P-0-1146, Cogging torque compensation: Upper position limit

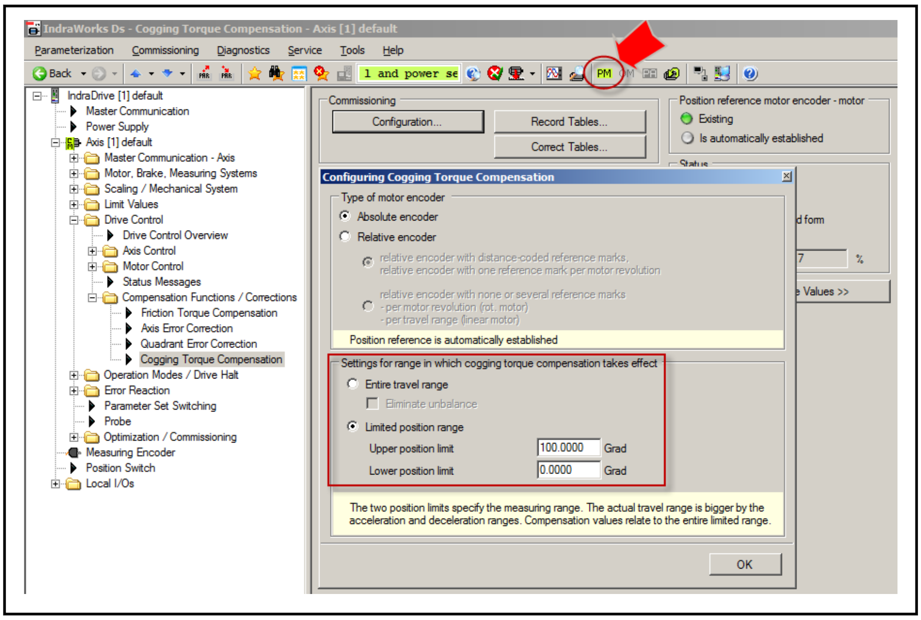

Fig. 8-44: IndraWorks Dialog for Defining the Effective Range and, if Necessary, the Effective Range Limits of the Clogging Torque Compensation

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☞ The effective range of the cogging torque compensation is defined in "PM" to ensure that neither the range itself nor, where applicable, the range limits can be changed during the operation by mistake!

Establishing the Position Reference

☞ To establish the position reference, the drive must be in the "operation mode" ("bb" or "Ab" or "AF") !

For the commissioning and the use of clogging torque compensation, the position reference between motor and motor encoder first needs to be established:

- Absolute motor encoder (single-turn or multi-turn motor encoder): Execute the command "S-0-0447, C0300 Set absolute position procedure command". No motion of the axis is required before measuring value detection.

When using a relative motor encoder, the type of the encoder must be specified as the position reference between encoder and motor is produced in different ways:

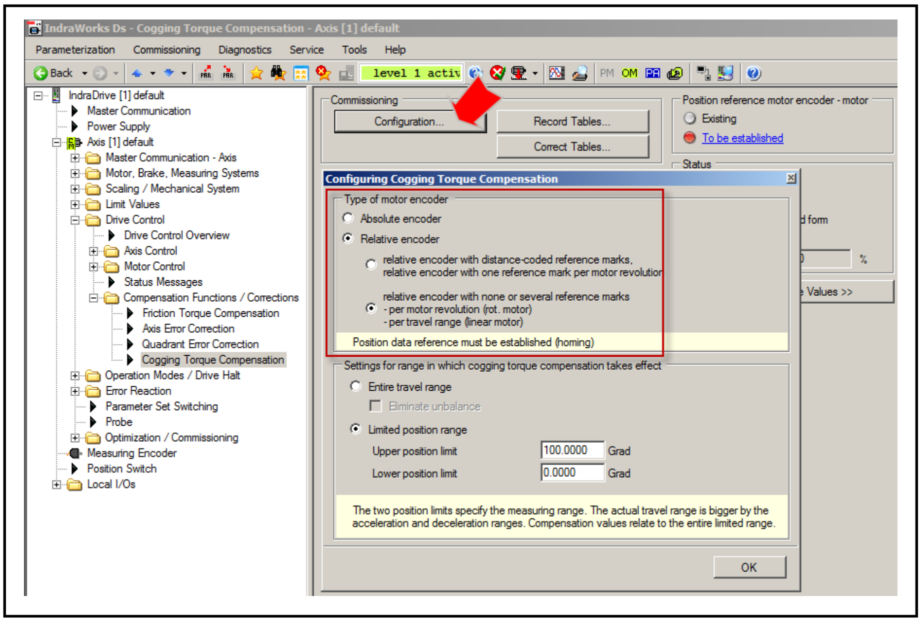


Fig. 8-45: IndraWorks Dialog for Indicating the Motor Encoder Used

- Relative motor encoder with reference mark: Movement of the motor over the reference mark of the encoder; with distance-encoded reference marks, movement over two neighboring marks is needed. This happens automatically through the movement for recording the cogging torque compensation tables.
- Relative motor encoder without or with several reference marks per motor revolution: Executing the command "S-0-0148, C0600 Drive-controlled homing procedure command" ("position reference by referencing" must be set in "P-0-1131 Control word of cogging torque compensation", e.g. via IWD dialog, see above).

☞ The status of the position reference motor encoder motor is is displayed in the IWD dialog for the cogging torque compensation top right!

Internally Determining the Correction Values for the Cogging Torque Compensation

The correction values for the cogging torque compensation are saved after recording the values in tables. The values are usually determined in a drive-controlled way, but can also be controller-guided:

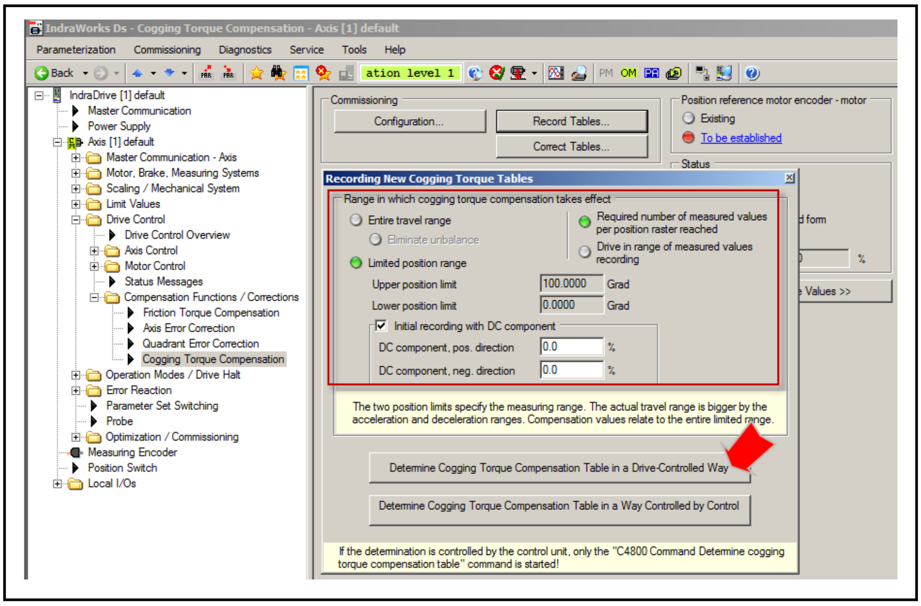
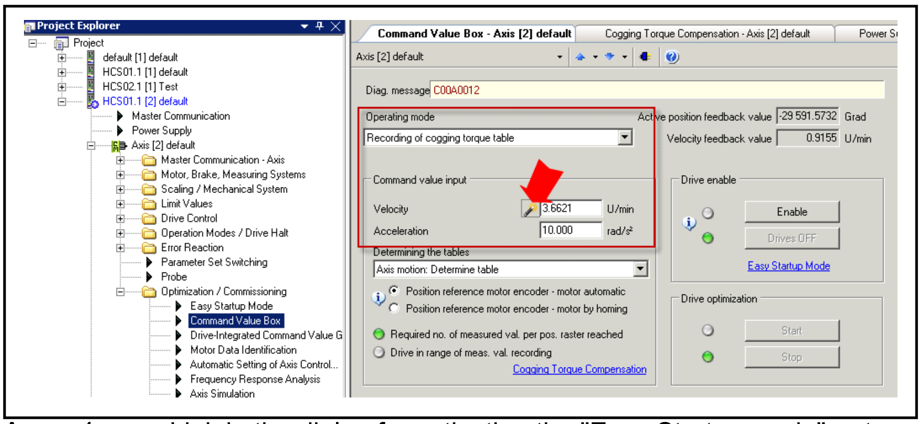


Fig. 8-46: IndraWorks Dialog for Determining the Cogging Torque Compensation Tables

By pressing the button for determining the drive-guided compensation tables, the dialog for the "Command value box" opens up. One link leads onto the dialog of the "Easy-Startup mode", the start of which, the motor can be moved independently of the higher-level control master over the (drive-internal) command value box (a link leads back to the dialog "Command value"). The command value output for recording compensation tables:



Arrow 1 Link in the dialog for activating the "Easy Startup mode", return via link for the "Command value box"

Arrow 2 Call proposal for the travel velocity. Result is displayed and where necessary are active as a command value.

Arrow 3 Start of the drive enable

Arrow 4 Start of"P-0-0162, C1800 Command Drive optimization / command value box"

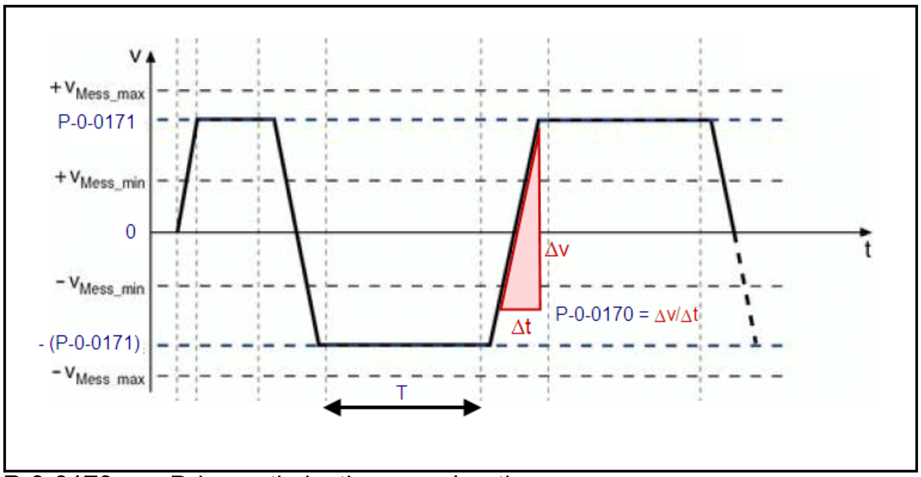
Fig. 8-47: IndraWorks Dialog for Start of Drive-Internal Recording of the Cogging Torque Tables with the Presetting of the Velocity and Acceleration

The controller generates a command value process which calls a motion with constant velocity across the measured value detection range. The travel speed is preset on the user-side via "P-0-0171, Drive optimization, velocity" (permissible value range see further above). The maximum acceleration occurring in the command value range is preset via "P-0-0170, Drive optimization, acceleration" and can be limited by the user to a value allowed for the mechanical axis system.

☞ In the case of bi-directional measured value recording, the entire movement range extends to measuring value detection and the turns/sections required for the reversal of motion (reversion).

A quasi-infinite travel range is required with unidirectional measured value detection, which is only possible with rotary axes!

Unidirectional (modulo) is not possible when the travel range is limited!



P-0-0170 Drive optimization, acceleration
P-0-0171 Drive optimization, velocity
T Duration of motion at constant velocity for measured value detection for a complete motor revolution or pole pair distance

Fig. 8-48: Velocity Command Value Curve for Bidirectional Recording of the Measured Values for Cogging Torque Compensation

NOTICE

The axis performs independent movements → Property damage might occur on inobservance of the general conditions when starting the command C1800!

- With "cogging torque compensation in the entire travel range", it must be ensured that the axis is not driven into a collision range using a suitable starting position!
- With "cogging torque compensation over a limited position range" suitable position range limits (P-0-1145, P-0-1146) must be selected to ensure that the axis is not moved into the collision range!
- Select as high an acceleration value as possible, in order to reach a constant velocity command value over the shortest possible distance! This minimizes the travel distance if the motion is carried out in both directions.
- Select as low a position control loop amplification as possible S-0-0104 (Kv) to improve smoothness of running at constant velocity!
- Ensure with the presetting of unidirectional command values (modulo format and unidirectional command value mode) that the motor shaft can rotate infinitely!

External Command Value Input for Determining the Correction Values

☞ Master-side command value input is only required, when the drive-internal command value input cannot be used, e.g. for mechanically connected axes which can only be moved together via the control master.

To record the cogging torque compensation tables via command values externally set, the control master must make available a routine, which provides the required velocity command value for the axes to be moved (for an explanation of the requirements on the master-side command value: see above).

External Command Value Input: Determining the Velocity for Measured Value Detection

The velocity for measuring value detection is to be determined according to the requirements of the above table ("Value Range for the Measuring Velocity"). With maximum velocity, passing the measuring value range up to 32 times may become necessary!

The minimum travel range of the motor is to be evaluated and a master-side command value profile is to be defined (programmed) such that the motor passes through the measuring value detection range an adequate number of times. The following applies to the direction of motion:

- Bidirectional for motion of the axis both positive and negative direction (starting position is the center of the measuring value detection range)
- Unidirectional in the direction of axis motion with motion of the axis in only one direction

External Command Value Input: Presetting the Command Value Profile

For recording the values for the cogging torque compensation tables, "P-0-1138, C4800 Command Determine cogging torque compensation table" must be activated and the required command value profile must be set.

☞ For recording the values for the cogging torque compensation table for axes with position scaling "modulo format" (setting in S_0_0076) the following conditions must be taken into consideration:

- If in the parameter "S-0-0393, Command value mode" the option "shortest distance" has been set, the controller expects command values for both motion directions of the motor ("bidirectional").
- If in "S-0-0393, Command value mode" the option "positive direction" or "negative direction" has been set, the controller expects that the axis has only one allowed direction of motion and therefore command values are only preset for one direction of motion ("unidirectional").

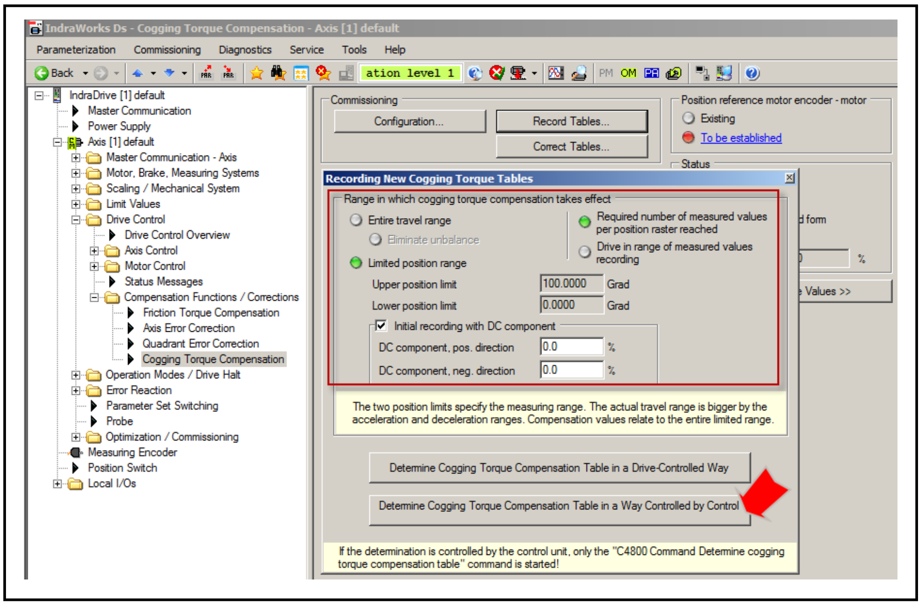


Fig. 8-49: IndraWorks Dialog for Starting Controller-Guided Recording of the Cogging Torque Tables

During the motion according to the command value input, measuring values are recorded, from which the values for the correction tables are determined. "P-0-1133, " displays when enough measuring values have been recorded in order to complete the command value input.

After completion of the measuring value detection, the correction values for the cogging torque compensation table are automatically determined and appropriately stored in the position pattern. Now the execution of the command C4800 can be completed.

☞ During the recording of measured values, "C48" flashes on the display. As soon as the measured value recording is completed, the flashing is stopped and "C48" is displayed continuously!

☞ After the replacement of the motor or motor encoder, the values for the cogging torque compensation table must be determined again!

Activating the Function

Cogging torque compensation is activated by setting the corresponding bit in "P-0-1131, Control word of cogging torque compensation"!

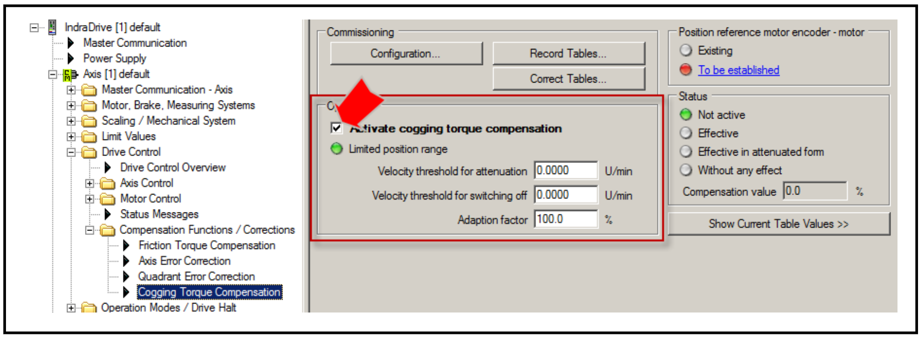


Fig. 8-50: IndraWorks Dialog for Activating Cogging Torque Compensation and Entry of the Adaption Factor and the Thresholds for Attenuation and Shut-Down

Checking the Effectiveness

The effectiveness of the cogging torque compensation can be evaluated by comparing various status variables of the drive between active and non-active function. With low travel velocities, the effect of the compensation can be recognized most clearly.

The values of the status variables relevant for the comparison are contained in the following parameters:

- S-0-0040, Velocity feedback value
- S-0-0189, Following distance
- P-0-0049, Effective torque/force command value

With "P-0-1139, " the effect of the stored compensation values can be attenuated or intensified and the compensation values can be attenuated depending on the velocity until the system switches off. The status of the cogging torque compensation can be called up in "P-0-1133, " and is displayed in the associated dialog (see above).

The corresponding velocity thresholds can be set in the following parameters:

- P-0-1134, Velocity threshold for attenuation of cogging torque compens
- P-0-1135, Velocity threshold for switching off cogging torque compens.

For this purpose, the axis must be controlled with command value characteristics which result in constant axis velocities of different levels. The amplitude of the above stated status variables must be evaluated without and with active cogging torque compensation. The values for P-0-1134 and P-0-1135 are to be determined such that the amplitudes have minimum values **with active compensation.**

Appropriate command value characteristics can be generated by:

- Internal command value box: Reversing between two axis positions or stepwise operation in velocity or position control, see IndraWorks dialog
- External command value input by control master, using the same command value profile as for the recording of the cogging torque compensation tables

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☞ The velocity range in which it is advantageous to use cogging torque compensation can be increased by adjusting the value "P-0-1136, Lead time cogging torque compensation", if necessary!

Possible Problems During Measured Value Detection

In case the command value does not comply with the requirements (see above), measured value detection is stopped and the execution of the command is aborted with the corresponding error message:

- C4801 Cogging torque compensation: Measuring vel. too high
- C4802 Cogging torque compensation: Measuring vel. too low
- C4803 Cogging torque compensation: Inadmissible acceleration

If an error occurs when the cogging torque compensation table is stored, the following message is generated:

- C4804 Cogging torque comp.: Err. when storing corr. val table

If, with a relative motor encoder, the drive has not read the reference mark(s) on activation of the command C4800, the following message is generated:

- C1808 Drive not homed

Operating the Drive

Establishing the Position Reference

☞ For the operation of the drive with active cogging torque compensation, the respective bit must be set in "P-0-1131, Control word of cogging torque compensation".

The cogging torque compensation activated in the drive parameter set only takes effect when the position reference between motor encoder and motor has been established.

With "cogging torque compensation in the entire travel range", the position reference is automatically established when the controller has scanned the reference mark of a relative motor encoder or two neighboring reference marks of a relative, distance-coded motor encoder. With absolute motor encoders, compensation takes immediate effect without the motor having to move.

If a relative motor encoder has no reference marks or has several per motor revolution, the drive must be homed to establish the position reference between the motor encoder and the motor.

☞ If the position reference can only be established by homing, this must be correspondingly configured in the control word (P-0-1131).

For "cogging torque compensation in limited position range" the position data reference between motor encoder and axis is established by "drive-" or "controller-guided referencing".

After establishing the position- and position data reference, the cogging torque compensation is immediately effective!

8.6.5 Correction of the Torque/Force Constant

Brief Description

Fields of Application

Base package of all firmware variants in **closed-loop** characteristic

Display of Motor Load, Load Limit Values

For IndraDrive devices, the current load of the motor is determined and displayed on the drive side. The load can be limited by means of the drive controller.

The unit of the load display and load limit value input can be selected:

- Percentage-based, in relation to the continuous motor current or nominal motor current
- Physically, values in "Nm" (rotary) or "N" (linear)

The load of the motor is determined by means of the measured motor current; with physical scaling, the controller determines the motor torque or force by using the currently flowing current for calculating the motor-type-specific torque or force constant.

If torque/force precision up to approx. +/- 5% is required (e.g., for load limitation) due to the mechanical axis system or process technology, the controller provides the "correction of torque/force constant". In this case, the motor-type-specific value is corrected depending on the current motor current, the motor temperature and the average speed.

☞ Due to the downward compatibility of the firmware and possibly unavailable parameter values (e.g., for third-party motors), this correction must be separately activated!

Pertinent Parameters

- P-0-0448, Temperature-dependent torque/force coefficient
- P-0-0449, Speed-dependent torque/force coefficient
- P-0-0450, Current torque/force constant
- P-0-0556, Config word of axis controller
- P-0-3055,
- P-0-3056,
- P-0-3057,
- P-0-3058,
- S-0-0533, Nominal torque/force of motor
- S-0-0534, Maximum torque/force of motor

Pertinent Diagnostic Messages

- None -

Functional Description

Determining the Torque/Force

The torque or force generated by a motor is determined on the drive side by means of the measured motor current and a so-called "torque/force constant":

$$\text{Rotary motor: } M_i = K_M\ I_q; \quad K_M = f_{(I_q,\ \vartheta)}$$

$$\text{Linear motor: } F_i = K_F\ I_q; \quad K_F = f_{(I_q,\ \vartheta)}$$

M_i	Inner torque of the rotary motor
K_M	Torque constant, current- and temperature-dependent
I_q	Motor current, torque-/force-generating component
F_i	Inner force of the linear motor
K_F	Force constant, current- and temperature-dependent
θ	Motor temperature

Fig. 8-51: Current Dependance and Temperature Dependance of the Motor Torque or Force

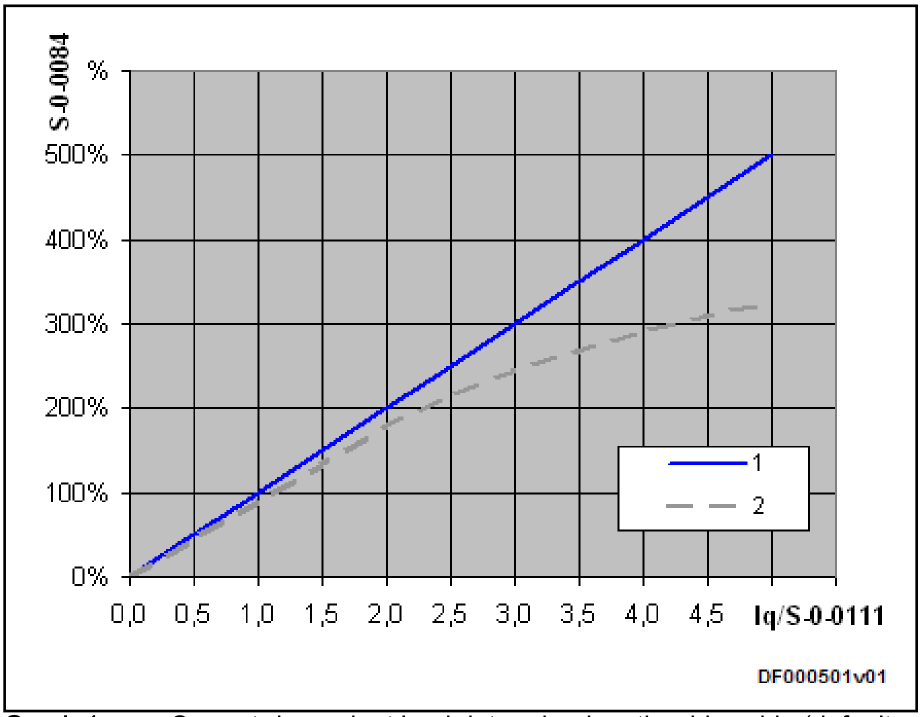
Physically, the so-called "torque or force constant" is, however, not a static value, it depends on:

- Value of the currently flowing motor current: Reduction of currents larger $I_{nominal}$
- Temperature of motor winding and rotor: Reduced when temperature rises

Percentage-Based Scaling

For reasons of compatibility with existing firmware, the percentage-based scaling of torque/force data is the default setting. The percentage of the drive load and percentage limit values are current-related and refer to "S-0-0111, Motor current at standstill".

With percentage-based scaling of the torque/force data, the default state generally is relation to the current, the reference value is "S-0-0111, Motor current at standstill" * "P-0-0051, Torque/force constant".



Graph 1 Current-dependent load determined on the drive side (default, without K_M correction)
Graph 2 Effective, current-dependent load at the motor (basic curve)
Iq Motor current, torque-generating component
S-0-0111 Motor current at standstill
S-0-0084 Torque/force feedback value in percent

*Fig. 8-52: Comparison of Torque/Force Curves, on Drive Side and Motor Side, Percentage-Based Scaling, 100%-Value=P-0-0051*S-0-0111*

Physical Scaling

If, for example, due to the setting of load limit values, physical scaling (rotary: Nm; linear: N) is selected, you must observe that the drive-internal load determination, in the default status, takes place with:

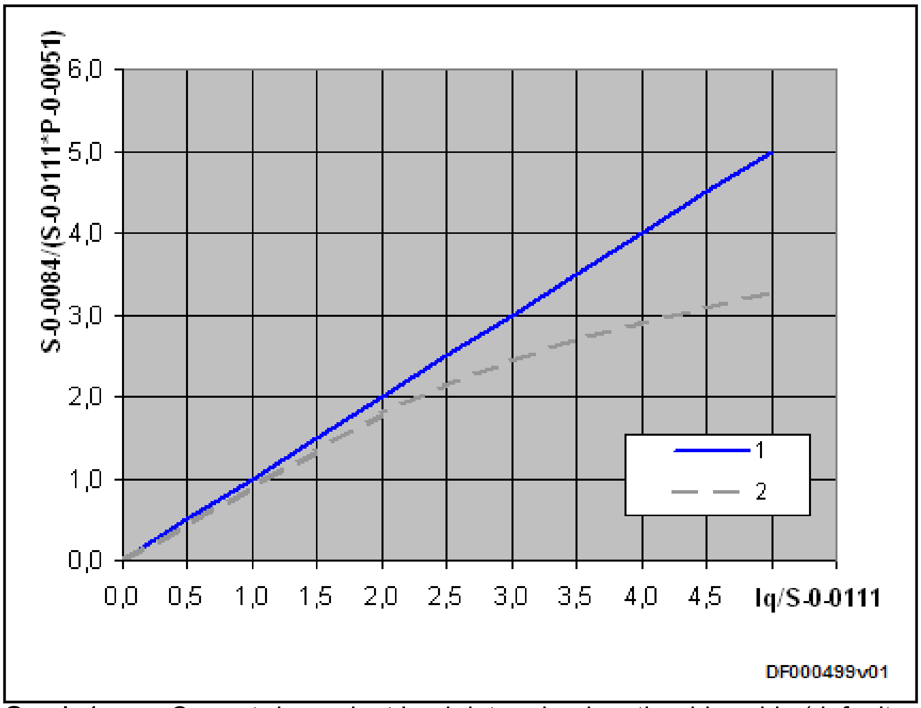
$$\text{Actual value:} \quad M_i \text{ or } F_i = (\text{P-0-0051}) \times (\text{P-0-0043})$$

$$\text{Command value:} \quad M_i \text{ or } F_i = (\text{P-0-0051}) \times (\text{P-0-0038})$$

M_i, F_i Inner torque or force of the motor
P-0-0051 Nominal value of the torque/force constant, static value, specific to motor type
P-0-0043 Torque-generating current, actual value
P-0-0038 Torque-generating current, command value

Fig. 8-53: Drive-Internal Calculation of Motor Torque or Force (Default)

This drive-internal calculation leads to deviations from the torque or force action at the motor. This has a particularly negative effect when entering torque/force limit values, because the value which the limit value causes at the motor can strongly deviate; this might possibly worsen the drive performance considerably:



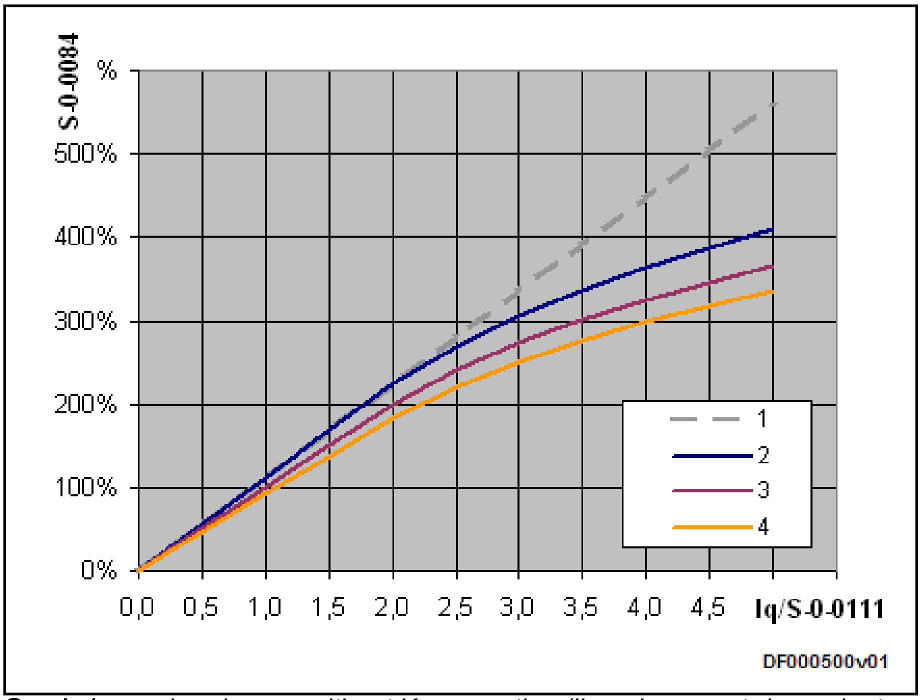
Graph 1	Current-dependent load determined on the drive side (default, without K_M correction)
Graph 2	Effective load at the motor (basic curve)
Iq	Motor current, torque-generating component
S-0-0111	Motor current at standstill
S-0-0084	Torque/force feedback value in Nm or N
P-0-0051	Torque/force constant

Fig. 8-54: Comparison of Torque/Force Curves, Physical Scaling

Correction Function

The "correction of the torque/force constant" can be activated to improve the torque/force precision. The following influences on the torque/force constant are taken into account:

- Magnetic field weakening by magnetic saturation due to increased motor current as compared to nominal current
- Magnetic field weakening by increased motor winding temperature
- Magnetic field weakening by increased rotor temperature depending on the average speed



Graph 1	Load curve without K_M correction (linearly current-dependent with P-0-0051)
Graph 2	Load curve with K_M correction (magnetic saturation taken into account)
Graph 3	Like graph 2, additional consideration of the measured winding temperature (in this case, nominal overtemperature at "S-0-0111, Motor current at standstill")
Graph 4	Like graph 3, additional consideration of the speed-dependent motor temperature rise
S-0-0084	Torque/force feedback value in percent
Iq	Motor current, torque-generating component
S-0-0111	Motor current at standstill

Fig. 8-55: Torque/Force Curves with K_M Correction, Percentage-Based Scaling, 100% Value =S-0-0533, Nominal Torque/Force of Motor

☞ With percentage-based scaling and active "correction of the torque/force constants", the displayed percentage or the percentage limitation that was set refers to "S-0-0533, Nominal torque/force of motor".

Magnetic saturation is considered by entering the maximum torque caused by "S-0-0109, Motor peak current" in "S-0-0534, Maximum torque/force of motor".

The change in the torque/force constant caused by the temperature rise is corrected by:

- Measured winding temperature ("S-0-0383, Motor temperature") and motor-type-dependent value of "P-0-0448, Temperature-dependent torque/force coefficient"
- Dynamically averaged speed (average absolute value) and motor-type-dependent value of "P-0-0449, Speed-dependent torque/force coefficient"

> ☞ The correction of the torque/force constant only works correctly, when the value of "P-0-0051, Torque/force constant" relates to the ambient temperature 20°C.

The value of the currently effective torque/force constant is displayed in

- P-0-0450, Current torque/force constant

Rexroth Motors

For synchronous Rexroth motors MSK, the parameter values for the correction are determined by the manufacturer and in the future will be provided in the motor encoder memory. For older motor versions, the values can, for manual input, be obtained via the manufacturer-side "DriveBase" database.

Third-Party Motors

The torque/force constant can be corrected for third-party motors, too. It is not obligatory to correct all of the mentioned influences. However, it is recommended that you correct the magnetic saturation, because in most of the cases it considerably improves the torque precision. For this purpose, enter the following parameters correctly:

Maximum data:

- S-0-0109, Motor peak current
- S-0-0534, Maximum torque/force of motor

Nominal data:

- S-0-0111, Motor current at standstill
- S-0-0533, Nominal torque/force of motor

It only makes sense to use the temperature-dependent and speed-dependent correction, when correct values are available or were determined for the required coefficients:

- P-0-0448, Temperature-dependent torque/force coefficient
- P-0-0449, Speed-dependent torque/force coefficient

> ☞ Depending on the respective precision requirements, it can be necessary to make complex series of measurements at the respective motor while checking the torque at the motor shaft!

Notes on Commissioning

Activation

You can access the dialogs for activating the correction of the torque/force constant via the "Project Explorer" of "IndraWorks Ds/D/MLD":

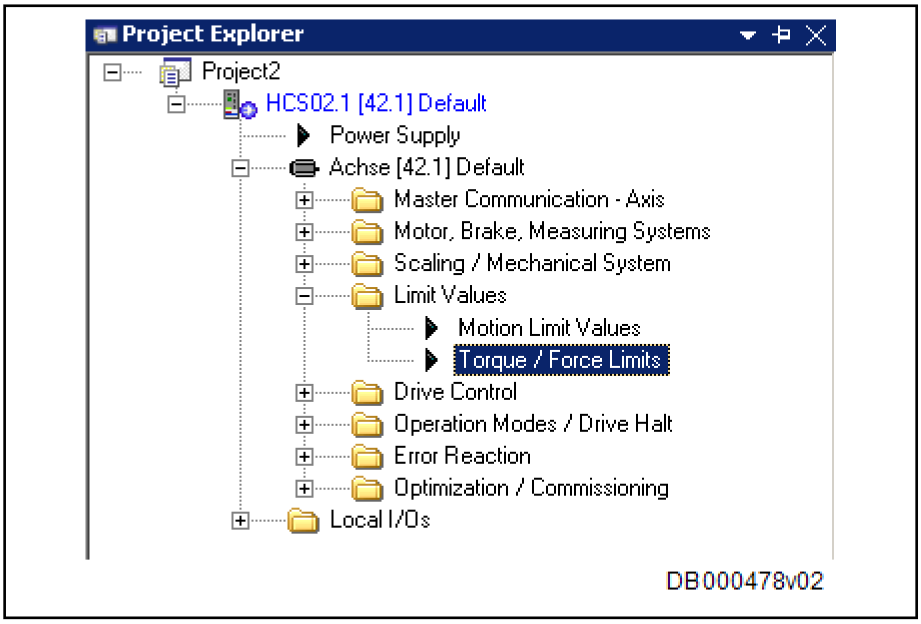


Fig. 8-56: Accessing the Dialog "Torque/Force Limits" in which "Correction of the Torque/Force Constant" can be Activated

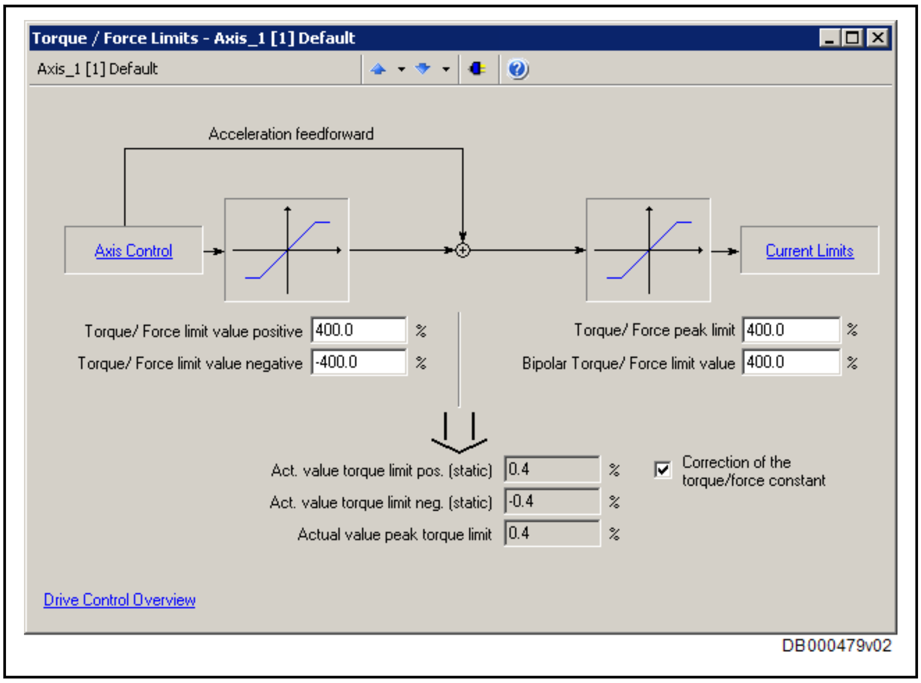


Fig. 8-57: Activating the "Correction of the Torque/Force Constant" in the Dialog for Torque/Force Limits by Marking (Ticking the Check Box Sets Corresponding Bit of "P-0-0556, Config Word of Axis Controller")

Parameter Display or Parameter Input

The corresponding parameters are motor-type-related values. They are displayed in the "Motor" dialog or entered for third-party motors, if necessary:

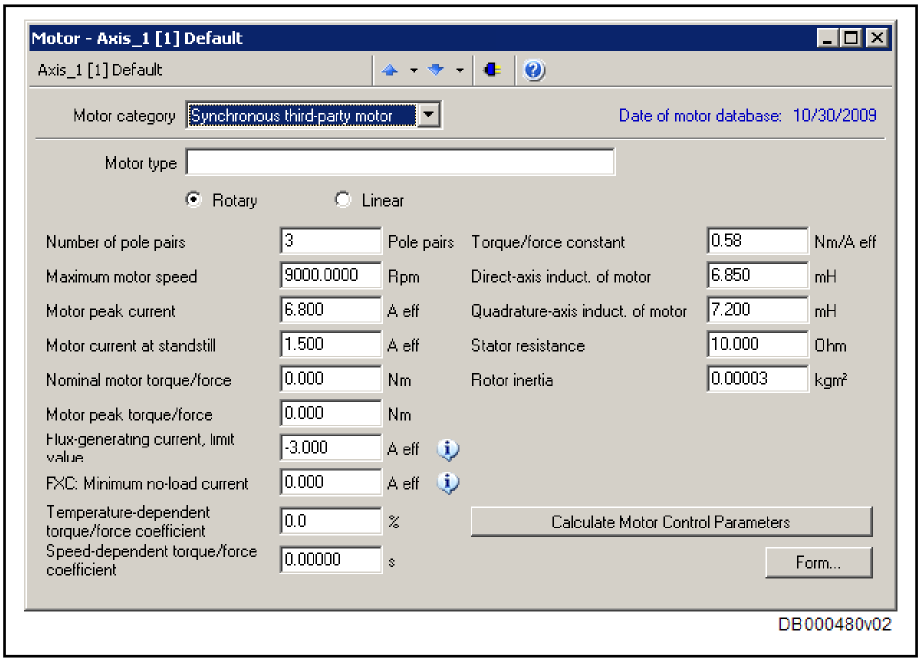


Fig. 8-58: Displaying or Inputting the Motor-Type-Specific Parameters, e.g. Parameters for Correction of Torque/Force Constant "S-0-0533, Nominal Torque/Force of Motor", "S-0-0534, Maximum Torque/Force of Motor", "P-0-0448, Temperature-Dependent Torque/Force Coefficient" and "P-0-0449, Speed-Dependent Torque/Force Coefficient"

Diagnostics, Status Message

With active correction, the torque/force constant is adjusted in accordance with the current influences and displayed:

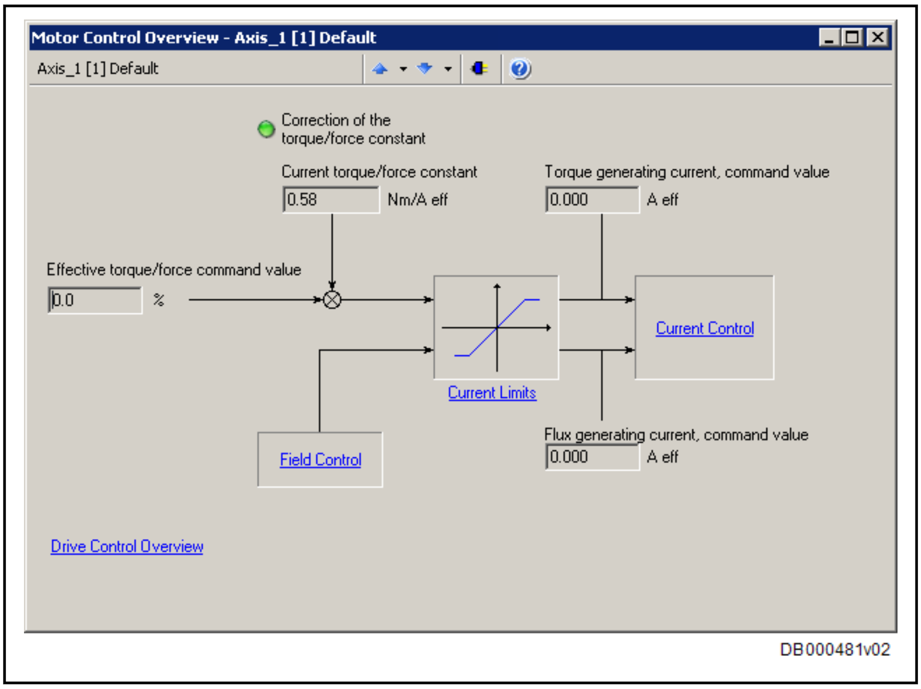


Fig. 8-59: Displaying the Activated Torque/Force Constant Correction by Green Marker; Displaying the Value of the Current Torque/Force Constant (P-0-0450, Current Torque/Force Constant)

8.7 Measuring wheel mode

8.7.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The measuring wheel mode is used for material feed axes, e.g. in sheet-metal machining. For direct measurement of the infeed of moved material, a rotary encoder that is detecting the infeed length is driven via a measuring wheel with frictionally engaged contact to the material surface.

The position control loop is closed via motor encoder and measuring wheel encoder, possible slip between motor and material does not cause incorrect measured values of material length.

The measuring wheel mode may only be activated when contact has been established between measuring wheel and material surface.

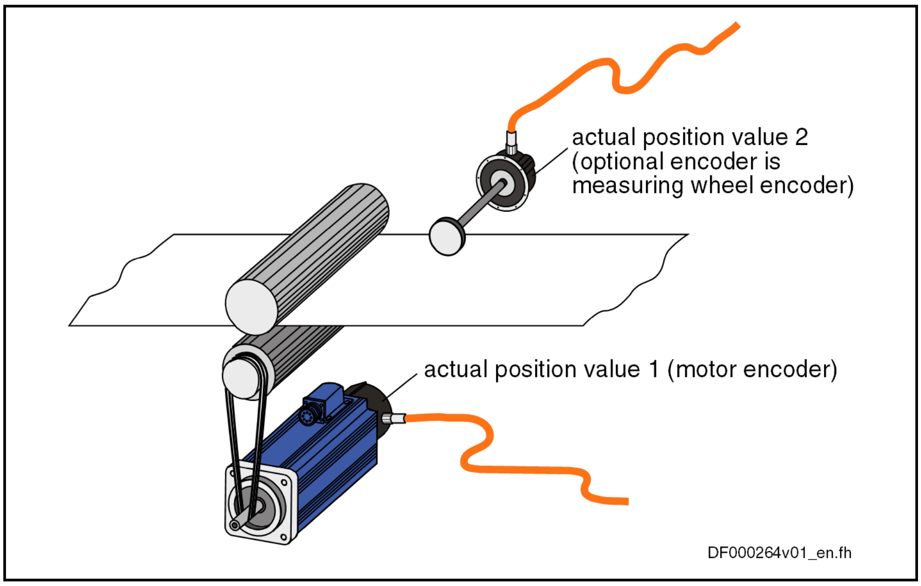


Fig. 8-60: Typical Arrangement of a Drive for Material Infeed with Measuring Wheel Encoder

Hardware Requirements

The measuring wheel encoder is an optional (external) encoder that is connected according to the connection diagram contained in the separate documentation (see "Reference Documentations").

See also Measuring Systems

Pertinent Parameters

The following parameters are used to parameterize this function:

- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0241, Actual pos. smoothing time constant for hybrid pos. control
- P-0-0242, Current actual slip value
- P-0-0243, Maximum occurred actual slip value
- P-0-0244, Monitoring window of slip

The following parameters are used to parameterize the measuring wheel encoder:

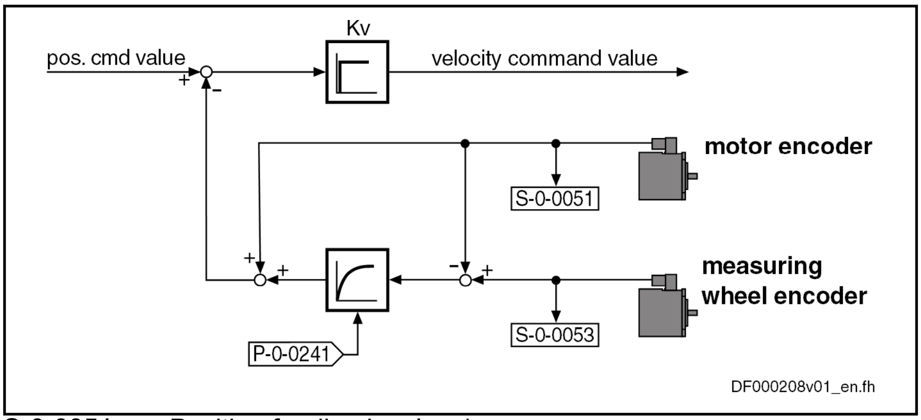
- S-0-0115, Position feedback 2 type
- S-0-0117, Resolution of feedback 2
- P-0-0123, Feed constant 2 (optional encoder)
- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)
- P-0-0185, Control word of encoder 2 (optional encoder)

Pertinent Diagnostic Messages

- F2036 Excessive position feedback difference

8.7.2 Functional Description

The measuring wheel mode can only be used in operation modes in which the drive is in position control. The actual position value detected by the measuring wheel encoder is added to the actual position value of the motor encoder and is used as "hybrid actual position value" for position control. The difference of both actual position values (by mechanical slip, elasticity, …) is smoothed via a filter to be set and compensated by addition to the actual position value of the motor encoder.



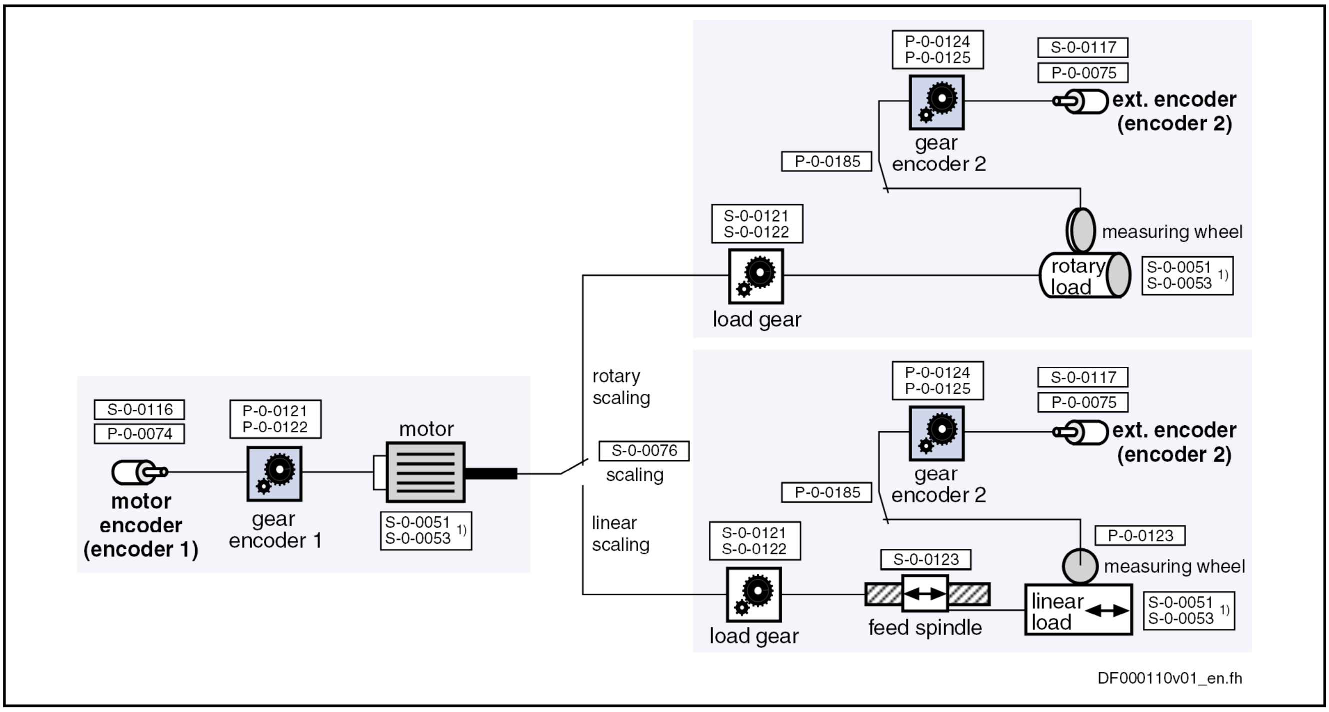
S-0-0051 Position feedback value 1
S-0-0053 Position feedback value 2
P-0-0241 Actual pos. smoothing time constant for hybrid pos. control

Fig. 8-61: Generating the "Hybrid Actual Position Value" in Measuring Wheel Mode

For measuring wheel mode you have to activate the optional encoder in "P-0-0185, Control word of encoder 2 (optional encoder)" as measuring wheel encoder (presetting). The measuring wheel mode itself is switched on by activating the "hybrid actual position value" in "S-0-0520, Axis control word".

☞ By the value "0" in "P-0-0241, Actual pos. smoothing time constant for hybrid pos. control", the actual position value of the motor encoder is ignored and only the actual position value of the measuring wheel encode is used for position control.

The mechanical arrangement of the measuring wheel encoder in the mechanical drive system is illustrated in the figure below:



1)	S-0-0051/S-0-0053; depending on scaling (S-0-0076)
S-0-0051	Position feedback value 1
S-0-0053	Position feedback value 2
S-0-0076	Position data scaling type
S-0-0116	Resolution of feedback 1
S-0-0117	Resolution of feedback 2
S-0-0121	Input revolutions of load gear
S-0-0122	Output revolutions of load gear
S-0-0123	Feed constant
P-0-0074	Encoder type 1 (motor encoder)
P-0-0075	Encoder type 2 (optional encoder)
P-0-0121	Gear 1 motor-side (motor encoder)
P-0-0122	Gear 1 encoder-side (motor encoder)
P-0-0123	Feed constant 2 (optional encoder)
P-0-0124	Gear 2 load-side (optional encoder)
P-0-0125	Gear 2 encoder-side (optional encoder)
P-0-0185	Control word of encoder 2 (optional encoder)

Fig. 8-62: Arrangement of the Measuring Wheel Encoder in the Mechanical Drive System

Operation Modes and Measuring Wheel Mode

The measuring wheel mode can only be used in position-controlled operation modes.

The actual position values of motor encoder and measuring wheel encoder are initialized with the actual position value of the encoder lastly active for position control if position control is switched between motor encoder and hybrid actual position value of the two encoders (switching in S-0-0520, bit 0). If the hybrid actual position value is not switched to the actual position value of the motor encoder the original initialization of the measuring wheel encoder is maintained.

Position Data Reference

In default condition, activating the measuring wheel mode clears a possibly existing position data reference to the axis for both encoders. In measuring wheel mode, the axis can only be moved in a relative way, the control master itself has to establish the position data reference to the material to be fed!

After the measuring wheel mode has been deactivated, the position data reference to the axis, if necessary, has to be established again for relative and absolute encoders.

It is also possible to maintain an existing position data reference of the encoders. The affected bit must be set in "P-0-0185, Control word of encoder 2 (optional encoder)". The option to maintain the position data reference when activating/deactivating the measuring wheel mode can be used only if it is ensured that the mechanical reference of the actual position value from the measuring wheel encoder to the motor encoder or the material to be measured is not shifted.

NOTICE **Risk of machine damage or reject if the material position is not displayed correctly due to slip effects between material and motor encoder!**

⇒ Only activate measuring wheel mode, if the measuring wheel is moved by the material in a frictionally engaged way!

Monitoring the Slip

Due to the measuring wheel mode, slip that can occur between material and drive motor is compensated via the position control. But slip also implies wear in the mechanical drive system and at the material. The controller supports reducing wear by allowing the monitoring of the occurring slip with regard to a maximum allowed value to be set.

The current actual slip value is displayed in "P-0-0242, Current actual slip value". It refers to

- One measuring wheel revolution, if the "feed constant 2" is active in P-0-0185 (typical case: measuring wheel is measuring linear infeed)

- or -

- one revolution of the external encoder, if "feed constant 2" is not active in P-0-0185 (encoder is measuring rotary infeed).

If the calculated slip exceeds the value in "P-0-0244, Monitoring window of slip" (value unequal

"0"), the slip monitoring function triggers with the error message "F2036 Excessive position feedback difference" and the drive reacts with the error reaction that has been set.

To determine the monitoring window, the maximum occurring slip, e.g. during a machining cycle, is stored in "P-0-0243, Maximum occurred actual slip value".

☞ The slip monitor is deactivated with the value "0" in parameter P-0-0244!

8.7.3 Notes on Commissioning

Presettings

First set the parameter values relevant to the mechanical arrangement of motor, motor encoder, axis and measuring wheel (see fig. 8-62 " Arrangement of the Measuring Wheel Encoder in the Mechanical Drive System" on page 788). In addition, the use of the external (optional) encoder as "measuring wheel encoder" must be configured in "P-0-0185, Control word of encoder 2 (optional encoder)".

Activating the Measuring Wheel Mode

NOTICE

Property damage caused by uncontrolled drive motion if measuring wheel encoder or feed motor do not have contact to the material!

⇒ Only activate measuring wheel mode, if the measuring wheel is moved by the material in a frictionally engaged way!

The measuring wheel mode is switched on by activating the "hybrid actual position value" in "S-0-0520, Axis control word". As a prerequisite, the drive has to be in a position-controlled operation mode.

As the possibly existing position data reference of both encoders to the axis gets lost, the control master can only move the drive with relative (material-related) position command value. The position data reference to the material has to be established on the control side by means of the actual position value of motor encoder or measuring wheel encoder transmitted by the drive and an installation-side signal!

Deactivating the Measuring Wheel Mode

The measuring wheel mode can be deactivated by

- Deactivating the "hybrid actual position value" in "S-0-0520, Axis control word"
- Switching to communication phase P2 (or parameter mode)
- Switching the drive off

If position data reference of the encoders to the axis should be required, it must be established again after the measuring wheel mode has been deactivated!

Setting the Jerk Attenuation

Jerky slip phenomena can be attenuated by entering a value greater than zero in "P-0-0241, Actual pos. smoothing time constant for hybrid pos. control".

☞ The value "0" in P-0-0241 switches off the attenuation and causes only the actual position value of the optional measuring wheel encoder to be effective.

Procedure:

1. Enter value "0" in P-0-0241 and move axis at low infeed velocity
2. Increase infeed velocity up to maximum velocity

   While increasing the velocity also increase the value of P-0-0241, if necessary, in order to achieve a satisfactory compromise of smoothness of running and positioning velocity (e.g., for cutting material into sections) (watch "P-0-0038, Torque-generating current, command value"!).

Slip Monitoring with Measuring Wheel Mode

The slip monitor with active measuring wheel mode is activated by entering a value greater zero in "P-0-0244, Monitoring window of slip".

☞ The value "0" in parameter P-0-0244 causes the slip monitor to be switched off! The value in "P-0-0242, Current actual slip value" is then is no longer reset after each revolution of measuring wheel or external encoder, but the total slip since the deactivation of the slip monitor is displayed (possibly continuously increasing value).

Procedure:

1. First enter high value in "P-0-0244, Monitoring window of slip" so that slip monitor cannot be triggered.

2. Enter value "0" in "P-0-0243, Maximum occurred actual slip value" and run complete positioning cycle of axis with maximum infeed velocity several times, if necessary.
3. After having cyclically moved axis, read parameter P-0-0243 and enter value, multiplied by a safety factor (e.g. "2"), in "P-0-0244, Monitoring window of slip".

If the value in "P-0-0242, Current actual slip value" exceeds the value of P-0-0244, the controller generates the error message "F2036 Excessive position feedback difference" and the drive reacts with the error reaction that has been set.

8.8 Positive stop drive procedure

8.8.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

For special applications, it is required to move machine axes operated in position or velocity control up to a limit stop in order to generate forces of pressure.

When an axis in the standard situation has moved up to a limit stop, the drive should signal a drive error by the monitoring facilities of the position or velocity control loop and react with shutdown.

But if the drive can detect the special case of operation "positive stop drive procedure", it can ignore the messages of the position and motions monitors and generate the required force of pressure, if necessary.

The control master signals this special case to the controller of IndraDrive devices via a command. Upon this command, the drive switches off the respective monitors and acknowledges axis standstill to have been detected and a parameterizable force or torque threshold to have been exceeded.

Pertinent Parameters

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0149, C1300 Positive stop drive procedure command
- S-0-0331, Status "n_feedback = 0"

Pertinent Diagnostic Messages

- C1300 Positive stop drive procedure command
- C1301 Class 1 diagnostics error at command start

8.8.2 Functional Description

Moving a machine axis to a limit stop in a position-controlled way, e.g. for generating a force of pressure, is a process specifically provoked on the master side. To do this, the master inputs a command value for the drive that the axis cannot reach because the mechanical limit stop is situated before it.

In order to avoid error messages and reactions with the drive having been blocked, the execution of "C1300 Positive stop drive procedure command" (S-0-0149) is started before the limit stop is reached. This switches off the following monitors that would cause class 1 diagnostics errors:

- Monitoring "drive does not follow command value"

→ F2028 Excessive deviation

- Velocity command value monitoring

  → "F2037 Excessive position command difference"
- Acceleration command value monitoring

  → "F2039 Maximum acceleration exceeded"
- Velocity control loop monitoring

  → "F8078 Speed loop error"

The command is acknowledged on the following conditions:

- The axis has stopped, i.e. the velocity feedback value (S-0-0040) has fallen below the velocity threshold in parameter "S-0-0124, Standstill window".

  \- and -
- The generated torque or force has exceeded a threshold value, i.e. the torque/force feedback value (S-0-0084) is greater than the value in one of the parameters S-0-0082, Torque/force limit value positive, "S-0-0083, Torque/force limit value negative" or "S-0-0092, Bipolar torque/force limit value".

The two criteria for command acknowledgment can be set axis-specifically.

By resetting the command C1300, the monitors are switched on again!

NOTICE **Property damage can be caused by moving to positive stop too rapidly!**

⇒ Reduce moving velocity and torque/force limit value (S-0-0092) to values that are not causing damage to the mechanical system!

☞ If the drive already signals a class 1 diagnostics error (e.g., has already reached positive stop), the "positive stop drive procedure" command cannot be started!

8.8.3 Notes on Commissioning

For acknowledgment of command C1300 it is necessary to set:

- Threshold value for detection of axis standstill in parameter
  - S-0-0124, Standstill window
- Torque/force threshold in the parameters
  - S-0-0082, Torque/force limit value positive
  - S-0-0083, Torque/force limit value negative
  - S-0-0092, Bipolar torque/force limit value

☞ The parameters S-0-0124, S-0-0082, S-0-0083 and S-0-0092 are used for other functions, too. Specific changes of values made for the "positive stop drive procedure" function have to be reset, if necessary!

Before positive stop is reached, start:

- S-0-0149, C1300 Positive stop drive procedure command

After drive has moved away from positive stop, reset the command, if necessary!

Diagnostic message

The command has been executed, when the "commands change bit" is set in parameter "S-0-0135, Drive status word" and there isn't any command error present.

If a class 1 diagnostics error is present at the start of command C1300 (e.g., because the axis has already reached positive stop), the command is not executed. The following message is displayed:

- C1301 Class 1 diagnostics error at command start

8.9 Redundant motor encoder

8.9.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Motor control of synchronous motors requires a position measuring system that measures the position of the moving part of the motor as opposed to the static part. If there is malfunction or defect in the position measuring system (motor encoder), a synchronous motor can no longer be decelerated in a controlled way.

Depending on the requirements, position control can require an external measuring system at the axis which detects the position at the load with the required precision.

For axis control, the entire mechanical drive system between motor encoder and load position of the external encoder is mapped via parameters. This allows calculating the position of the motor encoder from the position of the external encoder or determining the load position from the motor encoder position, if the mechanical drive system is without slip.

If there is a defect in the motor encoder, the motor position, when an external encoder is used, can be determined via the position of the external encoder and the synchronous motor can be decelerated in a controlled way.

For asynchronous motors with motor encoder, it is also possible to use an external measuring system for controlled deceleration, if there is a defect in the motor encoder. But if the asynchronous motor, depending on the drive task, is operated without encoder, controlled deceleration via external encoder in the case of error is not possible!

You can only use measuring systems with U_{pp} = 1V or resolvers as redundant motor encoders!

Pertinent Parameters

- P-0-0185, Control word of encoder 2 (optional encoder)

Pertinent Diagnostic Messages

- F2031 Encoder 1 error: Signal amplitude incorrect
- F2042 Encoder 2: Encoder signals incorrect
- F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)
- F8042 Encoder 2 error: Signal amplitude incorrect

8.9.2 Functional Description

Relevance of the Function

By means of the "redundant motor encoder" function, the axis can be shut down, even if the motor encoder is defective, with the error reaction that has been set. For this purpose, the position data of the motor encoder required for motor control are replaced by the position data of the external (optional) measuring system derived from the motor shaft position or primary part position.

Requirements

To use the "redundant motor encoder" function, the axis must be equipped with an external (optional) measuring system (U_{pp} = 1V or resolver) and the mechanical connection between the measuring systems must be without slip. In addition, the optional encoder must have been activated as redundant motor encoder in the parameter "P-0-0185, Control word of encoder 2 (optional encoder)".

Operating Principle

When the redundant motor encoder has been activated, the error message "F2031 Encoder 1 error: Signal amplitude incorrect" is triggered and a possibly existing position data reference is cleared, if the motor encoder is defective. The controller switches the internal signal paths of the encoder evaluation so that both parameter "S-0-0051, Position feedback value 1" and parameter "S-0-0053, Position feedback value 2" receive the signals of the external encoder (activated as redundant motor encoder). The signal path for the commutation of the motor is switched, too.

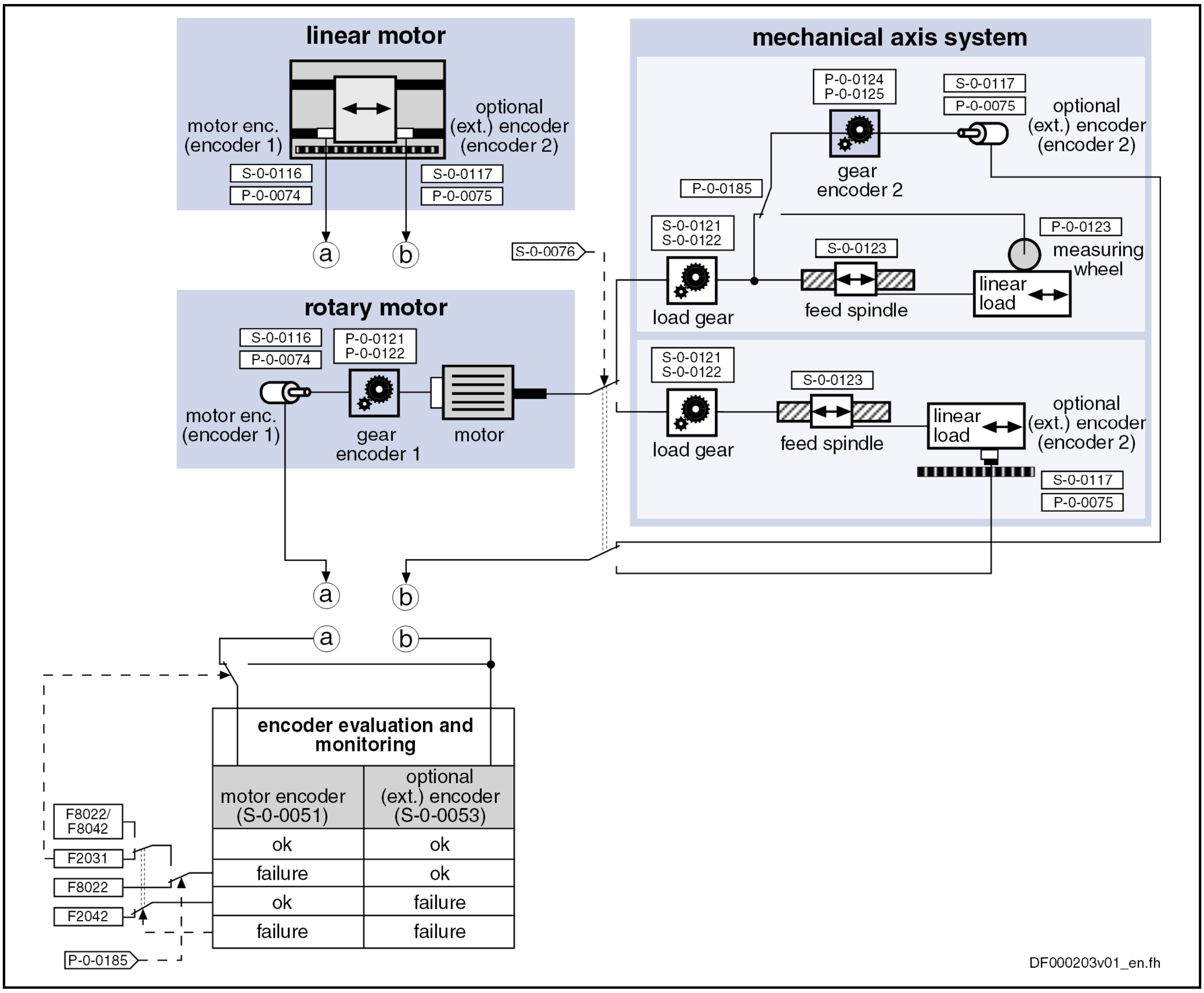


Fig. 8-63: Redundant Encoder Evaluation for Axes with Rotary Motors and Linear Motors

Reactions if Motor Encoder Defective

If a defect occurs with the motor encoder when the external encoder (redundant motor encoder) is intact, this triggers error message "F2031 Encoder 1 error: Signal amplitude incorrect". Due to the intact position data of the external encoder derived from the motor position, it is possible to carry out master-controlled deceleration (P-0-0117, Activation of control unit reaction on error) or the error reaction of the axis set in parameter "P-0-0119, Best possible deceleration".

Without redundant motor encoder it would only have been possible to disable the motor torque!

Reactions if External Encoder Defective

If a defect occurs in the redundant motor encoder with the motor encoder being intact, the error message "F2042 Encoder 2: Encoder signals incorrect" is triggered and the axis is shut down with master-side NC reaction or according to the error reaction that was set.

Reconfiguration Options of the Error Reaction

If a defect occurs with only one of the two encoders, the error reaction of the drive can be completely deactivated by reconfiguring it as a warning for the motor encoder and/or for the external encoder. This is done in "P-0-0173, List of configurable axis-specific monitoring functions". There is no drive-side error reaction when the error reaction has been configured as a warning. The user is then responsible for initiating an appropriate reaction via the control master.

Reactions if Both Encoders Defective

If a defect occurs simultaneously in the motor encoder and the redundant encoder, the message of a fatal F8xxx error is triggered:

- "F8042 Encoder 2 error: Signal amplitude incorrect" if motor encoder was defective first,
- "F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)" if redundant motor encoder was defective first.

The drive torque is disabled and the drive coasts to stop.

> ☞ There is no option to reconfigure errors into warnings with F8 errors!

Resetting F2 Errors of Motor Encoder and External Encoder

The message of a motor encoder defect (F2031) or a defect of the external encoder (F2042) cannot be cleared in communication phase 4, it is necessary to switch to communication phase 2 or to the parameter mode. If for removing the cause of the error it is necessary to replace the motor encoder or dismount and mount it again, check the commutation setting and carry it out again, if necessary.

If the external encoder is a relative measuring system, the position data reference has to be established again, if necessary. If the external encoder is an absolute measuring system and was replaced or dismounted and mounted again, the position data reference has to be established again, if necessary.

> ☞ The same applies if the aforementioned error messages have been reconfigured into warnings!

8.9.3 Notes on Commissioning

Presettings

First make basic settings:

- Set parameter values for mechanical axis system (see "Mechanical Axis System and Arrangement of Measuring Systems")
- Set parameter values for motor encoder and external encoder (see also Measuring Systems) and, with the external (optional) encoder, select the usage as "Redundant motor encoder" "P-0-0185, Control word of encoder 2 (optional encoder)"

Extended Axis Functions

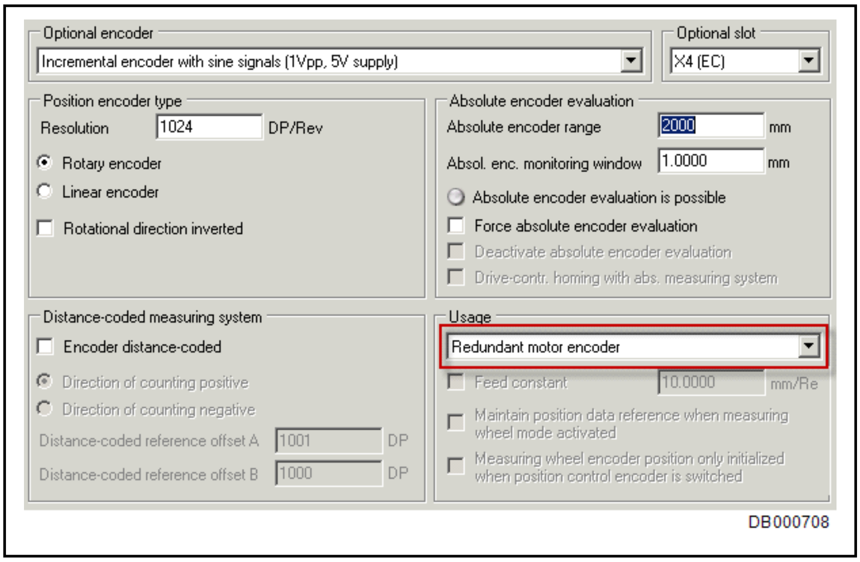


Fig. 8-64: IndraWorks Dialog for Using the External (Optional) Encoder as a "Redundant Motor Encoder"

- Determine behavior of drive in the case of error (see "Error Reactions")

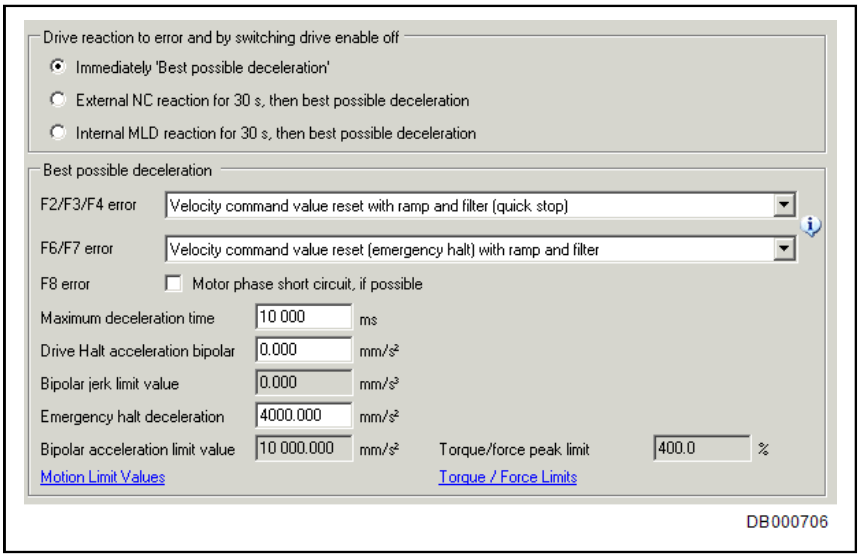


Fig. 8-65: IndraWorks Dialog for Setting the Error Reaction

- If required, reconfiguration of error messages F2031 and/or F2042 into warnings

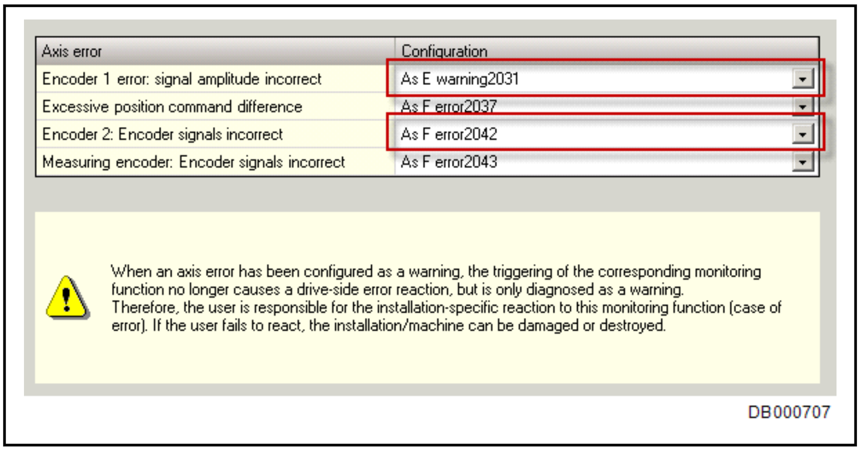


Fig. 8-66: IndraWorks dialog for Reconfiguring the Error Messages F2031 and/or F2042 into Warnings

Setting Parameters for Velocity and Position Control Loop

Make sure that the axis runs steadily in the velocity and position control loop, both with the motor encoder and with the redundant motor encoder:

- Optimize parameters of velocity and position control loops with active motor encoder at a value of parameter "P-0-1119, Velocity mix factor feedback 1 & 2" of 0% (see "Closed-Loop Axis Control (Closed-Loop Operation)")
- With P-0-1119 = 100%, test settings of velocity and position control loop made with P-0-1119 = 0%

  → Velocity and position control loops only closed via redundant motor encoder (see "Closed-Loop Axis Control (Closed-Loop Operation)")

Make the setting for velocity and position control loop such that the axis shows steady behavior in operation both with motor encoder and with redundant motor encoder.

8.10 Spindle positioning

8.10.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

With the drive function "spindle positioning", the drive, at a command of the master, aligns the spindle independently with regard to the spindle zero position. The command position is transmitted to the drive controller via parameter and can be preset as absolute or relative position.

By means of the "position spindle" command, the spindle can be positioned in a position-controlled way (e.g. within the "velocity control" mode) without having to switch the operation mode from velocity to position control.

How to use the drive function "spindle positioning":

- For **milling and drilling spindles**
  - To prepare tool change → spindle remains at a defined position to allow changing the tool
- For **turning machine main spindles**
  - To change the workpiece (if required)
  - To place balancing drillings for workpieces to be balanced
  - To index the workpiece for further machining

- For **revolving transfer machines**
  - To advance the turntable in order to bring workpieces to a defined machining position at the different stations

Hardware Requirements

The use of a home switch may be required.

See "Establishing Position Data Reference for Relative Measuring Systems"

Pertinent Parameters

- S-0-0152, C0900 Position spindle procedure command
- S-0-0153, Spindle angle position
- S-0-0154, Spindle positioning parameter
- S-0-0180, Spindle relative offset
- S-0-0222, Spindle positioning speed
- S-0-0372, Drive Halt acceleration bipolar
- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode
- S-0-0437, Positioning status
- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- P-0-1201, Ramp 1 pitch
- P-0-1202, Final speed ramp 1
- P-0-1203, Ramp 2 pitch
- P-0-1211, Deceleration ramp 1
- P-0-1213, Deceleration ramp 2

Pertinent Diagnostic Messages

- C0900 Position spindle command
- C0902 Spindle positioning requires drive enable
- C0903 Error during initialization
- C0906 Error during search for zero pulse

8.10.2 Functional Description

Basic Sequence of the Function

Spindle positioning is started via "S-0-0152, C0900 Position spindle procedure command". During the execution of the command, the controller ignores the current command value of the active operation mode.

The presetting for the kind of positioning and motion of the spindle towards the target position in made in "S-0-0152, C0900 Position spindle procedure command".

Sequence of Spindle Positioning

The process of spindle positioning takes place in several steps (see figure below):

1. First the spindle is decelerated in velocity control with the deceleration ramps of this control mode (P-0-1202, P-0-1211 and P-0-1213).
2. At the end of the deceleration process, the drive switches to position control and moves to the target position with the inputs from the parameters "S-0-0222, Spindle positioning speed" and "S-0-0372, Drive Halt acceleration bipolar".
3. If the spindle has not yet been in reference, homing is carried out using the inputs from the parameters "S-0-0042, Homing acceleration" and

"S-0-0041, Homing velocity", before the drive moves to the target position according to step 2.

Type of Positioning

The spindle can be positioned at

- absolute target position

- or -

- relative target position.

When "absolute target position" was set, the value from parameter "S-0-0153, Spindle angle position" is applied, at the start of spindle positioning, as the target position effective in the drive ("S-0-0430, Effective target position").

When "relative target position" was set, the target position (S-0-0430) effective in the drive at the start of spindle positioning is generated by addition of the current actual position value and the value from "S-0-0180, Spindle relative offset".

Direction of Motion During Positioning

In the case of modulo scaling of position data, it is possible to choose between the following directions of motion for spindle positioning:

- Clockwise rotation
- Counter-clockwise rotation
- Shortest distance

Positioning Velocity

The allowed maximum velocity during the spindle positioning process is entered in parameter "S-0-0222, Spindle positioning speed".

> ☞ The initial speed of the operation mode can be limited, for one axis with safety technology, to an additional speed value [product from "SMO: active speed threshold" (P-0-3238) and "SMO: evaluation factor speed limit "(P-0-3218)] when activated in the parameter "SMO: Configuration support functions" (P-0-3219), see also the separate documentation "Rexroth IndraDrive, Integrated Safety Technology "Safe Motion" (as of MPx-18)" (DOK-INDRV*-SI3*SMO-VRS-AP**-EN-P; Mat. No. R911338920), chapter "Additional and auxiliary functions".

Acceleration/Deceleration

The maximum acceleration or deceleration during the spindle positioning process is determined by parameter "S-0-0372, Drive Halt acceleration bipolar".

Control Encoder

For spindle positioning, the position control loop can be closed via the motor encoder or the optional encoder.

> ☞ In the case of a mechanical system with slip (e.g. V-belt) between motor and spindle, an optional encoder is obligatory!

The encoder used for spindle positioning is defined by the bit for encoder selection in "S-0-0147, Homing parameter".

Spindle Positioning with Non-Homed Control Encoder

If the encoder selected for spindle positioning does not yet have the position data reference to the spindle (see "S-0-0403, Position feedback value status"), the position data reference is automatically established during the execution of spindle positioning!

See also "Establishing the Position Data Reference"

The figure below illustrates the basic sequence of the drive function "spindle positioning".

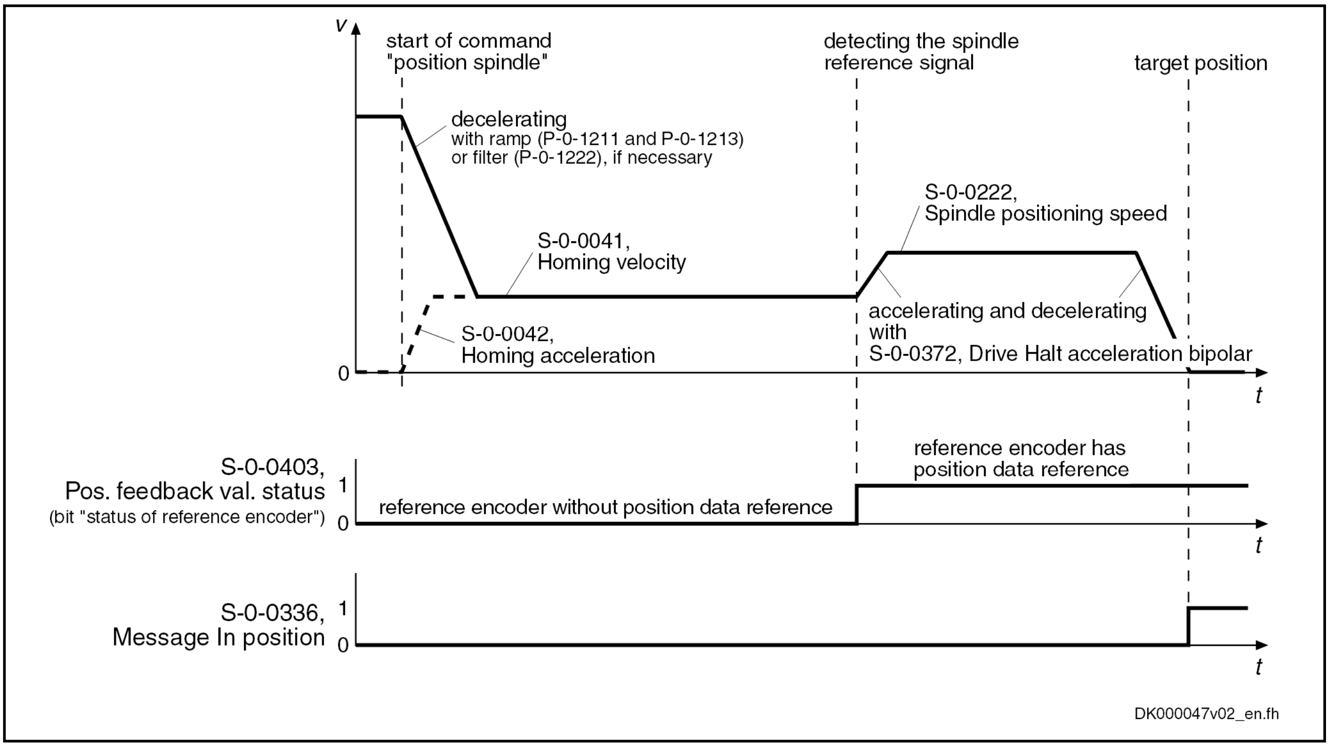


Fig. 8-67: Basic Sequence of Spindle Positioning (Including Establishing the Position Data Reference)

"Target Position Reached" Message

The following parameters signal that the target position for spindle positioning has been reached:

- S-0-0336, Status "In position"

  - and -

- S-0-0013, Class 3 diagnostics

The target position is signaled to have been reached when

- Velocity command value and actual velocity value are lower than the threshold value in parameter "S-0-0124, Standstill window"

  - and -

- The distance to target position is smaller than the value in parameter "S-0-0057, Position window".

See also Parameter Description "S-0-0013, Class 3 diagnostics"

Specific Features with "Modulo" Position Data Format

Infinitely Turning Axis

Spindles on machine tools or rotary axes are generally infinitely turning axes, their required position being within one revolution (0…360 dgr). For those axes it is recommended to use the "modulo" position data format because it allows displaying the actual position values with reference to one axis revolution only.

Ambiguity of Target Position

With modulo scaling, the target position is ambiguous because it occurs within every spindle revolution. Depending on the direction of motion ("clockwise/counter-clockwise" or "shortest distance") preset for spindle positioning and the velocity at which spindle positioning is started, the positioning distance can be of different length. In addition, one or several additional revolutions can be required until the target position has been reached!

Spindle Positioning Out of Standstill

Out of standstill the spindle or rotary axis positions as determined in "S-0-0154, Spindle positioning parameter":

- With the selected direction of motion ("clockwise" or "counter-clockwise")

- or -

- With the direction of motion in which the target position can be reached over the shortest possible distance ("shortest distance")

Spindle Positioning Out of Motion

Apart from the determined direction of motion (in parameter S-0-0154), decelerating and positioning the spindle out of motion depends on

- the absolute value of the current velocity

  - and -

- the distance between current axis position and target position

at the start of spindle positioning.

The actual sequences of the positioning process of a turning axis can differ in spite of the determined direction of positioning motion.

In order to improve the reproduction of the positioning process, further limiting conditions are taken into account for the drive behavior:

- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode

	Start position of spindle positioning …	
Current direction of rotation at start of spindle positioning	**… within target position window (S-0-0418)**	**… outside of target position window (S-0-0418)**
as selected direction of positioning motion (clockwise or counter-clockwise)	Positioning takes place over shortest distance, if values do not leave target position window during deceleration. If values leave target position window during deceleration, drive positions according to selected direction of positioning motion at next target position to be reached.	Positioning takes place to the next target position that can be reached, while maintaining the velocity direction. If "braking distance > distance start position-target position", the positioning process can require one to several revolutions, depending on the velocity at the start of the positioning process.
against selected direction of positioning motion (clockwise or counter-clockwise)	If "braking distance < distance start position-target position", drive moves to target position over shortest distance. If "braking distance > distance start position-target position", positioning takes place after deceleration of motor, with reversal of velocity direction, at next target position to be reached.	The motor is decelerated to standstill. The positioning process then takes place at next target position to be reached, according to the determined direction of positioning motion.

Tab. 8-7: Dependence of the Positioning Process on the Start Position with Determined Direction of Positioning Motion "Clockwise" or "Counter-Clockwise"

Current velocity at start of spindle positioning …	
… higher than value of S-0-0417 (velocity threshold)	… lower than value of S-0-0417 (velocity threshold)
Positioning takes place at next target position to be reached, while maintaining the velocity direction. If "braking distance > distance start position-target position", the positioning process can require one to several revolutions, depending on the velocity at the start of the positioning process.	If "braking distance < distance start position-target position", positioning takes place at next target position to be reached, while maintaining the velocity direction. If "braking distance > distance start position-target position", positioning takes place after deceleration of motor, with reversal of velocity direction, at next target position to be reached.

Tab. 8-8: Dependence of the Positioning Process on the Velocity at the Start of Spindle Positioning with Determined Direction of Positioning Motion "Shortest Distance"

8.10.3 Notes on Commissioning

Presettings

Determining type of positioning and direction of positioning motion:

- S-0-0154, Spindle positioning parameter

Determining maximum velocity for spindle positioning:

- S-0-0222, Spindle positioning speed

Determining threshold values for "in position" message:

- S-0-0057, Position window
- S-0-0124, Standstill window

See also Parameter Description "S-0-0013, Class 3 diagnostics"

If the position data are scaled in modulo format, it is possible to specify limiting conditions that improve the reproduction of the positioning process:

- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode

Presetting Target Position

The target position of the spindle is preset via

- S-0-0153, Spindle angle position (absolute positioning)

- or -

- S-0-0180, Spindle relative offset (relative positioning).

Starting Spindle Positioning

Spindle positioning is started by starting the command

- S-0-0152, C0900 Position spindle procedure command

Diagnosing Spindle Positioning

The target position effective for the positioning process is displayed in

- S-0-0430, Effective target position.

End of Spindle Positioning

When the target position has been reached, this is displayed in

- S-0-0336, Status "In position"

  - and -

- S-0-0013, Class 3 diagnostics.

The respective message bit changes from "0" to "1" when the conditions for the message have been fulfilled. The execution of the "position spindle" command is thereby acknowledged as having been "completed without error".

8.10.4 Diagnostic Messages

The execution of spindle positioning requires drive enable (AF). Diagnostic message in the case of error:

- C0902 Spindle positioning requires drive enable

If an absolute encoder is used as control encoder, the position data reference of the encoder must have been established before the first-time start of spindle positioning. Diagnostic message in the case of error:

- C0903 Error during initialization

If a relative encoder is used as control encoder and a home switch is to be evaluated, the position data reference is established with the first-time spindle positioning (unless already done). If the drive does not recognize the home switch signal, the following diagnostic message is generated:

- C0903 Error during initialization

If a relative encoder is used as control encoder, the position data reference is established with the first-time spindle positioning (unless already done). If the drive does not recognize any reference mark signal, the following diagnostic message is generated:

- C0906 Error during search for zero pulse

8.11 Parameter set switching

8.11.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

IndraDrive devices are equipped with eight parameter sets (MPB-18VRS, MPC-18VRS, MPE-18VRS) or four parameter sets (MPM-18VRS), and it is possible to switch between these parameter sets during operation. One of the switchable parameter sets is always active. Switching takes place upon command of the control master.

Notes on Application

By switching parameter sets during operation, the values of specific parameters can be adjusted to the different operating phases or machining processes. This supports the work flow in flexible production facilities.

Examples of application:

- Changing from C-axis to roughing or finishing operation in the case of spindles
- Positioning mode for tool change with different gear ratios
- Changing motor spindles for different machining phases
- Adjusting the control loop gains to different load inertia or load masses (e.g. with very different workpieces)
- Star-delta switching of motors with switchable winding to increase the torque in short-time operation

Classification of Switchable Parameters

Under the application-related point of view, the parameters to be switched are divided into the following groups:

- Application Parameters
- Control Loop Parameters
- Load Gear Parameters (for MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional package Main spindle function)

- Winding Parameters (for MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional package Main spindle function)
- Motor Control and Motor Encoder Parameters (for MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional package Main spindle function)

Pertinent Parameters

- S-0-0216, C4100 Switch parameter set command
- S-0-0217, Preselect parameter set command
- S-0-0219, IDN-list of parameter set

☞ List parameters S-**0**-0219 to S-**7**-0219 contain parameter sets no. 0 to no. 7

- S-0-0254, Current parameter set
- P-0-2216, Parameter set switching, configuration
- P-0-2217, Parameter set switching, preselection range
- P-0-2218, Parameter set switching, delay time

Pertinent Diagnostic Messages

- C0273 Modulo value for motor encoder cannot be displayed
- C0278 Modulo value for optional encoder cannot be displayed
- C0280 Maximum travel range cannot be displayed internally
- C4100 Switch parameter set command
- C4101 Switching only possible without AF
- C4103 Preselect parameter set forbidden value
- C4104 Error during parameter set switching (->S-0-0423)

8.11.2 Functional Description

General Information

Parameter set switching is activated

- By triggering command "C4100 Switch parameter set command" (S-0-0216) via control master

- or -

- In "drive-controlled" form by changing parameter "S-0-0217, Preselect parameter set command"

The triggering of parameter set switching is set in parameter "P-0-2216, Parameter set switching, configuration".

The drive firmware then activates the parameter set determined by the value of parameter "S-0-0217, Preselect parameter set command". The currently active parameter set is displayed in parameter "S-0-0254, Current parameter set". After switching on, it is always set 0 that is active.

To minimize the times required for switching and storing or loading the parameter sets of a drive, the switchable parameters are permanently assigned to the following groups:

- Application (e.g. parameters for limit values for torque/force, position, velocity, etc.)
- Control loop (e.g. parameters for gain factors of position and velocity loop, etc.)

- **Load gear** (parameters for load gear input and load gear output revolutions, load inertia, etc.) with MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional package main spindle function
- **Winding** (current controller parameters for winding switching, star-delta switching, etc.), with MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional package main spindle function
- **Motor control and motor encoder parameters** (changes in the control method, motor switching, etc.), with MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional package main spindle function

Parameter "P-0-2216, Parameter set switching, configuration" determines which of the mentioned parameter groups are to be switchable. In addition, parameter "P-0-2217, Parameter set switching, preselection range" determines how many of the eight parameter sets are to be used. The parameters intended for parameter set switching can be taken from the list parameters S-**0**-0219 to S-**7**-0219 (IDN list of the respective parameter set). These list parameters are generated by the drive depending on the settings in the parameters P-0-2216 and P-0-2217.

☞ Parameters of non-configured sets or groups:

- Are not listed in "S-0-0192, IDN-list of all backup operation data".
- Are write-protected in the operation mode.

Parameters are addressed via their IDNs. In the case of the switchable parameters, it is necessary to observe the number for the respective parameter set, parameter set number (0 to 7).

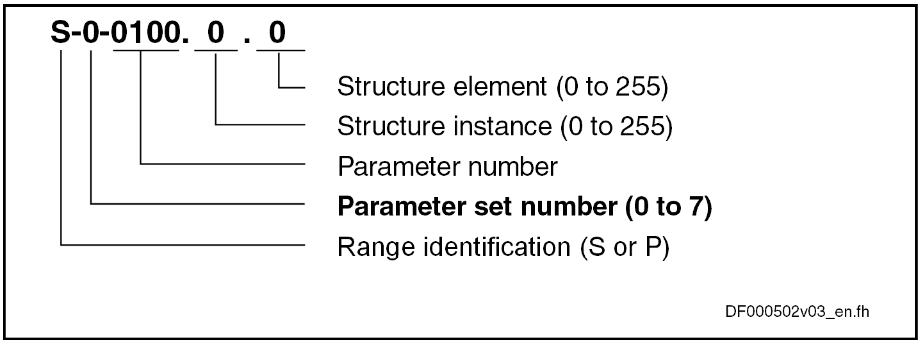


Fig. 8-68: Structure of the IDN of a Switchable Parameter (Example)

Defining the Parameter Groups

Application Parameters

The following switchable parameters are permanently assigned to the "application" group (with MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional packages servo function, main spindle function and synchronization):

- S-0-0038, Positive velocity limit value
- S-0-0039, Negative velocity limit value
- S-0-0057, Position window
- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0091, Bipolar velocity limit value
- S-0-0092, Bipolar torque/force limit value

- S-0-0124, Standstill window
- S-0-0125, Velocity threshold nx
- S-0-0126, Torque threshold Tx
- S-0-0138, Bipolar acceleration limit value
- S-0-0157, Velocity window
- S-0-0158, Power threshold Px
- S-0-0193, Positioning jerk
- S-0-0222, Spindle positioning speed
- S-0-0261, Coarse position window
- S-0-0349, Bipolar jerk limit
- S-0-0372, Drive Halt acceleration bipolar
- S-0-0446, Ramp reference velocity for acceleration data
- S-0-0822, Torque/force ramp
- S-0-0823, Torque/force ramp time
- P-0-0041, Position command average value filter time constant
- P-0-0641, Interpolation cmd value average value filter time constant
- P-0-1201, Ramp 1 pitch
- P-0-1202, Final speed ramp 1
- P-0-1203, Ramp 2 pitch
- P-0-1211, Deceleration ramp 1
- P-0-1213, Deceleration ramp 2
- P-0-1222, Velocity command filter
- P-0-4010, Load inertia

The following parameters can no longer be switched in MPx-18VRS vis-a-vis firmware MPx-17VRS:

- P-0-0214, Analog input, assignment A, scaling
- P-0-0215, Analog input, assignment A, signal value at 0
- P-0-0216, Analog input, assignment A, dead zone
- P-0-0217, Analog input 1, time constant input filter
- P-0-0237, Analog input, assignment B, scaling
- P-0-0238, Analog input, assignment B, signal value at 0
- P-0-0239, Analog input, assignment B, dead zone

Control Loop Parameters

The following switchable parameters are permanently assigned to the "application" group (with MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional packages servo function, main spindle function and synchronization):

- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- S-0-0104, Position loop Kv-factor
- S-0-0348, Acceleration feedforward gain
- S-0-0826, Torque/force window
- P-0-0004, Velocity loop smoothing time constant
- P-0-0040, Velocity feedforward evaluation

- P-0-0180, Acceleration feedforward smoothing time constant
- P-0-1118, Velocity controller command filter
- P-0-1119, Velocity mix factor feedback 1 & 2
- P-0-1120, Velocity control loop filter: Filter type
- P-0-1121, Velocity control loop filter: Limit frequency of low pass
- P-0-1122, Velocity control loop filter: Bandwidth of band-stop filter
- P-0-1123, Vel. cont. loop filter: Center frequency of band-stop filter
- P-0-1126, Velocity control loop: Acceleration feedforward

Load Gear Parameters

The following switchable parameters are permanently assigned to the "load gear" group (with MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional package main spindle function):

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- S-0-0052, Reference distance 1
- S-0-0121, Input revolutions of load gear
- S-0-0122, Output revolutions of load gear
- S-0-0222, Spindle positioning speed
- S-0-0299, Home switch offset
- P-0-0109, Torque/force peak limit

☞ Gear switching combined with an absolute measuring system as a motor encoder and load-side data reference can lead to wrong reference data. The encoder reference is shown as being available, in certain circumstances, although the load-side reference is not available. In the event of this configuration, homing must always be repeated after gear switching.

Winding Parameters

The following switchable parameters are permanently assigned to the "winding" group (with MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional package main spindle function):

- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- S-0-0109, Motor peak current
- S-0-0111, Motor current at standstill
- S-0-0113, Maximum motor speed
- S-0-0141, Motor type
- S-0-0201, Motor warning temperature
- S-0-0204, Motor shutdown temperature
- S-0-0533, Nominal torque/force of motor
- S-0-0534, Maximum torque/force of motor
- S-0-1300.20.1, Component Name
- S-0-1300.20.3, Vendor Code
- S-0-1300.20.4, Device Name
- S-0-1300.20.5, Vendor Device ID
- S-0-1300.20.8, Hardware version
- S-0-1300.20.9, Software version

- S-0-1300.20.11, Order Number
- S-0-1300.20.12, Serial Number
- S-0-1300.21.1, Component Name
- S-0-1300.21.3, Vendor Code
- S-0-1300.21.4, Device Name
- S-0-1300.21.5, Vendor Device ID
- S-0-1300.21.8, Hardware version
- S-0-1300.21.9, Software version
- S-0-1300.21.11, Order Number
- S-0-1300.21.12, Serial Number
- S-0-1300.22.1, Component Name
- S-0-1300.22.3, Vendor Code
- S-0-1300.22.4, Device Name
- S-0-1300.22.5, Vendor Device ID
- S-0-1300.22.8, Hardware version
- S-0-1300.22.9, Software version
- S-0-1300.22.11, Order Number
- S-0-1300.22.12, Serial Number
- S-0-1300.23.1, Component Name
- S-0-1300.23.3, Vendor Code
- S-0-1300.23.4, Device Name
- S-0-1300.23.5, Vendor Device ID
- S-0-1300.23.8, Hardware version
- S-0-1300.23.9, Software version
- S-0-1300.23.11, Order Number
- S-0-1300.23.12, Serial Number
- P-0-0018, Number of pole pairs/pole pair distance
- P-0-0051, Torque/force constant
- P-0-0508, Commutation offset
- P-0-0528, Flux control loop proportional gain
- P-0-0529, Scaling of stall current limit
- P-0-0530, Slip increase
- P-0-0532, Premagnetization factor
- P-0-0533,
- P-0-0534, Voltage loop integral action time
- P-0-0535, Motor voltage at no load
- P-0-0536, Maximum motor voltage
- P-0-0568, Voltage boost
- P-0-0569, Maximum stator frequency slope
- P-0-0570, Stall protection loop proportional gain
- P-0-0571, Stall protection loop integral action time
- P-0-0572, Slip compensation factor

- P-0-0573, IxR boost factor
- P-0-0574, Oscillation damping factor
- P-0-0577, Square characteristic: Lowering factor
- P-0-0578, Current for deceleration, absolute value
- P-0-0579, Current for deceleration, time period
- P-0-0590, Motor model frequency loop proportional gain
- P-0-0591, Motor model frequency loop integral action time
- P-0-0592, Motor model adjustment factor
- P-0-0594, FXC: Total flux loop integral action time
- P-0-0595, Frequency loop proportional gain (FXC)
- P-0-0596, FXC: Frequency loop scaling factor of inertia
- P-0-0597, FXC: Current loop proportional gain
- P-0-0598, FXC: Current loop integral action time
- P-0-0599, FXC: Slip frequency filter time constant
- P-0-0600, FXC: Rated slip frequency
- P-0-0602, FXC: Minimum no-load current
- P-0-4002, Charact. of quadrature-axis induct. of motor, inductances
- P-0-4003, Charact. of quadrature-axis inductance of motor, currents
- P-0-4004, Magnetizing current
- P-0-4005, Flux-generating current, limit value
- P-0-4013, Current limit value of demagnetization
- P-0-4016, Direct-axis inductance of motor
- P-0-4017, Quadrature-axis inductance of motor
- P-0-4032, Motor type plate data
- P-0-4036, Rated motor speed
- P-0-4039, Stator leakage inductance
- P-0-4040, Rotor leakage inductance
- P-0-4041, Motor magnetizing inductance
- P-0-4042, Characteristic of motor magnetizing inductance
- P-0-4043, Rotor time constant
- P-0-4048, Stator resistance

Motor Control and Motor Encoder Parameters

The following switchable parameters are permanently assigned to the "motor control and motor encoder parameters" group (with MPB-18VRS, MPC-18VRS, MPM-18VRS only in the alternative functional package main spindle function):

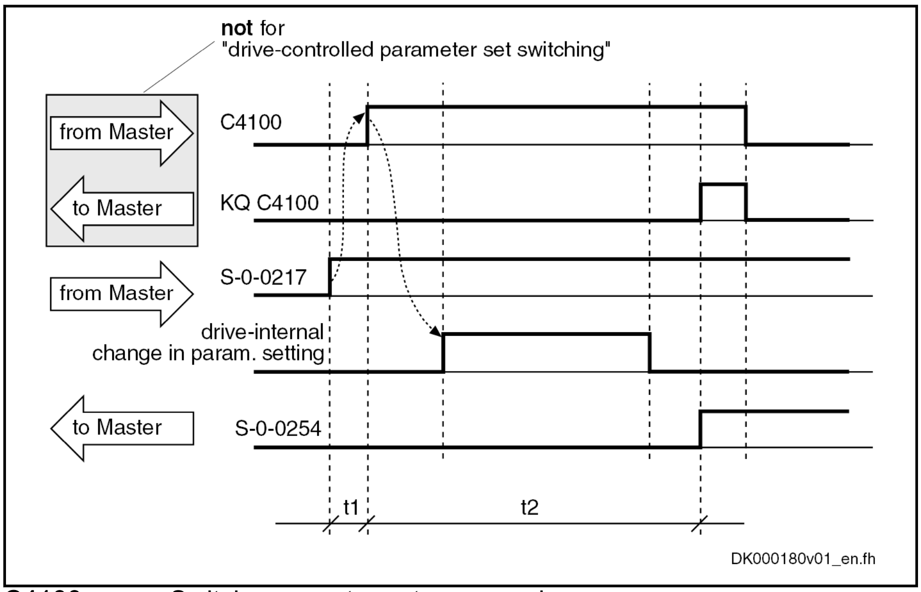
- S-0-0116, Resolution of feedback 1
- S-0-0206, Drive on delay time
- S-0-0207, Drive off delay time
- S-0-0277, Position feedback 1 type
- P-0-0045, Control word of current controller
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0077, Assignment motor encoder->optional slot
- P-0-0121, Gear 1 motor-side (motor encoder)

- P-0-0122, Gear 1 encoder-side (motor encoder)
- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)
- P-0-0506, Amplitude for angle acquisition
- P-0-0507, Holding brake control word
- P-0-0510, Rotor inertia
- P-0-0512, Temperature sensor
- P-0-0513,
- P-0-0517, Commutation: Required harmonics component
- P-0-0522, Control word for commutation setting
- P-0-0540, Torque of holding brake
- P-0-0575, Search mode: Search current factor
- P-0-0576, Search mode: Finding point slip factor
- P-0-0640, Cooling type
- P-0-4014, Type of construction of motor
- P-0-4034, Thermal time constant of winding
- P-0-4035, Thermal time constant of motor
- P-0-4037, Thermal short-time overload of winding

Conditions and Timing for Parameter Set Switching

Parameter Groups "Application", "Control Loop" and "Load Gear"

Parameter set switching of application, control loop and load gear parameters can take place in operation, i.e. with drive enable ("AF"). For "drive-controlled parameter set switching", the timing is as follows:



C4100	Switch parameter set command
KQ C4100	Switch parameter set command acknowledgment
S-0-0217	Preselect parameter set command
S-0-0254	Current parameter set
t1	Approx. 6 ms (drive-controlled parameter set switching)
t2	Approx. 5…30 ms

Fig. 8-69: Sequence Diagram for Switching Application, Control Loop and Load Gear Parameters

Parameter Group "Load Gear"

If the gear ratio of the load gear is changed through parameter set switching, the position data reference will be maintained ("homed" in parameter "S-0-0403, Position feedback value status"), if the position data directly refer to an encoder:

- Data reference to load with position control on an external encoder
- Data reference to motor shaft with position control on the motor encoder

Otherwise, the reference of the position data will be lost through the changes in the gear ratio of the load gear and the position data reference has to be established again.

The following command errors might occur:

- C0273 Modulo value for motor encoder cannot be displayed
- C0278 Modulo value for optional encoder cannot be displayed
- C0280 Maximum travel range cannot be displayed internally

For remedy in case of an error, see description of diagnostic messages for the respective error message!

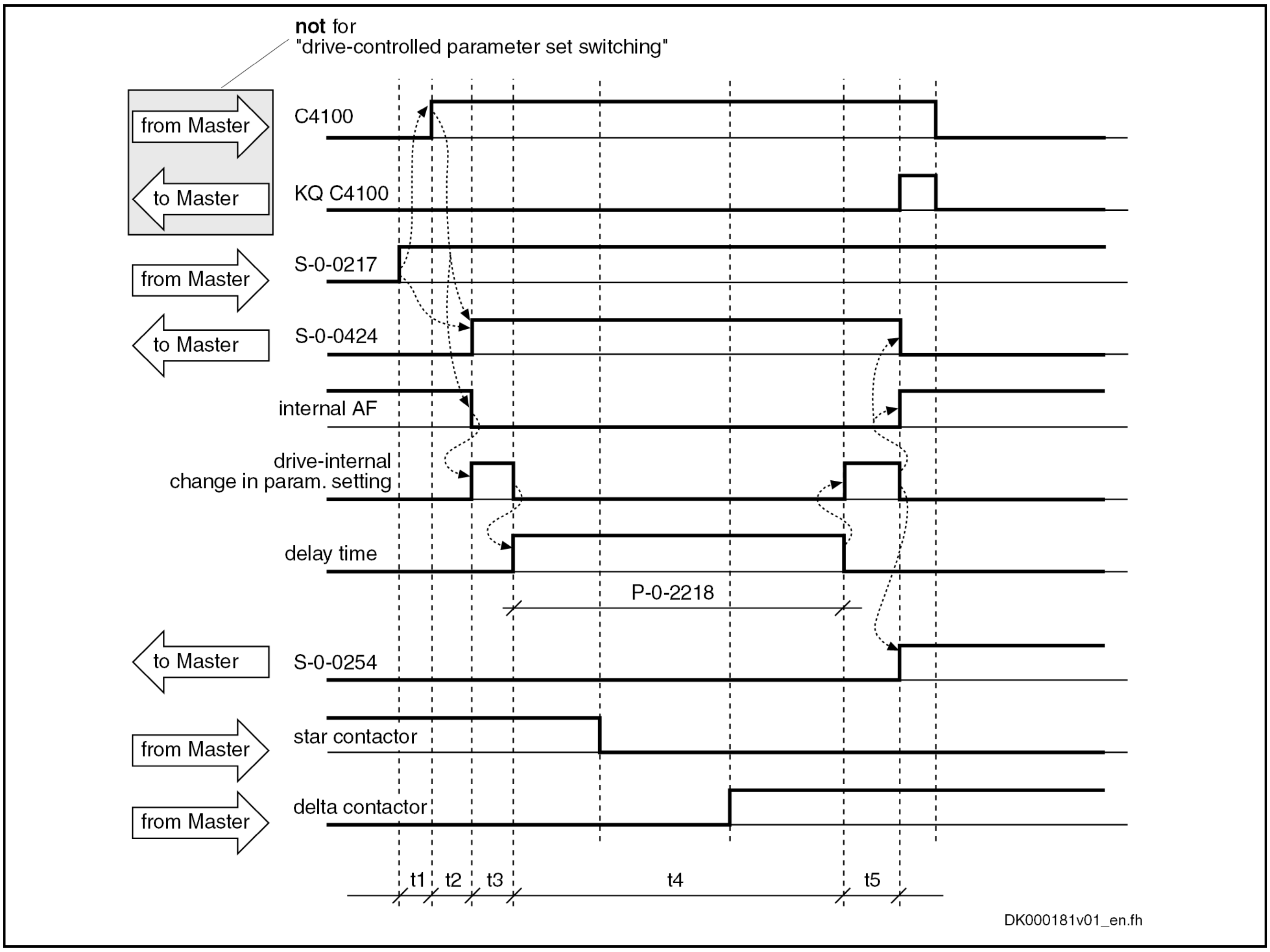
NOTICE **By parameter set switching with "AF", the command values can change internally. This can cause accidental axis motion!**

⇒ Via the control master, make sure that the changes in the controlled system really took place (query the feedbacks)!

Parameter Group "Winding"

The parameter group "winding", too, can be switched in operation, i.e. with drive enable ("AF"). During the switching process, drive enable is internally deactivated and reactivated in the drive controller after the delay time which can be set (see P-0-2218) (see "chapter "Conditions and Timing for Parameter Set Switching" on page 810").

Winding switching thereby takes place in the shortest possible time. By the appropriate setting in parameter P-0-2218, you have sufficient delay until switching times of contactors, relays etc. are over.



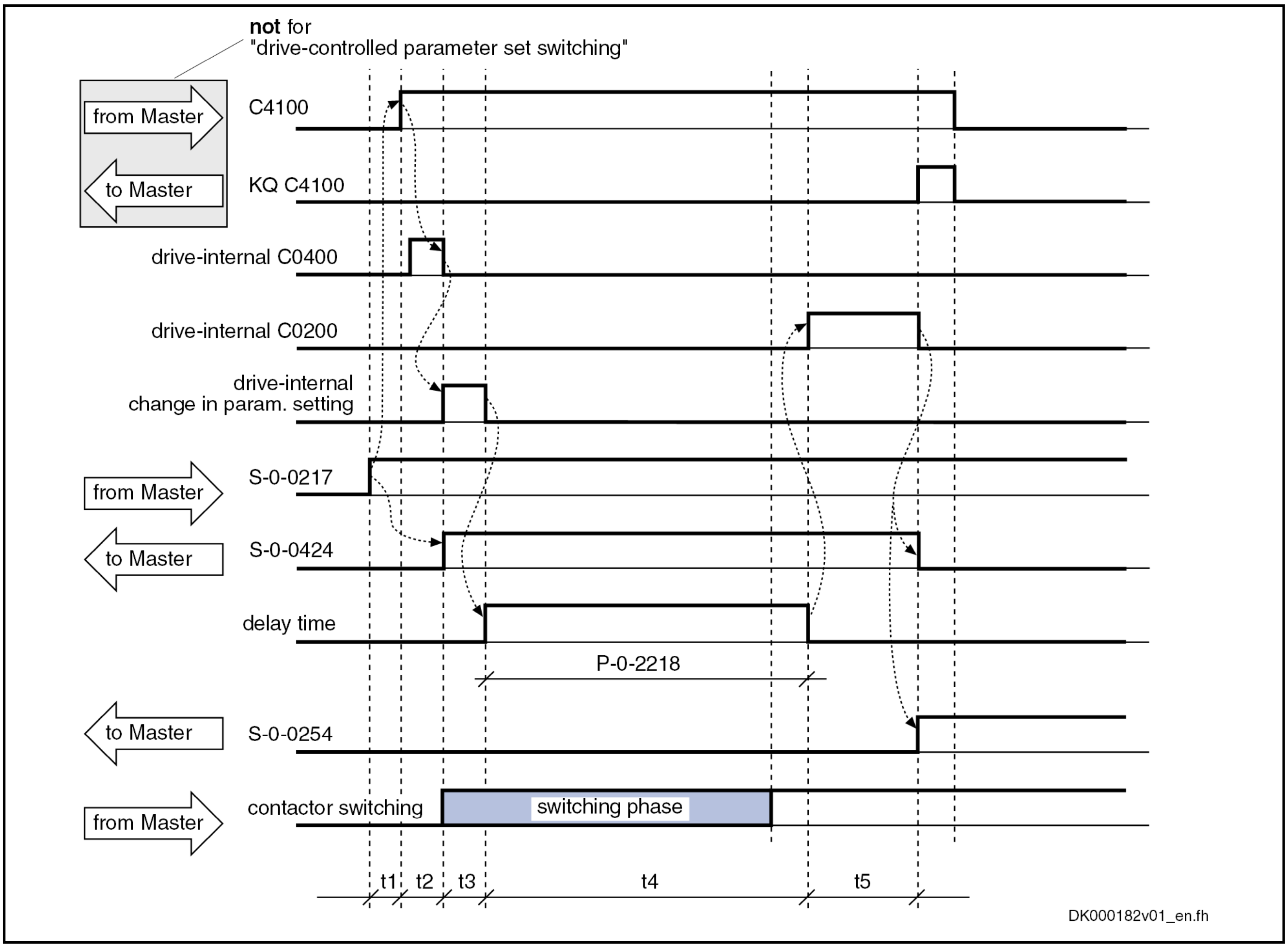
C4100	Switch parameter set command
KQ C4100	Switch parameter set command acknowledgment
S-0-0217	Preselect parameter set command
S-0-0254	Current parameter set
S-0-0424	Status parameterization level
P-0-2218	Parameter set switching, delay time
t1	Approx. 6 ms (drive-controlled parameter set switching)
t2	Approx. 5…30 ms
t3	Approx. 10…20 ms
t4	According to the value of P-0-2218
t5	Approx. 10…20 ms

Fig. 8-70: Sequence Diagram for Switching the Winding Parameters

Parameter Group "Motor Control and Motor Encoder Parameters"

If the drive, at the start of parameter set switching, is in operating mode ("bb" or "Ab") and drive enable ("AF") has not been set, it switches internally to parameter mode ("C0400 Activate parameterization level 1 procedure command"), carries out parameter set switching and automatically goes back to operating mode ("C0200 Exit parameterization level procedure command"). Switching is impossible in "AF"!

For switching the encoder parameters, it is possible, by means of "P-0-2218, Parameter set switching, delay time", to delay the return to operating mode via "C0200 Exit parameterization level procedure command" to have sufficient delay until switching times of contactors, relays etc. are over.



C4100	Switch parameter set command
KQ C4100	Switch parameter set command acknowledgment
C0400	Activate parameterization level 1 procedure command
C0200	Exit parameterization level procedure command
S-0-0217	Preselect parameter set command
S-0-0254	Current parameter set
S-0-0424	Status parameterization level
P-0-2218	Parameter set switching, delay time
t1	Approx. 6 ms (drive-controlled parameter set switching)
t2	Approx. 50 ms, for resolver measuring system approx. 250 ms
t3	Approx. 6 ms
t4	According to the value of P-0-2218
t5	approx. 1…15 s

Fig. 8-71: Sequence Diagram for Switching the Motor Control and Motor Encoder Parameters

☞ During the execution of "C4100 Switch parameter set command", command error messages C02xx might possibly occur, if inadmissible states (e.g. switching times) are still present before switching back to operating mode takes place!

8.11.3 Notes on Commissioning

Presettings

Parameter groups to be switched are preselected in:

- P-0-2216, Parameter set switching, configuration

Number of switchable parameter sets is determined in:

- P-0-2217, Parameter set switching, preselection range

If desired, activate "drive-controlled parameter set switching" in parameter P-0-2216, too.

Writing the Switchable Parameters

Depending on the selected presettings, those parameters can be written in communication phase 4 the IDNs of which are displayed in parameters S-0-0219 to S-7-0219 (IDN list of respective parameter set).

☞ All other parameters that could be included in the parameter set switching (S-1-xxxx to S-7-xxxx or P-0-xxxx to P-0-xxxx) but are not listed in in S-x-0219:

- Are not listed in "S-0-0192, IDN-list of all backup operation data".
- Are write-protected in the operation mode.

Initial State

After switching on, it is always "parameter set 0" that is active first. Parameter "S-0-0254, Current parameter set" displays "0".

Carrying Out Parameter Set Switching

Before the function is activated, the number of the parameter set to which switching is to take place must be entered in parameter "S-0-0217, Preselect parameter set command".

Sequence of the function:

- Command "C4100 Switch parameter set command" (S-0-0216) is started via control master
- Successful parameter set switching is checked in parameter "S-0-0254, Current parameter set" (new parameter set number must have been acknowledged in this parameter)
- Command C4100 is cleared by control master

Diagnostic Messages

During execution of the command, the message "C41" appears on the display of the drive controller.

Possible failures are displayed by the following diagnostic messages:

- C4101 Switching only possible without AF
- C4103 Preselect parameter set forbidden value
- C4104 Error during parameter set switching (->S-0-0423)

In conjunction with the gear switching the following diagnosis messages are possible:

- C0273 Modulo value for motor encoder cannot be displayed
- C0278 Modulo value for optional encoder cannot be displayed
- C0280 Maximum travel range cannot be displayed internally

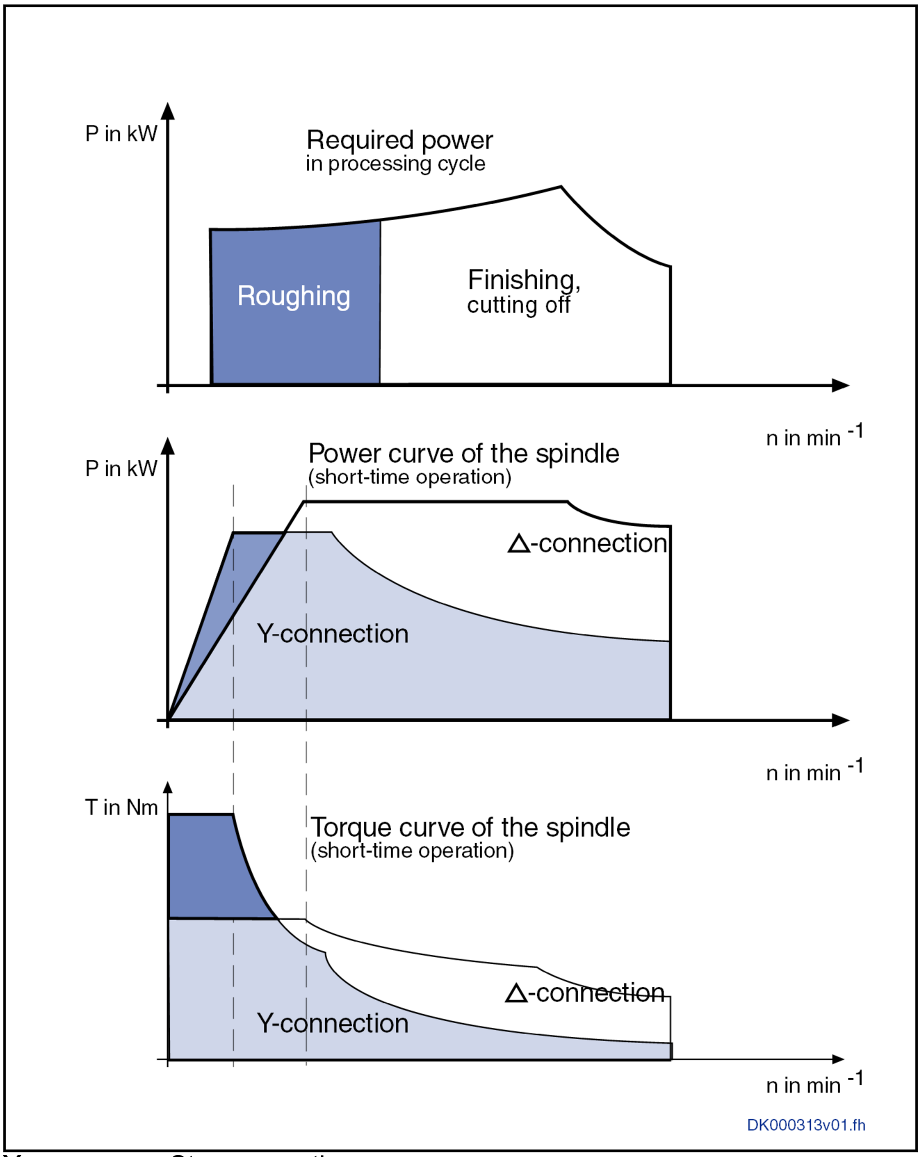
8.12 Star-Delta Switching

8.12.1 Brief Description

Fields of Application

With star(Y)-delta(D) switching, the torque power characteristic of a spindle for short-time operation without mechanical transmission elements can be adjusted to various processing requirements:

- Removing material (roughing): High torque, low speed
- Fine machining (finishing): High speed, low torque



Y Star connection
D Delta connection
Fig. 8-72: Schematic Operating Characteristic of a Spindle Drive with a Star-Delta-Switchable Motor

The spindle output capacity with star connection is just 2/3 of the output capacity with delta connection, i.e. the star-delta-switching is not a complete replacement for gear switching because the same output capacity is available for each gear stage! The increased torque in short-time operation with star connection in comparison with delta connection is not associated with an increase in the continuous torque of the spindle!

☞ Instead of with star-delta-switching, the increase in the short-time operation torque can also be achieved with an increased type current of the controller by a motor the winding of which has internally been unchangeably star-connected or delta-connected. This eliminates the contactor circuit that is not maintenance-free over the long term and with which additional wiring effort and braking problems in case of mains power failure are associated!

For milling spindles, due to long run-up times for star connection, star-delta switching is usually not suitable!

Features

Motor Design

Star-delta switching can only be used with Rexroth motors specially designed for this purpose or with third-party motors. With these motors, all six winding ends of the three-phase motor are run into the motor terminal box. Standard motors are interconnected internally in a fixed manner; only three power connections are accessible!

Procedure for Star-Delta Switching

IndraDrive controllers support star-delta switching of synchronous and asynchronous three-phase a.c. motors in the following way:

- Using switchable parameters, a parameter set with all of the relevant motor parameters is assigned to every type of motor connection in the controller. To do this, the functional package "Main spindle" is required, which provides "parameter set switching".
- Star-delta switching can be performed during operation, i.e. with an active drive. The controller converts the motor control voltage to the new type of connection and, in so doing, implements a connection type transition without it being noticed. However, the controller does not control the contactors for switching the motor windings; this must be carried out externally by the control master.
- Each connection type must be put into operation individually and each is independently effective and functional. There is no conversion of winding-specific parameter values based on the respective connection type.

Triggering Star-Delta Switching

The change to the other connection type is triggered by the switching of parameters (parameter set switching).

Pertinent Parameters

- P-0-2216, Parameter set switching, configuration
- S-0-0216, C4100 Switch parameter set command
- S-0-0217, Preselect parameter set command
- S-0-0219, IDN-list of parameter set

Pertinent Diagnostic Messages

- C4100 Switch parameter set command

8.12.2 Functional Description

Specific Features of Asynchronous Motors

Asynchronous Rexroth motors with a winding configuration for star-delta switching (prefix "Y" in the first position of the winding characteristic number of the motor type code) are delivered in principle without motor parameters in the encoder memory, even if a memory is available (motor encoder option "S2" or "M2").

The motor parameter set for the star and delta connection of asynchronous Rexroth motors is provided by the "IndraWorks" tool. It must be loaded to the controller during commissioning.

For details, see "Notes on Commissioning".

Specific Features of Synchronous Motors

Synchronous motors with motor encoder are only operational if they are operated with the correct commutation offset in addition to the motor type-specific parameters. For star-delta switchable motors, a commutation offset must therefore be identified for each connection type and stored in the controller so that it can be reactivated for the respective winding connection.

Absolute Motor Encoder

The use of motor encoders that can be evaluated in absolute form is basically recommended for synchronous motors. This is advantageous, as the motor is immediately operational following initial commissioning after switching on again (see chapter "Commutation Setting"). The majority of motor encoders that can be evaluated in absolute form also provide an encoder memory, and the commutation offset is also stored here so that the motor is immediately operational even at different controllers.

However, two type-specific motor parameters sets, including different commutation offset values, have to be stored for star-delta switchable synchronous motors. This is not possible in the encoder data memory, therefore these data are only stored in the drive controller. When the drive is switched on, normally the commutation offset at "PM" -> "OM" is automatically read from the encoder memory (P-0-3008), and the value (P-0-0508, Commutation offset) is thereby overwritten in the drive. This would be unusable for star-delta switching and must therefore be deactivated in "P-0-0522, Control word for commutation setting"!

☞ Synchronous Rexroth housing motors are as a standard equipped with absolute motor encoders and encoder memories. Thereby, the correct motor parameters, including the commutation offset value, are available when the drive is commissioned. These motors are not star-delta switchable!

☞ Please refer to the corresponding chapters of the documentation as regards the parameterization and commissioning of synchronous third-party motors and the commutation offset setting for absolute motor encoders!

Relative Motor Encoder

The use of relative motor encoders is also possible with synchronous motors. This has the disadvantage that the commutation offset for operating the motor has to be determined each time the motor is switched on. This is done automatically when the drive is enabled (AF) for the first time after switching on, but can result in values with different qualities which could lead to less motor torque/force development than expected. This potential shortcoming can be eliminated by "optimum commutation setting with regard to reference point" (see chapter "Commutation Setting").

The motor type-specific parameters for the star and delta connection of a synchronous motor are stored in the controller in a parameter set with switchable parameters. However, the respective value of "P-0-0521, Effective commutation offset" is still to be optimized before it is saved in the drive (P-x-0508), in order to be able to use the benefits of "optimum commutation setting with regard to reference point" (see chapter "Commutation Setting").

☞ Using the "optimum commutation setting with regard to reference point" is strongly recommended when using relative motor encoders! This results in reproducible torque/force development of the motor!

☞ Please refer to the corresponding chapters of the documentation as regards the parameterization and commissioning of synchronous third-party motors and the commutation offset setting for relative motor encoders!

Timing of Star-Delta Switching

Star-delta switching is triggered by parameter set switching, provided that the parameter group "winding" (P-0-2216, Parameter set switching, configuration) has been included in the switching.

☞ The timing of the parameter set switching for the parameter group "winding" is described in detail in the chapter "Conditions and Timing for Parameter Set Switching".

The control master causes the contactors to be controlled for star-delta switching. The time required for the contactor switching determines the value of "P-0-2218, Parameter set switching, delay time", by means of which the control master can adjust the star-delta switching time to the hardware-side conditions. If star-delta switching does not take place with each parameter set switch when using more than two switchable parameters sets, the control master can correspondingly reduce the current value of P-0-2218 prior to the switching.

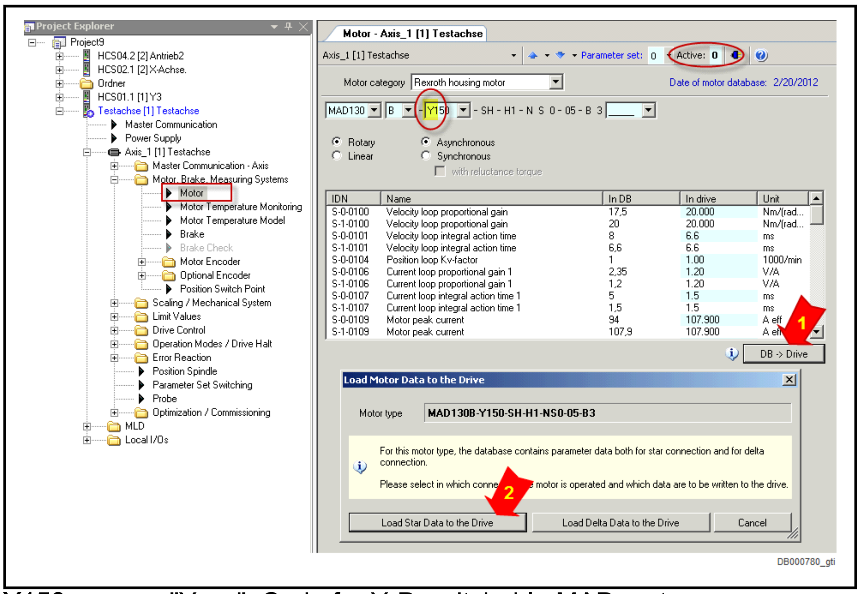
8.12.3 Notes on Commissioning

Generating Parameter Sets for Star-Delta Switching of Asynchronous Rexroth Motors

☞ Only asynchronous Rexroth motors are available for star-delta switching!

Each connection type of the motor corresponds to a set of switchable parameters. The sets of switchable parameters first need to be generated. Recommended procedure:

- First parameterize the motor for a connection type! This is supported by IndraWorks by the "Motor" dialog. Select the relevant motor in the configurator in the dialog. The database values are listed, with identification numbers of parameter sets "0" (star connection) and "1" (delta connection) appearing for star-delta switchable motors:



Y150 "Yxxx": Code for Y-D switchable MAD motor

Fig. 8-73: IndraWorks Dialog for Loading Motor Parameters to the Active Switchable Parameter Set with a Star-Delta Switchable MAD Motor

After "loading the database values" ("DB→Drive") has been requested, a further dialog appears with a selection as to whether the parameters for star or delta connection are to be loaded to the displayed, active parameter set (parameter set "0" in this case).

☞ For reasons of clarity, parameter set "0" is assigned to the star connection and "1" to delta connection. Other assignments are also possible!

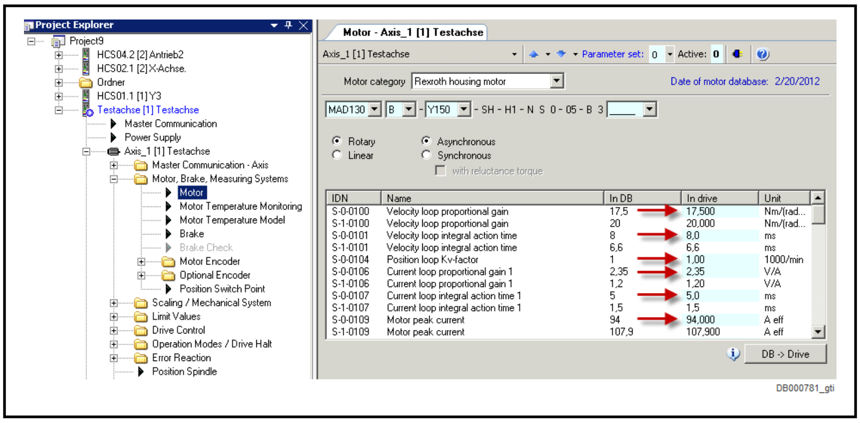


Fig. 8-74: Completed Loading of Star Motor Parameters to the Active Parameter Set "0" of the Switchable Parameter Sets with a Star-Delta Switchable MAD Motor

- Defining parameter groups to be switched: The respective parameter groups must be selected, which contain parameters that require different values depending on their connection type ("P-0-2216, Parameter set switching, configuration"), see also "Parameter Set Switching, Defining the Parameter Groups").
  - Compulsory: Winding parameter group
  - Optional: "Control loop parameters", "application parameters" and "load gear parameters" groups (required if one or more parameters are contained in these groups for which different parameter values are to be possible depending on the motor connection)
  - Not recommended: Motor control and motor encoder parameters group, as switching is only possible in "Bb" or "Ab" and not "on the fly" (with "AF").
- Copy parameter set "0" to parameter set "1" after having activated all required parameter groups relevant for switching. The values of parameter set "0" are therefore also contained in parameter set "1" (duplication).

Extended Axis Functions

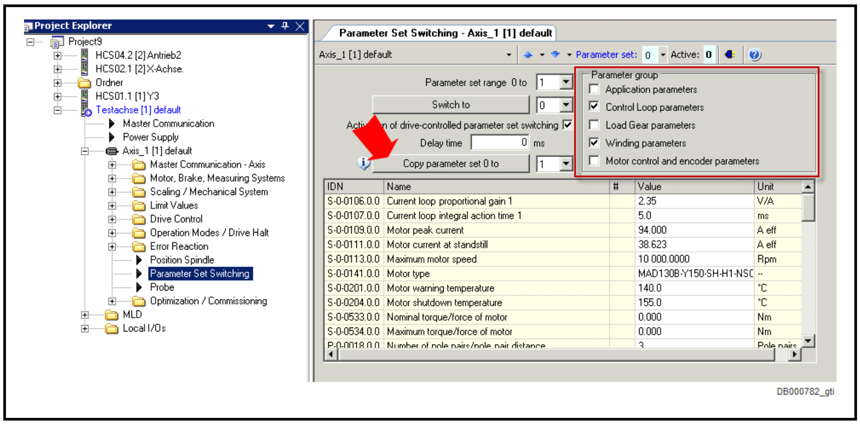


Fig. 8-75: IndraWorks Dialog for Selecting Parameter Groups which are Included in Parameter Set Switching, in this Case only the "Winding Parameters", Copying Parameter Set "0" to "1"

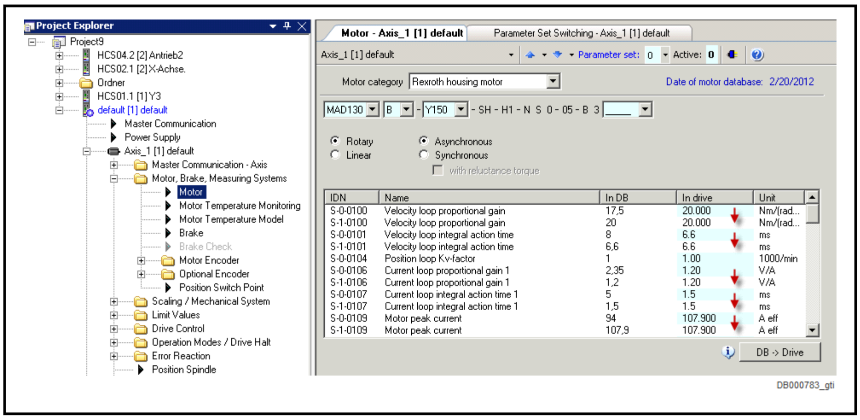


Fig. 8-76: Completed Copying of Motor Parameters to Parameter Set "1" of the Switchable Parameter Sets with a Star-Delta Switchable MAD Motor

- Only load the parameter values for the delta connection to parameter set "1" of the switchable parameter sets.

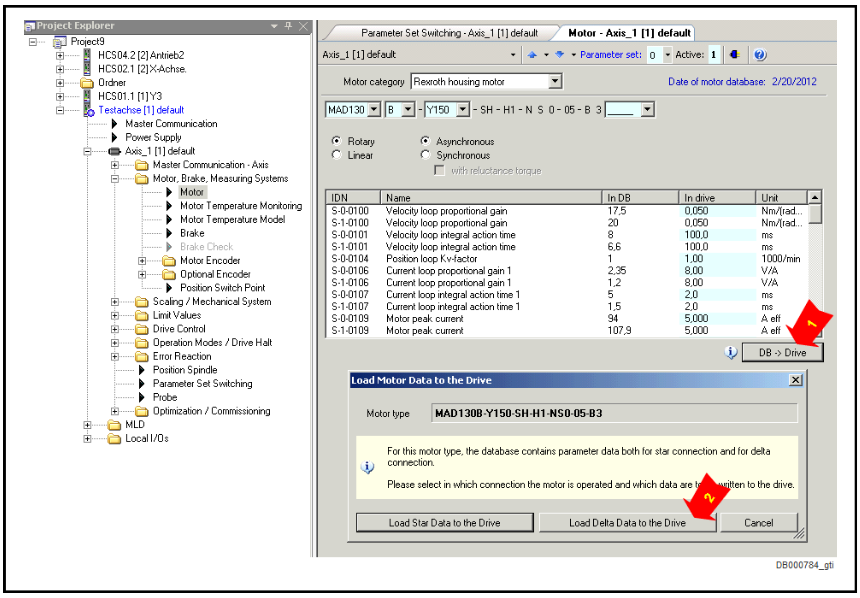


Fig. 8-77: IndraWorks Dialog for Loading Motor Parameters to the Active Switchable Parameter Set with a Star-Delta Switchable MAD Motor

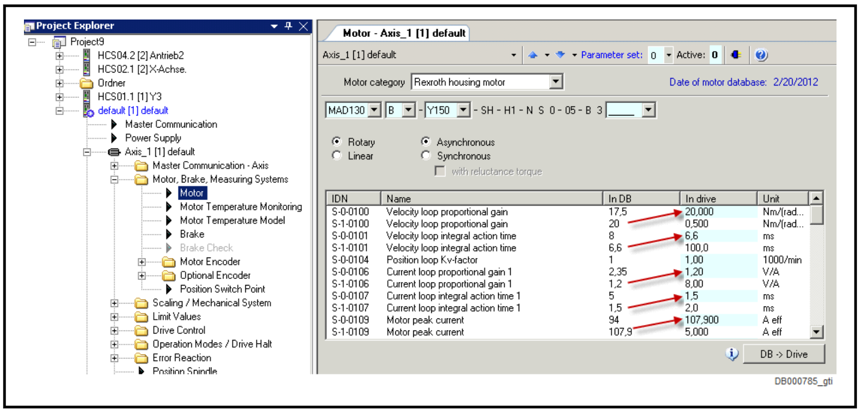


Fig. 8-78: Completed Loading of Delta Motor Parameters to Parameter Set "1" of the Switchable Parameter Sets with a Star-Delta Switchable MAD Motor

Generating Parameter Sets for Star-Delta Switching of Third-Party Motors

First parameterize and commission the motor for each connection type: See chapter "Motor, Mechanical Axis System, Measuring Systems, Third-Party Motors"

As switchable winding parameters are needed for star-delta switching, it is useful to prepare for parameter switching via the relevant IndraWorks dialog:

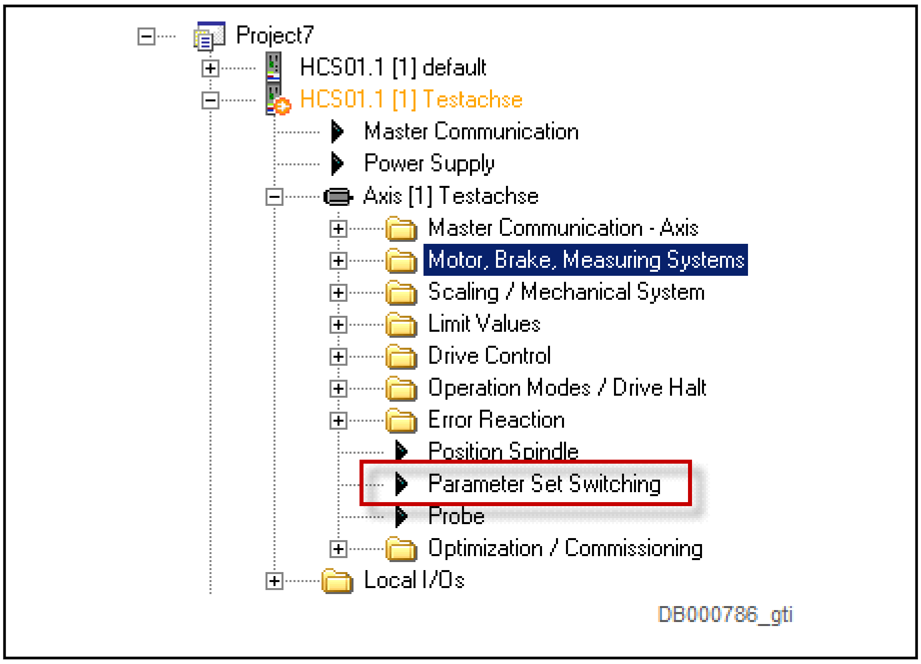


Fig. 8-79: Position of the Dialog for Parameter Set Switching in the IndraWorks Explorer

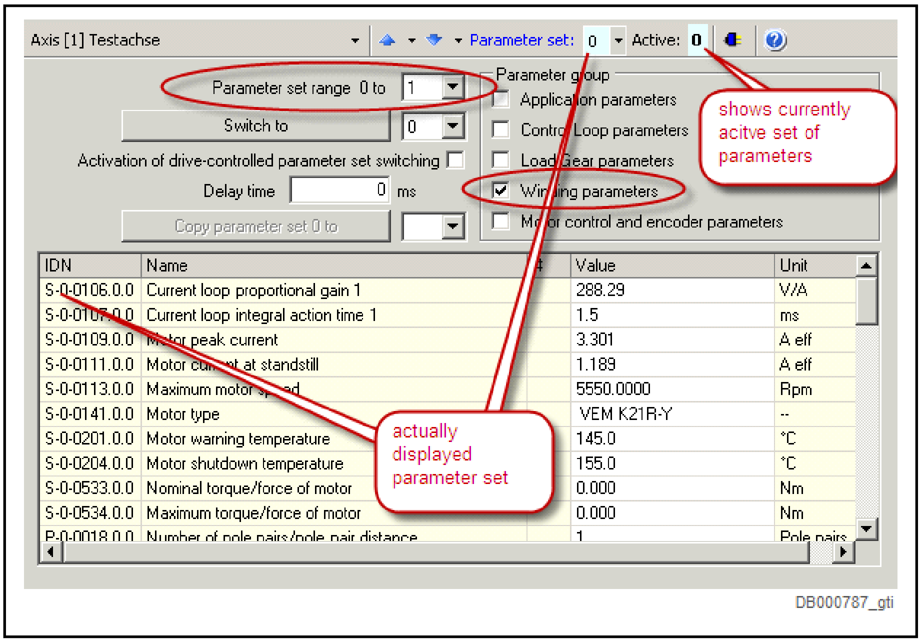


Fig. 8-80: Setting the Switchable Parameters: Parameter Set Range (0...max.7), Parameter Groups of Switchable Parameters, Start of Switching

Select at least "0" and "1" for the parameter set range; a maximum of "0" to "7" is possible. Select at least the winding parameters as the parameter group or select further groups, if parameters relevant for Y-D switching are contained in another parameter group.

Asynchronous Third-Party Motors

Asynchronous third-party motors are advantageously parameterized by inputting the data from the motor type plate. Usually, Y/D data are specified there.

☞ See chapter "Motor, Mechanical Axis System, Measuring Systems, Third-Party Motors, Data of Asynchronous Motors"

The input of the type plate data is supported by the IndraWorks motor dialog. Please note that the data are input in the parameter set "displayed", although the specific motor parameters are only calculated in the "active" parameter set!

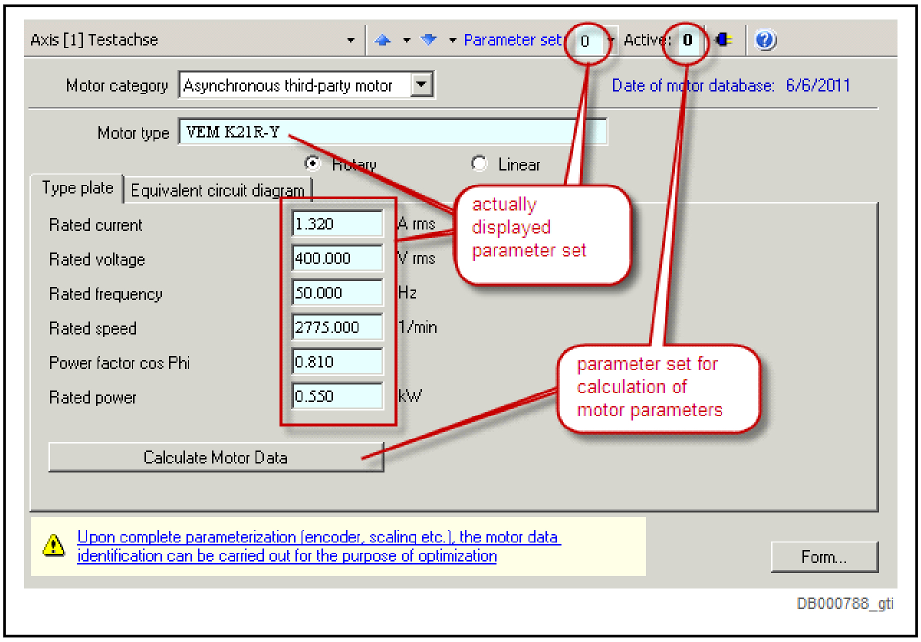


Fig. 8-81: Dialog for Inputting the Type Plate Data of Asynchronous Third-Party Motors Using the Switchable Parameter Sets

Synchronous Third-Party Motors

Synchronous third-party motors are parameterized by inputting the motor data. The motor data must be available for star and delta connection of the motor windings or be given on the manufacturer side.

☞ See chapter "Motor, Mechanical Axis System, Measuring Systems, Third-Party Motors, Data of Asynchronous Motors"

The input of motor data for third-party motors is supported by the IndraWorks motor dialog. Please note that the data are input in the parameter set "displayed", although the specific motor control parameters are only calculated in the "active" parameter set!

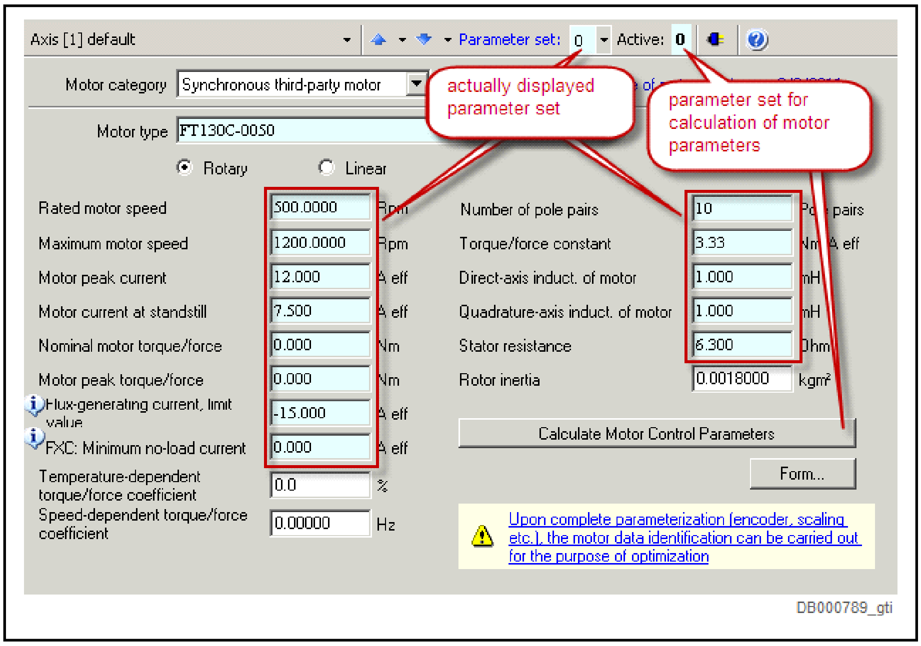


Fig. 8-82: Dialog for Inputting the Type Plate Data of Synchronous Third-Party Motors Using the Switchable Parameter Sets

Commissioning the Motor in Star and in Delta Connection

Asynchronous Rexroth Motors

Asynchronous Rexroth motors are operational when the connection type and corresponding motor parameters have been correctly assigned. Only the velocity control loop still has to be adjusted to the mechanical conditions of the axis.

Third-Party Motors

With third-party motors, the "motor parameter identification" is to be carried out during initial commissioning in each connection type of the motor windings, ideally "with motion", provided this is possible at the axis. To do so, first switch to the respective assigned set of switchable parameters.

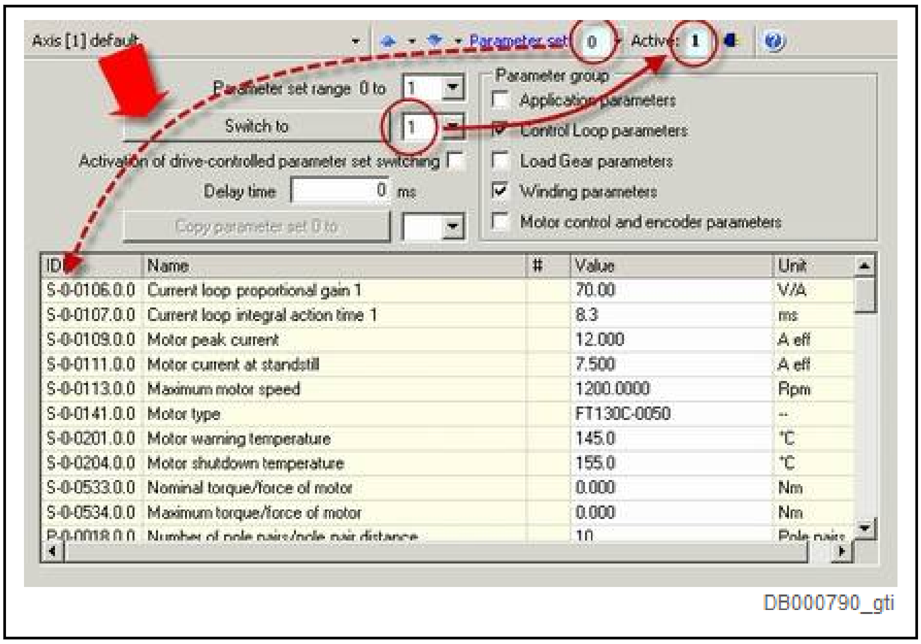


Fig. 8-83: IndraWorks Dialog for Switching Parameters, in this Example: Active: Parameter Set 1, Display: Parameter Set 0

Also check the validity of the motor and motor encoder. This is done with "P-0-0565, C3600 Command Motor data identification", and with "P-0-0601, Configuration motor data identification" the different actions are configured.

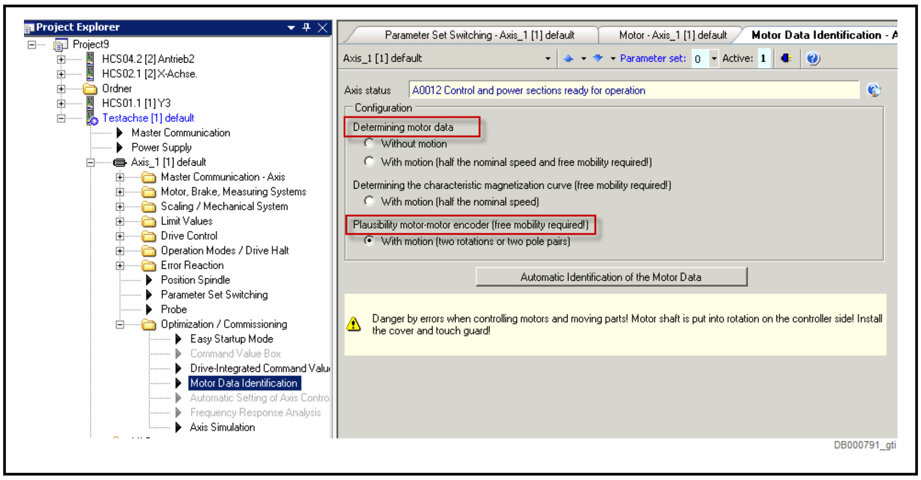


Fig. 8-84: IndraWorks Dialog for the Configuration and Start of "C3600 Command Motor Data Identification"

See also chapter "Third-Party Motors at IndraDrive Controllers"

Asynchronous Third-Party Motors

When the motor parameters have been determined and the validity of motor encoder and motor has been ascertained, drive enable ("AF") can be set. The motor must now follow the command value. If this is not the case, the velocity control loop still has to be adjusted to the mechanical conditions of the axis. This, however, is basically required.

See also chapter "Third-Party Motors at IndraDrive Controllers"

Synchronous Third-Party Motors

When the motor parameters have been determined and the validity of the motor encoder and motor has been ascertained, the commutation setting must still be made for synchronous motors. This is done depending on the configuration of the motor encoder and the arrangement of its reference marks, as explained in the chapter "Commutation Setting".

See also "Notes on Commissioning" in the chapter "Basics on Commutation Setting" and the respective method (with current) for commutation setting!

When the commutation offset has been set, drive enable ("AF") can be set. The motor must now follow the command value. If this is not the case, the velocity control loop still has to be adjusted to the mechanical conditions of the axis. This, however, is basically required.

Using the "optimum commutation setting with regard to reference point" is strongly recommended when using relative motor encoders! This results in reproducible torque/force development of the motor!

Triggering Star-Delta Switching

Star-delta switching is triggered by switching to another parameter set which has been assigned to the other connection type. The control master causes the contactors in the motor supply line to be switched. The switching time is adjusted to the hardware-side conditions via "P-0-2218, Parameter set switching, delay time".

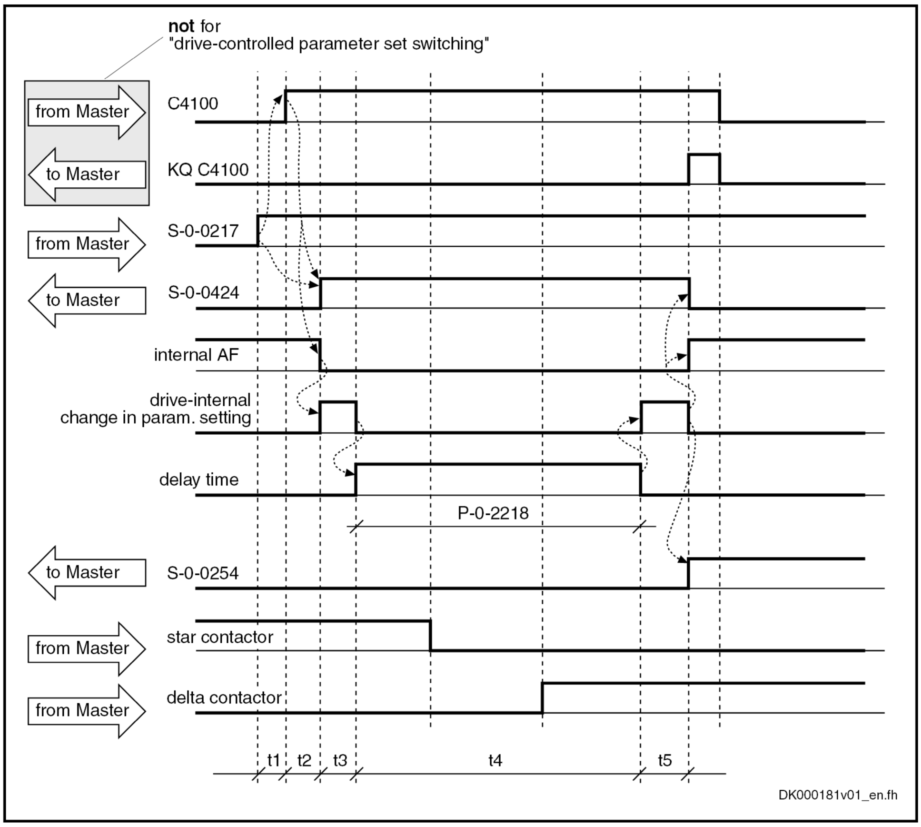


Fig. 8-85: Sequence Diagram for Switching the Winding Parameters

8.13 Drive-controlled oscillation

8.13.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Upon a command of the control master, the drive ignores the cyclic command value input and independently turns alternately in positive and negative direction (speed oscillation). The cyclic speed characteristic can be set via parameters and can be realized symmetrically or asymmetrically.

Notes on Application

With speed oscillation the main drive supports the following applications, for example:

- Meshing the toothed wheels when switching a gear train
- Engaging positive clutches (e.g. connecting IC engine equipment under test to test stands)

Pertinent Parameters

- S-0-0190, C4200 Drive-controlled oscillation procedure command
- S-0-0213, Oscillation speed
- S-0-0214, Oscillation offset speed
- S-0-0215, Oscillation cycle time

Pertinent Diagnostic Messages

- C4200 Drive-controlled oscillation command

- C4201 Oscillation requires drive enable
- C4202 Oscillation command speed cannot be reached

8.13.2 Functional Description

Drive-controlled oscillation is adjusted to the individual requirements of the meshing/engaging procedure via parameters. Oscillation cycle time, oscillation speed and oscillation offset speed can be set.

By means of the oscillation offset speed, oscillation can be asymmetrically configured in order to overcome tooth-to-tooth positions during the meshing procedure.

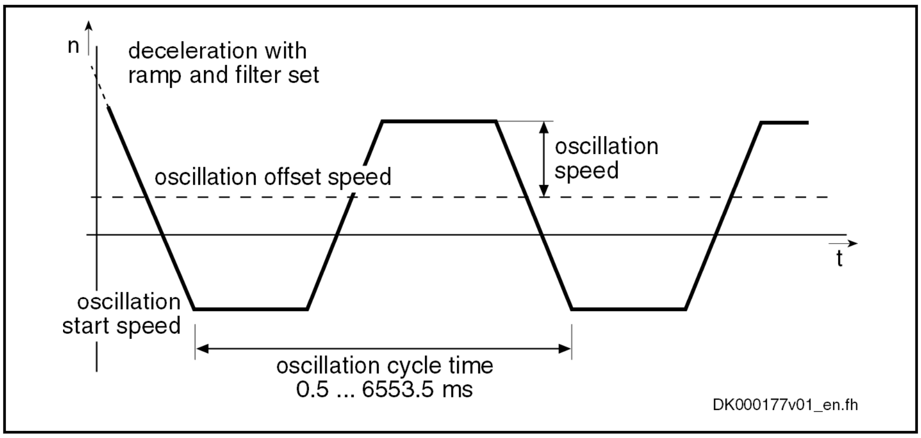


Fig. 8-86: Speed Characteristic with Drive-Controlled Oscillation

Starting "Drive-Controlled Oscillation"

Triggering the command "C4200 Drive-controlled oscillation command" causes the following reaction:

- When the motor is turning, the velocity is decelerated to the oscillation start speed, taking possibly activated ramps and filters into account.
- When the motor has stopped, acceleration to the oscillation start speed takes place.

Acknowledgment

If within 5 s after start of command, the deviation of the actual velocity value from the oscillation start speed is smaller than the value of "S-0-0157, Velocity window", the execution of the command is acknowledged and the command value curve for speed oscillation is internally generated.

Command Value Generation

The drive-internal command value for oscillation is cyclically generated from oscillation offset speed +/- oscillation speed. Drive-internal ramps and command value filters that were set then aren't active.

The parameter values for drive-controlled oscillation can be changed during the oscillation process. At the latest after the oscillation cycle time is over, the drive reacts to the new values.

After execution of command C4200 has been completed, the drive follows the currently present command value.

8.13.3 Notes on Commissioning

Presettings/Checks

Before activating the function "drive-controlled oscillation" the following presettings or checks have to be made:

- Value in parameter ""S-0-0215, Oscillation cycle time"" has to be unequal zero.
- Values of parameters "S-0-0215, Oscillation cycle time", "S-0-0213, Oscillation speed" and "S-0-0214, Oscillation offset speed" must be

checked and values allowed for the spindle mechanics must be entered, if necessary.

Value in parameter "S-0-0215, Oscillation cycle time" must be between 0.5 ms and 6553.5 ms (steps of 0.5 ms)!

Activating the Oscillation

The function is activated by starting command "C4200 Drive-controlled oscillation command" (S-0-0190) via the control master.

Terminating the Oscillation

The function is terminated by clearing command C4200 by the control master, when the master has detected the meshing of the gearbox shaft to have been carried out.

Diagnostic Messages

During execution of the command, the message "C42" appears on the display of the drive controller.

Possible failures are displayed by the following diagnostic messages:

- C4201 Oscillation requires drive enable
- C4202 Oscillation command speed cannot be reached

8.14 Parking axis

8.14.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

If individual axes within a master communication group (e.g. sercos ring, PROFIBUS) are to be temporarily deactivated, without taking them out of the axis group on the hardware and communication side, the "parking axis" function can be activated via command.

When a drive has been put into the "parking axis" state, it behaves "neutrally" with regard to hardware and master communication. Errors possibly detected by the drive are suppressed and have no effect on the axes in operation. This allows, for example, uncoupling the motor and the motor encoder in the "parking axis" state without errors being signaled.

The axis that has been "parked" behaves as if it would not exist!

Pertinent Parameters

- S-0-0139, C1600 Parking axis procedure command

Pertinent Diagnostic Messages

- C1600 Parking axis command

8.14.2 Functional Description

Parameter "S-0-0139, C1600 Parking axis procedure command" can only be activated in parameter mode (communication phase "P2" or "P3"). Executing the command causes the following actions:

- Monitoring functions of measuring systems are deactivated
- Motor temperature monitoring is deactivated
- Reference bits in "position feedback value status" are disabled
- If "S-0-0128, C5200 Communication phase 4 transition check" is executed, there is no initialization of drives
- "PA" is displayed on control panel and in diagnostic system
- Master-side drive enable is ignored

☞ The execution of command C1600 is not acknowledged as completed on the drive side, in order to keep the command change bit of parameter "S-0-0135, Drive status word" free for diagnosis of other commands!

The command C1600 can only be cleared in communication phase "P2" or "P3" or by switching back to "P0". Completing the execution of command C1600 causes the following actions:

- Monitoring functions of measuring systems are activated
- Motor temperature monitoring is activated
- Standard diagnostic messages appear again on display and in diagnostic system
- Drive enable is possible again in communication phase "P4"

☞ As the position data reference of relative measuring systems gets lost when command C1600 is started, the position data reference for these measuring systems has to be established again (homing procedure) after drive enable has been set!

☞ To activate the function "parking axis", there is an alternative to switching to communication phase "P2"; you can switch to the parameter mode from the operating states "bb" or "Ab" via "S-0-0420, C0400 Activate parameterization level procedure command". By activating "S-0-0422, C0200 Exit parameterization level procedure command", the drive returns to the operating mode.

8.15 Integrated Safety Technology

8.15.1 Brief Description

Optional Modules of the Integrated Safety Technology

To employ the integrated safety technology with the corresponding control sections or drive systems, at least the following firmware version or higher must be used in the drive:

Device	Optional modules for **IndraDrive Cs**	Safety functions selected via	Firmware version
HCS01.1	L3, STO (Safe Torque Off)	24 V inputs at the drive controller	As of MPx-17V06
	L4, STO (Safe Torque Off) and SBC (Safe Brake Control)	24 V inputs at the drive controller	As of MPx-16V14
	S4, SMO (Safe Motion)	24 V inputs at the safety zone module "HSZ01" or safety bus	As of MPB/MPC-18V08
	Optional modules for **IndraDrive Mi**		Firmware version
KSM02.x KMS02.x	L3, STO (Safe Torque Off)	24 V inputs at the drive controller	As of MPB-17V08 (KSM02.x) As of MPB-17V10 (KMS02.x)
	S3, SMO (Safe Motion)	Safety bus	As of MPB-18V08

	Optional modules for IndraDrive M / IndraDrive C		Firmware version
Cxx02.x	L3, STO (Safe Torque Off)	24 V inputs at the drive controller	As of MPx-18V08
	S4, SMO (Safe Motion)	24 V inputs at the safety zone module "HSZ01" or safety bus	

Tab. 8-9: Integrated Safety Technology and Required Firmware

Certification

The safety technology was certified by TÜV Rheinland ®; certificates are available on the Internet or Extranet. The NRTL listing by TÜV Rheinland of North America is in preparation.

Requirements That Can Be Realized

The integrated safety technology is independent of

- Type of master communication
- Higher-level control unit
- Supply modules

It is available as a functional characteristic of the standard drive system. The requirements below can be realized in the machine or in the installation:

- Measures according to ISO 12100-2, if accessing the danger zone is required, for example, for equipping, teaching or material withdrawal.
- Requirements for safety-related parts of control units according to ISO 13849-1 Category 4 PL e and IEC 62061 SIL 3, as required in EN 1010-1 (printing and paper converting machines), EN 12415 (turning machines) and EN 12417 (machining centres).
- Control functions in the case of error according to IEC 60204-1 (homogeneous redundancy).

8.15.2 Integrated Safety Technology "Safe Torque Off" and "Safe Brake Control"

Overview of Safety Functions

Definition

- "Safe Torque Off" means application-related safety functions which are applicable for personal protection at machines according to ISO 13849-1 Category 4 PL e and IEC 62061 SIL 3.
- "Safe Brake Control" means application-related safety functions which are applicable for personal protection at machines according to ISO 13849-1 Category 4 PL e and IEC 62061 SIL 3.

The optional safety technology modules "L3" (STO) and "L4" (STO and SBC) are used to exclusively support the safety technology function group "Safe standstill" with the following functions:

Safety technology functions	Optional modules		
	IndraDrive Cs (HCS01.1)	IndraDrive Mi (KSM02.x, KMS02.x)	IndraDrive M / IndraDrive C (Cxx02.x)
The energy supply to the drive is interrupted in a safe way. The drive cannot generate any torque/force and, as a consequence, it cannot generate any dangerous motions, either.	L3, STO (Safe Torque Off) L4, STO (Safe Torque Off) and SBC (Safe Brake Control)	L3, STO (Safe Torque Off)	L3, STO (Safe Torque Off)
With "Safe brake control", the motor holding brake is switched off safely (via two channels).	L4, STO (Safe Torque Off) and SBC (Safe Brake Control)	-	-
With "Safe stop 1", the energy supply to the motor is safely interrupted. The motor cannot generate any torque/any force and therefore no dangerous movements. The duration of the transition to "Safe stop 1" is monitored. "Safe stop 1" (Emergency stop) is only possible in conjunction with an external, time-delayed safety selection device.	L3, STO (Safe Torque Off) L4, STO (Safe Torque Off) and SBC (Safe Brake Control)	L3, STO (Safe Torque Off)	L3, STO (Safe Torque Off)

Tab. 8-10: Safety Technology Functions Depending on the Optional Modules

Notes on Commissioning

Using the optional safety technology modules "L3" (STO) or "L4" (STO and SBC) does not require any kind of separate commissioning. The corresponding wiring is sufficient.

For details on the function, commissioning and application examples, see separate documentation "Rexroth IndraDrive, Integrated Safety Technology "Safe Torque Off" (as of MPx-16)" (DOK-INDRV*-SI3-OP-MAN*-APxx-EN-P; Mat. No. R911332634.)

8.15.3 Integrated Safety Technology "Safe Motion"

Overview of Safety Functions

As of firmware MPx18V08, the following functions for safe motion and standstill monitoring are available with the optional safety technology modules "Safe Motion" ("S3" and "S4")

Extended Axis Functions

<table>
<tr><th rowspan="3">Safety functions which, according to
ISO 13849-1 Category 4 PL e
and
IEC 62061 SIL 3,
are applicable for personal protection at machines.</th><th colspan="3">Optional module "Safe Motion"</th></tr>
<tr><th>"S3"</th><th colspan="2">"S4"</th></tr>
<tr><th>IndraDrive Mi
(KSM02.x
KMS02.x)</th><th>IndraDrive Cs
(HCS01.1)</th><th>IndraDrive M /
IndraDrive C
(Cxx02.x)</th></tr>
<tr><td>Safety Zone Acknowledge (SZA)
By means of "Safety Zone Acknowledge" and the safety zone module "HSZ", an acknowledgment master can monitor the safety of a safety zone and acknowledge the safety to a higher-level control unit.
It is also possible for the acknowledgment master of the safety zone to directly control a safety door locking device connected to the safety zone module.</td><td>-</td><td colspan="2">■</td></tr>
<tr><td>Safe Door Locking (SDL)
The locking device of an interlocking guard is controlled via two channels when the safe zone acknowledgment signals "Safety" and the user by means of a pushbutton requests the safety door to be unlocked. The position of the locking device is safely monitored</td><td>-</td><td colspan="2">■</td></tr>
<tr><td>Safe Zone Error (SZE)
The "Safe Zone Error" function is a subfunction of the safety function "Safety Zone Acknowledge". The "Safe Zone Error" function allows the zone nodes to signal locally present safety technology errors to all zone nodes via a safe output and to trigger individual error reactions.
It is also possible for the acknowledgment master of a safety zone to signal zone errors via the safe communication to the higher-level control unit.</td><td>-</td><td colspan="2">■</td></tr>
<tr><td>Safe Torque Off (STO)
The energy supply to the drive is interrupted in a safe way. The drive cannot generate any torque/force and, as a consequence, it cannot generate any dangerous motions, either.</td><td>■</td><td colspan="2">■</td></tr>
<tr><td>Safe Brake Control (SBC)
With the safety function "Safe brake control", the motor holding brake is switched off safely (via two channels).</td><td>-</td><td colspan="2">□</td></tr>
<tr><td>Safe stop 1 (SS1), time-prioritized [Safe Stop 1 (SS1)]
When the transition function "Safe stop 1" is activated, the drive is stopped in a safely monitored way. After the stopping process has been completed, but at the latest after the parameterized delay is over, the safety function "Safe torque off" is activated and the energy supply to the motor is safely interrupted. The motor cannot generate any torque/any force and therefore no dangerous movements.
Activation of STO function in standstill with drive enable removed, but at the latest after the parameterized delay is over</td><td>■</td><td colspan="2">■</td></tr>
</table>

■ Available
□ In preparation for Cxx02.x
- Not available

Tab. 8-11: Safety Technology Functions Depending on the Optional Modules

Safety functions which, according to ISO 13849-1 Category 4 PL e and IEC 62061 SIL 3, are applicable for personal protection at machines.	Optional module "Safe Motion"		
	"S3"	"S4"	
	IndraDrive Mi (KSM02.x KMS02.x)	IndraDrive Cs (HCS01.1)	IndraDrive M / IndraDrive C (Cxx02.x)
Safe stop 1 (SS1), standstill-prioritized [Safe Stop 1 (SS1)] When the transition function "Safe stop 1" is activated, the drive is stopped in a safely monitored way. After the stopping process has been completed, the safety function "Safe torque off" is activated and the energy supply to the motor is safely interrupted. The motor cannot generate any torque/any force and therefore no dangerous movements.	■	■	
Safe Operating Stop (SOS) In the case of the safety function "safe operating stop", the drive is in controlled standstill, i.e. all control functions between the electronic control unit and the drive are maintained. The dual-channel monitoring prevents the drive from carrying out dangerous movements due to errors although the energy supply is not interrupted.	■	■	
Safe Stop 2 (SS2) When the transition function "Safe stop 2" is activated, the drive is stopped in a safely monitored way. After the stopping process has been completed, the safety function "Safe Operating Stop" is activated and it is safely prevented that the motor deviates from the stopping position by more than a specified absolute value.	■	■	
Safe Maximum Speed (SMS) In the case of the safety function "Safe Maximum Speed", dual-channel monitoring prevents the drive from exceeding the preset velocity limit value.	■	■	
Safe Direction (SDI) In the case of the safety function "Safe Direction", dual-channel monitoring guarantees that motion is only possible in one direction.	■	■	
Safely-Limited Speed (SLS) In the case of the safety function "Safely-Limited Speed", dual-channel monitoring is used to monitor that the drive does not exceed a previously defined limitation of the velocity window.	■	■	
Safely-Monitored Transient Oscillation (SLS-LT) In the case of the safety function "Safely-Monitored Transient Oscillation", the transient oscillation with regard to a "Safely-limited speed" is monitored by means of a velocity window and a tolerance time.	■	■	

Safety functions which, according to ISO 13849-1 Category 4 PL e and IEC 62061 SIL 3, are applicable for personal protection at machines.	Optional module "Safe Motion"		
	"S3"	"S4"	
	IndraDrive Mi (KSM02.x KMS02.x)	IndraDrive Cs (HCS01.1)	IndraDrive M / IndraDrive C (Cxx02.x)
Safely-Limited Increment (SLI) In the case of the safety function "Safely-Limited Increment", dual-channel monitoring makes sure that the drive moves only within the maximum increment.	■	■	
Safely-Monitored Deceleration (SMD) In the case of the safety function "Safely-Monitored Deceleration", dual-channel monitoring is used to detect whether the actual velocity of the drive, given a change in the operating status or given an error reaction, is within a parameterized velocity envelope curve.	■	■	

■ Available

Tab. 8-12: Safety Functions according to ISO 13849-1 Category 3 PL d and IEC 62061 SIL 2

Notes on Commissioning

The optional safety technology modules "Safe Motion" ("S3" and "S4") are commissioned via dialogs by means of the "IndraWorks Ds/D/MLD" commissioning tool (supported ≥ IndraWorks 13V08).

☞ In the condition as supplied, i.e. also after a firmware update / firmware upgrade, the safety technology is in the following "SafetyDefault" state:

- The output stage is locked, i.e. the axis has gone torque-free
- Safety status: "Axis not safe"
- The digital local outputs have been set to "0"
- The brake output has been deactivated (an electrically releasing brake is applied)

For the functional commissioning, it is first necessary to set "P-0-3201, SMO: Configuration of functional commissioning", bit 0 = 1.

For details on the function, commissioning and application examples, see separate documentation "Rexroth IndraDrive, Integrated Safety Technology "Safe Motion" (as of MPx-18)" (DOK-INDRV*-SI3*SMO-VRS-APxx-EN-P; Mat. No. R911338920)

9 Optional Device Functions

9.1 Safety Instructions

⚠ WARNING **Dangerous movements! Danger to life, risk of injury, serious injury or property damage!**

- Keep free and clear of the ranges of motion of machines and moving machine parts.
- Prevent personnel from accidentally entering the machine's range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

9.2 Availability of the Optional Device Functions

For an overview that illustrates in which base or functional packages the respective optional device function is available, see chapter "Overview of Functions/Functional Packages, Availability of the Optional Device Functions".

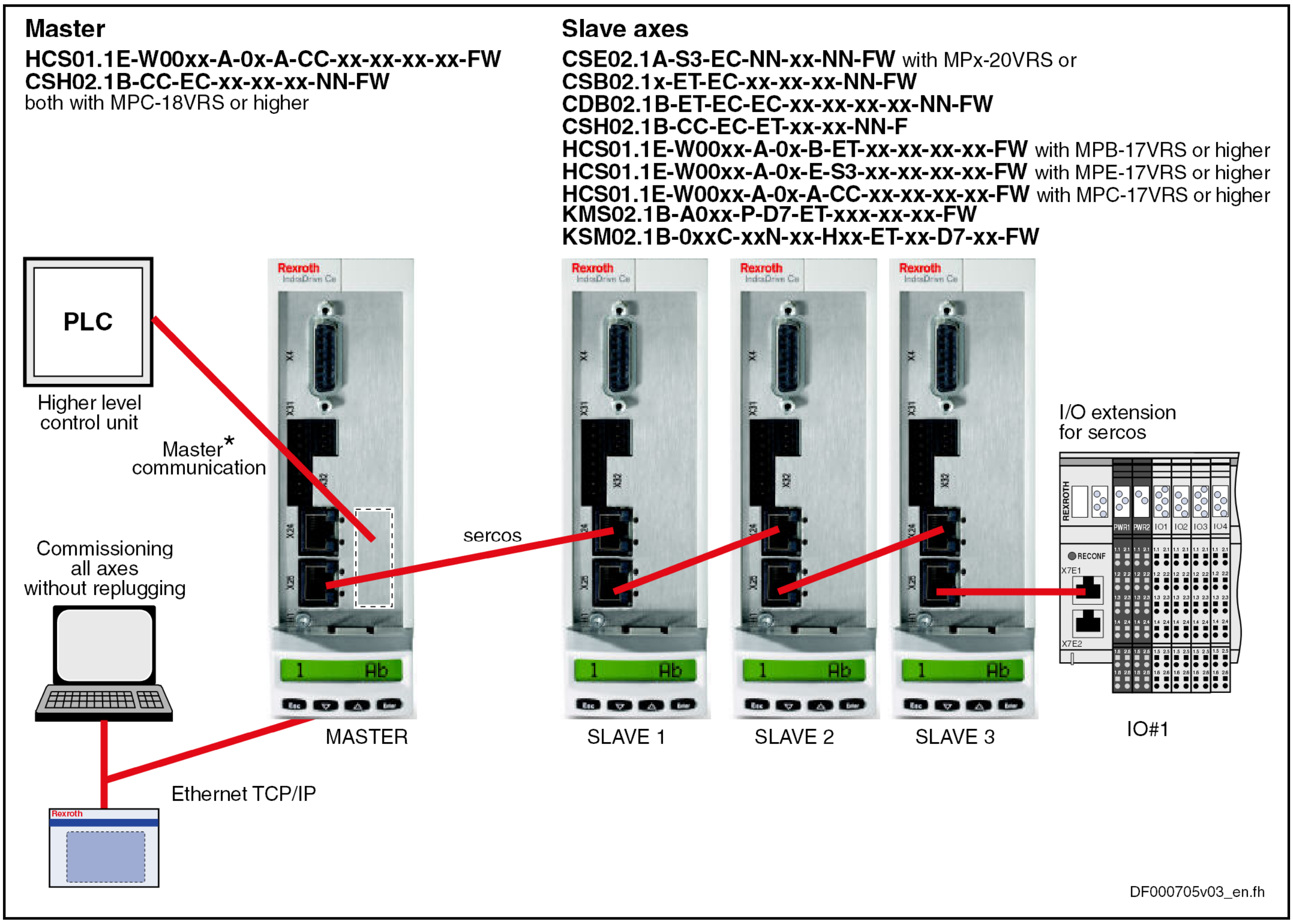
9.3 Cross communication (CCD)

9.3.1 Brief Description

Overview

The IndraDrive "cross communication" device function (Cross Communication Drives → CCD) allows electronic (digital) coupling of axes and the connection of I/O modules for IndraMotion MLD.

Optional Device Functions



* Master communication (MC), optional (alternatively no MC or PROFIBUS® or MultiEthernet)

Fig. 9-1: Hardware Topology of Drive Cross Communication (CCD)

Bus Topology

Configuration of the CCD slaves and communication with the external control unit always takes place via the CCD master drive, as the individual CCD slaves are connected to the master via a sercos interface. Therefore, external access always takes place via the drive acting as the CCD master, which requires a master communication interface (e.g. PROFIBUS®) in addition to the CCD optional module ("sercos master connection").

CCD Modes (Types of Coupling)

When cross communication (CCD) is used between the drives, we distinguish the following variants (CCD modes):

- CCD system mode

  CCD slaves have a direct logic connection to the field bus master. Command triggering and input of process data take place via an external control unit.

- CCD basic mode

  The same functions as for the CCD system mode are available. However, the user has to program them. It is not possible to use the MLD-M functionality in the master axis.

- MLD-M system mode

  The CCD slaves have no direct logic connection to the external control unit, but only to MLD-M in the CCD master. Command triggering and input of process data take place by the MLD-M in the CCD master.

Features

The device function "cross communication (CCD)" is characterized by the following features:

- Synchronization of CCD slaves to CCD master
- Transmission of freely configurable external **process data** (command values and actual values of the external control unit)
- Command value linking by transmission of freely configurable process data of the CCD axes (e.g. master/slave, Gantry axis)
- SLc03 safety control is supported
- Connection of I/O extensions for sercos via CCD (a maximum of 4 modules per CCD master) (only in MLD-M system mode)
- CCD (sercos) cycle time can be parameterized (0.25 ms to 4 ms; depends on CCD mode, controller performance and number of axes)
- Max. baud rate: 100 MBaud
- CCD communication protocol: sercos (see "sercos")
- Data channels:
  - Cyclic data channel (MDT, AT): Max. 48 bytes and 16 IDN
  - Parameter or service channel: 4 bytes
- Parameterization of all axes in the CCD group via the CCD master interfaces (RS232, engineering port, field bus, …)
- Command triggering of the CCD slaves depending on selected CCD mode via external control unit or internally via MLD in CCD master
- Possible compensation of transmission time / dead time of the cyclic process data
- Generation of up to 3 master axis positions for master axis linking
- Max. number of CCD slaves: 7 or 9 (depends on CCD mode; see "Functional Description of the CCD Modes, Performance Features")

Fields of Application

Typical fields of application for cross communication:

- Control tasks for multi-axis applications
  - Anti backlash
  - Synchronous operation control
  - Load control of several axes
- Simple command value linking
  - Position command value linking (Gantry axes)
  - Torque/force linking
- Simple motion controls with decentralized command value adjustment for single-axis positioning and master axis linking
- I/O extension by connection of I/O modules for sercos via CCD

Restrictions

When using cross communication, observe the following restrictions:

- With the cross communication function, "Coordinated Motion" is not possible!
- In the MLD-M system mode, the multiplex channel for external control units is not available in the CCD master.
- sercos I/O extensions only possible in MLD-M system mode

Hardware Requirements

The drive function "cross communication" requires the following control section design:

CCD master	
HCS01.1E-W00xx-A-0x-A-CC-xx-xx-xx-xx-FW	IndraDrive Cs Advanced - single-axis
CSH02.1B-CC-EC-xx-xx-xx-NN-FW	IndraDrive: Advanced control section - single-axis
CCD slaves	
CSB02.1x-ET-EC-xx-xx-xx-NN-FW	IndraDrive: Basic control section - single-axis
CDB02.1B-ET-EC-EC-xx-xx-xx-xx-NN-FW	IndraDrive: Basic control section - double-axis
CSH02.1B-CC-EC-ET-xx-xx-NN-FW	IndraDrive: Advanced control section - single-axis
HCS01.1E-W00xx-A-0x-B-ET-xx-xx-xx-xx-FW	IndraDrive Cs Basic - single-axis
HCS01.1E-W00xx-A-0x-E-S3-xx-xx-xx-xx-FW	IndraDrive Cs Economy - single-axis
HCS01.1E-W00xx-A-0x-A-CC-xx-xx-xx-xx-FW	IndraDrive Cs Advanced - single-axis
KMS02.1B-A0xx-P-D7-ET-xxx-xx-xx-FW	IndraDrive Mi, distributed drive controller
KSM02.1B-0xxC-xxN-xx-Hxx-ET-xx-D7-xx-FW	IndraDrive Mi, distributed servo drive

Tab. 9-1: Hardware Requirements

See documentation "Control Sections for Drive Controllers; Project Planning Manual"

Firmware Requirements

When using the drive function "cross communication", observe the following aspects regarding the firmware:

- This drive function is supported as of the firmware version MPx04.
- The CCD master must be operated with the MPC-18VRS firmware.

  In this case, CCD slaves with MPx04 to MPx08 cannot be operated.
- As for integrated safety technology, this firmware function does not require separate enabling of functional packages; the function of drive cross communication is available with the corresponding hardware design.

Pertinent Parameters

The parameters listed below only exist for the CCD master:

- P-0-1640, CCD: MAC address
- P-0-1641, CCD: IP address
- P-0-1642, CCD: Network mask
- P-0-1643, CCD: Gateway address
- P-0-1644, CCD: Status IP communication
- P-0-1800.0.1, CCD: Configuration
- P-0-1800.0.10, CCD: Cycle time
- P-0-1800.0.3, CCD: Control word
- P-0-1800.0.30, CCD: Extrapolated cmd value IDN list signal selection
- P-0-1800.0.31, CCD: Extrapolated cmd value signal selection
- P-0-1800.0.32, CCD: Number of extrapolation steps
- P-0-1800.0.33, CCD: Extrapolated command value
- P-0-1800.0.5, CCD: Allowed telegram failures
- P-0-1801.0.1, CCD: Slave identification
- P-0-1801.0.10, CCD: Addresses of projected drives
- P-0-1801.0.11, CCD: Addresses of projected I/Os

- P-0-1801.0.2, CCD: Command topology addresses
- P-0-1801.0.20, CCD: Command topology
- P-0-1801.0.21, CCD: Actual topology
- P-0-1801.0.22, CCD: Slave addresses at end of line
- P-0-1801.0.23, C7100 CCD: Command Close ring
- P-0-1801.0.3, CCD: Actual topology addresses
- P-0-1801.0.4, CCD: Slave information at topology location
- P-0-1801.0.5, C7000 CCD: Command adjust slave addresses
- P-0-1802.0.1, C7400 CCD: Switching to phase 2
- P-0-1802.0.2, C7500 CCD: Switching to phase 4
- P-0-1802.0.3, CCD: Command communication phase
- P-0-1802.0.4, CCD: Actual communication phase
- P-0-1803.2.1 - P-0-1803.8.1,
  CCD: Slave address in high level network
- P-0-1803.2.11 - P-0-1803.10.11,
  CCD: Configuration list master communication cmd values
- P-0-1803.2.12 - P-0-1803.10.12,
  CCD: Configuration list master communication actual values
- P-0-1803.2.20 - P-0-1803.10.20,
  CCD: Master comm. C0100 Comm. phase 3 transition check
- P-0-1803.2.21 - P-0-1803.10.21,
  CCD: Master comm. C5200 Comm. phase 4 transition check
- P-0-1803.2.22 - P-0-1803.10.22,
  C5300 CCD: sercos SYNC delay measuring procedure command
- P-0-1803.2.24 - P-0-1803.10.24,
  CCD: Master communication gateway parameter pool 1
- P-0-1803.2.25 - P-0-1803.10.25,
  CCD: Master communication gateway parameter pool 2
- P-0-1804.1.1 - P-0-1804.10.1,
  CCD: Configuration list signal status word
- P-0-1804.1.2 - P-0-1804.10.2,
  CCD: Configuration list signal control word
- P-0-1804.1.3 - P-0-1804.10.3,
  CCD: Assignment list signal status word
- P-0-1804.1.4 - P-0-1804.10.4,
  CCD: Assignment list signal control word
- P-0-1805.1.1 - P-0-1805.10.1,
  CCD: Configuration list master cmd values
- P-0-1805.1.2 - P-0-1805.10.2,
  CCD: Configuration list actual master values
- P-0-1805.1.3 - P-0-1805.10.3,
  CCD: Configuration list slave cmd values

- P-0-1805.1.4 - P-0-1805.10.4,
  CCD: Configuration list actual slave values
- P-0-1806.1.1 - P-0-1806.14.1,
  CCD: Slave IP address
- P-0-1806.1.10 - P-0-1806.14.10,
  CCD: Resource-Status (S-Res)
- P-0-1806.1.11 - P-0-1806.14.11,
  CDD: Resource-Control (C-Res)
- P-0-1806.1.2 - P-0-1806.14.2,
  CCD: Device Status (S-Dev)
- P-0-1806.1.3 - P-0-1806.14.3,
  CCD: Device Control (C-Res)
- P-0-1806.1.4 - P-0-1806.14.4,
  CCD: Connection-Control #0 (C-Con)
- P-0-1806.1.5 - P-0-1806.14.5,
  CCD: Connection-Control #1 (C-Con)
- P-0-1807.x.1, CCD connection: Configuration
- P-0-1807.x.10, CCD connection: Producer cycle time
- P-0-1807.x.11, CCD connection: Allowed losses of producer data
- P-0-1807.x.12, CCD connection: Error counter data losses
- P-0-1807.x.2, CCD connection: Connection number
- P-0-1807.x.20, CCD connection: IDN allocation of real-time bits
- P-0-1807.x.21, CCD connection: Bit number allocation of real-time bits
- P-0-1807.x.3, CCD connection: Telegram assignment
- P-0-1807.x.4, CCD connection: Max. length of connection
- P-0-1807.x.5, CCD connection: Current connection length
- P-0-1807.x.6, CCD connection: Configuration list
- P-0-1807.x.7, CCD connection: Assigned connection capability
- P-0-1807.x.8, CCD connection: Connection control (C-Con)
- P-0-1807.x.9, CCD connection: State
- P-0-1808.1.1 - P-0-1808.10.1,
  CCD: Diagnostic message number, slave
- P-0-1808.1.10 - P-0-1808.10.10,
  CCD: Active actual position value
- P-0-1808.1.11 - P-0-1808.10.11,
  CCD: Actual velocity value
- P-0-1808.1.12 - P-0-1808.10.12,
  CCD: Actual torque/force value
- P-0-1808.1.13 - P-0-1808.10.13,
  CCD: Status word synchronous operation modes
- P-0-1808.1.2 - P-0-1808.10.2,
  CCD: Signal status word

- P-0-1808.1.20 - P-0-1808.10.20,
  CCD: Command value data container 1 4Byte
- P-0-1808.1.21 - P-0-1808.10.21,
  CCD: Command value data container 2, 4Byte
- P-0-1808.1.22 - P-0-1808.10.22,
  CCD: Command value data container 3, 4Byte
- P-0-1808.1.23 - P-0-1808.10.23,
  CCD: Command value data container 4, 4Byte
- P-0-1808.1.3 - P-0-1808.10.3,
  CCD: Signal control word
- P-0-1808.1.30 - P-0-1808.10.30,
  CCD: Command value data container 1, 2Byte
- P-0-1808.1.31 - P-0-1808.10.31,
  CCD: Command value data container 2, 2Byte
- P-0-1808.1.32 - P-0-1808.10.32,
  CCD: Command value data container 3, 2Byte
- P-0-1808.1.33 - P-0-1808.10.33,
  CCD: Command value data container 4, 2Byte
- P-0-1808.1.40 - P-0-1808.10.40,
  CCD: Actual value data container 1, 4Byte
- P-0-1808.1.41 - P-0-1808.10.41,
  CCD: Actual value data container 2, 4Byte
- P-0-1808.1.42 - P-0-1808.10.42,
  CCD: Actual value data container 3, 4Byte
- P-0-1808.1.43 - P-0-1808.10.43,
  CCD: Actual value data container 4, 4Byte
- P-0-1808.1.50 - P-0-1808.10.50,
  CCD: Actual value data container 1, 2Byte
- P-0-1808.1.51 - P-0-1808.10.51,
  CCD: Actual value data container 2, 2Byte
- P-0-1808.1.52 - P-0-1808.10.52,
  CCD: Actual value data container 3, 2Byte
- P-0-1808.1.53 - P-0-1808.10.53,
  CCD: Actual value data container 4, 2Byte
- P-0-1810.0.10, CCD: Diagnostic message text
- P-0-1810.0.11, CCD: Diagnosis code
- P-0-1810.0.12, CCD: Error counter Port-1
- P-0-1810.0.13, CCD: Error counter Port-2
- P-0-1810.0.15, CCD: AT error counter
- P-0-1810.0.16, CCD: Axis error
- P-0-1810.0.2, CCD: Status word
- P-0-1810.0.3, CCD: Timing settings

- P-0-1815.0.1, CCD: Master communication, synchronization input value
- P-0-1815.0.2, CCD: Master communication, synchronization output value
- P-0-1816.0.1, CCD: Master communication, synchronization counter
- P-0-1816.0.2, CCD: Master communication, synchronization P-gain
- P-0-1816.0.3, CCD: Master communication, synchronization I-gain
- P-0-1816.0.4, CCD: Master communication, synchronization error window
- P-0-1816.0.5, CCD: Master communication, synchronization delay
- P-0-1820.0.1, CCD: Master axes configuration list
- P-0-1820.0.2, CCD: Source of measuring encoder position feedback value
- P-0-1820.0.3, CCD: Actual position value of measuring encoder
- P-0-1820.0.4, CCD: Axis position selection
- P-0-1821.1.1 - P-0-1821.3.1,
  CCD: Position command value for master axis n
- P-0-1821.1.2 - P-0-1821.3.2,
  CCD: Master axis n, filter type
- P-0-1821.1.3 - P-0-1821.3.3,
  CCD: Master axis n, filter corner frequency
- P-0-1821.1.4 - P-0-1821.3.4,
  CCD: Master axis n, number of extrapolation steps
- P-0-1821.1.5 - P-0-1821.3.5,
  CCD: Master axis n, master axis position
- P-0-1822.0.1,
  CCD: Default master axis selection for the IndraDrive axes
- P-0-1822.0.2,
  CCD: Master axis selection for the IndraDrive axes
- P-0-1823.1.1 - P-0-1823.10.1,
  CCD: Default synchronization mode for axis n
- P-0-1823.1.2 - P-0-1823.10.2,
  CCD: Master axis position for axis n

☞ For configuring the sercos communication in the slaves, the standard sercos parameters are used (e.g. "S-0-1002, sercos: Communication Cycle time (tScyc)" etc.).

Pertinent Diagnostic Messages

- C0265 Incorrect CCD address configuration
- C0266 Incorrect CCD phase switch
- C0267 CCD timeout phase switch
- C0403 Switching to CCD phase 2 impossible
- C7000 CCD: Command Close ring
- C7001 CCD: Impossible to close ring
- C7100 CCD: Command Close ring
- C7101 CCD: Impossible to close ring

- C7400 CCD: Switching to phase 2
- C7401 CCD: Impossible to switch to phase 2
- C7500 CCD: Switching to phase 4
- C7501 CCD: Impossible to switch to phase 4
- E4012 Maximum number of CCD slaves exceeded
- E4013 Incorrect CCD addressing
- E4014 Incorrect phase switch of CCD slaves
- E4016 CCD: Topology error
- E4017 CCD: Unknown I/O configuration
- F2140 CCD slave error
- F4012 Incorrect I/O length
- F4140 CCD communication error
- F6140 CCD slave error (emergency halt)
- F8140 Fatal CCD error

9.3.2 Functional Description of the CCD Modes

Comparison of the CCD Modes

For IndraDrive, cross communication is available in different variants (CCD modes) which are distinguished by the performance features contained in the following table:

Feature	CCD system mode	CCD basic mode	MLD-M system mode
Acyclic communication between CCD-master-side field bus interface and CCD slaves1)	Yes	No	No
Process data gateway and profile interpreter from the external master (e.g. field bus interfaced PLC) to the CCD slaves4)	Yes	No	No
Synchronization of CCD slaves to CCD master	Yes	Yes	Yes
Cross communication for command value linking in CCD group	Yes	Yes	Yes
Command triggering via external control unit, i.e. the slaves receive elementary information on device control (e.g. drive enable, operation mode input) for slaves from the external master (e.g. field bus interfaced PLC)	Yes	With restrictions 2)	With restrictions 3)
Command triggering by MLD-M in the CCD master, i.e. the slaves receive elementary information on device control (e.g. drive enable, operation mode input) from MLD in the CCD master	No	With restrictions 2)	Yes
Use of up to four I/O extensions as CCD slaves	Yes	Yes	Yes

1) Acyclic communication not available with CANopen interface
2) Command triggering is possible if the control words are configured and used correspondingly (e.g. P-0-1806.1.11)
3) Command triggering is possible, if MLD registers (e.g. P-0-1370 et seq.) are configured and used correspondingly and interpreted in the MLD-M of the CCD master
4) Process data gateway not available with CANopen interface

Tab. 9-2: Comparison of the CCD Modes

Optional Device Functions

Performance Features

The table below contains the main features and important data of the CCD modes:

	Command triggering (Motion Control)		Possible master communications					Max. number Axes
	CCD Master	CCD Slave	PROFIBUS® PROFINET® EtherNet/IP™	CANopen	Parallel, Analog, et al.	EtherCAT®	sercos	
CCD System mode	Remote	Remote	Profiles 0xFFFE, 0xFFFD for all CCD nodes	-	-	Yes	Yes	9+1 (7+1)*
CCD Basic mode	Local	Local	All profiles (only for CCD master)		Yes		Yes	9+1
MLD-M System mode	Local	Remote MLD-M	All profiles (only for CCD master)		Yes		Yes, without profile	9+1

* EtherCAT® and sercos only 7+1, otherwise 9+1
Remote Control by external master
Remote MLD-M Control by MLD-M in CCD master
Local Control by local MLD-S of the respective axis

Tab. 9-3: Performance Features of the CCD Modes

Maximum Number of Axes and CCD Cycle Time

The maximum number of possible drives in the group (CCD slaves) depends on:

- Selected CCD mode
- CCD cycle time which was set
- Quantity of cyclic data (MDT, AT) per CCD slave

CCD cycle time	CCD system mode	MLD-M system mode[1)]	CCD basic mode
250 µs [2)] / 500 µs	1 slave + 1 master (2 slaves + +1 master)	--	1 slave + 1 master (2 slaves + +1 master)
1000 µs[5)]	6 slaves + 1 master	6 slaves[4)] + 1 master	6 slaves + 1 master
2000 µs / 4000 µs	9 slaves + 1 master 7 slaves + 1 master[3)]	9 slaves + 1 master	9 slaves + 1 master

(...) The values in brackets are only valid for 24 bytes or less of MDT/AT data per slave.
1) MLD-M system mode can only be chosen in Basic performance of the CCD master.
2) 250 µs cycle time is only possible if all drives in the CCD group are operated in Advanced control (CSH01.x control sections required).
3) A maximum of 7 CCD slaves are possible for sercos and EtherCAT®; independent of the MDT/AT data
4) Economy performance is not possible for CSB01.1 control sections in the CCD slaves
5) Not possible, if a slave has been equipped with HCS01.1 Economy

Tab. 9-4: Maximum Number of Drives Depending on CCD Cycle Time sercos I/O slaves are not included in the above overview and must be added to the maximum possible number of axes specified. Therefore, 4 sercos I/O slaves are always possible in addition to the above specifications.

Cyclic Data

It is possible to transmit up to 16 IDNs, with a total data volume of 48 bytes, in each direction (command values and actual values).

In the **CCD system mode** (does not apply to sercos and EtherCAT®), only the freely configurable profile (0xFFFE and 0xFFFD) is supported in the CCD master (only applies to PROFIBUS®, PROFINET®, EtherNet/IP™)!

The resulting connection length between the CCD master and CCD slaves in the **CCD system mode** results from the cyclic command values and actual values exchanged between the master communication master (control) and the CCD slaves (P-0-1803.x.11, P-0-1803.x.12) and the data from the parameters (P-0-1805.x.1, P-0-1805.x.2, P-0-1805.x.3, P-0-1805.x.4) which are additionally needed for cyclic communication between CCD master and CCD slaves.

In the CCD system mode, for example, a max. of 48 bytes of AT data and 48 bytes of MDT data are allowed with 9 CCD slaves; i.e. the sum from P-0-1803.x.11 and P-0-1805.x.3 must not be more than a max. of 48 bytes per slave (sum from P-0-1803.x.12 and P-0-1805.x.4 max. 48 bytes per slave).

The maximum data volume that can be transmitted in the CCD system mode from the master communication master (external control) to the CCD master depends on the master communication of the CCD master and consists of the data from parameters P-0-1803.x.11, P-0-1803.x.12, P-0-4080 and P-0-4081:

- PROFIBUS®: 208 bytes (of both command values and actual values)
- PROFINET®/EtherNet/IP™: 480 bytes (of both command values and actual values)

The functionality of the CCD cross communication is based on sercos communication between CCD master and connected slaves. This sercos communication is connection-oriented, see chapter "Master Communication, sercos".

In all CCD modes, the CCD master uses the first two connections of a CCD slave. The connection instance "0" (S-0-1050.0.x) is used in the CCD slave as a synchronous producer connection (actual values from CCD slaves to CCD master; AT data) and is automatically parameterized. The connection instance "1" (S-0-1050.1.x) is parameterized in the CCD slave as a synchronous consumer connection (command values from CCD master to CCD slaves; MDT data).

All data channels (master communication data, motion channel data, user process data etc.) of the CCD modes are included in these two connections and automatically parameterized by the master. As a maximum of 4 connections is possible per device or drive, the user can freely use and parameterize the remaining two connections, which the master does not need for the CCD functionality, for so-called CC connections.

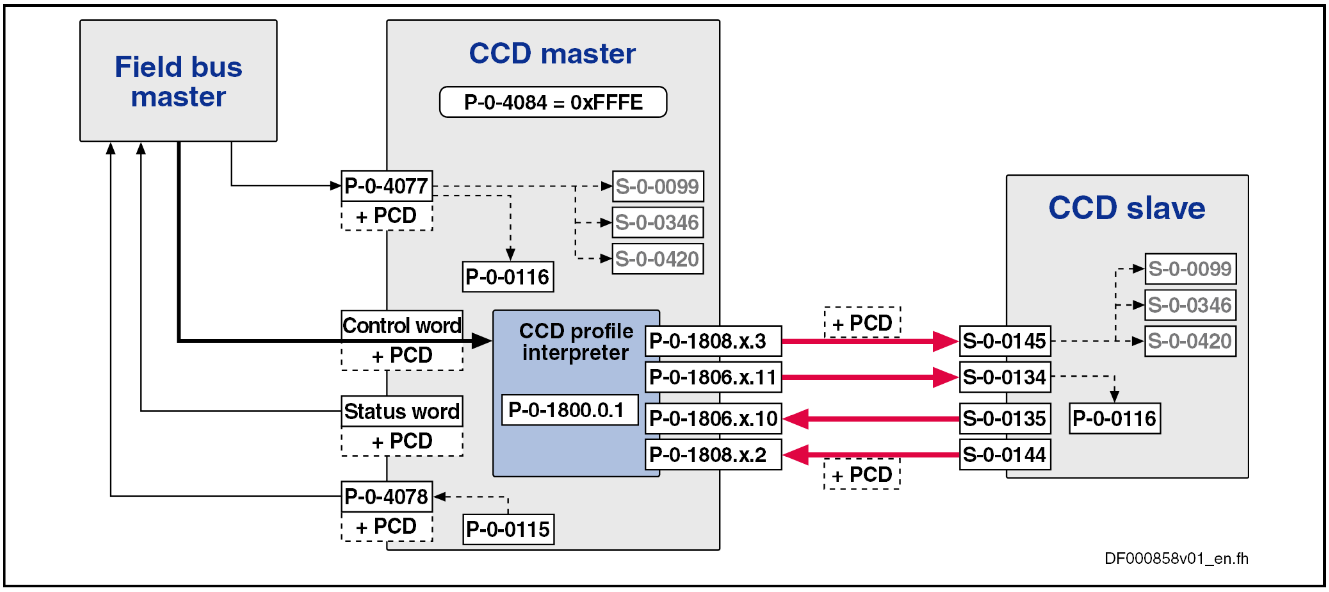
CCD system mode

In the CCD system mode, the higher-level (external) master has control over the CCD slaves. Command triggering and input of process data take place via the external master (e.g. field bus interfaced PLC).

Optional Device Functions

System Structure (not with sercos, EtherCAT®)

The figure below illustrates the system structure of the CCD system mode with field bus master communication (as regards command triggering and process data communication for collective bus connection). The figure only contains the command triggering and the process data of the external control unit. It does not show the data between CCD master and CCD slaves.



PCD Process data (cyclic command values and actual values)

Fig. 9-2: Overview of CCD System Mode with Field Bus Interface

S-0-0099	C0500 Reset class 1 diagnostics
S-0-0144	Signal status word
S-0-0145	Signal control word
S-0-0346	Positioning control word
S-0-0420	C0400 Activate parameterization level procedure command
S-0-0134	Master control word
S-0-0135	Drive status word
P-0-0115	Device control: Status word
P-0-0116	Device control: Control word
P-0-1800.0.1	CCD: Configuration
P-0-1806.1.11 - P-0-1806.14.11	CDD: Resource-Control (C-Res)
P-0-1806.1.10 - P-0-1806.14.10	CCD: Resource-Status (S-Res)
P-0-1808.x.2	CCD: Signal status word, slave x
P-0-1808.x.3	CCD: Signal control word, slave x
P-0-4077	Field bus: Control word
P-0-4078	Field bus: Status word
P-0-4084	Field bus: Profile type

Tab. 9-5:

Configuration with sercos

As a standard, the sercos slaves are parameterized in the higher-level control unit with reference to the master-side master communication. The cyclic data are configured via the parameters "S-0-1050.x.1 sercos Connection: Connection setup" and "S-0-1050.x.6 sercos Connection: Configuration list" for the CCD master and also for the CCD slaves in the control unit configuration.

Configuration with EtherCAT®

As a standard, the EtherCAT® subcarrier slaves are parameterized in the higher-level control unit with reference to the master-side master communication. The cyclic data are configured via the parameters "S-0-0016, Configuration list of AT" and "S-0-0024, Configuration list of MDT" for the CCD master and also for the CCD slaves in the control unit configuration.

Features

The following applies to the CCD system mode (not with sercos and EtherCAT®):

- For each logic field bus slave (CCD slave), the field bus/drive control word for the respective CCD slave is segmented and converted by the CCD master to a master control word (S-0-0134) and a signal control word (S-0-0145). The higher-level master thereby has full control over the slaves (e.g. enable signal, operation mode selection).
- For each logic field bus slave (CCD slave), the field bus/drive status word is generated by means of the drive status word (S-0-0135) and the signal status word (S-0-0144) of the respective CCD slave in the CCD master. The higher-level master thereby has the status of each slave (e.g. error).
- In addition, free process data can be used for master/slave cross communication. The parameters "P-0-1805.x.1, CCD: Configuration list master cmd values" up to "P-0-1805.x.4, CCD: Configuration list actual slave values" are to be configured as appropriate.
- Bits 12 to 15 of the signal status word (S-0-0144) and of the signal control word (S-0-0145) of the CCD slaves can be used by the field bus master. For this purpose, the parameters S-0-0144 and S-0-0145 have to be taken into account and written with values in the data exchange between external control unit and CCD master. Parameter setting takes place in the parameters P-0-1803.x.11 and P-0-1803.x.12 in the CCD master. The master then transmits the signals at bits 12 and 15 of the signal status word (S-0-0144) and of the signal control word (S-0-0145) to the corresponding CCD slaves.

☞ Exception: With sercos and EtherCAT®, the bits of the signal control and status words are not required, all 15 bits can be used freely. The signal control word and the signal status word must be taken into account for each slave in the respective MDT (S-0-1050.1.6) and AT (S-0-1050.0.6) data (see following section).

- The cyclic process data (command values and actual values) of master communication (P-0-1803.x.11 and P-0-1803.x.12 in the CCD master) are directly mapped to the CCD bus in the AT and MDT (and vice versa). Via these parameters, the external field bus master can access the parameters of the CCD slaves.

☞ Exception: With EtherCAT®, the parameters P-0-1803.x.11 and P-0-1803.x.12 are not taken into account. The configuration of the cyclic data from the control to the CCD slaves is made individually for each axis (CCD master and slave) via the configuration lists for drive (S-0-0016) and master data (S-0-0024) telegram.

Notes on utilization

When using the CCD system mode, observe the following aspects:

- In addition to the process data of master communication, free process data can be used in the CCD system mode for mere master/slave cross communication. For this purpose, the contents of the configuration lists in the parameters P-0-1805.x.1 to P-0-1805.x.4 have to be manually extended!

- In the case of field bus master communication, the freely configurable profile type (P-0-4084 = 0xFFFE and 0xFFFD) is supported.
- When using EtherNet/IP™ with CCD system mode, data consistency between a CCD master and CCD slaves (container consistency) (synchronization between external control unit to drives) can only be ensured, if the "virtual slave" function (see "Dead Time Compensation") is used for the CCD master data.
- In sercos CCD system mode, the timing in the CCD group is set in such a way that the cyclic data from the higher-level control unit (-->sercos master) take effect simultaneously in the CCD master (-->sercos slave) and CCD slave. This does not cause any delay in the processing of cyclic data in the drives. Dead time compensation, such as extrapolation, is therefore not necessary.
- When using the (unassigned) bits of the signal control word and the signal status word (S-0-0145, S-0-0144), take the following aspects into account:
  - The MDT for the slaves must at least contain the signal control word and the AT must at least contain the signal status word (to be configured in P-0-1803.x.11 and P-0-1803.x.12, with sercos in S-0-1050.0.6 and S-0-1050.1.6 see also above).
  - Only the bits 12 to 15 of the signal status word (S-0-0144) and of the signal control word (S-0-0145) can be used.

☞ Exception: All bits can be used with sercos and EtherCAT®.

  - Bits 0 to 11 in the signal status word of the CCD slaves are always zero for the control unit (this does not apply to sercos and EtherCAT® master communication).
  - The signal control word of the slaves is parameterized by the master using parameters P-0-1804.x.2 and P-0-1804.x.4, with sercos and EtherCAT®, as usual, in each axis via the usual standard parameters (S-0-0027 and S-0-0329).
  - The signal control word of the slaves is parameterized by the master using parameters P-0-1804.x.1 and P-0-1804.x.3, with sercos and EtherCAT®, as usual, in each axis via the usual standard parameters (S-0-0026 and S-0-0328).

Control Word in CCD System Mode

The table below shows the conversion of the bits in the control word of the "emulated field bus slave" of the CCD master to the actual parameters of the CCD slave. The external master thereby has control over the CCD slaves. This control word for the slave emulated in the CCD master corresponds to the structure of the field bus control word (P-0-4077) and has to be taken into account accordingly in the cyclic output data of the external control unit.

☞ This does not apply to sercos and EtherCAT®. In this case, the master control word (S-0-0134) has to be used. This data is copied to the corresponding bits of the sercos and EtherCAT® parameter (S-0-0134) of the respective CCD slaves in the CCD master.

Bit in P-0-4077	Significance in field bus profile	Target parameter in slave	Access to slave via ...
0	Command value acceptance	S-0-0346, Positioning control word; bit 0	S-0-0145: Bit 0
1	Operating mode setting	S-0-0420, C0400 Activate parameterization level procedure command; S-0-0422, C0200 Exit parameterization level procedure command	S-0-0145: Bit 7 S-0-0145: Bit 8
2	Going to zero	S-0-0148, C0600 Drive-controlled homing procedure command	S-0-0145: Bit 1
3	Absolute / relative	S-0-0346: Bit 3	S-0-0145: Bit 2
4	Immediate block change	S-0-0346: Bit 5	S-0-0145: Bit 3
5	Clear error	S-0-0099: Command clear error (S-0-0099, C0500 Reset class 1 diagnostics)	S-0-0145: Bit 4
6.7	Positioning / jogging	S-0-0346: Bit 1, 2	S-0-0145: Bit 5, 6
8.9	Command operation mode	S-0-0134, Master control word; bit 8, 9	Direct access to S-0-0134
10.11	--	--	--
12	IPOSYNC	S-0-0134, Master control word; bit 10	Direct access to S-0-0134
13	Drive Halt	S-0-0134, Master control word; bit 13	Direct access to S-0-0134
14	Drive enable	S-0-0134, Master control word; bit 14 (is only automatically set with active field bus communication)	Direct access to S-0-0134
15	Drive ON	S-0-0134, Master control word; bit 15	Direct access to S-0-0134

Tab. 9-6: Conversion of Field Bus Control Word (P-0-4077) to CCD Slave Parameters with Field Bus Profile Type 0xFFFE

☞ (Does not apply to sercos and EtherCAT® master communication)

As "S-0-0145, Signal control word" is used for mapping the control bits not contained in "S-0-1134, Master control word", it has been, in the CCD system mode, by default configured in the cyclic master data telegram (MDT → S-0-1050.1.6) of the corresponding CCD slave! In addition, other bits have been permanently configured so that the user can only define the bits 12 to 15! To transmit these unassigned bits to the slaves, the signal control word (S-0-0145) has to be additionally configured in the cyclic command values of the control unit to the slaves (in parameter P-0-1803.x.11).

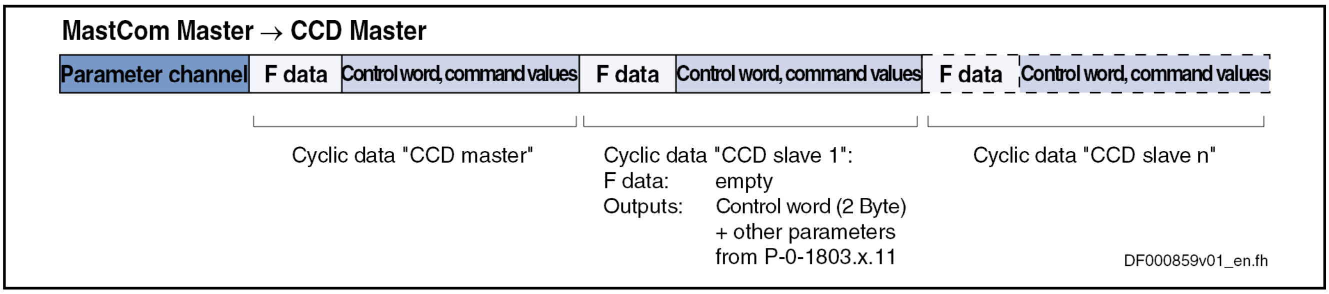
Cyclic Command Values of the Master Communication (does not apply to sercos and EtherCAT® master communication)

The cyclic command values for a CCD slave consist of at least 2 bytes control word (same structure as field bus control word; see P-0-4077) and the data from parameter "P-0-1803.x.11, CCD: Configuration list master communication cmd values". The control word is always transmitted at the beginning of the cyclic data for a slave (not contained in P-0-1803.x.11, but has to be taken into account accordingly in the cyclic output data of the control unit!), followed by the data from P-0-1803.x.11.

☞ The 2-byte status word P-0-4077 is converted to 4 bytes master status word + 2 bytes signal status word!

☞ For profile type P-0-4084 = 0xFFFD, the bits 0, 2, 3, 4, 6 and 7 are not evaluated in the control word!

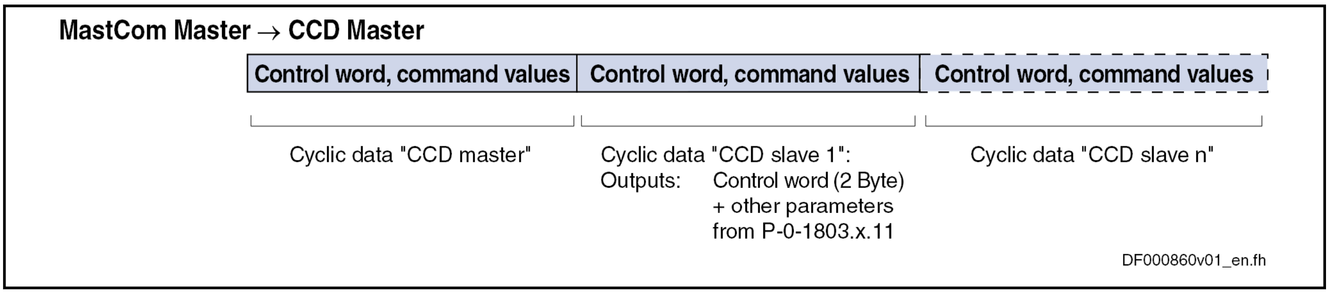
PROFIBUS® and PROFINET



P-0-1803.x.11 Configuration list of master communication command values for CCD

Fig. 9-3: Command Value Channel from Master Communication Master to CCD Group with PROFIBUS® and PROFINET

EtherNet/IP(TM):



P-0-1803.x.11 Configuration list of master communication command values for CCD

Fig. 9-4: Structure of an Assembly/Cyclic Data Container with EtherNet/IP(TM)

Status Word in CCD System Mode

The table below shows the assignment of the bits in the status word of the "emulated field bus slave" of the CCD master to the actual parameters of the CCD slave. The external master thereby gets the information on the CCD slaves. This status word for the slave emulated in the CCD master corresponds to the structure of the field bus status word (P-0-4078) and has to be taken into account accordingly in the cyclic input data of the external control unit.

☞ This does not apply to sercos and EtherCAT®. In this case, the bits of the drive status word (S-0-0135 for sercos) of the CCD slaves in the CCD master are copied to the sercos and EtherCAT® status word (S-0-0135) of the respective slaves.

Bit in P-0-4078	Significance in field bus profile	Source parameter in slave	Access to slave via ...
0	--	--	--
1	Operating mode acknowledgment	S-0-0424, Status parameterization level	S-0-0144: Bit 0
2	In_Reference	S-0-0403, Position feedback value status	S-0-0144: Bit 1
3	In_Standstill	S-0-0331, Status "n_feedback = 0"	S-0-0144: Bit 2
4	Command value reached	P-0-0115, Device control: Status word; bit 12	S-0-0144: Bit 3
5	Command change bit	S-0-0135, Drive status word; Bit 5	Direct access to S-0-0135
6	--	--	--
7	Status of command value processing	S-0-0135, Drive status word; Bit 3	Direct access to S-0-0135
8.9	Actual operation mode	S-0-0135, Drive status word; bit 8, 9	Direct access to S-0-0135
10	Command value acknowledgment	S-0-0419: Bit 0	S-0-0144: Bit 4
11	Class 3 diagnostics message	S-0-0135, Drive status word; Bit 11	Direct access to S-0-0135
12	Class 2 diagnostics warning	S-0-0135, Drive status word; Bit 12	Direct access to S-0-0135
13	Class 1 diagnostics drive error	S-0-0135, Drive status word; Bit 13	Direct access to S-0-0135
14/15	Readiness for operation	S-0-0135, Drive status word; bit 14, 15	Direct access to S-0-0135

Tab. 9-7: Conversion of Field Bus Status Word (P-0-4078) to CCD Slave Parameters with Profile 0xFFFE

☞ (Does not apply to sercos or EtherCAT® master communication)

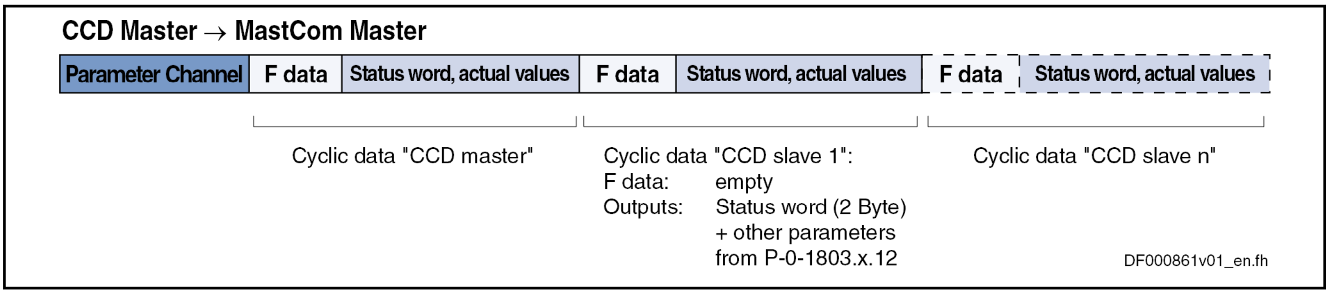
As "S-0-0144, Signal status word" is used for mapping the status bits not contained in "S-0-0135, Drive status word", it has by default been configured in the cyclic drive telegram (AT → S-0-1050.0.6)! In addition, other bits have been permanently configured so that the user can only define the bits 12 to 15! To be able to read these unassigned bits of the slaves, the signal status word (S-0-0144) has to be additionally configured in the cyclic actual values of the CCD slaves to the control unit (in parameter P-0-1803.x.12).

Cyclic Actual Values of the Master Communication (Does not Apply to sercos and EtherCAT® Master Communication)

The cyclic actual values for a CCD slave consist of at least 2 bytes status word (same structure as field bus control word; see P-0-4078) and the data from "P-0-1803.x.11, CCD: Configuration list master communication actual values". The status word is always transmitted at the beginning of the cyclic data for a slave (is not contained in parameter P-0-1803.x.12, but has to be taken into account accordingly in the cyclic input data of the control unit!), followed by the data from P-0-1803.x.12.

☞ The 2-byte status word P-0-4078 is composed of 4 bytes drive status word + 2 bytes signal status word!

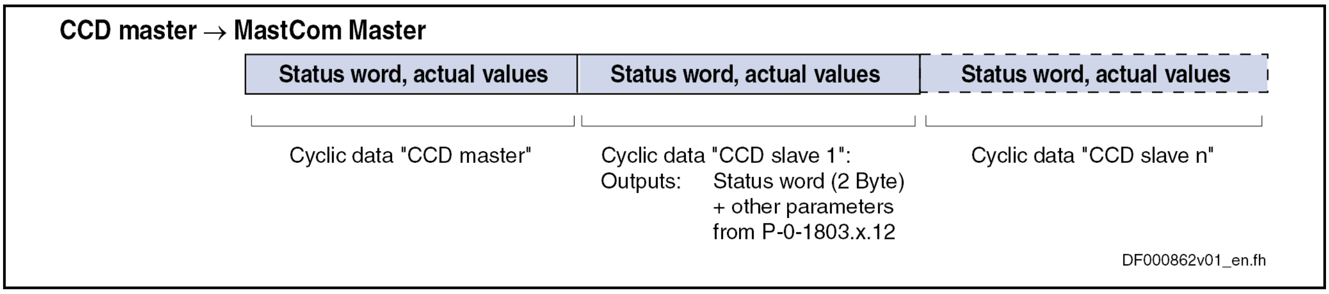
PROFIBUS® and PROFINET



P-0-1803.x.12 Configuration list of master communication actual values for CCD

Fig. 9-5: Actual Value Channel from CCD Group to Master Communication Master with PROFIBUS® and PROFINET

EtherNet/IP(TM):



P-0-1803.x.12 Configuration list of master communication actual values for CCD

Fig. 9-6: Structure of an Assembly/Cyclic Data Container with EtherNet/IP(TM)

Cyclic Command Values with sercos and EtherCAT®

The master data telegram is configured on the control side, as usual, using the standard parameters

- with EtherCAT® "S-0-0024, Configuration list of MDT"
- with sercos with "S-0-1050.x.1 sercos Connection: Connection setup" and "S-0-1050.x.6 sercos Connection: Configuration list"

Cyclical Actual Values with sercos and EtherCAT®

The master data telegram is configured on the control side, as usual, using the standard parameters

- with EtherCAT® "S-0-0016, Configuration list of AT"
- with sercos with "S-0-1050.x.1 sercos Connection: Connection setup" and "S-0-1050.x.6 sercos Connection: Configuration list"

> ☞ Class 3 diagnostics bit (S-0-0135, bit 11) does not exist with sercos CCD slaves. This information is therefore not supplied. The bit is always "0".

Configuring the Cyclic Process Data in the CCD Slave with CCD System Mode

The process data are transmitted between CCD master and CCD slave in connection-oriented form (see "Functional description, sercos"). These connections are configured automatically by the CCD master in accordance with the configuration of the cyclic data:

The process data for field bus master communication in the connections #0 and #1 to the CCD slaves (from the slaves' point of view) consist of:

- Producer connection #0

  S-0-0135 + S-0-0144 + FKM data from P-0-1803.x.12 + free process data from P-0-1805.x.4

- Consumer connection #1

  S-0-0134 + S-0-0145 + FKM data from P-0-1803.x.11 + free process data from P-0-1805.x.3

The process data for EtherCAT master communication in the connections #0 and #1 to the CCD slaves (from the slaves' point of view) consist of:

- Producer connection #0

  S-0-0135 + FKM data from S-0-0016 of the FKM slave + free process data from P-0-1805.x.4

- Consumer connection #1

  S-0-0134 + FKM data from S-0-0024 of the FKM slave + free process data from P-0-1805.x.3

The process data for sercos master communication in the connections #0 and #1 to the CCD slaves (from the slaves' point of view) consist of:

- Producer connection #0

  S-0-0135 + FKM data from S-0-1050.x.6 of the FKM slave + free process data from P-0-1805.x.4

- Consumer connection #1

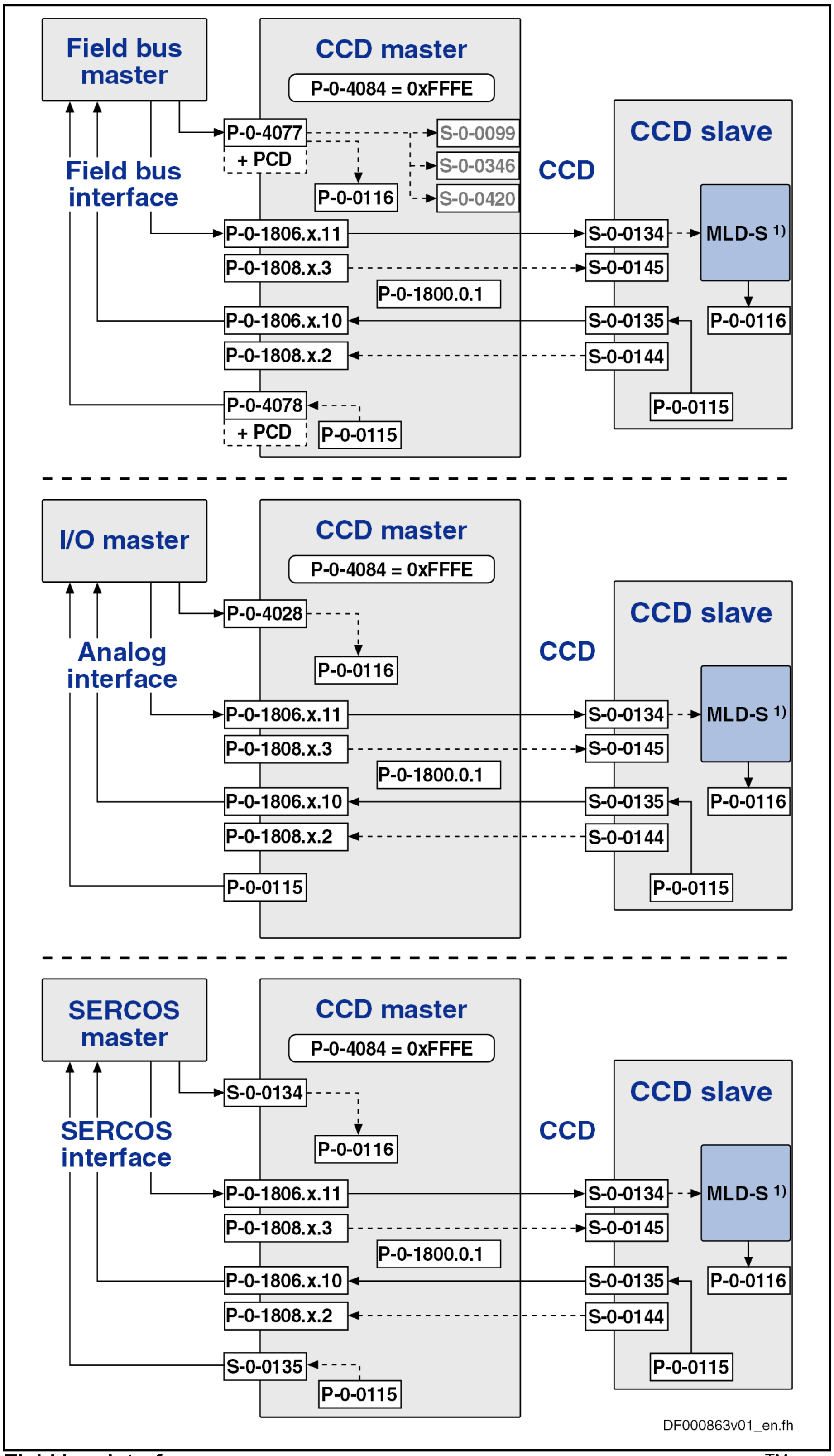
  S-0-0134 + FKM data from S-0-1050.x.6 of the FKM slave + free process data from P-0-1805.x.3

CCD basic mode

In the CCD basic mode, automatic interpretation of control information by the CCD master does not take place. The CCD master cannot automatically route cyclic data of the master communication to the CCD slaves. The master communication "sees" only the CCD master. It is only possible to exchange data via the CCD process data exchange between CCD master and CCD slave.

System Structure The figure below illustrates the system structure for the CCD basic mode with field bus master communication, sercos interface and analog interface:

Optional Device Functions



Field bus interface	PROFIBUS®, PROFINET®, CANopen, EtherNet/IP™
sercos interface	sercos, EtherCAT®
PCD	Process data (cyclic command values and actual values)
PCD	Process data (cyclic command values and actual values)

1) With permanent control

Fig. 9-7: Overview of CCD Basic Mode for Different Master Communication Interfaces

Features

In CCD basic mode, the external master (field bus, sercos interface, analog interface) has **restricted access** to the CCD slaves. The following applies:

- The CCD basic mode is used when only process data are to be exchanged between the CCD master and the CCD slaves. The parameters P-0-1805.x.1 to P-0-1805.x.4 are relevant for parameterizing the data exchange. Only the data listed in these parameters are exchanged between master and slave.
- Even with active field bus card in the CCD master, the profile interpreter is not active. The parameters P-0-1804.x.1 to P-0-1804.x.4 do not take effect. The signal control word/signal status word of the slaves is not configured via the master and not automatically transmitted in the MDT/AT. If the master nevertheless writes data to the signal control words and signal status words of the CCD slaves (S-0-0144, S-0-0145), the free process data between CCD master and CCD slave (P-0-1805.x.1 to P-0-1805.x.4) must be used for this purpose. In the CCD master, the parameters P-0-1808.x.3 and P-0-1808.x.2 have to be written or read for this purpose.
- As the drive status word of the slaves in the AT is always transmitted in the case of sercos, it can be read via the corresponding parameter P-0-1806.x.10 to P-0-1806.x.11 in the master.
- As the master control word of the slaves in the MDT is always transmitted in the case of sercos, it has to be written via the corresponding parameter P-0-1806.x.11. In the CCD basic mode, this allows controlling basic input, such as enable signal, operation mode selection etc., for the slaves via the CCD master.

Configuring the Cyclic Process Data in the CCD Slave with CCD Basic Mode

The process data are transmitted between CCD master and CCD slave in connection-oriented form (see "Functional description, sercos"). These connections are configured automatically by the CCD master in accordance with the configuration of the process data:

The process data in the connections #0 and #1 to the CCD slaves (from the slaves' point of view) consist of:

- Producer connection #0

  S_0_0135 + free process data from P-0-1805.x.4
- Consumer connection #1

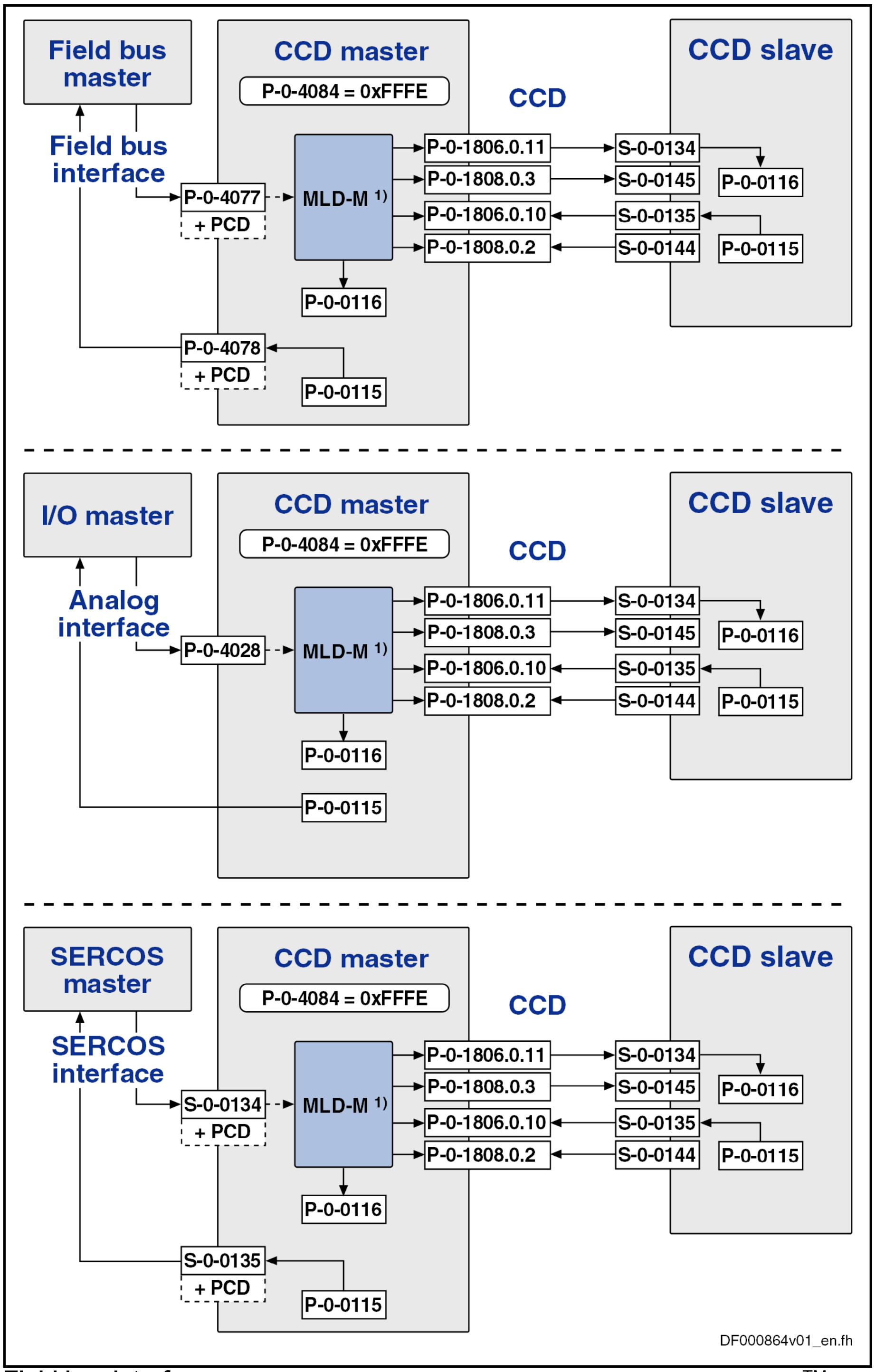
  S-0-0134 + free process data from P-0-1805.x.3

MLD-M system mode

In the MLD-M system mode, the drive-integrated MLD in the master has control over the axes. Additionally, MLD has access to the CCD slaves. The CCD master cannot automatically route cyclic data of the master communication to the CCD slaves. The master communication "sees" only the CCD master. Data from master communication have to be interpreted and, if necessary, transmitted in the MLD-M of the CCD master.

System Structure

The figure below illustrates the system structure of the MLD-M system mode with field bus master communication, sercos interface and analog interface:



Field bus interface	PROFIBUS®, PROFINET®, CANopen, EtherNet/IP™
sercos interface	sercos, EtherCAT®
PCD	Process data (cyclic command values and actual values)
1)	With permanent control

Fig. 9-8: Overview of MLD-M System Mode for Different Master Communication Interfaces

Features

In this mode, the external master only has indirect control over the CCD slaves via the CCD master. The following applies:

- The drive PLC in the master generates the master control word for the CCD slaves. The higher-level control unit therefore does not have any influence on individual slaves. The master control word of a slave can be read via the corresponding parameter P-0-1806.x.11.
- The drive PLC in the master evaluates the status words of the CCD slaves. The higher-level control unit therefore does not have any information on individual CCD slaves. The drive status word of a slave can be read via the corresponding parameter P-0-1806.x.10.
- The cyclic process data for the CCD slaves are generated by the CCD master and vice versa (master/slave cross communication). Part of them has been permanently pre-assigned for motion input from the drive PLC. The rest can be freely configured for other purposes (process controller, access to slave peripherals, etc.).
- Parameters of the CCD slaves can be read and written by the MLD in the CCD master.
- Via the corresponding motion function blocks, the MLD in the master can move the CCD slaves.
- In the MLD-M system mode, the multiplex channel for external control units is not available in the CCD master.

Signal control word/status word (S-0-0144 / S-0-0145) are permanently parameterized by the internal PLC for the motion channel, but only partly used. For the unassigned bits, the PLC makes available a function which allows the user accessing them from the PLC program (so-called "AxisData structure").

The unassigned bits in the signal control word/status word of the CCD slaves are parameterized in the master via the parameters P-0-1804.x.1 to P-0-1804.x.4.

Configuring the Cycl. Process Data in the CCD Salve with MLD-M System Mode

The process data are transmitted between CCD master and CCD slave in connection-oriented form (see "Functional description, sercos"). These connections are configured automatically by the CCD master in accordance with the required motion data of MLD-M and the configured process data:

The process data in the connections #0 and #1 to the CCD slaves (from the slaves' point of view) consist of:

- Producer connection #0 -> motion channel of MLD-M + free process data from P-0-1805.x.4
- Consumer connection #1 -> motion channel of MLD-M + free process data from P-0-1805.x.3

ℹ See also separate documentation "Rexroth IndraMotion MLD".

State Machine and Phase Input

General Information

As of MPC-08VRS and with P-0-1800.0.1, bit 5, the behavior or the coupling of the state machine/phase progression of the CCD slaves can be configured. It is possible, when doing so, to decouple phase input for the CCD slaves from the state machine of the CCD master (as of MPC-08VRS, P-0-1800.0.1, bit 5 = 0 applies for the default setting), see "Decoupled CCD Phase Progression".

The previous behavior of the firmware versions up to MPC-07VRS can be set, i.e. the fixed coupling of state machine of the CCD master and phase input of the CCD slaves: P-0-1800.0.1, bit 5 = 1; see "Coupled CCD Phase Progression".

Diagnostic Options of the State Machine and Phase Input in the CCD Group

The following parameters are involved in the switching of the CCD phase:

- The input value of the state machine is the value of parameter "P-0-1802.0.3, CCD: Command communication phase".
- The present communication phase of the CCD bus is displayed in parameter "P-0-1802.0.4, CCD: Actual communication phase".
- The parameter "P-0-1810.0.2, CCD: Status word" contains information on the phase state machine, such as "target phase", "actual phase", "phase switch active", "phase switch aborted with error" etc.

Decoupled CCD Phase Progression

sercos Phase Input for CCD Slaves

The separation of the parameter mode (PM) <--> operating mode (OM) switching (sub-device state machine) of the CCD master and the sercos phase switch of the CCD slaves results in the following behavior: After the devices have been switched on, the sercos communication of the CCD group in most cases is in phase 4 or, as far as possible, remains in phase 4, independent of the PM/OM state of the CCD master. Accessing sercos I/Os, for example, is thereby possible independently of the CCD master's sub-device state machine (PM/OM).

The time at which the CCD master sets the target phase for the CCD group to phase 4 after switching on depends on the master communication of the CCD master:

- With sercos, EtherCAT® in transition command "C5200 Communication phase 4 transition check" (S-0-0128, C5200 Communication phase 4 transition check)
- With other master communication in the transition command "C0200 Exit parameterization level procedure command" (S-0-0422, C0200 Exit parameterization level procedure command)

☞ The sercos-CCD system mode is an exception: In this case, the sercos phase input for the CCD group is coupled directly to the sercos phase switch of the CCD master (PM<-->OM switching is unaffected by this). When the control unit switches the CCD master to phase 2/4, then (in the CCD system mode) the CCD slaves are also automatically switched to phase 2/4 (see also: "Communication State Machine with sercos CCD System Mode").

To avoid an error in the PM->OM switching of a CCD slave (drive only) preventing phase progression to phase 4, the sub-device state machine is decoupled from the phase progression in the CCD slaves. This is done for the projected drives and is set by the CCD master once phase 2 has been reached by setting bit 0 = "1" in parameter "P-0-4088, Master communication: Drive configuration" of the CCD slaves.

Automatic PM/OM Switching of the CCD Slaves

In the CCD group, the sub-device state machine of the CCD master is coupled to the sub-device state machines of the CCD slaves. That way not every CCD slave in the CCD group has to be individually switched to OM or PM. If PM is switched to OM in the CCD master (automatically during run-up or later, depending on P-0-4088, bit 0, in the CCD master), the CCD master also performs the PM->OM switching for the CCD slaves (drives only), as soon as the CCD group is in phase 4. The OM->PM switching in the CCD master does not influence the sercos phase, but also switches the CCD slaves (drives only) to PM.

Properties:

- The OM-->PM switching in the CCD master does not lead to the CCD slaves leaving sercos phase 4. (Up to now this has caused the target phase of the CCD group (P-0-1802.0.3, CCD: Command communication phase) and thus the CCD slaves to be set to phase 2)
- The CCD slaves are switched to PM/OM in the same way as the CCD master
- An error in the transition command of a CCD slave does not lead to the termination of phase progression to phase 4
- If CCD communication is not in phase 4, the cyclic data are exchanged (as it has been to date) via the service channel

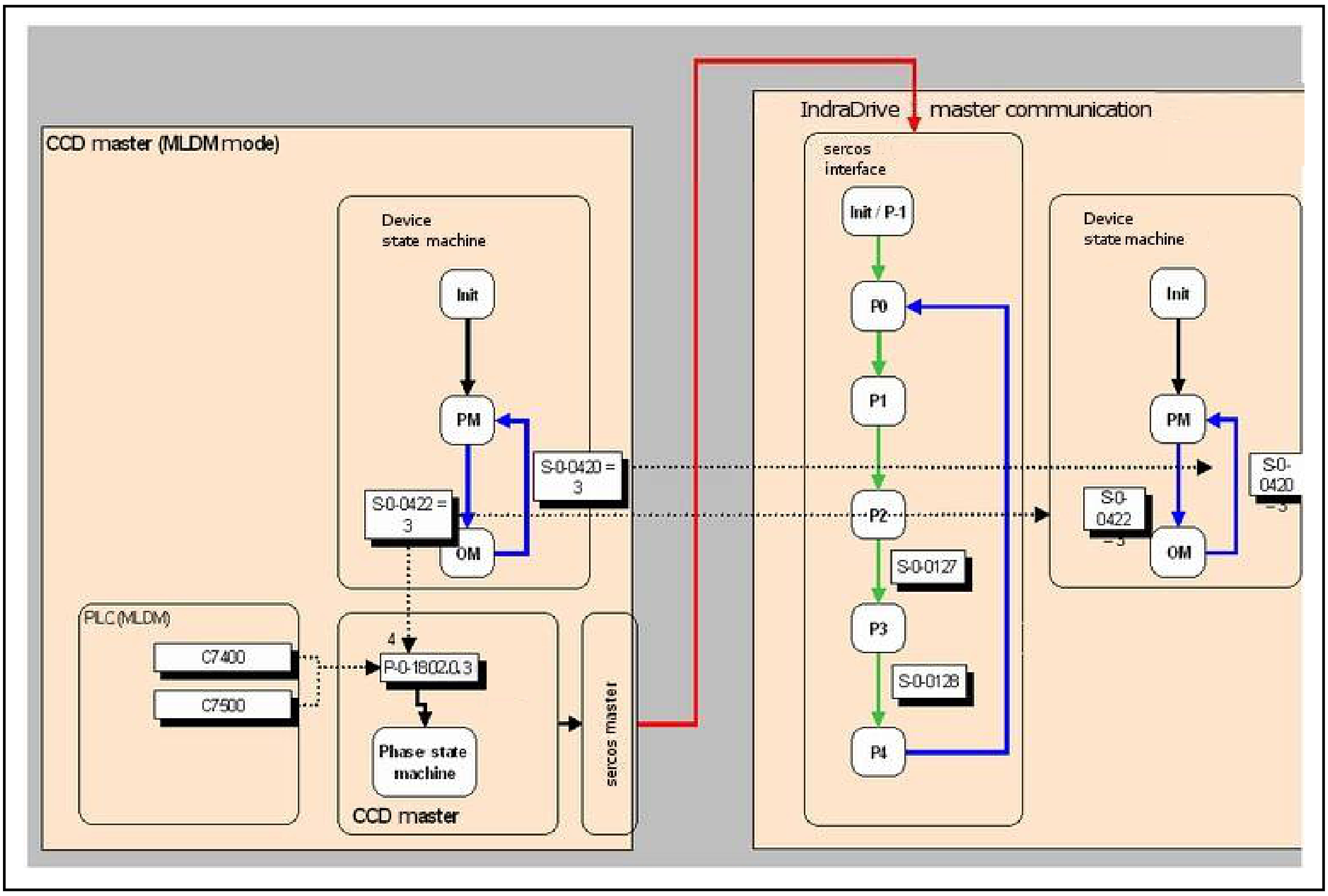


Fig. 9-9: CCD Master Sub-Device State Machine Decoupled from sercos Phase Input of the CCD Slaves

The CCD slaves do not reach sercos phase 4 or leave it in the following exceptional cases:

1. Error during communication:
   - Actual topology and command topology are different
   - Telegram failures > than parameterized in "P-0-1800.0.5, CCD: Actual value data container 4, Master 4Byte"
2. Changed configuration of CCD communication:
   - Changes in telegram times
   - Changes in telegram contents

3. During phase progression, an error occurs in the commands S-0-0127 (C0100) or S-0-0128 (C5200) due to incorrect parameterization of the telegram timing or telegram contents.

(Manual) Input of the CCD Communication Phase

The sercos phases of the CCD group can also be manually input. This is necessary, for example, for changes of the telegram contents or of the timing. For this purpose, the CCD master provides two new commands:

- P-0-1802.0.1, C7400 CCD: Switching to phase 2
- P-0-1802.0.2, C7500 CCD: Switching to phase 4

☞ The command "P-0-1802.0.1, C7400 CCD: Switching to phase 2" can only be executed when the CCD master is in the parameter mode (PM)

Coupled CCD Phase Progression

For reasons of compatibility, the previous behavior can be set (as in firmware versions up to and including MPC07VRS), that is a fixed coupling of the state machine in the CCD master and phase input for the CCD slaves: P-0-1800.0.1, bit 5 = "1". To generate unequivocal phase input (communication phase) for the CCD slaves in the case of multi-axis field bus connection (in the system mode), this input is realized in the CCD master by a CCD phase state machine.

Data are primarily provided to the phase state machine of the CCD bus, and thus the CCD slaves, from the device state machine of the CCD master. If the CCD master is switched to the operating mode (OM), the command communication phase of the CCD group is phase 4 (P-0-1802.0.3 = 4). If, in contrast, the CCD master is in the parameter mode (PM), the command communication phase of the CCD group is phase 2 (P-0-1802.0.3 = 2).

☞ The sercos EtherCAT®-CCD system mode is an exception: In this case, the sercos phase input for the CCD group is coupled directly to the sercos phase switch or EtherCAT® state machine switching of the CCD master. When the control unit switches the CCD master to phase 2/4, then (in the CCD system mode) the CCD slaves are also automatically switched to phase 2/4. The CCD slaves are switched to phase 2/4 by PM/OM switching in the CCD master. (See also: "Communication state machine in sercos CCD system mode")

Switching from parameter mode to operating mode (and vice versa) of the device takes place in the CCD master by the following commands:

- S-0-0422, C0200 Exit parameterization level procedure command

  → By activating the command C0200, all functions are switched to the status"active" again (operating mode → P-0-1802.0.3 = 4).
- S-0-0420, C0400 Activate parameterization level procedure command

  → By activating the command C0400, all functions are switched to the status "inactive" again (parameter mode → P-0-1802.0.3 = 2).

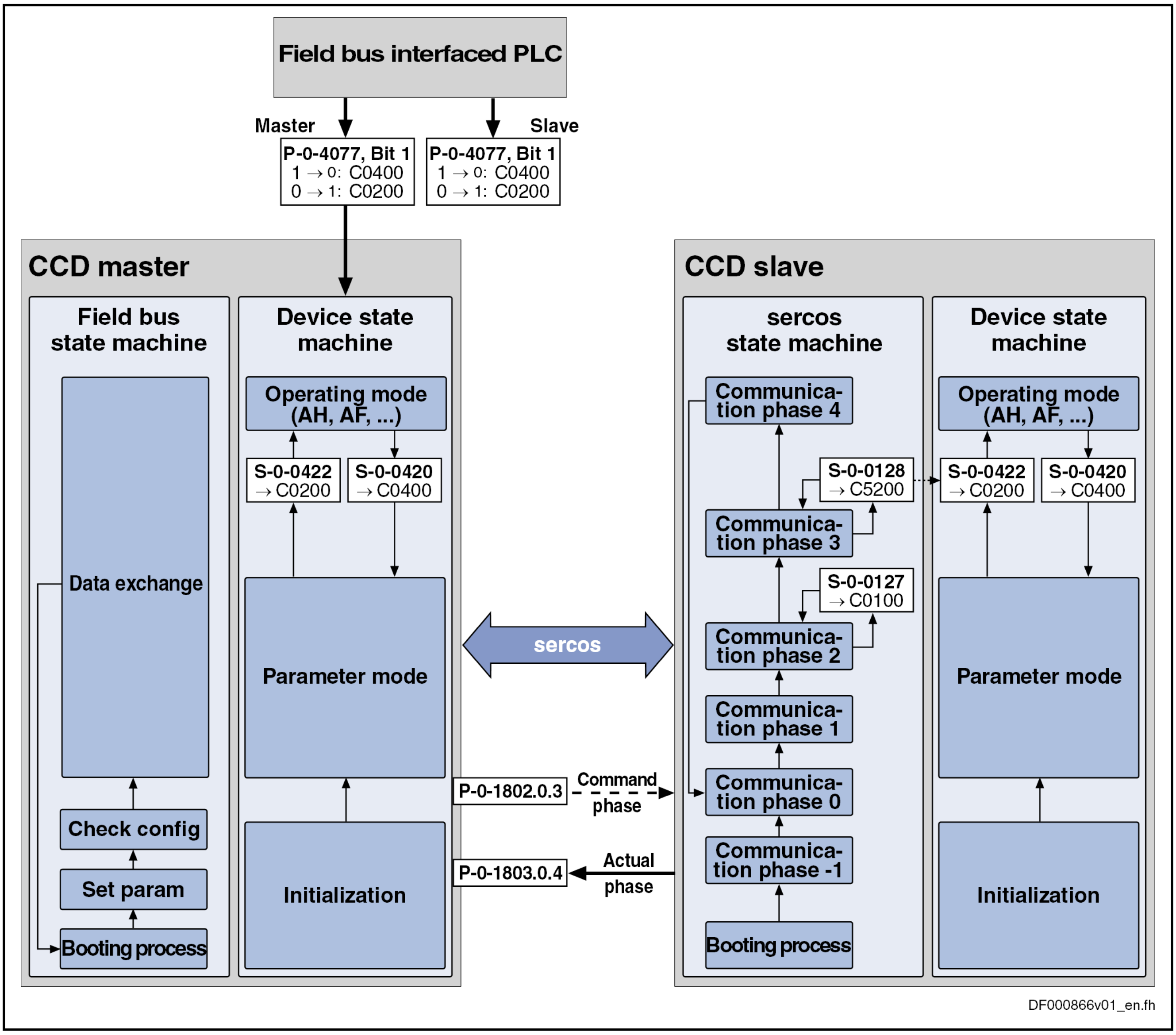


Fig. 9-10: State Machine of Cross Communication

Communication State Machine with sercos and EtherCAT® CCD System Mode

The basic phase input with sercos and EtherCAT® state machine switching in CCD system mode is independent of the setting in P-0-1800.0.1, bit 5:

After switching on, the CCD master initializes the sercos communication and tries to switch the projected CCD slaves to phase 2.

In phase 1, the sercos master communication of the CCD master already takes into account all addresses in the CCD group available in the sercos ring [addresses of local slave (CCD master) + (projected CCD slaves)], even if the the CCD group is not in phase 2.

In phase 2, the control unit can talk to all slaves in the CCD group via the service channel. To do this, the CCD group must also be in phase 2. Otherwise an SVC error will occur (SVC not open). The command "S-0-0127, C0100 Communication phase 3 transition check" from the control to the CCD slaves is detected by the CCD master, not transmitted and always acknowledged with or without error, depending on the parameterisation of sercos communication. It is only in the transition command "S-0-0128, C5200 Communication phase 4 transition check" of the master that the phase switch of the CCD slaves takes place.

If the sercos communication lies between controller and CCD master in Phase 3, the sercos communication between CCD master and CCD slaves is still in Phase 2. Starting the command S-0-0128 has the effect in the CCD master that it executes the phase progression for the CCD slaves from phase 2 to phase 4. At the end of the command S-0-0128 in the CCD master, the S3 communication between the CCD master and the CCD slaves is in phase 4. The command S-0-0128 from the control to the CCD slaves is detected by the CCD master, not transmitted and always acknowledged without error.

In phase 4, cyclic and acyclic communication with the CCD slaves is possible without restrictions and behaves as if the CCD slaves were directly in the sercos ring.

If the device state of the CCD master is changed by the command S-0-0420, or S-0-0422 (PM/OM switching), the behavior of the CCD slaves depends on the setting in P-0-1800.0.1, bit 5:

With P-0-1800.0.1, bit 5 = "0"(decoupled CCD phase progression): The device state machine (PM/OM switching) in the CCD slave is directly coupled to the device state machine of the CCD master. If the command S-0-0422 (-->OM)/S-0-0420 (-->PM) is started in the CCD master, the CCD slaves are also switched to OM/PM. The command S-0-0420 in the CCD master does NOT change the sercos phase of the CCD group!

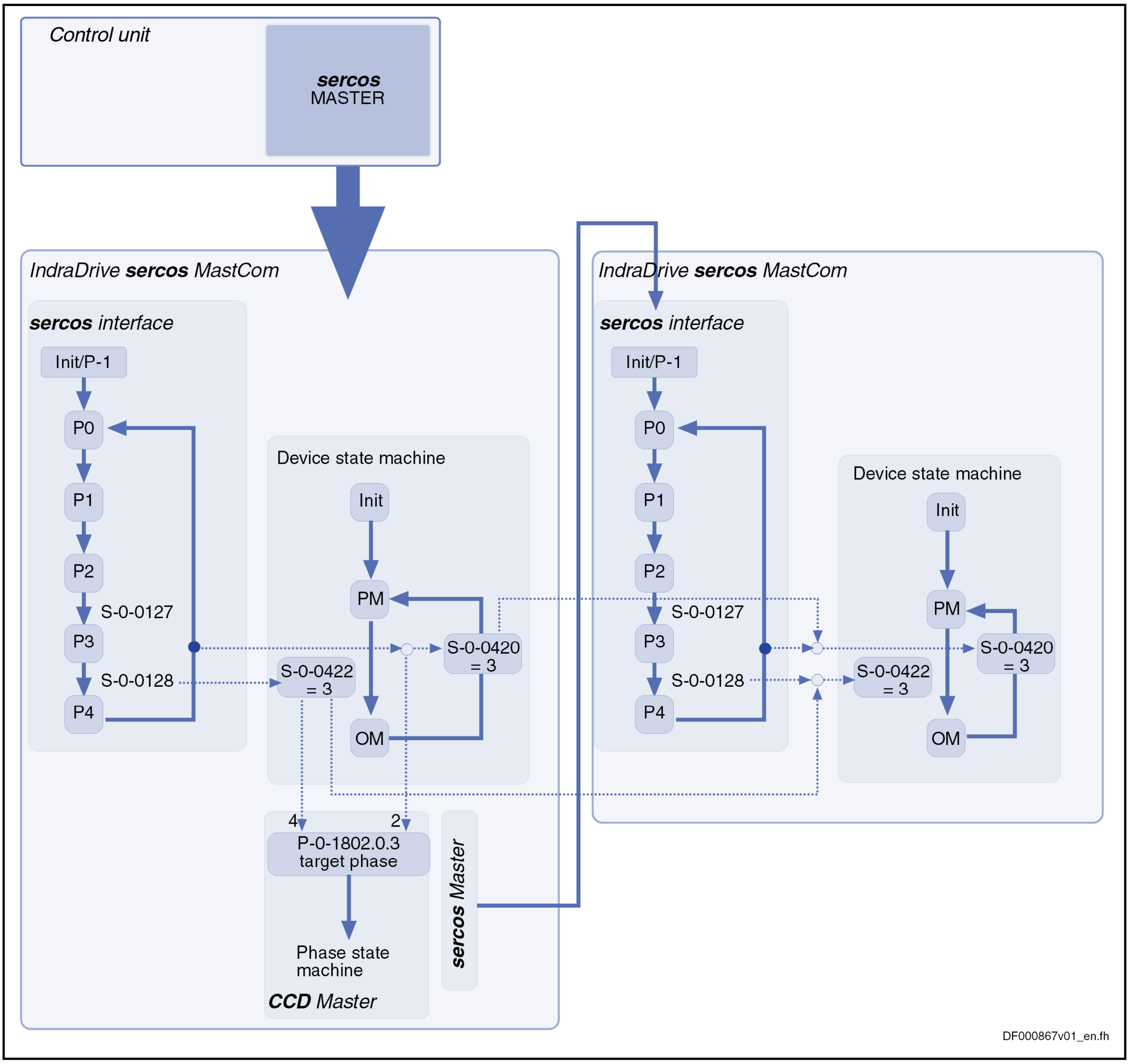


Fig. 9-11: sercos phase progression in CCD system mode for sercos and EtherCAT® at P-0-1800.0.1, bit 5 = "0"

With P-0-1800.0.1, bit 5 = "1"(decoupled CCD phase progression): If the command S-0-0422 (-->OM) is started in the CCD master, the sercos phase of the CCD group is switched to phase 4. The command S-0-0420 in the CCD master switches the sercos phase of the CCD group to phase 2. The PM/OM switching in the CCD slave is not directly coupled to the device state machine of the CCD master.

Optional Device Functions

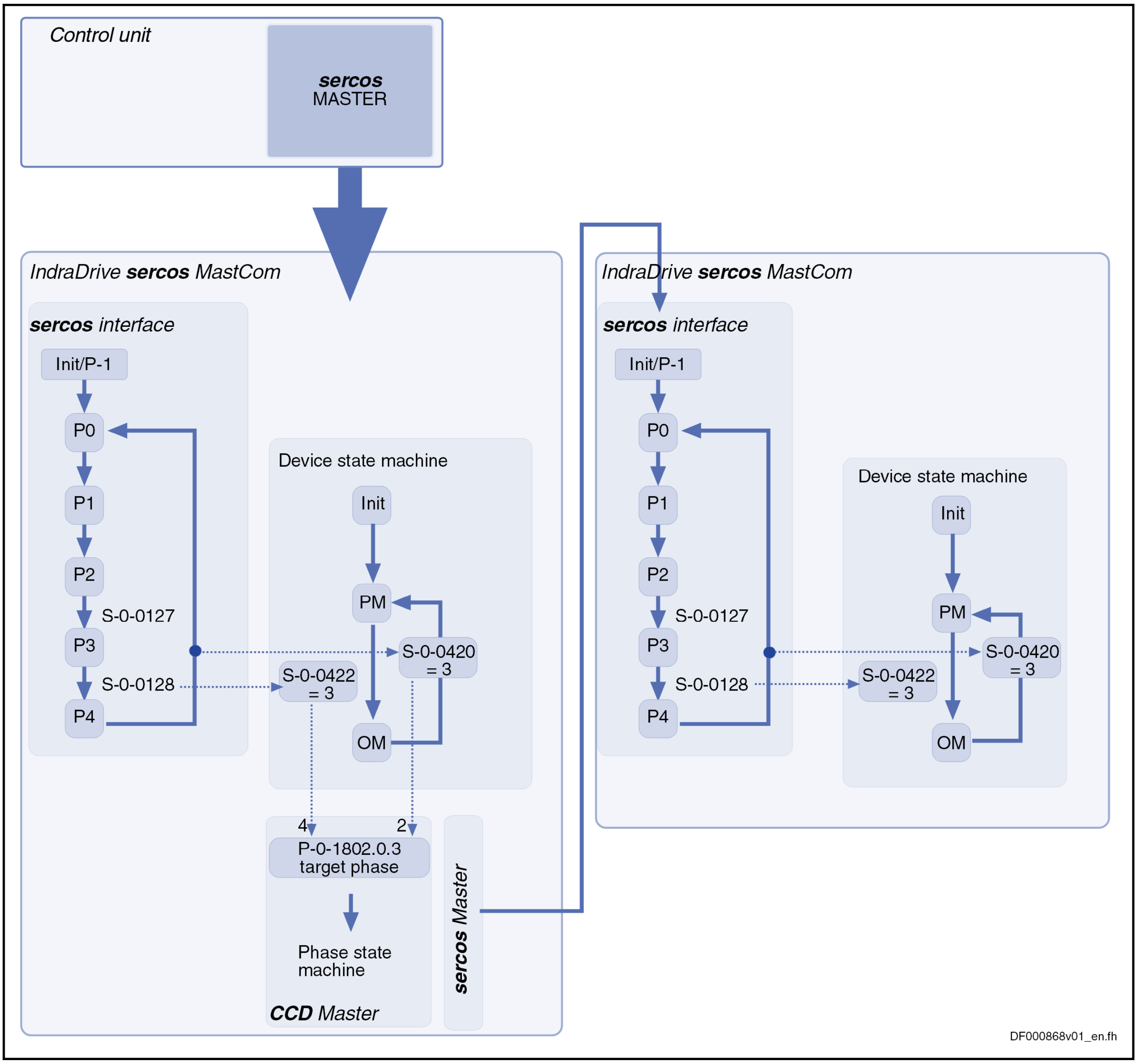


Fig. 9-12: sercos phase progression in CCD system mode for sercos and EtherCAT® at P-0-1800.0.1, bit 5 = "1"

CCD - Diagnostic System

Displaying and Evaluating the Diagnostic Message Numbers in the CCD Group

The following parameters are available in the CCD master for displaying the states of all axes in the CCD group and their evaluation via the CCD master:

- P-0-1810.0.10, CCD: Diagnostic message text

  This parameter displays the state of the CCD group in the CCD master in plain text.

☞ Together with the diagnostic message numbers of the slaves and the master, via this parameter it is possible, in the case of error, to obtain detailed information on causes of error and trouble-shooting.

- "P-0-1808.2.1, CCD: Diagnostic message number, slave 1" to "P-0-1808.10.1, CCD: Diagnostic message number, slave 9"

These parameters are used for displaying and evaluating the diagnostic message number for each slave (see Parameter Description "S-0-0390, Diagnostic message number"). By configuring P-0-1808.x.1 in parameter "P-0-1805.x.2, CCD: Configuration list actual master values" and S-0-0390 in parameter "P-0-1805.x.4, CCD: Configuration list actual slave values" the diagnostic message number of the CCD slave is sent to the master.

Identifying the CCD Slave Type

If the CCD group is in phase 2, it is possible to identify which slave type is at which position in the CCD group. This enables, for instance, the topology and wiring sequence to be checked to ensure correct remote address assignment.

List parameter P-0-1801.0.4 (binary format) provides various pieces of information on the identified slaves at their topology positions. The slave number relates to the topology position (physical position in the wiring sequence, cf. "P-0-1801.0.3, CCD: Actual topology addresses"). Various information on the respective sercos slave is displayed at the corresponding topology position (see overview below). The parameter is filled by the CCD master when phase 2 is reached. If the corresponding parameter is not available with a slave, then the field remains empty.

☞ Phase 2 is also reached by the CCD master if the slave addresses are not unequivocal or addresses other than the projected slave addresses are found. The user cannot access the CCD slaves in this case. It is first necessary to resolve the addressing problem. For this purpose, information from parameter "P-0-1801.0.4, CCD: Slave information at topology location" can be used, for example, to start the correct remote address assignment for unequivocal addressing.

The binary list parameter P-0-1801.0.4 has the following structure (the respective content with the associated data and attribute is reached/addressed via the byte offset):

Offset byte	Contents	Assignment
0x0	3812	Const. real length
0x2	3812	Const. max. length
0x4	13	Max. no. of slaves
0x8	**0x00018653**	**Vendor code #0**
0xC	Attr.	Attribute
0x10	Data	Data S-0-1300.0.3 slave 1
...	...	
0x40	Data	Data S-0-1300.0.3 slave 13

Optional Device Functions

Offset byte	Contents	Assignment
0x44	0x00028653	Device name #0
0x48	Attr.	Attribute
0x4C	Actual length	Data S-0-1300.0.4 slave 1
0x4E	Max. length	
0x50	Data	
...	...	
0x37C	Actual length	Data S-0-1300.0.4 slave 13
0x37E	Max. length	
0x380	Data	
...	...	
0x3C0	0x00038653	Device ID #0
0x3C4	Attr.	Attribute
0x3C8	Actual length	Data S-0-1300.0.5 slave 1
0x3CA	Max. length	
0x3CC	Data	
...	...	
0x6F8	Actual length	Data S-0-1300.0.5 slave 13
0x6FA	Max. length	
0x6FC	Data	
...	...	
0x73C	0x00048653	Connected to sub-device #0
0x740	Attr.	Attribute
0x744	Data	Data S-0-1300.0.6 slave 1
...	...	
0x774	Data	Data S-0-1300.0.6 slave 13
0x778	0x00058653	Serial number #0
0x77C	Attr.	Attribute
0x780	Actual length	Data S-0-1300.0.12 slave 1
0x782	Max. length	
0x784	Data	
...	...	
0xAB0	Actual length	Data S-0-1300.0.12 slave 1
0xAB2	Max. length	
0xAB4	Data	
...	...	
0xAF4	0x00068653	FSP type #0

Offset byte	Contents	Assignment
0xAF8	Attr.	Attribute
0xAFC	Data	Data S-0-1302.0.1 slave 1
...	...	
0xB2C	Data	Data S-0-1302.0.1 slave 13
0xB30	**0x00078653**	**Application type #**
0xB34	Attr.	Attribute
0xB38	Actual length	Data S-0-1302.0.2 slave 1
0xB3A	Max. length	
0xB3C	Data	
	...	
0xE68	Actual length	Data S-0-1302.0.2 slave 13
0xE6A	Max. length	
0xE6C	Data	
...	...	
0xEAC	**0x00088653**	**Addressing version**
0xEB0	Unsigned decimal	Attribute
0xEB4	Data	Data of addressing version slave 1
...	...	
0xEE4	Data	Data of addressing version slave 13

Tab. 9-8: Structure of the Binary List Parameter P-0-1801.0.4

"Pinging" a Specific CCD Slave

From the CCD master, the diagnostic LED of a specific sercos slave (if this slave supports the function) in the CCD group can be activated to identify its actual/physical mounting position. It is therefore possible to determine which sercos slave belongs to which topology position (-->CCD slave) in the CCD group. The parameter "P-0-1801.0.1, CCD: Slave identification" can be used to activate the diagnosis LED from the CCD master with a sercos slave in phase 2 by entering a topology position (cf. P-0-1801.0.3). It is therefore possible to identify a specific sercos slave at a topology position by "pinging" (activating the diagnostic LED). The value "0" switches off the function.

Example:

- P-0-1801.0.1 = 0 -> Function not active
- P-0-1801.0.1 = 1 -> "ping" slave on topology position 1
- P-0-1801.0.1 = 2 -> "ping" slave on topology position 2
- …
- P-0-1801.0.1 = n -> "ping" slave on topology position n

Synchronizing the System Time

In each CCD mode, the CCD master automatically/always sets P-0-0197 in the CCD slaves to the value of P-0-0197 in the CCD master in phase progression (directly after CCD phase 2 has been reached, and also briefly before switching to phase 4). The system time in the CCD slaves (P-0-0197) is also set to the value of P-0-0197 in the CCD master if P-0-0197 is written in the CCD master. Counting then continues from the new value. This allows (almost) synchronous error diagnosis of the CCD group. The delay when setting/transmitting the system time in the CCD slaves is taken into account and compensated for by the CCD master.

☞ Bit 6 in P-0-1800.0.1 can be used to deactivate this function of the automatic writing of the system time (P-0-0197) by the CCD master in the CCD slaves.

Properties of the System Time

In the CCD master, the system time is stored in P-0-0197 and it is maintained after the drive has been switched off. If another value is written to parameter P-0-0197, counting continues from this time on from this value (see also parameter description P-0-0197). If no value has been entered in P-0-0197, counting automatically continues from 01.01.2000 in the CCD master. P-0-0197 is not contained in P-0-0192 and is not overwritten either when "loading basic parameters".

Diagnostic Parameters of sercos Communication

There are different parameters that make it possible, in the event of problems with sercos communication, to get information on causes of errors or set conditions for an error reaction:

- Parameter "P-0-1810.0.15, CCD: AT error counter" contains the number of AT telegrams which have failed. The error counter is incremented once per communication cycle. It is incremented, when the corresponding AT fails both on Port 1 and on Port 2.
- Parameters "P-0-1810.0.12, CCD: Error counter Port-1" and "P-0-1810.0.13, CCD: Error counter Port-2" can be used to read the error count of the sercos FPGA according to the sercos specification (see parameter description).

Parameter "P-0-1800.0.5, CCD: Allowed telegram failures" can be used to set the number of allowed telegram failures (recorded in parameter P-0-1810.0.15) which can occur directly one after another before the error message "F4140 CCD communication error" is triggered.

Error Reaction of the CCD Group

The CCD error reaction is selected and activated via the bits 7 and 8 of the parameter "P-0-1800.0.1, CCD: Configuration".

Basic setting:

- Configuration "P-0-1800.0.1, CCD: Configuration" the CCD group error reaction can be activated for all CCD slaves via bit 10. In this case, the master automatically configures the parameter S-0-0390 to the corresponding actual value telegram (AT) of the slaves and copies the content to P-0-1808.1.1 (axis 1 local), to P-0-1808.2.1 (axis 2), to P-0-1808.3.1 (axis 3), etc.
- If a slave in the CCD axis group is not to participate in the activated error reaction in the master, the automatic parameterization of the slave diagnosis for all slaves must be switched off with bit 10 of P-0-1800.0.1. In this case, the inputs for the diagnostic message numbers of the slaves, which are to participate in the error reaction, must be made manually in P-0-1805.x.2 and P-0-1805.x.4 (P-0-1805.x.2 = P-0-1808.x.1 and P-0-1805.x.4 = S-0-0390).

☞ The **CCD error reaction is switched off by default**, i.e. bits 7, 8 and 10 in parameter P-0-1800.0.1 have not been set!

Specific Features of sercos and EtherCAT® CCD System Mode

In addition to the possibilities described above regarding the error reaction, the following aspects are to be observed when using the sercos CCD system mode:

- A communication error in the sercos ring or EtherCAT® results in the CCD slaves being automatically switched via phase 0 to phase 2 by the CCD master.
- A communication error of a CCD slave always results in "F4140 CCD communication error" in the master. Thus, all axes are decelerated in the same way, independent of the error reaction parameterized via "P-0-1800.0.1, CCD: Configuration".

Cyclic Process Data

For the MDT data (cyclic command values), the process data channel of CCD knows two data sources (master communication and CCD master) and one data sink (CCD slave).

For the AT data (cyclic actual values), there is one data source (CCD slave) and two data sinks (master communication and CCD master).

☞ The parameterization of the process data channel of the CCD group is made exclusively at the CCD master via the parameters P-0-1803.x.11/12 and P-0-1805.x.1-4. During phase progression, the master automatically assumes parameterization of the slaves via S_0_1050.0.6, S_0_1050.1.6, ...

The figure below illustrates the parameterization of the process data channel and the effect of parameters P-0-1803.x.11/12 and P-0-1805.x1-4 for the following cases (does not apply to sercos and EtherCAT® master communication in the CCD master):

1. Configuration of the MDT data (cyclic command values)
2. Configuration of the AT data (cyclic actual values)

Optional Device Functions

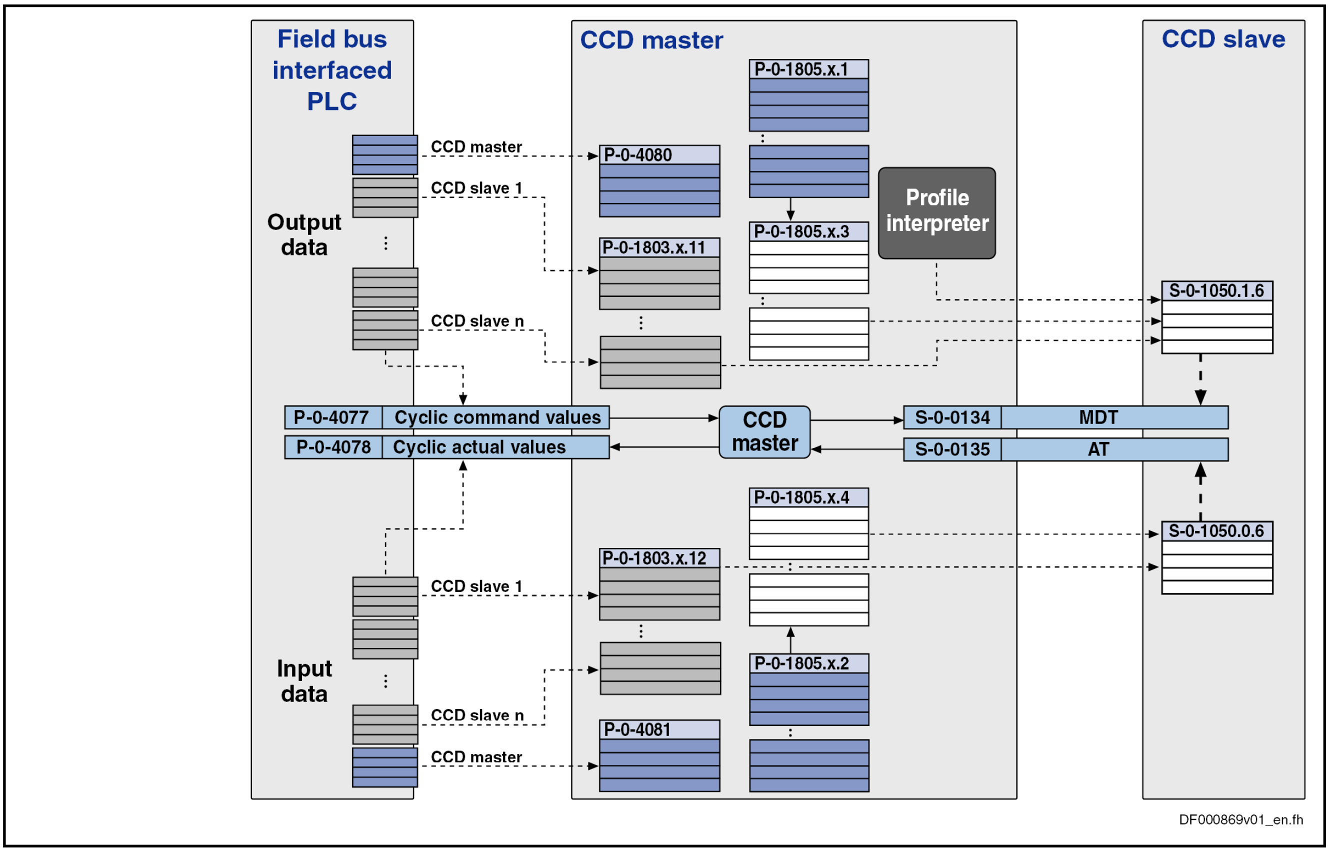


Fig. 9-13: Configuring the Cyclic Process Data

Configuration takes place as follows:

- In the CCD master, the required cyclic process data between the external PLC and the CCD slave are configured in the parameters P-0-1803.x.11 (MDT) or P-0-1803.x.12 (AT). With sercos and EtherCAT®, the control unit does not configure the cyclic data for the CCD slaves using the aforementioned parameters P-0-1803.x.11 and P-0-1803.x.12, but the data are configured directly from the control unit using the usual parameters. With
  - EtherCAT® the parameters "S-0-0016, Configuration list of AT" and "S-0-0024, Configuration list of MDT"
  - sercos with "S-0-1050.x.1 sercos Connection: Connection setup" and "S-0-1050.x.6 sercos Connection: Configuration list"
- The command values (MDT) to be transmitted from the CCD master to the CCD slave are configured in the relationship P-0-1805.x.1 ↔ P-0-1805.x.3. The list parameter P-0-1805.x.1 contains the parameters that the master puts into the MDT for the slave. The list parameter P-0-1805.x.3 contains information about which parameters in the slave the data from the master are intended for (S-0-1050.1.6).
- The actual values (AT) to be transmitted from the CCD slave to the CCD master are configured in the relationship P-0-1805.x.2 ↔ P-0-1805.x.4. The list parameter P-0-1805.x.2 contains information about which parameters in the master the data from the slave are intended for. The list parameter P-0-1805.x.4 contains information about which parameters the slave puts into the AT for the master (S-0-1050.0.6).

I/O Extensions for sercos

Compact I/O extensions for sercos are only used in the CCD group with MLD-M or MLD-S. There isn't any connection to master communication in the CCD master. Configuration and assignment to the CCD master and the slaves take place via IndraWorks.

I/O extensions are included/projected like a drive as CCD slaves in the CCD group. With MLD, it is possible to access these extension modules (see separate documentation "Rexroth IndraMotion MLD").

CCD: sercos-I/O

All (sercos) I/O slaves are supported by the I/O configurator integrated in IndraWorks (as of IndraWorks MLD 13VRS).

These I/Os are exclusively configured via this "I/O configurator", only the addressing and setting of the order are still made in the CCD master (CCD dialog in IndraWorks).

The "I/O configurator" is only available with the functional package MLD. Consequently, I/O slaves can only be used with the functional package MLD.

Exception: SLC03 (the safety control) can also be configured and used via parameters in the CCD master, i.e. in this case without the functional package MLD.

Addressing

We distinguish the following schemes of addressing:

- Logic individual axis addressing → for CCD communication, set the master communication address at each axis (e.g. 09, 02, 03, 05)
- Device address with automatic subindex → for PROFIBUS® (e.g. 9.02)
- Subindex address is used via PLC → 1st slave axis has address 1

The following aspects apply to the addressing of the individual CCD nodes:

- The master communication address is set as usual at the respective drive in parameter "P-0-4025, Drive address of master communication" (e.g. via the control panel).
- In the CCD master, the CCD slave addresses belonging to the respective CCD slave are to be entered in "P-0-1801.0.10, CCD: Addresses of projected drives". The addresses of the compact I/O extension connected to the CCD master are to be entered in "P-0-1801.0.11, CCD: Addresses of projected I/Os". The assignment of slave number and address takes place via the order of the list elements, so that CCD slave 1 is the drive with the address entered in list element 0 (etc.).
- The slave addresses found by the CCD master in phase 0 of the CCD axis group are displayed in the list parameter "P-0-1801.0.3, CCD: Actual topology addresses" in ascending order according to their actual line topology order (i.e. how they have been connected to the CCD master one after the other). Up to phase 2, this parameter can contain double addresses.
- All addresses of the CCD slave connected to the CCD master have to be indicated in ascending order according to their (desired) topology order in parameter "P-0-1801.0.2, CCD: Command topology addresses". Only the slaves contained in this list can be addressed as of CCD phase 2. Also those addresses of the sercos slaves must be listed which are only connected to the CCD master, but have not been projected.
- If the command topology (P-0-1801.0.2) contains addresses that were not listed/found in the actual topology, the warning "E4013 Incorrect CCD addressing" is generated in CCD phase 2. Advancing to CCD phase 3 or 4 is impossible.

- From phase 2 onwards, all addresses contained in the actual topology (P-0-1801.0.3) must also be contained in the command topology (P-0-1801.0.2). The order is irrelevant for monitoring. It is only important that all the respective addresses are contained, and no further/other addresses are only contained in P-0-1801.0.3 or only in P-0-1801.0.2. Either the addresses of the command topology (P-0-1801.0.2) must be adjusted to those of the actual topology (P-0-1801.0.3) or the addresses of the CCD slaves must be set to those of the command topology via the command "C7000 CCD: Command adjust slave addresses" (P-0-1801.0.5). Only in this way is it possible, for example, to assign an unequivocal address for the compact I/O extensions!
- The slaves found in the actual or command topology and projected in parameter P-0-1801.0.10 or P-0-1801.0.11 are entered in the list parameter "P-0-4031, " during the transition to phase 1:
  - List element 0: Address of CCD master
  - List element 1: Address of CCD slave (drive) from P-0-1801.0.10 [0]
  - List element 2: Address of CCD slave (drive) from P-0-1801.0.10 [1]
  - List element n: Address of CCD slave (drive) from P-0-1801.0.10 [n]
  - List element n+1: Address of compact I/O from P-0-1801.0.11 [0]
  - List element n+m: Address of compact I/O from P-0-1801.0.11 [m]

☞ The slave addresses contained in P-0-1801.0.10 and P-0-1801.0.11 must be found in the list parameters P-0-1801.0.3 or P-0-1801.0.2 otherwise, the message "E4013 Incorrect CCD addressing" or "C0265 Incorrect CCD address configuration" may arise in the phase progression of the master.

Specific Features of sercos

The CCD system mode for sercos comprises 2 networks: the high-level network for the controller (sercos FKM) and the low-level network between CCD master and CCD slaves based on the sercos communication. In both networks the individual nodes (slaves) are addressed via the sercos address. The CCD master must be able to unequivocally establish the connection between slave address in the high-level network (sercos) and slave address in the low-level network (sercos). Thus, any address within the allowed address frame can be assigned in both networks. Therefore, with the sercos CCD system mode, addressing of the nodes (including the CCD slaves to be addressed) within the sercos ring is independent of the addressing of the CCD slaves in the sercosnetwork of the CCD communication.

To enable the CCD master to establish the connection of the addresses in the high-level network to the addresses of the CCD slaves in the sercos network, the parameters "P-0-1803.x.1 CCD: Slave address in high level network" exist in the CCD master. Which x, i.e. which parameter stands for which CCD slave is based on the sequence parameterized in "P-0-1801.0.10, CCD: Addresses of projected drives". Addresses must be assigned for each CCD slave in the CCD master in the parameters P-0-1803.x.1. The CCD slaves in the high-level network are detected and addressed via the same addresses.

Example: In this case, the address set in P-0-1803.2.1 corresponds to the address via which the first (->actual drive address: P-0-1801.0.10, element 0) CCD slave is reached from the high-level network control. With the address set in P-0-1803.3.1, the second slave (P-0-1801.0.10, element 1) etc. is reached from the high-level network. It is therefore possible to address the CCD slave with the drive address (address in display) 3 from the high-level network control with address 55.

Deactivating CCD Slaves

In "P-0-1801.0.10, CCD: Addresses of projected drives" and "P-0-1801.0.11, CCD: Addresses of projected I/Os" all physically present/connected CCD Slaves (drives and I/Os) must be listed. To deactivate physically existing CCD slaves, it is possible to leave out/remove addresses (drives, I/Os). The concerned slaves in this case are no longer taken into account by the CCD master and signal "E4010 Slave not scanned or address 0".

⚠ WARNING

When addresses are left out/removed, possible gaps in P-0-1801.0.10 and P-0-1801.0.11 are automatically filled so that changes in the logic order (Axis2, Axis3, ...) can occur. This has a direct effect on the MLD program and the CCD process data! To avoid the (undesired) effects of gaps being filled up, use the "parking axis" function in the axis to be deactivated (and do not remove the corresponding address). See also "Parking axis" function

To deactivate physically **inexistent** slaves, use the corresponding firmware functionality as of MPH-05 (deactivate addresses in P-0-1801.0.10/ P-0-1801.0.11, set bit 15 in the respective list element) (supported by IndraWorks). The deactivated slaves in this case are not taken into account by the CCD master, but the logic order is not changed so that the rest of the CCD configuration can be maintained.

☞ When all CCD slaves have been deactivated, X24 has to be connected to X25 with a sercos cable.

Acyclic Communication (Parameterization Gateway)

To allow access of the individual parameters of the slaves from the CCD master, there is a so-called "parameterization gateway" available which processes requests of an interface of the master (via master communication, Ethernet, …) regarding parameters of the slaves.

Acyclic parameter services, requested via the master communication or drive PLC in the CCD master, must be transmitted to the slaves by the cross communication.

For this purpose, the following interfaces with the following possibilities are supported:

- sercos service channel "sercos communication"
- Field bus interface with the available parameterization options (DPV1, …)

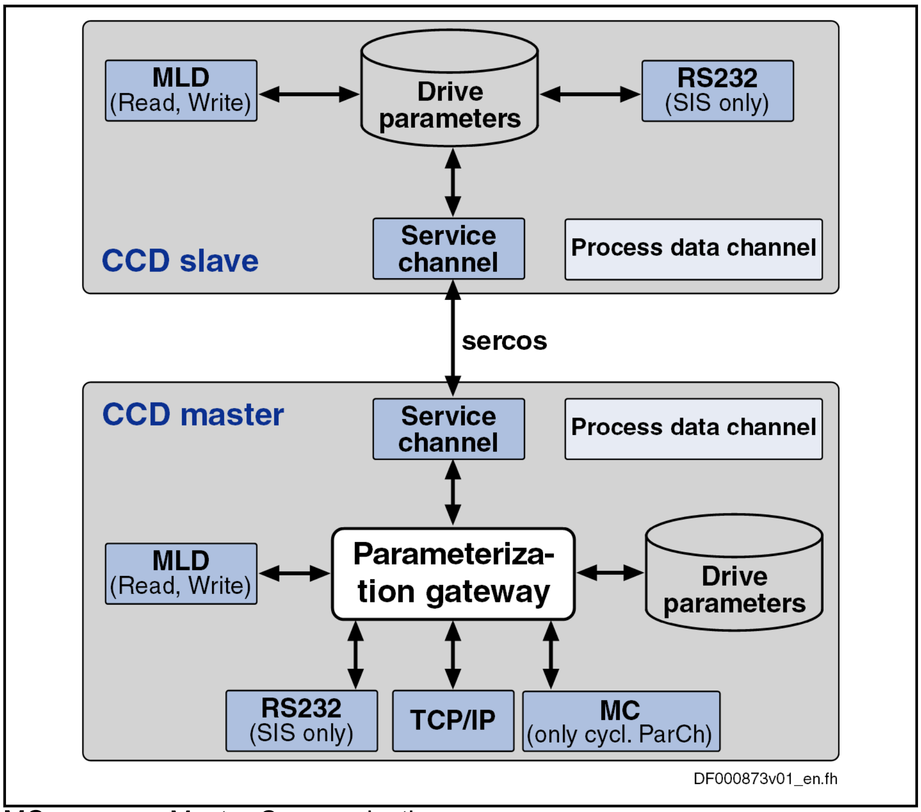
☞ With EtherNet/IP™, the parameterization gateway is not supported.

- EtherNet interface with TCP/IP

For this application, the inactive EtherNet connection (so-called "Engineering Port") at the CCD master can be used for parameterization.

As regards the access to CCD slaves by means of SIS protocol, the following aspects must be taken into account during implementation:

The address of the CCD master must be entered as receiver address in the general SIS telegram header. The receiver address (component address) to be entered in the service-dependent section for the parameter services 0x80, 0x10, etc. is the address of the slave. The master will accept the telegram and route the request to the slave via CCD.



MC Master Communication

Fig. 9-14: Functional Scheme of the Parameterization Gateway

Cycle Time

Configuring the CCD Cycle Time

The CCD cycle time is set in the master via parameter "S-0-0001, NC cycle time (TNcyc)" and "P-0-1800.0.10, CCD: Cycle time". The CCD master then presets this time for the slaves in parameter "S-0-1050.x.10, sercos Connection: Producer cycle time".

The resulting cycle time which is preset for the CCD slaves in parameter S-0-1050.x.10 (→ actual CCD cycle time) corresponds to the smaller value from the parameters S-0-0001 and P-0-1800.0.10 of the master (if P-0-1800.0.10 unequal zero).

The sercos cycle time of the CCD slaves in parameter "S-0-1002, sercos: Communication Cycle time (tScyc)" are automatically determined by the CCD master and set to the smallest processing cycle time.

The timing settings made by the master can be seen in the parameter "P-0-1810.0.03, CCD: Timing settings"

The number of CCD slaves limits the possible CCD cycle time (see "Performance Features").

Special Case sercos CCD System Mode

In the sercos CCD system mode, S-0-1002 is set to a fixed value in the CCD slaves, depending on the NC cycle time (S-0-0001) of the sercos communication of the CCD master:

S-0-0001, (sercos-) NC cycle time in the CCD master	500 µs	1000 µs	2000 µs-4000 µs and high performance in all CCD axes	2000 µs-4000 µs and standard performance in at least one CCD axis	2000 µs-4000 µs and economy performance in at least one CCD axis
S-0-1002 in the CCD slave	250 µs	500 µs		1000 µs	2000 µs

Tab. 9-9: Set by CCD Master in the CCD Slave

This results in a dead time compensation and it is possible in the sercos CCD system mode that the cyclic data of CCD master (-->sercos slave) and CCD slave take effect simultaneously.

The sercos cycle time set by the CCD master in S-0-1002 of the CCD slaves must be supported by every CCD slave. Where necessary, the sercos cycle time of the high-level network of sercos communication must be increased (cf. table above).

Ring Recovery and Redundancy

Redundancy in the master means that, in the event of a ring interruption, the CC data that were previously exchanged directly between the slaves are copied from one line to the other by the CCD master. This causes a sercos cycle offset with the CC data. This does not affect the MS data.

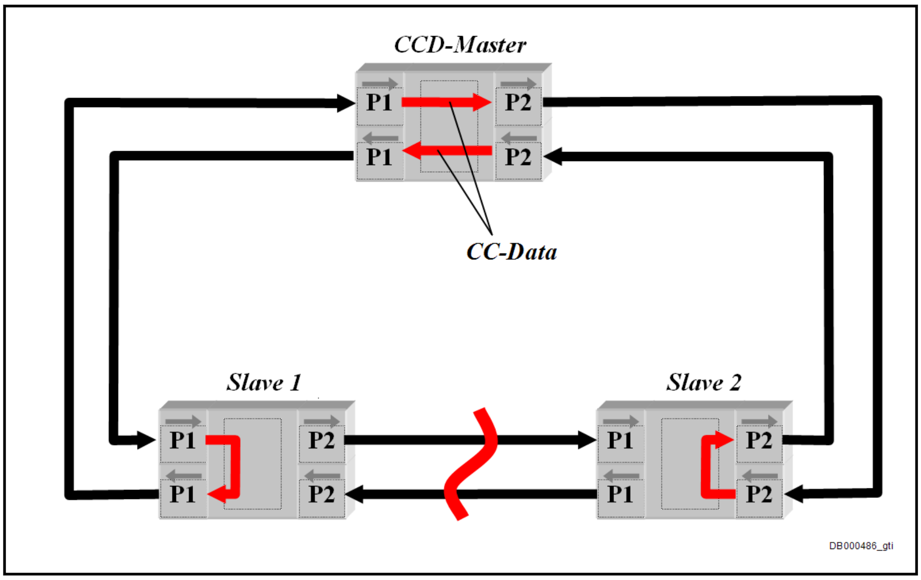


Fig. 9-15: Redundancy in the Master

In the case of a ring interruption, the double ring is split into 2 lines. In the case of a ring recovery, the topology is changed vice versa. To ensure that this works without errors, bus master and bus slave must be able to handle both the respective topology states and the transitions. The values in parameter "S-0-1003, sercos: Allowed MST losses" must not be exceeded, even during the transitions.

For display of the ring interruption and for ring recovery the CCD master has the following functions:

- Parameterization of command topology (P-0-1801.0.20) and display of a warning (E4016) in the case of differing command topology and actual topology (P-0-1801.0.21)
- Command function for ring recovery (C7100) via parameter P-0-1801.0.23

Redundancy

The redundancy in the master is a function becoming active if a ring interruption is detected and the slaves activate LoopBack at the interruption point. The CC data that were previously exchanged directly between the slaves are then copied from one line to the other by the CCD master. This causes a sercos cycle offset with the CC data. This does not affect the MS data. In the case of a difference between the parameterized command topology and the actual topology, the CCD master displays the warning "E4016 CCD: Topology error" for the identification of this condition.

In parameter "P-0-1801.0.22, CCD: Slave addresses at end of line", created as a list with two elements, the CCD master shows the address of the CCD slaves at the end of the line. This allows to locate the ring brake.

- List element 1: Address of slave at the end of the line at X24 (port 1)
- List element 2: Address of slave at the end of the line at X25 (port 2)

Ring Recovery

The CCD master offers the command "P-0-1801.0.23, C7100 CCD: Command Close ring" (C7100) for ring recovery. With the command topology P-0-1801.0.20 = 4 (double ring) this makes it possible to close the line or 2 lines to form a double ring. Due to the change of topology, the ring delay is measured again, transmitted to the slaves, if necessary, and the command S-0-1024 (synchronization measuring procedure) is triggered. If an error occurs with the command C7100, the message "C7101 CCD: Impossible to close ring" is displayed. Possible causes of the message C7101:

- CCD group not in phase 4
- Topology is not line or double line
- No line between the last nodes of the lines.
- New ring delay could not be transmitted to the slave.

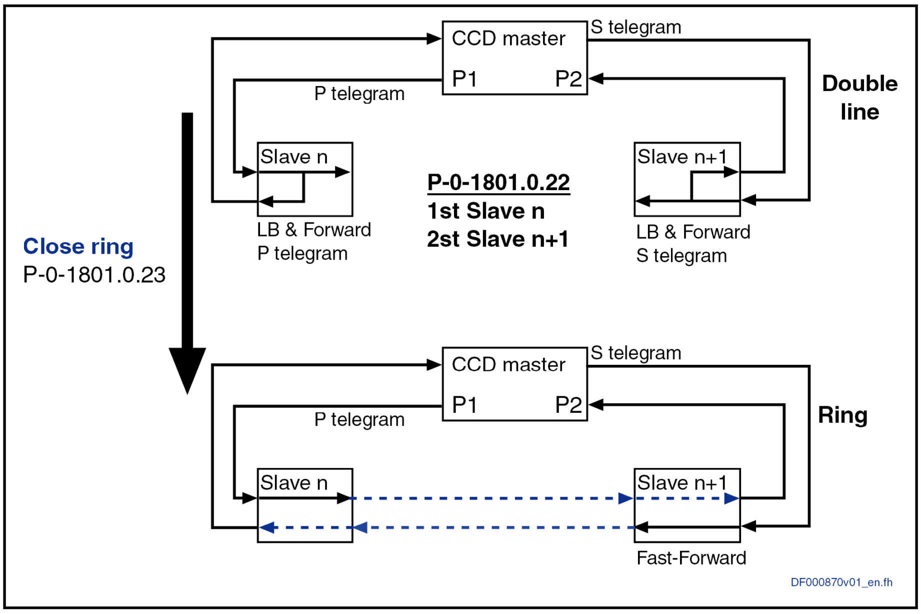


Fig. 9-16: Ring Recovery

Dead Time Compensation

With command value linking (e.g. with Gantry axes) via CCD, it is necessary that the command values take effect at the same point of time in the individual axes. To prevent the master axis from preceding the slaves, dead time compensation was realized for the command value input to the slaves.

Dead time compensation by virtual slave:

For command value synchronization of the cyclic data in the CCD master and the slaves for the actual values and command values, it is possible to use the "virtual slave". The command values and actual values of the CCD master can be delayed by one connection cycle, by analogy with the CCD slaves. The cyclic command values and actual values for the virtual slave can be configured via the first 16 elements of the parameters P-0-1805.x.1 to P-0-1805.x.4. By using the virtual slave, the values of CCD master **and** CCD slave are thus delayed in equal measure. Thereby, the CCD master, too, reacts with a delay to the higher-level master communication.

☞ In the MLD-M system mode (with permanent control in the CCD master), dead time compensation takes place by calculating a virtual slave in the CCD master to artificially delay the command values for the master axis (see also separate documentation "Rexroth IndraMotion MLD").

Dead time compensation by extrapolation:

Basic Function

In the CCD system mode or MLD-M system mode (without permanent control in the CCD master), extrapolation of a selected command value is carried out for each CCD slave to compensate the internal processing dead times. The parameter of the CCD master to be transmitted to the CCD slave first is extrapolated. The extrapolated value is then contained in parameter "P-0-1800.0.33, CCD: Extrapolated command value". This parameter with the extrapolated value has to be copied to the corresponding parameter of the slave (free process data). The parameter "P-0-1800.0.32, CCD: Number of extrapolation steps" indicates for how many CCD cycles in advance the parameter value of the master is calculated.

In the CCD master, the extrapolator is only available once so that only one parameter of the CCD master can be extrapolated.

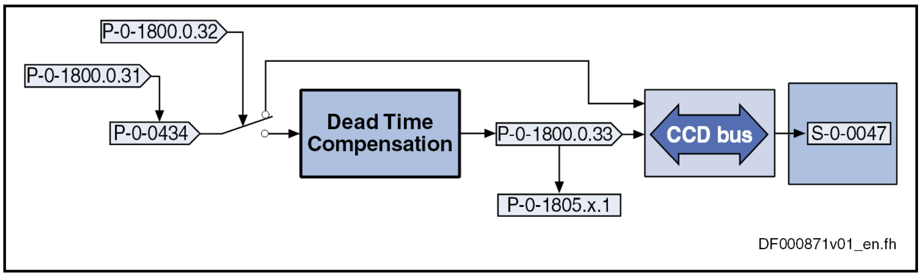


Fig. 9-17: Command Value Extrapolation for Dead Time Compensation of the Command Values for the CCD Slaves

Example of Application with Configuration

The operating principle of the function is described for a Gantry axis (position command value linking).

The CCD master is to preset the position controller command value (P-0-0434) for the slaves as the value for parameter S-0-0047. The position controller command value is active in the master the next time the position controller is called. For the CCD slaves there is a delay of up to two sercos cycles until this command value takes effect in the position controller.

To avoid this, activate the dead time compensation by the following setting:

- Dead time compensation is activated when a value is entered in "P-0-1800.0.32, CCD: Number of extrapolation steps" which is unequal to "0" (default setting).
- Enter the desired command value (with position command value linkage → P-0-0434) in the parameter "P-0-1800.0.31, CCD CCD: Extrapolated cmd value signal selection".
- In the parameter "P-0-1805.x.1, CCD: Configuration list master cmd values" the value of parameter "P-0-1800.0.33, CCD: Extrapolated command value" is then entered for the slaves instead of P-0-0434 .

Due to extrapolation, position deviations (worse profile) result for the extrapolated command value as compared to the original command value, the extrapolated command value becomes greater as the number of extrapolation steps (P-0-1800.0.32) increases.

Master Axis Linking

Basic Function

Up to 3 master axes are formed in the CCD master. Generating a master axis in each case means to retrieve the value of a source parameter, convert it to the master axis format, filter it and extrapolate it to compensate transmission times.

The resulting master axis positions then are transmitted to the CCD slave axes in order to be used as command values for synchronization modes in the slave axes.

The parameters needed for the master axis linkings in MLD-M system mode are automatically configured in the telegrams of the CCD master and slave axes. The information about master and slave entries of synchronous motion function elements are evaluated for assigning of master axes to slave axes.

In the CCD system mode, free process data in the telegrams must be used to transfer the needed actual values to the CCD master axis and the send the data for the synchronous operation types to the CCD slave axes. The assignment of a preprocessed master axis position to a slave axis must take place directly by changing the selection parameter.

Selecting Source Parameters

The following parameters can be used as a source for the preprocessed master axis:

- P-0-0761, Master axis position for slave axis
  (only from CCD master axis)
- P-0-0053, Master axis position
  (only from CCD master axis)
- P-0-0052, Actual position value of measuring encoder
  (from each CCD slave axis)
- S-0-0386, Active position feedback value
  or
  P-0-0434, Position command value of controller
  (from each CCD axis)

Which parameter shall serves as the source for the master axes must be entered in the master axis configuration list (P-0-1820.0.1, CCD: Master axes configuration list). 3 entries are possible.

The constant logical axis number associated with it in the configuration list is specified in order to indicated in select the parameters from the CCD master axis. The master axis position of the virtual axis (P-0-0761, Master axis position for slave axis) is selected by the axis number 20 (VMA_1), that of the group axis position (P-0-0053, Master axis position) buy number 26 (MA_LINK_1).

When selecting the actual measuring encoder position value (P-0-0052, Actual position value of measuring encoder) alongside the constant logical axis number 23 (RMA_1) the axis from which the actual measuring encoder position value comes must also be indicated. The logical axis number of the axis to which the measuring encoder is connected is entered in parameter "P-0-1820.0.2, CCD: Source of measuring encoder position feedback value".

The logical axis numbers of the real axes are set by the CCD axis configuration list (P-0-1801.0.10, CCD: Addresses of projected drives). The axis in the CCD master has the logical axis number 1, the first element in the CCD axis configuration list has the logical axis number 2, etc.

If the position-actual or command value of an IndraDrive axis be the source of a master axis, the logical axis number of the source axis is entered in the master axis configuration list. In parameter "P-0-1820.0.4, CCD: Axis position selection", it must also be entered additionally whether the position command (P-0-0434) of this axis is to be used instead of the actual position value (S-0-0386) The use of the actual position value leads to a smoother master axis position than a noisy actual position value.

☞ The master axes are numbered continuously in sequence by the sequence of logical axis numbers in the master axis configuration list. The structure index SI in the parameters "P-0-1821.SI.1, CCD: Position command value for master axis n" to "P-0-1821.SI. 5, CCD: Master axis n, master axis position" which exist for each master axis corresponds to the numbers of the master axis.

Master Axis Adjustment

Format Conversion

To form the master axis position of a master axis, the source parameter must be converted to the master axis format of the control (CCD master axis) The master axis format of the control is determined by the parameters "P-0-0084, Number of bits per master axis revolution", and "P-0-0750, Master axis revolutions per master axis cycle".

The master axis format of the virtual axis (logical axis number VMA_1) and a master axis resulting from it can alternatively be set by the parameters "P-0-0763, Modulo factor, master axis format converter", and "P-0-0773, Number of bits per master axis revolution, format converter".

The following lists which parameters are used during the conversion depending on the type (source parameter).

- Measuring encoder axis (P-0-0052, Actual position value of measuring encoder)

  No conversion takes place. The "P-0-0765, Modulo factor measuring encoder" in the source axis must be identical to the "P-0-0750, Master axis revolutions per master axis cycle".
- Virtual axis (P-0-0761, Master axis position for slave axis)

  The format of the master axis position of this master axis depends on bit 4 of the "P-0-0917, Control word of master axis generator". The format is identical to that of the source parameter "P-0-0761, Master axis position for slave axis" which means a conversion is not required.
- Group axis (P-0-0053, Master axis position)

  No conversion takes place.
- IndraDrive axis ("S-0-0386, Active position feedback value" or "P-0-0434, Position command value of controller")

  Depending on the type of position scaling, the parameters "S-0-0103, Modulo value" or "P-0-0159, Slave drive feed travel" from the source access are needed for the conversion. The conversion factor also depends on the master axis format of the control which is determined by the parameters "P-0-0750, Master axis revolutions per master axis cycle" and "P-0-0084, Number of bits per master axis revolution". A distinction is drawn between the following cases:

  – Rotary or linear modulo scaling and P-0-0750 not equal to 0

    Conversion factor = P-0-0750 * 2^P-0-0084 / modulo value of source axis

  – Rotary or linear modulo scaling and P-0-0750 equal to 0

    Conversion factor = 2^32 / modulo value of source axis; followed by subtraction of 2^31

  – Rotary absolute scaling and P-0-0750 not equal to 0

    Conversion factor = P-0-0750 * 2^P-0-0084 / 360°

  – Rotary absolute scaling and P-0-0750 equal to 0

    Conversion factor = 2^P-0-0084 / 360°

  – Linear absolute scaling and P-0-0750 not equal to 0

    Conversion factor = P-0-0750 * 2^P-0-0084 / feed travel of source axis

  – Linear absolute scaling and P-0-0750 equal to 0

    Conversion factor = 2^P-0-0084 / feed travel of source axis

Filtering

The values of the source parameter are filtered after format conversion. One of the following filters can be selected in parameter "P-0-1821.SI,2, CCD: Master axis n, filter type":

Value	Filter type
0	Filter deactivated
1	Low-pass filter 1st order with velocity feedforward
2	Low-pass filter 2nd order with velocity feedforward
3	Low-pass filter 3rd order with velocity and acceleration feedforward

The filter order frequency can be preset in another parameter. The filters are designed such that the signal is not delayed by filtering at constant speed. With filter 3, the output signal is delayed during acceleration.

Extrapolation

To compensate for the time needed to make a fine interpolation and the transfer times between CCD master and CCD slaves, the master axis position of a master axis can be extrapolated. To determine how many NC cycles the built master axis position is extrapolated by, for each master axis n is specified in a parameter "P-0-1821.SI,4, CCD: Master axis n, number of extrapolation steps".

Assignment of Adjusted Master Axes to Slave Axes

After adjustment, 3 master axis positions are in the parameters P-0-1821.1.5, P-0-1821.2.5 and P-0-1821.3.5 (CCD: Master axis n, master axis position).

For each possible CCD slave axis, there is a parameter "P-0-1823.n.2, CCD: Master axis position for axis n". The structure index n corresponds to the logical axis numbers of the CCD slave axis (n = 1, 2, ...10).

The assignment of master axis position n to a CCD slave axis takes place via the parameter "P-0-1822.0.2, CCD: Master axis selection for the IndraDrive axes". In this parameter, for each CCD slave axis, 2 bits are used in each case to determine which of the 3 master axis positions are copied into the parameters provided for them P-0-1823.n.2.

In the MLD-M system mode, in the command triggering of a synchronous motion function module in the PLC, a check is performed to see whether the logical axis number of the axis specified at the master entry exist in the master axis configuration list. If so, the number of the master axis is taken from the position in the configuration list and the assignment parameter "P-0-1822.0.2, CCD: Master axis selection for the IndraDrive axes" is changed for the slave axis specified via the input of the function module as well.

Telegram Configuration in MLD-M System Mode

The maximum of 3 master axis positions are adjusted and the events are stored in the parameters P-0-1821.1.5, P-0-1821.2.5 and P-0-1821.3.5 (CCD: Master axis n, master axis position).

The assignment of these master axes to the CCD slave axes are in the parameter "P-0-1822.0.2, CCD: Master axis selection for the IndraDrive axes". The adjusted master axis positions are distributed to the P-0-1823.1.2 to P-0-1823.10.2 (CCD: Master axis position for axis n. A master axis position to be transferred for each CCD slave axis in the CCD master.

The CD master sends this master axis position in the MDT (master data telegram) to the CCD slaves. The parameter "P-0-0053, Master axis position" is configured in the MDT in the remote CCD slaves so that the master axis position of the CCD master arrives there. Since the parameter P-0-0053 in the IndraDrive axis in the CCD master is reserved for a higher-level control, this slave axis gets its axis position in the parameter P-0-0787, Group axis 1 position.

When a measuring encoder is to serve as a source of a master axis in the CCD master, the parameter "P-0-0052, Actual position value of measuring encoder" in the AT (drive telegram) of the same CCD slave axis from which this position feedback value should come. The received value for further processing in parameter "P-0-1820.0.3, CCD: Actual position value of measuring encoder" is stored in the CCD master.

When the axis position of a CCD slave is to serve as a source of a master axis in the CCD master, then it depends of the parameter "P-0-1820.0.4, CCD: Axis position selection" whether the existing configuration of the drive telegrams is extended in the slave. When the actual position values (P-0-0434) is to be used instead of actual position value (S-0-0386), then the position command value is sent to the CCD master in the AT in addition to the actual position value. In the CCD master, one of the parameters P-0-1821.1.1, P-0-1821.2.1 or P-0-1821.3.1 (CCD: Position command value for master axis n) is used to store a returned position command value as per the leading axis

9.3.3 Notes on Commissioning and Utilization

Navigating in IndraWorks

The dialogs for parameterizing the CCD communication can be found in IndraWorks under the sercos branch (→ right mouse key):

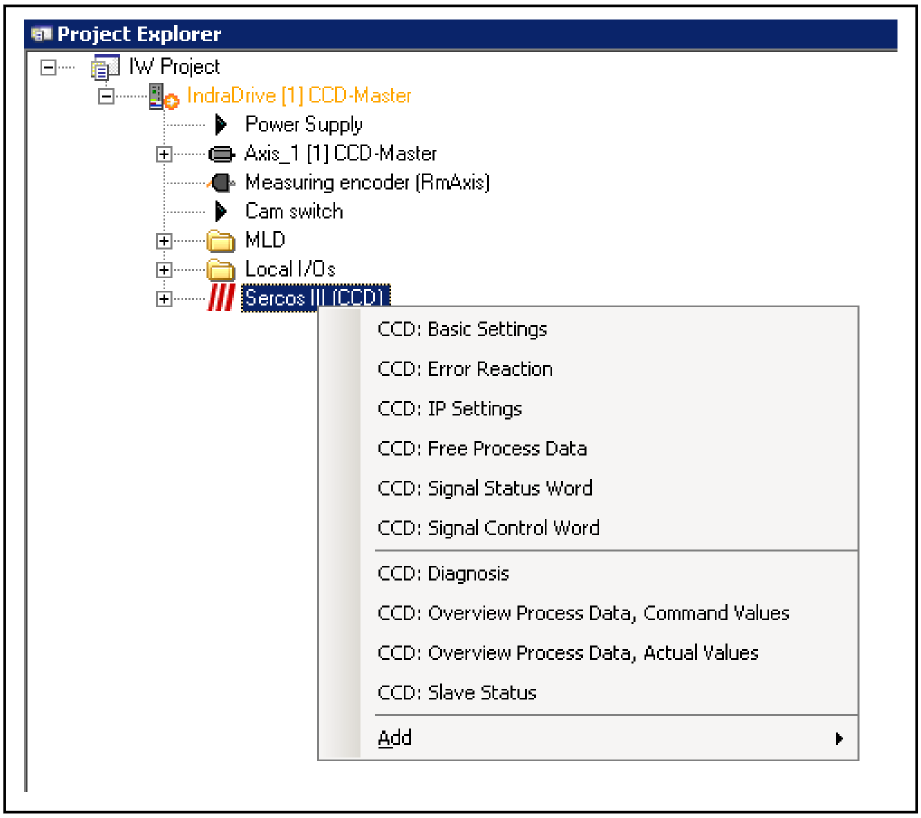


Fig. 9-18: Overview of IndraWorks Dialog Windows for CCD Communication

By analogy with drives under a control unit, the slaves of the CCD group are displayed below a sercos branch in the project tree.

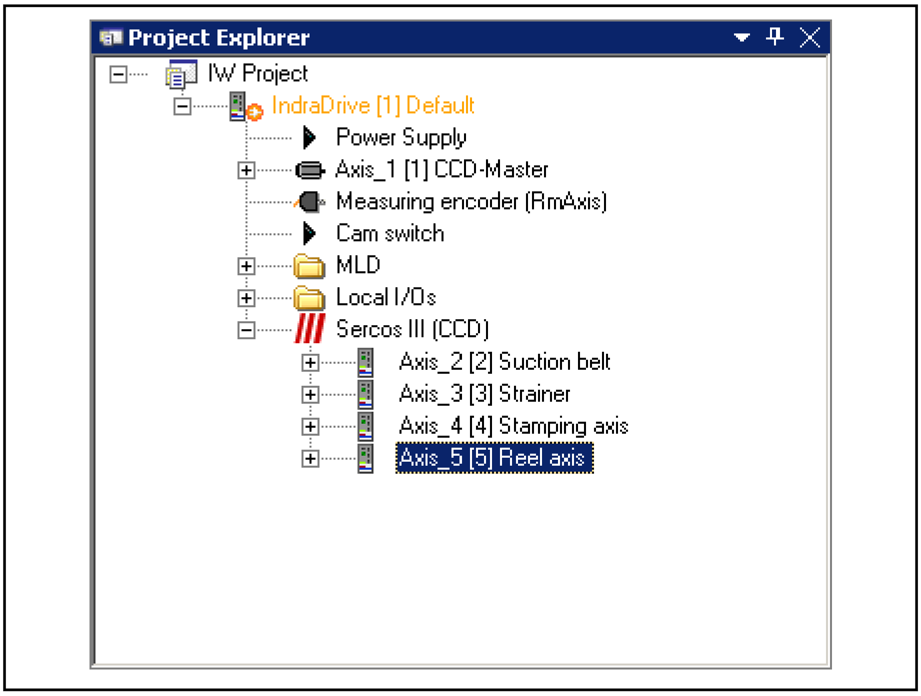


Fig. 9-19: CCD Display in the Project Explorer

The slaves can be addressed in the same way as drives under a control unit. In the offline mode, it is possible to drag drives from the library under the sercos branch. The configuration found is used in the online mode.

Basic Settings

The figure below shows the basic settings for parameterizing the CCD communication.

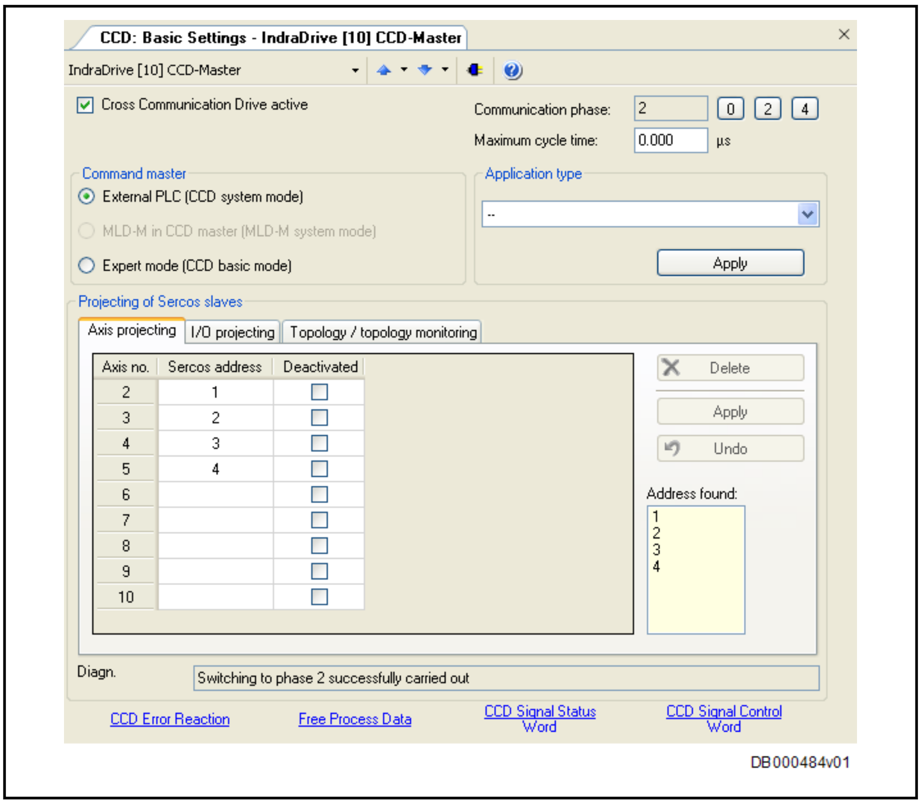


Fig. 9-20: IndraWorks Dialog for Basic Settings of CCD Communication

Selecting the Cross Communication Modes

Possible Applications of the CCD Modes

Due to their different properties, there are preferred applications for the respective CCD modes:

- Preferably use the **CCD system mode (command triggering master: external PLC)**, when mere command value linking must be realized with field bus master communication and control over all drives still is in the external control unit.

  Other features:

  – Command triggering of the CCD slaves by higher-level control unit ("remote" external with profile interpreter or possibly via local MLD with permanent control)

  – Process data exchange possible between CCD master and slaves, as well as between external control unit and CCD slaves

  – CCD slaves are known to external control unit (logic nodes)

- Preferably use the **CCD basic mode (expert mode)**, when an MLD with permanent control is used in at least one CCD slave

  - or -

  when mere command value linking is to be realized with "sercos" or "Analog" master communication and control still is in the external control unit.

  Other features:

  – Command triggering of CCD slaves can take place by higher-level control unit ("remote" external, but without profile interpreter) via parameter P-0-1806.x.11 in the master, via MLD in the master drive or, where possible, via local MLD-S with permanent control

  – Only process data exchange between CCD master and slaves; CCD slaves are **not** known to external control unit (no logic nodes)

- Preferably use the **MLD-M system mode (command triggering master: MLD-M in CCD master)**, when multi-axis motion is to be realized in the master and the MLD in the master is to access the remote axes (CCD slaves), too.

  Other features:

  – Command triggering of the CCD slaves takes place via MLD-M in the master drive or, where possible, via local MLD-S with permanent control

  – Only process data exchange between CCD master and slaves

  – CCD slaves are **not** known to external control unit (no logic nodes)

The figure below illustrates how to select the appropriate CCD mode:

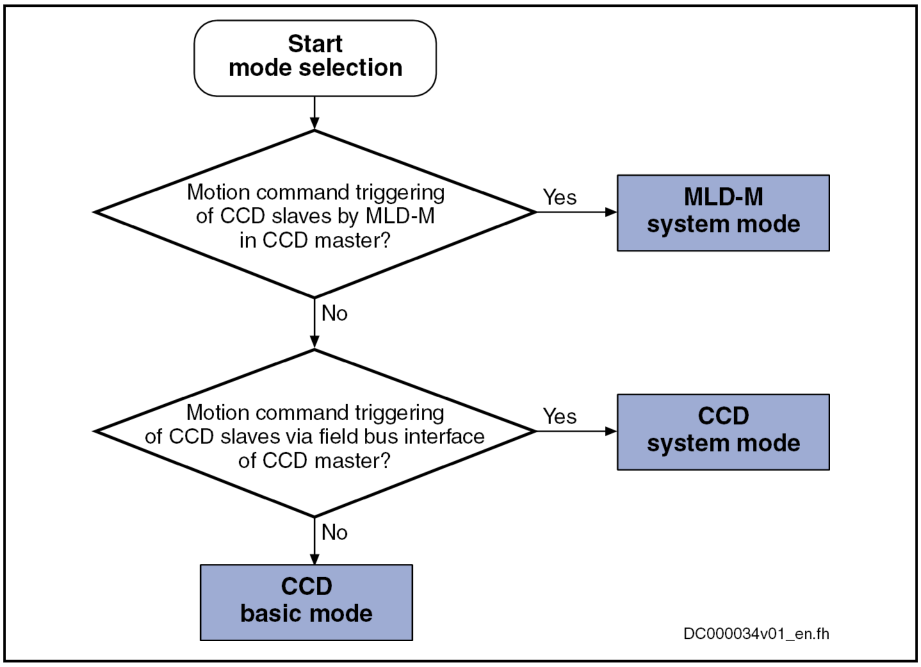


Fig. 9-21: Selection Criteria for CCD Mode (See P-0-1800.0.1)

Selection Criteria

Using the **CCD system mode** makes sense when:

- The external master is to have control over the CCD slaves,
- process data (command values and actual values) must be exchanged between the external master (e.g. field bus interfaced PLC) and the CCD slaves,
- other process data apart from the external process data are preset by the CCD master for the CCD slaves (e.g. command value linking).

Using the **CCD basic mode** makes sense when:

- The external master is to have control over the CCD slaves,
- only process data are preset by the CCD master for the CCD slaves (e.g. command value linking),
- an MLD with permanent control is used in the slave axes.

Using the **MLD-M system mode** makes sense when:

- The CCD master is to have control over the CCD slaves,
- only data between CCD master and CCD slaves are exchanged.

Setting the Cycle Time

Depending on the slowest controller performance (position controller clock), the minimum CCD cycle time to be set can be selected in the CCD group. The CCD cycle time must not be smaller than the slowest position controller clock in the CCD group:

- Advanced performance: 0.25 ms, 0.5 ms, 1 ms, 2 ms, 4 ms
- Basic performance: 0.5 ms, 1 ms, 2 ms, 4 ms
- Economy performance with CSB01.1 control sections: 1 ms, 2 ms, 4 ms
- HCS01.1 Economy: 2 ms, 4 ms

☞ The MLD-M mode is only possible in Basic performance of the CCD master; in addition, the CCD cycle time which was set has to be greater than the slowest position controller clock in the CCD group!

The possible CCD cycle time results from the number of CCD slaves and the selected CCD mode (see "Performance Features").

☞ The CCD cycle time should always be greater than the slowest position controller clock of the CCD group. If both cycle times are equal, only half of the cyclic data can be transmitted to the corresponding CCD slave.

Assigning the Addresses

By means of the fields for projecting the CCD slaves, the sercos address is assigned to the slave number (Axis_x) for the drives and compact I/Os of the CCD group.

Axis No. The axis no. (slave no.) refers to the CCD slave number relevant to the CCD configuration in the CCD master. This number is also equivalent to the logic axis number Axis_x of MLD-M (Axis2 to Axis_10).

sercos Address The sercos address establishes an unequivocal relationship between the logic axis number and the physical device. Any access to the logic axis number by the CCD master or the MLD-M is executed on the device with this sercos address (S-0-1040 in the sercos slave) via the address entered here.

Deactivated If a projected CCD slave does not physically exist, it can be deactivated for the CCD master by marking this field. This does not result in a displacement of the logic order and the remaining CCD configuration can be maintained. This provides the advantage that projects of similar applications, which only differ in the existence of individual slaves, can be easily changed.

Error reaction

CCD error reaction With regard to the error reaction of the CCD group, you have to observe that apart from the module bus connection there is an additional digital connection of the master communication. That is why there are different possibilities for the group to react in the cause of error which must be specifically selected and coordinated. The possible error reactions are summarized in the table below.

Kind of error reaction	Description
Independent error reaction	All axes in the group carry out an independent error reaction, when package reaction has not been activated and the CCD error reaction has not been activated either.
Package reaction	The axes operated in the axis group at a DC bus are interconnected via the module bus and carry out a collective coordinated error reaction (package reaction) in the case of error (see "Error Reactions: Package Reaction on Error")
CCD error reaction	For certain applications (e.g. Gantry axes) it can be useful to shut down the complete CCD group in a controlled way or at least equally in all axes when an error occurs in a CCD slave or in the CCD master. If required, it is therefore possible to activate a CCD error reaction in the CCD master!

Tab. 9-10: Overview of Error Reactions of the CCD Group

Configuring the Error Reaction The CCD error reaction is set in the IndraWorks dialog window shown below:

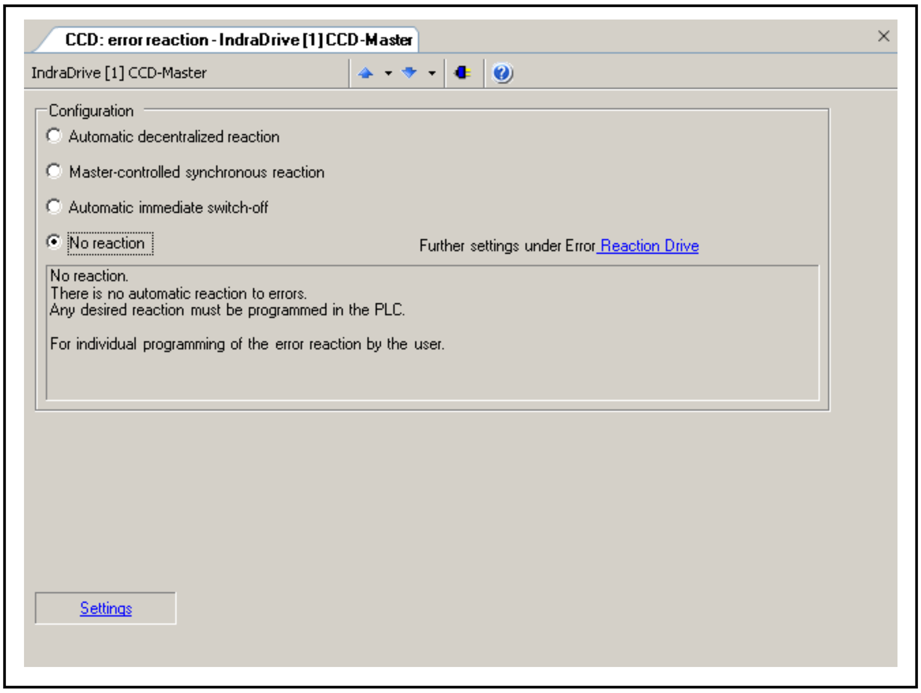


Fig. 9-22: IndraWorks Dialog for Configuring the CCD Error Reaction

Explanation of possible settings:

- No reaction

  In the case of an error in a CCD axis, other CCD axes do not react automatically. A group error reaction has to be explicitly programmed by the control unit (example of application: master-axis-synchronous deceleration).

☞ In the MLD-M mode, motion function blocks of MLD do not trigger any error in the case of faulty parameter setting.

- Automatic decentralized reaction

  In the case of errors in a CCD slave, the warning "E2140 CCD error at node" is displayed in the master (example of application: master-axis-synchronous deceleration).

☞ In the MLD-M mode, this warning is also displayed when a motion function block with faulty parameters is called in MLD-M, if this has been set in "P-0-1367, ".

- Master-Controlled Synchronous Error Reaction

  The error reactions of master and slaves take place depending on the error class (F2xxx, F4xxx, …) and the configuration in parameter "P-0-1800.0.1, CCD: Configuration" see figure below (usage example: mechanically coupled axes).

☞ In the MLD-M mode, the error "E2140 CCD error at node" is displayed in the master, when a motion function block with faulty parameters is called in MLD-M, if this has been set in parameter "P-0-1367, ". For the remote CCD slaves, automatic deceleration does not take place in the case of a motion function block error, but the error reaction has to be programmed by means of MLD!

- **Automatic immediate switch-off**

  When the CCD master detects that an axis in the CCD group (master or slave) signals a class 1 diagnostics error, all axes are decelerated with "best possible deceleration" (see P-0-0119). The CCD master outputs the error message "F2140 CCD slave error". If the CCD master is not in control, only the warning "E2140 CCD error at node" is displayed (the axes are nevertheless decelerated!).

Special Case: Master-Controlled Synchronous Error Reaction

When the **master-controlled synchronous error reaction** is active, the content of the parameters P-0-1808.x.1 ("x" number of the slave) is cyclically evaluated and interpreted in the CCD master. Depending on the error class of the slave diagnosis number, the corresponding error message is generated in the CCD master when the slave signals an error and the master is in control. The other CCD slaves react directly to the error message of the master (see fig. below).

We distinguish between:

- Non-fatal (safety technology) errors (F2xxx, F3xxx)
- Interface errors (F4xxx)
- Travel range errors, safety technology errors (F6xxx, F7xxx)
- Fatal errors (F8xxx)

In addition, the F8xxx and F4xxx errors of the slaves are specifically treated in the master with the error reaction active:

- In the case of a fatal error (F8xxx), the CCD error reaction of master and slaves (torque disable, best possible deceleration) is defined depending on the setting in parameter P-0-1800.0.1 (bit 9).
- If an F4xxx error is present, it is always the error reaction "best possible deceleration" which is triggered.

As regards the master-controlled synchronous error reaction of the CCD group, we must basically distinguish two cases of possible errors:

- Error in a CCD slave
- Error in the CCD Master

Error in the CCD Slave

The figure below illustrates the cases of possible errors in the CCD slave and the corresponding error reaction in the CCD master for the master-controlled synchronous error reaction.

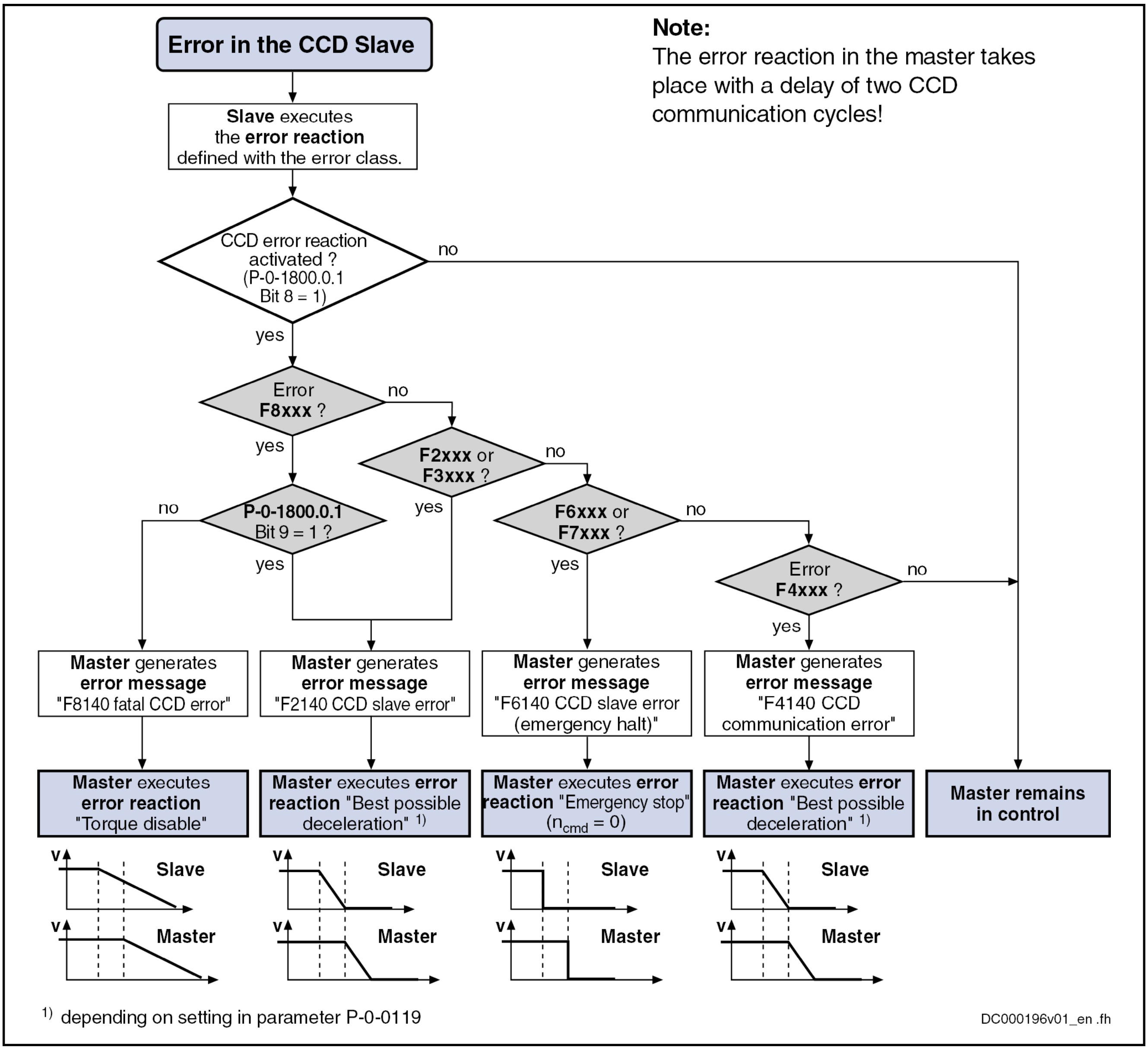


Fig. 9-23: CCD Error Reaction for Master-Controlled Synchronous Error Reaction to Error in the Slave

Error in the CCD Master

The figure below illustrates the cases of possible errors in the CCD master and the resulting reaction of the slaves for the master-controlled synchronous error reaction.

☞ The reactions of the slaves are (implicitly) preset, run automatically and do not need to be activated!

Optional Device Functions

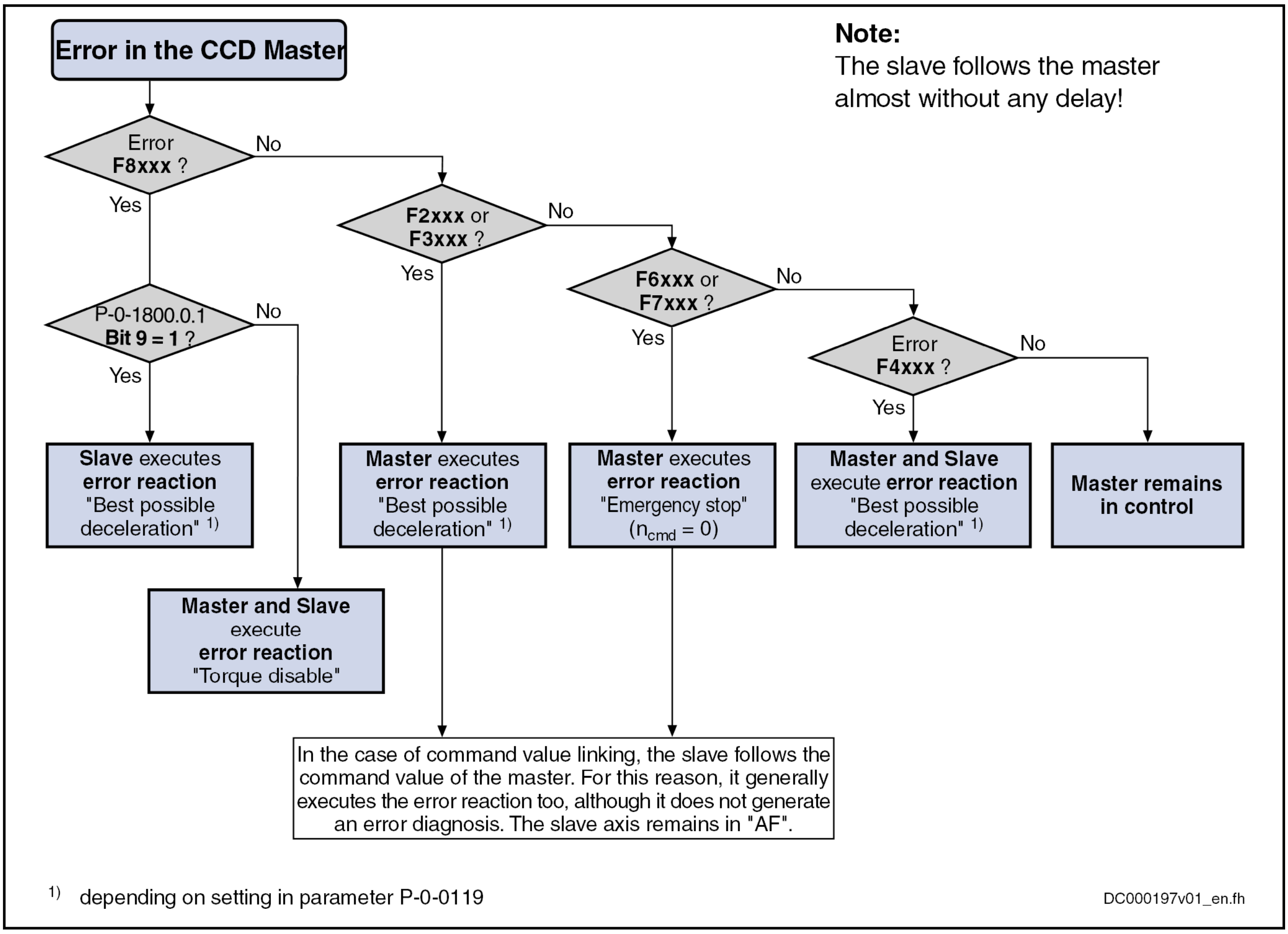


Fig. 9-24: CCD Error Reaction for Master-Controlled Synchronous Error Reaction to Error in the Master

IP Settings

To establish an EtherNet connection with the CCD master, the IP address of the Engineering Port can be read or set in the IndraWorks dialog window shown below.

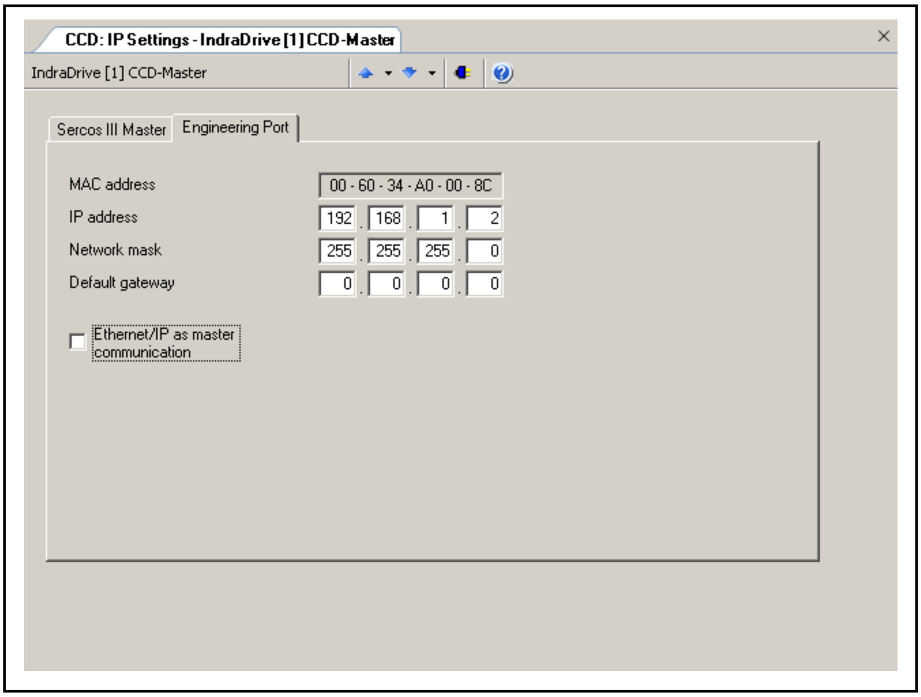
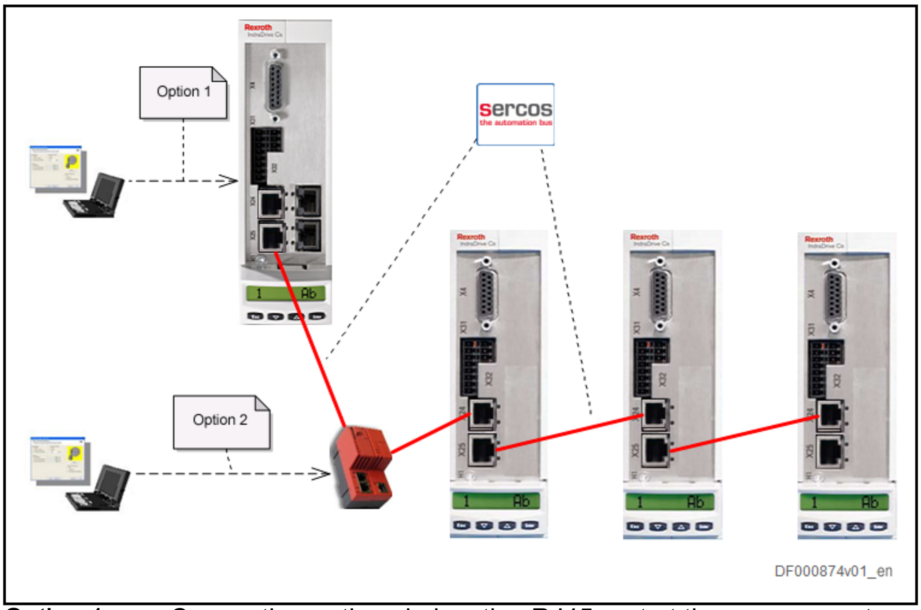


Fig. 9-25: IndraWorks Dialog for IP Settings

Connection Options

The IP communication with the sercos master can take place via different connections, as schematically illustrated in the figure below.



Option 1 Connection option via inactive RJ45 port at the sercos master (CCD interface)

Option 2 Connection option via a sercos NRT Plug

Fig. 9-26: Connection Options for IP Communication for sercos Master (CCD Interface)

The information for setting the IP configuration for the sercos interface (CCD master) are included in the status parameter "P-0-1644, CCD: Status IP communication". Besides, other pieces of information on the IP communication are made available via the parameter.

With the CCD master, parameters can be accessed by means of IP communication via two different protocols. The S/IP protocol (TCP port 35021) or the

SIS protocol (TCP port 5002). The parameters of the CCD master can be set via both protocols. Accessing the parameters of the CCD slaves is only possible via the SIS protocol. The following must be taken into account during the implementation of the access to CCD slaves using SIS protocol:

- The address of the CCD master must be entered as receiver address in the general SIS telegram header.
- The receiver address (component address) to be entered in the service-dependent section for the parameter services 0x80, 0x10, etc. is the address of the CCD slave.
- The master will accept the telegram and transmits the request to the CCD slave via the cross communication.

Free process data

By means of the free process data, parameter values of the CCD master (command values) can be copied to parameters of the CCD slaves. The other way round it is possible to copy parameter values of the CCD slaves (actual values) to parameters of the CCD master.

Only in the CCD system mode is it additionally possible to exchange data between higher-level control unit and the CCD slaves.

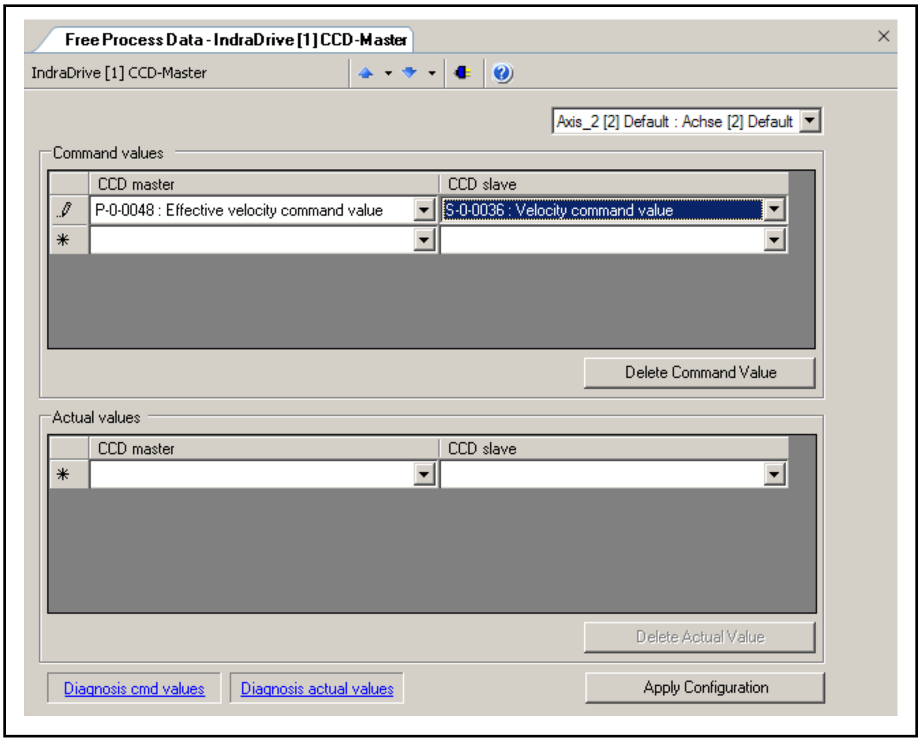


Fig. 9-27: IndraWorks Dialog for Configuring the Process Data Between CCD Master and CCD Slave

Under the command values in the column of the CCD master, enter the parameter the value of which is to be copied to the selected CCD slave. In the column of the CCD slave in the same row, set the parameter of the CCD slave to which this value is to be copied.

Under the actual values in the column of the CCD master, enter the parameter to which the parameter value of the CCD slave is to be copied. In the column of the CCD slave in the same row, set the parameter value of the CCD slave which is to be copied to the parameter of the CCD master.

Please observe:

- You first have to select for which CCD slave (Axis_x) the free process data are to be configured.
- With Axis_1 you address the so-called "virtual slave". This slave is used for artificially delaying command values in the CCD master for dead time compensation and is automatically configured in the MLD-M system mode.
- The parameter of the CCD master and the belonging target or source parameter in the CCD slave must have the same data length.

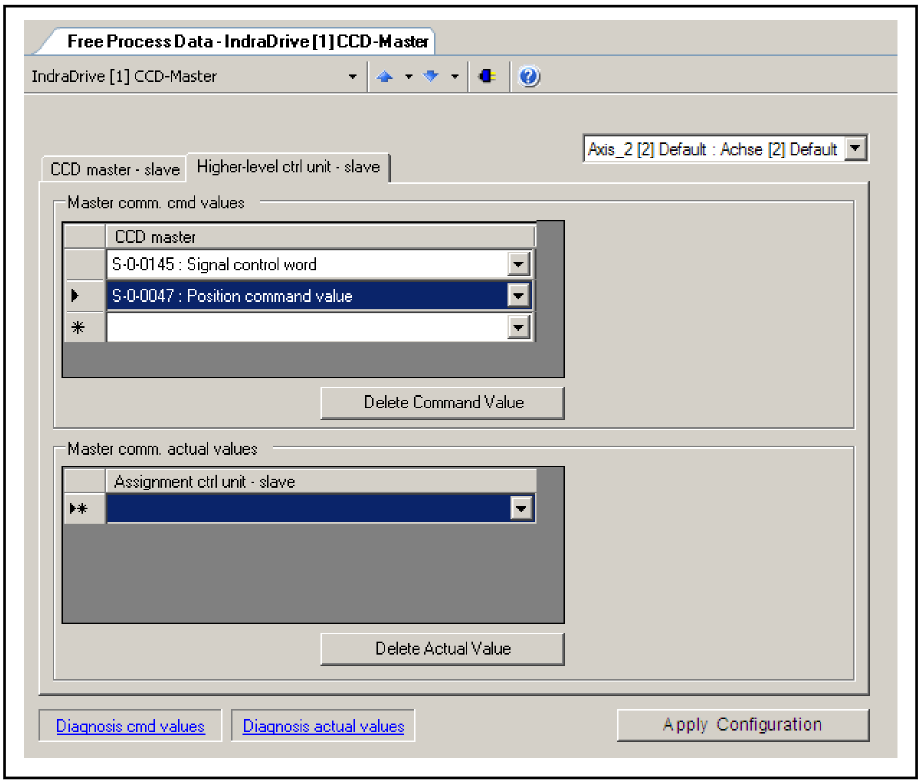


Fig. 9-28: IndraWorks Dialog for Configuring the Process Data Between Higher-Level Control Unit and CCD Slave (with CCD System Mode Only)

Under the command values of master communication, enter the parameters of the CCD slave which are directly and cyclically written by the external control unit. Under the actual values of master communication, enter the parameters of the CCD slave which are to be cyclically read by the external control unit. The entered parameters have to be taken into account in the output and input data of the external control unit.

Please observe:

- If the four unassigned bits of the signal control word (see below) are to be used, the parameter "S-0-0145, Signal control word" always has to be contained in the master communication command values.
- If the four unassigned bits of the signal status word (see below) are to be used, the parameter "S-0-0144, Signal status word" always has to be contained in the actual master communication values.
- A control word for the CCD slave, with a structure identical to the parameter "P-0-4077, Field bus: Control word", is always contained in the master communication command values. For this word you do not have to make any entry. Therefore, the 2 bytes always have to be taken into account at the first place in the output data of the control unit for the corresponding CCD slave (see "Overview Process Data, Command Val-

ues"). Via these bytes, the control unit can command each CCD slave individually like a normal field bus drive.

- A status word of the CCD slave, with a structure identical to the parameter "P-0-4078, Field bus: Status word", is always contained in the actual master communication values. For this word you do not have to make any entry. Therefore, the 2 bytes always have to be taken into account at the first place in the input data of the control unit of the corresponding CCD slave (see "Overview Process Data, Actual Values"). Via these bytes, the external control unit cyclically gets the status of each CCD slave.

Signal status word

Use in the CCD System Mode (Does not Apply to EtherCAT® and sercos)

By means of the CCD signal status word, individual bits of the CCD slave can be directly read by the external control unit in the CCD system mode (see "S-0-0144, Signal status word" for normal field bus slave). It is necessary to indicate which bit of which parameter of the CCD slave is output via the corresponding bit in the CCD signal status word.

☞ To read the CCD signal status word in the external control unit in the CCD system mode, the corresponding CCD slave must have entered the parameter S-0-0144 in the (cyclic) free process data of the control unit!

Only the bits 12 to 15 can be configured. The other bits are reserved (bits 0 to 11 are always zero in the control unit)!

Used in the MLD-M System Mode

By means of the CCD signal status word, individual bits in the CCD slave, in the MLD-M system mode, can be directly read by MLD-M in the CCD master via the so-called AxisData structure (AxisData elements: wUserActualDataBitA_q to wUserActualDataBitD_q). It is necessary to indicate which bit of which parameter of the CCD slave is addressed via the corresponding element of the AxisData structure.

Used in the CCD Basic Mode

If the signal status word of the CCD slaves (S-0-0144) is to be read by the CCD master, the free process data between CCD master and CCD slave (P-0-1805.x.2 and P-0-1805.x.4) have to be used for this purpose. The parameter S-0-0144 of the CCD slave has to be copied to parameter P-0-1808.x.2 of the CCD master. The parameter P-0-1808.x.2 then has to be read in the CCD master.

IndraWorks Dialog

Via the dialog window below, IndraWorks supports the configuration of the signal status word. This IndraWorks dialog is **not available in the CCD basic mode.**

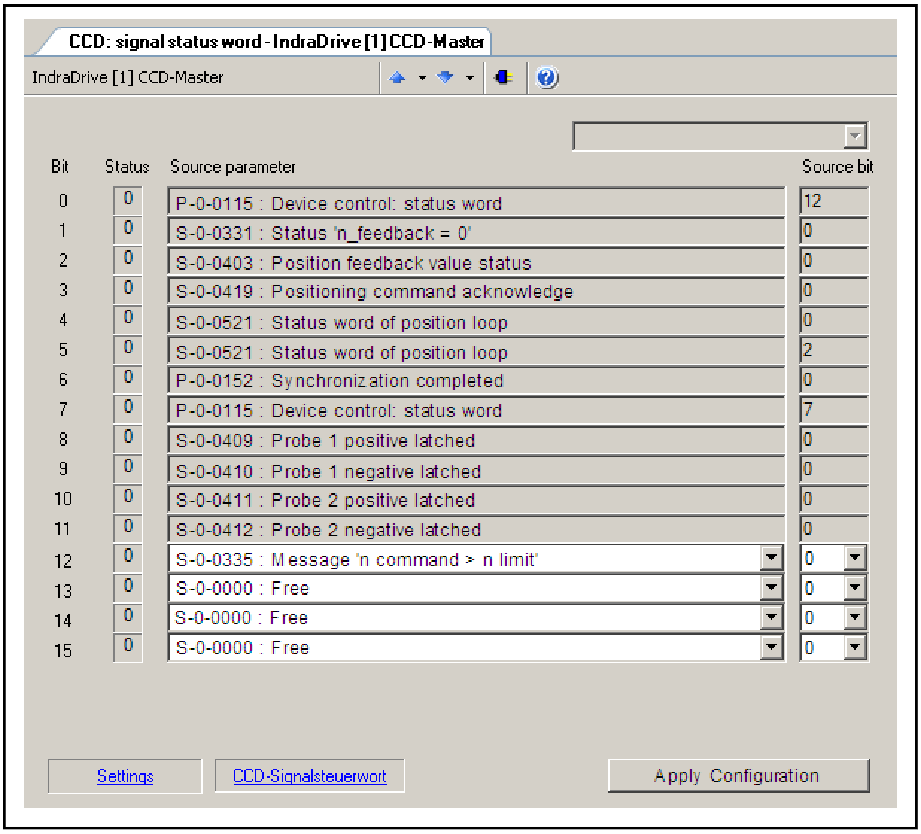


Fig. 9-29: IndraWorks Dialog for Configuring the Signal Status Word

Signal control word

Use in the CCD System Mode (Does not Apply to EtherCAT® and sercos)

By means of the CCD signal control word, individual bits in the CCD slave can be directly addressed by the external control unit in the CCD system mode (see "S-0-0145, Signal control word" for normal field bus slave). It is necessary to indicate which bit of which parameter of the CCD slave is addressed via the corresponding bit in the CCD signal control word.

> To use the CCD signal control word of the external control unit in the CCD system mode, the parameter S-0-0145 must have been entered in the (cyclic) free process data of the control unit to the corresponding CCD slave!

> Only the bits 12 to 15 can be configured. The other bits are reserved.

Used in the MLD-M System Mode

By means of the CCD signal control word, individual bits in the CCD slave, in the MLD-M system mode, can be directly addressed by MLD-M in the CCD master via the so-called AxisData structure (AxisData elements: wUserCmdDataBitA_q to wUserCmdDataBitD_q). It is necessary to indicate which bit of which parameter of the CCD slave is addressed via the corresponding element of the AxisData structure.

Used in the CCD Basic Mode

If the signal control word of the CCD slaves (S-0-0145) is to be written by the CCD master, the free process data between CCD master and CCD slave (P-0-1805.x.1 and P-0-1805.x.3) have to be used for this purpose. The parameter P-0-1808.x.3 of the CCD master has to be copied to parameter S-0-0145 of the CCD slave. The parameter P-0-1808.x.3 then has to be written in the CCD master.

IndraWorks Dialog

Via the dialog window below, IndraWorks supports the configuration of the signal control word. This IndraWorks dialog is **not available in the CCD basic mode.**

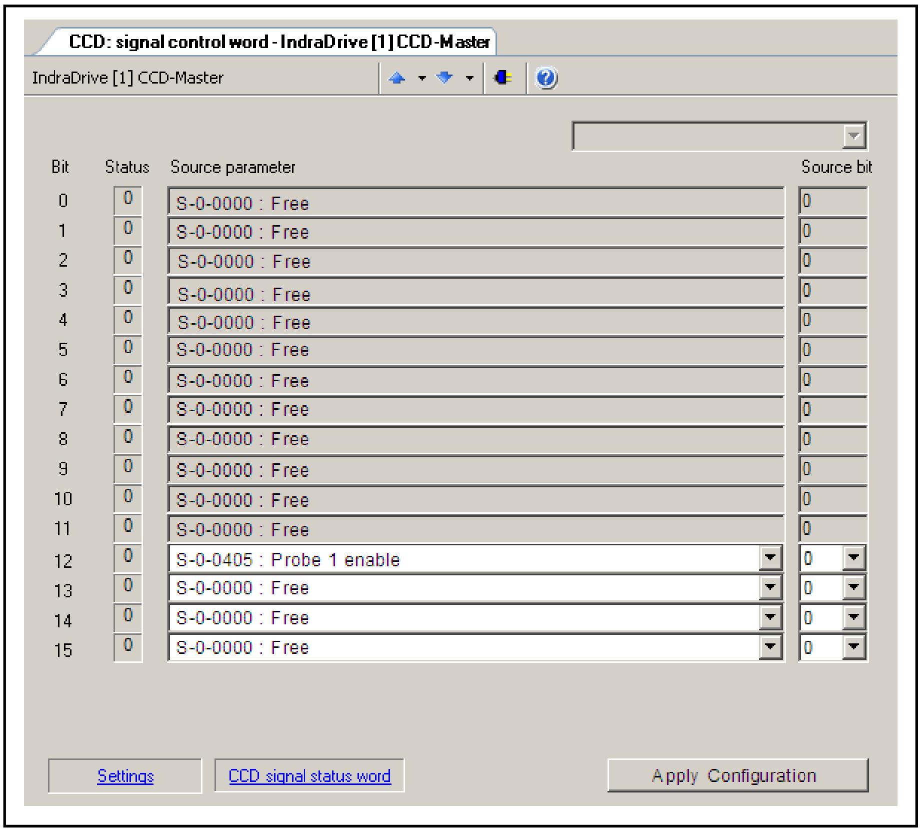


Fig. 9-30: IndraWorks Dialog for Configuring the Signal Control Word

Master Axis Linking

Parameterization of the Master Axis Linking in IndraWorks

The dialog for configuring the synchronous multi-axis movement can be called from the dialog for the CCD basis settings:

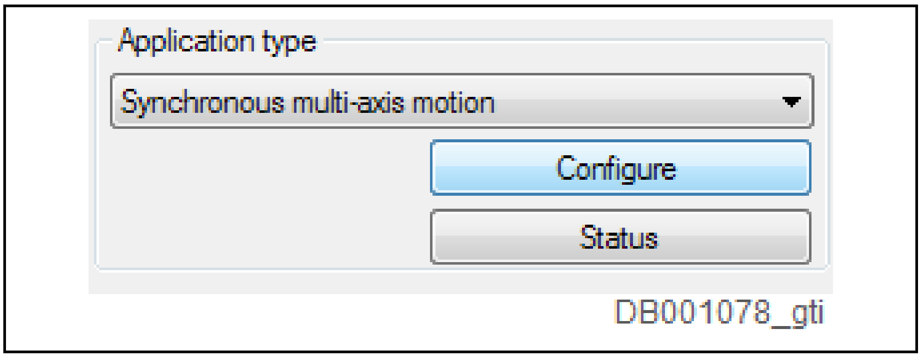


Fig. 9-31: Configuration via the CCD Basis Settings

The dialog can also be called up directly via the menu item "sercos(CCD) -> CCD: application type configuration":

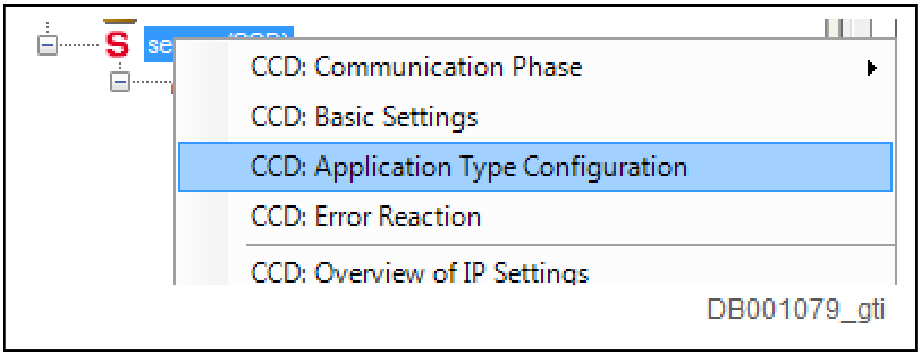


Fig. 9-32: Configuration via Menu Item "sercos(CCD) -> CCD: Application type configuration"

The dialog comprises the following:

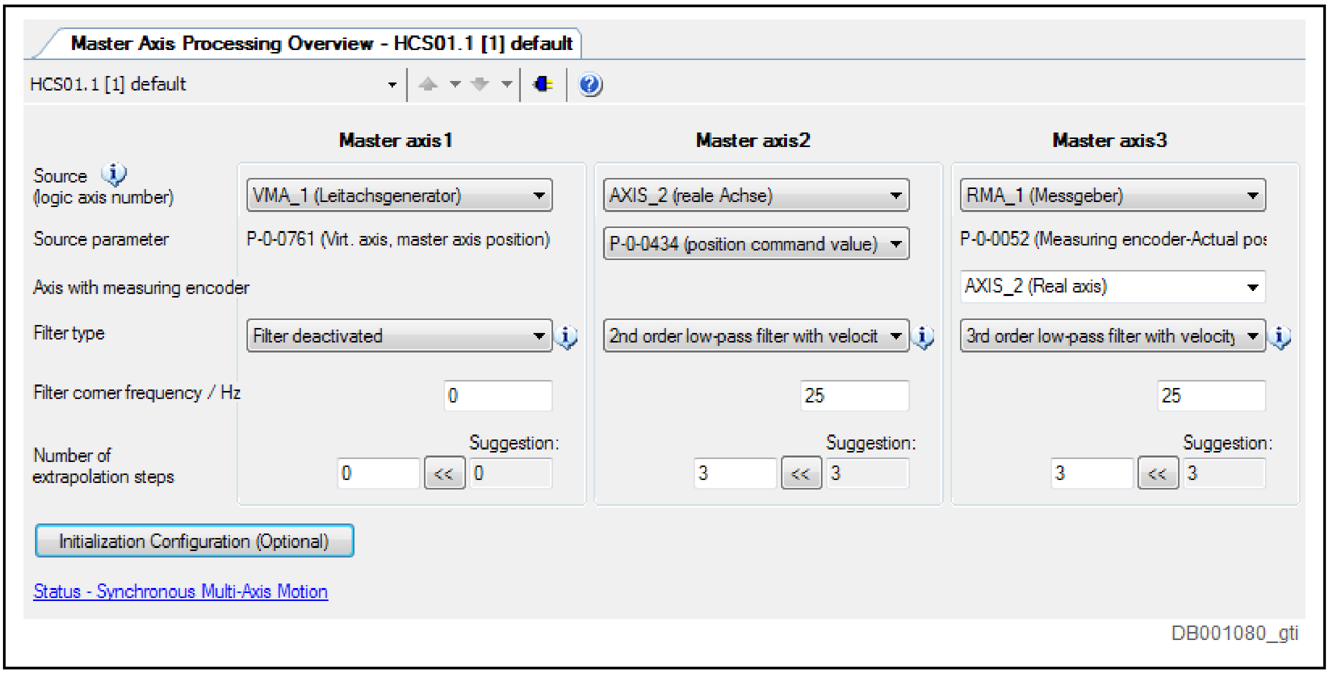


Fig. 9-33: Dialog for Configuring Synchronous Multi-Axis Movement

The master axis configuration list is set by specifying the logical axis numbers of the sources in the top row.

For master axis 2, the position of axis 2 is specified as the source. In row 2, it must also be indicated whether the position command or actual value is to be used.

If, as with master axis 3, a measuring encoder is indicated as a source, in row 3, it can also be indicated from which axis of the "P-0-0052, Actual position value of measuring encoder" is to be retrieved.

☞ Only one measuring encoder can be used as a master axis source.

The required filter is selected in the fourth row of the dialog. The filter 1st order corresponds, in terms of its structure, to the filter which also exists in the source axis to smoothen the position actual value measuring encoder (P-0-0052).

The filter corner frequency is set in the fifth row. The smaller the defined value, the larger the filter effect.

The sixth row shows by how many NC cycles the adjusted master axis position is to be extrapolated. The extrapolation is required in order to compensate for transfer times and the time for a fine interpretation. The larger the number of extrapolation cycles however, the more faults are amplified, and the larger the deviations when accelerating and braking.

In the lower part of the dialog, you can open the dialog for initialization configuration:

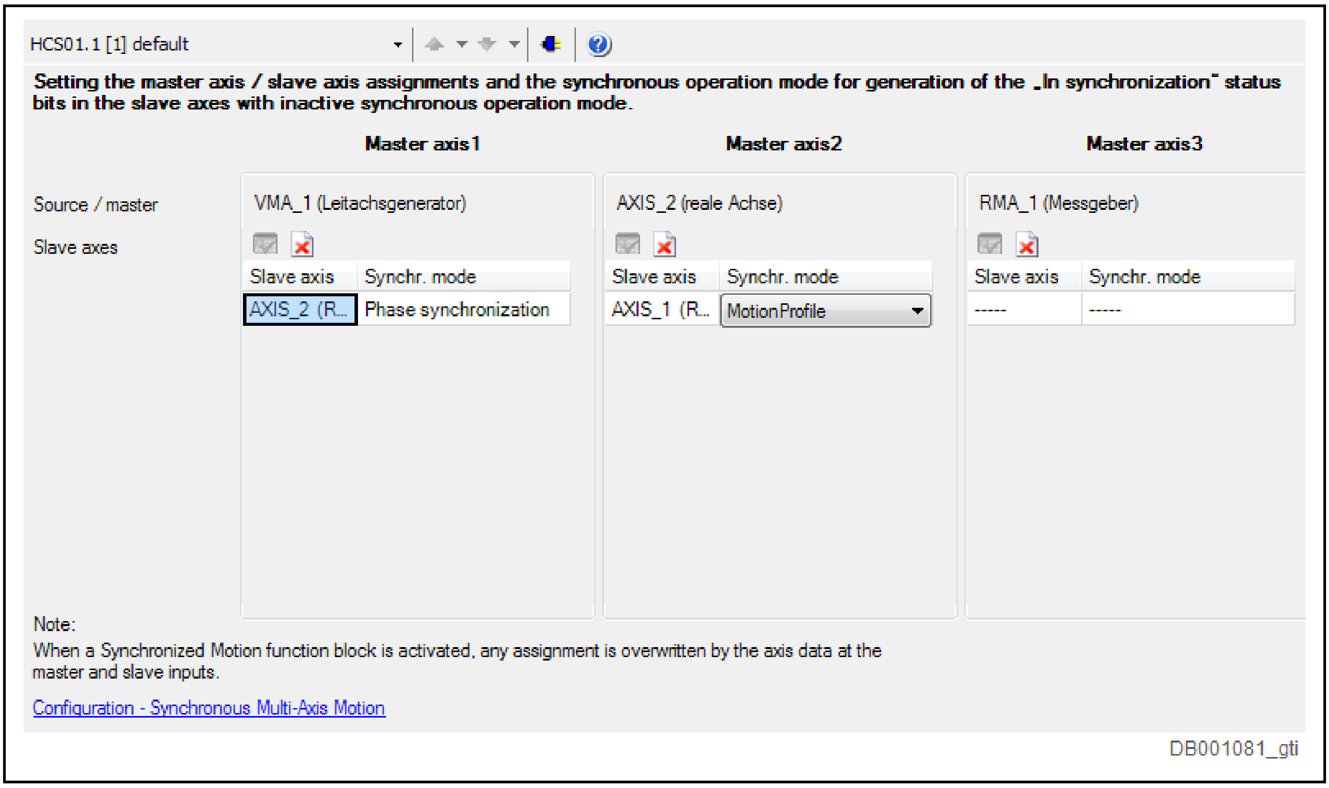


Fig. 9-34: Dialog for the Initialization Configuration

In this dialog, you must specify how the assignment of the 3 adjusted master axes to the CCD slave axes takes place after reaching the operating mode. It is also specified for which synchronization operating mode after reaching the operating mode the Bit "In Synchronization" in a CCD slave axis is form.

The parameters "P-0-1822.0.1, CCD: Default master axis selection for the IndraDrive axes" and "P-0-1823.n.1, CCD: Default synchronization mode for axis n" are changed. Basic settings for the parameter "P-0-1822.0.2, CCD: Master axis selection for the IndraDrive axes" in the CCD master axis and for the parameter "P-0-0088, Control word synchronization modes" in the relevant CCD slave axis.

☞ Both settings only remain active up to one change. A change can either be direct or through the activation of a synchronous motion function module.

Status of the Master Axis Linking

In IndraWorks the current status of the master axis linking is displayed in the following dialog:

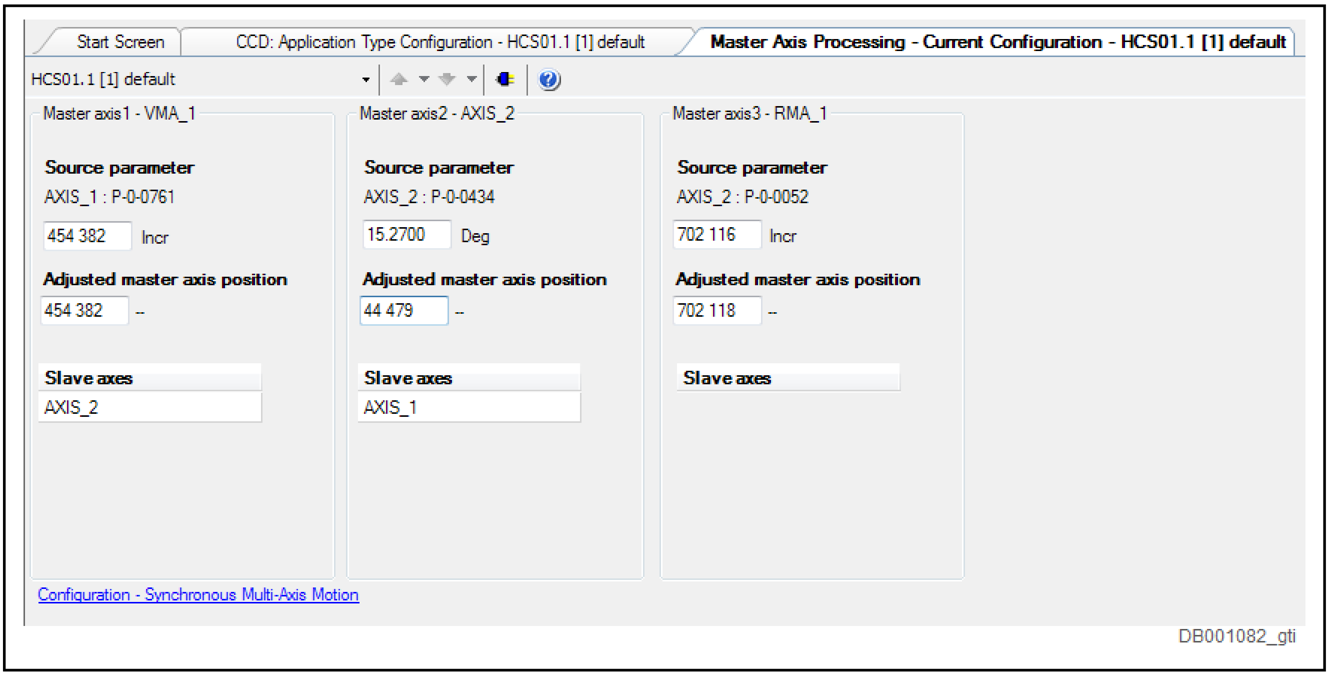


Fig. 9-35:

The master axis configuration is shown in the upper-most row.

In the next row, the data of the source parameters are shown. The prepared master axis positions are displayed.

The evaluation of the parameter "P-0-1822.0.2, CCD: Master axis selection for the IndraDrive axes" delivers the information shown below about which CCD slave axis is assigned to which master axis.

9.3.4 Diagnostic and Status Information

Diagnostic Information

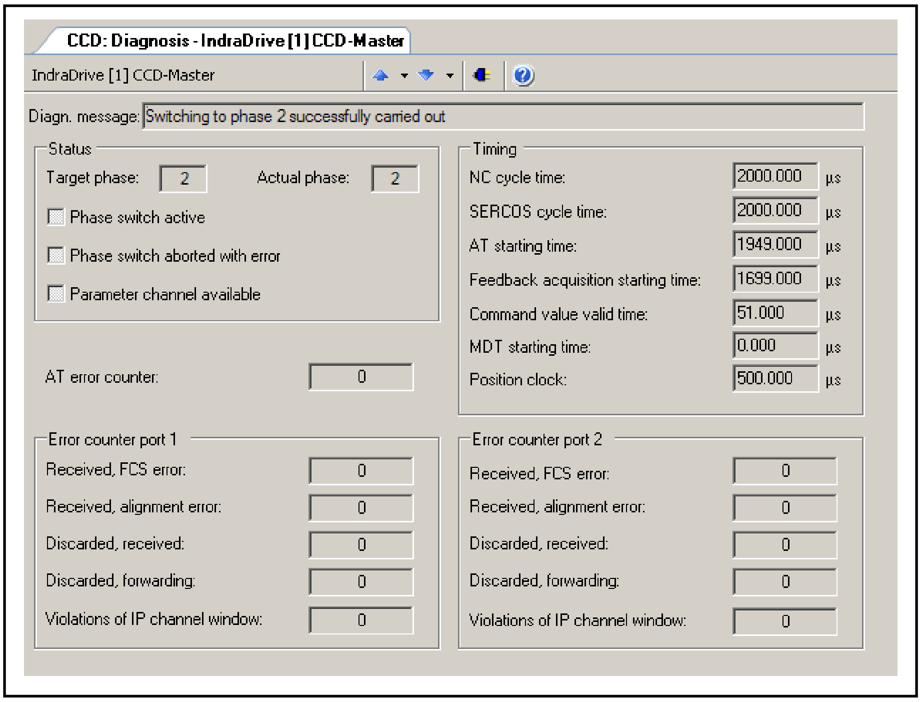


Fig. 9-36: Diagnostic Information in IndraWorks for CCD Communication

In the case of problems with the sercos cross communication between CCD master and connected CCD slaves, you can get different kinds of information in this IndraWorks window:

- Diagnostic message text for CCD cross communication
- Status of phase switch of the entire CCD group
- Timing of the sercos connection
- Number of AT telegrams which have failed in "AT error counter"
- Count of error counters of sercos FPGA according to sercos specification in "Error counter port 1" and "Error counter port 2"

Overview Process Data, Command Values

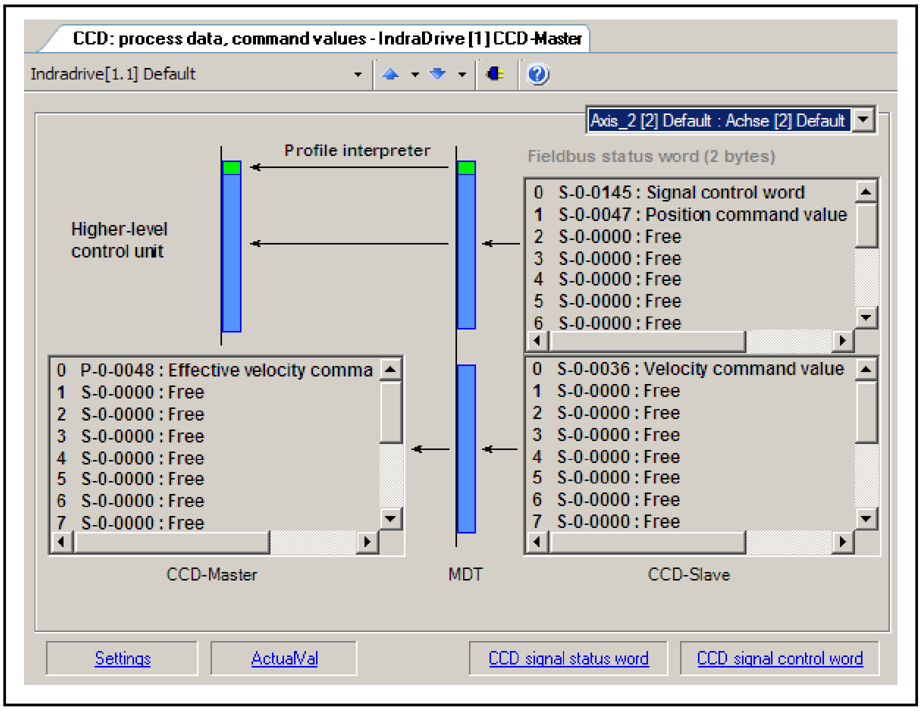


Fig. 9-37: IndraWorks Overview Window of Process Data Command Values

This overview shows all process data command values for the selected CCD slave. The lower part displays the process data command values which are copied from the CCD master (left side) to the corresponding parameters of the CCD slave (right side). In the MLD-M system mode, the data configured in the AxisData structure are displayed here, too.

In the CCD system mode and apart from the process data between CCD master and CCD slave, the upper part displays the cyclic command values which directly go from the external control unit to the slave. The output data which the control unit has to take into account can be seen here. The field bus control word for the CCD slave which is always existing is displayed (and to be taken into account in the output data of the control unit), too.

Overview Process Data, Actual Values

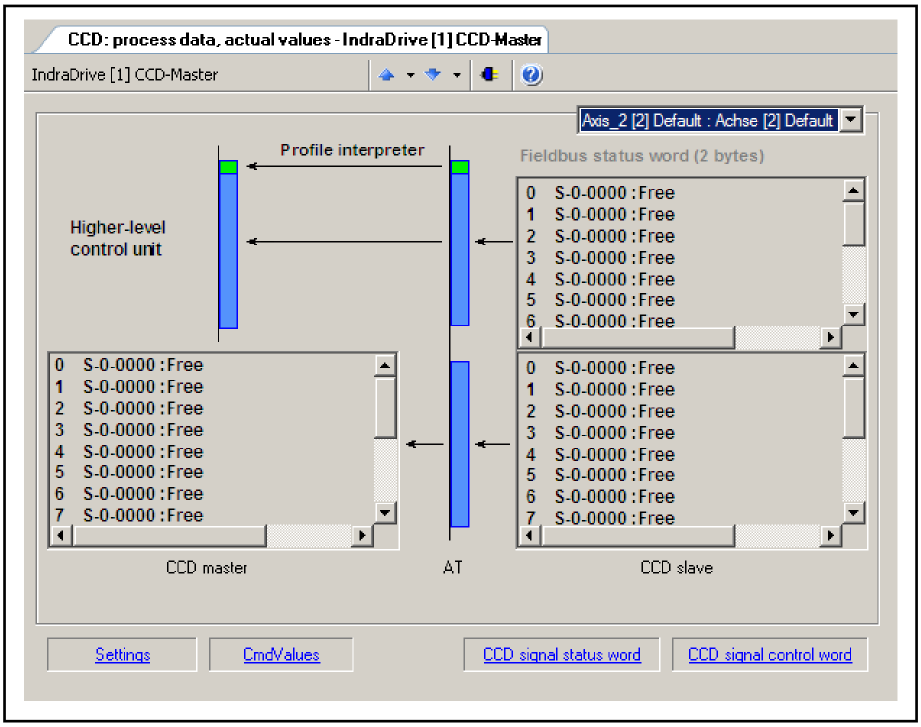
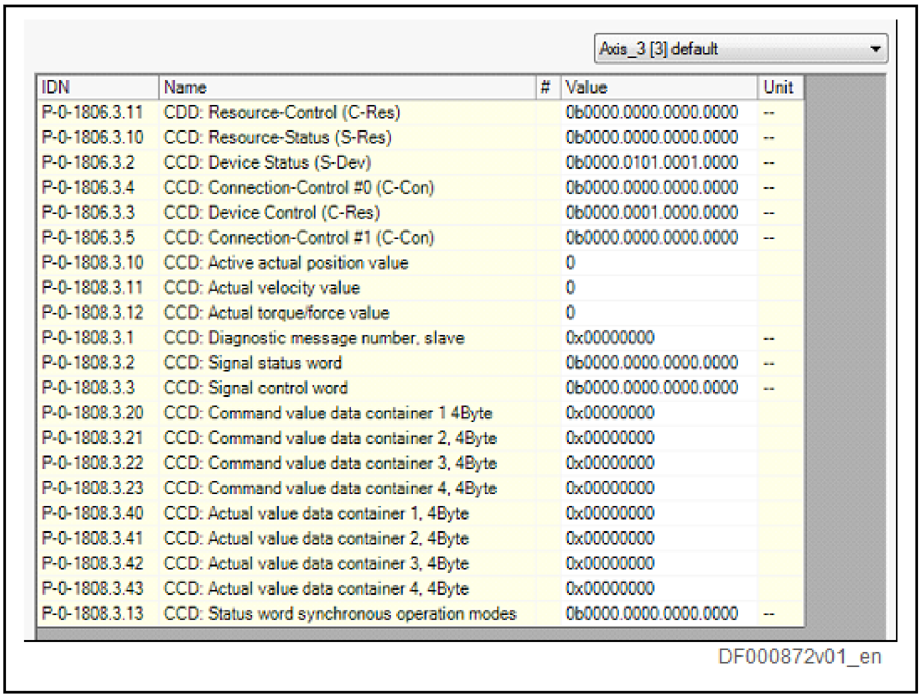


Fig. 9-38: IndraWorks Overview Window of Actual Process Data Values

This overview shows all actual process data values for the selected CCD slave. The lower part displays the actual process data values which are copied from the CCD slave (right side) to the corresponding parameters of the CCD master (left side). In the MLD-M system mode, the data configured in the AxisData structure are displayed here, too.

In the CCD system mode and apart from the process data between CCD master and CCD slave, the upper part displays the cyclic actual values which directly go from the CCD slave to the external control unit. The input data which the control unit has to take into account can be seen here. The field bus status word of the CCD slave which is always existing is displayed (and to be taken into account in the input data of the control unit), too.

Slave Status


Axis_3 [3] default

IDN	Name	#	Value	Unit
P-0-1806.3.11	CDD: Resource-Control (C-Res)		0b0000.0000.0000.0000	--
P-0-1806.3.10	CCD: Resource-Status (S-Res)		0b0000.0000.0000.0000	--
P-0-1806.3.2	CCD: Device Status (S-Dev)		0b0000.0101.0001.0000	--
P-0-1806.3.4	CCD: Connection-Control #0 (C-Con)		0b0000.0000.0000.0000	--
P-0-1806.3.3	CCD: Device Control (C-Res)		0b0000.0001.0000.0000	--
P-0-1806.3.5	CCD: Connection-Control #1 (C-Con)		0b0000.0000.0000.0000	--
P-0-1808.3.10	CCD: Active actual position value		0	
P-0-1808.3.11	CCD: Actual velocity value		0	
P-0-1808.3.12	CCD: Actual torque/force value		0	
P-0-1808.3.1	CCD: Diagnostic message number, slave		0x00000000	--
P-0-1808.3.2	CCD: Signal status word		0b0000.0000.0000.0000	--
P-0-1808.3.3	CCD: Signal control word		0b0000.0000.0000.0000	--
P-0-1808.3.20	CCD: Command value data container 1 4Byte		0x00000000	
P-0-1808.3.21	CCD: Command value data container 2, 4Byte		0x00000000	
P-0-1808.3.22	CCD: Command value data container 3, 4Byte		0x00000000	
P-0-1808.3.23	CCD: Command value data container 4, 4Byte		0x00000000	
P-0-1808.3.40	CCD: Actual value data container 1, 4Byte		0x00000000	
P-0-1808.3.41	CCD: Actual value data container 2, 4Byte		0x00000000	
P-0-1808.3.42	CCD: Actual value data container 3, 4Byte		0x00000000	
P-0-1808.3.43	CCD: Actual value data container 4, 4Byte		0x00000000	
P-0-1808.3.13	CCD: Status word synchronous operation modes		0b0000.0000.0000.0000	--

DF000872v01_en

Fig. 9-39: Overview Window of Slave Status Information

This overview displays all pieces of status information on the selected CCD slave available in the CCD master (incl. the containers for copying).

9.4 Rexroth IndraMotion MLD (Drive-Integrated PLC)

9.4.1 Brief Description

Assignment to Functional Firmware Package: Expansion packages **IndraMotion MLD** (order code **ML, MA or TF**)

The optional expansion packages "IndraMotion MLD" provide the function of a PLC integrated in the drive according to IEC 61131-3 with the following scope of functions:

- **Integrated logic control** (standard PLC tasks)
  - Compliant with IEC-61131-3
  - Online Change
  - Debugging
- **Integrated multi-axis/single-axis motion control**

  → Motion function block according to PLCopen positioning and synchronization mode
  - Programming via ST, SFC, FBD and LD
  - Library management with system and user libraries
- **Basis for technology functions**

  → Examples: Following-on cutting devices, process controller (register controller, winding computation, Productivity Agent, IndraMotion for Handling, IndraMotion for Metal Forming, …

This optional extension of the drive functionality is described in detail in the separate documentation "Rexroth IndraMotion MLD (2G) as of MPx18" (DOK-INDRV*-MLD3-**VRS*-AP**-EN-P; mat. No. R911338914).

Hardware Requirements / Characteristics

According to the design, the expansion packages "IndraMotion MLD" require one of the following control section designs:

- **IndraMotion MLD-M** (multi-axis motion control; only firmware "MPC")
  - Single-axis ADVANCED (HCS01.1E-W0xx-A-02-**A**-...)
  - As stand-alone multi-axis Motion Logic Control using CCD (Cross Communication Drives) on the basis of sercos
- **IndraMotion MLD-S** (single-axis motion control; only firmware "MPB" / "MPC")
  - Single-axis ADVANCED (HCS01.1E-W0xx-A-02-**A**-...)
  - Single-axis BASIC (HCS01.1E-W0xx-A-02-**B**-...)
  - IndraDrive Mi, distributed drive controller (KMS02.1B-A0xx-P-D7-ET-...)
  - IndraDrive Mi, distributed servo drive (KSM02.1B-0xxC-xxN-xx-Hxx-ET-...)
  - As intelligent servo axis (extension of drive functionality) - stand-alone single-axis Motion Logic Control

Firmware Requirements

In the **MPx-18VRS** firmware, the "IndraMotion MLD" function is available in the following variants:

- Advanced design (**MPC**)
- Basic single-axis design (**MPB**)

Using the "IndraMotion MLD" function generally requires the enabling of one of the additive expansion packages **ML, MA or TF**.

See also sections:

- "Overview of Functions/Functional Packages"

- "Enabling of Functional Packages"

Features/Characteristic Values

The functional packages "IndraMotion MLD" include the following general features/characteristic values:

- It is possible to configure up to 4 different user tasks. Possible task types:
  - Periodic (min. cycle time: 1 ms for Advanced; 2 ms for Basic)
  - Free-running (permanently cyclic)
  - Event-triggered (min. reaction time: 1 ms for Advanced; 2 ms for Basic)
- Memory resources:

  MPB-18
  - Internal code memory: 2 MB (program, constants, management)
  - Data memory: 3 MB (variables, instances, management)
  - Storage of the boot project: 650 kB in parameters
  - Retain memory: 472 bytes (incl. persistent variables)

MPC-18

- Internal code memory: 12 MB (program, constants, management)
- Data memory: 4 MB (variables, instances, management)
- Storage of the boot project: 650 kB in parameters, 8 MB on µSD card
- Retain memory: 31704 bytes (incl. persistent variables)

- Digital inputs/outputs:
  - 1…7 digital inputs, 1 switchable digital input/output at x31

    → PLC and drive are sharing the inputs!
  - 1 relay output at x47

    → PLC and drive are sharing the inputs!
- Analog inputs/outputs:
  - 1 analog input (+/-10 V differential input) at x32
- Inputs/outputs on remote axes:
  - Digital and analog inputs/outputs of the slaves connected to sercos can be read and written.
  - Number of inputs/outputs depends on the used hardware of the slaves
- sercos I/O
  - Evaluation of Inline Block IOs - each block with 32 inputs or with 16 inputs and 16 outputs
  - Evaluation of Inline Modular IOs - max. 4 bus terminals with 16 modules (nodes) each
- Parameters for general purpose:
  - Parameters for process image: PII inputs
    - 20 input words per 2 bytes
    - 8 input words per 4 bytes
  - Parameters for process image: POI outputs
    - 20 output words per 2 bytes
  - Global registers (4 bytes)
    - 32 buffered parameters
    - 32 unbuffered parameters
  - List parameters (4 bytes)
    - 1 list register with 8192 values (not buffered)
    - 3 list registers with 1024 values (buffered)
  - 2 global text registers with 255 characters each
  - Display format of the global registers that can be parameterized
  - Name, unit and limit values of the global registers can be configured via PLC functions
- Other features:
  - Extensive debug possibilities (Single-Step, Watch, Force/Write, Breakpoints, Powerflow)
  - File access from the PLC (save source code on µSD card, …)

- Symbol files are stored on µSD card for accessing PLC variables of the HMI
- Source download (only with µSD card)
- Access to Ethernet interface

Pertinent Parameters

PLC parameters for general purpose:

- P-0-1350, PLC control word
- P-0-1351, PLC status word
- P-0-1352, PLC user program administration data
- P-0-1361, PLC program name
- P-0-1362, PLC boot project info
- P-0-1363, PLC project info
- P-0-1367,

User program (filing):

- P-0-1353, PLC user program area 0
- P-0-1354, PLC user program area 1
- P-0-1355, PLC user program area 2
- P-0-1356, PLC user program area 3
- P-0-1357, PLC user program area 4
- P-0-1358, PLC user program area 5

Process input images PIIs

- P-0-1390,
  to
  P-0-1409, PLC input WORD19 AT %IB38
- P-0-1440,
  to
  P-0-1447, PLC input DWORD32 AT %IB128

Process output images POIs

- P-0-1410,
  to
  P-0-1429, PLC output WORD19 AT %QB38

Global PLC registers, unbuffered:

- P-0-1270, PLC Global Register A0
  to
  P-0-1301, PLC Global Register A31

Global text registers, unbuffered:

- P-0-1387,
  to
  P-0-1388,

Global list register, unbuffered:

- P-0-1368, PLC Global Register AL0

Global PLC registers, buffered:

- P-0-1370, PLC Global Register G0

to

P-0-1385, PLC Global Register G15

- P-0-1316, PLC Global Register G16

  to

  P-0-1331 PLC Global Register G31

Global list registers, buffered:

- P-0-1389, PLC Global Register GL0
- P-0-1311, PLC Global Register GL1
- P-0-1312, PLC Global Register GL2

To configure the display format of the registers:

- P-0-1386, PLC display format Global Register

9.4.2 Notes on Installation / System Configuration

Installation

For installing "IndraMotion MLD" on the PC, it is necessary to install the current version of the **"IndraWorks MLD" commissioning tool** on the PC.

After successful installation the **"IndraLogic" PLC programming system** and **"IndraWorks"** can simultaneously communicate with the drive.

System Configuration

The system configuration of "IndraMotion MLD" is carried out via a PC with the "IndraLogic" program installed that communicates with the drive via TCP/IP communication.

The projects are filed on the PC. The generated binary code is loaded to the drive and stored in parameters or on the optional memory card. With the µSD card plugged, the source code, symbols and user files can also be stored there.

9.4.3 Specific Features as Compared to IndraMotion MLD in MPx-08

Big Endian

The "IndraDrive C"/"IndraDrive M" ranges (firmware up to MPx08) used the "Little Endian" byte order. The new "IndraDrive Cs" range uses the "Big Endian" byte order. The change in byte order with the "IndraDrive Cs" range also affects the drive-integrated PLC (IndraMotion MLD).

☞ Chapter "'Big Endian' / 'Little Endian'" of the separate documentation "Rexroth IndraMotion MLD as of MPx-17" (DOK-INDRV*-MLD2-**VRS*-AP**-DE-P; Mat.-No. R911334350), describes the adjustments necessary for using a PLC program written for firmware MPx-08 and above with a firmware MPx-17 and above.

Restrictions / Limitations

Restrictions

There are the following restrictions and limitations:

- The time slice available for the PLC depends on the control and workload of the drive caused by the operation modes.
- The minimum PLC time slot is shorter than with a CSH01.1 control section with MPH08VRS. PLC tasks with a short periodic time thereby have comparable average but higher maximum runtimes.

- In the case of "online change", there is a short delay of the PLC because the cache is rejected and has to be reloaded.

Performance

IndraMotion MLD has the following performance data:

- The minimum PLC cycle time does not depend on the control section and is 1 ms.
- The performance depends on
  – the time slice available for the PLC task
  – the code size
  – the kind of operation: REAL, DWORD, WORD, BYTE, BIT, etc. [Due to the integrated FPU (Floating Point Unit) on the processor, the processing velocity of REAL is very high.]

The processing time depends on several factors, such as load by control/operation mode, kinds of arithmetic operations. At best, the processing time for 1000 lines of instruction list is less than 4 µs, at worst it is more than 100 µs.

The following processing times were measured during a test program which was used to process 1000 mixed instructions:

- BASIC control section: 99 µs
- ADVANCED control section: 49 µs

9.4.4 Overview of Available Libraries

☞ This chapter only gives a short explanation of the basic libraries and functions. The details are described in the separate documentation "Rexroth IndraMotion MLD libraries, MPx18 and above".

NOTICE **Property damage caused when non-supported libraries are included.**

Only the libraries listed below are allowed to be included.

Library	Description
IecSfc	Makes available IEC steps conforming to standard in sequential language ["Sequential Function Chart" (SFC)]
MX_Base (IndraDrive) / MY_Base (HydraulicDrive)	• Data Types or Structures • Cyclic Parameters as Direct Variables (System-Wide Variables) • Axis Structures [for Multi-Axis System (MLD System Mode)]
MX_CanL2 (IndraDrive only)	Contains data types, functions and function blocks for CAN communication on level 2
MX_CheckRtv	For program-internal use only!: Functions for checking or signaling runtime errors
MX_Debug	For internal test purposes only (laboratory)!
MX_PLCopen	• Functions for Diagnostics • Function Blocks/Functions for Drive Control • Function Blocks/Functions for Parameters • Functions for Scaling • General Functions
MX_CommonTypes	Contains data types and structures most of which are only used internally
RIL_Fieldbus	Makes available common data types (field bus types) for the Rexroth field bus libraries
RIL_HMI_Utilities	Contains function blocks supporting the HMI devices
RIL_LoopControl	Provides basic elements and controllers of control technology

Optional Device Functions

Library	Description
RIL_ModbusTCP	Makes available function blocks which enable the communication between Ethernet devices supporting the Modbus protocol
RIL_SercosIII (IndraDrive only)	Makes available functions which enable the communication between the PLC programming environment and the sercos III nodes
RIL_SocketComm	Functions and function blocks which allow using the TCP/UDP communication
RIL_Utilities	Functions and function blocks for converting and influencing different data types
CmpIecTask	System library containing, amongst others, interface functions used to switch off a watchdog (and switch it on again afterwards) (see MLD Application Manual: "Task Monitoring (Watchdog)")
SysDir / SysDir23*1	Functions for synchronously accessing a file directory system on the target
SysFile / SysLibFile23*1	Functions for synchronously accessing files
SysFileAsync / SysFileAsync23*1	Functions for asynchronously accessing files
SysIecTasks23	Supports the "SysIECTaskGetConfig" function by means of which the task configuration can be read
SysMem / SysMem23*1	Functions for memory management
NetVarUdp	For program-internal use only!: Functions for processing network variables
Standard	Functions and function blocks that are required by IEC 61131-3 as standard blocks for an IEC programming system
SysCallback23*1	Functions for activating defined callback functions for runtime events
SysSem / SysSem23*1	Functions for creating and using semaphores for task synchronization
SysSockets / SysSockets23*1	Functions supporting the access to sockets for communication via TCP/IP and UDP
SysStr23*1	Functions for handling strings
SysTime	Makes available functions allowing to read and set the real-time clock of the local system, as well as enabling various conversions of the time data. **NOTE:** To begin with, please check whether the "RIL_Utilities" library can fulfill your requirements.
Util	Function blocks that can be used for BCD conversion, bit/byte functions, mathematical auxiliary functions, as controllers, signal generators, function manipulators and for analog value processing
OSCAT	Free PLC library "OSCAT" ("Open Source Community for Automation Technology"). This open-source library contains many useful functions in the areas of "automation technology" and "building automation".

***1** Libraries with the extension "23" (such as in "SysSockets23") are used to port projects; for new projects, use the libraries without the extension "23"

☞ "*.library" is the standard format for libraries.

The codes of the libraries supplied via IndraWorks are protected, they have the "*.compiled-library-ge33" format.

9.4.5 Overview of the Function of the Parameters for General Purpose

The following parameters are available for communication between "IndraMotion MLD" and external devices:

- Global registers G0 to G31 (buffered)

  → P-0-1370 to P-0-1385 and P-0-1316 to P-0-1331

→ Global registers with a data length of 4 bytes; parameters as registers with individual values for data exchange of the PLC with the drive or a higher-level PLC or control unit

- Global registers A0 to A31 (unbuffered)

  → P-0-1270 to P-0-1301

  → Parameters for data exchange (input and output data) of the PLC with a higher-level control unit or HMI

- Global text registers AT (unbuffered)

  → P-0-1387, P-0-1388

  → Freely usable text parameter with a maximum of 255 characters plus terminating zero character.

- Global list registers GL (buffered)

  → P-0-1389, P-0-1311, P-0-1312

  → List parameters with 1024 elements (4 bytes each) for data exchange of the PLC with an external control or HMI

- Global list register AL (unbuffered)

  → P-0-1368

  → List parameters with 8192 elements (4 bytes each) for data exchange of the PLC with an external control or HMI

- Process input images PIIs

  → P-0-1390 to P-0-1409 (with 2 bytes each → word-wise)

  → P-0-1440 to P-0-1447 (with 4 bytes each → double-word-wise)

  → Parameters contain the process image of the PLC inputs (PIIs); at the beginning of the task, the PLC reads the values to the PIIs and before the beginning of the task updates the process image of the inputs

- Process output images POIs

  → P-0-1410 to P-0-1429 (with 2 bytes each → word-wise)

  → Parameters contain the process image of the PLC outputs (PIIs); At the end of the task, the PLC writes the value from the POIs in the outputs.

9.5 Digital Inputs/Outputs

9.5.1 Brief Description

General Information

In their basic variant, all IndraDrive systems and control sections already have configurable digital inputs/outputs.

Hardware Requirements The table below shows the number and function of the digital inputs/outputs.

Drive system / control section	Basic device (on board)		Option "DA"1)		
	Number of standard inputs (probe inputs thereof)	Number of switchable Inputs/outputs	number Inputs	number Outputs	Number of switchable Inputs/outputs
HCS01.1	7 (2)	1	6	6	2
HCQ02.1, HCT02.1	16 (-)	-	-	-	-
KSM02.1, KMS02.1	-	4	-	-	-

Optional Device Functions

Drive system / control section	Basic device (on board)		Option "DA"[1)]		
	Number of standard inputs (probe inputs thereof)	Number of switchable Inputs/outputs	number Inputs	number Outputs	Number of switchable Inputs/outputs
CSB02.1A	7 (2)	1	-	-	-
CDB02.1B	14 (4)	8	6	6	2
CSB02.1B, CSH02.1B	11 (2)	5	6	6	2

1) As of MPx18V10

Tab. 9-11: Drive System / Control Section, Number of Inputs/Outputs

For further hardware properties, see the respective Project Planning Manual.

Features

- Sampling of digital inputs and outputs or transmitting data to them is done in the position controller clock $T_{A\_position}$ (see "Performance Data")
- Configurable digital inputs/outputs with effective direction that can be freely set to some extent (input or output):
- Probe inputs are queried in steps of µs
- All inputs/outputs refer to the level of 0 V (LOW) or 24 V (HIGH)
- Assignment of the inputs/outputs on several axes within one device possible
- Several axes within one device can be addressed by one digital input
- Within a device, each axis can access each input/output present on the hardware side
- Multiple assignments for an input possible with multiple parameters
- An axis output can be used simultaneously as an input on the same parameter.
- Signal states of digital inputs/outputs of a device are mapped to their respective individual parameters.
- In addition, the signal states of digital inputs/outputs of an axis are mapped to their respective individual parameters.
- Digital outputs can be directly controlled by the control master, if not used on drive-side

Pertinent Parameters

- S-0-0398, IDN-list of configurable data in signal status word
- S-0-0399, IDN-list of configurable data in signal control word

Digital inputs

- P-0-0300, Digital inputs, assignment list
- P-0-0301, Digital inputs, bit numbers
- P-0-0303, Digital inputs, input image of device
- P-0-0306, Digital inputs, assignment connector and pin
- P-0-0307, Digital inputs, input image sub-device

Digital Outputs

- P-0-0304, Digital outputs, output image of device
- P-0-0310, Digital outputs, assignment list
- P-0-0311, Digital outputs, bit numbers
- P-0-0312, Digital outputs, assignment sub-device

- P-0-0313, Digital outputs, output image sub-device
- P-0-0316, Digital outputs, assignment connector and pin

Pertinent Diagnostic Messages

- F2010 Error when initializing digital I/O (-> S-0-0423)

9.5.2 Functional Description

General Information

☞ Assignment of each individual input or output to drive parameters possible. The IDN of the permitted parameters can be found in the IDN lists of S-0-0398 and S-0-0399.

Cases to Distinguish for Determining Source or Target

Depending on whether an IDN is parameterized in the parameter "P-0-0300, Digital inputs, assignment list" or "P-0-0310, Digital outputs, assignment list" the IDN entry is used as a target or source.

- **Input of an axis (subdevice)**

  For an entry, the bit configured in the parameter "P-0-0301, Digital inputs, bit numbers" of an identification number defined in P-0-0300 is written with the logic value (0 or 1) provided at the input.

- **Output of an axis (subdevice)**

  In the case of an output, the content of the bit configured in "P-0-0311, Digital outputs, bit numbers" is taken from the identification number (source parameter) determined in P-0-0300 and transmitted to the output of the subdevice (P-0-0313).

☞ When P-0-0300[i] = "S-0-0000", the respective entry in P-0-0301 is ignored! If P-0-0310[i] = "S-0-0000" is parameterized, the respective entry in P-0-0301 is not significant!

- **Access to the axis on a hardware input**

  Via parameter P-0-0306, any hardware input can be assigned to the input image of an axis (P-0-0307). For example, with HCS01.1, value 3107 is to be entered for input 7. 31 corresponds to the connector designation (X31) and 07 corresponds to Pin 7 of the plug. For CSH02.1B, the interface X35 is fitted with 2-series connectors, as a result, the sequence is to be specified, i.e. the value 35207 must be parameterized for a digital input 14. 35 for the connector designation, 2 for the 2nd sequence and 07 for the PIN for the plug.

- **Description of a hardware output**

  The output image of an axis (P-0-0313) is linked to any hardware output using P-0-0312 and P-0-0316.

State map of the assigned parameters of an axis

☞ The following parameters can be used as a state map of the assigned parameters:

- P-0-0307, Digital inputs, input image sub-device
- P-0-0313, Digital outputs, output image sub-device

Status of Device-side Inputs/Outputs

☞ The signal status of the digital inputs/outputs is displayed in the following parameters:

- P-0-0303, Digital inputs, input image of device
- P-0-0304, Digital outputs, output image of device

Deactivation

To deactivate an input, in parameter P-0-0300 in the respective list element, the IDN "S-0-0000" must be entered; alternatively, in P-0-0306 the corresponding list element can be written with "0".

When deactivating an output, in parameter P-0-0310 the corresponding list element can be written with the IDN "S-0-0000" or in parameter P-0-0312 or P-0-0316 the corresponding list element can be written with "0".

Validity Check of Configuration Lists

When a new assignment list is input or an element of the list is changed, all entries are checked for validity. If an entry is invalid (i.e. no allowed IDN entered) only this invalid entry is rejected.

☞ Incorrect entries are rejected when the list is checked and set to the respective default value.

Special Cases and Exceptions

Probe and Reference Cam Input

In some special cases, there is no direct bit transfer, because the function assigned to the input/output is more complex. The probe function is an example. In this case, the entry in P-0-0301 is irrelevant, it is only a valid value that must be contained (e.g. "0").

All special functions are listed in the following table:

Function	P-0-0300[i]	P-0-0301[i]	Notes
Probe 1	S-0-0401	Not relevant	With HCS1, CSB02.1 CSH02.1: Only possible via X31.1!
			With CDB02.1: Only possible via X31/1.1, X31/2.1!
Probe 2	S-0-0402	Not relevant	With HCS1, CSB02.1 CSH02.1: Only possible via X31.2!
			With CDB02.1: Only possible via X31/1.2, X31/2.2!
Reference cam	S-0-0400	Not relevant	

i = index List element / terminal slot

Tab. 9-12: Special Functions via Digital Inputs/Outputs

Fixed Assignment of Function-Relevant Inputs and Default Configuration

As a matter of principle, the inputs/outputs can be freely configured. Only for the special function "probe" is the fixed assignment of the corresponding parameters to the appropriate inputs on the hardware side obligatory!

By the default configuration (condition as supplied or state after "load defaults procedure (factory settings)"), the inputs/outputs are appropriately predefined (see above).

NOTICE

All changes in the parameters P-0-0300 to P-0-0316 have to be carefully made, because important functions might be deactivated (e.g. E-Stop).

Direct Access to Digital Inputs/Outputs of the Control Section via Master Communication

Accessing Digital Inputs/Outputs

In order to directly control ("set") the digital outputs of the device via the master communication or directly poll ("read") the digital inputs, the parameters

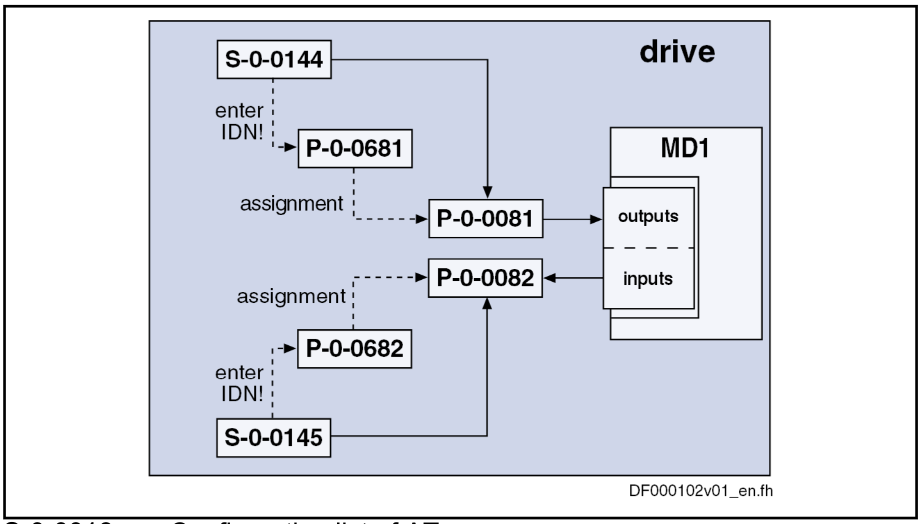
"P-0-0303, Digital inputs, input image of device" and "P-0-0304, Digital outputs, output image of device" can be included in the cyclic data of the master communication.

Requirements:

- Including parameter P-0-0303 in the group of cyclic actual values (sercos: "S-0-0016, Configuration list of AT", field bus: "P-0-4080, Field bus: Config. list of cyclic actual value data ch.")
- Including parameter P-0-0304 in the group of cyclic command values (sercos: "S-0-0024, Configuration list of MDT", field bus: "P-0-4081, Field bus: Config. list of cyclic command value data ch.")
- Deactivating the axis access to the digital inputs/outputs are required, in P-0-0306 the list element assigned to the digital input is set to 0 and accordingly in the P-0-0312 for digital outputs.

☞ The digital outputs can only be directly controlled by the master communication if they are not used on the drive side.

The figure below illustrates the access to the digital inputs/outputs of the control section via the master communication (sercos in this case).



S-0-0016	Configuration list of AT
S-0-0024	Config. list of the master data telegram
P-0-0303	Digital inputs, input image of device
P-0-0304	Digital outputs, output image of device

Fig. 9-40: Accessing Digital Inputs/Outputs of the Control Section via sercos Master Communication

Behavior when Master Communication Fails

When the cyclic communication fails, the value "0" is written to the parameters; this means that those digital outputs are cleared to which the master transmits data via the cyclic communication.

9.5.3 Notes on Commissioning

Configuring the Inputs/Outputs

Configuring the Inputs/Outputs via IndraWorks Dialog

To configure the digital inputs/outputs, it is recommended that you use the dialog-based parameterization via IndraWorks. The IndraWorks dialog for configuring the digital inputs is used by double-clicking "I/O X31/X32" in the project explorer: Here in the context with control unit CDB02.1B:

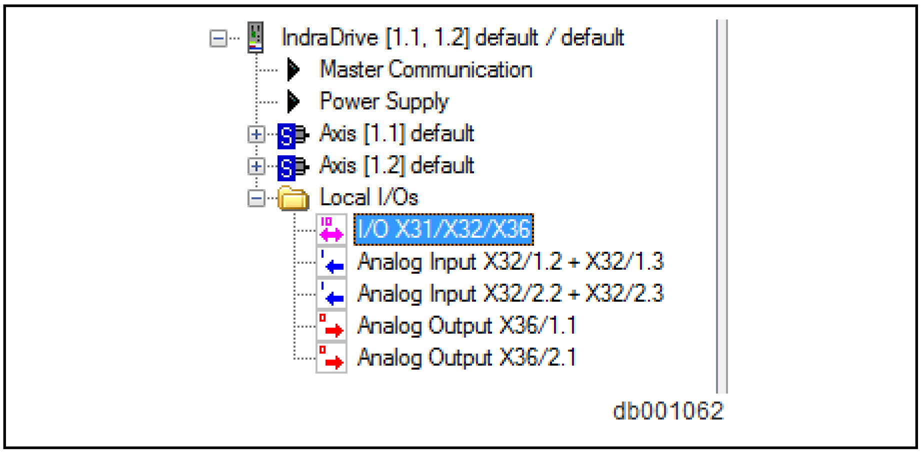


Fig. 9-41: Dialog - Digital Inputs

The following dialog will open in which you can parameterize the digital inputs/outputs.

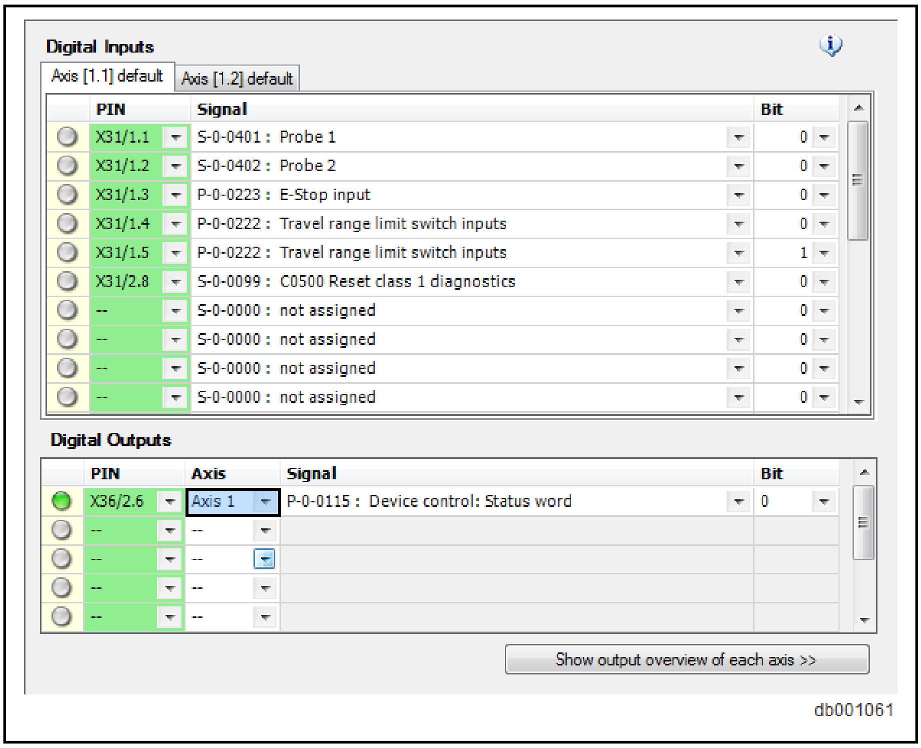


Fig. 9-42: Default Setting of the Digital Inputs/Outputs

By means of the pull-down menus, the parameters and bit numbers can be assigned to the inputs/outputs of the drive controller. In the "PIN" column, the pin of the interface is parameterized from which input the data are read or which output is set.

Corrected!!-->On output is in principle configured such as an input, in other words, the axis is also selected for each output, as a result, the parameter P-0-0312 is described with the corresponding axis numbers.

☞ On the left side of the dialog window, there is a status LED for each input/output; the LED shows the current state of the device interface.

Assignment of the Device Interface

When you move the cursor over the information symbol "i" on the top right side of the dialog, a colored text box opens; it shows the assignment of the digital inputs/outputs of the device interface.

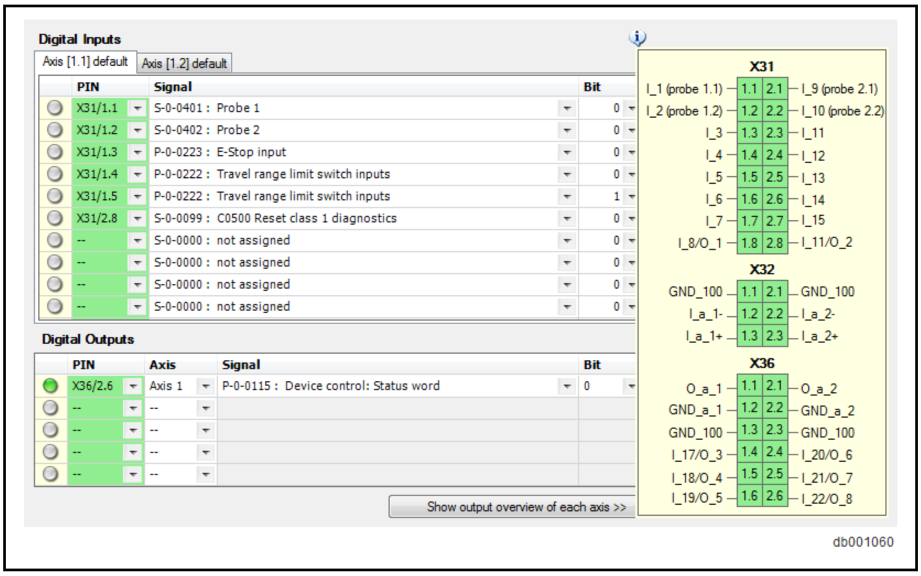


Fig. 9-43: Assignment of the Device Interface

Configuring Inputs via Single Parameter Editor

As an alternative to the dialog-based parameterization of the digital inputs/outputs, you can make the settings directly in the drive parameters. For this purpose, call the single parameter editor in IndraWorks.

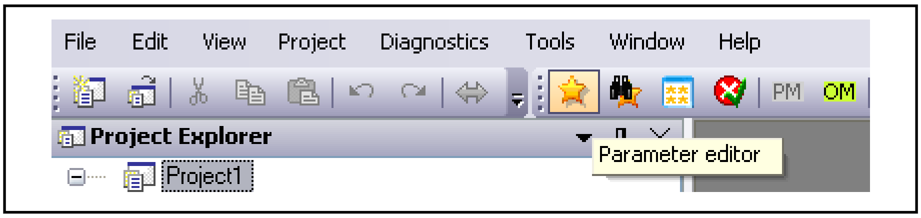


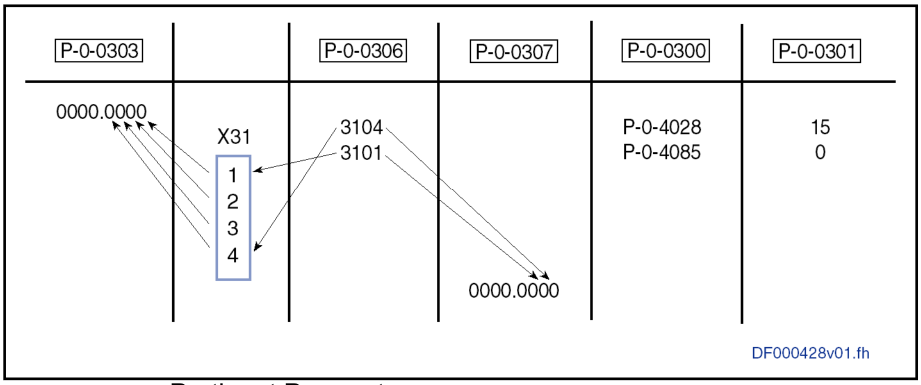
Fig. 9-44: Parameter Editor

With the single parameter editor, a parameter and a bit can be assigned to a selected input by entering the corresponding parameter IDN. The configuration procedure is described below.

In the parameter "P-0-0306, Digital inputs, assignment connector and pin", define which pin of the respective connector is copied to parameter "P-0-0307, Digital inputs, input image sub-device". Each bit of parameter P-0-0307 has a fixed assignment to the list elements from parameter P-0-0300 or P-0-0301, i.e. P-0-0307, bit 0, is related to the list element 0 of parameters P-0-0300 and P-0-0301, bit 1 to list element 1, etc.

The IDNs of the target parameters are entered in the list parameter "P-0-0300, Digital inputs, assignment list". The bits are selected via parameter "P-0-0301, Digital inputs, bit numbers".

The status of the interface plug is reflected in "P-0-0303, Digital inputs, input image of device".



Pertinent Parameters:

P-0-0300, Digital inputs, assignment list
P-0-0301, Digital inputs, bit numbers
P-0-0303, Digital inputs, input image of device
P-0-0306, Digital inputs, assignment connector and pin
P-0-0307, Digital inputs, input image sub-device

Fig. 9-45: Digital inputs

Configuring Outputs via Single Parameter Editor

As an alternative to the dialog-based parameterization of the digital inputs/outputs, you can make the settings directly in the drive parameters. For this purpose, call the single parameter editor in IndraWorks.

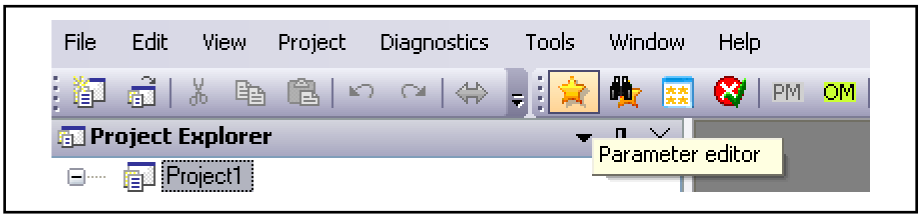


Fig. 9-46: Parameter Editor

With the single parameter editor, a selected bit of a parameter can be assigned to an output by entering the corresponding parameter IDN. The configuration procedure is described below.

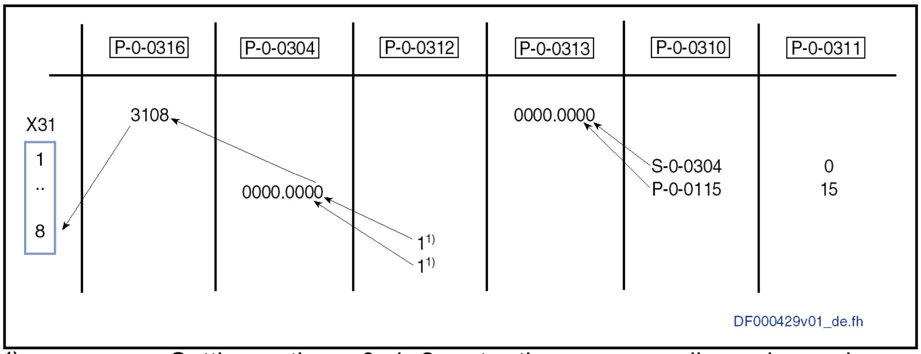
The IDNs of the source parameters are parameterized in the list parameter "P-0-0310, Digital outputs, assignment list". The bits are selected via parameter "P-0-0311, Digital outputs, bit numbers".

Each list element of parameters P-0-0310 or P-0-0311 has a fixed assignment to the bits of parameter "P-0-0313, Digital outputs, output image sub-device", i.e. list element 0 of parameters P-0-0310 and P-0-0311 is related to bit 0 of P-0-0313, list element 1 to bit 1, etc.

As with multi-axis controllers, there are several parameters P-0-0313, you need parameter "P-0-0312, Digital outputs, assignment sub-device" in order to determine which sub-device output images are switched to the digital outputs.

Parameter "P-0-0304, Digital outputs, output image of device" reflects the status of the digital outputs. The list elements of parameter P-0-0312 are directly related to the bits of P-0-0304. The assignment behaves adequately to P-0-0310.

Using parameter "P-0-0316, Digital outputs, assignment connector and pin", you determine to which pin of connector X31 or X32 the respective bits of P-0-0304 are copied.



1) Setting options: 0, 1, 2; enter the corresponding axis numbers, "0" for no axis selection, "1" for all single axis control units, "1" or "2" for double-axis control units.

Pertinent Parameters:

P-0-0310, Digital outputs, assignment list
P-0-0311, Digital outputs, bit numbers
P-0-0304, Digital outputs, output image of device
P-0-0316, Digital outputs, assignment connector and pin
P-0-0313, Digital outputs, output image sub-device
P-0-0312, Digital outputs, assignment sub-device

Fig. 9-47: Digital Outputs

9.5.4 Diagnostic and Status Messages

Digital Inputs/Outputs on Control Section

Status of Digital Inputs/Outputs

The state (= signal status) of the digital inputs/outputs is displayed in the parameters P-0-0303 and P-0-0304:

- Bit set ("1")

  → At the assigned input/output, a HIGH level (+24 V) is applied.

- Bit not set ("0")

  → At the assigned input/output, a LOW level (0 V) is applied.

Check for Invalid Bit Numbers

When entering data in parameter P-0-0301 or P-0-0311, a check is run to find out whether the indicated bit number is a valid bit of the parameter (IDN) configured in parameter P-0-0300 or P-0-0310.

The following applies:

- **2-byte** parameter → Bit numbers between **0 and 15** allowed
- **4-byte** parameter → Bit numbers between **0 and 31** allowed

In the case of invalid inputs or inputs/outputs that have not been configured yet, "0" is displayed as bit number.

9.6 Analog Outputs

9.6.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

In accordance with the drive system or control section, IndraDrive controllers have a different number of analog outputs.

The drive function "analog outputs" allows outputting analog signal values for commissioning and optimizing drives with appropriate measuring devices (e.g. oscilloscope, multimeter), as well as for visualizing the contents of drive parameters.

Hardware Requirements

The table below shows the number of analog outputs in accordance with the drive system or control section type:

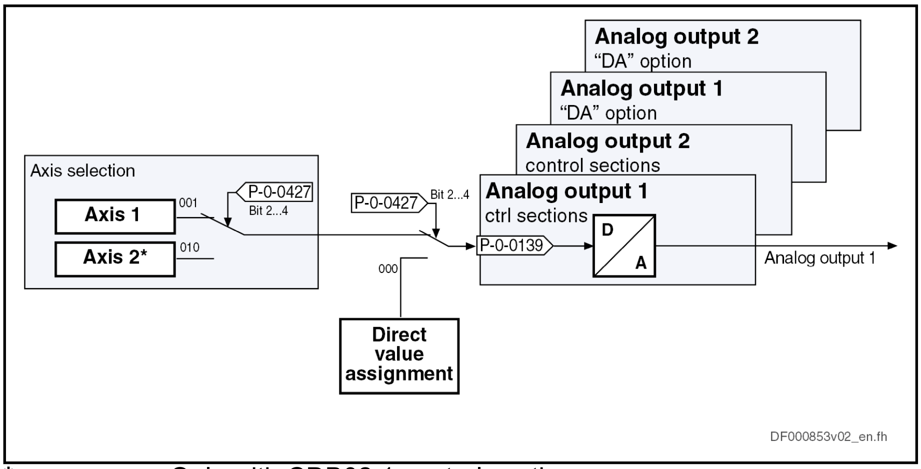
Drive system / control section	Basic device (on board)	Option "DA"[1)]
	Number of analog outputs	Number of analog outputs
HCS01.1	-	2 [2)]
HCQ02.1, HCT02.1	-	-
KSM02.1, KMS02.1	-	-
CSB02.1A	-	-
CDB02.1B CSB02.1B, CSH02.1B	2	2

1) As of MPx18V10
2) Not with HCS01 Economy

Tab. 9-13: Analog Inputs

Overview

The figure below illustrates the interaction of the two analog output channels with the analog outputs.



* Only with CDB02.1 control section

Fig. 9-48: Assignment Mechanism for the Analog Outputs

Features

General features:

- Analog outputs are updated in position controller clock (see "Performance Data")
- Analog outputs can be written via master communication (cyclic or acyclic channel)
- Internal status variables and signals (= parameter contents) are output as analog voltage signals at output terminal connectors of the drive controller (see separate documentation "Control Sections for Drive Controllers; Project Planning Manual")
- Monitoring function with regard to double assignment of outputs
- Variable scaling of analog outputs
- Switching of the behavior at the limits of voltage range that can be displayed between overflow and limitation
- Parameterizable output offset or parameterizable reference value

☞ For the technical properties of the analog inputs, see the respective Project Planning Manual.

Pertinent Parameters

Configuring the analog outputs:

- P-0-0426, Analog output IDN list of assignable parameters
- P-0-0427, Control parameter of analog output

Analog output 1:

- P-0-0418, Analog output 1, signal value at 0V
- P-0-0420, Analog output 1, signal selection
- P-0-0422, Analog output 1, scaling [1/V]
- P-0-0139, Analog output 1

Analog output 2:

- P-0-0419, Analog output 2, signal value at 0V
- P-0-0423, Analog output 2, signal selection
- P-0-0425, Analog output 2, scaling [1/V]
- P-0-0140, Analog output 2

Analog output 3:

- P-0-0428, DA: Analog output 1, signal value at 0V
- P-0-0459, DA: Analog output 1, signal selection
- P-0-0463, DA: Analog output 1, scaling [1/V]
- P-0-0414, DA: Analog output 1

Analog output 4:

- P-0-0429, DA: Analog output 2, signal value at 0V
- P-0-0462, DA: Analog output 2, signal selection
- P-0-0464, DA: Analog output 2, scaling [1/V]
- P-0-0415, DA: Analog output 2

9.6.2 Functional Description

General Information

For assigning the signal sources for the analog outputs of the drive controller, it is possible to choose between two methods:

- Direct output of **voltage signals** independent of the drive (signals of control master or IndraMotion MLD)

  → Output parameters directly written via master communication or by IndraMotion MLD
- Output of the values of predefined **drive parameters** (contents of standard parameters of the drive)

  → free configuration of analog outputs 1...4

  For the selection of this signal source, there is the so-called "bit output" carried out for parameters with binary format; the content to be output in this case has to be determined by the bit number.

In addition, **extended output of internal storage locations** can be carried out under certain conditions.

Determining the Signal Source

The signal source is determined for each analog output in "P-0-0427, Control parameter of analog output".

Direct Output of Voltage Signals

☞ The selection of the signal source option "direct output of voltage signals" is the default setting for the analog outputs (basic parameter set). This setting can be changed or assigned again in "P-0-0427, Control parameter of analog output".

If this signal source has been assigned, the control master can use the drive as digital/analog converter. For this purpose, the parameters definitely assigned to the analog outputs can be directly written.

The following parameters used to display the output analog values are assigned to the individual analog outputs:

- P-0-0139, Analog output 1
- P-0-0140, Analog output 2
- P-0-0414, DA: Analog output 1
- P-0-0415, DA: Analog output 2

By writing data to the above parameters, the master can directly influence the analog signal to be output. For this purpose, the corresponding parameter is configured as cyclic data.

Behavior when Master Communication Fails

When cyclic communication fails, the value "0" is written to the parameters which causes 0 V to be output via the analog outputs.

Output of Predefined Drive Parameters

List of Assignable Parameters

Values of drive parameters are output on the basis of a predefined selection list. "P-0-0426, Analog output IDN list of assignable parameters" includes all parameters of state values and signals of the riev which can be output via analog outputs.

Assignment

The assignment is made by entering the IDN of the parameter in the respective signal selection parameter:

- P-0-0420, Analog output 1, signal selection
- P-0-0423, Analog output 2, signal selection
- P-0-0459, DA: Analog output 1, signal selection
- P-0-0462, DA: Analog output 2, signal selection

Via the parameters it is possible to determine, separately for each output channel, the reference definition (P-0-0418, P-0-0419, P-0-0428, P-0-0429) and the scaling (P-0-0422, P-0-0425, P-0-0463, P-0-0464) of the output values.

See also "Notes on Commissioning" in the same section

Bit Output of Drive Parameters

Within the output of predefined drive parameters, the analog output of parameters in the binary format takes place as so-called "bit output".

The bit output allows outputting individual bits of a binary format parameter like, for example, parameter "S-0-0403, Position feedback value status".

Which bit of the respective parameter is to be output is determined in the following parameters:

- P-0-0422, Analog output 1, scaling [1/V]
- P-0-0425, Analog output 2, scaling [1/V]
- P-0-0463, DA: Analog output 1, scaling [1/V]

- P-0-0464, DA: Analog output 2, scaling [1/V]

☞ The output voltage is 1V when the respective bit has been set; otherwise 0 V is output.

For bit output, the following parameters are not active:

- P-0-0418, Analog output 1, signal value at 0V
- P-0-0419, Analog output 2, signal value at 0V
- P-0-0428, DA: Analog output 1, signal value at 0V
- P-0-0429, DA: Analog output 2, signal value at 0V

Extended Output of Internal Storage Locations

For diagnostic purposes, it is possible to extend the setting for the analog outputs, but using this setting requires knowledge of the structure of the drive firmware. Consequently, this function can only be used after approval by the drive development department.

See also "Extended Diagnostic Possibilities: Patch Function"

9.6.3 Notes on Commissioning

Sequence of Setting for Analog Outputs

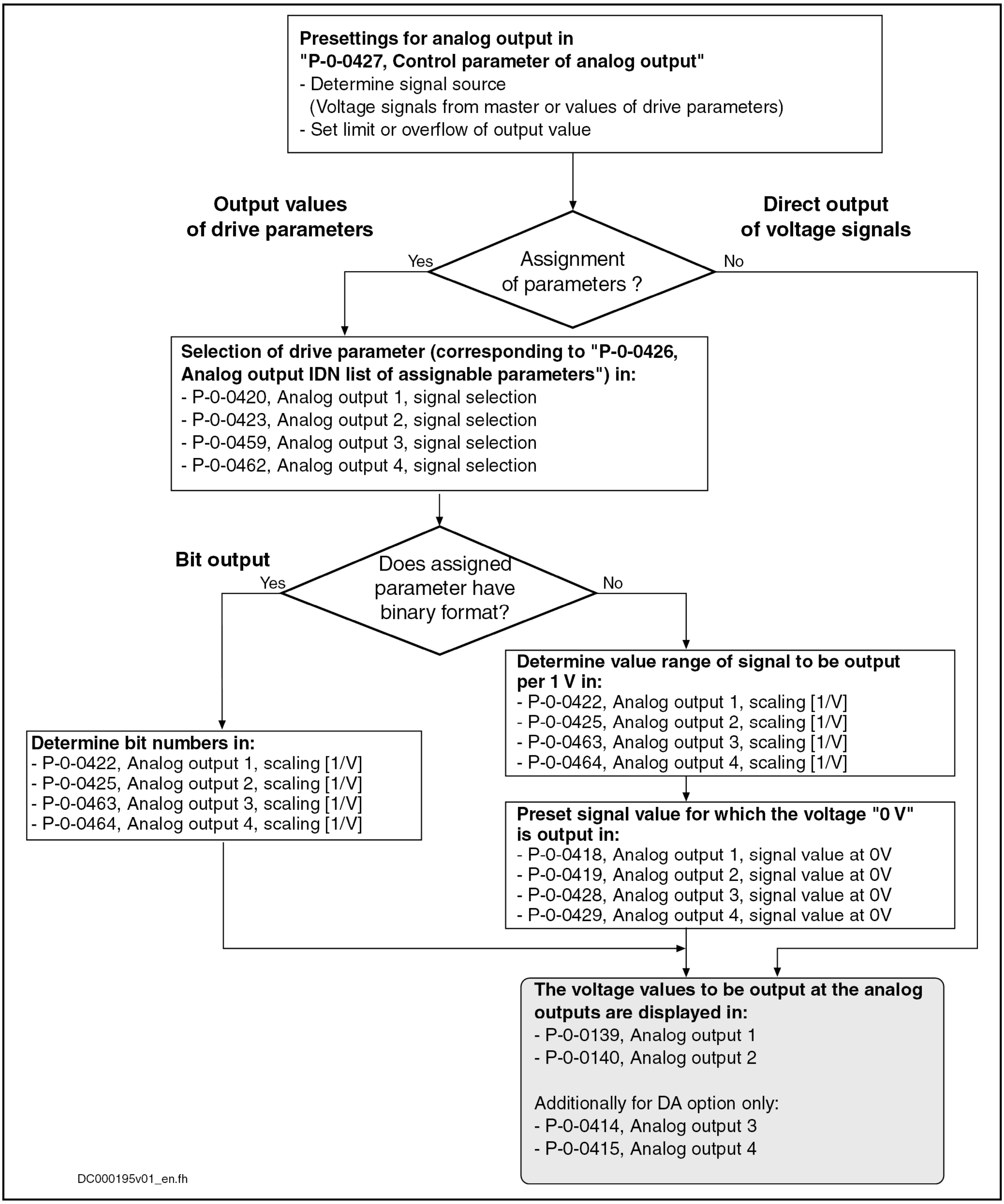


Fig. 9-49: Commissioning the Analog Outputs

Signal Source for the Analog Outputs

For each of the possible analog outputs, the signal source for the voltage to be output can be determined:

- **Direct input of voltage signals** in the parameters P-0-0139, P-0-0140, P-0-0414, P-0-0415, P-0-0416 or P-0-0417

- or -

- Values of drive parameters according to **assignment A or assignment B**

> The signal source for the analog outputs is determined in "P-0-0427, Control parameter of analog output".

Scaling and Reference Point

Scaling the Analog Outputs

The two analog output channels are scaled (range of values per V) in the following parameters:

- P-0-0422, Analog output 1, scaling [1/V]
- P-0-0425, Analog output 2, scaling [1/V]
- P-0-0463, DA: Analog output 1, scaling [1/V]
- P-0-0464, DA: Analog output 2, scaling [1/V]

Example of "Scalable" Output

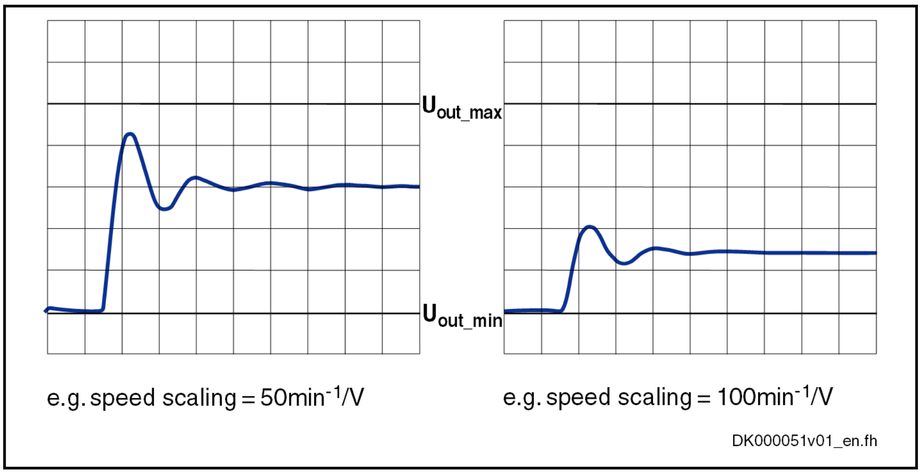


Fig. 9-50: Example of Scaleable Analog Output

Reference Point

The reference of the analog outputs is defined (value at output of 0 V) in the following parameters:

- P-0-0418, Analog output 1, signal value at 0V
- P-0-0419, Analog output 2, signal value at 0V
- P-0-0428, DA: Analog output 1, signal value at 0V
- P-0-0429, DA: Analog output 2, signal value at 0V

Optional Device Functions

Example of "Reference-Defined" Output for Analog Output 1 and 2

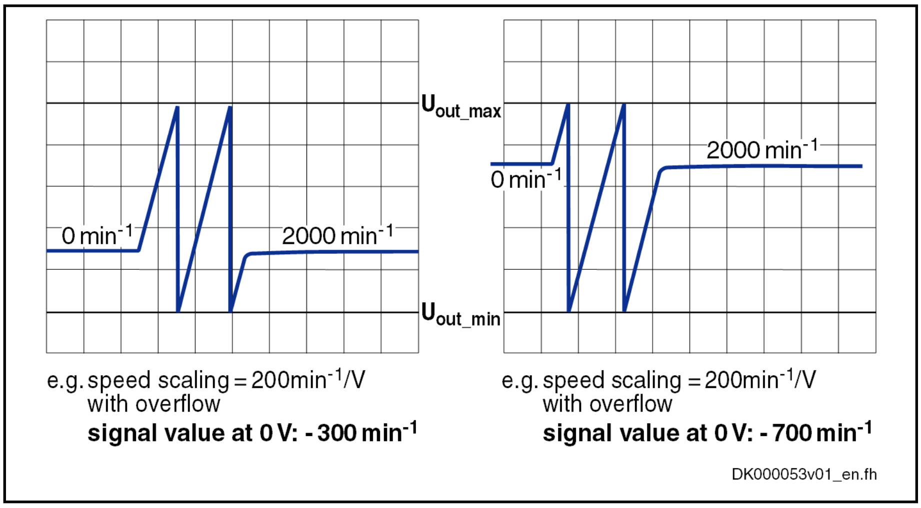


Fig. 9-51: Example of Reference-Defined Analog Output

Determining the Overflow Behavior

Via "P-0-0427, Control parameter of analog output", it is possible to determine the output format of the analog outputs in the following ways:

- Limited or overflowing output due to the limited voltage range of the analog outputs
- Definable reference value for the output value

Example of "Limited" or "Overflowing" Output

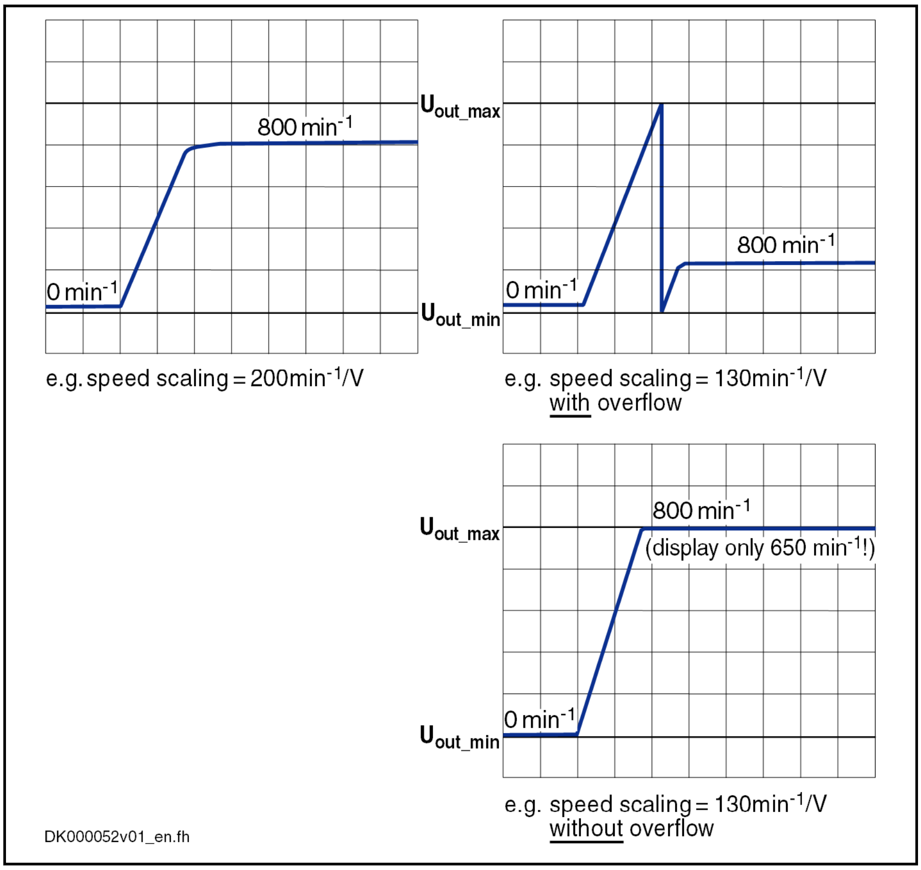


Fig. 9-52: Example of Limited or "Overflowing" Analog Output

In the case of "overflowing" analog output, the assignment of a signal value to the output voltage is ambiguous due to the overflow!

The output of 0 V, for example, can be:

Signal value (at 0 V) ± n × output voltage range × scaling (in 1/V)

(n = 1, 2, 3, …)

9.7 Analog Inputs

9.7.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

In accordance with the drive system or control section, IndraDrive controllers have a different number of analog inputs. This allows processing analog voltage and current values from command values in the drive.

Hardware Requirements The table below shows the number of analog inputs in accordance with the drive system or control section type:

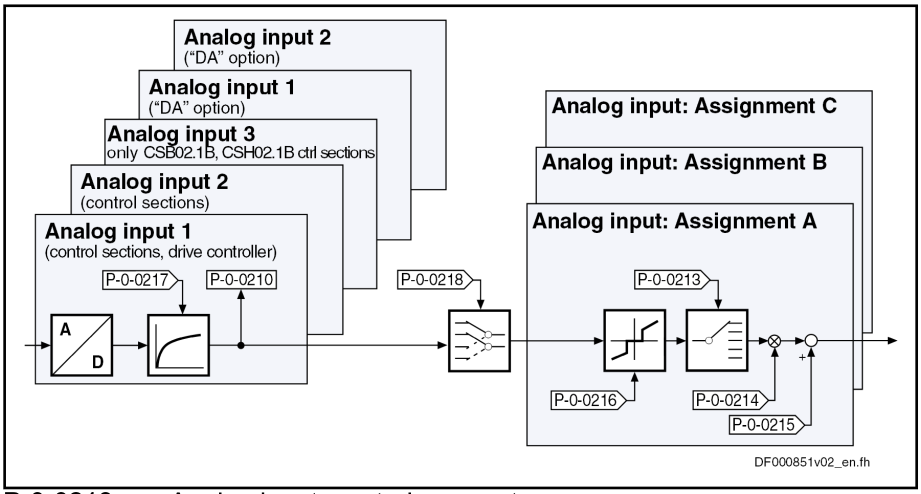
Drive system / control section	Basic device (on board)	Option "DA"[1)]
	Number of analog inputs	Number of analog inputs
HCS01.1	1	2 [2)]
HCQ02.1, HCT02.1	-	-
KSM02.1, KMS02.1	-	-
CSB02.1A	1	-
CDB02.1B	2	2
CSB02.1B, CSH02.1B	3	2

1) As of MPx18V10
2) Not with HCS01 Economy

Tab. 9-14: Analog Inputs

For further hardware properties, see the respective Project Planning Manual.

Overview The figure below illustrates the assignment options of the analog inputs.



P-0-0218 Analog input, control parameter

Fig. 9-53: Overview: Analog Input and Assignment ("DA" Option is Supported as of MPx18V10)

Features

General features:

- 3 assignment mechanisms (assignment A, B, C) with different sampling rates are possible
  - Assignment channel A works in position controller clock (see "Performance Data")
  - Assignment channels B and C work in 2 ms clock
- Assignment to command value/limit value/control parameters of the drive by means of adjustable scaling
- Variable scaling
- Parameterizable dead zone to suppress zero drift
- Automatic offset and amplification adjustment via command is possible
- Low-pass filtering to be activated for the analog channel
- Analog input designed as differential input
- Parameterizable wire break monitoring
- Input voltage range of ± 10V
- Analog inputs 2 (not with CDB02.1B) and 3, as well as analog inputs 1 and 2 of optional module DA, can also be set as current inputs +/-20 mA or +4...+20 mA. Optional module DA is supported as of 18V10.

☞ For the technical properties of the analog inputs, see the respective Project Planning Manual.

Pertinent Parameters

Connection Setup

- P-0-0255, Analog input; hardware configuration
- P-0-0212, Analog input, list of assignable parameters
- P-0-0218, Analog input, control parameter
- P-0-0219,
- P-0-0220,

Analog input values:

- P-0-0210, Analog input 1
- P-0-0211, Analog input 2

- P-0-0228, Analog input 3
- P-0-0229, DA: Analog input 1
- P-0-0208, DA: Analog input 2
- P-0-0217, Analog input 1, time constant input filter
- P-0-0231, Analog input 2, time constant input filter
- P-0-0232, Analog input 3, time constant input filter
- P-0-0233, DA: Analog input 1, time constant input filter
- P-0-0234, DA: Analog input 2, time constant input filter

Assignment A:

- P-0-0213,
- P-0-0214, Analog input, assignment A, scaling
- P-0-0215, Analog input, assignment A, signal value at 0
- P-0-0216, Analog input, assignment A, dead zone

Assignment B:

- P-0-0236,
- P-0-0237, Analog input, assignment B, scaling
- P-0-0238, Analog input, assignment B, signal value at 0
- P-0-0239, Analog input, assignment B, dead zone

Assignment C:

- P-0-0245, Analog input, assignment C, target parameter
- P-0-0246, Analog input, assignment C, scaling
- P-0-0247, Analog input, assignment C, signal value at 0
- P-0-0248, Analog input, assignment C, dead zone

Pertinent Diagnostic Messages

- C2800 Analog input adjustment command
- C2801 Analog input not configured
- C2802 Oscillations of input signal outside tolerance range
- C2803 Measured values at zero point and max. value identical
- C2804 Automatic adjustment failed
- F2270 Analog input, wire break

9.7.2 Functional Description

Reading and Assigning an Analog Input

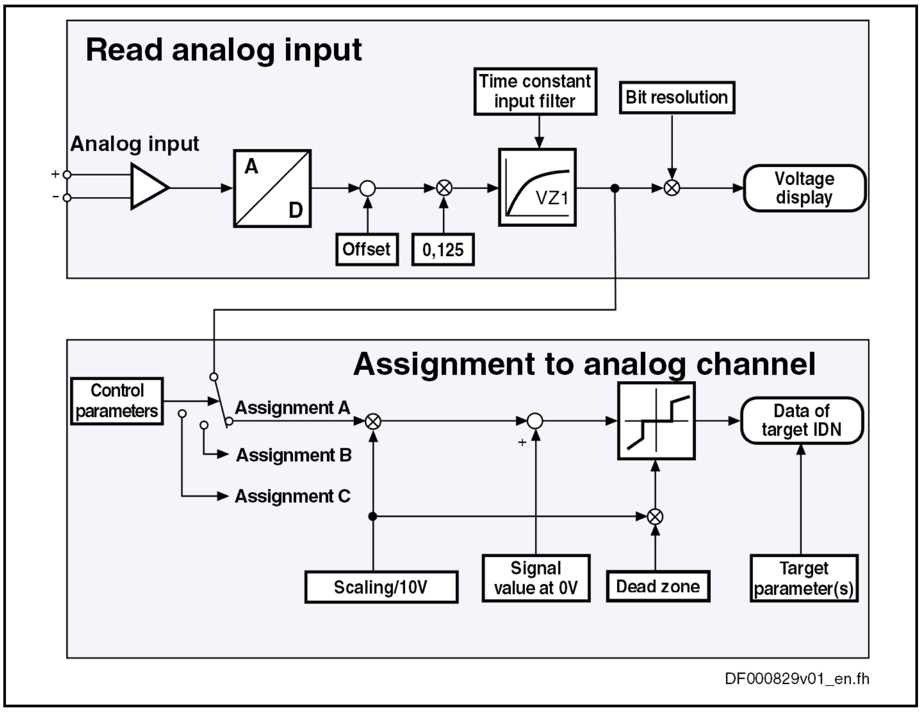


Fig. 9-54: Overview of Functions: Reading and Assigning an Analog Input

Sampling and Signal Adjustment

Sampling The analog inputs are sampled in the position controller clock (see "Performance data").

Filtering The sampled analog input signal can be smoothed by a PT1 filter. A separate input filter is available for each analog input, the filter constant can be set via parameters P-0-0217, P-0-0231, P-0-0232, P-0-0233, P-0-0234.

When the filter has been activated, its limit frequency results from the following relationship:

$$f_g = \frac{1000}{2\pi \times T}$$

f_g Limit frequency (in Hz)

T Time constant of input filter (in ms)

Fig. 9-55: Limit Frequency of the Activated Filter

Entering a time constant < T_{A_pos} deactivates the filter.

Signal Type The analog inputs 2...5 can be reparameterized from voltage to current signals. Parameters "P-0-0255, Analog input; hardware configuration" can be used to set the signal type for each analog input individually.

> ☞ Analog input 2 can not be reparameterized to current signals for control unit CDB02.1B. Option DA is needed for analog inputs 4 and 5.

Voltage/Current Display The sampled and where applicable smoothed signal value of analog inputs 1...5 is displayed in the parameters P-0-0210, P-0-0211, P-0-0228, P-0-0229 and P-0-0208.

The parameter can be transmitted to the higher-level master or directly processed in the drive-integrated PLC (IndraMotion MLD).

Internal Processing of Analog Input Values

Via three assignment mechanisms, the analog input value can be assigned to drive parameters.

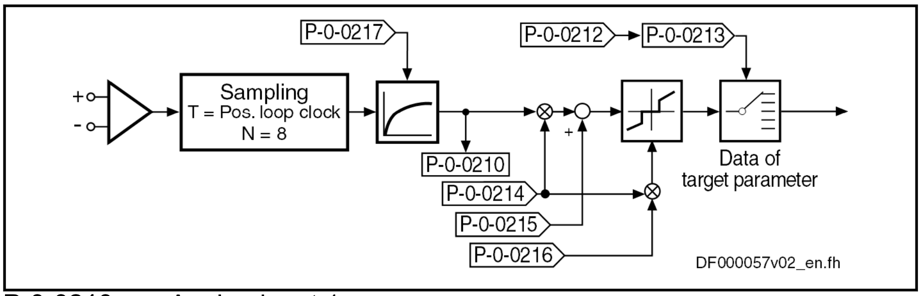
Assignment of Analog Inputs

Analog inputs are assigned to the assignments A to C via parameter "P-0-0218, Analog input, control parameter".

- Bit 7.-4 → Assignment of the analog inputs for assignment A
- Bit 11-8 → Assignment of the analog inputs for assignment B
- Bit 15-12 → Assignment of the analog inputs for assignment C

See also Parameter Description "P-0-0218, Analog input, control parameter"

The assignments to internal parameters available in the drive basically have the same functionality. Therefore, we will only show how the parameters work for the assignment A. This also applies for assignment B and C.



P-0-0210	Analog input 1
P-0-0212	Analog input, list of assignable parameters
P-0-0213	Analog input, assignment A, target parameter
P-0-0214	Analog input, assignment A, evaluation
P-0-0215	Analog input, assignment A, signal value at 0
P-0-0216	Analog input, assignment A, dead zone
P-0-0217	Analog input 1, time constant input filter

Fig. 9-56: Functional Principle of Analog Input (Example for Assignment A)

Processing Clock of Assignments

The processing clock of assignments varies:

- **Assignment A**

  → Update takes place in the **position controller clock** (see "Performance Data")

- **Assignment B and C**

  → Update takes place with **T = 2 ms**

Controlling the Internal Processing

Settings in parameter "P-0-0218, Analog input, control parameter" control the internal processing functions (adjustment and assignment):

- Bit 0 → Determining the adjustment mode for zero point and amplitude comparison for command"C2800 Analog input adjustment command"
- Bit 2/1 → Determining the assignment which is adjusted using command "C2800 Analog input adjustment command".
- Bits 15...4 → Assignment of the analog inputs to assignments A..C

Automatic Scaling

Apart from manual adjustment or scaling of the analog inputs (assignment A...C), it is also possible to adjust them automatically by activating the command "C2800 Analog input adjustment command".

In the case of automatic scaling, the parameters P-0-0214 and P-0-0215 are described by the drive for assignment A, the parameters P-0-0237 and P-0-0238 for assignment B, and the parameters P-0-0246 and P-0-0247 for assignment C.

Zero Point Shifting

The zero point for processing the analog input value can be automatically shifted by activating command C2800 which allows compensating a possibly existing offset.

The following settings can be made in "P-0-0218, Analog input, control parameter":

- Bit 0 → Defines the step of adjustment ("0" → zero point shifting)
- Bit 2/1 → defines the assignment A...C for the adjustment

The result of automatic zero point shifting is directly entered in

- P-0-0215, Analog input, assignment A, signal value at 0
- P-0-0238, Analog input, assignment B, signal value at 0
- P-0-0247, Analog input, assignment C, signal value at 0

The dedicated point can be manually determined. To do this, enter the value, that is to be contained in the target parameter with an analog input voltage of 0 V / 0 mA, in parameter P-0-0215, P-0-0238 or P-0-0247.

☞ Unit, decimal places and data type of the value in the parameter P-0-0215, P-0-0238 or P-0-0247 are based on the target parameters selected in P-0-0213, P-0-0236 or P-0-0245.

Scaling

For scaling the analog input value to the desired range of values it is possible to use the automatic amplification adjustment. To do this, command C2800 is started. With scaling, however, there are different starting conditions (cf. P-0-0218 and P-0-0219) and the following parameters are relevant:

- P-0-0218, Analog input, control parameter
  - Bit 0 → defines the step of adjust ("1" → amplification adjustment)
  - Bit 2/1 → defines the assignment A...C for the adjustment
- P-0-0219,

  This parameter indicates the value to which the analog input is set when the amplification adjustment (P-0-0218, bit 0 = 1) is carried out.

The result of automatic amplification adjustment is directly entered in parameter

- P-0-0214, Analog input, assignment A, scaling
- P-0-0237, Analog input, assignment B, scaling
- P-0-0246, Analog input, assignment C, scaling

In addition, it is possible to define the scaling manually. To do this, enter a value, that corresponds to an analog input voltage difference of 10 V or input current difference of 20mA in the target parameter (→ pitch), in P-0-0214, P-0-0237 or P-0-0246.

Unit, decimal places and data type of the value in the parameter P-0-0214, P-0-0237 or P-0-0246 are based on the target parameters selected in P-0-0213, P-0-0236 or P-0-0245.

Parameterizable "Dead Zone"

To "stabilize" the analog signal in the zero range it is possible to parameterize a so-called "dead zone":

- P-0-0216, Analog input, assignment A, dead zone
- P-0-0239, Analog input, assignment B, dead zone
- P-0-0248, Analog input, assignment C, dead zone

In the case of noisy analog values, the dead zone allows a steady output signal of the analog channel assignment in the signal zero range.

Assignment to Drive Parameters

Assignment to Parameters

The analog input values are saved for the display and internal further processing in the following parameters.

- P-0-0210, Analog input 1
- P-0-0211, Analog input 2
- P-0-0228, Analog input 3
- P-0-0229, DA: Analog input 1
- P-0-0208, DA: Analog input 2

By the assignment mechanisms via the parameters P-0-0213 (assignment A) and P-0-0236 (assignment B) P-0-0245 (assignment C), it is possible to assign an input value (P-0-0210) to up to 3 drive parameters and process them cyclically. The three assignments are available once for all analog inputs.

Parameters to be Assigned

All parameters which are contained in the list parameter "P-0-0212, Analog input, list of assignable parameters" can be assigned.

Configuring the Analog Input

The assignment of an analog input to a parameter is activated when a value not equal to "S-0-0000, Dummy parameter" was parameterized in parameter P-0-0213, P-0-0236 or P-0-0245. The corresponding assignment is deactivated when entering "S-0-0000, Dummy parameter" in parameters P-0-0213, P-0-0236 or P-0-0245.

9.8 Virtual master axis generator

9.8.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

The master axis generator serves for generating a master axis position which can be used as input variable for the position synchronization modes and the "velocity synchronization" mode.

There are three ways of generating the master axis position:

- Format conversion of an actual position value or a command position value of the local axis or of an axis connected via CCD **[1]**
- Generation of a virtual actual position value via a positioning motion and subsequent format conversion **[2]**

- Phase-synchronous motion of the master axis position to a primary master (secondary master mode) **[3]**

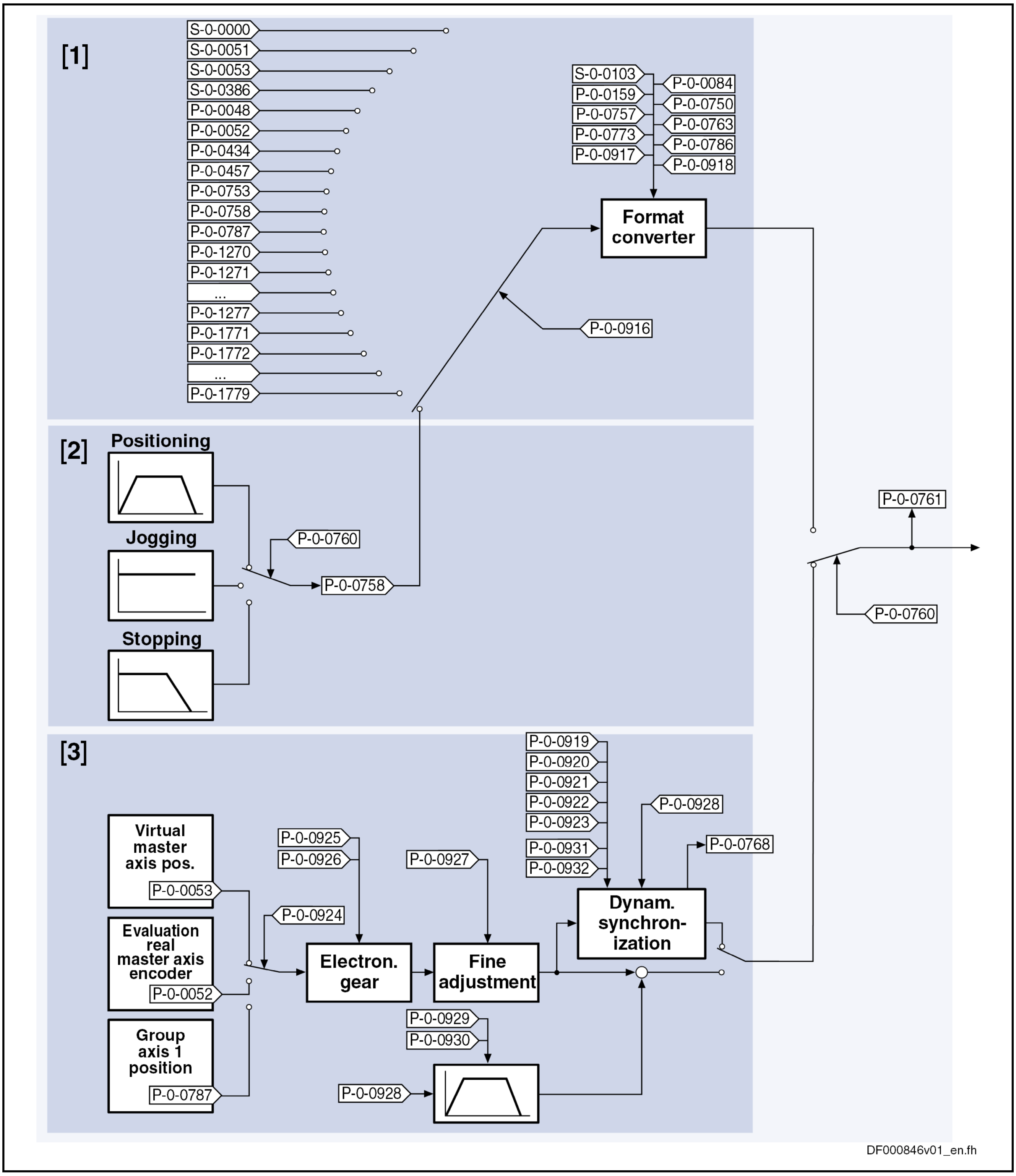


Fig. 9-57: Possibilities of Generating the Master Axis Position for the Slave Axis

Features Features of generating the virtual actual position value with the master axis generator:

- 3rd order command value interpolator
- Absolute, relative and additive positioning capability
- "Infinite travel" (jogging) is possible
- Position data format to be set:
  - Linear → 0.0001 mm / 0.0001 inch
  - Rotary → 0.0001 degrees
- Modulo value to be set
- "Absolute" or "modulo" master axis
- Format conversion from position format "virtual master axis" to master axis format (modulo value "virtual master axis" → $2^{P\text{-}0\text{-}0084}$ × P-0-0750 or $2^{P\text{-}0\text{-}0773}$ × P-0-0763)
- Virtual master axis generator realized as virtual axis in IndraMotion MLD with individual scaling system
- Setting of virtual master axis generator, either directly via parameters or via the following function blocks:
  - MC_MoveVelocity / MX_MoveVelocity
  - MC_MoveAbsolut / MX_MoveAbsolut
  - MC_MoveAdditiv / MX_MoveAdditiv
  - MC_MoveRelativ / MX_MoveRelativ
  - MC_Stop
  - MB_Stop

  Note:

  The function blocks for the virtual axis behave exactly like those for a real axis. The diagnostic and error messages, however, are different.

Features of the secondary master mode:

- Real and virtual primary master can be selected
- Electronic gear with fine adjust
- Dynamic synchronization to the primary master
- Master axis position is added as an offset with parameterization of the acceleration and velocity that can be changed
- Activating by means of the functional block "MB_GearInPos"; deactivating by means of the functional block "MB_GearOut"

Pertinent Parameters

- P-0-0084, Number of bits per master axis revolution
- P-0-0750, Master axis revolutions per master axis cycle
- P-0-0756, Virtual master axis, scaling type
- P-0-0757, Virtual master axis, modulo value
- P-0-0758, Virtual master axis, actual position value
- P-0-0759, Virtual master axis, actual velocity value
- P-0-0760, Virtual master axis, positioning control word
- P-0-0761, Master axis position for slave axis
- P-0-0762, Virtual master axis, velocity limit value
- P-0-0763, Modulo factor, master axis format converter
- P-0-0766, Virtual master axis, positioning command value
- P-0-0767, Virtual master axis, effective target position

- P-0-0768, Virtual master axis, positioning status
- P-0-0769, Virtual master axis, command value mode
- P-0-0770, Virtual master axis, positioning velocity
- P-0-0771, Virtual master axis, positioning acceleration
- P-0-0772, Virtual master axis, positioning deceleration
- P-0-0773, Number of bits per master axis revolution, format converter
- P-0-0774, Virtual master axis, positioning window shortest distance
- P-0-0911, Virtual master axis, positioning window
- P-0-0912, Virtual master axis, standstill window
- P-0-0913, Virtual master axis, positioning jerk
- P-0-0914, Virtual master axis, velocity threshold positioning
- P-0-0915, Master axis format converter IDN list signal selection
- P-0-0916, Master axis format converter signal selection
- P-0-0917, Control word of master axis generator
- P-0-0918, Feed travel internal virtual master axis
- P-0-0919, Synchronization mode, secondary master
- P-0-0920, Synchronization acceleration, secondary master
- P-0-0921, Synchronization velocity, secondary master
- P-0-0922, Preferred synchronization direction, secondary master
- P-0-0923, Synchroniz. window for shortest distance, secondary master
- P-0-0924, Selection primary master
- P-0-0925, Master drive gear input revolutions, secondary master
- P-0-0926, Master drive gear output revolutions, secondary master
- P-0-0927, Master drive gear fine adjustment, secondary master
- P-0-0928, Additive master axis position, secondary master
- P-0-0929, Change velocity of add. master axis posit., secondary master
- P-0-0930, Change accel. of add. master axis posit., secondary master
- P-0-0931, Synchronous position, secondary master
- P-0-0932, Synchronization range, secondary master

Pertinent Diagnostic Messages

- E2100 Positioning velocity of master axis generator too high
- F2063 Internal overflow master axis generator
- F2064 Incorrect cmd value direction master axis generator

9.8.2 Functional Description

Positioning Mode of Virtual Master Axis Generator

The virtual master axis generator is activated or deactivated via parameter "P-0-0917, Control word of master axis generator".

The figure below illustrates the functional principle of the generation of the virtual actual position value with the virtual master axis generator and the effect of the individual parameters.

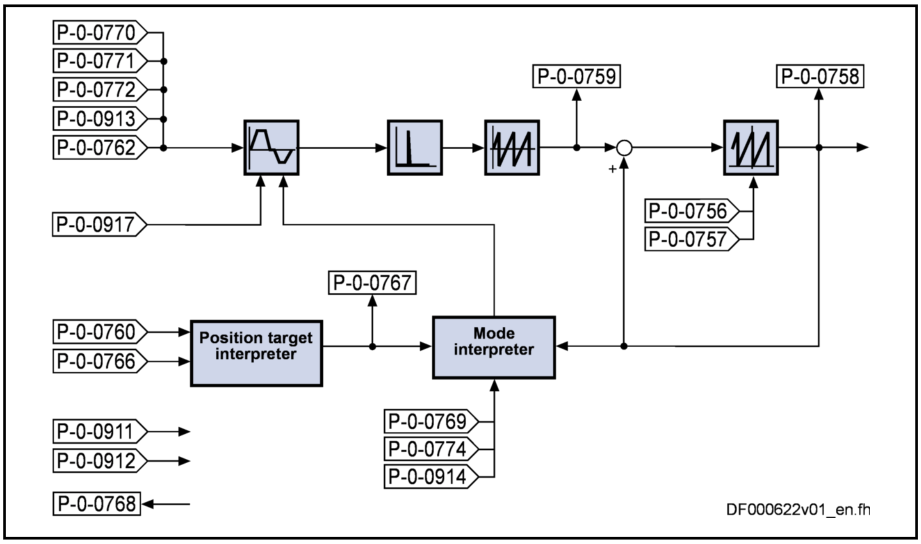


Fig. 9-58: Overview of Function "Virtual Master Axis Generator"

Positioning by means of the virtual master axis generator basically works in the same way as with the positioning generator of the "drive-controlled positioning" mode (see description of the operation mode "drive-controlled positioning").

Please note that the parameters which take effect for the virtual master axis generator are different from those for drive-controlled positioning (see comparative table below).

Name/significance of the parameter	Drive-controlled positioning	Virtual master axis generator
Positioning command value	S-0-0282	P-0-0766
Command value mode	S-0-0393	P-0-0769
Positioning velocity	S-0-0259	P-0-0770
Positioning acceleration	S-0-0260	P-0-0771
Positioning deceleration	S-0-0359	P-0-0772
Positioning control word	S-0-0346	P-0-0760
Positioning status	S-0-0437	P-0-0768
Positioning jerk	S-0-0193	P-0-0913
Positioning window shortest distance	S-0-0418 Target position window in modulo format	P-0-0774 Virtual master axis, positioning window shortest Distance
Effective target position	S-0-0430	P-0-0767
Velocity threshold	S-0-0417	P-0-0914

Tab. 9-15: Parameter Comparison

Differences to operation mode "drive-controlled positioning"

General Information

A 3rd order interpolator is used with the master axis generator instead of a 2nd order interpolator with subsequent filter for jerk limitation. This means that even very small values for "P-0-0913, Virtual master axis, positioning jerk" can be realized correctly.

The parameters for the interpolator basically are not immediately active in the case of a change, but only after the next command triggering. Command triggering is done by toggling bit 0 in the positioning control word (P-0-0760). Bit 1 is set in the positioning status (P-0-0768) to acknowledge acceptance.

Selecting the Acceleration Curve

A sine-shaped acceleration curve can be selected alongside the trapezoidal acceleration curve (jerk square-shaped) with bit 2 of "P-0-0917, Control word of master axis generator" A sine^2-shaped acceleration curve is selected as well as the trapezoid acceleration curve. Then there aren't any jumps in the jerk curve and the motion is more gentle.

☞ Jerk limitation is not active with sine^2-shaped acceleration curves. The parameterizable position jerk is not effective.

The interruption of a motion during acceleration or deceleration by a new command triggered leads to a jump in acceleration. That is why cyclic command triggering of the interpolator is to be avoided with sine^2-shaped acceleration curves.

Dynamic Jerk Adjustment

Parameter "P-0-0762, Virtual master axis, velocity limit value" is available to monitor and limit a preset positioning velocity.

This parameter is also used with "dynamic jerk adjustment". This function is active if it has not been deactivated via bit 3 of the "control word of master axis generator". "Dynamic jerk adjustment" is used if, during an acceleration phase, a new command triggering takes place which leads to an overshooting of the velocity. The effective jerk is then increased so that the preset velocity limit value is not exceeded.

☞ "Dynamic jerk adjustment" is only possible with trapezoidal acceleration curves.

Processing Clock

The generator function of the master axis generator runs in the NC clock. The calculated values are fine interpolated in linear form with regard to the position controller clock.

Residual Path Processing

For the virtual master axis generator, there is no residual path processing available.

Intermediate Stop

The new position target is applied "on-the-fly" **without** the possibility of intermediate stop (positioning command value memory).

☞ The conversion of the value of "P-0-0758, Virtual master axis, actual position value" to the master axis format (increments per master axis revolution) takes place by means of the master axis format converter. The converted value is displayed in parameter "P-0-0761, Master axis position for slave axis".

Scaling System

Features

The virtual master axis generator has its own scaling system with the following features:

- Position data format to be set:
  - Linear: 0.0000 in / 0.0001 in
  - Rotary: 0.0001 degrees
- Modulo value to be set
- Possible modulo ranges (0.0000 to 214748.3647)
- Fixed absolute range (-214748.3648 to 214748.3647)

Scaling Parameters

There are the following scaling parameters for the virtual master axis generator:

- P-0-0756, Virtual master axis, scaling type
- P-0-0757, Virtual master axis, modulo value
- P-0-0758, Virtual master axis, actual position value
- P-0-0759, Virtual master axis, actual velocity value

☞ When the master axis generator has been deactivated, the parameters "P-0-0758, Virtual master axis, actual position value" and "P-0-0759, Virtual master axis, actual velocity value" can be pre-initialized.

Format Converter from Position Data Format into the Master Axis Format

It is possible to generate the internal virtual master axis position "P-0-0761, Master axis position for slave axis" from different sources. The source signals are available in the position data format and must be converted to the master axis format. The master axis format is displayed in increments per master axis revolution and, depending on the setting in parameter P-0-0917, bit 4, encompasses either $2^{P\text{-}0\text{-}0084}$ or $2^{P\text{-}0\text{-}0773}$ increments per master axis revolution.

☞ In cases in which the result of format conversion is not used as the master axis for local axes but for remote axes (CCD slave axes) with deviating master axis scaling, the master axis format of the internal virtual master axis can be decoupled from the setting of the local axis.

By setting Bit 4 in "P-0-0917, Control word of master axis generator" the format conversion no longer takes place via parameters

- P-0-0750, Master axis revolutions per master axis cycle
- P-0-0084, Number of bits per master axis revolution

but using parameters

- P-0-0763, Modulo factor, master axis format converter
- P-0-0773, Number of bits per master axis revolution, format converter

If the internal virtual master axis VmAxisInt (P-0-0761, Master axis position for slave axis) is formed in its own master axis format, the axes which are to follow this master axis, are set the same master axis format in order to prevent an incorrect processing of the master axis position by the synchronous operating modes.

☞ One master axis format converter and thus only one internal master axis is available per double-axis device. This master axis, however, can be used by both axes.

Pertinent Parameters

The following parameters, amongst others, are involved in conjunction with the format converter function:

- S-0-0103, Modulo value
- P-0-0084, Number of bits per master axis revolution
- P-0-0159, Slave drive feed travel

- P-0-0750, Master axis revolutions per master axis cycle
- P-0-0753, Position actual value in actual value cycle
- P-0-0757, Virtual master axis, modulo value
- P-0-0761, Master axis position for slave axis
- P-0-0763, Modulo factor, master axis format converter
- P-0-0773, Number of bits per master axis revolution, format converter
- P-0-0786, Modulo value actual value cycle
- P-0-0915, Master axis format converter IDN list signal selection
- P-0-0916, Master axis format converter signal selection
- P-0-0917, Control word of master axis generator
- P-0-0918, Feed travel internal virtual master axis

Signal Sources

The format converter can process the values of the following signal sources:

- S-0-0051, Position feedback value 1
- S-0-0053, Position feedback value 2
- S-0-0386, Active position feedback value
- P-0-0048, Effective velocity command value
- P-0-0052, Actual position value of measuring encoder
- P-0-0434, Position command value of controller
- P-0-0457, Position command value generator
- P-0-0753, Position actual value in actual value cycle
- P-0-0758, Virtual master axis, actual position value
- P-0-1270, PLC Global Register A0
- P-0-1271, PLC Global Register A1
- P-0-1272, PLC Global Register A2
- P-0-1273, PLC Global Register A3
- P-0-1274, PLC Global Register A4
- P-0-1275, PLC Global Register A5
- P-0-1276, PLC Global Register A6
- P-0-1277, PLC Global Register A7
- P-0-1771, CCD: Actual value data container 1, Slave 1 4Byte

  - to -

  P-0-1777, CCD: Actual value data container 1, Slave 7 4Byte

Implementation

The master axis format converter is activated by selecting a parameter unequal S-0-0000 in parameter "P-0-0916, Master axis format converter signal selection"

.

The master axis format converter is deactivated, when the dummy parameter S-0-0000 is selected in parameter P-0-0916.

The following relations apply to the conversion of the actual position value format to the master axis format:

If the master axis format is decoupled from the internal virtual master axis of the local axis ("P-0-0917, Control word of master axis generator", Bit 4 = 1), the parameters must be replaced in the following formulas:

- P-0-0750 must be replaced by P-0-0763

and

- P-0-0084 replaced by P-0-0773

- Signal source S-0-0051, S-0-0053, S-0-0386 or P-0-0457

$$\text{P-0-0761} = \frac{\text{S-0-0051}}{\text{S-0-0103}} \times \text{P-0-0750} \times 2^{\text{P-0-0084}}$$

$$\text{P-0-0761} = \frac{\text{S-0-0053}}{\text{S-0-0103}} \times \text{P-0-0750} \times 2^{\text{P-0-0084}}$$

$$\text{P-0-0761} = \frac{\text{S-0-0386}}{\text{S-0-0103}} \times \text{P-0-0750} \times 2^{\text{P-0-0084}}$$

$$\text{P-0-0761} = \frac{\text{P-0-0457}}{\text{S-0-0103}} \times \text{P-0-0750} \times 2^{\text{P-0-0084}}$$

Fig. 9-59: Rotary/Linear Modulo Scaling of the Signal Source

$$\text{P-0-0761} = \frac{\text{S-0-0051}}{360°} \times 2^{\text{P-0-0084}}$$

$$\text{P-0-0761} = \frac{\text{S-0-0053}}{360°} \times 2^{\text{P-0-0084}}$$

$$\text{P-0-0761} = \frac{\text{S-0-0386}}{360°} \times 2^{\text{P-0-0084}}$$

$$\text{P-0-0761} = \frac{\text{P-0-0457}}{360°} \times 2^{\text{P-0-0084}}$$

Fig. 9-60: Rotary Absolute Scaling of the Signal Source

$$\text{P-0-0761} = \frac{\text{S-0-0051}}{\text{P-0-0159}} \times 2^{\text{P-0-0084}}$$

$$\text{P-0-0761} = \frac{\text{S-0-0053}}{\text{P-0-0159}} \times 2^{\text{P-0-0084}}$$

$$\text{P-0-0761} = \frac{\text{S-0-0386}}{\text{P-0-0159}} \times 2^{\text{P-0-0084}}$$

$$\text{P-0-0761} = \frac{\text{P-0-0457}}{\text{P-0-0159}} \times 2^{\text{P-0-0084}}$$

Fig. 9-61: Linear Absolute Scaling of the Signal Source

- Signal source P-0-0048

$$P\text{-}0\text{-}0761 = P\text{-}0\text{-}0761 + P\text{-}0\text{-}0048 \times \text{Position controller cycle time} \times S\text{-}0\text{-}0045 \times 1E(S\text{-}0\text{-}0046) \times \frac{S\text{-}0\text{-}0079}{S\text{-}0\text{-}0103} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

Fig. 9-62: Rotary Modulo Scaling

$$P\text{-}0\text{-}0761 = P\text{-}0\text{-}0761 + P\text{-}0\text{-}0048 \times \text{Position controller cycle time} \times S\text{-}0\text{-}0045 \times \frac{1E(S\text{-}0\text{-}0046)}{S\text{-}0\text{-}0103 \times S\text{-}0\text{-}0077 \times 1E(S\text{-}0\text{-}0078)} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

Fig. 9-63: Linear modulo scaling

$$P\text{-}0\text{-}0761 = P\text{-}0\text{-}0761 + P\text{-}0\text{-}0048 \times \text{Position controller cycle time} \times S\text{-}0\text{-}0045 \times 1E(S\text{-}0\text{-}0046) \times 2^{P\text{-}0\text{-}0084}$$

Fig. 9-64: Rotary Absolute Scaling

$$P\text{-}0\text{-}0761 = P\text{-}0\text{-}0761 + P\text{-}0\text{-}0048 \times \text{Position controller cycle time} \times S\text{-}0\text{-}0045 \times \frac{1E(S\text{-}0\text{-}0046)}{P\text{-}0\text{-}0159 \times S\text{-}0\text{-}0077 \times 1E(S\text{-}0\text{-}0078)} \times 2^{P\text{-}0\text{-}0084}$$

Fig. 9-65: Linear Absolute Scaling

- Signal source P-0-0052

$$P\text{-}0\text{-}0761 = P\text{-}0\text{-}0052$$

Fig. 9-66: For All Scalings of the Signal Source

- Signal source P-0-0434 (special case)

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0434}{360°} \times 2^{P\text{-}0\text{-}0084}$$

Fig. 9-67: Rotary Absolute Scaling

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0434}{P\text{-}0\text{-}0159} \times 2^{P\text{-}0\text{-}0084}$$

Fig. 9-68: Linear Absolute Scaling

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0434}{S\text{-}0\text{-}0103} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

Fig. 9-69: Rotary/Linear Modulo Scaling and no Synchronous Position Control Mode Active

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0434}{P\text{-}0\text{-}0786} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

Fig. 9-70: Rotary/Linear Modulo Scaling and a Synchronous Position Control Mode Active

- Signal source P-0-0753

$$\text{P-0-0761} = \frac{\text{P-0-0753}}{\text{P-0-0786}} \times \text{P-0-0750} \times 2^{\text{P-0-0084}}$$

Fig. 9-71: Rotary/Linear Modulo Scaling of the Signal Source

$$\text{P-0-0761} = \frac{\text{P-0-0753}}{360°} \times 2^{\text{P-0-0084}}$$

Fig. 9-72: Rotary Absolute Scaling of the Signal Source

$$\text{P-0-0761} = \frac{\text{P-0-0753}}{\text{P-0-0159}} \times 2^{\text{P-0-0084}}$$

Fig. 9-73: Linear Absolute Scaling of the Signal Source

- Signal source P-0-0758

$$\text{P-0-0761} = \frac{\text{P-0-0758}}{\text{P-0-0757}} \times \text{P-0-0750} \times 2^{\text{P-0-0084}}$$

Fig. 9-74: Modulo Scaling of the Position Data Master Axis Generator (for P-0-0750 > 0)

$$\text{P-0-0761} = \frac{\text{P-0-0758}}{\text{P-0-0757}} \times 4294967295 \text{ incr.} - 2147483648 \text{ incr.}$$

Fig. 9-75: Modulo Scaling of the Position Data Master Axis Generator (for Special Case P-0-0750 = 0)

4096 master axis revolutions correspond to one modulo revolution of the virtual axis of the master axis generator.

$$\text{P-0-0761} = \frac{\text{P-0-0758}}{\text{P-0-0918}} \times 2^{\text{P-0-0084}}$$

Fig. 9-76: Absolute Scaling of the Position Data Master Axis Generator

- Signal sources P-0-1270 to P-0-1277

$$\text{P-0-0761} = \text{P-0-127x}$$

x Selected parameter from range P-0-1270 to P-0-1277

Fig. 9-77: For All Scalings of the Signal Source

☞ The parameters P-0-1270 to P-0-1277 are only available with the additional package MLD.

- Signal sources P-0-1771 to P-0-1777

P-0-0761 = P-0-177x

x	Selected parameter from range P-0-1771 to P-0-1777

Fig. 9-78: For All Scalings of the Signal Source

Secondary Master Mode

Activation/Settings

For the output value of the format converter (P-0-0761, Master axis position for slave axis), the "secondary master" mode can be selected in bit 12 of the parameter "P-0-0760, Virtual master axis, positioning control word".

If this option has been selected, the master axis position for the slave axis (P-0-0761) synchronizes to a primary master and subsequently moves phase-synchronously to it.

In parameter "P-0-0924, Selection primary master", the real master axis, which is written by "P-0-0052, Actual position value of measuring encoder", the external master axis position (P-0-0053) or the group axis position (P-0-0787) can be determined as the primary master.

Master Axis Format/Cycle

When using secondary master mode, the master axis format and the master axis cycle of the virtual internal master axis must comply with the specified primary master! The master axis format and the master axis cycle of the internal virtual master axis depend on the settings in P-0-0917, Control word of master axis generator, bit 4:

Bit4 = 0 (default):

Cycle defined by parameter "P-0-0750, Master axis revolutions per master axis cycle" and format defined by "P-0-0084, Number of bits per master axis revolution".

Bit4 = 1 :

Cycle defined by parameter "P-0-0763, Modulo factor, master axis format converter" and format defined by "P-0-0773, Number of bits per master axis revolution, format converter".

Electric Gearboxes and Fine Adjustment

An electronic gearbox with fine adjustment is mounted between the primary master and the secondary master. In this gearbox, the value of the primary master is multiplied with the quotient of the output and input revolutions of the gearbox, as well as with the factor "1+ fine adjustment". The result is limited to the master axis cycle ($2^{P\text{-}0\text{-}0084}$ × P-0-0750 or $2^{P\text{-}0\text{-}0773}$ × P-0-0763). After the output of the electronic gearbox has been initialized, the gearbox is differentially processed. A change in the gearbox thereby only results in a velocity jump, not in a position jump.

Offset of Secondary Master

Parameter "P-0-0928, Additive master axis position, secondary master" can be used to offset the secondary master with respect to the master axis position which is calculated from the primary master and the electronic gearbox with fine adjustment.

For synchronization of the secondary master the value of the additive master axis position is taken into account and the drive moves with the synchronization parameter values for velocity and acceleration. The motion of the secondary master for a subsequent change of the additive master axis position is limited by the parameters "P-0-0929, Change velocity of add. master axis posit., secondary master" and "P-0-0930, Change accel. of add. master axis posit., secondary master".

If relative synchronization has been set in the synchronization mode, only one velocity adjustment is made. In this case, the absolute value of "P-0-0928, Additive master axis position, secondary master" is without effect.

Following changes of this additive master axis position are processed in relative form. This means that they result in corresponding changes of the secondary master.

Synchronization of Secondary Master

Double-Step Synchronization

Synchronization is carried out in two steps. First, a velocity adjustment is carried out and then the position reference is established.

Relative or absolute synchronization can be selected for synchronization mode. With relative synchronization, only one velocity adjustment is carried out. The velocity of the secondary master is adjusted to the velocity of the primary master by acceleration or deceleration.

The value for acceleration or deceleration is determined in parameter "P-0-0920, Synchronization acceleration, secondary master".

With absolute synchronization, the velocity adjustment is followed by a position adjustment. The offset between the primary master and the secondary master is moved by an added motion with synchronization acceleration and synchronization velocity of the secondary master so that subsequently the master axes are absolutely phase-synchronous.

At the end of the velocity adjustment with relative synchronization or of the position adjustment with absolute synchronization, bit 8 of parameter "P-0-0768, Virtual master axis, positioning status" is set ("synchronization completed").

Subsequently, the value of parameter P-0-0761 is directly generated from the position of the primary master (differential processing). In this process, the electronic gearbox and the fine adjustment are taken into account.

It is possible to select between a master axis revolution and the master axis cycle as the synchronization range.

Single-Step Synchronization

As an alternative to double-step synchronization, a master-axis-synchronous, single-step synchronization method can be selected. Master-axis-synchronous means that the synchronization process of the secondary master is coupled to a range of the primary master to be passed.

It is necessary to define whether the synchronization process is to start immediately (relatively master-axis-synchronous) or not until the primary master passes a start angle (after gearbox and fine adjustment) (absolutely master-axis-synchronous). The start angle is the difference of the parameters "P-0-0931, Synchronous position, secondary master" and "P-0-0932, Synchronization range, secondary master".

This synchronization motion is added to the synchronous motion. The additive master axis positions causing the synchronization motion are calculated for the required velocity in rest motion by a 5th order polynomial: $f(x) = A_5 * x^5 + A_4 * x^4 + A_3 * x^3 + A_1 * x$.

The coefficients of the polynomial are calculated from the states at the beginning of the synchronization motion (synchronization range of the primary master, synchronization distance of secondary master, velocities of primary master and secondary master). The position within the parameterized synchronization range provides the argument for calculating a functional value of the polynomial.

The secondary master synchronization distance is not unequivocal with modulo scaling. It can be increased or reduced by one or several synchronization ranges. By setting bit 9 in the parameter "P-0-0919, Synchronization mode, secondary master", it is possible to select the optimization of the secondary master synchronization distance by the drive. As an alternative, the secondary master synchronization distance can be influenced by parameters "P-0-0922, Preferred synchronization direction, secondary master" and "P-0-0923, Synchroniz. window for shortest distance, secondary master".

- **Distance optimization** (P-0-0919, bit 9 = "1"): An ideal value for the secondary master synchronization distance is firstly calculated from the values available for master axis velocity, master axis synchronization distance and secondary master axis velocity and from the ideal value of the standardized velocity (2.08333) for the motion profile "velocity in rest" that is used. The required secondary master synchronization distance (difference of synchronous secondary master position and actual position of secondary master) is then approximated as near as possible to the ideal value by adding or subtracting synchronization ranges. The optimization aims at not having any reversal point in the position curve in the added synchronization profile. In this case, there won't be any maximum in the velocity curve (overshooting) and no change of the acceleration sign. When the user significantly increases the master axis synchronization distance, this also increases the secondary master synchronization distance. The occurring acceleration values can thus be reduced.
- **No distance optimization** (P-0-0919, bit 9 = "0"): The polarity of the added secondary master synchronization distance is set by parameter "P-0-0922, Preferred synchronization direction, secondary master". However, this only applies if the absolute value of the shortest synchronization distance is greater than the value of "P-0-0923, Synchroniz. window for shortest distance, secondary master". The maximum variable (absolute value) of the added slave axis synchronization distance corresponds to one synchronization range.

If "absolute master-axis-synchronous synchronization" has been set, a velocity adjustment is performed until the master axis start angle is passed. This means that the velocity of the secondary master is approximated to the velocity of the primary master (after gearbox and fine adjustment) with the acceleration parameterized in parameter "P-0-0920, Synchronization acceleration, secondary master". If the synchronization acceleration is set to "0", the slave axis maintains its velocity until the master axis start angle is passed (standstill at v = 0)

> The single-step synchronization is only possible in conjunction with absolute synchronization.

Deactivating the Secondary Master Mode

To deactivate the secondary master mode, bit 12 is reset in parameter "P-0-0760, Virtual master axis, positioning control word". On the basis of the current velocity, the drive is then switched to the mode selected by bit 1 and bit 2 (positioning, jogging or stopping).

> For this switching, the parameter "P-0-0758, Virtual master axis, actual position value" must have been configured in the format converter.

9.9 Drive-Integrated Command Value Generator

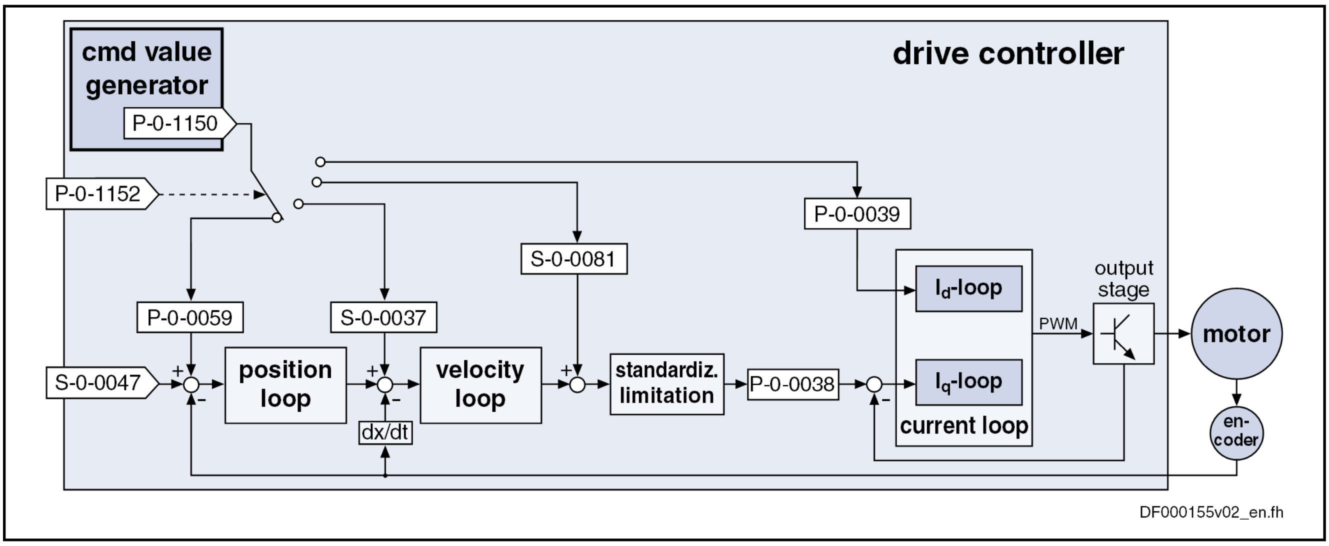
9.9.1 Brief Description

> Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

The drive-integrated command value generator can be used for commissioning and controller optimization of drives. The command value generator is used to generate various signal shapes (square wave, sine, noise, sine sweep) that are added to the closed control loop as command values.

☞ In conjunction with the integrated oscilloscope function, the drive-integrated command value generator also provides the possibility of measuring the frequency response.

The figure below illustrates the points at which the drive-integrated command value generator can take effect:



S-0-0037	Additive velocity command value
S-0-0047	Position command value
S-0-0081	Additive torque/force command value
P-0-0038	Torque-generating current, command value
P-0-0039	Flux-generating current, command value
P-0-0059	Additive position command value, controller
P-0-1150	Command value generator output
P-0-1152	Command value generator, target parameter assignment

Fig. 9-79: Points at which "Command Value Generator" Function can Take Effect

Features

- Possibility of generating different signal shapes that are added as additive command values to the respective control loop command value (position, velocity or current)

  The following signal shapes are possible:
  - Square-wave signals
  - Sine signals
  - Noise signals
  - Modified sine signals
  - Sine sweep
- Generating **velocity and position command values** in the position controller clock; **current command values** in the velocity controller clock
- With regard to **amplitude and frequency**, generated command values can be freely defined

Pertinent Parameters

- P-0-1150, Command value generator output

- P-0-1151, Command value generator, list of possible target parameters
- P-0-1152, Command value generator, target parameter assignment
- P-0-1153, Command value generator, control word
- P-0-1154, Command value generator, offset
- P-0-1155, Command value generator, amplitude
- P-0-1156, Command value generator, duration 1
- P-0-1157, Command value generator, duration 2
- P-0-1158, Command value generator, periodic time
- P-0-1159, Command value generator, sine sweep start frequency
- P-0-1160, Command value generator, sine sweep end frequency
- P-0-0028, Oscilloscope: Control word
- P-0-0031, Oscilloscope: Time resolution
- P-0-0032, Oscilloscope: Size of memory

9.9.2 Functional Description

Setting/Activating the Function

Clock Rate

The integrated command value generator provides the possibility of generating velocity and position command values in the position controller clock for commissioning and adding them to the respective main command value.

The current command values are generated in the velocity loop clock.

Activation

The command value generator is activated and controlled via parameter "P-0-1153, Command value generator, control word" by setting the enable bit. When the enable signal has been set, the generator generates command values in the position loop clock (or velocity loop clock).

In parameter P-0-1153, you can also set that the enabling of the command value generator is automatically deactivated in the case of drive errors. In this case, you have to set the enable signal again after each drive error or after the control voltage has been switched on.

Drive Enable

In order that the generated additive command values take effect, drive enable (bit "drive on" = 1) has to be set.

This can be done in the following ways:

- Via a digital input
- Via the engineering port in "Easy-Startup" mode
- Via the master communication

Selecting the Target Parameter

The IDN of that parameter is entered in parameter "P-0-1152, Command value generator, target parameter assignment" on which the output signal of the command value generator is to take effect.

The IDNs of the possible target parameters for the generator output are given in parameter "P-0-1151, Command value generator, list of possible target parameters".

The following list shows possible target parameters to which the output signal of the command value generator (P-0-1150) can be assigned:

- S-0-0037, Additive velocity command value
- S-0-0081, Additive torque/force command value
- P-0-0039, Flux-generating current, command value
- P-0-0059, Additive position command value, controller

See also Parameter Description "P-0-1151, Command value generator, list of possible target parameters"

☞ The unit and attribute of the generated signal are adjusted according to attribute and unit of the assigned parameter. S-0-0000, Dummy parameter can also be assigned as the target parameter for the command value generator in order to use the command value generator as a pure signal shape generator.

☞ The target parameter is described to a limited extent according to its minimum and maximum values set while the signal in the command value generator output (P-0-1150) is output with the parameterized amplitude without restriction. If an amplitude is set which leads to the value exceeding the maximum value or dropping below minimum value of the target signal, the signal progress in the command value generator output and in the target parameter do not match!

Selecting the Signal Shape

The shape of the desired output signal is determined by means of the respective bits in parameter "P-0-1153, Command value generator, control word".

You can choose between the following signal shapes of the command value:

- Square-wave signals

  → Pulse generator with definable pulse/pause relationship, variable frequency and direct voltage component (offset)

- Sine signals

  → Sine generator generates signal up to theoretical maximum frequency of 2 kHz with variable frequency and direct voltage component (offset)

- Noise signals

  → Noise generator generates wide-band "white noise"; amplitude of the noise signal can be defined as a mere factor or by means of envelope curve (= square-wave signal)

- Modified sine signals

  → Modified sine generator generates composite sine shape consisting of two joined half-waves of different signs and different periodic times

- Sine sweep

  → The sine sweep generator produces a sine the frequency of which varies, with an amplitude and offset that can be set. The frequency rises in a linear pattern from the starting frequency to the end frequency.

Advanced Settings

Other possible settings in the control word of the command value generator:

- Activation of periodic signal generation

  → Selected signal is cyclically generated and output with a periodic time (frequency) that can be defined

- Switch-off delay

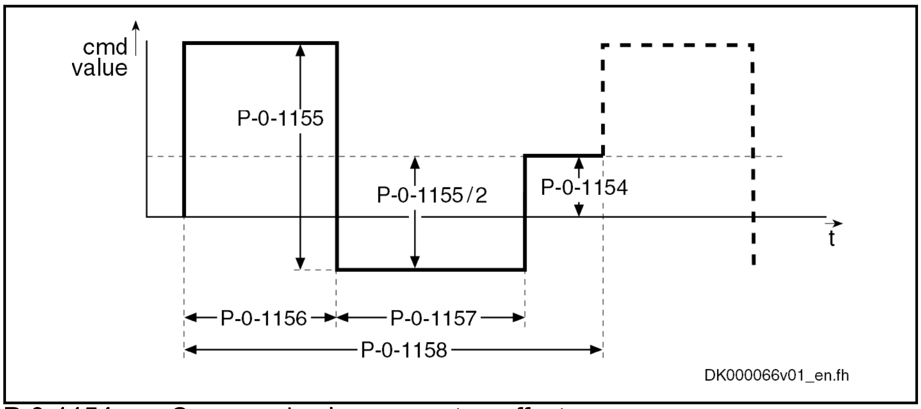
  → The shutdown of the command value generator (command value generator output = "0") can be delayed, that is shutdown is delayed until the signal period is complete.

Pulse Generator (for Square-Wave Signal)

The pulse generator generates a square-wave signal that can be varied in the following properties:

- Frequency or periodic time of the signal
- Amplitude
- Offset (DC offset; positive/negative)
- Pulse/pause relationship

The exemplary figure below illustrates the output signal of the pulse generator with the points at which the generator can take effect:



P-0-1154	Command value generator, offset
P-0-1155	Command value generator, amplitude
P-0-1156	Command value generator, duration 1
P-0-1157	Command value generator, duration 2
P-0-1158	Command value generator, periodic time

Fig. 9-80: Output Signal of Pulse Generator

☞ If periodic command value generation has been selected in the control word, parameter "P-0-1158, Command value generator, periodic time" determines the cycle time or periodic time.

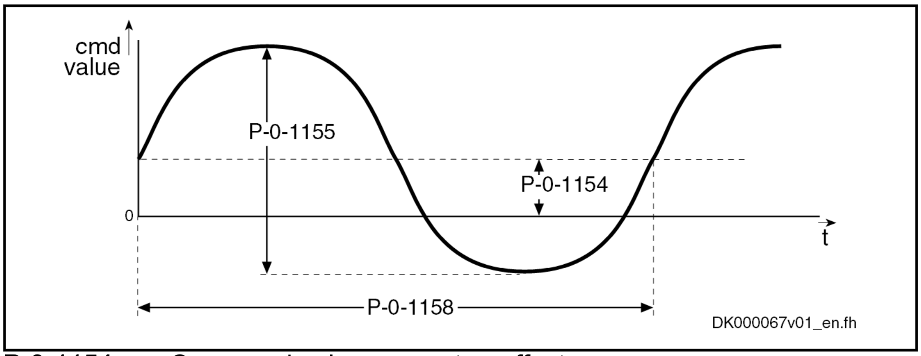
In the case of P-0-1158 = (P-0-1156) + (P-0-1157), there is a periodic square-wave signal resulting, if the periodic output has additionally been activated in the control word.

Sine Generator

The sine generator generates a sine that can be varied in the following properties:

- Frequency or periodic time of the signal
- Amplitude
- Offset (DC offset; positive/negative)

The exemplary figure below illustrates the output signal of the sine generator with the points at which the generator can take effect:



P-0-1154 Command value generator, offset
P-0-1155 Command value generator, amplitude
P-0-1158 Command value generator, periodic time

Fig. 9-81: Output Signal of Sine Generator

☞ The target parameter selected in parameter P-0-1152 determines the initial angle of the signal. For currents and torque command values the initial angle is 90° so that the position deviation of the drive is zero again after a complete period.

Advanced Settings

Advanced settings can be made in parameter "P-0-1153, Command value generator, control word":

- In many cases it is important that the sine signal does not contain any offset (surface under the curve). The shutdown of the command value generator can therefore be delayed until the period is complete (P-0-1153, bit 6).
- If no target parameter (P-0-1152 = S-0-0000) has been assigned for the output of the command value generator, the signal shape can be switched from sine to cosine (P-0-1153, bit 9).

Noise Generator

The method of the feedback shift register is used for generating the random numbers. In each sequence a bit for the output is generated which is set or cleared at random so to speak. The periodic time of the noise signal in this case is set to 4095 clocks ($T_{A\_position}$ or $T_{A\_velocity}$).

☞ The generated noise signal is free of mean values over an entire period so that the drive does not drift due to the additional noise.

Output Format (Amplitude Modulation)

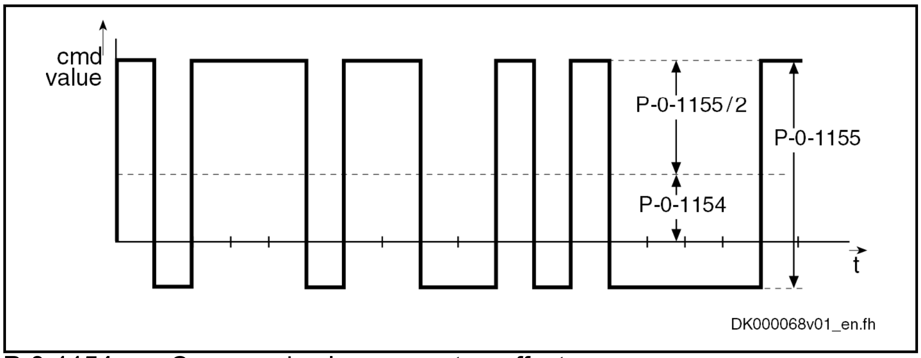
For outputting the pulse sequences, there are the following options:

- Noise signal as square-wave signal with parameterizable amplitude and, if necessary, offset component

  → Positive or negative amplitude is set according to the sign of the feedback shift register
- Noise signal with continuous amplitude

  → Feedback shift register is interpreted as numeric value and evaluated with amplitude

The exemplary figure below illustrates the output signal of the noise generator with the points at which the generator can take effect:



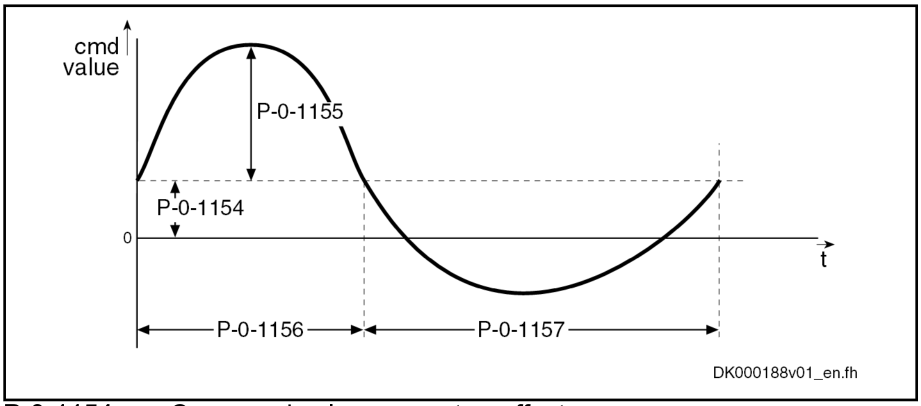
P-0-1154 Command value generator, offset
P-0-1155 Command value generator, amplitude
Fig. 9-82: Output Signal of Noise Generator

Modified Sine Generator

In addition, a modified sine generator is available with two different half-waves of the same amplitude; the output signal of the generator can be varied in the following properties:

- Frequency or periodic time of the signal
- Duration of the first half-wave
- Duration of the second half-wave
- Amplitude
- Offset (DC offset; positive/negative)

The exemplary figure below illustrates the modifiable output signal of the sine generator with the points at which the generator can take effect:



P-0-1154 Command value generator, offset
P-0-1155 Command value generator, amplitude
P-0-1156 Command value generator, duration 1
P-0-1157 Command value generator, duration 2
Fig. 9-83: Output Signal of Noise Generator

Sine Sweep Generator

The sine sweep generator generates a sine with varying frequency. The frequency rises in linear form from the starting frequency to the end frequency ("sweeping up") and then falls in linear form to the starting frequency ("sweeping down").

The output signal can be varied in the following properties:

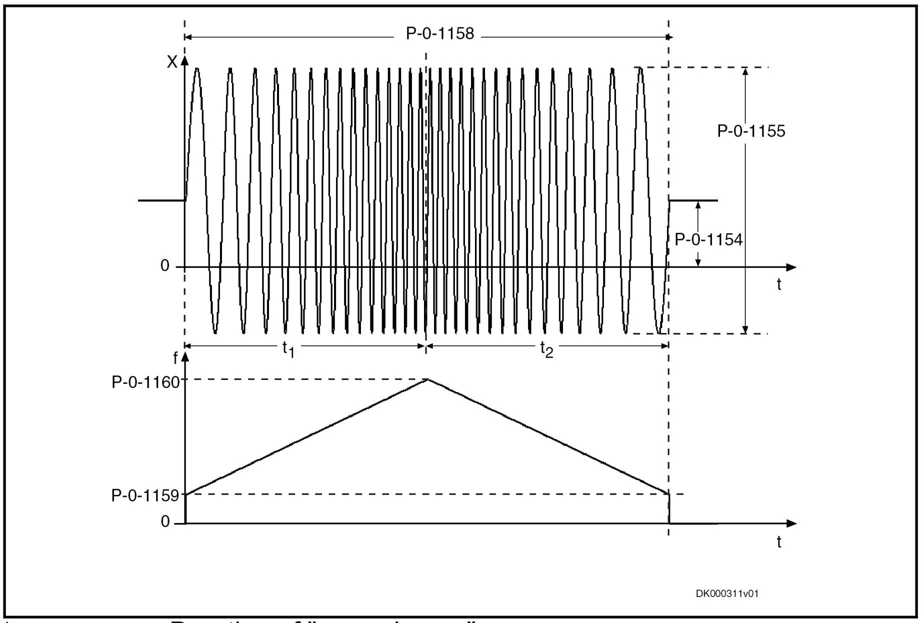
- Starting frequency
- End frequency

- Periodic time of the signal (duration of "sweeping up" and "sweeping down" combined)
- Amplitude
- Offset (DC offset, positive/negative)

☞ The periodic time of the sweep must correspond to at least four-times the duration of the minimum frequency to be run through (start and end frequency). Otherwise, the command value generator cannot generate any sensible signals.

If e.g. 0.1 Hz is entered as a start frequency and the end frequency is larger, the periodic time of the sweep must be at least 4 × 1/0.1Hz = 40 s.

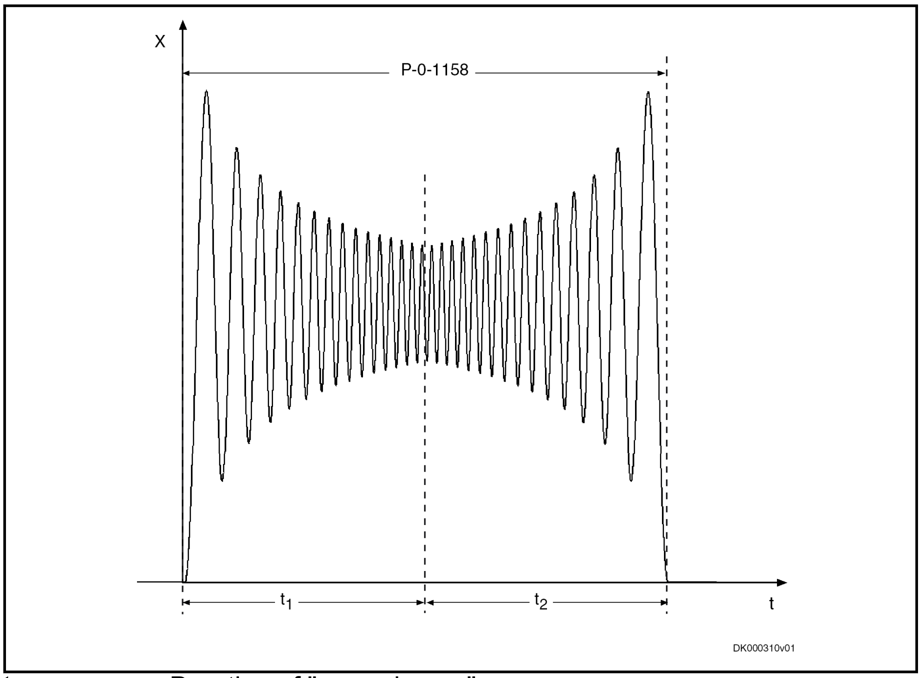
The exemplary figure below illustrates a sine sweep with the points at which the sine sweep can take effect:



t_1	Duration of "sweeping up"
t_2	Duration of "sweeping down"
P-0-1154	Command value generator, offset
P-0-1155	Command value generator, amplitude
P-0-1158	Command value generator, periodic time
P-0-1159	Command value generator, starting frequency of sine sweep
P-0-1160	Command value generator, end frequency of sine sweep

Fig. 9-84: Output Signal of Sine Sweep Generator

☞ The generated sine sweep without offset is free of mean values over an entire periodic time ("sweeping up and sweeping down"). During "sweeping up", an offset is formed which is then reduced during "sweeping down", as shown in the figure below.



t_1	Duration of "sweeping up"
t_2	Duration of "sweeping down"
P-0-1158	Command value generator, periodic time

Fig. 9-85: Integral Sine Sweep without Offset (Offset, P-0-1154 = "0")

9.9.3 Notes on Commissioning

Bandwidth and Frequency Response Measurement

Frequency response measurement always requires accordingly wide-band excitation that is provided by the noise generator or sine sweep generator. In addition to the generation of the excitation signal, the recording of measured values (= sampling) is required which is carried out with the oscilloscope function integrated in the drive.

It is therefore necessary to adjust the recording time of the oscilloscope function to the periodic time of the excitation signal.

- Noise signal
  - The periodic time is: T_R= 4096 * $T_{excitation}$ (cycle time of excitation)

    The cycle time of excitation $T_{excitation}$ depends on the selected target parameter
    - Position and velocity command value: $T_{excitation}$= $T_{A\_position}$(cycle time of position control)
    - Current and torque command values: $T_{excitation}$= $T_{A\_velocity}$(cycle time of velocity control)
  - Oscilloscope settings
    - Oscilloscope, time resolution: P-0-0031 = $T_{excitation}$
    - Oscilloscope, size of memory: P-0-0032 = 4096
    - Trigger settings
      - Trigger method: Signal trigger
      - Pre-trigger: 0%
      - Trigger signal: P-0-1150

- Edge: Rising edge
- Trigger value: P-0-1154 + P-0-1155/2

- Sine sweep

  As a maximum of 4096 values are used for frequency response measurement in the oscilloscope, it is useful to coordinate the settings for the sine sweep and those of the oscilloscope.

  1. Selecting starting (P-0-1159) and end frequency (P-0-1160) of sine sweep
  2. Make oscilloscope settings
     - Oscilloscope, time resolution: select P-0-0031 >= 1 / (2*P-0-1160)
     - Oscilloscope, size of memory: P-0-0032 = 4096
     - Trigger settings
       - Trigger method: Signal trigger
       - Pre-trigger: 0%
       - Trigger signal: P-0-1150
       - Edge: Rising edge
       - Trigger value: P-0-1154 + 0.1*P-0-1155
  3. Define periodic time of sine sweep (P-0-1158): P-0-1158 = 2*P-0-0031*P-0-0032

     As the parameterized periodic time (P-0-1158) with sine sweep is made up of the time for "sweeping up" and "sweeping down" combined, it is sufficient to record half of the periodic time.

With the noise signal, the bandwidth of the excitation signal depends on the cycle time of the excitation $T_{excitation}$ with which the signal is generated and, with sine sweep, it depends on the end frequency (P-0-1160)

- Noise signal: Bandwidth of excitation: $BW_{excitation}$[Hz] =1 / (2*$T_{excitation}$);
- Sine sweep signal: Bandwidth of excitation: $BW_{excitation}$[Hz] = P-0-1160;

The overview below illustrates the possible excitation signals and measuring signals for the recording:

Control loop	Command value generator excitation signal	Cycle time of excitation $T_{excitation}$	Measuring signals of oscilloscope function
Torque	Additive torque/force cmd value (S-0-0081)	$T_{A\_velocity}$	Additive torque/force cmd value (S-0-0081) Torque/force feedback value (S-0-0084)
Current (Iq)	Torque-generating current, command value (P-0-0038)	$T_{A\_velocity}$	Torque-gener. current, command value (P-0-0038) Torque-generating current, actual value (P-0-0043)
Current (Id)	Flux-generating current, cmd value (P-0-0039)	$T_{A\_velocity}$	Flux-generating current, cmd value (P-0-0039) Flux-generating current, actual value (P-0-0044)

Control loop	Command value generator excitation signal	Cycle time of excitation $T_{excitation}$	Measuring signals of oscilloscope function
Velocity	Additive velocity command value (S-0-0037)	$T_{A\_position}$	Effective velocity command value (P-0-0048) Velocity feedback value (S-0-0040)
Position	Additive position cmd val., controller (P-0-0059)	$T_{A\_position}$	Position command value controller (P-0-0434) Position feedback value 1 (S-0-0051) or Position feedback value 2 (S-0-0053)

$T_{A\_velocity}$ Velocity controller cycle time
$T_{A\_position}$ Position controller cycle time

Tab. 9-16: Signals for Excitation and Recording

The cycle times for position and velocity control depend on the control section design and the performance level, see chapter "Control Section Design and Performance".

"IndraWorks Ds/D/MLD" provides a dialog for bandwidth and frequency response measurement which automatically makes the settings for excitation and measurement according to the type of frequency response.

Controller Optimization

The drive-integrated command value generator is very well suited for optimizing the control loops (current, velocity and position), as it generates a defined command value characteristic (e.g. pulse or square-wave signals).

Current controller

The field-oriented current controller that takes effect in controlled operation ("closed loop"), realizes the following subfunctions:

- Closed-loop control of d-component (field-generating current)
- Closed-loop control of q-component (torque-generating current)

See "Motor Control: Field-Oriented Current Control"

To evaluate the current controller for the torque-generating current control loop, excitation has to take place via parameter "S-0-0081, Additive torque/force command value" ("P-0-0038, Torque-generating current, command value" as an alternative) and the parameters S-0-0081 (or P-0-0038) and "S-0-0084, Torque/force feedback value" have to be recorded with the oscilloscope function.

To evaluate the current controller for the flux-generating current, excitation has to take place via parameter "P-0-0039, Flux-generating current, command value" and the parameters P-0-0039 and "P-0-0044, Flux-generating current, actual value" have to be recorded with the oscilloscope function.

Velocity controller

To evaluate the velocity controller, excitation has to take place via via parameter "S-0-0037, Additive velocity command value" and the parameters "P-0-0048, Effective velocity command value" and "S-0-0040, Velocity feedback value" have to be recorded with the oscilloscope function.

Position controller

To examine the position controller, the drive has to be in one of the operation modes "position control with cyclic command value input", "drive-internal interpolation", "drive-controlled positioning" or in the "Drive Halt" state.

Under this condition, the excitation via parameter "P-0-0059, Additive position command value, controller" can take place directly for the position controller and the parameters "P-0-0434, Position command value of controller" and "S-0-0051, Position feedback value 1" or "S-0-0053, Position feedback value 2" have to be recorded with the oscilloscope function.

9.10 Internal "Command Value Box"

9.10.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

With IndraDrive controllers, a so-called "command value box" is internally available for manual drive optimization. It provides the possibility to internally (independent of the master) generate a command value characteristic that can be defined by the user. In this way, an axis drive can be moved in the same way as with an external command value box, without an external command value being effective (→ drive-internal "command value box"). Drive enable must merely be set for the drive.

The command value characteristic that can be defined by the user, allows for an axis to be moved within determinable position limits in continuous sequence in the velocity control loop or position control loop. This can be made use of, in order to manually optimize the control loop parameters of the drive, by e.g. moving the drive with a low velocity command value and by evaluating the status variables "actual current value" and "actual velocity value".

More details on the manual control loop setting are described in the "Overview of Drive Control: Notes on Commissioning for Control Loop Setting".

By the internal command value box, an axis can be continuously moved in an "oscillating movement" (oscillating between two position limit values) or in "stepper mode" (unidirectional moving over a defined path or a travel range).

The internal command value box is configured via a command word, the command value characteristic is defined via the respective parameters. The drive-internal command value box is activated via a command.

Pertinent Parameters

- P-0-0162, C1800 Command Drive optimization / command value box
- P-0-0165, Drive optimization, control word
- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive
- P-0-0169, Drive optimization, travel distance
- P-0-0170, Drive optimization, acceleration
- P-0-0171, Drive optimization, velocity
- P-0-0172, Drive optimization, dwell time

Pertinent Diagnostic Messages

- C1800 Command Drive optimization / command value box
- C1801 Start requires drive enable
- C1806 Travel range exceeded

9.10.2 Functional Description

Configuring and Activating the Function

The internal command value box is configured in parameter "P-0-0165, Drive optimization, control word". In this parameter, the presettings for a total of three functions are made which operate with internal command value input:

1. Recording the table for cogging torque compensation (highest priority)
2. Configuring internal command value box (medium priority)
3. Configuring automatic control loop setting (lowest priority)

The functions mentioned above **cannot be used simultaneously**, although they can be selected simultaneously by means of the respective bits. Prioritization is valid as stated in the list above.

The "internal command value box" function is activated, if the execution of "C1800 Command Drive optimization / command value box" is started with correct setting of parameter P-0-0165.

Operating mode

With the function activated, the controller can move the drive in one of the following operating modes:

- Velocity Control
- Position Control

Velocity control is carried out via the motor encoder, and position control via the position encoder selected in parameter "S-0-0520, Axis control word".

Type of Motion

With both velocity control and position control, the types of motion below can be selected for the command value characteristic:

- Oscillating motion
- Stepwise operation

The motion can be continuous (periodic) or take place only once.

Definition of the Internal Command Value Characteristic

Oscillating motion

With the oscillating motion, the drive reciprocates between two position limit values that can be set. The limit values are determined by the parameters below:

- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive

The oscillating motion can be continuous (periodic) or take place only once.

Between the subsequent reciprocating movements of the oscillating operation, the axis dwells in a standstill position for a period that can be set in parameter "P-0-0172, Drive optimization, dwell time".

Stepwise operation

With stepper mode, the axis only moves in one direction. The distance or angle is preset by the value of parameter "P-0-0169, Drive optimization, travel distance", the direction is determined by the sign of the value in parameter P-0-0169.

The stepper motion can be continuous (periodic) or take place only once.

Between the subsequent travel motions of the stepwise operation, the axis dwells in a standstill position for a period that can be set in parameter "P-0-0172, Drive optimization, dwell time".

Velocity command value

For both velocity control and position control, the maximum velocity command value of the axis is preset in parameter "P-0-0171, Drive optimization, velocity".

Acceleration Command Value

In position control, the maximum acceleration of the axis is preset in parameter "P-0-0170, Drive optimization, acceleration".

In velocity control, parameter P-0-0170 is ineffective; the velocity command value is preset in an abrupt manner! A possibly required acceleration limitation can, however, be realized via the command value ramp parameters (P-0-1201, P-0-1202, …)!

9.10.3 Notes on Commissioning

Configuring the function

The function of the drive-internal command value box is configured in parameter "P-0-0165, Drive optimization, control word". The following settings are to be made:

- Set operating mode "position control" or "velocity control"
- Select type of motion "oscillating motion" or "stepper mode"

> The motion type "stepwise operation" can only be used with axes with unlimited travel range (e.g. modulo axes). For axes with limited travel range, the motion type "oscillating motion" must be used!

- Set motion sequence; perodic or only one-off.

> It must be taken into account that the option "including the cogging torque compensation table", which can also be configured in parameter P-0-0165, has **not** been selected as it has a higher priority than the internal command value box.

Motion Limits

For the oscillating motion the motion limits are set in the following parameters:

- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive

These limit values are effective for both position control and velocity control. In the velocity control mode, the limit values cause a change in polarity of the velocity command value.

Travel Distance

In the stepwise operation mode the travel distance or travel angle is set in parameter "P-0-0169, Drive optimization, travel distance". The sign determines the direction of movement!

Dwell Time

With periodic motion sequence, the standstill time of the axis is set between the individual travel movements in the parameter "P-0-0172, Drive optimization, dwell time".

Velocity command value

The maximum velocity command value for both control modes (operation modes) is preset in parameter "P-0-0171, Drive optimization, velocity".

Acceleration Command Value

In position control, the acceleration command value is preset in parameter "P-0-0170, Drive optimization, acceleration". With velocity control, the predefined command value ramps (P-0-1201, P-0-1202, …) must be used, if necessary!

9.11 Encoder emulation

9.11.1 Brief Description

> Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

By means of encoder emulation is it possible to convert available encoder signals (encoder 1, encoder 2 or measuring encoder) or internal position command values into one of the following two formats:

- **Signals of an incremental encoder (track A, track B and zero pulse with 5V TTL or 24V level)**
- **Serial 24-bit position of an absolute encoder (SSI format, Gray-coded)**

This allows, for example, evaluating the signals in a higher-level master in order to close the position control loop in the external control unit in conjunction with the freely parameterizable resolution and the data reference.

☞ Using the encoder emulation in **precision applications** (mostly in machine tool applications) is considered as **critical** and always **has to be carefully considered** beforehand!

For sophisticated applications for which the position control loop is closed by means of emulation, Rexroth recommends to use digital interfaces, such as sercos.

See "Restrictions" in the section "Notes on Commissioning"

Incremental Encoder Emulation

Incremental encoder emulation is the simulation of a real incremental encoder by the drive controller.

With incremental encoder emulation we distinguish between

- Signal emulation

  - and -

- Motor encoder emulation.

In the form of **incremental encoder signals**, a higher-level numeric control (NC) receives information about the velocity of the motor connected to the controller. By integration of these signals, the control unit receives the required position information and it is thereby possible to close a higher-level position control loop.

☞ Emulation takes place in scaling-dependent (see S-0-0076) or encoder-related form, the resolution is input in lines/revolution (1 line corresponding to 4 increments) or in mm or inch.

Features of Incremental Encoder Emulation

- Cyclic calculation of the increments output by the emulator in the position controller clock (see "Performance Data")
- Freely selectable position signals for emulation (P-0-0900, P-0-0901.x.1)
- Parameterizable resolution (lines/revolution or mm resp. inch)
- Encoder-related emulation (incremental)
- Dead time compensation that can be activated (P-0-0901.x.2, bit 3)
- Shiftable zero pulse (P-0-0901.x.4)
- Parameterizable cyclic zero pulse output for zero pulse distance (P-0-0901.x.4) and position data reference (P-0-0901.x.2)
- Encoder emulation can be switched off in operation (→ pause)
- Internal clock increase of incremental encoder emulation to reduce zero pulse jitter and frequency jitter
- Signal-related or motor-encoder-related emulation to be freely selected (→ influence on position of zero pulse!)

Absolute Encoder Emulation

Absolute encoder emulation means that the drive controller has the option of simulating a real absolute encoder in **SSI data format**. It is thereby possible to transmit the position in the SSI data format to the connected control unit (NC) and to close the position control loop via the control unit.

> ☞ Emulation takes place in scaling-dependent form (see S-0-0076) and the resolution is input in bits.

Features of Absolute Encoder Emulation

- Cyclic calculation of the position output by the emulator in the position controller clock (see "Performance Data")
- Freely selectable position signals for emulation (P-0-0900, P-0-0901.x.1)
- Parameterizable resolution (bits)
- Scaling-related emulation (S-0-0076)
- Synchronization of SSI emulation to SSI clock

Hardware Requirements

The encoder emulation function of the firmware requires the following device design:

IndraDrive Cs	
BASIC	HCS01.1E-W00xx-A-0x-B-ET-EC-EM-xx-NN-FW
ADVANCED	HCS01.1E-W00xx-A-0x-A-CC-EC-EM-xx-NN-FW
IndraDrive control sections	
Basic control section - double-axis	CDB02.1B-ET-EC-EC-EM-xx-xx-xx-NN-FW
	CDB02.1B-ET-EC-EC-yy-xx-xx-EM-NN-FW for yy = PB, EC or EM
Advanced control section - single-axis	CSH02.1B-CC-EC-EM-xx-xx-NN-FW
	CSH02.1B-CC-EC-yy-xx-EM-NN-FW for yy = ET, PB, CN or EC
Basic control section - single-axis	CSB02.1B-ET-EC-yy-xx-EM-NN-FW for yy = PB, CN or EC
	CSB02.1x-ET-EC-EM-xx-xx-NN-FW

PB PROFIBUS
EC Encoder IndraDyn / Hiperface / 1 Vpp /TTL / EnDat
EM Encoder emulation
ET MultiEthernet
CN CANopen

Tab. 9-17: Control Section Design for Encoder Emulation

> ☞ With double-axis control sections, encoder emulation is simultaneously possible in both axes. Requirements for the device configuration: See Project Planning Manual for Control Sections

Pertinent Parameters

- P-0-0900, Encoder emulation signal selection list
- P-0-0901.x.1, Encoder emulation signal selection
- P-0-0901.x.2, Encoder emulation control parameter
- P-0-0901.x.3, Encoder emulation resolution
- P-0-0901.x.4, Encoder emulation zero pulse offset

- P-0-0901.x.5, Encoder emulation zero pulse distance
- P-0-0901.x.6, Encoder emulation assignment
- P-0-0901.0.7, Encoder emulation, external signal
- P-0-0901.0.8, Encoder emulation, modulo value of external signal

☞ The structure instance ("x" digit) of the parameter IDN represents the optional slot of encoder emulation (EM) in the corresponding control section or HCS01 device, e.g. P-0-0901.x.1 with x = 2 means that the optional slot of the encoder emulation is slot 2.

Pertinent Diagnostic Messages

- C0242 Multiple configuration of a parameter (->S-0-0423)
- C0260 Incremental enc. emulator resol. cannot be displayed
- F2053 Incr. encoder emulator: Pulse frequency too high
- F2054 Incr. encoder emulator: Hardware error

9.11.2 Basic Information on the Function

Activating the Function

The kind of encoder emulation including its activation is determined via bit 0 and bit 1 of "P-0-0901.x.2, Encoder emulation control parameter".

The following settings can be selected via parameter "P-0-0901.x.2, Encoder emulation control parameter":

- No encoder emulation activated
- Incremental encoder emulation (IGS) activated
  - Signal emulation
  - Motor encoder emulation
- Absolute encoder emulation (SSI) activated
  - Signal emulation

☞ The settings in parameter "P-0-0901.x.2, Encoder emulation control parameter" only take effect after progression to the operating mode!

With double-axis units, the parameter "P-0-0901.x.6, Encoder emulation assignment" is used to set which of the two axes are to be emulated. As a result, both axes must then be selectable when only one emulator card is inserted.

Example: The emulator card on interface 3 should emulate axis 2. The axis number 2 must be entered in parameter P-0-0901.3.6: P-0-0901.3.6 = 2

ℹ See also Parameter Description "P-0-0901.x.2, Encoder emulation control parameter"

Selecting the Signal to be Emulated

Supported Emulation Signals

☞ The emulation signals currently supported by the drive are contained in the list parameter "P-0-0900, Encoder emulation signal selection list".

The input of the signals that the drive supports for emulation depends on the following factors:

- Firmware version and enabled functional packages
- Hardware of the control section and its configuration

Selecting the Emulation Signal

The emulation signal is determined by inputting the desired IDN from the list parameter P-0-0900 in the parameter "P-0-0901.x.1, Encoder emulation signal selection".

> ☞ The resolution of the emulated signal is determined for both kinds of emulation (SSI and IGS) in parameter "P-0-0901.x.3, Encoder emulation resolution".

Determining the Kind of Emulation (Only for Incremental Encoder Emulation)

In bit 12 of "P-0-0901.x.2, Encoder emulation control parameter", determine whether it is directly the signal of the motor encoder that is to be emulated or the signal that was defined via the parameter "P-0-0901.x.1, Encoder emulation signal selection".

9.11.3 Incremental Encoder Emulation

General Information

The incremental encoder emulation provides three square-wave signals (UA0, UA1, UA2) with variable frequency. The position difference of the selected signal in the last position controller clock is calculated (see "Performance Data"). The number of lines to be output and therefore the periodic time of the square-wave signals for the next output interval is calculated depending on the input in parameter "P-0-0901.x.3, Encoder emulation resolution".

Incremental Encoder Signals

Tracks A and B

By outputting two signals offset by 90 degrees (track A and track B) the resolution is increased by the factor 4 when the two tracks are evaluated in differential form. One line then corresponds to 4 increments.

Zero Pulse

In addition, the incremental encoder outputs a third signal, the zero pulse. The zero pulse has a fixed reference to the emulated signal (e.g. of the encoder shaft, if an encoder signal is emulated) and can, in case position data reference is existing (axis homed), be emulated with reference to the machine zero point.

> ☞ It is possible to influence both the output frequency and the position of the zero pulse (see "P-0-0901.x.5, Encoder emulation zero pulse distance" and "P-0-0901.x.4, Encoder emulation zero pulse offset")!

The figure below illustrates the format and time flow of the incremental encoder signals:

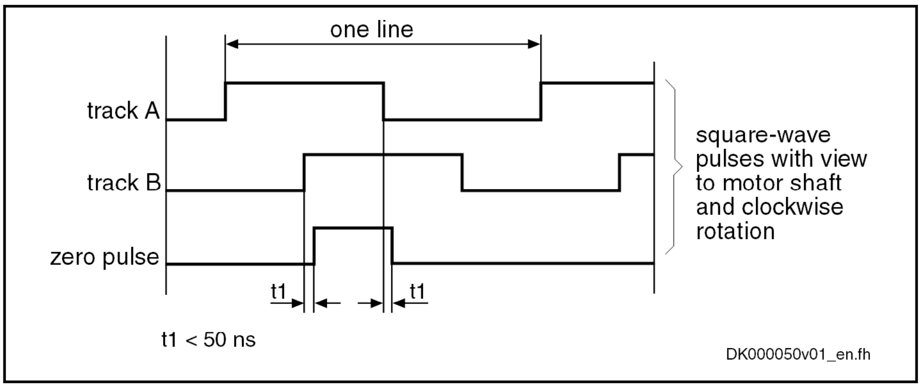


Fig. 9-86: Time Flow of the Incremental Encoder Signals

Resolution and Unit of the Emulated Signal

Resolution

The number of increments of the emulated incremental encoder can be determined in "P-0-0901.x.3, Encoder emulation resolution" in lines/revolution (or mm or inch with linear motors).

Unit of the Emulated Position

The input range and the unit of the value in parameter P-0-0901.x.3 depend on the following settings:

- Type of construction of motor
  - Rotary motors → lines/revolution
  - Linear motors → mm or inch
- Parameterized scaling (see "S-0-0076, Position data scaling type")

☞ The emulated encoder therefore is parameterized according to the usual formats for rotary and linear square-wave encoders in lines/revolution or mm or inch.

Reference of the Emulated Position - Zero Pulse Output

The zero pulses are output immediately after the drive was run up to the operating mode in the distance of the lines resp. mm or inch entered in parameter "P-0-0901.x.5, Encoder emulation zero pulse distance".

Zero Pulse Offset

With the parameter "P-0-0901.x.4, Encoder emulation zero pulse offset", the output of the zero pulse, with incremental encoder emulation having been selected, can be offset by the input value in lines (or mm or inch). The input range in P-0-0901.x.4 is determined by the setting in parameter "P-0-0901.x.3, Encoder emulation resolution", because the maximum offset for rotary motors, for example, is one revolution.

Cyclic Zero Pulse Output

If the zero pulse is to be cyclically output depending on the travel distance, the distance between two zero pulses can be entered in lines (or mm or inch) in parameter "P-0-0901.x.5, Encoder emulation zero pulse distance".

The following applies to the zero pulse output:

- Parameter setting of **P-0-0901.x.5 = P-0-0901.x.3** (standard case!)

  → **One zero pulse per revolution** (or per mm) is generated.
- Parameter setting of **1 < P-0-0901.x.5 < P-0-0901.x.3** (cyclic zero pulse output)

  → **Several zero pulses per revolution** (or per mm) are generated (if a zero pulse is demanded after 180 degrees, for example, parameter setting has to be P-0-0901.x.5 = ½ × P-0-0901.x.3).

☞ For cyclic output you have to take into consideration that a maximum of one zero pulse can be output per output cycle (i.e. position controller clock)!

- Parameter setting of **P-0-0901.x.5 = n × P-0-0901.x.3**

  → **One zero pulse within n revolutions** (or per n millimeters) is generated. This allows, for example, generating only one single zero pulse over the entire travel range at the machine zero point!

☞ Inputting "0" in parameter P-0-0901.x.5 is not allowed!

Kind of Emulation

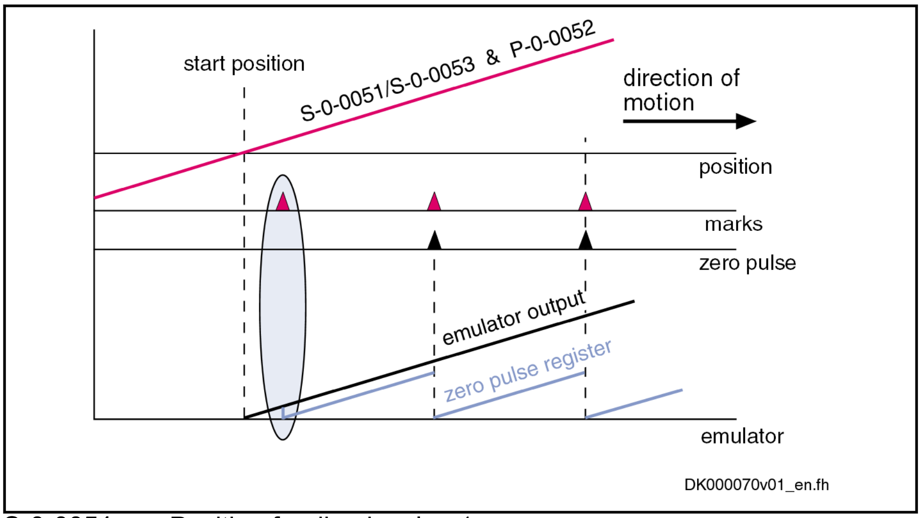
According to the kind of emulation, the zero pulse is emulated with relation to encoder mark or with relation to signal. The kind of emulation is selected in bit 12 of "P-0-0901.x.2, Encoder emulation control parameter".

Emulation with Relation to Motor Encoder (P-0-0901.x.2, Bit 12 = 1)

In the case of emulation with relation to the motor encoder, emulation takes place with relation to the encoder shaft. With relation to the position of the encoder mark, the zero pulse is emulated under the following conditions:

- For relative measuring systems for which there is no absolute position reference when switching on, zero pulse output only takes place after an encoder mark of the encoder system has been passed for the first time (see figure below).
- For absolute measuring systems which have absolute position reference after switching on, output takes place immediately.

☞ In case the drive has not been homed (see S-0-0403), zero pulses are generated without reference to the machine zero point existing!



S-0-0051	Position feedback value 1
S-0-0053	Position feedback value 2
P-0-0052	Actual position value of measuring encoder

Fig. 9-87: Zero Pulse Generation for Incremental Measuring System and Motor Encoder Relation (P-0-0901.x.2, Bit 12 = 1)

Signal-Related Emulation (P-0-0901.x.2, Bit 12 = 0)

In the case of signal-related emulation, the zero pulse is emulated with reference to the coordinate system. The zero pulse is output with reference to the zero point at "position 0" plus zero pulse offset. There are the following possible settings:

- The further zero pulses are defined via parameter "P-0-0901.x.5, Encoder emulation zero pulse distance".
- Via parameter "P-0-0901.x.4, Encoder emulation zero pulse offset", the emulated coordinate system can be shifted.

☞ The zero pulse is only output when the drive has been homed (see S-0-0403). The generated zero pulses are then always referring to the actual machine zero point!

The emulation signals that can be selected via parameter "P-0-0901.x.1, Encoder emulation signal selection" are divided into two groups:

- **Emulation of actual values**

  → For the output of zero pulses "reference" (see S-0-0403) is obligatory. For relative measuring systems, zero pulse output only takes place when the corresponding actual position value was homed (see figure below).

- **Emulation of command values**

  → Command values can always be considered as homed so that zero pulse output takes place independent of the "reference" (cf. S-0-0403).

Example: Incremental Measuring System and Actual Value Signal Output

The figure below illustrates the emulation of an actual value signal with incremental measuring system and signal relation:

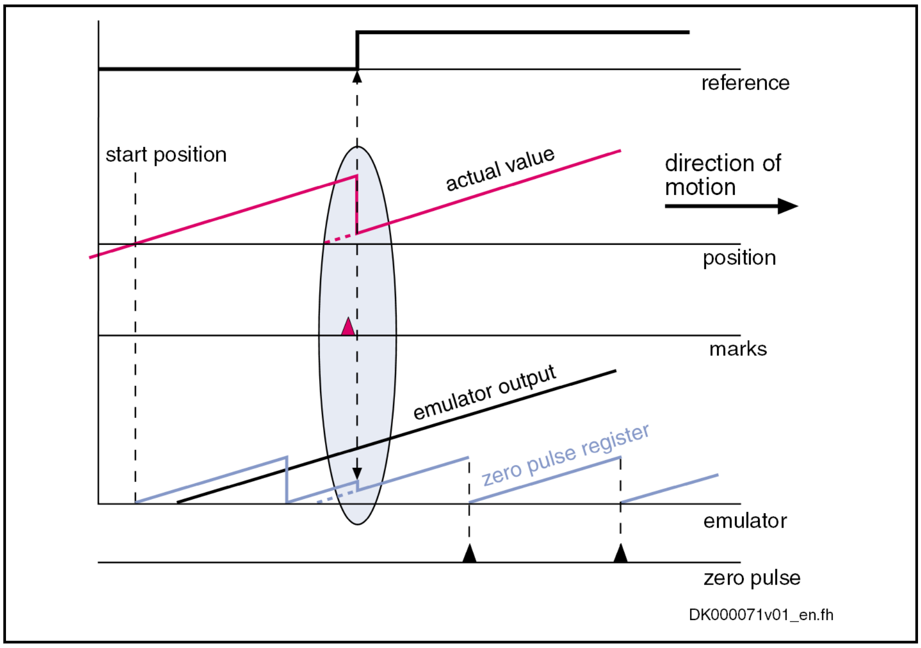
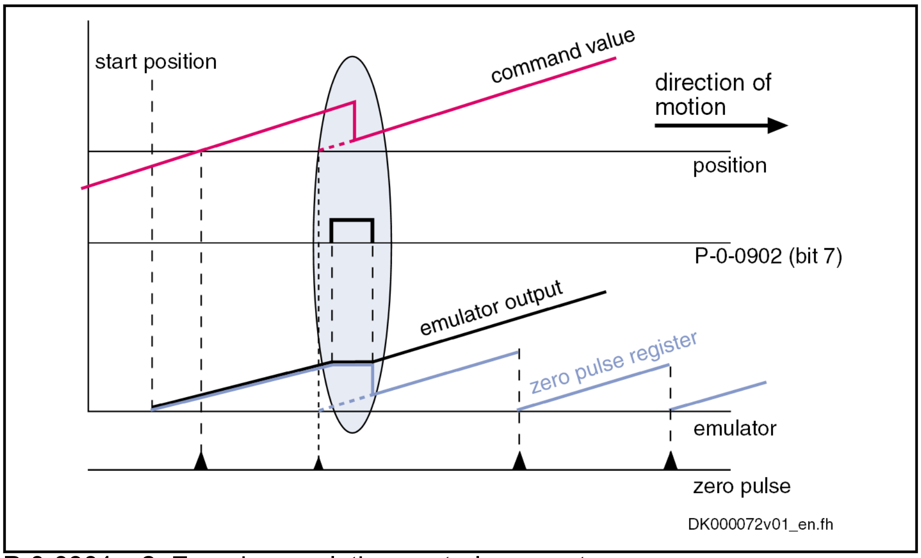


Fig. 9-88: Zero Pulse Generation for Incremental Measuring System and Signal Relation (P-0-0901.x.2, Bit 12 = 0) with Actual Value Signals

Example: Incremental Measuring System and Command Value Output with Command Value Jump

For emulation of command values you have to take into account that the master might possibly want to preset command value jumps that are not to be emulated or cannot be emulated. For this case, it is possible to stop emulation for a short time (see P-0-0901.x.2, bit 7). During this time, a command value jump does neither cause the internal monitoring functions with regard to the emulation signals to trigger nor misadjustment of the emulator output.

After the stop is over, emulation can be enabled again via bit 7 and the emulator then follows the preset command value signal.



P-0-0901.x.2 Encoder emulation control parameter

Fig. 9-89: Zero Pulse Generation for Incremental Measuring System and Signal Relation (P-0-0901.x.2, Bit 12 = 0) with a Command Value Jump

Establishing the Position Data Reference (Drive-Controlled Homing)

With signal-based emulation (P-0-0901.x.2, bit 12 = 0) of actual values and the use of incremental measuring systems, the drive must have been homed to output a zero pulse (see also above section "Zero Pulse Output").

When the homing procedure is carried out, the emulated signals jumps from the original position to the reference position. **In this case, the error message"F2053" is suppressed on purpose.**

See also "Establishing Position Data Reference for Relative Measuring Systems"

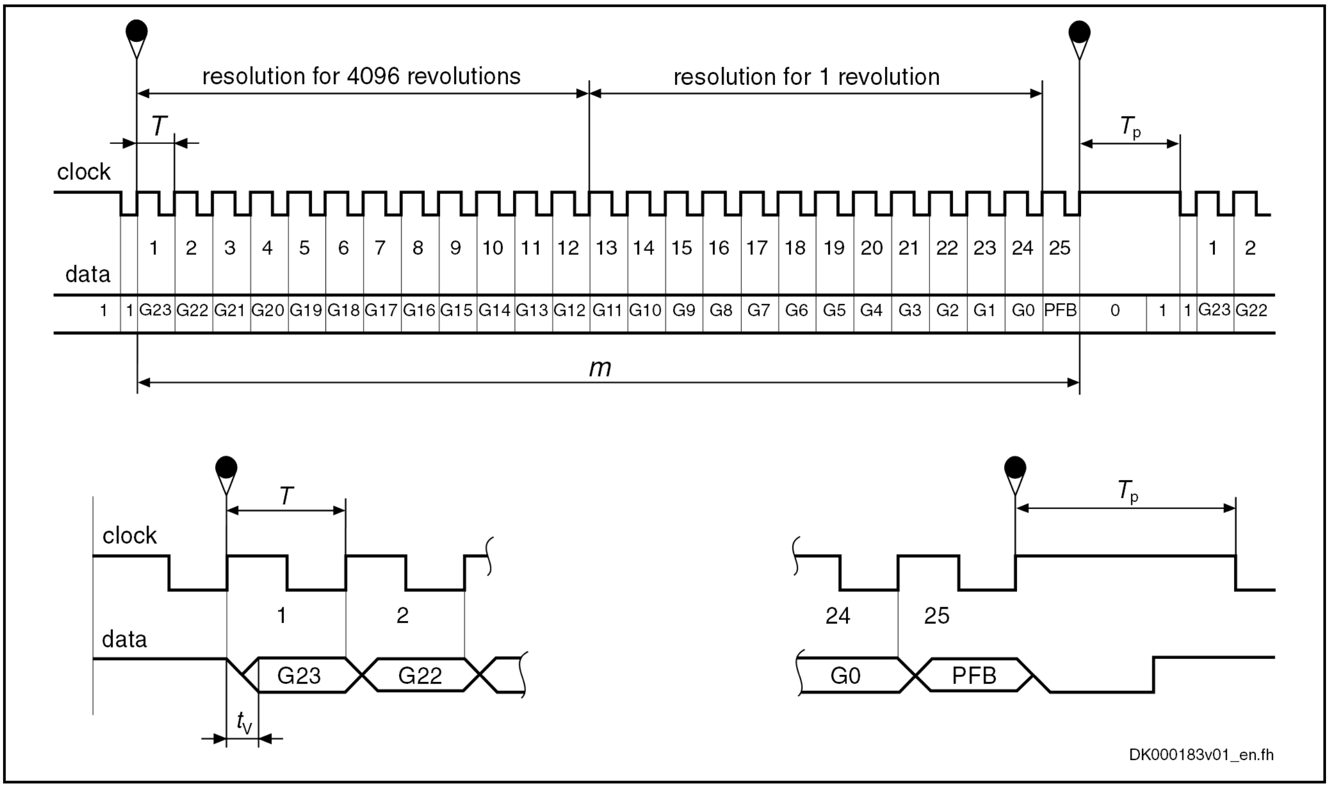
9.11.4 Absolute Encoder Emulation

General Information

Absolute encoder emulation provides a digital, Gray-coded, absolute position signal which can be serially read in the position controller clock (see "Performance Data"). The resolution of the absolute position and therefore the travel range that can be displayed in absolute form depend on the input in parameter "P-0-0901.x.3, Encoder emulation resolution".

Absolute Encoder Signals in SSI Format

The figure below illustrates the format of the SSI data transmission of the absolute encoder emulation:



G0	Least significant bit in Gray code
G23	Most significant bit in Gray code
m	Stored parallel information
T	Clock time
T_P	Clock break ≥ 20 µs
t_V	Delay time max. 650 ns
PFB	Power failure bit (not used and always logically LOW)

Fig. 9-90: Pulse Diagram SSI Format

☞ IndraDrive controllers do not support the power failure bit!

Resolution and Unit of the Emulated Signal

Resolution

The output data format (i.e. the resolution) for the emulated SSI position is determined in parameter "P-0-0901.x.3, Encoder emulation resolution".

☞ The unit displayed in parameter P-0-0901.x.3 is bit.

Unit of the Emulated Position

The input range and the unit of the value in parameter P-0-0901.x.3 depend on:

- Type of construction of motor:
  - Rotary motors → bits/revolution
  - Linear motors → bits/mm or bits/inch
- Parameterized scaling (see "S-0-0076, Position data scaling type")

☞ The emulated digital position value is always displayed with 24 bits, the setting in P-0-0901.x.3 defining the resolution of one revolution (= decimal place). With P-0-0901.x.3 = 12 bits, 12 bits of places before decimal point and 12 bits of decimal places take effect, for example.

Reference of the Emulated Position

The emulation of the signals "position feedback value 1", "position feedback value 2" and "position command value" depends on the scaling set in parameter "S-0-0076, Position data scaling type".

The values of the emulator and the parameters "S-0-0051, Position feedback value 1", "S-0-0053, Position feedback value 2" or "S-0-0047, Position command value" are synchronous. This simplifies, among other things, controlling the emulation, e.g. with the "IndraWorks Ds/D/MLD" commissioning tool.

Scaling-Dependent Emulation

If the option "motor reference" is set in parameter S-0-0076, emulation with relation to encoder is possible.

If the option "load reference" is set in parameter S-0-0076, the feed constant and gear ratio must be additionally entered according to the application.

☞ The values for position feedback value 3 (measuring encoder) and master axis position are always emulated in encoder-related form. Parameter S-0-0076 in this case is irrelevant.

See also "Scaling of Physical Data"

Establishing the Position Data Reference (Set Absolute Position)

Using parameter "S-0-0447, C0300 Set absolute position procedure command", it is possible to home the absolute position that is output by the absolute encoder emulator. When the absolute position is set, the value of parameter "S-0-0052, Reference distance 1" is processed.

See also "Establishing Position Data Reference for Absolute Measuring Systems"

9.11.5 Notes on Commissioning

General Information

In contrast to a "real" encoder, encoder emulation uses a simulated encoder. In motion the real encoder signal and the output of the emulator can differ. The causes for such differences can be:

- Application errors (e.g. inadequate wiring, exceeded frequencies, voltage dips, incorrect programming)
- Systematic errors due to the technical conditions (e.g. beat effects, position jitter)

The restrictions and limits described in the following sections have to be taken into account when encoder emulation is used.

Restriction of Incremental Encoder Emulation

In contrast to the conventional incremental encoder for which the pulse output frequency can be infinitely changed in fine increments (i.e. the pulses are always assigned to fixed positions), emulated incremental encoder signals are subject to certain restrictions which primarily result from the digital mode of operation of the drive controller.

Maximum Output Frequency

If the maximum pulse frequency is exceeded, pulses can be missing. A position offset of the emulated position in contrast to the real position occurs. Therefore, when the maximum pulse frequency is exceeded, the error message "F2053 Incr. encoder emulator: Pulse frequency too high" is output.

☞ The max. output frequency always, i.e. independent of the selected number of lines, has to be taken into account for dimensioning the evaluation electronics.

The maximum output frequency f_{max} is limited by the hardware and is reduced as the clock increase is increased (see P-0-0901.x.2): It can be calculated by means of the following formula:

$$f_{max} = \frac{511\ \text{Inkremente}}{31{,}25\mu s \times 4 \times n}$$

f_{max}	Allowed maximum frequency in Hz
n	Oversampling set in P-0-0901.x.2

Fig. 9-91: Formula for Calculating the Maximum Output Frequency of the Incremental Encoder Emulation

Without clock increase (n = 1) the resulting maximum output frequency thereby is approx. 4 MHz, with 128-fold clock increase (n = 128) the resulting maximum output frequency is approx. 32 kHz.

The maximum possible resolution of encoder emulation is scaling-dependent and calculated according to the following formulas:

$$\text{Linear scaling} \qquad (\text{P-0-0901.x.3})_{max} = \frac{v_{max}}{f_{max}}$$

$$\text{Rotary scaling} \qquad (\text{P-0-0901.x.3})_{max} = \frac{f_{max}}{v_{max}}$$

P-0-0901.x.3	Encoder emulation resolution
v_{max}	Demanded maximum velocity in mm/s or 1/s (For velocity in mm/min or 1/min, take factor 60 into account!)
f_{max}	Allowed maximum frequency in Hz

Fig. 9-92: Determining the Maximum Resolution of Encoder Emulation

Delay Between Real and Emulated Position Value

Between the position detection and output of the emulated pulses there is a delay (dead time) between real and emulated position value.

Solution:

When incremental encoder emulation has been activated (see P-0-0901.x.2, bit 0 = 1), it is possible to activate dead time compensation in "P-0-0901.x.2, Encoder emulation control parameter". However, this dead time compensation is only effective and useful if there aren't any repeated acceleration and deceleration processes (ideal v = constant).

Rounding Off the Number of Increments in Short Time Intervals

In a time interval of the internal control cycle TA it is only possible to output an integer number of increments (1 increment = ¼ line) at a time. The remainder that cannot be output is added in the next time interval. If there is another remainder of **0 < remainder < 1**, it is added again in the next interval etc.

This effect is the reason why the "emulated velocity" is exact on average, but can be by a maximum of **one increment too low** in each of the individual TA time intervals.

Solution:

- Use the highest possible number of lines ("P-0-0901.x.3, Encoder emulation resolution") so that as many lines as possible are output per control cycle TA. The percentage error then is reduced accordingly.

- In addition, this effect can be reduced or nearly removed by means of the implemented, internal clock increase of the emulated signals (see P-0-0901.x.2, bits 8, 9 and 10). By default, the clock increase has been set to factor 1 (no clock increase). If required, it can be increased up to factor 128 which will clearly reduce the zero pulse and frequency jitter.

Oscillating Signal Frequency within One Output Cycle

Due to the internal signal processing, the periodic time and duty cycle of the output signals are varied. The periodic time (or frequency) of the resulting cycles can therefore be shorter or longer, too.

This is why the signals of incremental emulation should **not** be used for measuring the speed by means of **frequency measurement**, but the signals may only be evaluated by **counting the increments.**

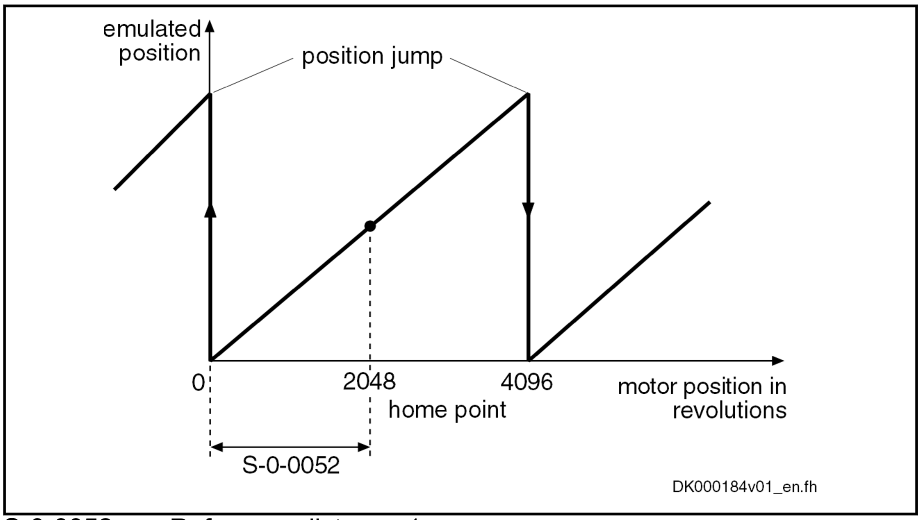
Restriction of Absolute Encoder Emulation

Using absolute encoder emulation, it is possible to display 4096 revolutions in absolute form.

Display Limits

When using this kind of emulation at the display limits, small fluctuations of the actual position lead to overflow and a position jump in the emulated position.

This is the case, for example, at position 0 and 4096 revolutions after position zero.



S-0-0052 Reference distance 1

Fig. 9-93: Display Limits with Absolute Encoder Emulation

This effect can be avoided by shifting the reference point by executing "S-0-0447, C0300 Set absolute position procedure command".

> **Note** By the respective setting in parameter "S-0-0052, Reference distance 1", shift the reference position to the middle of the display range. This allows moving 2048 revolutions to the left and to the right.

Beat Effects in the Emulated Position

In case the position processing in the control unit and the position detection (sampling) in the drive are not synchronized, beat effects can occur in the emulated signal with a periodic time according to the formula below, if the quartz frequencies on the drive and in the control unit cannot be exactly (integrally) divided:

$$T = \Delta t = \frac{1}{\Delta f}$$

T Periodic time for the occurring beat frequency
Δf Frequency deviation of the quartzes in control unit and drives

Fig. 9-94: Determining the Periodic Time

These beat effects are avoided by synchronizing the adjustment of the SSI emulation data in the drive to the SSI clock of the external control unit. The "SSI synchronization" mechanism required for this purpose is available and active as a standard.

☞ Synchronization only works correctly, when the "sampling rate" of the external control unit is lower than the internal position controller clock which depends on the performance of the firmware variant used!

See "Performance Data"

9.11.6 Diagnostic and Status Messages

The following diagnostic messages **can only occur with incremental encoder emulation**:

- **F2053 Incr. encoder emulator: Pulse frequency too high**

  → The output frequency resulting from the resolution that has been set (P-0-0901.x.3) and the travel velocity exceeds the value of the maximum pulse frequency of 4088 kHz.
- **F2054 Incr. encoder emulator: Hardware error**

  → At the end of each output interval (= position controller clock), a check is run to find out whether all increments to be output have been output before the next increment output is started. Exceeding the runtime or hardware errors can cause overlapping that is detected during the check and signaled by this error message.
- **C0260 Incremental enc. emulator resol. cannot be displayed**

  → In the case of incremental encoder emulation, inadmissible overflow can occur for increment output. In order to avoid this overflow, P-0-0901.x.3has to be parameterized accordingly.

9.12 Programmable position switch

9.12.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

The firmware function "programmable position switch" can be used instead of a mechanical position switch that has to be externally mounted.

Features

- Realization of a maximum of **8 dynamic position switch points** (switch cams) in the position controller clock
- Freely **selectable reference signals** (P-0-0130) for generating the switch cams, all 8 cams are referring to the same signal (P-0-0131)

- **Switch-on and switch-off position can be separately parameterized** via list parameters (P-0-0132, P-0-0133); corresponding position switch bit can be inverted by selecting the switch-on and switch-off threshold
- **Lead time that can be separately parameterized** via list parameter (P-0-0134) for compensating internal processing times (dead time compensation)
- **8 position switch bits displayed** in the position switch status word (P-0-0135) which can be assigned to digital outputs or cyclically transmitted via master communication interface
- Permanently defined **switch hysteresis** to avoid position switch bit flicker when the switch-on or switch-off threshold is reached

Pertinent Parameters

- P-0-0130, Position switch signal selection list
- P-0-0131, Position switch signal selection
- P-0-0132, Position switch switch-on threshold
- P-0-0133, Position switch switch-off thresholds
- P-0-0134, Position switch lead times
- P-0-0135, Position switch status word

Pertinent Diagnostic Messages

- C0242 Multiple configuration of a parameter (->S-0-0423)

9.12.2 Functional Description

Basic Principle of Cam Generation

The basis of the "programmable position switch" function is the registration of the information whether the selected reference value is within the range between switch-on and switch-off threshold or not.

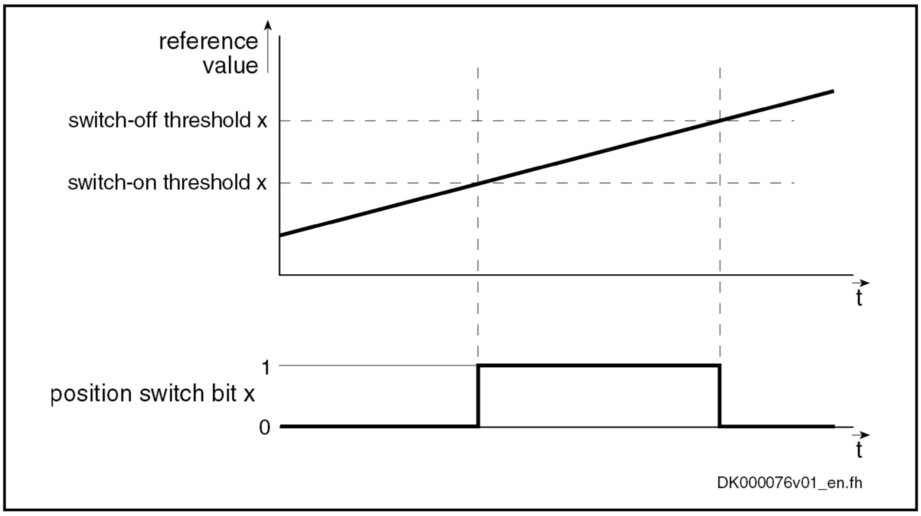


Fig. 9-95: General Functional Principle of the Programmable Position Switch

☞ By setting the switch-on and switch-off threshold the corresponding bit in the status word of the programmable position switch can be inverted.

We distinguish the following cases with regard to cam generation:

- Switch-on threshold < switch-off threshold
- Switch-on threshold > switch-off threshold

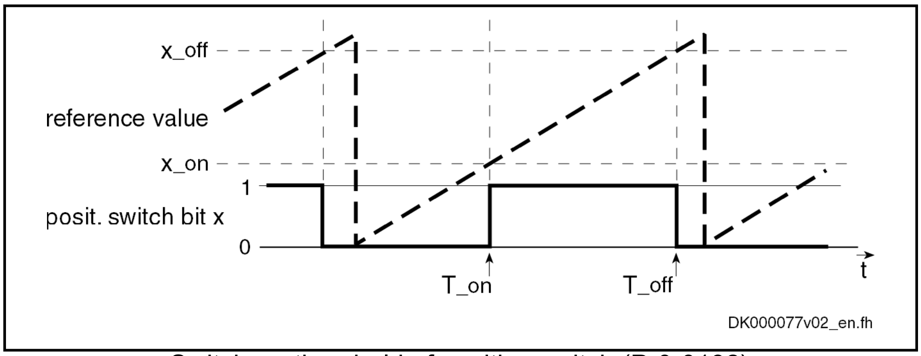
Switch-On Threshold Smaller than Switch-Off Threshold

With "switch-on threshold < switch-off threshold" programmed, the position switch bit is set in parameter "P-0-0135, Position switch status word", if:

- Reference value > switch-on threshold [i] → P-0-0131 > P-0-0132 [i]

- AND -

- Reference value < switch-off threshold [i] → P-0-0131 < P-0-0133 [i]



x_on Switch-on threshold of position switch (P-0-0132)
x_off Switch-off threshold of position switch (P-0-0133)

Fig. 9-96: Position Switch Bit with "Switch-on Threshold < Switch-off Threshold" (P-0-0132 [i] < P-0-0133 [i])

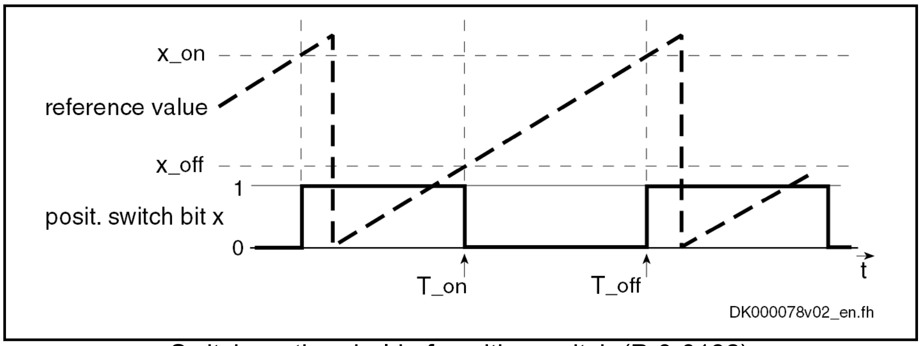
Switch-On Threshold Greater than Switch-Off Threshold

With "switch-on threshold > switch-off threshold" programmed, the position switch bit is set in parameter "P-0-0135, Position switch status word", if:

- Reference value > switch-on threshold [i] → P-0-0131 > P-0-0132 [i]

- OR -

- Reference value < switch-off threshold [i] → P-0-0131 < P-0-0133 [i]



x_on Switch-on threshold of position switch (P-0-0132)
x_off Switch-off threshold of position switch (P-0-0133)

Fig. 9-97: Position Switch Bit with "Switch-on Threshold > Switch-off Threshold" (P-0-0132 [i] > P-0-0133 [i])

Lead Time for Cam Generation

By setting a lead time the delay of an external switch element that is controlled by a position switch bit can be compensated. To do this, a theoretical correction value for the respective switch-on and switch-off threshold is calculated from the programmed lead time and the current drive velocity. The position switch bit switches by the lead time before reaching the corresponding threshold.

☞ When using a lead time, the velocity of the drive in the (time) range between theoretical and actual switch-on and switch-off thresholds should be constant.

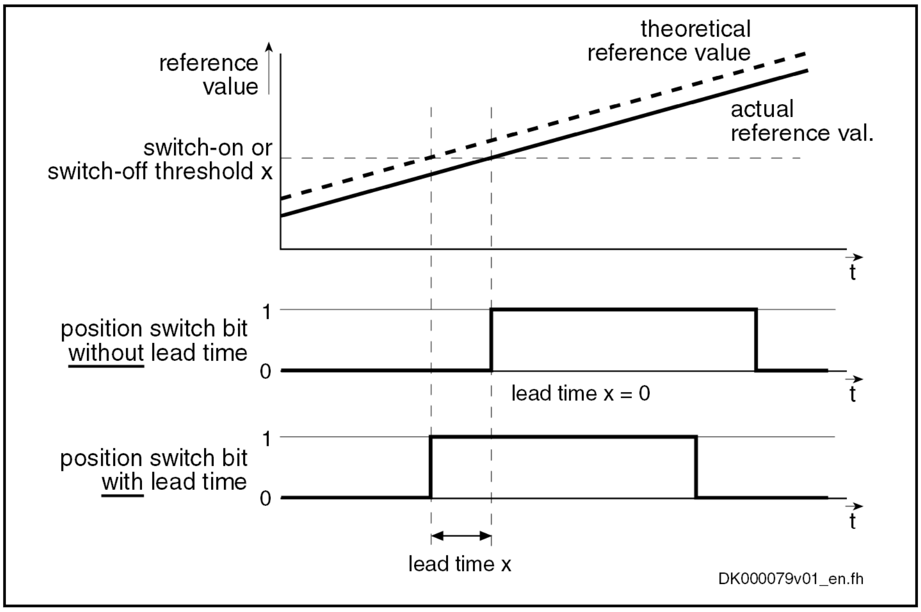


Fig. 9-98: Functional Principle "Lead Time" for Programmable Limit Switch

9.12.3 Notes on Commissioning

General Information

☞ The reference value selected in parameter "P-0-0131, Position switch signal selection" applies to all 8 cams, only the switch-on/switch-off thresholds and lead times can be individually parameterized for each cam!

Activating the Function and Signal Selection

To activate the position switch, the IDN of the parameter that maps the reference signal has to be entered in parameter "P-0-0131, Position switch signal selection".

The possible reference signals are given and listed in parameter "P-0-0130, Position switch signal selection list".

☞ The units and attributes of the parameters P-0-0132 or P-0-0133 (switch-on threshold/switch-off threshold) depend on the signals selected in parameter "P-0-0131, Position switch signal selection"!

☞ Inputting "S-0-0000" in parameter P-0-0131 deactivates the function!

Configuring Switch-On/Switch-Off Thresholds and Lead Time

The switch-on and switch-off thresholds and the corresponding lead time are parameterized via the following parameters:

- P-0-0132, Position switch switch-on threshold
- P-0-0133, Position switch switch-off thresholds
- P-0-0134, Position switch lead times

Each of these list parameters contains 8 elements, element 1 being provided for position switch bit 1, element 2 for bit 2 etc.

Determining the Switch-On/Switch-Off Thresholds

According to the resolution of the measuring system, there must be a minimum distance between the switch-on and switch-off thresholds of the switch cams, as a switch hysteresis is internally used for generating the cam signal.

Setting the Lead Time

Parameter "P-0-0134, Position switch lead times" always should be parameterized completely (i.e. all 8 elements) even if the lead times are not used; if necessary, a lead time of "0" has to be entered.

> To compensate the internal processing dead time, a lead time of $t = T_{A\_position}$ has to be set!

9.12.4 Diagnostic and Status Messages

Status Message of the Individual Cams

The status of the individual cam bits is displayed in parameter "P-0-0135, Position switch status word". The cams, beginning with bit 0, are assigned in ascending order (see Parameter Description P-0-0135).

9.13 Probe Function

9.13.1 Brief Description

> Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

Features

- 2 probes (S-0-0401 / S-0-0402) can be evaluated per axis.
- The two probe evaluations (S-0-0401, S-0-0402) can be assigned to any input that can handle probes. Several probe evaluations can use the same input. For HCS01 it is the digital inputs I_1 and I_2, for HCT, HCQ it is the inputs I2 and I3.
- Measuring signals can be actual position values of motor encoder, external encoder or measuring encoder, in addition master axis position values
- Measurement of absolute signal values, of signal value differences, detection of time intervals between measuring signals
- Measurement triggered by positive and/or negative probe signal edges
- Single measurement or continuous measurement to be selected, measurement events are counted in the case of continuous measurement
- Position value range ("expectation window") per probe can be defined within which measurement can take place (activation of a "failure counter" when expectation window is passed through without measuring event)
- Quick stop triggered via probe input
- Adjustable dead time compensation for each probe, separately for each edge (positive / negative) up to 50000 µs
- Measuring accuracy depends on hardware design, see section "X31, Digital Inputs, Digital Output" and section "Digital Inputs - Probe" in the documentation "Rexroth IndraDrive Cs, Drive Systems with HCS01" (DOK-INDRV*-HCS01******-PR01-EN-P; mat. No. R911322210)

Pertinent Parameters

- S-0-0130, Probe value 1 positive edge
- S-0-0131, Probe value 1 negative edge
- S-0-0132, Probe value 2 positive edge
- S-0-0133, Probe value 2 negative edge

- S-0-0169, Probe control parameter
- S-0-0170, Probing cycle procedure command
- S-0-0179, Probe status
- S-0-0401, Probe 1
- S-0-0402, Probe 2
- S-0-0405, Probe 1 enable
- S-0-0406, Probe 2 enable
- S-0-0409, Probe 1 positive latched
- S-0-0410, Probe 1 negative latched
- S-0-0411, Probe 2 positive latched
- S-0-0412, Probe 2 negative latched
- S-0-0426, Signal selection probe 1
- S-0-0427, Signal selection probe 2
- S-0-0428, Probe, IDN-list signal selection
- S-0-0524, Dead time compensation, positive edge, probe 1
- S-0-0525, Dead time compensation, negative edge, probe 1
- S-0-0526, Dead time compensation, positive edge, probe 2
- S-0-0527, Dead time compensation, negative edge, probe 2
- P-0-0200, Start position probe function 2 active
- P-0-0201, End position probe function 2 active
- P-0-0202, Difference probe values 1
- P-0-0203, Difference probe values 2
- P-0-0204, Start position probe function 1 active
- P-0-0205, End position probe function 1 active
- P-0-0206, Probe 1, max. number of marker failures
- P-0-0207, Probe 2, max. number of marker failures
- P-0-0224, Probe 1, number of marker failures
- P-0-0225, Probe 2, number of marker failures
- P-0-0226, Probe, extended control word
- P-0-0300, Digital inputs, assignment list
- P-0-0306, Digital inputs, assignment connector and pin

Pertinent Diagnostic Messages

- A0403 Quick stop with probe detection is active
- C0250 Probe inputs incorrectly configured

9.13.2 Functional Description

General Probe Function

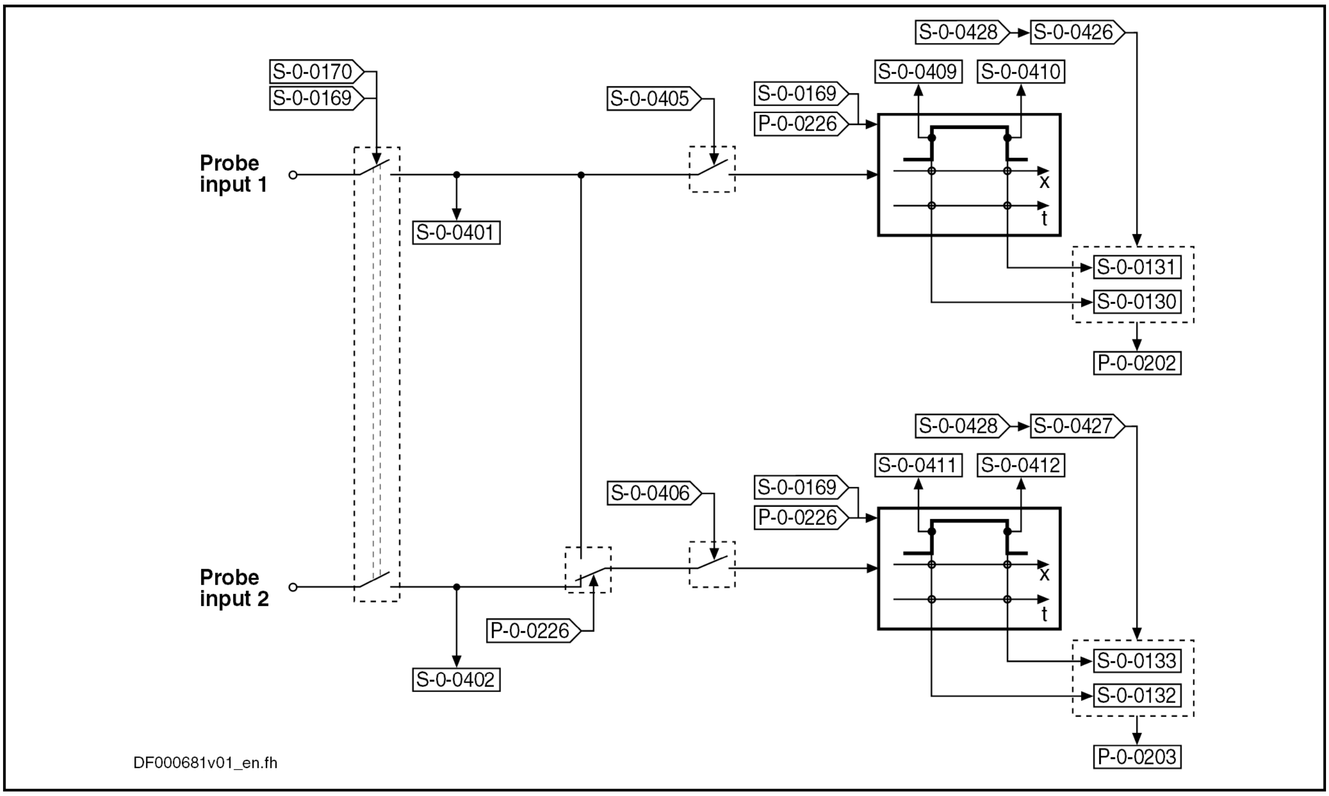
The probe input evaluates the voltage level of the probe signal in digital form, i.e. only the "high" (1) or "low" (0) signal states are recognized. When the probe is activated, the signal status changes; the probe input signals a rising (positive) or falling (negative) switching edge.

The ranges of the signal levels for "high" (1) and "low" (0) of the "fast" digital inputs are described in the documentation "Drive Controllers, Control

Sections, project planning" (DOK-INDRV*-CSH********-PR09-DE-P; Mat.-No. R911295011).

Operating Principle of Probe-Related Parameters

The figure below illustrates the operating principle of the probe-related parameters.



S-0-0130	Probe value 1 positive edge
S-0-0131	Probe value 1 negative edge
S-0-0132	Probe value 2 positive edge
S-0-0133	Probe value 2 negative edge
S-0-0169	Probe control parameter
S-0-0170	Probing cycle procedure command
S-0-0401	Probe 1
S-0-0402	Probe 2
S-0-0405	Probe 1 enable
S-0-0406	Probe 2 enable
S-0-0409	Probe 1 positive latched
S-0-0410	Probe 1 negative latched
S-0-0411	Probe 2 positive latched
S-0-0412	Probe 2 negative latched
S-0-0426	Signal selection probe 1
S-0-0427	Signal selection probe 2
S-0-0428	Probe, IDN list signal selection
P-0-0202	Difference probe values 1
P-0-0203	Difference probe values 2
P-0-0226	Probe, extended control word

Fig. 9-99: Overview and Operating Principle of Probe-Related Parameters

With active measured value detection (see below), the currently detected signal status at the respective probe input is displayed in the following parameters:

- S-0-0401, Probe 1

- S-0-0402, Probe 2

For the assignment of digital inputs, see "Digital Inputs/Outputs"

Activating the Measured Value Detection

A switching edge at the probe input can "trigger" the recording of a measured value. Switching edges, however, only cause a measured value to be recorded when the following requirements have been fulfilled:

- The presetting for measured value detection with positive and/or negative switching edge at the respective probe input was activated in "S-0-0169, Probe control parameter".
- The measured value detection was activated via "S-0-0170, Probing cycle procedure command". The following options are available to do this:
  - Directly write parameter S-0-0170 in the operating mode (OM)
  - Set bit 8 in "S-0-0169, Probe control parameter"

    → At the transition from parameter mode (PM) to operating mode (OM), command S-0-0170 is automatically set (see Parameter Description S-0-0169)
- The respective probe for measured value detection was enabled (parameter "S-0-0405, Probe 1 enable" or "S-0-0406, Probe 2 enable").

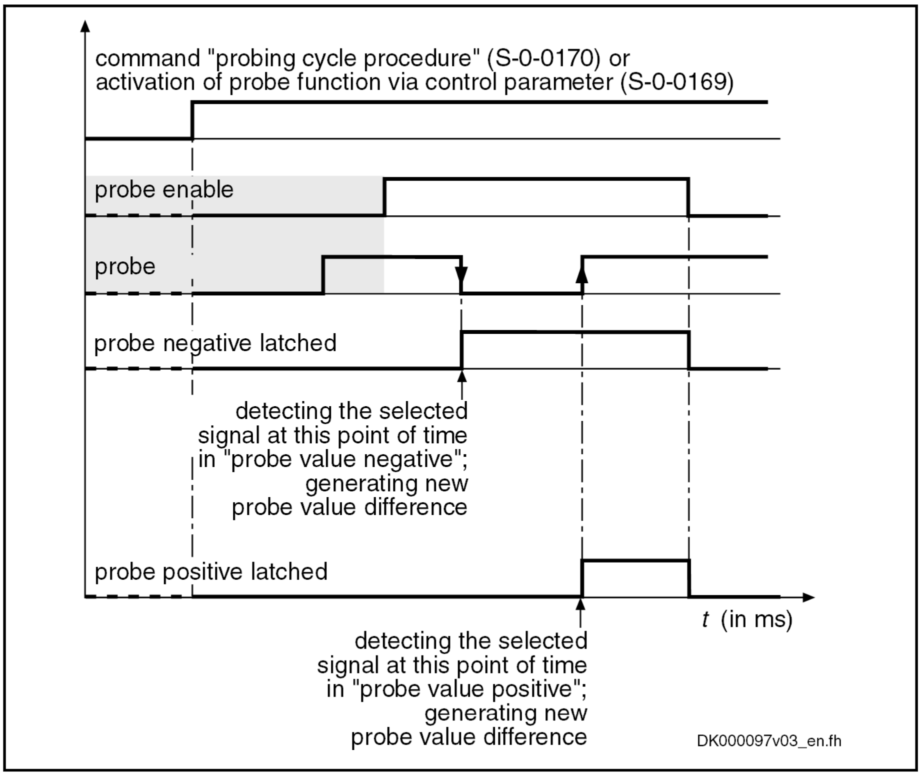


Fig. 9-100: Evaluating the Probe Signal Edges (Evaluation of Positive and Negative Edges Activated in Parameter S-0-0169)

Mode of Measured Value Recording

In parameter "S-0-0169, Probe control parameter", it is possible to set, separately for probe 1 and probe 2, in which mode the measurement is to take place. The measured value recording must have been activated.

The following enable modes are possible:

- Single Measurement

→ After the respective probe has been enabled (S-0-0405 or S-0-0406), a value is only recorded at the first measured value trigger. Before every other measurement, repeated probe enable is required!

- Continuous Measurement

  After the respective probe has been enabled (S-0-0405 or S-0-0406), a new measured value is recorded at each measured value trigger.

Time Measurement, Monitoring, Simultaneous Triggering

In addition, other modalities of measured value detection can be preset in parameter "P-0-0226, Probe, extended control word":

- Switching from position measurement to time measurement.
- Limitation of a range for actual position values ("expectation window") in which measurements can take place. A "trigger failure monitor" can be activated for the "expectation window" which registers the passing through of this range without probe event.
- Simultaneous triggering of both probe evaluations via probe input 1, e.g. for simultaneous position and time measurement.

Selecting the Measuring Signal

The selection of the signal the value of which is measured at the respective measured value trigger takes place by entering the respective IDN in the corresponding parameter

- S-0-0426, Signal selection probe 1
- S-0-0427, Signal selection probe 2

The IDNs of the parameters assigned to the selectable measuring signals are listed in parameter "S-0-0428, Probe, IDN-list signal selection":

- S-0-0051, Position feedback value 1
- S-0-0053, Position feedback value 2
- P-0-0052, Actual position value of measuring encoder
- P-0-0227, Cam table, access angle
- P-0-0753, Position actual value in actual value cycle
- P-0-0775, Resulting master axis position
- P-0-0776, Effective master axis position
- P-0-0789, Master axis position, fine-interpolated

Should the time measurement for a probe input have been activated in parameter "P-0-0226, Probe, extended control word", the signal selection made for this probe is inactive.

☞ The time measurement is only relative! The generation of the measured value difference (P-0-0202, P-0-0203, see below) therefore is especially advantageous for the time measurement. Time differences up to 1000 s can be measured.

Activating Switch-on Level Monitoring for Probe (Valid as of MPx-18V10)

By setting bit 11 of parameter "P-0-0226, Probe, extended control word" a state monitoring of the input of probe 1 (S-0-0401, Probe 1) can be activated when activating the release of probe 1 (S-0-0405, Probe 1 enable).

Pre-requisites for state monitoring are:

- in "S-0-0169, Probe control parameter" is configured for probe 1 individual measurement
- in "S-0-0169, Probe control parameter" only the evaluation of one edge (positive or negative) of probe 1 is configured.

Once the prerequisites have been met, the following applies:

- Evaluation of positive signal edges configured:

  When activating probe 1 enable, a one-time checked is made on "S-0-0401, Probe 1" = 1 (24V). If the status of S-0-0401 is equal 1 (24V), the error " Incorrect switching state of probe 1 input signal" is generated.
- Evaluation of negative signal edges configured:

  When activating probe 1 enable, a one-time checked is made on "S-0-0401, Probe 1" = 0 (0V), wire break monitor. If the status of S-0-0401 is equal 0 (0V), the error " Incorrect switching state of probe 1 input signal" is generated.

Storing Measured Values and Measured Value Differences

Depending on the switching edge of the probe signal that was activated as measured value trigger (setting in S-0-0169), the measured value of the signal selected from the list parameter S-0-0428 is stored in one of the following parameters:

- S-0-0130, Probe value 1 positive edge
- S-0-0131, Probe value 1 negative edge
- S-0-0132, Probe value 2 positive edge
- S-0-0133, Probe value 2 negative edge

In the case of continuous measurement, as in the case of single measurement, the difference from the last two measured values of the same probe, that were measured with opposed (positive/negative/positive …) measured value trigger, is always generated in addition (setting in S-0-0169). This difference is stored in the corresponding parameter:

- P-0-0202, Difference probe values 1
- P-0-0203, Difference probe values 2

Measured Value Status

With each measuring event, a status information is generated and incremented for each probe, depending on the polarity of the respective measured value trigger. This is particularly advantageous for continuous measurement in order to detect new measuring events. This status information is stored in the corresponding parameter:

- S-0-0409, Probe 1 positive latched
- S-0-0410, Probe 1 negative latched
- S-0-0411, Probe 2 positive latched
- S-0-0412, Probe 2 negative latched

☞ By integration of the probe status information and the measured values or measured value differences in the cyclic data of the master communication, the current measuring processes are signaled to the control master and the corresponding measured values are supplied.

Accuracy

The measuring signals (actual values / command values) are generated by the controller on a fixed time base, depending on the available hardware and firmware, as well as on the performance setting in parameter "P-0-0556, Config word of axis controller", see also "Control Section Design and Performance", table "Performance Depending on the Control Section Design", column "T_{A_pos}".

A probe signal edge normally occurs between the fixed measurement starting times of the time base. The related measuring signal value or relative time value is determined by means of linear interpolation between the last and the next measuring signal value or relative time value.

The accuracy of the measurement results basically depends on the hardware used (controller type) and the peripherals (sensors/switches/line capacitances) connected to the probe input. Depending on the controller type, the signal edge detection has a dead time which is caused device-internally. It is largely compensated by the firmware. The temporal "inaccuracy" between edge reversal at the probe input and taking effect in the controller is described in the "Probe" section in the documentation "Control Sections for Drive Controllers; Project Planning Manual".

The dead time additionally caused by the connected peripherals can also be compensated by the drive firmware for each edge of a probe in a size of up to 50000 µs. This dead time can be preset in the parameters:

- S-0-0524, Dead time compensation, positive edge, probe 1
- S-0-0525, Dead time compensation, negative edge, probe 1
- S-0-0526, Dead time compensation, positive edge, probe 2
- S-0-0527, Dead time compensation, negative edge, probe 2

Restart or Deactivation of Measured Value Recording

A restart of the single measurement or the continuous measurement is triggered by resetting (1 → 0) and repeated setting (0 → 1) of the parameters for probe enable:

- S-0-0405, Probe 1 enable
- S-0-0406, Probe 2 enable

When doing this, the following data are cleared:

- Information on probe value trigger status (S-0-0409/S-0-0410 or S-0-0411/S-0-0412) and bits for respective probe in parameter "S-0-0179, Probe status"
- The counter in parameter "P-0-0224, Probe 1, number of marker failures" or "P-0-0225, Probe 2, number of marker failures" (see below)

☞ By activating or deactivating the probe evaluation ("S-0-0170, Probing cycle procedure command" or via corresponding bit in "S-0-0169, Probe control parameter"), reinitialization (resetting all bits in parameter "S-0-0179, Probe status") is carried out.

Using the "Expectation Window"

The position range of an axis or shaft within which probe signal edges cause measured values to be recorded can be limited. In the case of limitation, measured value trigger signals are only expected within position limits that can be set, this range is therefore called "expectation window". The measured value detection limited to the "expectation window" is activated in parameter "P-0-0226, Probe, extended control word".

Detecting marker failures with activated "expectation window":

- If the actual position value is outside of the "expectation window", probe signal edges do not cause measured values to be recorded!

  If no "marker" causing a measured value trigger was detected, after completely passing through the expectation window (both position limits exceeded), this state can be stored and displayed in parameter "P-0-0224, Probe 1, number of marker failures" or "P-0-0225, Probe 2, number of marker failures". For this purpose, it is necessary to activate the option "marker failure monitoring" in parameter P-0-0226! In case of recurrence, the value of P-0-0224 or P-0-0225 is incremented. When the value of P-0-0224 or P-0-0225 has reached a threshold that the user can set ("P-0-0206, Probe 1, max. number of marker failures" or "P-0-0207, Probe 2, max. number of marker failures"), one bit per probe is set in parameter "S-0-0179, Probe status".

- When a measured value trigger occurs within the "expectation window", the value in parameter "P-0-0224, Probe 1, number of marker failures" or "P-0-0225, Probe 2, number of marker failures" is cleared.

☞ The "expectation window" cannot be used with "time measurement"!

Marker Detection

The requirement for detecting a "marker" is determined by activating positive and/or negative signal edge for probe 1 or probe 2. A "marker" is detected when, while the measuring signal was passing through the complete "expectation window", the following event occurred depending on the setting in parameter "S-0-0169, Probe control parameter":

- At "activation negative edge of probe", a negative signal edge was detected
- At "activation positive edge of probe", a positive signal edge was detected
- At "activation positive and negative edge of probe", positive and negative signal edges were detected

---

☞ When the measuring signal only enters the "expectation window" and leaves it on the same side, all detected signal edges are cleared. The parameter values of the marker failure counters P-0-0224 and P-0-0225, however, are not changed!

Setting the Expectation Window

The limitation values for the "expectation window" are set in the following parameters.

Setting for probe 1:

- P-0-0204, Start position probe function 1 active
- P-0-0205, End position probe function 1 active

Setting for probe 2:

- P-0-0200, Start position probe function 2 active
- P-0-0201, End position probe function 2 active

In the case of modulo scaling of the position data, a maximum value for the "expectation window" must not be exceeded, as otherwise it exceeds the modulo value range and therefore is without effect:

$$s_{max} = (S\text{-}0\text{-}0103) - (v_{max} \times \Delta t)$$

s_{max}	Maximum value for expectation window
v_{max}	Maximum velocity of the axis with activated measured value detection (select time reference of v-unit as for Δt–unit!)
Δt	1.00 × 10^-3 s for Economy performance; 0.50 × 10^-3 s for Basic performance; 0.25 × 10^-3 s for Advanced performance (see P-0-0556)
S-0-0103	Modulo value

Fig. 9-101: Determining the Maximum Value for the "Expectation Window" With Modulo Scaling

Quick Stop via Probe Input

The edge reversal of a digital voltage signal can trigger the quick stop of an axis, if the drive is ready for this action. For quick stop, a velocity command value reset is internally triggered which causes the axis to decelerate. The following conditions are taken into account in this case:

- The current torque/force limit value for drives in closed-loop operation
- The maximum stator frequency slope (P-0-0569) for drives in V/Hz [U/f] operation or in sensorless, flux-controlled motor operation
- "P-0-0119, Best possible deceleration", see reaction probe detection

When the drive has detected the quick stop signal, it ignores the setting of command values by the control master, decelerates in a drive-controlled way and remains in a drive-internal operation mode until the readiness for quick stop is reset.

To keep the delay between edge reversal of the signal and triggering of quick stop as short as possible, the rapid digital input for probe 1 is used for this function.

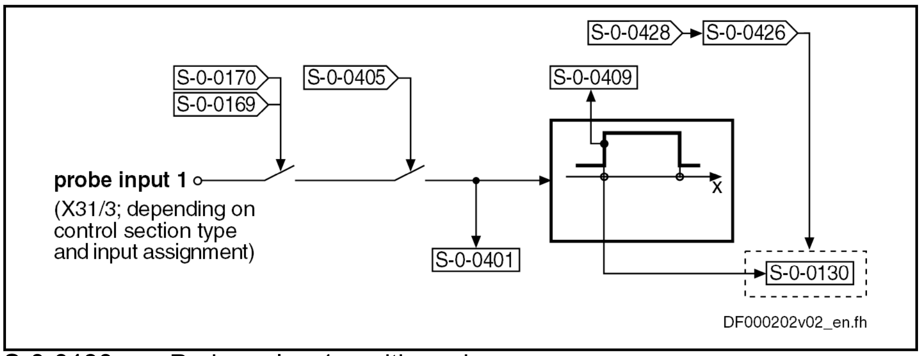
The rapid digital input (probe input 1) evaluates the voltage level of the stop signal in digital form, i.e. only the signal states "high" (1) or "low" (0) are recognized.

Quick stop is triggered at a rising (positive) switching edge. As of MPx-18V10, the quick stop of configured switching edge (P-0-0226, bit 3, bit 10) is configured.

The regions on the signal levels for "high" (1) and "low" (0) of the "fast" digital inputs are described in section "I/O extensions" in documentation "Control Sections for Drive Controllers; Project Planning Manual".

Operating Principle of Relevant Parameters

The figure below illustrates the interaction of the parameters relevant for quick stop via probe input:



S-0-0130	Probe value 1 positive edge
S-0-0169	Probe control parameter
S-0-0170	Probing cycle procedure command
S-0-0401	Probe 1
S-0-0405	Probe 1 enable
S-0-0409	Probe 1 positive latched
S-0-0426	Signal selection probe 1
S-0-0428	Probe, IDN list signal selection

Fig. 9-102: Overview and Operating Principle of Parameters Relevant for Quick Stop via Probe

The currently detected signal state at the rapid digital input is displayed in parameter "S-0-0401, Probe 1", when readiness for quick stop (see below) is given.

The rapid digital input (probe 1) must have been assigned to parameter S-0-0401 (default setting of "P-0-0300, Digital inputs, assignment list", etc.)!

See "Digital Inputs/Outputs"

Selecting the Measuring Signal

The status variable the value of which is measured when the quick stop edge is read, is selected by inputting the respective IDN in parameter "S-0-0426, Signal selection probe 1".

The IDNs of the selectable parameters assigned to the status variables are listed in "S-0-0428, Probe, IDN-list signal selection".

Storing Measured Values

The value of the signal selected from list parameter S-0-0428 is stored in parameter "S-0-0130, Probe value 1 positive edge" when the signal edge occurs.

Activating the Readiness for Quick Stop

A switching edge at the rapid digital input (probe input 1) triggers the quick stop, when the following conditions have been fulfilled:

- Readiness for quick stop was activated by:
  - Starting "S-0-0170, Probing cycle procedure command"

  - or -

  - Setting the "activation of probe function" bit in "S-0-0169, Probe control parameter"
- Bit 3 (probe 1, quick stop configuration activated) of the parameter "P-0-0226, Probe, extended control word" is set.
- Enabling of rapid digital input (probe 1) for signal evaluation in parameter "S-0-0405, Probe 1 enable"

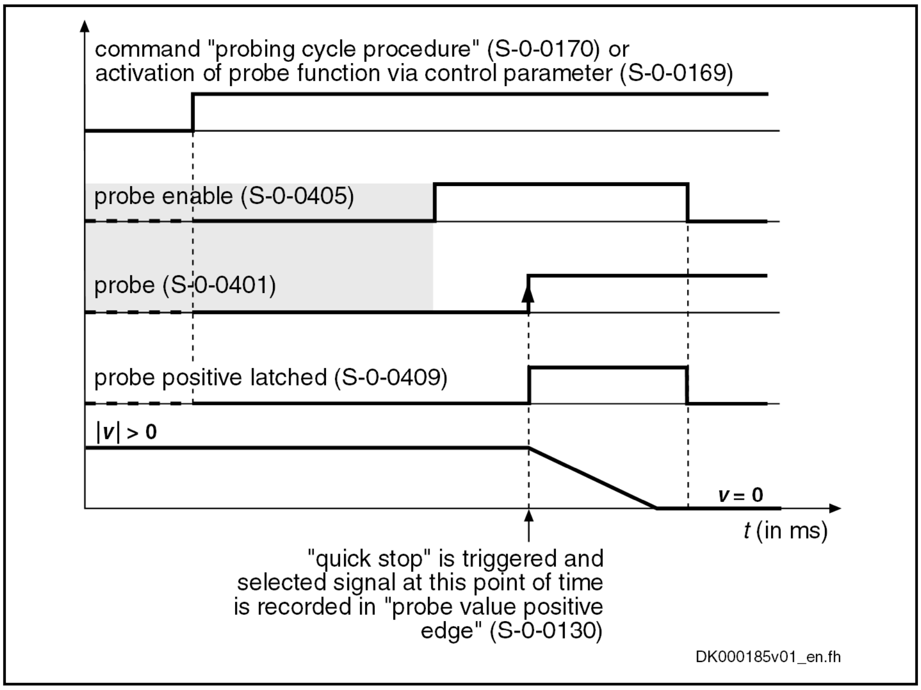


Fig. 9-103: Evaluating the Signal for the Quick Stop Function

Configuration of Signal Edge for Triggering Probe 1 Quick Stop (Valid as of MPx-18V10)

The signal edge is configured in Bit 10 (Configuration of signal edge for triggering probe 1 quick stop) of parameter "P-0-0226, Probe, extended control word":

- 0: Switching to speed cmd value = 0 at a 0 -> 1 (positive) edge
- 1: Switching to speed cmd value = 0 at a 1 -> 0 (negative) edge

Executing the Quick Stop Function

The readiness for quick stop and the detection of the quick stop signal internally trigger the speed command value reset which causes the axis to be shut down. This happens taking the following values into account:

- The current torque/force limit value for drives in closed-loop operation

- The maximum stator frequency slope (P-0-0569) for drives in open-loop operation

In the case of quick stop, the drive ignores the setting of command values by the control master, decelerates in a drive-controlled way and remains in a drive-internal operation mode until the readiness for quick stop is reset. Quick stop is displayed by the drive by means of diagnostic status message "A0403 Quick stop with probe detection is active" in parameter "S-0-0095, Diagnostic message" and by means of the **operation status "AR" on the display** of the control panel.

Behavior after Deactivation of Quick Stop Function

At deactivation of the readiness for quick stop, the drive leaves the quick stop state. The drive now follows the command value of the control master again.

9.13.3 Notes on Commissioning

Commissioning the Probe Function

Presettings

Make the following settings in "S-0-0169, Probe control parameter":

- Evaluation of probe signal edge as measured value trigger
- Select enabling mode of probe (single measurement or continuous measurement)

Make further settings in parameter "P-0-0226, Probe, extended control word":

- Activation of expectation window and failure monitor
- Activation of time measurement
- Enter the affected probe "S-0-0401, Probe 1" or "S-0-0402" into the list "P-0-0300, Digital inputs, assignment list". The list element of the list is irrelevant. Subsequently, enter the digital input that is to be evaluated as probe in list "P-0-0306, Digital inputs, assignment connector and pin", namely at the list element where you have earlier entered the corresponding probe in list P-0-0300. A digital input that can be used as probe input can be assigned to any probe and also to several probes at the same time. Regarding the question which digital inputs can be used as probe inputs, please refer to the Project Planning Manual "Control Sections for Drive Controllers".

Select measuring signals from "S-0-0428, Probe, IDN-list signal selection"; enter the selected parameters in:

- S-0-0426, Signal selection probe 1
- S-0-0427, Signal selection probe 2

Activating the Measurement

The measured value detection can be activated via:

- "S-0-0170, Probing cycle procedure command" (only in operating mode)

- or -

- "S-0-0169, Probe control parameter" (bit 8)

  → S-0-0170 is automatically activated during transition PM → OM

Then enable the probe input for triggering the measured value recording:

- S-0-0405, Probe 1 enable
- S-0-0406, Probe 2 enable

Single Measurement

Every repeated "single measurement" has to be enabled by resetting and repeatedly setting S-0-0405 or S-0-0406.

Continuous Measurement

If enabling of the probes via S-0-0405 or S-0-0406 has been set with "continuous measurement", a measured value is stored at every measured value trigger. How many measured values were stored by positive or negative trigger of the respective probe, is contained in the status information on the measured value trigger (see below "Identifying the Measured Value Detection").

Identifying the Measured Value Detection

When a measuring event took place, the measured value trigger status is updated, i.e. the value of the respective parameter is incremented, starting with the value "0":

- S-0-0409, Probe 1 positive latched
- S-0-0410, Probe 1 negative latched
- S-0-0411, Probe 2 positive latched
- S-0-0412, Probe 2 negative latched

The corresponding measured value is stored in:

- S-0-0130, Probe value 1 positive edge
- S-0-0131, Probe value 1 negative edge
- S-0-0132, Probe value 2 positive edge
- S-0-0133, Probe value 2 negative edge

In addition, after recording of a new measured value, the difference from the measured values of the positive and negative edges is automatically generated and the absolute value is stored:

$$\text{P-0-0202} = |(\text{S-0-0130}) - (\text{S-0-0131})|$$

$$\text{P-0-0203} = |(\text{S-0-0132}) - (\text{S-0-0133})|$$

P-0-0202	Difference probe values 1
S-0-0130	Probe value 1 positive edge
S-0-0131	Probe value 1 negative edge
P-0-0203	Difference probe values 2
P-0-0132	Probe value 2 positive edge
P-0-0133	Probe value 2 negative edge

Fig. 9-104: Subtraction of the Measured Values

☞ The differences from the measured values of the positive and negative edges are always generated, even if only one edge polarity has been activated for the measured value trigger!

Setting the "Expectation Window"

Set the limits of the "expectation window" taking the minimum value and, if necessary, the maximum value (for modulo scaling) into account. The "expectation window" must have been activated in parameter P-0-0226.

Setting for probe 1:

- P-0-0204, Start position probe function 1 active
- P-0-0205, End position probe function 1 active

Setting for probe 2:

- P-0-0200, Start position probe function 2 active
- P-0-0201, End position probe function 2 active

If "marker failure monitoring" has been activated (P-0-0226), the number of times the "expectation window" is passed through without marker detection is displayed in:

- P-0-0224, Probe 1, number of marker failures
- P-0-0225, Probe 2, number of marker failures

The user can set a threshold for the counted marker failures:

- P-0-0206, Probe 1, max. number of marker failures
- P-0-0207, Probe 2, max. number of marker failures

When the number of marker failures has reached the threshold, the respective bit is set in:

- S-0-0179, Probe status

Resetting

The measuring data, the measured value trigger status and the information on the marker failure are cleared by writing data to:

- S-0-0405, Probe 1 enable → Write value "0"
- S-0-0406, Probe 2 enable → Write value "0"
- S-0-0170, Probing cycle procedure command

All detected information on failed markers is cleared by writing data to:

- P-0-0226, Probe, extended control word

Commissioning Quick Stop via Probe Input

Requirements

The probe function must have been parameterized for probe 1 with evaluation of positive edge (see "General Probe Function").

To use quick stop, additionally make the following setting in parameter "P-0-0226, Probe, extended control word":

- Set bit for activation "quick stop via probe input 1"

From "S-0-0428, Probe, IDN-list signal selection", you can select the parameter of the measuring signal the value of which is stored when the quick stop signal is read. Enter the selected parameter in:

- S-0-0426, Signal selection probe 1

Activating the Readiness for Quick Stop

With the corresponding presetting, the readiness for quick stop can now be activated via the enable signal of the rapid digital input (probe 1) by setting:

- S-0-0405, Probe 1 enable

Measured Value at Quick Stop Request

When quick stop is executed, the measured value belonging to the quick stop signal edge is stored in:

- S-0-0130, Probe value 1 positive edge

Deactivation

The quick stop situation or the readiness for quick stop is deactivated by

- Resetting "S-0-0405, Probe 1 enable"

- or -

- Deactivating "S-0-0170, Probing cycle procedure command"

- or -

- Resetting bit 8 in "S-0-0169, Probe control parameter"
  → Function only deactivated when changing to parameter mode

---

☞ If the control master operates the drive in cyclic position control, set the actual position value of the drive as start value for the cyclic position command values, when the quick stop function is deactivated!

9.14 Measuring encoder

9.14.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

Position measurement

Measuring encoders are used for position evaluation of a rotary motion that takes effect as a command variable for drive control. The actual position value of the measuring encoder therefore is of command value nature for drive control, the measuring encoder can be connected to a shaft or axis via a gearbox and acts as a master axis encoder, for example.

Evaluating Position Measurement

Depending on its design and the mechanical arrangement at the axis, the measuring encoder can be evaluated as

- Relative encoder (incremental encoder)

- or -

- Absolute encoder (absolute value encoder).

Relative Position Measurement

In the case of relative position measurement, only position differences can be evaluated by means of the measuring system. The actual position values signaled by the measuring system refer to the (mostly undefined) position at the time the drive is switched on. If the actual position value is to refer to an axis or shaft, it is necessary to establish position data reference ("homing").

Absolute Position Measurement

In the case of absolute position measurement, the encoder signals actual position values with a fixed encoder-dependent reference point to the controller. After the drive is switched on, the correct actual position value is immediately available for each axis or shaft position. Due to the mostly undefined mounting situation of the encoder, it is necessary during initial commissioning to once adjust the actual position value to the axis or shaft ("set absolute position").

Precision, Resolution

The precision of the position measurement depends on

- the resolution of the measuring system (division periods = DP),
- the absolute encoder precision,
- the digitalization quality of the analog encoder signals,
- the size of the selected modulo range of the encoder.

Monitoring Functions

The correct position information of the measuring encoder is required for correct recording of a command variable. The encoder signals are therefore monitored for validity and compliance with the allowed tolerances.

In addition, it is possible to monitor drives with an encoder that can be evaluated in absolute form for compliance with the position when switching on compared to the last time the drive was switched off.

See "Monitoring the Measuring Systems"

Hardware Requirements

For connecting the measuring systems to the controller, the control section has to be equipped with the corresponding interfaces. Parameter "P-0-0079, Assignment measuring encoder->optional slot" is used to determine the interface to which the respective encoder is connected.

For multi-axis drive controllers (HCT, HCQ), it is only possible to assign a measuring encoder to one axis. The assignment is made in parameter "P-0-0076, Encoder type 3 (measuring encoder)". If a measuring encoder was assigned to several axes, an error message will be displayed!

☞ For multi-axis control sections (HCQ / HCT), the measuring encoder can only be connected to the X8 interface (option 5)!

Pertinent Parameters

- P-0-0052, Actual position value of measuring encoder
- P-0-0076, Encoder type 3 (measuring encoder)
- P-0-0079, Assignment measuring encoder->optional slot
- P-0-0084, Number of bits per master axis revolution
- P-0-0087, Actual position value offset of measuring encoder
- P-0-0097, Absolute encoder monitoring window for measuring encoder
- P-0-0127, Input revolutions of measuring gear
- P-0-0128, Output revolutions of measuring gear
- P-0-0179, Absolute encoder buffer 3 (measuring encoder)
- P-0-0326, Multiplication of measuring encoder
- P-0-0327, Encoder resolution of measuring encoder
- P-0-0328, Type of position encoder for measuring encoder
- P-0-0329, Smoothing of actual position value 3 of measuring encoder
- P-0-0330, Control word of measuring encoder
- P-0-0331, Status of measuring encoder
- P-0-0332, Actual velocity value of measuring encoder
- P-0-0334, Absolute encoder range of measuring encoder
- P-0-0347, Encoder 3, cosine signal
- P-0-0348, Encoder 3, sine signal
- P-0-0765, Modulo factor measuring encoder
- P-0-1020, Kind of encoder 3, encoder memory
- P-0-1021, Encoder 3 resolution, encoder memory
- P-0-1022, Absolute encoder offset 3, encoder memory

Pertinent Diagnostic Messages

- C0291 Incorr. parameterization of measuring enc. (hardware)
- C0292 Measuring encoder unknown
- C0293 Modulo value for measuring encoder cannot be displayed
- C0294 Incorrect measuring encoder configuration
- C0227 Error when initializing position of measuring encoder
- C0228 Initialization velocity measuring encoder too high
- E2076 Measuring encoder: Encoder signals disturbed
- F2043 Measuring encoder: Encoder signals incorrect

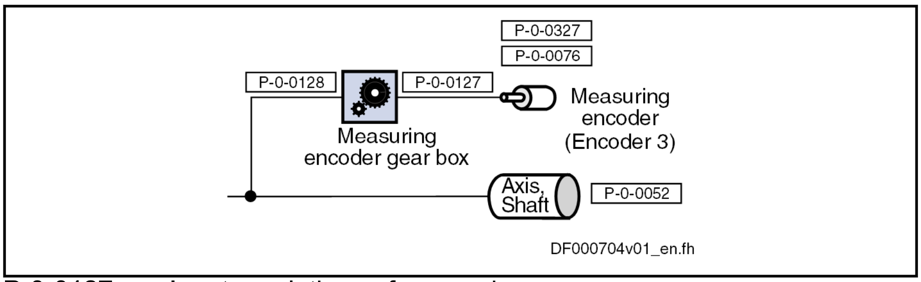
☞ The error message F2043 can also be configured as a warning. In this case, there is no error reaction on the drive side. The user is then responsible for initiating an appropriate reaction via the control master

- F2076 Actual pos. value 3 outside absolute encoder window
- F2176 Loss of measuring encoder reference
- F2179 Modulo limitation error of measuring encoder

9.14.2 Functional Description

Basics on Measuring Encoder, Resolution

The measuring encoder is connected to an axis or shaft directly mechanically or via a gearbox, and detects its position data. These position data can be used as measured values or command variable, but not as control variable.



P-0-0127	Input revolutions of measuring gear
P-0-0128	Output revolutions of measuring gear
P-0-0327	Encoder resolution of measuring encoder
P-0-0076	Encoder type 3 (measuring encoder)
P-0-0052	Actual position value of measuring encoder

Fig. 9-105: Arrangement of Measuring Encoder, Measuring Encoder Gearbox and Axis or Shaft

Encoders to be Used

Only rotary encoders can be used as measuring encoders. The possible encoders are listed in parameter "P-0-0076, Encoder type 3 (measuring encoder)".

Scaling of Measuring Encoder Position Data

The scaling of the position data generated with a measuring encoder is rotary and axis- or shaft-related. Due to the infinite motion range of the measuring encoder and the limited value range of the position data, modulo scaling is set automatically. For position data scaling, it is possible, via "P-0-0330, Control word of measuring encoder", to choose between:

- Incremental scaling (for master axis)
- Rotary preferred scaling, 360° at measuring encoder gearbox output (not for master axis applications)

See also "Scaling of Physical Data"

Incremental Scaling

With incremental scaling, the modulo range via P-0-0330 can be selected as an integral multiple of an axis- or shaft-side revolution and has an upper limit:

$$\text{Modulo range} = n \times (\text{Axis or shaft revolutions})$$
$$n = (\text{P-0-0765}) \leq 2^{31-(\text{P-0-0084})} - 1\ ;\quad n \in N$$
$$n = 2^{32-(\text{P-0-0084})} \text{ for P-0-0765} = 0$$

n	Number of axis or shaft revolutions (or of measuring encoder gearbox output), until the actual position value "recurs"
P-0-0084	Number of bits per master axis revolution
P-0-0765	Modulo factor measuring encoder

Fig. 9-106: Determining the Modulo Range of the Axis or Shaft

Rotary Preferred Scaling

With the rotary preferred scaling that can be selected via "P-0-0330, Control word of measuring encoder", one revolution of the measuring encoder gearbox output is 360° modulo. The preferred scaling is intended for the position detection of independently driven tool spindles, for example, it is unsuitable for master axis encoders.

For the measuring encoder gearbox, the value of "P-0-0127, Input revolutions of measuring gear" corresponds to the revolutions of the measuring encoder.

Absolute Precision of Measuring Encoder

The absolute precision is a feature of the encoder and is determined by its construction and the quality of its components. The data for the absolute precision are indicated by the manufacturer.

Resolution (Division Periods)

The resolution of the measuring system (division periods or cycles per encoder revolution) is input in parameter

- P-0-0327, Encoder resolution of measuring encoder.

Maximum Measuring Encoder Resolution after Digitalization

The analog encoder signals are converted to digital position data via A/D converter. This increases the resolution of the position data available for the axis compared to the resolution of the measuring system (see above)!

$$\text{Measuring encoder (rotary only): (P-0-0327)} \times 2^{15}$$

P-0-0327 Encoder resolution of measuring encoder

Fig. 9-107: Maximum Possible Encoder Resolution of Measuring Encoder per Encoder Revolution

Value Range of the Position Data, Incremental Scaling

In the case of incremental scaling the value range of the position data of the measuring encoder depends on the modulo factor of the measuring encoder (P-0-0765):

$$\text{Position data value range: } 0 < \varphi_{Incr.} < (\text{P-0-0765} \times 2^{(\text{P-0-0084})})-1 \; ; \; \varphi_{Incr.} \in N$$
$$\text{if } 0 < \text{P-0-0765} < (2^{31-(\text{P-0-0084})})-1 \; ; \; \text{P-0-0765} \in N$$
$$\text{Position data value range: } -2^{31} < \varphi_{Incr.} < 2^{31}-1 \; ; \; \varphi_{Incr.} \in N$$
$$\text{if } \text{P-0-0765} = 0$$

φ incr. Position within the modulo range in incremental scaling (acc. to P-0-0052, Actual position value of measuring encoder)
P-0-0084 Number of bits per master axis revolution
P-0-0765 Modulo factor measuring encoder

Fig. 9-108: Position Data Value Range at Axis or Shaft (or of Measuring Encoder Gearbox Output)

Depending on "P-0-0327, Encoder resolution of measuring encoder" and the gear ratio of the measuring encoder gearbox (P-0-0127, P-0-0128), a multiple of position data results from one division period of the measuring encoder due to digitalization. By adjusted multiplication, the available range of measuring encoder position data of (2^{30}-1) values is observed.

Value Range of Position Data, Rotary Preferred Scaling

With rotary preferred scaling, one revolution of the measuring encoder gearbox output is 360° modulo with 4 decimal places. The rotary preferred scaling cannot be changed to a different number of angular degrees per revolution of the measuring encoder gearbox output!

Drive-Internal Resolution of Measuring Encoder Position Data

The resulting drive-internal encoder resolution is as follows:

Measuring encoder resolution = (P-0-0326) × (P-0-0327)

Drive-internal calculation:

$$\text{P-0-0326} = 2^{30} \times \frac{(\text{P-0-0128})}{(\text{P-0-0127}) \times (\text{P-0-0327}) \times (\text{P-0-0765})} \leq 2^{n}; \qquad n \leq 15 \text{ (integral)}$$

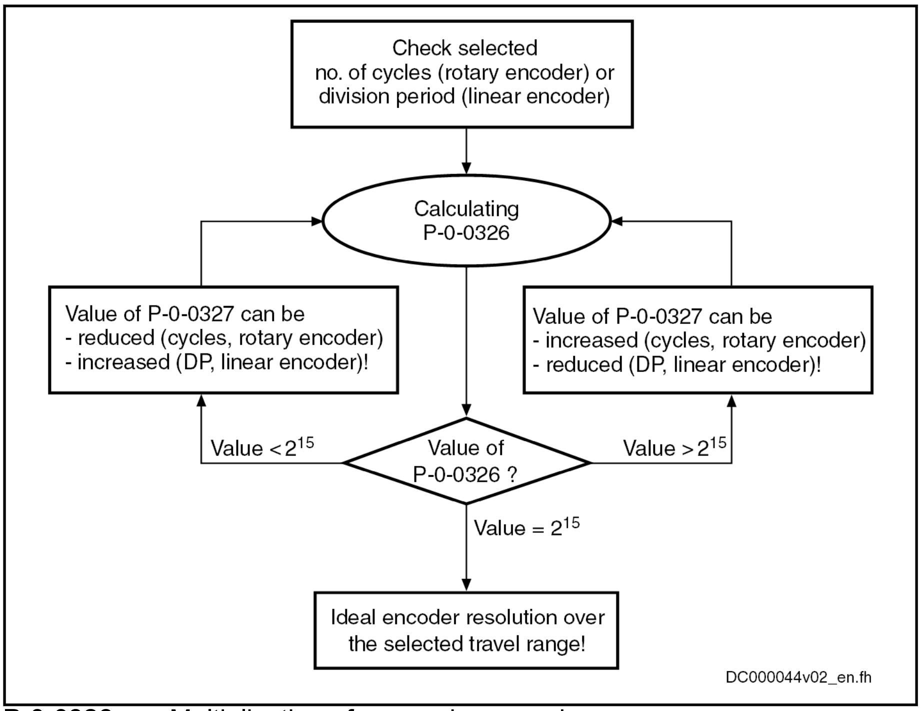
P-0-0326 Multiplication of measuring encoder
P-0-0327 Encoder resolution of measuring encoder
P-0-0128 Output revolutions of measuring gear
P-0-0127 Input revolutions of measuring gear
P-0-0765 Modulo factor measuring encoder
n Number of revolutions at axis or shaft

Fig. 9-109: Drive-Internal Measuring Encoder Resolution

☞ The multiplication of the measuring encoder (P-0-0326) is determined automatically and drive-internally!

Encoder Dimensioning

The multiplication value (P-0-0326) calculated according to the "drive-internal measuring encoder resolution" formulas characterizes the encoder dimensioning.



P-0-0326 Multiplication of measuring encoder
P-0-0327 Encoder resolution of measuring encoder

Fig. 9-110: Checking the Selected Resolution and Determining the Ideal Resolution for the Measuring Encoder

☞ The value of P-0-0326 calculated according to the "drive-internal measuring encoder resolution" formulas normally will never be exactly 2^{15} (= 32768). With results that are, depending on the encoder, as little as possible greater than 2^{15}, the conditions with regard to the selected number of cycles and the possibilities of encoder evaluation are ideal!

Real Resolution of Measuring Encoder

The lower value from "drive-internal resolution of master axis position data" and "maximum measuring encoder resolution after digitalization" is the real resolution of the position data.

Actual Measuring Encoder Position Value and Smoothing of the Actual Position Value

The actual position value of the measuring encoder (P-0-0052) consists of the internal actual position value and the value in "P-0-0087, Actual position value offset of measuring encoder":

P-0-0052 = internal actual position value + P-0-0087

Fig. 9-111: Values of which the Actual Measuring Encoder Position Value Consists

The actual position value of the measuring encoder (P-0-0052) can be smoothed via a filter. The time constant of smoothing is entered in parameter "P-0-0329, Smoothing of actual position value 3 of measuring encoder". Smoothing can also be deactivated (see Parameter Description).

Velocity of the Axis or Shaft to be Measured

The velocity of the axis or shaft to be measured is displayed in parameter "P-0-0332, Actual velocity value of measuring encoder". The scaling of the velocity is axis or shaft revolutions per minute.

Monitoring Functions of Measuring Encoder

For the measuring encoder there are signal monitoring functions that correspond to the monitoring functions for motor encoder and optional encoder. However, warnings and error messages specific to the measuring encoder are output.

See "Monitoring the Measuring Systems"

Signal Monitoring for Sine Encoders

For signal monitoring of sine encoders as measuring encoders the following diagnostic messages can be generated:

- E2076 Measuring encoder: Encoder signals disturbed
- F2043 Measuring encoder: Encoder signals incorrect

Monitoring the Axis or Shaft Position

When the drive is switched off, the internal actual position value of an absolute measuring encoder is stored in the parameter

- P-0-0179, Absolute encoder buffer 3 (measuring encoder).

When a drive with an absolute measuring encoder is switched on, a check is run to determine in how far the current actual position value of the measuring encoder differs from the actual position value at the time the drive was switched off the last time. The maximum allowed difference is determined in parameter

- P-0-0097, Absolute encoder monitoring window for measuring encoder

If the difference exceeds the determined value, the following error message is output:

- F2076 Actual pos. value 3 outside absolute encoder window

This monitoring function can be deactivated!

Monitoring the Position Data Reference

The position data reference of a measuring encoder that can be evaluated in absolute form gets lost after the following measures have been taken:

- Change of parameter values of mechanical connection
- Change of encoder resolution
- Change of modulo range
- Replacement of measuring encoder

During the transition from communication phase "P2" to "bb" or "Ab", the drive recognizes that the former position data reference of the encoder does no longer exist. It sets "P-0-0331, Status of measuring encoder" to "not homed" and signals the loss of position data reference by the error message "F2176 Loss of measuring encoder reference".

Establishing the Position Data Reference to the Axis or Shaft

Procedures for Establishing the Position Data Reference

Whether absolute evaluation is possible or not depends on the encoder type (P-0-0076, P-0-0327), the resolution of the measuring encoder and on the modulo range that was set (P-0-0765). This is displayed by a bit in parameter "P-0-0328, Type of position encoder for measuring encoder".

☞ The value range of position data, that can be displayed in absolute form, of the encoder used is displayed in parameter "P-0-0334, Absolute encoder range of measuring encoder". If the value range of the measuring encoder is smaller, absolute evaluation is possible!

Depending on relative or absolute evaluation of the measuring encoder, the drive controller makes available different procedures for establishing the position data reference. Depending on the kind of evaluation there are the following options:

- "Set absolute position" for measuring encoders to be evaluated in absolute form
- "Homing" for measuring encoders to be evaluated in relative form

☞ After having successfully established the position data reference, the actual position value refers to the axis or shaft. The measuring encoder then is "in reference" or has been "homed".

NOTICE **When the position data reference is established, the actual position value of the measuring encoder can change abruptly!**

⇒ If the actual position value is used as the command variable of the drive, the control master has to take this into account when establishing the position data reference!

Establishing Position Data Reference for Measuring Encoder to be Evaluated in Absolute Form

Activating "Set Absolute Position"

The position data reference of a measuring encoder to be evaluated in absolute form (see respective bits of P-0-0328) to an axis or shaft is established by "S-0-0447, C0300 Set absolute position procedure command".

As it is possible to connect several encoders to be evaluated in absolute form to the drive controller, the absolute encoder to be homed is selected by a bit in parameter "S-0-0448, Set absolute position control". The "set absolute position procedure" command only takes effect for the selected encoders.

Dedicated Position

By starting the "set absolute position procedure" command, the previous incremental actual position value of the measuring encoder at a dedicated position of the axis or shaft is set to a defined value. The dedicated position corresponds to the current axis position at the start of the command.

The new actual position value at the dedicated position after "set absolute position" is the value of parameter "P-0-0087, Actual position value offset of measuring encoder".

$$[P\text{-}0\text{-}0052]_{NEW} = P\text{-}0\text{-}0087$$

P-0-0052 Actual position value of measuring encoder
P-0-0087 Actual position value offset of measuring encoder

Fig. 9-112: Actual Position Value of the Measuring Encoder after "Set Absolute Position"

Storing the Absolute Encoder Offset

In order that an encoder to be evaluated in absolute form maintains the position data reference to the axis or shaft after "set absolute position", the absolute encoder offset is stored in the encoder data memory ("P-0-1022, Absolute encoder offset 3, encoder memory") and in the parameter memory ("P-0-0179, Absolute encoder buffer 3 (measuring encoder)").

☞ Storing the absolute encoder offset in the encoder data memory and in the parameter memory allows recognizing whether the absolute encoder that had been homed was replaced!

Storage Mode

If the "set absolute position procedure" command is cyclically used in the operational sequence, it makes sense to store the absolute encoder offset temporarily only. This type of storage does not affect the service life of the encoder data memory and the parameter memory. In parameter "S-0-0269, Storage mode", it is possible to select whether the values are to be stored permanently or temporarily.

☞ When the absolute encoder offset is stored temporarily, the measuring encoder loses the position data reference to the axis when the drive controller is switched off or when the parameter mode ("PM") is activated.

"Set Absolute Position" Procedure

For the measuring encoder, the "set absolute position procedure" command can only be activated when the drive is ready for operation but inactive ("bb", "AB").

When the "set absolute position procedure" command is started, the reference of the selected encoder is cleared first ("P-0-0331, Status of measuring encoder"). After the reference was cleared, the new actual position value ("P-0-0087, Actual position value offset of measuring encoder") takes effect immediately and the reference bit is set again.

Establishing Position Data Reference for Relative Measuring Encoder

Activating the Homing Procedure

The position data reference of a relative measuring encoder to an axis or shaft is established by means of a reference mark signal of the encoder. For this purpose, it is first necessary to activate the reference mark evaluation for the measuring encoder in the respective bit of "P-0-0330, Control word of measuring encoder".

If the reference mark evaluation is still active, it first has to be deactivated and then activated again.

☞ In the case of rotary encoders, reference mark signals usually occur once per encoder revolution!

Dedicated Position

When the reference mark signal is read the next time, the previous, encoder-related actual position value at a dedicated position of the axis or shaft is set to a defined value. The dedicated position corresponds to the current axis position at the occurrence of the reference mark signal.

☞ When reference mark evaluation has been activated, only the reference mark that was read first is evaluated, other reference marks are ignored!

The new actual position value at the dedicated position after homing is the value of parameter "P-0-0087, Actual position value offset of measuring encoder".

$$[P\text{-}0\text{-}0052]_{NEW} = P\text{-}0\text{-}0087$$

P-0-0052 Actual position value of measuring encoder
P-0-0087 Actual position value offset of measuring encoder

Fig. 9-113: Actual Position Value of the Measuring Encoder after Homing Procedure

When the position reference of the measuring encoder has been successfully established, this is displayed in parameter "P-0-0331, Status of measuring encoder". The reference mark evaluation for the measuring encoder should then be deactivated in the respective bit of parameter "P-0-0330, Control word of measuring encoder"!

☞ When a measuring encoder gear is used, the occurrence of the reference mark of the encoder with reference to the actual position value of the axis or shaft to be measured mostly is not unequivocal! On the control side, it is necessary to make sure that the reference mark evaluation is activated at the appropriate axis or shaft position (identification via initiator or the like)!

Shifting the Position Data Reference

Operating Principle

Shifting the position data reference affects the current actual position value of the measuring encoder connected to the drive. Whether the current actual position value has position data reference to the axis or not is irrelevant for the shifting of the position data reference! The shifting is triggered on the master side by writing "P-0-0087, Actual position value offset of measuring encoder" and is immediately carried out on the drive side.

☞ The reference state of the actual position values is not affected by the shifting of the position data reference.

When the drive is switched on the first time, the offset, set by the current value of P-0-0087, with regard to the original actual position value of the measuring encoder takes immediate effect.

If the position data reference is shifted several times in succession, each new value in P-0-0087 refers to the original actual position value of the measuring encoder, i.e. the shifted values do not act in an additive way!

Resetting the Offset

The offset of the position data reference is reset by entering the old value (before the value was shifted) in parameter P-0-0087.

9.14.3 Notes on Commissioning

Configuration and Setting

Configuring the Drive Controller

Optional Device Functions

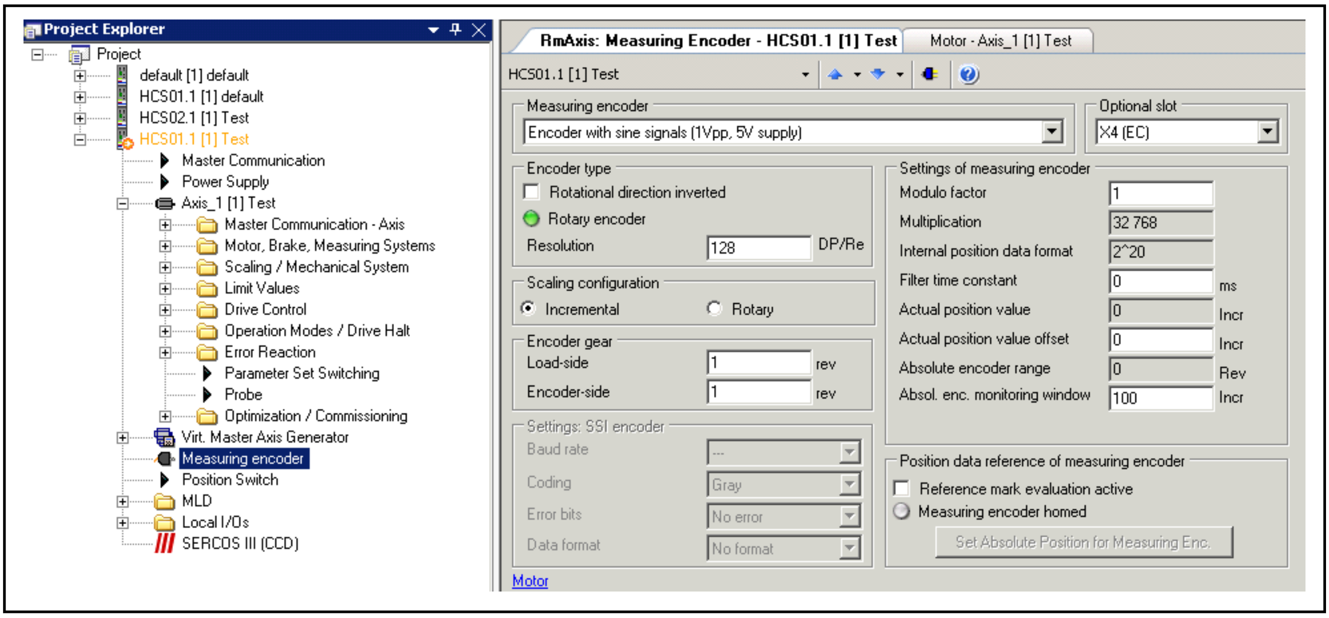


Fig. 9-114: IndraWorks Dialog for the Measuring Encoder

The optional interfaces have to be assigned to the measuring encoder connection:

- P-0-0079, Assignment measuring encoder->optional slot

Configuring the Encoder

Setting the measuring encoder type:

- P-0-0076, Encoder type 3 (measuring encoder)

Setting the resolution (number of lines, division period) of the measuring encoder:

- P-0-0327, Encoder resolution of measuring encoder

Setting the type of encoder and the rotational direction of the measuring encoder:

- P-0-0328, Type of position encoder for measuring encoder

Measuring Encoder Connection

The measuring encoder connection (via gearbox or direct) is specified by the relationship of measuring encoder revolutions to axis or shaft revolutions:

- P-0-0127, Input revolutions of measuring gear
- P-0-0128, Output revolutions of measuring gear

☞ For the measuring encoder gearbox, the value of "P-0-0127, Input revolutions of measuring gear" corresponds to the revolutions of the measuring encoder!

Setting the Scaling

Select between:

- Incremental parameter scaling or
- Rotary Preferred Scaling

Incremental Scaling

With incremental scaling, the modulo range of the axis or shaft to be measured must be entered:

- P-0-0765, Modulo factor measuring encoder

Message if the entered value is too high:

- C0293 Modulo value for measuring encoder cannot be displayed

Rotary Preferred Scaling

With this scaling, one revolution of the measuring encoder gearbox output is fixed to 360° with 4 decimal places.

☞ The scaling can only be set in "PM"!

Setting the Smoothing of Actual Position Value

Setting or deactivating the time constant of the smoothing:

- P-0-0329, Smoothing of actual position value 3 of measuring encoder

Possibility of Absolute Evaluation and Position Monitoring (Position when Drive Switched On)

Checking Possibility of Absolute Evaluation

Checking absolute encoder range of measuring encoder:

- P-0-0334, Absolute encoder range of measuring encoder

☞ The scaling of the parameter P-0-0334 is revolutions of the measuring encoder gearbox output!

When the position data range of values is smaller than the absolute encoder range of the measuring encoder, it can be evaluated as an absolute encoder. This is displayed in the measuring encoder dialog of IndraWorks and signaled in the corresponding bit of the parameter

- P-0-0328, Type of position encoder for measuring encoder.

By means of this parameter, it is possible to deactivate the absolute evaluation of an encoder. The actual position values then are only relative, i.e. the encoder has to be homed again each time the machine is restarted or the drive changes to communication phase "PM"!

Setting the Axis or Shaft Position Monitor (Only with Absolute Encoder)

If position monitoring of the axis or shaft to be measured is required when the drive is switched on, enter the threshold value for the error message in parameter

- P-0-0097, Absolute encoder monitoring window for measuring encoder.

☞ The threshold of the error message depends on application-specific aspects of operational safety. The monitor is deactivated by the value "0"!

If the change of actual position value between the switching off and switching on is greater than the threshold value that was set, the following error message is generated:

- F2076 Actual pos. value 3 outside absolute encoder window.

Information on Measuring Encoder and Position Evaluation

Current information on measuring encoder and position evaluation is stored in the following parameters:

- P-0-0052, Actual position value of measuring encoder
- P-0-0331, Status of measuring encoder
- P-0-0326, Multiplication of measuring encoder

☞ When parameter P-0-0326 has the value "32768", encoder evaluation is ideal!

Establishing Position Data Reference for Measuring Encoder to be Evaluated in Absolute Form

Making the Presetting

Presettings for "set absolute position" are to be made by determining the measuring encoder for "set absolute position" in parameter "S-0-0448, Set absolute position control".

Actual Position Value at Dedicated Position

Determine the actual position value at the dedicated position in parameter

- P-0-0087, Actual position value offset of measuring encoder.

Executing "Set Absolute Position"

Start "S-0-0447, C0300 Set absolute position procedure command"; after its execution the command has to be cleared again.

See also "Basic Functions of Master Communication: Command processing"

Checking the Position Data Reference

The position status of the measuring encoder is displayed in parameter

- P-0-0331, Status of measuring encoder.

Loss of Reference

If the position data reference of the measuring encoder evaluated in absolute form got lost, the following message appears:

- F2176 Loss of measuring encoder reference.

The position data reference must be established again!

Establishing Position Data Reference for Relative Measuring Encoder

Activating Homing Procedure of Measuring Encoder

Activate reference mark detection in the respective bit of parameter

- P-0-0330, Control word of measuring encoder.

Actual Position Value at Dedicated Position

Determine the actual position value at the dedicated position in parameter

- P-0-0087, Actual position value offset of measuring encoder.

Checking Position Data Reference and Deactivating Homing Procedure

The reference mark signal first read sets the actual position value of the measuring encoder in reference. This is displayed in parameter

- P-0-0331, Status of measuring encoder.

Shifting the Position Data Reference

Master-side writing of parameter

- P-0-0087, Actual position value offset of measuring encoder.

The shifting of the actual position values can be checked in parameter

- P-0-0052, Actual position value of measuring encoder.

Other Diagnostic Messages Relevant to Measuring Encoder

- C0291 Incorr. parameterization of measuring enc. (hardware)
- C0292 Measuring encoder unknown
- C0294 Incorrect measuring encoder configuration
- C0227 Error when initializing position of measuring encoder
- C0228 Initialization velocity measuring encoder too high
- E2076 Measuring encoder: Encoder signals disturbed
- F2043 Measuring encoder: Encoder signals incorrect
- F2179 Modulo limitation error of measuring encoder

10 Handling, Diagnostic and Service Functions

10.1 Safety Instructions

⚠ WARNING **Dangerous movements! Danger to life, risk of injury, serious injury or property damage!**

- Keep free and clear of the ranges of motion of machines and moving machine parts.
- Prevent personnel from accidentally entering the machine's range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

10.2 Parameters, Basics

10.2.1 Properties/Features of Parameters

Brief Description

The controller firmware via data maps the drive to an internal mathematical model. All operating data relevant therefor are mapped to parameters. An identification number (IDN) is assigned to each parameter. The IDN allows accessing operating data via

- the Engineering Port

- or -

- a master communication interface suited for data transfer.

The operating data stored in parameters can be identified by means of the IDN. They can be read and transferred, if required. The user write access to parameters depends on the properties of the respective parameter and the current communication phase. Specific parameter values (operating data) are checked for validity by the drive firmware.

Functional Description

Parameter Structure Each parameter consists of seven data block elements.

Element no.	Description	Notes
1	Identification number (IDN)	Parameter identification/ reading of data status
2	Name	Can be changed by means of language selection
3	Attribute	Contains decimal places, data length, data type and display format, function
4	Unit	Can be changed by means of scaling or language selection

Element no.	Description	Notes
5	Minimum input value	Minimum input value of operating data
6	Maximum input value	Maximum input value of operating data
7	Operating data	Parameter value

Tab. 10-1: Data Block Elements of a Parameter

See also "Definitions" in the separate documentation "Parameter Description for IndraDrive Drive Controllers".

Writing and Reading a Parameter

All data block elements can be read via an appropriate master communication interface or the engineering port. Only the operating data can be written.

The operating data of a parameter can be permanently write-protected or always resp. temporarily be written. This write access depends on

- the communication phase

- and -

- the activation of a password.

When reading and writing the operating data, error messages can occur (see "Terms, Basic Principles: Errors").

Data Status

Each parameter has a data status. The data status contains information on:

- Validity/invalidity of the operating data (parameter value)
- State of commands (command acknowledgment) for parameters used for activating commands (see "Terms, Basic Principles: Commands").

The controller checks the data status of the parameters for validity of the operating data when changing from parameter mode to operating mode. When this happens, the operating data (parameter values) of the parameters contained in the following list parameters are checked for validity:

- S-0-0018, IDN-list of operation data for CP2
- S-0-0019, IDN-list of operation data for CP3

The control master can query the IDNs of the parameters with invalid operating data (parameter values) via:

- S-0-0021, IDN-list of invalid operation data for CP2
- S-0-0022, IDN-list of invalid operation data for CP3
- S-0-0423, IDN-list of invalid data for parameterization levels

The data status is signaled when the control master executes a write command to the data block element no. 1 of a parameter. This allows the control master to recognize the state of a command which was started.

See "Basic Functions of Master Communication: Command processing"

Language Selection

In parameter "S-0-0265, Language selection", you can set the language in which parameter names and text in units of parameter values will be displayed.

The language selection made via parameter S-0-0265 will only take effect in parameter "S-0-0095, Diagnostic message", when the diagnostic message changes, too, after language selection.

Notes on Commissioning

During the drive-internal check of parameter values carried out when changing from parameter mode to operating mode, the following command errors can be signaled:

- C0201 Invalid parameters (->S-0-0423)
- C0202 Parameter limit error (->S-0-0423)

- or -

- C0201 Invalid parameters (->S-0-0423)
- C0202 Parameter limit error (->S-0-0423)
- C0203 Parameter conversion error (->S-0-0423)

When errors of this category are detected, the IDNs of the parameters with the incorrect operating data are listed in:

- S-0-0021, IDN-list of invalid operation data for CP2
- S-0-0022, IDN-list of invalid operation data for CP3
- S-0-0423, IDN-list of invalid data for parameterization levels

A valid value has to be written to the listed IDNs. The value range limits are contained in the data block elements no. 5 and no. 6. When inputting single parameters, the limits are directly displayed via the "IndraWorks Ds/D/MLD" commissioning tool.

Language Setting

The desired display language of parameter names and text in units of parameter values has to be set in parameter

- S-0-0265, Language selection.

10.2.2 Loading, Storing and Saving Parameters

Brief Description

Parameters

All relevant operating data are mapped to parameters and stored in the controller.

Data Memory

Several non-volatile data memories are available in an IndraDrive device:

- In the controller
- In the motor encoder (depending on motor type)

In addition, the controller has a volatile data memory (working memory).

Condition as Supplied

Condition as supplied of the Rexroth drive components:

- The controller memory contains the drive firmware and the controller-specific parameter values.
- The motor encoder memory contains the encoder-specific and, depending on the motor type, the motor-specific parameter values.

Storing the Application-Specific Parameter Values

The application-specific parameter values are stored in the controller. Due to the limited number of writing cycles of non-volatile storage media, application-specific parameter values can be stored in the working memory (volatile memory), too.

Saving Parameter Values

Saving application-specific parameter values is required in the following cases:

- After initial commissioning of the machine axis or the motor
- Before replacing the controller for servicing (if possible)

Application-specific parameter values can be saved via:

- "IndraWorks Ds/D/MLD" commissioning tool → saving the parameter values to an external data carrier
- Control master → saving parameter values on master-side data carrier

Parameter IDN Lists

The drive supports master-side saving of parameter values by listing parameter identification numbers (IDNs). Using these lists guarantees complete storage of the application-specific parameter values. It is also possible to determine IDN lists defined by the customer.

Loading Parameter Values

Loading parameter values is required in the following cases:

- Initial commissioning of the motor (loading default values and motor-specific parameter values)
- Serial commissioning of machine axes at series machines (loading the values saved after initial commissioning)
- Reestablishing a defined initial state (repeated loading of the values saved after initial commissioning)
- Replacing the controller for servicing (loading the current parameter values saved before servicing)

Possibilities of loading parameter values to the controller:

- Motor encoder data memory → loading the parameter values by command or via the control panel during initial motor commissioning
- "IndraWorks Ds/D/MLD" commissioning tool → loading the parameter values from an external data carrier
- Control master → loading the parameter values from master-side data carrier

Checksum of Parameter Values

By means of checksum comparison, the control master can determine whether the values of the application-specific parameter values currently active in the drive correspond to the values saved on the master side.

Pertinent Parameters

- S-0-0017, IDN-list of all operation data
- S-0-0192, IDN-list of all backup operation data
- S-0-0262, C07_x Load defaults procedure command
- S-0-0263, C2300 Load working memory procedure command
- S-0-0264, C2200 Backup working memory procedure command
- S-0-0269, Storage mode
- S-0-0270, IDN-list of selected backup operation data
- S-0-0293 , C2400 Selectively backup working memory procedure command
- S-0-0326, Parameter checksum
- S-0-0327, IDN list of checksum parameter
- S-0-0531, Checksum of backup operation data
- P-0-0013, List of all IDNs not corresponding to default value
- P-0-0660.0.1, Configurable factory default values
- P-0-4023, C0400 Communication phase 2 transition
- P-0-4065, Active non-volatile memory
- P-0-4090, Configuration for loading default values

Pertinent Diagnostic Messages

Load default values:

- C0700 Load defaults proced. command (motor-spec. controller val.)

- C0702 Default parameters not available
- C0703 Default parameters invalid
- C0704 Parameters not copyable
- C0706 Error when reading the controller parameters
- C0720 SMO: Load defaults procedure command
- C0721 SMO: Load defaults procedure not possible
- C0722 SMO: Error in load defaults procedure
- C0723 SMO: Error in deactivation
- C0730 Load defaults procedure command (MLD)
- C0740 Command Activate field bus profile settings
- C0743 Error in activation of field bus profile settings
- C0750 Load defaults procedure command (factory settings)
- C0751 Parameter default value incorrect (-> S-0-0423)
- C0752 Locked with password
- C0761 Factory default values incorrect (->S-0-0423)
- C0799 An invalid index was set

Backup working memory procedure:

- C2202 Error when writing data to non-volatile memory
- C2200 Backup working memory procedure command

Load working memory:

- C2300 Load working memory procedure command
- C2301 Error when reading non-volatile memory
- C2302 Error when converting parameters

Selectively backup working memory procedure:

- C2400 Selectively backup working memory procedure command
- C2402 Error when saving parameters

Other diagnostic messages:

- F2100 Incorrect access to command value memory
- F2102 It was impossible to address I2C memory
- F2103 It was impossible to address EnDat memory

Functional Description

Data Memory in the Controller

All operating data referring to hardware are stored in the controller. They cannot be changed by the user.

Each circuit board is provided with a non-volatile memory. It carries the circuit board code and circuit board-specific operating data.

On the main circuit board there is a non-volatile memory (flash) and a volatile memory (working memory). The flash memory contains the circuit board-specific operating data. The drive firmware is stored in the flash memory, too.

An image of all data available in the drive (retain data, identification data and operating data) is stored in the working memory.

Motor Data Storage with Motors of MSK Type

The data memory of the motor encoder contains all motor- and motor-encoder-specific parameter values. In addition, it contains motor-specific control loop parameter values which allow an easy initial start of the motor.

Motor Data Storage with Motors of MSM Type

The controller recognizes the motor by means of identification data in the motor encoder. All motor- and motor-encoder-specific parameter values have been stored in the controller and are automatically loaded by means of the identified motor type. This allows an easy initial start of the motor.

Parameter and Operating Mode

Parameters the operating data of which can be changed, can be written with values in one or possibly several communication phases. We basically distinguish between

- Parameter mode (PM) and
- Operating mode (OM).

As a matter of principle, all parameters that can be changed can be written in the parameter mode.

"Load Defaults Procedure" Command

Via the command "S-0-0262, C07_x Load defaults procedure command", it is possible to establish a defined initial state of the parameter values.

For controllers supplied with factory settings (additional FWS option was ordered), the factory settings, too, are reestablished after the default values have been successfully reestablished.

The scope of functions of this command can be determined by means of the configuration of parameter "P-0-4090, Configuration for loading default values":

- **Command selection** (bits 0...3):
  - Load defaults procedure (motor-specific controller values)

    Loads the motor-specific default parameter values for the control loop available in the motor encoder data memory (see "Axis Control: Default Settings in the Motor Encoder Data Memory (Load Defaults Procedure)")
  - Load defaults procedure (factory settings)

    Loads the non-volatile parameters to their default values.

    A software option can be assigned to each drive controller to preassign specific values to individual parameters ex-works. These values are reestablished in place of the default values during the load defaults procedure.
  - Load defaults procedure (MLD)

    Resets parameters (incl. boot project) of the drive-integrated PLC
  - Activate field bus profile settings

    The field bus-dependent parameters are activated according to the profile

    → See "Profile Types (with Field Bus Interfaces)"
  - Load Safe Motion default values

    Safe Motion parameters are set to their default values. Loading of the SMO default values is only possible in the parameter mode (PM) and password level is not equal to 2. See separate documentation "Rexroth IndraDrive Integrated Safety Technology "Safe Torque Off" (as of MPx-16), Application Manual" (DOK-INDRV*-SI3-**VRS**-AP; Mat. No.: R911332634).
- **Scaling of command execution** (bits 4...8):

  It is only possible to execute the command "Factory settings-," "default values-" and "Loading the Field Bus Profile Settings" in PM. Execution is not possible when the drive is locked with a customer password, see also "C0752 Locked with password".

With the "load defaults procedure" command, you have the option to load default values for all parameters or to selectively exclude the following groups:

– Master communication parameters
– MLD parameters
– Engineering interface
– CCD configuration parameters
– Safe Motion

See also Parameter Description "P-0-4090, Configuration for loading default values"

Storage Mode

Depending on "S-0-0269, Storage mode", the application-specific parameter values are stored in the controller in volatile form (in the working memory) or non-volatile form (in the flash memory).

Non-volatile storage is carried out with each write access to the respective operating data.

Volatile storage of parameter values is recommended when application-specific parameters are cyclically written. Otherwise, the service life of the non-volatile storage media is affected.

NOTICE **Damage to the internal memory (flash) caused by cyclic command execution (write accesses to the flash)!**

During the execution of some commands (see description of the respective diagnostic command message; e.g. C0500), data are written to the internal memory (flash), too. This memory, however, only allows a limited number of write accesses. For this reason, you should make sure that such write accesses are not carried out too often (a maximum of approx. 100,000 writing cycles).

Parameter IDN Lists

For saving the relevant application-specific parameter values the drive makes lists of IDNs available that support the complete storage of the values of parameter groups:

- S-0-0192, IDN-list of all backup operation data
- S-0-0270, IDN-list of selected backup operation data

Parameter S-0-0192 contains a list of IDNs that cannot be modified. Parameter S-0-0270 contains an empty list in which it is possible to enter certain IDNs according to application-specific requirements.

For saving all parameter values, the drive makes available the list of the IDNs of all parameters in

- S-0-0017, IDN-list of all operation data

For identifying the parameters the value of which has changed compared to their default value, the drive makes available the parameter

- P-0-0013, List of all IDNs not corresponding to default value

Command "Backup Working Memory" or "Selectively Backup Working Memory"

If the option "volatile storage" was set in parameter "S-0-0269, Storage mode", the values of the parameters contained in the list parameter S-0-0192 can be saved in the non-volatile flash memory when "S-0-0264, C2200 Backup working memory procedure command" is started.

If the parameter values of the list of S-0-0270 are to be saved, "S-0-0293, C2400 Selectively backup working memory procedure command" has to be activated. Unless the storage mode (S-0-0269) is changed, the values once saved in the flash memory via the commands C2200 or C2400 remain unchanged.

"Load Working Memory Procedure" Command

Via "S-0-0263, C2300 Load working memory procedure command" the values from the non-volatile flash memory are copied to the volatile working memory.

☞ This only makes sense when volatile storage mode was set (S-0-0269) and parameter values were saved in the controller-internal flash memory!

Saving Application-Specific Parameter Values

To save the application-specific parameter values, e.g. after initial commissioning, there are the following possibilities:

- "IndraWorks Ds/D/MLD"commissioning tool

  → The parameter values of the list of S-0-0192 are stored on an external data carrier (hard disk, floppy disk or the like); the target assignment is carried out via the menu of the tool. This requires an Engineering connection to the drive.

- Control master

  → The parameter values of the list of S-0-0192 or S-0-0270 and/or other parameters, if necessary, are stored on a master-side data carrier by command of the control master.

Loading Application-Specific Parameter Values

To load saved parameter values or transmit axis-specific parameter values to controllers of other axes, there are the following possibilities:

- "IndraWorks Ds/D/MLD"commissioning tool

  → The parameter values (according to the list of S-0-0192) stored on an external data carrier (hard disk, floppy disk or the like) are loaded into the controller; source assignment is carried out via the menu of the tool. This requires an Engineering connection to the drive.

- Control master

  → The parameter values of the list of S-0-0192 or S-0-0270 and/or other parameters, if necessary, are loaded from a master-side data carrier to the controller by command of the control master.

Parameter Checksum via List Parameter S-0-0327

When reading the parameter "S-0-0326, Parameter checksum", the checksum of all parameter values is generated the IDNs of which are contained in parameter "S-0-0327, IDN list of checksum parameter". Changes in the parameter settings can be detected by comparing the checksums.

By comparing the checksum of the parameter values currently active in the drive to a checksum value stored at the time of parameter saving, it is possible to determine whether the active application-specific parameter values are correct.

By default, there haven't any IDNs been entered in parameter S-0-0327!

Parameter Checksum via List Parameter S-0-0192

When reading the parameter "S-0-0531, Checksum of backup operation data", the checksum of the active non-volatile memory of those parameters is generated the IDNs of which are contained in parameter "S-0-0192, IDN-list of all backup operation data".

☞ In list parameter S-0-0192, the IDNs of those parameters are stored the values of which are axis-specific and for regular operation have to be loaded to the drive of the respective axis.

When the installation has been completely set up, the checksum for each drive can be read via the parameter S-0-0531. The control master can store these values. By comparing the checksum which was saved to the new checksum which was read, it is possible to find out whether data relevant to operation have changed.

Notes on Commissioning

Initial Commissioning

At the beginning of the initial commissioning of a motor or a machine axis, first make sure the desired firmware is active in the drive. To do this, read parameter

- S-0-0030, Manufacturer version.

If the desired firmware is not available in the controller, carry out firmware update or firmware upgrade (see "Firmware Replacement").

Load Defaults Procedure

If the desired firmware is available in the controller, the default values of the firmware are loaded by carrying out the following steps:

1. Make settings in parameter "P-0-4090, Configuration for loading default values"
2. Start "S-0-0262, C07_x Load defaults procedure command"

Respective diagnostic command message:

- C0750 Load defaults procedure command (factory settings)

Respective diagnostic messages in the case of possible command errors:

- C0751 Parameter default value incorrect (-> S-0-0423)
- C0752 Locked with password

See also "Initial Commissioning/Serial Commissioning"

Loading Motor-Specific Control Loop Parameter Values

After the default values have been loaded, the controller signals "RL" if a Rexroth motor with motor encoder data memory has been connected. By one of the following actions, the motor-specific control loop parameter values saved in the motor encoder are loaded for adjusting the controller to the motor:

- Pressing the "Esc" key at the control panel

- or -

- Starting the command "S-0-0099, C0500 Reset class 1 diagnostics"

If the initial state of the motor-specific control loop parameter values is to be reestablished during commissioning, this is done, in the case of motors with encoder data memory, by starting

- S-0-0262, C07_x Load defaults procedure command

NOTICE

By executing this command, control loop parameter values that have already been optimized are possibly overwritten!

Enter optimized control loop parameter values again!

☞ By automatic reset, the parameter "P-0-4090, Configuration for loading default values" is correctly preset!

☞ For motors without encoder data memory, loading the motor-specific control loop parameter values is not possible by the "load defaults procedure" command! The values can be loaded from a database of the "IndraWorks Ds/D/MLD" commissioning tool.

Respective diagnostic command message:

- C0700 Load defaults proced. command (motor-spec. controller val.)

Respective diagnostic messages in the case of possible command errors:

- C0702 Default parameters not available
- C0703 Default parameters invalid
- C0704 Parameters not copyable
- C0706 Error when reading the controller parameters

See also "Initial Commissioning/Serial Commissioning"

With Storage Mode "Volatile Storage"

When the "volatile storage" option has been set in parameter "S-0-0269, Storage mode", the parameter values are not automatically stored in the drive-internal flash memory. After complete input, the application-specific parameter values therefore have to be saved drive-internally in the flash memory by

- Start of "S-0-0264, C2200 Backup working memory procedure command"

This guarantees that the parameter values suitable for the axis are automatically loaded to the controller's working memory from the flash memory after the drive is switched on again.

Respective diagnostic command message:

- C2200 Backup working memory procedure command

Respective diagnostic messages in the case of possible command errors:

- C2202 Error when writing data to non-volatile memory

After all application-specific parameter values are saved (C2200), it is also possible to only save selected parameter values in the flash memory. These parameters are overwritten with a current value. This is done by

- Start of "S-0-0293, C2400 Selectively backup working memory procedure command"

The C2400 command can be used for internally saving a parameter group the values of which have to be optimized again during operation, for example. It is advisable to determine the IDNs of this parameter group by clearing IDNs that are not required from the default setting of the list parameter

- S-0-0270, IDN-list of selected backup operation data

☞ In the case of the "volatile storage" mode, the command C2200 has to be executed at least once before starting the command C2400, because otherwise default values are maintained for some parameter values in the flash memory.

Respective diagnostic command message:

- C2400 Selectively backup working memory procedure command

Respective diagnostic messages in the case of possible command errors:

- C2402 Error when saving parameters

Loading and Saving Parameter Values via Control Master or "IndraWorks Ds/D/MLD"

An appropriate master communication interface or the engineering port of the controller can be used for loading and saving parameter values via the control master or "IndraWorks Ds/D/MLD".

Loading saved parameter values acc. to list parameter S-0-0192 to reestablish the initial status after initial commissioning is impossible in the case of drives with absolute value encoder and modulo scaling (see note).

NOTICE

The backup of the parameter values made after initial commissioning according to S-0-0192 cannot reestablish the initial state of the parameters. The actual position value after the loading process would be incorrect, but this cannot be detected on the controller side!

In the case of drives with absolute value encoder and modulo scaling, the backup of parameter values made after initial commissioning acc. to S-0-0192 mustn't be loaded for reestablishing the initial parameter status!

For how to reestablish the initial status of parameters for drives with absolute value encoder and modulo scaling, see "Initial Commissioning/Serial Commissioning"!

Communication phase 2 or the parameter mode must be activated for the successful loading of parameters.

- P-0-4023, C0400 Communication phase 2 transition

Respective diagnostic command message:

- C0400 Activate parameterization level 1 procedure command

☞ The drive returns to the operating mode by starting the commands "S-0-0127, C0100 Communication phase 3 transition check" and "S-0-0128, C5200 Communication phase 4 transition check" one after the other!

When reading and writing individual parameters via the control master or"IndraWorks Ds/D/MLD" (without command), the following error messages can occur:

- F2100 Incorrect access to command value memory
- F2102 It was impossible to address I2C memory
- F2103 It was impossible to address EnDat memory

10.2.3 IDN Lists of Parameters

General Information

Some of the parameters stored in the drive contain, as their operating data (parameter value), a list of IDNs of drive parameters corresponding to a specific, given criterion. These so-called IDN lists enable the master or a commissioning software to handle drive parameters in a specific way.

IDN List of All Operation Data (S-0-0017)

The parameter "S-0-0017, IDN-list of all operation data" contains the IDNs of all parameters available in the drive.

IDN List of Backup Operation Data (S-0-0192)

The parameter "S-0-0192, IDN-list of all backup operation data" contains the IDNs of all parameters that are stored in the non-volatile memory (flash memory). These parameters are required for correct operation of the drive. With the master or a commissioning software, it is possible to use this IDN list for making a backup copy of the drive parameters.

IDN List of Invalid Operation Data Phase 2 (S-0-0021)

In parameter "S-0-0021, IDN-list of invalid operation data for CP2" the IDNs of those parameters are automatically entered which the drive software detects as being invalid when executing the command "S-0-0127, C0100 Communication phase 3 transition check".

Parameters are detected as being invalid, if:

- Their checksum does not match the operating data [the checksum is stored together with the operating data in a non-volatile memory (flash memory, amplifier or motor encoder data memory)]

- or -

- Their operating data is outside of the minimum or maximum input limits

- or -

- Their operating data violates specific validation rules.

In any event, the parameters entered in "S-0-0021, IDN-list of invalid operation data for CP2" upon negative acknowledgement of command "S-0-0127, C0100 Communication phase 3 transition check" must be corrected.

IDN List of Invalid Operation Data Phase 3 (S-0-0022)

In parameter "S-0-0022, IDN-list of invalid operation data for CP3" the IDNs of those parameters are automatically entered which the drive software detects as being invalid or unduly configured when executing the command "S-0-0128, C5200 Communication phase 4 transition check".

Parameters are detected as being invalid, if:

- Their checksum does not match the operating data [the checksum is stored together with the operating data in a non-volatile memory (flash memory, amplifier or motor encoder data memory)]

- or -

- Their operating data is outside of the minimum or maximum input limits

- or -

- Their operating data violates specific validation rules.

Parameters are detected as being unduly configured, if

- they were configured more than once for writing by a cyclic interface.

In any event, the parameters entered in "S-0-0022, IDN-list of invalid operation data for CP3" upon negative acknowledgement of command "S-0-0128, C5200 Communication phase 4 transition check" must be corrected.

IDN List of Invalid Data for Parameterization Levels (S-0-0423)

When the command "C0200 Exit parameterization level procedure command" is executed, the drive parameters are checked and converted. If errors occur during this check, the IDNs of the faulty parameters are written to the list parameter "S-0-0423, IDN-list of invalid data for parameterization levels".

IDN List of Operation Data Communication Phase 2 (S-0-0018)

The IDNs that are checked for validity when the command "S-0-0127, C0100 Communication phase 3 transition check" is executed are stored in the operating data of parameter "S-0-0018, IDN-list of operation data for CP2".

IDN List of Operation Data Communication Phase 3 (S-0-0019)

The IDNs that are checked for validity when the command "S-0-0128, C5200 Communication phase 4 transition check" is executed are stored in the operating data of parameter "S-0-0019, IDN-list of operation data for CP3".

IDN List of All Command Parameters (S-0-0025)

The IDNs of all the command parameters available in the drive are stored in the operating data of parameter"S-0-0025, IDN-list of all procedure commands".

IDN List of Selected Operation Data to Backup (S-0-0270)

The IDNs of parameters that are to be saved when command "S-0-0293 , C2400 Selectively backup working memory procedure command" is executed are stored in the parameter "S-0-0270, IDN-list of selected backup operation data".

IDN List of Password-Protected Operating Data (S-0-0279)

The parameter "S-0-0279, IDN-list of password-protected operation data" contains the IDNs of those parameters that can be protected by a customer password (S-0-0267). By default, there haven't been any IDNs entered in this parameter.

IDN List of the Checksum Parameters (S-0-0327)

The parameter "S-0-0327, IDN list of checksum parameter" contains the IDNs of those parameters from which the content of parameter "S-0-0326, Parameter checksum" is to be generated. By default, there haven't been any IDNs entered in this parameter.

IDN List of All Parameter Values that Correspond to the Default Value (P-0-0013)

All parameters the operating data of which was changed with regard to the default value are stored in "P-0-0013, List of all IDNs not corresponding to default value".

10.2.4 Using a Password

Brief Description

IndraDrive controllers provide the possibility to protect parameter values against accidental or unauthorized change by means of a password. With regard to write protection, there are 3 groups of writable parameters:

- Parameters that are generally write-protected, such as motor parameters, hardware code parameters, encoder parameters, error memories, etc. ("administration parameters"). The values of these parameters ensure correct function and performance of the drive.
- Parameters the customer can combine in groups and protect them with a so-called customer password. This allows protecting parameter values, that are used for adjusting the drive to the axis, after having determined them.
- All other writable parameters and are not contained in the above-mentioned groups. They are not write-protected.

The drive firmware allows activating and deactivating the write protection for parameter values by means of three hierarchically different passwords:

- Customer password

  → The parameter values of a parameter group combined by the customer can be protected.
- Control password

  → Parameters protected by a customer password are writable; "administration parameters" remain read-only.
- Master password

  → All writable parameters, including "administration parameters" and parameters protected by a customer password, can be changed.

☞ The customer password can be defined by the customer, the control password and the master password are defined by the manufacturer!

Pertinent Parameters

- S-0-0192, IDN-list of all backup operation data
- S-0-0267, Password
- S-0-0279, IDN-list of password-protected operation data
- P-0-4064, Password level

Functional Description

The activation and deactivation of the write protection for parameter values by the three hierarchically different passwords is carried out by an input in parameter "S-0-0267, Password".

Customer password

By a password defined by the customer, the parameters of a parameter group to be defined can be protected against unauthorized or accidental write access.

The customer password has to comply with the following conditions:

- At least 3 characters long
- A maximum of 10 characters long
- may only contain the characters a…z, A…Z and the numbers 0…9

The group of parameters the values of which can be protected by the customer password is defined in "S-0-0279, IDN-list of password-protected operation data". In the condition as supplied the parameter S-0-0279 does not yet contain any data. In the list parameter S-0-0279 it is possible to enter parameter IDNs according to application-specific requirements.

☞ The customer password is not obligatory! If it has not been activated, the values of the parameters listed in the list parameter S-0-0279 can still be written.

Control password

After entering the firmware-specific control password defined by the manufacturer, it is also possible to write parameters protected by a customer password. The control password therefore allows the NC control unit to ignore the write protection established by the individual (unknown) customer password.

☞ The control password valid for the respective firmware is only available from the manufacturer on demand!

Master password

The master password is defined by the manufacturer, too, but is exclusively available to the Rexroth development and service staff.

> ☞ The master password is secret! It must not be used on the control unit side or by the customer, because it also allows changing the values of "administration parameters" (motor parameters, hardware code parameters, encoder parameters, error memory, etc.).

Activating/Deactivating the Write Protection

In the condition as supplied "S-0-0267, Password" contains the value "007". The write protection is activated and deactivated by means of the customer password according to the following procedure:

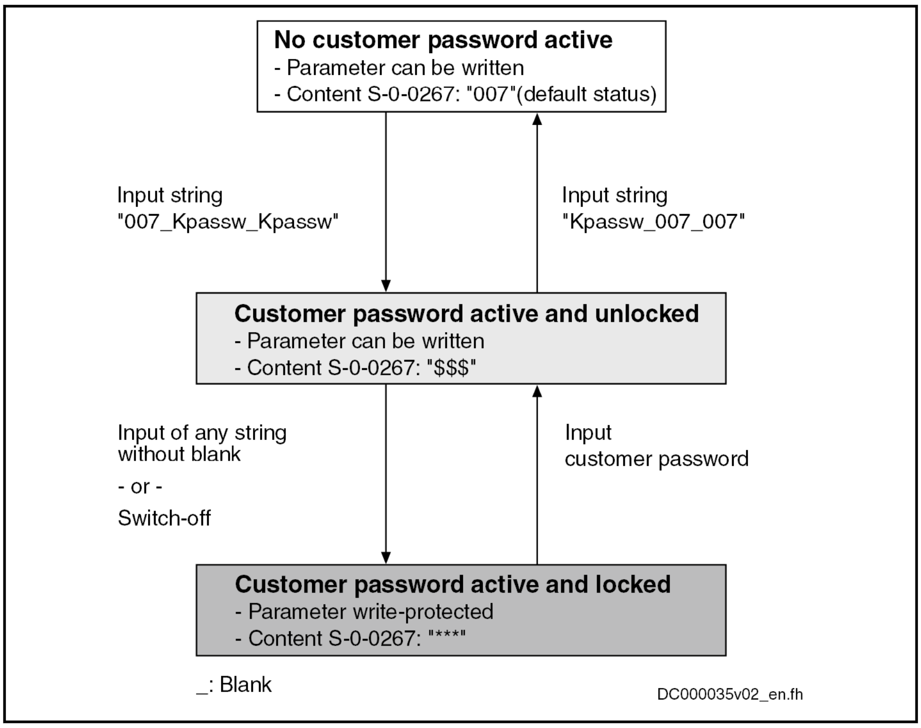


Fig. 10-1: Activating and Deactivating the Write Protection by Means of the Customer Password

The write protection activated via customer password is deactivated by means of the control password by entering the control password in S-0-0267. The write protection required by the customer can be activated again by entering any string in S-0-0267.

The write protection for all parameters that can basically be written can only be deactivated by means of the master password and the right to do this is exclusively reserved to the Rexroth development and service staff!

NOTICE **Incorrect control of motors when changing parameter values write-protected on the firmware side ("administration parameters")!**

⇒ The master password mustn't be used on the control unit side or by the customer!

Notes on Commissioning

Define the IDNs of the group of parameters the values of which are to be write-protected in parameter

- S-0-0279, IDN-list of password-protected operation data.

The customer-side write protection via the customer password for the parameters contained in S-0-0279 can be activated and deactivated by writing the parameter

- S-0-0267, Password.

Observe the conditions for defining the customer password!

If the active write protection for the parameters defined in S-0-0279 is to be disabled on the master side or without knowledge of the customer password, enter the control password in parameter

- S-0-0267, Password.

Ask the manufacturer for the control password!

Status Query for Write Protection The current status of the write protection can be queried via parameter

- P-0-4064, Password level.

Diagnostic message When trying to write data to a write-protected parameter, an error code is sent to the sercos master via the non-cyclic data channel, according to the sercos specification. The master then recognizes that the respective parameter is write-protected and that it is impossible to write data to it.

10.3 Central Backup & Restore

10.3.1 Brief Description

Fields of Application

This function allows managing the device data of a complete CCD group by means of a central machine archive. The machine archive is stored on the optional memory card of the CCD master. It is possible to store the active parameterization of all drives in the CCD group in centralized form and to restore it, if required, or to load an existing machine archive to another installation.

The machine archive contains all the application-relevant data (parameters according to the list of backup operation data, MLD program, retain variables, firmware).

The following actions are possible:

- Save, restore or update an MLD project including the MLD retain data
- Save, restore or update the operating data of one or several axes
- Carry out a firmware update
- After a device has been replaced, put the new device into operation with the configuration of the old device
- Duplicate an existing installation

Overview of Functions

Creating a Machine Archive Using the command C6500, all application-relevant data are centrally stored on the SD card of the CCD master.

- Backup operation data ("S-0-0192, IDN-list of all backup operation data")

- MLD application ("P-0-1353, PLC user program area 0" to "P-0-1358, PLC user program area 5") incl. retain data ("P-0-1359, PLC retain data") or boot project of optional memory card
- Retain data of the device ("P-0-0192, Error memory of diagnostic numbers")
- Firmware

☞ When machine archive is created, the operating data of all CCD slaves are saved on the SD card of the CCD master. Therefore, the execution of the command might take several minutes. During this time, write access to the operating data to be saved should be avoided to ensure the consistency of the machine archive.

Restoring the Device Data Using the command "C6600 Restore device data", the device data stored in the machine archive are automatically restored on all drives of the CCD group. When the replacement of a device was detected, the data of the machine archive in the strict mode are automatically loaded to the replacement device, before the progression to the operating mode takes place.

Updating the Device Data It is possible to make available a valid machine archive as an update. Using the command "C6700 Update of device data", these data are activated in the drives.

☞ The update does not modify the retain data.

Hardware Requirements

IndraDrive Cs Advanced with SD card required.

Pertinent Parameters

- P-0-0665, C6500 Command Archive device data
- P-0-0666, C6600 Command Restore device data
- P-0-0668, Device data archiving, configuration
- P-0-0669, Device data archiving, status
- P-0-0195, IDN list of retain data (replacement of devices)
- P-0-1360, PLC program identifier
- P-0-1518, Module code of control section
- P-0-1521, Programming module identifier
- S-0-0030, Manufacturer version
- S-0-0192, IDN-list of all backup operation data
- S-0-0531, Checksum of backup operation data

Pertinent Diagnostic Messages

- C0200 Exit parameterization level procedure command
- C0201 Invalid parameters (->S-0-0423)
  to
  C0299 Configuration changed. Restart
- C6500 Archive device data
- C6501 Error when creating machine archive
- C6502 Error when reading device data
- C6503 Inconsistent backup of machine archive

- C6600 Restore device data
- C6601 Error when accessing machine archive
- C6602 Error when writing device data
- C6604 Error when reading device data
- C6605 Device data incompletely restored

- C2200 Backup working memory procedure command
- C2202 Error when writing data to non-volatile memory
- E2667 Machine archive is not up-to-date

10.3.2 Functional Description

General Information

The Backup & Restore function allows the user to completely and centrally save an already tested installation parameter setting. In doing so, the data of the local device and all data relevant to operation of the connected and parameterized CCD slave drives are saved, if the drive is used as a CCD master.

The automatic check during phase switch to the operating mode always ensures that the tested and saved data are valid in the drive. If this check fails, the data are restored. For this purpose, the relevant data are centrally stored on the optional memory card of the device and in a zip file. By means of the appropriate reader, a saved installation configuration can be easily read via FTP client or directly from the memory card.

It is generally possible to save the current data (backup), restore the data once saved or set an archive once created valid on another axis group (update).

Function Modes

The Backup & Restore function can be operated in 2 modes. The mode is selected via the parameter "P-0-0668, Device data archiving, configuration".

1. Passive mode

   In the passive mode, the drive does not perform any checks, all actions must be manually triggered via the commands

   - C6500 Archive device data
   - C6600 Restore device data
   - C6700 Update of device data

2. Strict mode

   When the strict mode is used, a check is initially run every time the drive is switched to the operating mode; this is done to find out whether the current data comply with the current machine archive on all devices. If the data do not comply with the machine archive, a switching error is generated.

   Importing new data via the update archive is only possible if the current operating data comply with the data stored in the machine archive. In this way is it possible to ensure that a faulty update can be completely reset via the machine archive.

Addressing

For the backup, the backup & restore function works with the sercos addresses (cf. "S-0-1020, Master comm. engineering over IP: IP address") of the drives. In other words, before executing the commands you must check that the sercos addresses with the projected addresses match, otherwise the restoration of the data fails.

⚠ CAUTION **Property damage caused by incorrect addressing of the sercos participants**

The correct distribution of the sercos addresses is not checked when operating data are restored or updated. If addresses have been interchanged, the operating data are loaded to the wrong drives!

File Structure of the Optional Memory Card

The following directories are automatically created on the memory card of the CCD master:

- Documentation
- PLC
- USER
- TEMP
- Tools
- Backup

The device archive can be found in the "User\Backup\Archive" folder; if required, this folder is automatically created. A "Backup.zip" is stored in the folder, the file contains all the device data. The table below illustrates the file structure of the machine archive.

The table additionally contains the comparative data by means of which the check is carried out to find out whether the data were changed. The comparison and thus the restoring is carried out manually via the command "P-0-0666, C6600 Command Restore device data" or automatically when the replacement of a device has been recognized and when the drive is switched from the parameter mode to the operating mode (cf. "P-0-0668, Device data archiving, configuration").

File name	File content	Comparative data
Axis?\RetainAxis?.par	Parameter set of the retain data (parameters contained in "P-0-0195, IDN list of retain data (replacement of devices)")	List element 4 of "P-0-1521, Programming module identifier"
Axis?\Axis?.par	Parameter set of the operating data (parameters contained in "S-0-0192, IDN-list of all backup operation data")	"S-0-0531, Checksum of backup operation data"
Axis?\MLD_Boot?.par	P-0-1352, PLC user program administration data "P-0-1353, PLC user program area 0" up to "P-0-1358, PLC user program area 5" are not backed up when the MLD boot project is backed up to the µSD card (cf. "P-0-1367, ")	List element 1 of "P-0-1360, PLC program identifier" S-0-0531, Checksum of backup operation data
Axis?\Retain_MLD?.par	Parameter set of the MLD retain data ("P-0-1359, PLC retain data")	List element 1 of "P-0-1360, PLC program identifier"
PLC*.*	**Only for the CCD master (Axis1):** All files in the "PLC" folder on the optional memory card are automatically saved.	List element 1 of "P-0-1360, PLC program identifier"

File name	File content	Comparative data
Backup.log	Log of the last command execution (see 'Additional Information in the Log File "Backup.log"')	
BackupInfo.txt	Contains the comparative data	

? Wild card for the number of the drive in cross communication; i.e. "1" = CCD master, "2" to "10" = CCD slave 1 to 9

Tab. 10-2: File/Folder Structure of the Machine Archive

Creating the Machine Archive

By executing the command "P-0-0665, C6500 Command Archive device data", the data relevant to operation are copied to the machine archive on the optional memory card. These data are:

- The backup operating data, cf. "S-0-0192, IDN-list of all backup operation data"
- The drive firmware, cf. "S-0-0030, Manufacturer version"
- The retain data, cf. P-0-0195, and MLD retain data, cf. P-0-1359
- The MLD project from the internal memory, cf. P-0-1352 - P-0-1358
- All files in the "PLC" directory

The backup is also carried out via the cross communication (CCD); i.e. upon successful command execution, the operating data of the entire drive group are saved on the optional memory card of the CCD master.

The boot project on the optional memory card can only be saved for the CCD master. If MLD is used on a CCD slave and the boot project is not contained in the internal memory, the boot project cannot be saved.

Before executing the backup, a parameters backup is automatically carried out on all drives the command "C2200 Backup working memory procedure command" to ensure that the data in the drive continue to match the backup data after the power has been switched off.

The command "P-0-0665, C6500 Command Archive device data" is completed when all operating data of all drives have been read. The backup parameters an retain data are stored as "par" files and can be interpreted by IndraWorks.

☞ While command is executed, the parameters should not be changed. If any change is detected during the backup procedure, this is signaled as the error C6503 and entered in the Backup.log.

To avoid errors, you should make sure that the parameters are not changed during the execution of "P-0-0665, C6500 Command Archive device data".

Restoring the Device Data

When "P-0-0665, C6500 Command Archive device data" has been successfully executed, the optional memory card of the CCD master contains an up-to-date machine archive.

To compare the data of the machine archive to the active data and restore them in the case of discrepancy, there are the following options:

- Manually execute the command "P-0-0666, C6600 Command Restore device data"
- Switch to the operating mode (OM) in the case of activated Backup & Restore function, cf. P-0-0668, bit 0 when replacing devices

If the data from the machine archive do not comply with the active data, the machine archive is set valid again.

Evaluating the Comparative Data

The decision as to whether the machine archive must be restored is taken on the basis of the comparative data stored in the "BackupInfo.txt" file. These data are compared to the current data of the drives:

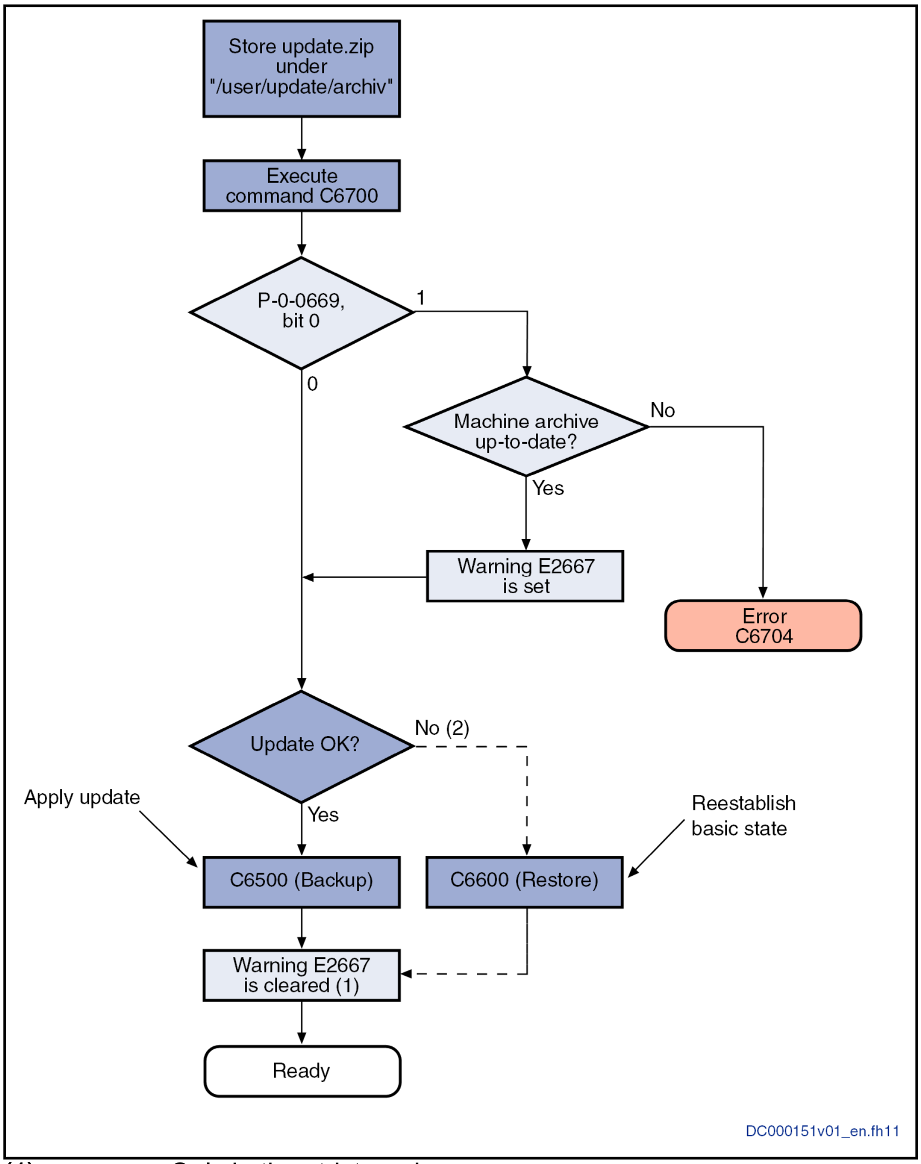
- If list element 4 of "P-0-1521, Programming module identifier" differs from the stored comparative data, a **device was replaced** (control panel was replaced). In case a device is replaced, the operating data including the retain data of the drive are restored.
- If the controller is replaced and the parameter P-0-1367.9 has the value 1, the MLD retain data are restored.
- If the content of "S-0-0531, Checksum of backup operation data" differs from the comparative data stored in the "BackupInfo.txt" file, the previously saved parameters are restored.
- If the list element 1 of "P-0-1360, PLC program identifier" differs from the comparative data stored in the "BackupInfo.txt" file, the saved **MLD parameters** are restored.

  All files from the "PLC" directory are restored.
- If "S-0-0030, Manufacturer version" is unequal to the firmware version saved in "BackupInfo.txt", the firmware is replaced on the affected drives and the previously valid firmware is automatically reactivated. After the firmware was replaced, the drive is automatically restarted and afterwards the remaining operating data are restored.

Importing the Device Data Update

It is possible to use a machine archive once created as an update archive for another installation. For this purpose, the original machine archive is copied from the memory card and loaded to another memory card. To this end, the archive is stored in the directory under "user/update/archive".

☞ Before executing the command "C6700 Update of device data", make sure that the address settings and IP settings of all drives match the update archive.



(1)	Only in the strict mode
(2)	Only makes sense if the machine archive was up-to-date before the command C6700 is started
P-0-0669	Device data archiving, status
C6500	Archive device data
C6600	Restoring the Device Data
C6700	Update of device data
C6704	Machine archive is not up-to-date
E2667	Machine archive is not up-to-date

Fig. 10-2: Illustration of an Update Procedure

☞ The actions to be taken which are marked with dark background in this figure represent the required user actions.

By starting the command "C6700 Update of device data", the update archive is automatically transmitted to the drives. If the strict mode has been activated, the warning E2667 ist automatically set, because the machine archive is no longer up-to-date. If the new configuration of the installation complies with the target state, the state can now be stored in the machine archive with the command C6500. If the previous state had been saved as a machine archive, the old state can be restored via the command C6600. In both cases, the warning "E2667 Machine archive is not up-to-date" is reset.

There are the following restrictions:

- Only 1 archive may be stored in the same directory. If 2 or more zip files have been stored, the error "C6702 Error when writing device data" is generated.
- The retain data are not loaded in the case of an update, even if they are contained in the update archive.
- When an update is carried out, the files are not deleted from the update directory. If the files are to be deleted, the user must do this.

10.3.3 Notes on Commissioning

General Notes on Commissioning

It is only possible to save an MLD application, which has been stored on the optional memory card, in the CCD master. It is impossible to save a boot project of a slave, if it has been stored on the optional memory card.

In some cases, it is necessary to reboot the drive after the backup data have been restored. If the functional packages are changed or the firmware is replaced, the drive is automatically restarted afterwards. This is the case when the functional packages are changed.

If, when switching from PM to OM ("C0200 Exit parameterization level procedure command"), the creation of the data or the restoring of the data is terminated with an error, one of the command errors belonging to "C6500 Archive device data" or "C6600 Restore device data" is returned as a transition command error of the command "C0200 Exit parameterization level procedure command".

10.3.4 Diagnostic and Status Messages, Monitoring Functions

Status of the Backup Function

The status of the Backup & Restore function can be generated in the CCD master via the "C6800 Control command device data archiving" Backup & Restore control command. The determined value is stored in the parameter "P-0-0669, Device data archiving, status".

Additional Information in the Log File "Backup.log"

In addition to the status display, the log file "Backup.log" contains the following pieces of information:

- The last executed command
  - C6500 Archive device data
  - C6600 Restore device data
  - C6700 Update of device data
- Stopped MLD programs
- Files opened for editing
- A list of all parameters that had been accessed and information on whether the access was successful

---

The "Backup.log" and "BackupInfo.txt" files are also used to monitor whether a defined installation configuration was changed (see "chapter "File Structure of the Optional Memory Card" on page 1017").

10.4 Diagnostic system

10.4.1 Coded Diagnostic Messages of the Drive

Brief Description

The drive provides a diagnostic system including different options that are basically divided into two groups:

- Recognizing and displaying the current drive state by means of drive-internal, priority-dependent generation of diagnostic messages

> ☞ As of MPx-18, the diagnostic message number is generated in accordance with the sercos specification. For this purpose, the bits 31-24 in the parameter "S-0-0390, Diagnostic message number" are written, too; these bits were always "0" in previous versions. In the control panel and in IndraWorks dialogs, these bits are hidden so the display remains unchanged there.
>
> If the diagnostic messages are to be displayed in S-0-0390 as in the previous versions, bit 0 must be set in "P-0-0006, Diagnostic message configuration".

- Collective messages for various status messages

Additionally, there are parameters for all important operating data the values of which can be transmitted both via master communication (e.g., sercos) and a parameterization interface (RS-232/485 in the ASCII protocol or SIS protocol; see "Serial Communication").

Pertinent Parameters

- S-0-0030, Manufacturer version
- S-0-0095, Diagnostic message
- S-0-0140, Controller type
- S-0-0375, Diagnostic numbers list
- S-0-0390, Diagnostic message number
- S-0-1302.0.3, Application type

  (S-0-0142 only exists as a legacy (or alias) parameter for S-0-1302.0.3.)
- P-0-0478, Logbook event
- P-0-0479, Logbook time stamp

Drive-internal generation of diagnostic messages

Operating states, activities and reactions of the drive controller are detected by drive-internal generation of diagnostic messages and appear in coded form on the display of the control panel. In addition, these diagnostic messages can be transferred to a master (control) and displayed and evaluated in a service and commissioning software (e.g., "IndraWorks Ds/D/MLD").

A distinction is made between the following categories (types of diagnostic messages):

- Error
- Warnings
- Commands/command errors
- Status displays/operating states

Generally, the current diagnostic message with the highest priority is displayed at the following locations in the drive:

- **Display of the operator panel**

→ The diagnostic message number and, if applicable, text appears on the 8-digit display of the standard control panel.

- **Parameter "S-0-0095, Diagnostic message"**

  → This parameter, in the form of plain text, contains the operating status of the drive at present relevant. Preceding the text is the respective content of parameter S-0-0390 in short form.

- **Parameter "S-0-0390, Diagnostic message number"**

  → The diagnostic number is stored in this parameter which is displayed in the display in abbreviated form.

In parameter "S-0-0375, Diagnostic numbers list", the last 50 diagnostic message numbers of parameter S-0-0390 are recorded in chronological order. When reading this list, the number of the diagnostic message that last occurred is displayed as parameter element 1.

Priorities of Display

The following priorities apply to the display of the current diagnostic message:

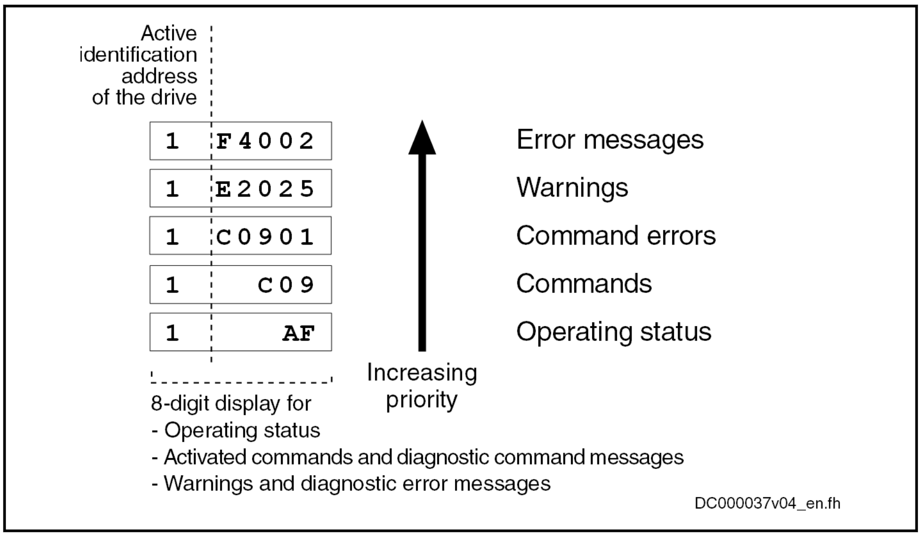


Fig. 10-3: Priorities of Displays (with Example Displays)

The documentation "Troubleshooting Guide (description of diagnostic messages)" contains an overview of all diagnostic messages and their meanings.

Structure of a Diagnostic Message

General Information

Each diagnostic message consists of

- Diagnostic message number

  - and -

- Diagnostic text

The diagnostic message for the non-fatal error "F2028, Excessive deviation", for example, has the following structure:

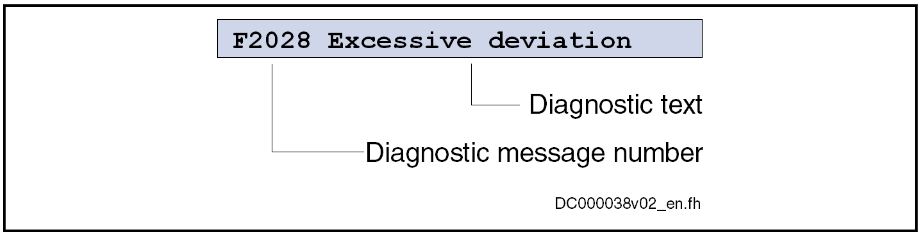


Fig. 10-4: Structure of a Diagnostic Message

"F2028" flashes on the display of the control panel. The diagnostic message number is contained in parameter "S-0-0390, Diagnostic message number" in hexadecimal form (for example: 0xC00F2028). The diagnostic message number and the diagnostic text appear in the parameter "S-0-0095, Diagnostic message" as a string "F2028 Excessive deviation".

Diagnostic Message on the Control Panel Display

The diagnostic message number appears on the 8-digit display of the standard control panel. This allows recognizing the current operating status of the drive quickly and without using a communication interface.

As a matter of principle, the following applies:

- Status displays (P0, Ab, AF …) are displayed in right-aligned form
- Warnings, command errors and other error messages are flashing

Type of diagnostic message	Diagnostic message number	Display
Error	F2xxx	F2xxx
Command	C20C0200	C02
Command error	C02xx	C02xx
Warning	E2xxx	E2xxx
Communication phase e.g. communication phase 1	C30A0001	P1
Drive ready for operation	C00A0012	Ab
Operation mode e.g. velocity control	C00A0101	AF

Tab. 10-3: Overview of Diagnostic Messages Displayed

The current operation mode is not shown on the display. When the drive follows the preset operation mode and no command was activated, the display reads "AF".

Diagnostic Message in Plain Text

The diagnostic message in plain text contains the diagnostic message number followed by the diagnostic message text. It can be read via parameter "S-0-0095, Diagnostic message" and directly displayed on an operator interface as a language-dependent description of the drive status.

The diagnostic message in plain text is switched to the selected language via parameter "S-0-0265, Language selection".

Diagnostic message number

The diagnostic message number contains only the diagnostic number without the diagnostic text. It can be read via parameter "S-0-0390, Diagnostic message number" and is a language-independent possibility of determining and displaying the drive state on an operator interface.

Display Text of Diagnostic Message

The display text of a diagnostic message is the text appearing on the display of the control panel. It is mapped together with the diagnostic message number in "S-0-0095, Diagnostic message".

List of Diagnostic Numbers

The last 50 diagnostic message numbers displayed are stored in chronological order in parameter "S-0-0375, Diagnostic numbers list". Every change in the content of "S-0-0390, Diagnostic message number" means that the old content is applied to S-0-0375. When the parameter S-0-0375 is read, the last transferred diagnostic message number appears in the first element of the parameter, the diagnostic message number transferred before from S-0-0390 in the second element, etc.

Language Selection

Via parameter "S-0-0265, Language selection", it is possible to define or switch the language of diagnostic message texts.

📖 See also Parameter Description "S-0-0265, Language selection"

10.4.2 Status Classes, Status Displays, Control Parameters

General Information

In the drive there are many parameters with important status information (bit lists). Some of the bits contained in these lists can be used for configuring real-time status bits and additionally can be assigned to digital outputs or to the configurable signal status word.

See "Digital Inputs/Outputs"

See "Configurable Signal Status Word"

The drive differentiates the error, warning and message states (status classes).

In the drive there are parameters

- with direct relation to the status of the sequence of different drive functions (fixed status displays)
- for controlling the drive functions (control parameters)

Status Classes

Brief Description

The drive differentiates between 3 states (error, warning and message) for which there is status information. To make the status information available, there are so-called class diagnostics parameters (S-0-0011, S-0-0012, S-0-0013) which contain the respective status bits.

In addition to these class diagnostics parameters, there are change bits contained in the status word of the field bus (e.g. S-0-0135 in the case of sercos) which display changes in one of the above-mentioned class diagnostics parameters (collective information).

Features

- Class diagnostics parameter for **errors** (cf. S-0-0011)
- Class diagnostics parameter for **warnings** (cf. S-0-0012)
- Class diagnostics parameter for **messages** (cf. S-0-0013)
- **Change bits in status word** of master communication (e.g. S-0-0135 in case of sercos)
- **Change bits of class** 2 and 3 diagnostics (S-0-0097 and S-0-0098) can be masked in the status word of master communication (e.g. S-0-0135 in case of sercos) to suppress individual bits or status messages

Pertinent Parameters

- S-0-0011, Class 1 diagnostics
- S-0-0012, Class 2 diagnostics

- S-0-0013, Class 3 diagnostics
- S-0-0097, Mask class 2 diagnostics
- S-0-0098, Mask class 3 diagnostics
- S-0-0135, Drive status word

Functional Description

Status Class Parameters

- **S-0-0011, Class 1 diagnostics** (status parameter for drive errors)
  - In case a drive error occurs, the bit assigned to the error is set in parameter S-0-0011. A separate bit is assigned in S-0-0011 to errors defined according to sercos.

    Manufacturer-specific errors cause bit 15 to be set in parameter S-0-0011 (see also Parameter Description "S-0-0011, Class 1 diagnostics").
  - In case a drive error occurs, bit 13 (drive lock-out; error in class 1 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in the case of sercos).

☞ All bits in class 1 diagnostics are cleared by executing the command C0500 (reset class 1 diagnostics).

See Parameter Description "S-0-0099, C0500 Reset class 1 diagnostics"

- **S-0-0012, Class 2 diagnostics** (Status parameter for drive warnings)
  - In case a drive warning occurs, the bit assigned to the warning is set in parameter S-0-0012. A separate bit is assigned in S-0-0012 to warnings defined according to sercos.

    Manufacturer-specific warnings cause bit 15 to be set in parameter S-0-0012 (see also Parameter Description "S-0-0012, Class 2 diagnostics").
  - In case a drive warning occurs, bit 12 (change bit class 2 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in case of SERCOS), when the content of S-0-0012 changes (i.e. at least one bit toggles).
  - The bits in parameter S-0-0012 are automatically cleared when the warning disappears. The change bit in the status word of the master communication (S-0-0135 in case of SERCOS) remains set, however, until parameter S-0-0012 has been read once.

☞ Using parameter "S-0-0097, Mask class 2 diagnostics", warnings can be masked in terms of their effect on the change bit.

- **S-0-0013, Class 3 diagnostics** (status parameter for drive messages)
  - Messages of the drive are listed in parameter S-0-0013. A separate bit is assigned in S-0-0013 to messages defined according to SERCOS (see also Parameter Description "S-0-0013, Class 3 diagnostics").
  - If a drive message occurs, bit 11 (change bit class 3 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in case of sercos).
  - The bits in parameter S-0-0013 are automatically cleared when the message disappears. The change bit in the status word of the

master communication (S-0-0135 in case of sercos) remains set, however, until parameter S-0-0013 has been read once.

☞ Each of these messages is stored in a separate parameter (S-0-0330 to S-0-0342).

Change Bits in Drive Status Word

If the status of a bit in "S-0-0012, Class 2 diagnostics" or "S-0-0013, Class 3 diagnostics" changes, the change bit for class 2 or 3 diagnostics is set in the field bus status word (e.g. S-0-0135 in the case of sercos). A change bit in the status word (bit 11 or 12) is always set due to a change of the parameter content of S-0-0012 or S-0-0013. This enables the master to recognize very quickly whether a change occurred in S-0-0012 or S-0-0013.

A read access to one of the two parameters clears the respective change bit again.

Masking the Change Bits

By means of the parameters "S-0-0097, Mask class 2 diagnostics" and "S-0-0098, Mask class 3 diagnostics", it is possible to mask certain bits in terms of their effect on the change bit of the status word (bit 12 or bit 11).

The figure below illustrates the principle of masking by means of an example:

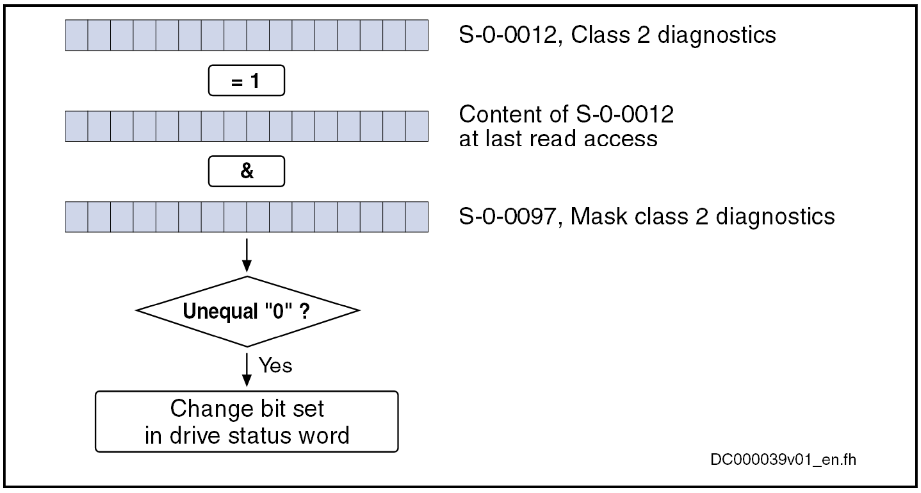


Fig. 10-5: Generating the Change Bit of Class 2 Diagnostics

Notes on Commissioning

The figure below illustrates the handling of the change bits in the status word and of the status class parameters:

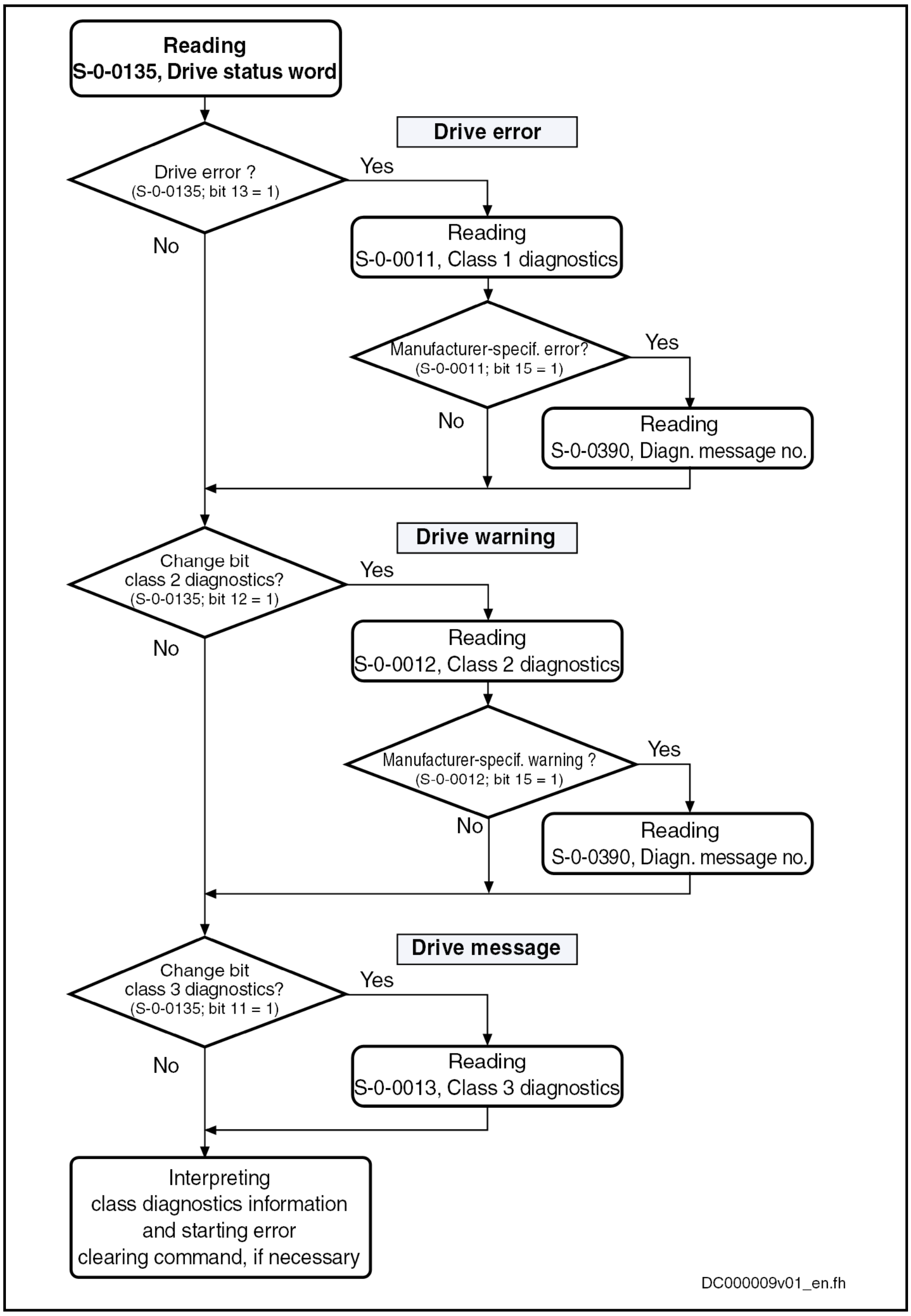


Fig. 10-6: Handling the Change Bits and Status Class Parameters

Fixed Status Displays

Function-Related Status Parameters

In the drive there are parameters the content of which has a direct relation to the status of the sequence of different drive functions. These parameters are used to display the current status information of the assigned function.

The following parameters are available for function-related status display:

- S-0-0014, Interface status

  This parameter displays the status of the communication phase transition and the cyclic communication.

- S-0-0135, Drive status word

This is the status word of the master communication (sercos) and contains all essential status information for the master.

- **S-0-0403, Position feedback value status**

  This parameter contains status bits for the position data reference of the individual measuring systems.
- **S-0-0419, Positioning command acknowledge**

  This status information is used for acknowledgment in "drive-controlled positioning" mode.
- **P-0-0046, Status word of current controller**

  This parameter contains status bits of the internal motor control (e.g. overvoltage in DC bus).
- **P-0-0115, Device control: Status word**

  This parameter contains status bits of device control (see also "Device Control and State Machines").
- **P-0-0222, Travel range limit switch inputs**

  This parameter displays the status of the travel range limit switch inputs (see also "Limitations: Travel Range Limit Switches").
- **P-0-0223, E-Stop input**

  This parameter displays the status of the E-Stop input (see also "E-Stop Function").
- **P-0-0445, Status word torque/current limit**

  This parameter contains status bits to display the activation of torque/current limitation (see also "Limitations: Current and Torque/Force Limitation").
- **P-0-0539, Holding brake status word**

  This parameter contains status bits for the status of the motor holding brake (see also "Motor Holding Brake").
- **P-0-0555, axis controller messages**

  This parameter displays messages with regard to velocity and limits that have been reached.
- **P-0-4029, Diagnostic report SCSB module**

  Parameter for reading master communication settings and states (with sercos).
- **P-0-4086, Master communication status**

  This parameter displays control information of the master communication for handling phase switch, drive enable etc., defined during initialization.

Status Parameters for Real-Time Status Bits

The following list contains status parameters that only contain one bit and can therefore be used for configuring real-time status bits (see "sercos"):

- S-0-0330, Status "n_feedback = n_command"
- S-0-0331, Status "n_feedback = 0"
- S-0-0332, Status "n_feedback < nx"
- S-0-0333, Status "T >= Tx"
- S-0-0334, Status "T >= Tlimit"
- S-0-0335, Status "n_command > n_limit"

- S-0-0336, Status "In position"
- S-0-0337, Status "P >= Px"
- S-0-0341, Status "In coarse position"
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0409, Probe 1 positive latched
- S-0-0410, Probe 1 negative latched
- S-0-0411, Probe 2 positive latched
- S-0-0412, Probe 2 negative latched

Control parameters:

Apart from the parameters for status display, there are parameters available in the drive that are used to control the drive functions (see also description of corresponding parameter):

- P-0-0045, Control word of current controller
- P-0-0522, Control word for commutation setting
- P-0-0556, Config word of axis controller
- P-0-4028, Device control word

10.4.3 Operating hours counter

Brief Description

There are operating hours counters available in the drive that separately record the operating time for control section and power section. The respective operating time is displayed in the parameters P-0-0190 or P-0-0191. These times are directly stored from the control section or power section so that assignment is maintained also for servicing.

Pertinent Parameters

- P-0-0190, Operating hours control section
- P-0-0191, Operating hours power section

Parameter "P-0-0190, Operating hours control section" displays the operating time of the control section of the drive. The unit is seconds.

The time the drive has been switched on is considered to be the operating time of the control section.

Parameter "P-0-0191, Operating hours power section" displays the operating time of the power section of the drive with drive enable having been set. The unit is seconds.

The time during which the output stage has been enabled is considered to be the operating time of the power section.

☞ Before delivery, the operating hours counters are set to a defined value at the factory. They can therefore indicate the total runtime of a component in field duty.

In addition, there is an operating hours counter for motors with which the dynamic operating data of the motor are collected and stored.

See the section "Diagnostic Data of Motor Operation"

10.4.4 Error Memory (Power Section and Control Section)

Brief Description

In the drive, all errors occurred are recorded in an error memory on the control section. If an error occurs in the power section, it is additionally stored in a separate error memory on the power section. It is thereby made sure that the relevant information is still available on the power section after separating the power section and control section.

☞ When an error occurs, the diagnostic message number and the current count of the operating hours counter are automatically stored.

Pertinent Parameters

- S-0-0390, Diagnostic message number
- P-0-0190, Operating hours control section
- P-0-0191, Operating hours power section
- P-0-0192, Error memory of diagnostic numbers
- P-0-0193, Error memory operating hours of control section
- P-0-0194, Error memory power section

☞ The contents of the parameters P-0-0192 and P-0-0193 are stored on the control section. The content of parameter P-0-0194 is stored on the power section.

Functional Description

Error Memory in Control Section

When the drive detects a class 1 diagnostics error, a bit is set in parameter "S-0-0011, Class 1 diagnostics" and bit 13 for "error in class 1 diagnostics" is set in the drive status word.

In order to allow a more detailed diagnosis

- the diagnostic message number appears on the display and is stored in parameter "S-0-0390, Diagnostic message number" (in "hex format"),
- the corresponding error number is stored in parameter "P-0-0009, Error number" (in "decimal format"),
- the plain text of the diagnostic message is stored in parameter "S-0-0095, Diagnostic message",
- the content of parameter "P-0-0190, Operating hours control section" at the time the error is detected is stored in parameter "P-0-0193, Error memory operating hours of control section",
- the diagnostic message number belonging to the error according to parameter "S-0-0390, Diagnostic message number" is stored in parameter "P-0-0192, Error memory of diagnostic numbers" in the same order.

The parameters P-0-0192 and P-0-0193 have a stack structure and contain, in chronological order, the diagnostic message numbers or the counts of the operating hours counter of the last **50 errors** that occurred.

☞ The count of the operating hours counter at the time the last error occurred is entered at the top of parameter P-0-0193, and the diagnostic message number of the last error occurred at the top of parameter P-0-0192.

Error Memory in Power Section

If the error concerns the power section, it is additionally stored in parameter "P-0-0194, Error memory power section".

The last 13 errors that occurred and the respective count of the operating hours counter (see P-0-0191) are stored in this parameter.

The error "F8060 Overcurrent in power section", for example, is an error which could occur in the power section. This error would be displayed both in parameter P-0-0193 and in parameter P-0-0194.

10.4.5 Diagnostic Data of Motor Operation

Brief Description

For preventive maintenance and service purposes, the firmware provides the option to collect dynamic operating data of the motor and store them in the controller.

The operating hours counter for motors allows planning maintenance intervals, minimize machine downtimes and reduce maintenance costs.

Features

- Recording the total time during which:
  - Operating state "AF" present
  - Velocity unequal zero
  - Motor temperature is greater than 10 K below shutdown threshold (parameter "S-0-0204, Motor shutdown temperature")
- Recording the maximum velocity of the motor in operation
- Determining the average value of the motor velocity in operation
- Recording the maximum temperature of the motor winding in motor operation
- Determining the average value of the motor winding temperature, referring to the duration of the operating status "AF"
- Determining the operational performance of the motor by multiplying average speed and duration with velocity unequal zero

Pertinent Parameters

- P-0-2051, Operating hours counter, motor
- P-0-2052, Thermal operating data, motor
- P-0-2053, Mechanical operating data, motor
- P-0-2054, Operational performance, motor
- P-0-2055, Serial number, motor

Functional Description

General Information

The drive controller records the operating hours, the thermal and mechanical data of the motor in a cycle of 8 ms and stores them in the following parameters:

- P-0-2051, Operating hours counter, motor
- P-0-2052, Thermal operating data, motor
- P-0-2053, Mechanical operating data, motor
- P-0-2054, Operational performance, motor

Due to the limited number of write accesses to the flash, the data are first stored in the volatile memory of the controller and every 60 min they are written to the active, non-volatile memory of the controller (flash).

If the control voltage is switched off before the hourly storing has taken place, operating data of the motor which have not yet been saved will get lost.

Motors with Encoder Data Memory

Rexroth motors of the "IndraDyn S" and "IndraDyn A" device ranges, when equipped with the encoder option "-x1", "-x2" or "-X3" (encoder memory version **4.3** and higher: "P-0-3000, Module code of motor, type plate" [5] 0x****0**4**0**3**), provide the option to write the operating data of the motor to the encoder data memory and thereby make them available in the respective motor itself. This means that important information for service and maintenance work is stored directly at the object and can be called there.

Each motor can be unequivocally identified by its serial number (type plate data under "SN") which can also be found in the encoder data memory. After the control voltage has been switched on, the serial number of the motor connected to the drive controller is read and compared to the serial number of the last operated motor which has been internally stored in the controller.

If the serial number is the same, the operating hours counter in the encoder data memory is compared to the operating hours counter in the controller and synchronized, if necessary. Depending on the value of the operating hours counter in the encoder data memory (P-0-3051), the following action is carried out:

- Value in P-0-3051 **greater** than value in controller (P-0-2051)

  → Operating data of motor from encoder data memory are applied to controller (always when switching to "bb", "Ab" or "OM")
- Value in P-0-3051 **smaller** than value in controller (P-0-2051)

  → Operating data of motor from controller are applied to encoder data memory of motor (only after control voltage has been switched on)

If the serial number stored in the controller does **not** match the one of the connected motor, the operating data of the new motor are written from its encoder data memory to the corresponding parameters of the controller.

The table below contains an overview of cases to be distinguished and the resulting storage processes for synchronization.

	Serial number of motor unchanged		Serial number of motor changed
	Comparison of operating hours counters		
Motor data	(P-0-3051) > (P-0-2051)	(P-0-3051) < (P-0-2051)	
Operating hours counter	(P-0-3051) → (P-0-2051) 1)	(P-0-2051) → (P-0-3051) 2)	(P-0-3051) → (P-0-2051) 1)
Thermal operating data	(P-0-3052) → (P-0-2052) 1)	(P-0-2052) → (P-0-3052) 2)	(P-0-3052) → (P-0-2052) 1)
Mechanical operating data	(P-0-3053) → (P-0-2053) 1)	(P-0-2053) → (P-0-3053) 2)	(P-0-3053) → (P-0-2053) 1)

1) Operating data of motor are read from encoder data memory when switching to operating mode
2) Operating data of motor are stored in encoder data memory only after control voltage has been switched on

Tab. 10-4: Synchronizing the Operating Data of the Motor after Switching Controller on

☞ To use the diagnostic data of motors with encoder data memory, observe the following points:

- To store, in the case of servicing, the current operating data of the motor, which have been stored in the controller, in the encoder data memory, switch control voltage on again before replacing the motor!
- For Rexroth motors with encoder data memory, it is impossible to reset the operating hours counter!

Motors without Encoder Data Memory

Due to their type of construction, kit motors do not have a predetermined motor encoder. Third-party motors equipped with a motor encoder typically do not have an encoder data memory.

Therefore, storing the operating data of the motor in the encoder data memory either is impossible or, if the mechanical motor/motor encoder connection has been disconnected for service work, does not make sense.

When these motors are used, their operating data are written to the non-volatile memory of the drive controller, too, as it is done for motors with encoder data memory. For diagnostic purposes, the user can evaluate these data which refer to a specific motor.

☞ The operating data of the motor stored in the controller can be changed in communication phase 2. Therefore, the initial state can be set manually. The operating data of the motor are saved hourly in the non-volatile memory of the controller.

Notes on Commissioning

Motors with Encoder Data Memory

For Rexroth motors of the "IndraDyn S" and "IndraDyn A" device ranges, when equipped with encoder option "-x1" or "-x2" (supplied as of 3rd quarter of 2007), the operating data of the motor are automatically initialized and stored correctly.

Motors without Encoder Data Memory

For motors without encoder data memory, the operating data of the motor should be manually set to start values during initial commissioning:

- P-0-2051, Operating hours counter, motor
- P-0-2052, Thermal operating data, motor
- P-0-2053, Mechanical operating data, motor
- P-0-2054, Operational performance, motor

☞ It is possible to use all values of the allowed range of values.

Recommendation: → Enter "0" as the respective start value!

As long as the motor (without encoder data memory) is operated at the same drive controller, its operating data are stored in the controller every hour. In the case of servicing, when the motor or controller is replaced, the values of the parameters P-0-2051, P-0-2052, P-0-2053 and P-0-2054 should be externally saved and assigned to the specific motor.

How to proceed after replacement:

- After having **replaced the controller**, load the values of parameters P-0-2051, P-0-2052 and P-0-2053 specific to the operated motor from the external storage medium to the new controller.

- After having **replaced the motor**, set the values of parameters P-0-2051, P-0-2052 and P-0-2053 to useful values for the replacement motor, e.g. start values "0" for a new motor or the specific values of a repaired motor.

10.4.6 Load Preview

Brief Description

When operating electric drives, there also is power dissipation when the motor delivers power or torque/force. For electrical equipment or electrical components, due to the materials used, there is a maximum permissible operating temperature up to which continuous operation is safe. This temperature determines the permissible continuous load for the electrical components.

Overload Capacity

The temperature rise of electrical components based on current supply runs in parallel with their thermal time constants. As long as the maximum permissible operating temperature has not be reached, an electrical component may be overloaded, i.e. short-time operation with more than the permissible continuous load. This causes the temperature rise to occur more quickly but does not pose a problem as long as the permissible operating temperature is not exceeded.

If the permissible operating temperature is reached, the overload must be reduced to the permissible continuous load so that the electrical components are not damaged. Functions for limiting overload are present on Rexroth drives for various drive components that are relevant to performance:

- Motor
- Inverter of the controller
- Braking resistor of the supply unit or converter

Protective Functions

The functions that supply protection from loads that are not permitted are realized in the hardware or firmware side:

- Hardware-side temperature measurement in the motor windings and on the controller heat sink
- Firmware-side temperature model calculation for temperatures at temperature-sensitive components that cannot be measured on the hardware-side.

With hardware-side temperature measurement, only the temperature rise processes that take place in the seconds range can be recorded; the temperature rise that takes place more quickly can only be monitored using firmware-side model calculation anyway.

Overload Limitation

The high overload capacity of electric drives can only be realized such that operational safety is ensured by using temperature model calculation and automatic overload limits:

- Current limitation with controller temperature model (inverter)
- Current limitation with motor temperature model
- Power limitation with braking resistor temperature model

Load Preview

Limits that intervene automatically do protect the electrical components from damage, but also affect the torque or power output of the drive and can lead to shutdown due to resulting errors or rejects during processing. Early detection and reporting of threatening limitations is possible with the "load preview" function for the three temperature model calculations mentioned above:

- Processing the machining cycle with the highest load

- Determining the difference of the load curve (difference between maximum value and start value)
- Determining a threshold value fo the load at which the expected load difference is still just possible without reaching the limit
- Message when the thermal load has reached the specified threshold value.

Pertinent Parameters

- P-0-0141, Thermal drive load
- P-0-0441, Thermal drive load warning threshold
- P-0-0446, Thermal motor load
- P-0-0465, Maximum value thermal drive load
- P-0-0466, Maximum value thermal motor load
- P-0-0467,
- P-0-0468, Prewarning threshold of therm. motor load
- P-0-0469, Prewarning threshold of therm. load of braking resistor
- P-0-0844, thermal load of Braking resistor

Pertinent Diagnostic Messages

- E2051 Motor overtemp. prewarning
- E2061 Device overload prewarning
- E2820 Braking resistor overload prewarning

Functional Description

Thermal Load

The firmware-side temperature models determine the thermal load of the

- Motor
- Inverter of the controller
- Braking resistor of the supply unit or converter

The thermal load of these components is displayed in

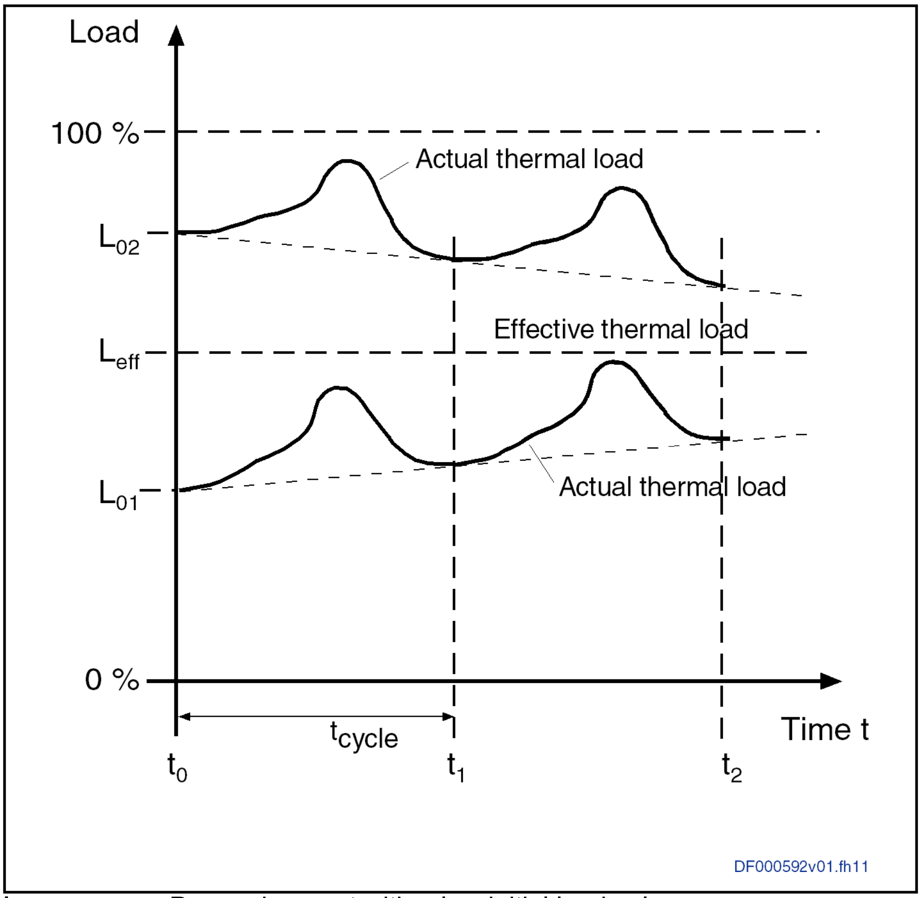
- P-0-0141, Thermal drive load
- P-0-0446, Thermal motor load
- P-0-0844, thermal load of Braking resistor

☞ For more information on the limitations caused by these temperature models, see chapter "Dynamic Current Limitation"

Estimating the Continuous Load

These parameters can also be pre-assigned with values for test purposes in order to estimate the effectively expected continuous load by running load cycles. The load at the end and at the start of one or more load cycles is to be compared for this purpose:

- Falling value: Pre-assigned value was higher than the effectively expected continuous load
- Rising value: Pre-assigned value was lower than the effectively expected continuous load

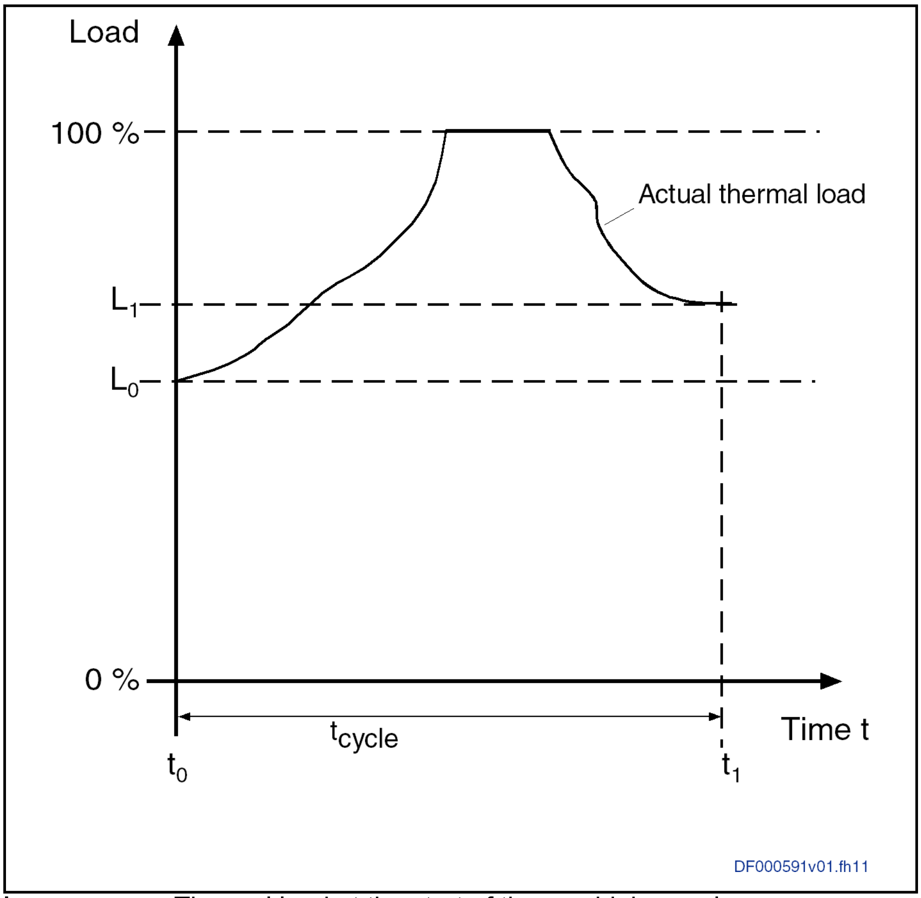


L_{01} Pre-assignment with a low initial load value
L_{eff} Effective continuous thermal load, theoretical end value
L_{02} Pre-assignment with a high initial load value

Fig. 10-7: Schematic Load Curves with Different Load Pre-Assignment

Conditions for Estimating the Continuous Load

It is possible to estimate the continuous load if the duration of the load cycle is within the range of the thermal time constant of the respective component (milliseconds to seconds with controllers and braking resistors, minutes to hours with motors). With frequent repetition of the load cycle, it is possible to slowly increase the level of load before the limitation intervenes, particularly with motors and controllers with high intensities of current, if the effective continuous load is closer to 100% than the load rise of a load cycle:



L_0	Thermal load at the start of the machining cycle
Thermal load	Thermal load of the component
L_1	Thermal load at the end of the machining cycle

Fig. 10-8: Exemplary Load Curve of a Load Cycle with Intervening Limitation

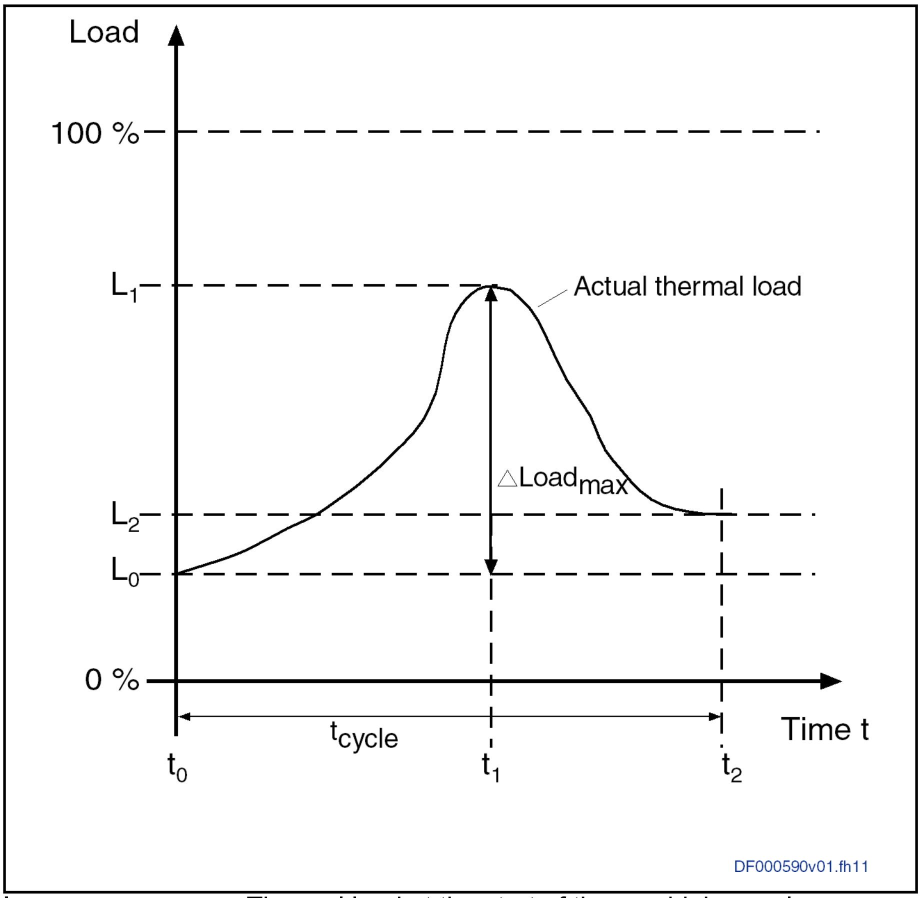
Maximum Load Value and Load Preview

Load rises occur when running load cycles. The maximum value of the occurred load is stored on the firmware-side in the parameters

- P-0-0465, Maximum value thermal drive load
- P-0-0466, Maximum value thermal motor load
- P-0-0467,

Load Rise

The repeated storage of maximum values can be forced when the value "0" is entered in these parameters. The maximum value of the next load cycle is then stored. The difference between the maximum value and the initial value of the thermal load is the "load rise":



L_0	Thermal load at the start of the machining cycle
L_1	Maximum value of the load (is stored)
Actual thermal load	Thermal load of the component
L_2	Thermal load at the end of the machining cycle

Fig. 10-9: Exemplary Load Rise of a Load Cycle

Load Preview

"Load preview" is possible by means of an appropriately set prewarning threshold. In this case, a message is generated when, at the next expected load rise, the thermal load comes close to 100% and the drive risks that a limitation intervenes. The respective threshold value can be set in:

- P-0-0441, Thermal drive load warning threshold
- P-0-0468, Prewarning threshold of therm. motor load
- P-0-0469, Prewarning threshold of therm. load of braking resistor

$$\text{Prewarning threshold} \leq 100\% - (\Delta \text{Load}_{max}) = 100\% - (L_1 - L_0)$$

L_0	Thermal load at the start of the machining cycle
$\Delta Load_{max}$	Expected load rise of the machining cycle
L_1	Maximum value of the load in the machining cycle

Fig. 10-10: Calculating the Limit Value for the Prewarning Threshold

The prewarning threshold to be entered must be smaller than the limit value (safety distance).

Signaling "Limitation Risk"

The corresponding warning signals that the respective prewarning threshold has been reached:

- E2051 Motor overtemp. prewarning

- E2061 Device overload prewarning
- E2820 Braking resistor overload prewarning

The prewarning is displayed in "S-0-0012, Class 2 diagnostics" and is to be read via this parameter by the control master. After the prewarning has triggered, the intervention of the limitation is to be anticipatorily expected during the next regular machining cycle. The control master now has the option to react preventatively to this in an appropriate way.

Overview of Thermal Protective Functions and Associated Diagnostic Messages

Component	Diagnostic message	Cause	Drive reaction	Status bit	Display
Motor	E2051, Motor over-temp. prewarning	Motor temperature model Load > P-0-0468	None	S-0-0012 bit 2	P-0-0446
		Temperature sensor Temperature > S-0-0201			S-0-0383
	E8055, Motor overload, current limit active	Motor temperature model Load > 100%	Motor current limit	S-0-0012 bit 0	P-0-0446
	F2019, Motor overtemperature shutdown	Temperature sensor Temperature > S-0-0204	P-0-0119, Best possible deceleration	S-0-0011 bit 2	S-0-0383
	F2021, Motor temperature monitor defective	Temperature sensor defective	P-0-0119, Best possible deceleration after 30 s, immediately with sensor KTY84		S-0-0383
Amplifier	E2061, Device overload prewarning	Amplifier temperature model Load > P-0-0441	None	S-0-0012 bit 1	P-0-0141
	E8057, Device overload, current limit active	Amplifier temperature model Load > 100%	Limiting the Output Current	S-0-0012 bit 0	P-0-0141
	E2050, Device over-temp. Prewarning	Temperature sensor Temperature > prewarning threshold (threshold is device-specific)	F2018 after 30 s	S-0-0012 bit 1	S-0-0384
	E2040, Device overtemperature 2nd prewarning		F2040 after 30 s		P-0-0816
	F2018, Device overtemperature shutdown	Temperature sensor Temperature > shutdown threshold (threshold is device-specific)	P-0-0119, Best possible deceleration and shutdown of power supply	S-0-0011 bit 1	S-0-0384
	F2040, Device overtemperature 2nd shutdown				P-0-0816
Braking Resistor	E2820, Braking resistor overload prewarning	Temperature model Load > P-0-0469	None	S-0-0012 bit 1	P-0-0844
	F2820, Braking resistor overload	Temperature model Load > 110%	P-0-0119, Best possible deceleration and shutdown of power supply	S-0-0011 bit 1	P-0-0844

Tab. 10-5: Thermal protective functions of IndraDrive and associated diagnostic messages

Notes on Commissioning

IndraWorks Dialogs for Setting the Load Preview

The parameters for setting the load preview can be found in the

- "Power Supply" dialog for the braking resistor
- "Current Limitation" subdialog of the "Torque/Force Limitation" dialog for motor and controller

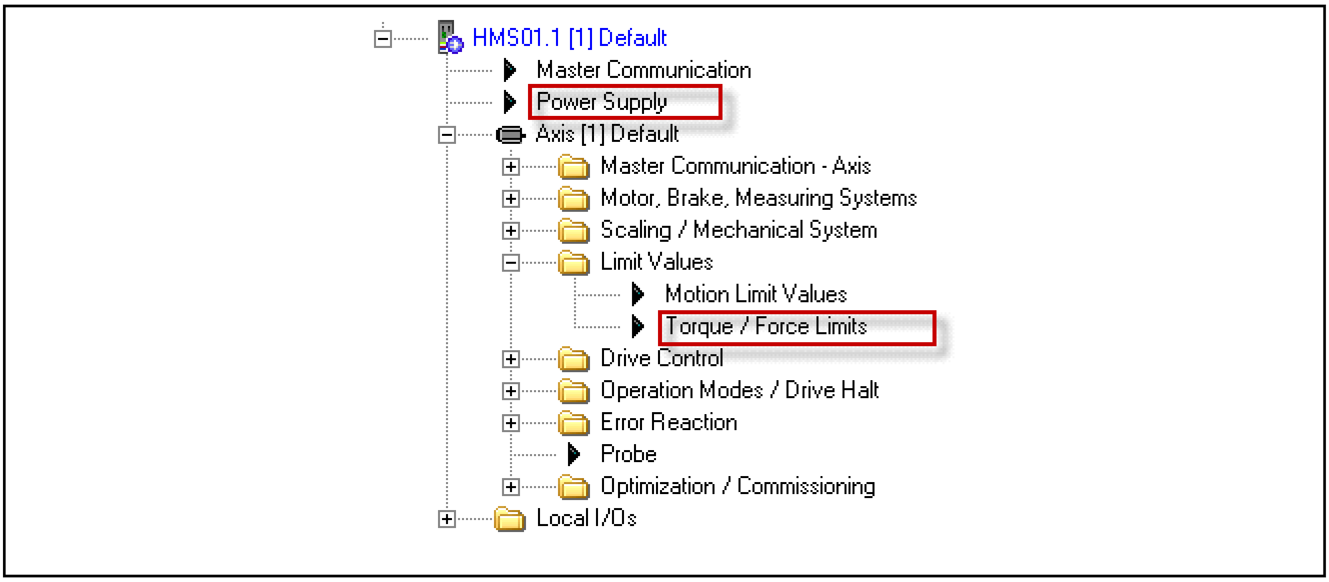


Fig. 10-11: IndraWorks Explorer Showing How to Find the Dialogs for Load and Load Preview

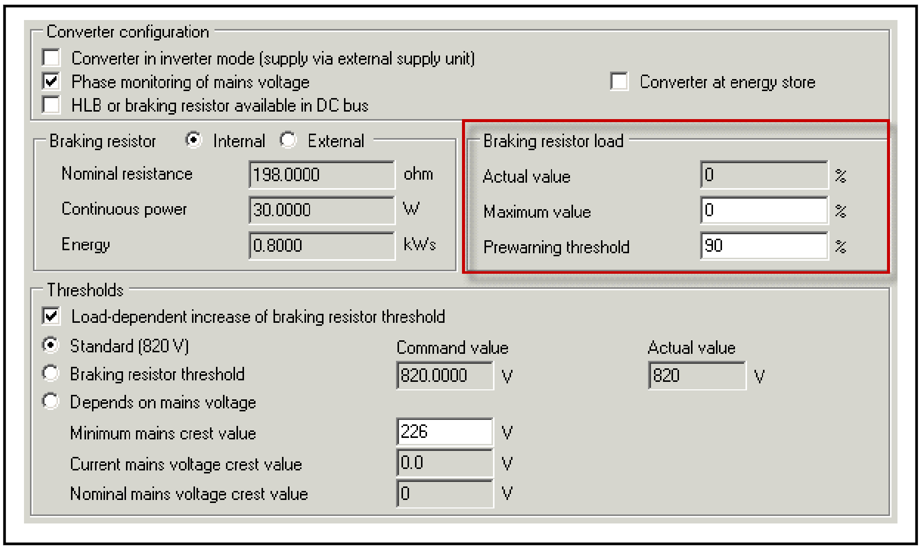


Fig. 10-12: IndraWorks "Power Supply" Dialog with Setting Options for the Pre-warning Threshold

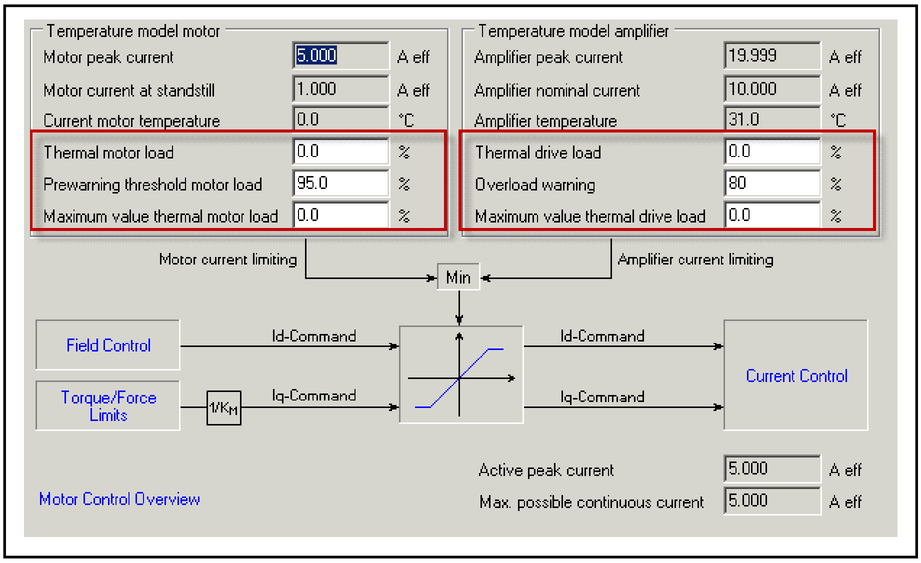


Fig. 10-13: IndraWorks "Current Limitation" Subdialog of "Torque/Force Limitation" with Setting Options for the Prewarning Threshold for the Motor and Controller Load

Procedure for Estimating the Effective Continuous Thermal Load

The effective thermal load can be estimated as follows for controllers and braking resistors:

- Prior to running the load cycle, write an estimated initial value for the effective continuous load to the value of the thermal load. Take a note of the initial value.
- After the machining cycle, compare the load value with the noted initial value.
  - If the load has increased, enter a significantly higher initial value for the next machining cycle
  - If the load has decreased, enter a significantly lower initial value for the next machining cycle
- Repeat the procedure with adjusted initial values until the load remains approximately the same before and after the machining cycle. The displayed load value then corresponds to the continuous thermal load caused by this machining cycle.

The stored maximum value of thermal load must not reach 100% if the drive is to operate without the risk of a limitation.

☞ For motors, this method mostly does not provide any reliable data on the continuous load

Procedure for Setting the Load Preview

The effective continuous load of motors can only be estimated very imprecisely by observing a few load cycles. The most accurate data can be obtained from the temperature sensor, although this requires long-term operation of more than 5 times the duration of the thermal time constant.

The "load preview" can be advantageously used with motors to avoid load-related intervention of limitations. It is possible to recognize in advance from when the motor runs the risk of being limited in its power or torque/force output.

Procedure:

- Write "0" to the maximum value of the thermal load before running the load cycle.
- After the machining cycle, take note of the value of the thermal load and subtract it from the automatically stored maximum value. Subtract the difference from 100%, possibly reducing the remaining value somewhat for safety reasons, and enter it in the parameter for the prewarning threshold.
- Query the signaling of the prewarning threshold having been reached in the relevant bit of S-0-0012 and take appropriate measures on the control master side prior to running the next machining cycle.

☞ It is also possible to use the "load preview" for controllers and braking resistors! It is particularly advantageous to use it for controllers with high intensities of current and braking resistors with high energy storage capacities.

10.5 Control panel

10.5.1 Brief Description

IndraDrive controllers are equipped with a "control panel"; its front consists of a display and four keys located below it. The display shows operating states, command and error diagnoses, as well as present warnings.

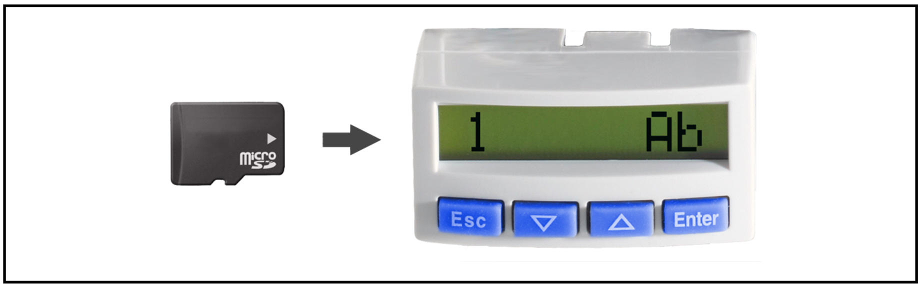


Fig. 10-14: Control Panel of IndraDrive Cs Advanced with Optional Memory Card

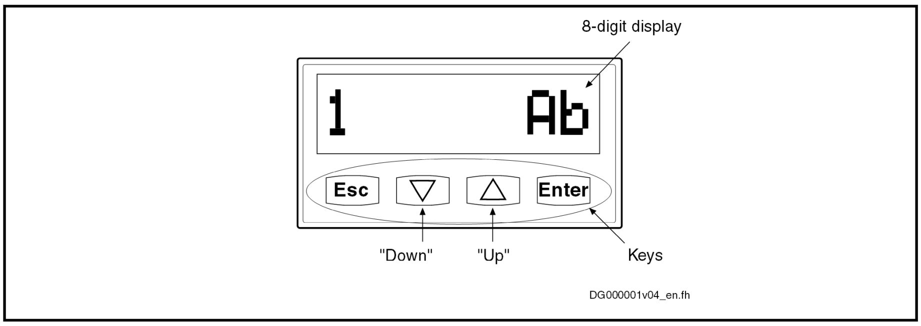


Fig. 10-15: Schematic Illustration of the IndraDrive Cs Control Panel

The four keys can be used to display extended diagnostic messages and trigger simple commands (in addition to master communication, IndraWorks or NC control). The menus are all in English; any present diagnostic and error messages are displayed in the language set in parameter "S-0-0265, Language selection".

Display Options of the Control Panel

The display of the IndraDrive controller automatically shows

- Status of the master communication
- Operating status

- Commands and diagnostic command messages
- Warnings and diagnostic error messages
- Extended displays such as contents of type designation of firmware active in the device or safety technology code (if safety technology option available)

Control Panel Variants

There are the following control panel variants

1. Standard Control Panel
2. Standard control panel incl. slot for optional memory card
3. Advanced control panel incl. slot for optional memory card

   In addition to the functions of the standard control panel, the Advanced control panel has an extended retain data memory for MLD. Using the Advanced control panel requires IndraDrive Cs Advanced.
4. VCP operator terminal, optional

   As an option, an operator terminal can additionally be connected to the drive via an Ethernet connection. VCP operator terminals are freely programmable, i.e. it is possible to implement application-dependent settings and diagnostic messages.

Possible Settings via the Control Panel

The following settings can be made using the control panel:

- Setting the drive address (drive number in the bus system of the master communication)
- Activating the easy startup mode for initial commissioning
- Setting the master communication protocol
- Setting IP addresses for engineering

Activating Commands via the Control Panel

The following commands can be activated using the control panel:

- Activating "S-0-0262, C07_x Load defaults procedure command" (load controller parameters or basic parameters)
- Activating other commands, such as:
  - C0300 Set absolute position procedure command
  - C2000 Command Release motor holding brake

Configuring the Control Panel

The main menu can be reached via the Enter key. The control panel can be configured to a limited extent:

- It is possible to choose between the edit mode and the view mode of the control panel.
  - "P-0-0680, Control panel: Configuration", bit 14 = 0, Edit Mode,

    changes can be made via the control panel.
  - "P-0-0680, Control panel: Configuration", bit 14 = 1, View Mode,

    editing via the control panel is locked. If the modification screen is activated on the display for a datum which basically can be changed, the "Edit disabled" message is generated, it is impossible to change the value.

    However, a temporary edit mode can be activated by keeping ESC +ENTER pressed for 8 seconds. If the main menu is started in this way, parameters can be adjusted as usual.
- Before a value is changed, the additional query "Ok?" is displayed. This query must be confirmed with the ENTER key before a value is actually changed. This is meant to prevent accidental changes.

- Bit 15 = "1" in "P-0-0680, Control panel: Configuration" can be used to deactivate the output of diagnostic text. In this case, the diagnostic message number is always output, the diagnostic text is not displayed.

10.5.2 Functional Description

Programming Module Variants

Programming Modules

Each controller is supplied with the appropriate programming module. The programming module contains the specific firmware for the drive controller; the firmware can be used for each particular performance (Economy, Basic and Advanced). For this reason, each programming module is specific to the performance and cannot be used for a device of a different performance (e.g., Basic programming module at Economy device).

If the display is plugged in wrong by mistake, the corresponding error (F9200) is displayed and the device does not boot.

In addition, each display holds the application-relevant data which are saved even if the control voltage fails. This allows easily replacing a device in case the hardware is defective, unless the display itself has been damaged.

The control panel consists of 4 keys, Enter, Esc, Up and Down. In addition, a display unit with 8 characters of 7x5 pixels each is available. The differences between the programming modules are due to functions that can be optionally used and different coloring.

The Advanced device is supplied with the Advanced programming module as standard.

The programming module is available in 3 configurations:

1. **Standard programming module**

   These programming modules had been supplied up to now and are replaced completely by the standard programming module incl. memory card slot. It can be distinguished from the other variants by the fact that it does **not** have a memory card slot on the left-hand side. The programming module contains the device firmware and the application-relevant memory.

2. **Standard programming module incl. memory card slot**

   All new Economy and Basic devices are supplied with an extended standard programming module that has an integrated additional memory card slot for the optional memory card.

   Like the standard programming module, the programming module contains the firmware and the application-relevant memory. In addition, machine-relevant data can be stored on the optional memory card; with Basic devices, the optional memory can be addressed from MLD (saving and loading application-relevant data/files).

   It visually differs from the standard programming module by a small slot on the left-hand side into which an optional memory card can be plugged (µSD card). The design of the programming module is exactly the same as for the Advanced programming module. To make it easy to visually distinguish the Advanced programming module from the standard programming module incl. memory card slot, the keys of the programming modules are supplied in different colors. The keys of this module are gray, the chassis is light gray.

3. **Advanced programming module incl. memory card slot**

   All Advanced devices are supplied with the so-called Advanced programming module which in addition to the memory card slot for the optional memory card contains an internal memory extension for the retain data of MLD. Thereby, the retain data memory for MLD is extended to 31728 bytes which the user can freely use.

Like the standard programming module, the programming module contains the firmware and the application-relevant memory. In addition, machine-relevant data can be stored on the optional memory card.

Its design is exactly the same as for the standard programming module incl. memory card slot. To make it easier to distinguish the Advanced programming module from the standard programming module incl. memory card slot, the keys of the programming modules are supplied in different colors. The keys of this module are blue, the chassis is light gray.

VCP Operator Terminal

In addition to the control panel, it is possible to connect a stand-alone **VCP operator terminal** that can, for example, be integrated in the front of the control cabinet, via an Engineering interface of the controller.

VCP control terminals are separate components (terminals) that can be used in addition to the control panel. They can be connected to the controller via Ethernet.

VCPs can be programmed by the user and it is possible to access all drive parameters and MLD variables.

Handling

Elements in This Documentation

Overview of the elements used in the following drawings and their meanings:

1 bb	Standard Mode
Enter	Enter key - Adopt change - Go to lower-level menu
Esc	ESC key - Reset changes - Go to upper-level menu
△ ▽	Arrow keys - Go to the previous/next element in the menu - Change value by one unit
Device Info	Flashing display The text regularly switches between both elements, a text more than 8 characters is needed.
Quick Setup opt. parameterizable IBN menu	Grey display Element is optional and is not displayed for some devices or settings.

Esc + Enter	Escape menu The ESC + Enter key combination is used to unlock in the active View mode. First press the ESC key and afterwards, press the Enter key.
IP-Address: 192.168.0.1	Display (continuous text) The text is displayed as continuous text. The value is an example and is hardware-dependent and setting-dependent.

Tab. 10-6: Elements

Menu Selection

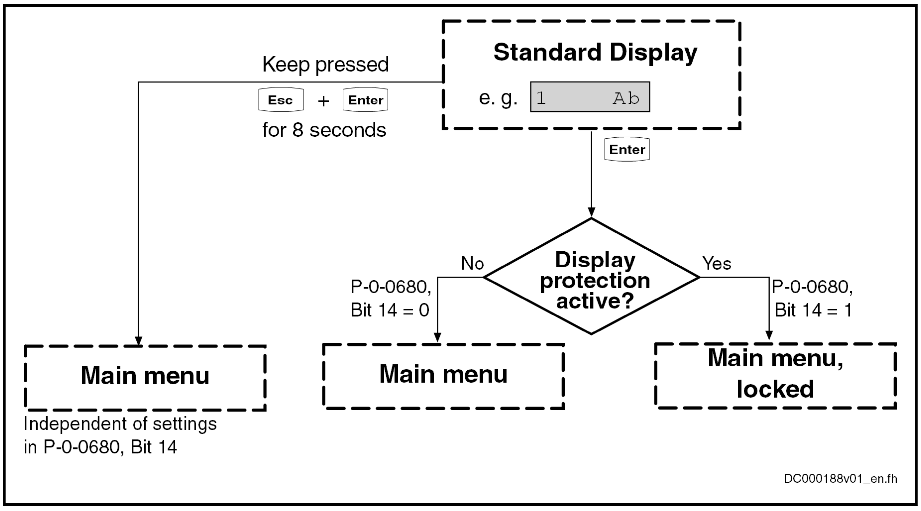
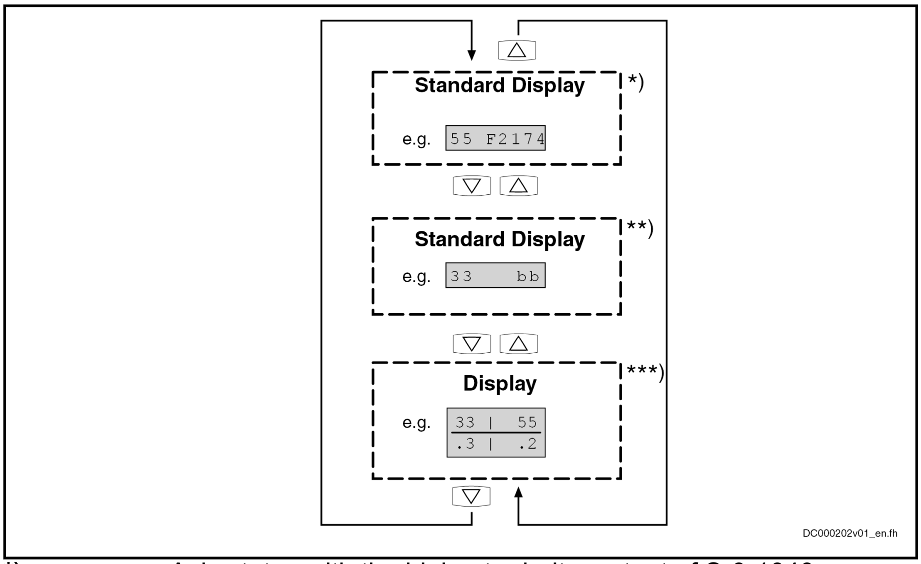


Fig. 10-16: Menu Selection, Depending on "P-0-0680, Control panel: Configuration"

Navigating in the Menu

You get from the standard display to the main menu by pressing Enter. From there it is possible, via the Enter key, to go to the different submenus.

If you are on the menu level of the standard display in a double-/multi-axis device, you can switch between he displays of the individual axes by pressing the Up or Down buttons. After booting, the highest-priority of the appropriate axis is displayed on the menu level of the standard display. Axis-dependent parameters are read and written in the corresponding menu items of the axis is currently selected.



*) Axis status with the highest priority, output of S-0-1040
**) Output of S-0-1040 and diagnosis of the next axis
***) Overview of drive addresses, separated by "|"

Fig. 10-17: Example Display of Double-Axis Unit with sercos as Master Communication

The menus provide a "View Level" in which the pieces of information are visualized. If information on changeable parameters is displayed, the Edit Level can be activated by continuing to press the Enter key. The current value is changed in the Edit level via the Up and Down button.

The changes will only become valid, when the "Enter" key is pressed one more time. The Edit Level can be exited at any time with the "Esc" key, the changes are not applied in this case.

When exiting the Edit Level, you always automatically get to the View Level in which you can again check the changes possibly made.

Displaying Continuous Texts

If the information displayed exceeds 8 characters in length (e.g. the IP address), the text is displayed as continuous text. The text is repeated until you exit the menu again with the "Esc" key.

Continuous text is shown as follows:

Fig. 10-18: Display of Operator Panel, Representation of Continuous Text

Quick Browsing

When you press the Up or Down key for a long time to change numerical values (e.g. changes in the drive address), the display automatically keeps browsing. If you keep the key pressed for about 5 seconds, the max. browsing speed is reached. This allows changing quickly between high values.

Consecutive Browsing

When you have reached the end of the value range of a data to be changed, or the last menu entry, browsing automatically continues in the same direction with the first element. For example, if you would like to change a digit of an IP address from 10 to 250, it is advisable to browse backwards. In this way you reach the desired value in 15 steps instead of 240 steps.

Access Protection

There are the two possibilities whose access is restricted via the operator panel.

- Standard password protection

Parameters can be write-protected via the standard password mechanism. These parameters are password-protected and can only be changed when the correct password was entered. Parameters in the operator panel are also affected by this mechanism.

- Display protection

  It is also possible to lock the display. Bit 14 in "P-0-0680, Control panel: Configuration" must be set.

When the display protection is activated, the following work flow results:

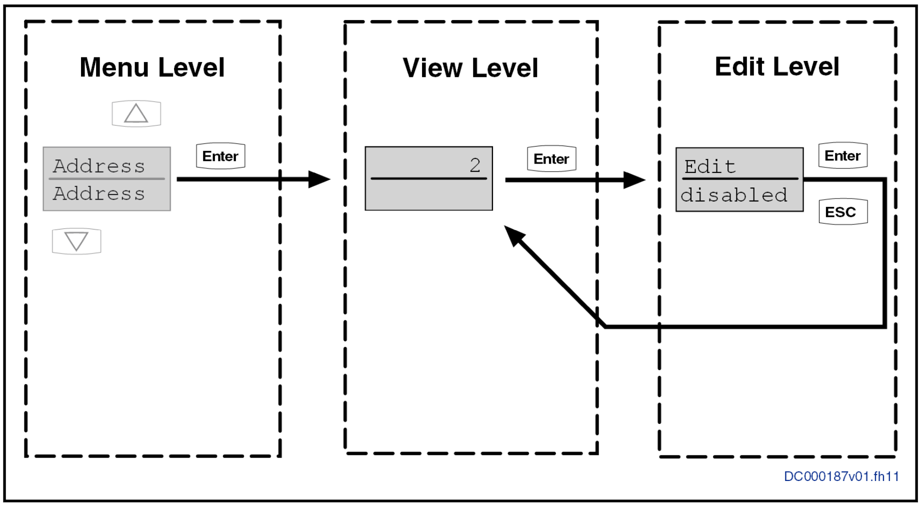
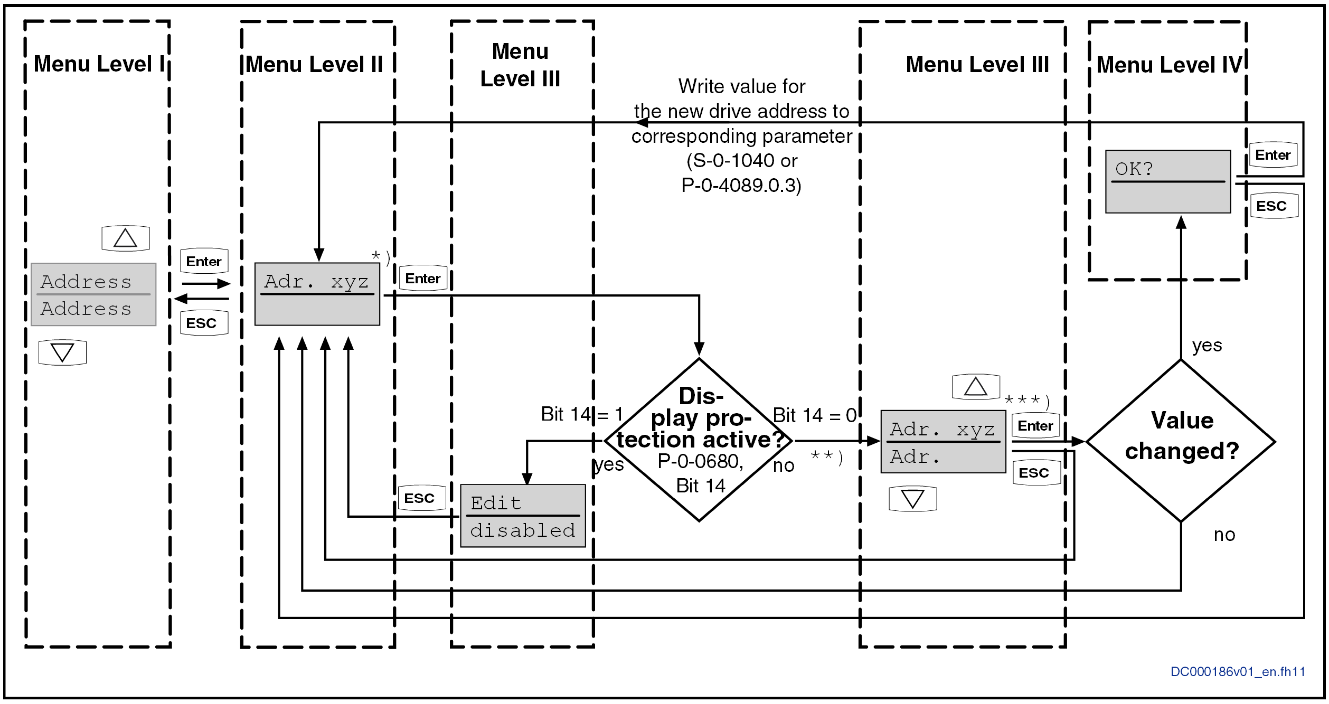


Fig. 10-19: Example with active display protection

Display protection can be temporarily deactivated via the display by pressing the ESC + Enter key for 8 seconds in the standard display. Display protection will be reactivated upon returning to the standard display.

Acknowledgment

If a value is changed from the operator panel, this must also be pressed. "OK?" is displayed in the display. The value is adopted with the "Enter" button and the Edit Level or View Level is exited. You can use the "ESC" key to return to the Edit Level or View Level.



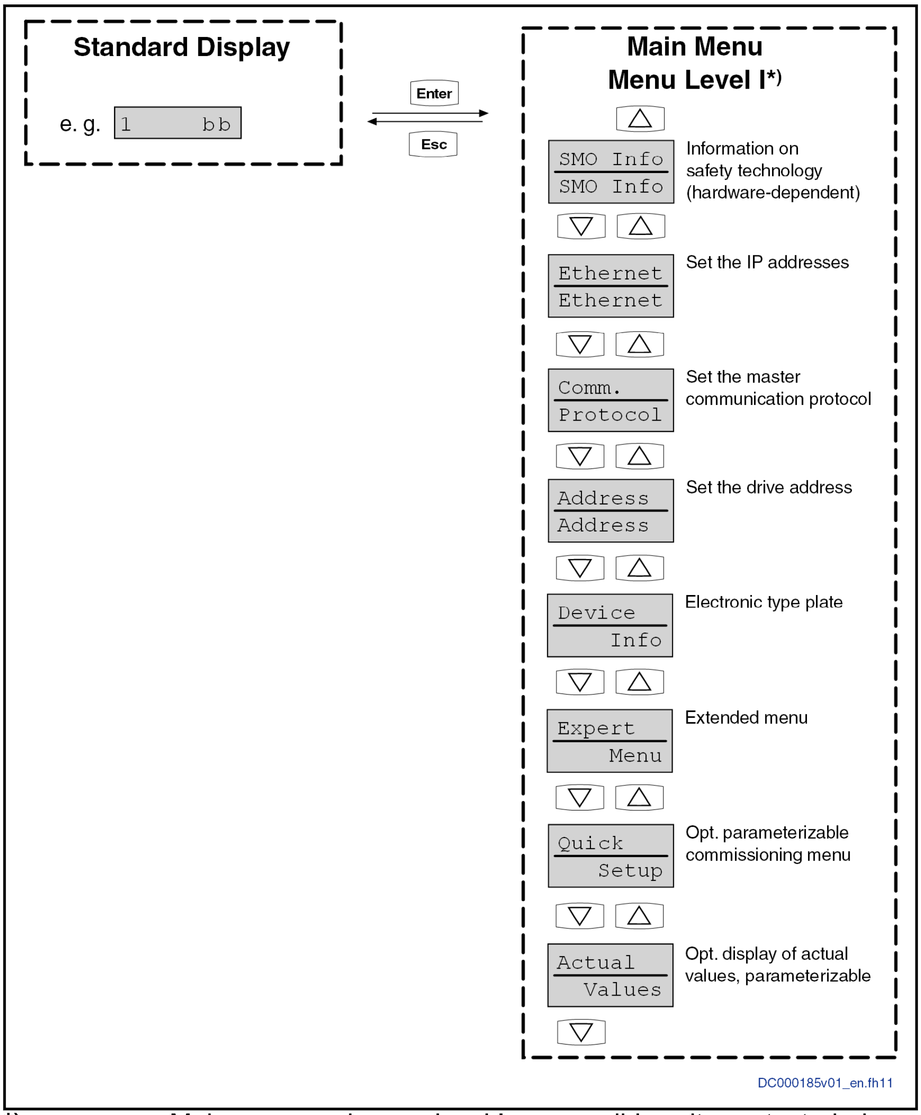
*)	"Adr. xyz", stands for the address to be entered "xyz"
**)	If you change from the active display protection (View mode) in the Edit mode, you must go back to the standard display and unlock the View mode from there by pressing ESC with ENTER for 8 seconds.
***)	A new address is set with the Up/Down button.

Fig. 10-20: Acknowledgment or implementation of Edit/View mode using Changing a value as an example

Menu Structure Overview

The display has a standard mode which displays axis-specific states. This mode also displays errors which can be directly cleared via the display, if the error cause has been removed.

The main menu can be accessed from the standard mode by pressing the "Enter" key.



*) Main menu and menu level I are possibly write-protected, depending on the setting in "P-0-0680, Control panel: Configuration"

Fig. 10-21: Menu Structure Overview of the Display

Standard Mode

Structure of the Display

The display functionally divided into 2 areas, the display of the active address of the drive in the respective master communication and in the case of errors/warnings, the display of current operating state corresponding to the content of S-0-0390. When the highest-priority state is a warning or a fault, this display flashes, changing with the associated diagnostic text in the language selected in parameter S-0-0265. As a standard, the diagnostic text (content of parameter S-0-0095) is output as a continuous text. The output of the continuous text can be deactivated via bit 15 of parameter "P-0-0680, Control panel: Configuration". After the continuous text has run through, the display changes again to the display of the master communication address and the error number until the error or warning is no longer present and has been cleared.

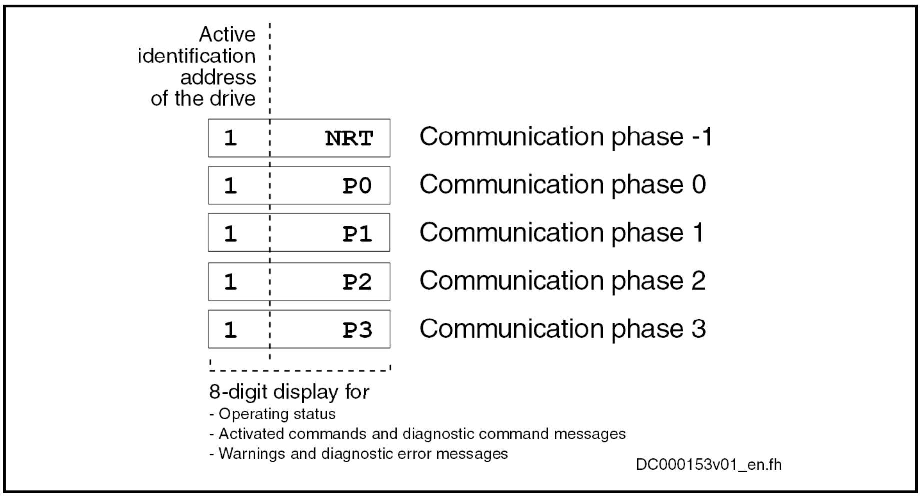


Fig. 10-22: Displays During Phase Progression of the Master Communication

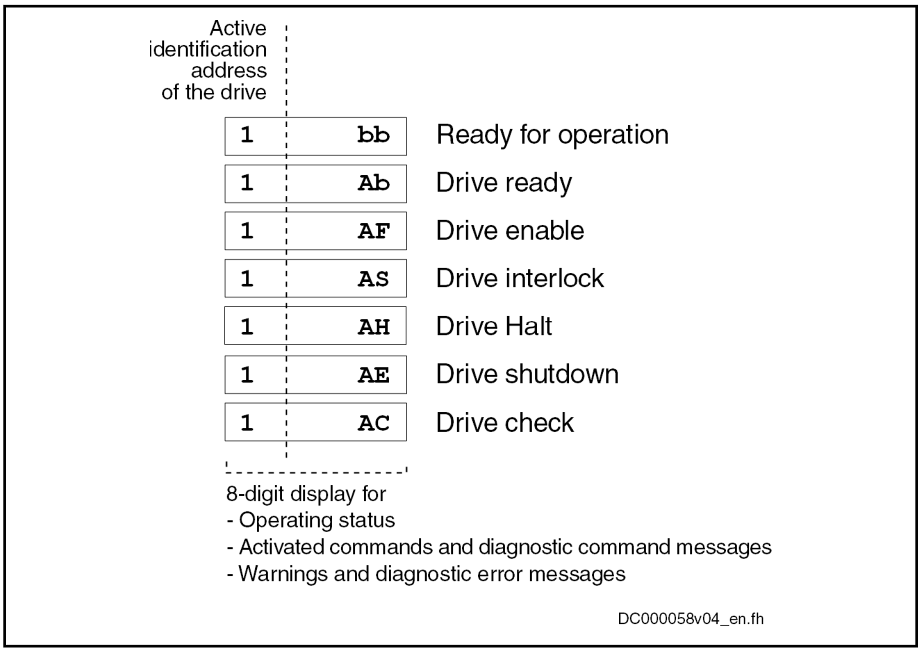


Fig. 10-23: Display of Operating States

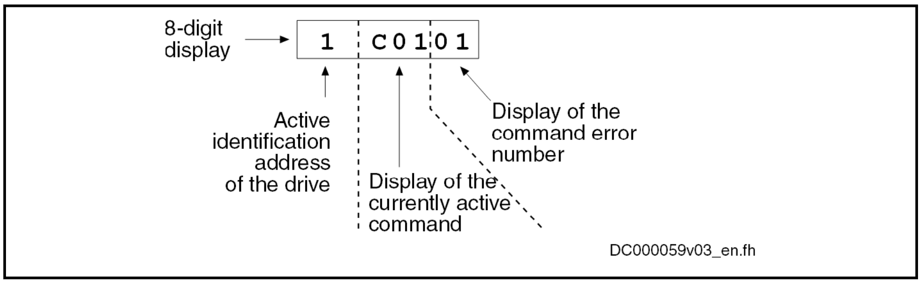


Fig. 10-24: Explanation of Command Error Displays

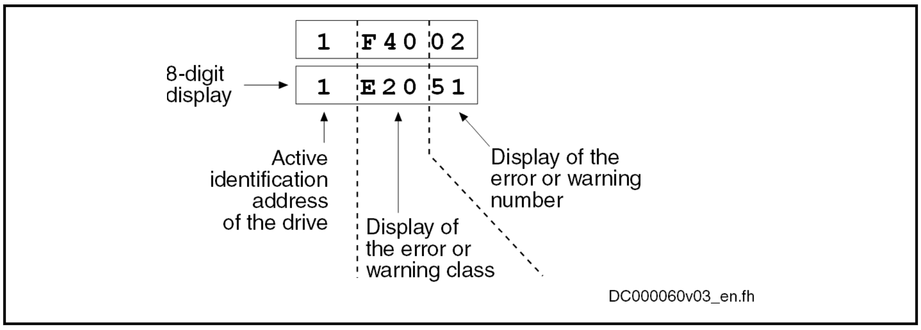


Fig. 10-25: Explanation of Error and Warning Displays

Priorities of Display

The displays have priorities, because it is impossible to display several messages at the same time.

The display shows the current drive state with the highest priority.

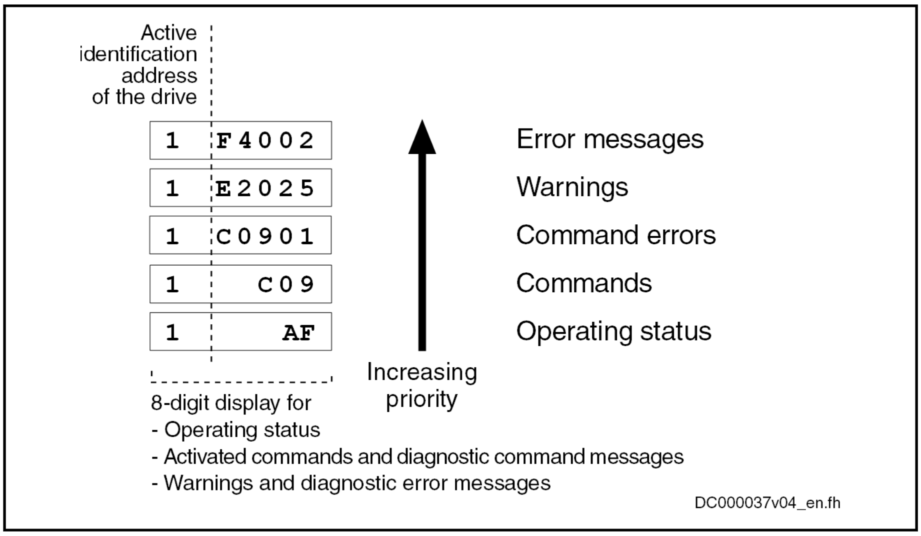


Fig. 10-26: Priorities of Displays (with Example Displays)

Displaying the Drive Address

The drive address is displayed in the standard display in the display. A 3-digit drive address is supported in the display. A drive address > 99 is displayed as a continuous text.

The displayed drive address is dependent on the type of addressing. A distinction is made between device-oriented addressing (P-0-4089.0.3) and slave-oriented addressing (S-0-1040).

The following table displays the parameters used with the corresponding addressing type:

Master communication	Read Access	Write Access
sercos	S-0-1040	S-0-1040
EtherCAT	P-0-4089.0.3	P-0-4089.0.3
PROFINET	P-0-4089.0.3	P-0-4089.0.3
EtherNet/IP	P-0-4089.0.3	P-0-4089.0.3
PROFiBUS	P-0-4089.0.3	P-0-4089.0.3

Master communication	Read Access	Write Access
CANopen	P-0-4089.0.3	P-0-4089.0.3
Analog/parallel interface	P-0-4089.0.3	P-0-4089.0.3

Tab. 10-7: Parameters of the Drive Address Depending on Master Communication

Pertinent Parameters:

S-0-1040, Drive address of master communication

P-0-4089.0.3, Device Address

Main Menu

General Information

The main menu has 6-8 menu entries by default. These are "SMO Info", "Ethernet", "Comm. Protocol", "Address", "Device Info" and "Expert menu". In addition, 2 optional menu items "Quick Setup" and "Actual Values" might be available, but only if the corresponding parameter setting was made.

Overview of standard menu entries:

Control panel text:	Note / information:
SMO Info	This menu item displays information about safety technology (Safe Motion V2).
Ethernet	Under this menu, the IP settings made for the engineering connections are displayed. They can be changed here, if required. The menu structure below "Ethernet" varies depending on the hardware used (see [External link could not be resolved.]).
Comm. Protocol	This submenu displays the master communication protocol currently set. It is possible to change or deactivate the protocol in this menu.
Address	This submenu displays the current drive address. The address can be changed, if required.
Device Info	This submenu displays information on the hardware used, e.g. firmware string (S-0-0030). No settings can be made in this submenu.
Expert menu	More complex function are available under this menu item, e.g. "Load defaults procedure command".

Overview of optional menu entries:

Control panel text:	Note / information:
Quick Setup	This optional submenu contains entries that can be parameterized on the user side. Each entry contains a scaled value directly connected to a parameter.
Actual Values	This optional submenu contains entries that can be parameterized on the user side. Each entry contains a scaled value directly connected to a parameter.

SMO Info menu

Parameter information about the safety technology is defined under the menu item "SMO Info" (Safe Motion V2).

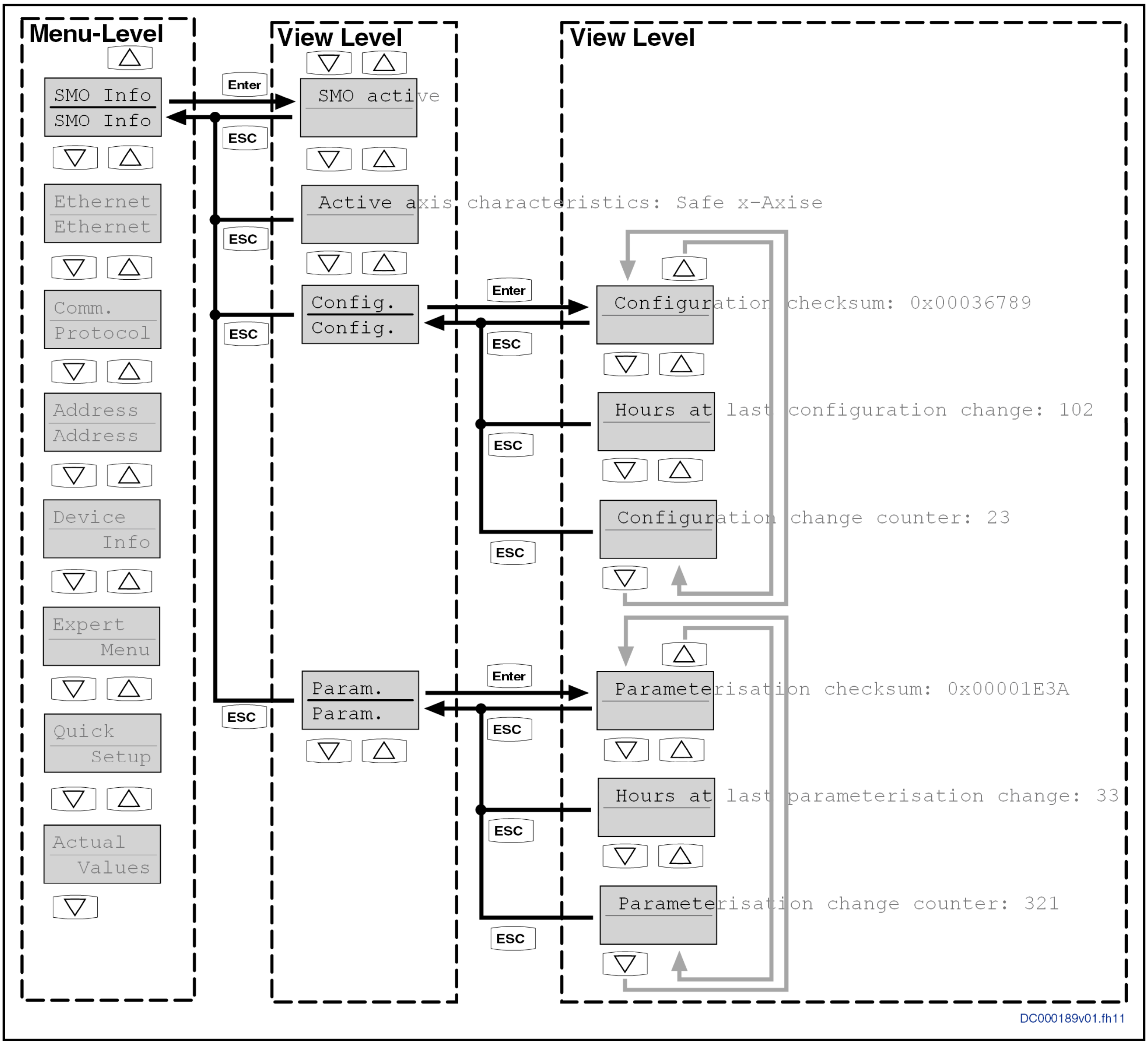


Fig. 10-27: SMO Info menu

Menu	Entry	Menu	Parameter used
SMO Info	SMO not active	-	P-0-3230.0.0, SMO: Password level
	Active axis characteristic: Safe x-Axis	-	P-0-3235.0.1, SMO: Active axis identifier
	Config.	Confguration checksum: 0x00036789	P-0-3234.0.1, SMO: Configuration checksum
		Hours at last configuration change: 102	P-0-3234.0.2, SMO: Operating hours at last change of configuration
		Configuration change counter: 23	P-0-3234.0.3, SMO: Configuration change counter
	Param.	Parameterisation checksum: 0x00001E3A	P-0-3234.0.4, SMO: Parameterization checksum
		Hours at last parameterisation change: 33	P-0-3234.0.5, SMO: Operating hours at last change of parameterization
		Parameterisation change counter: 321	P-0-3234.0.6, SMO: Parameterization change counter

Tab. 10-8: Parameters Used Under the SMO Info Menu

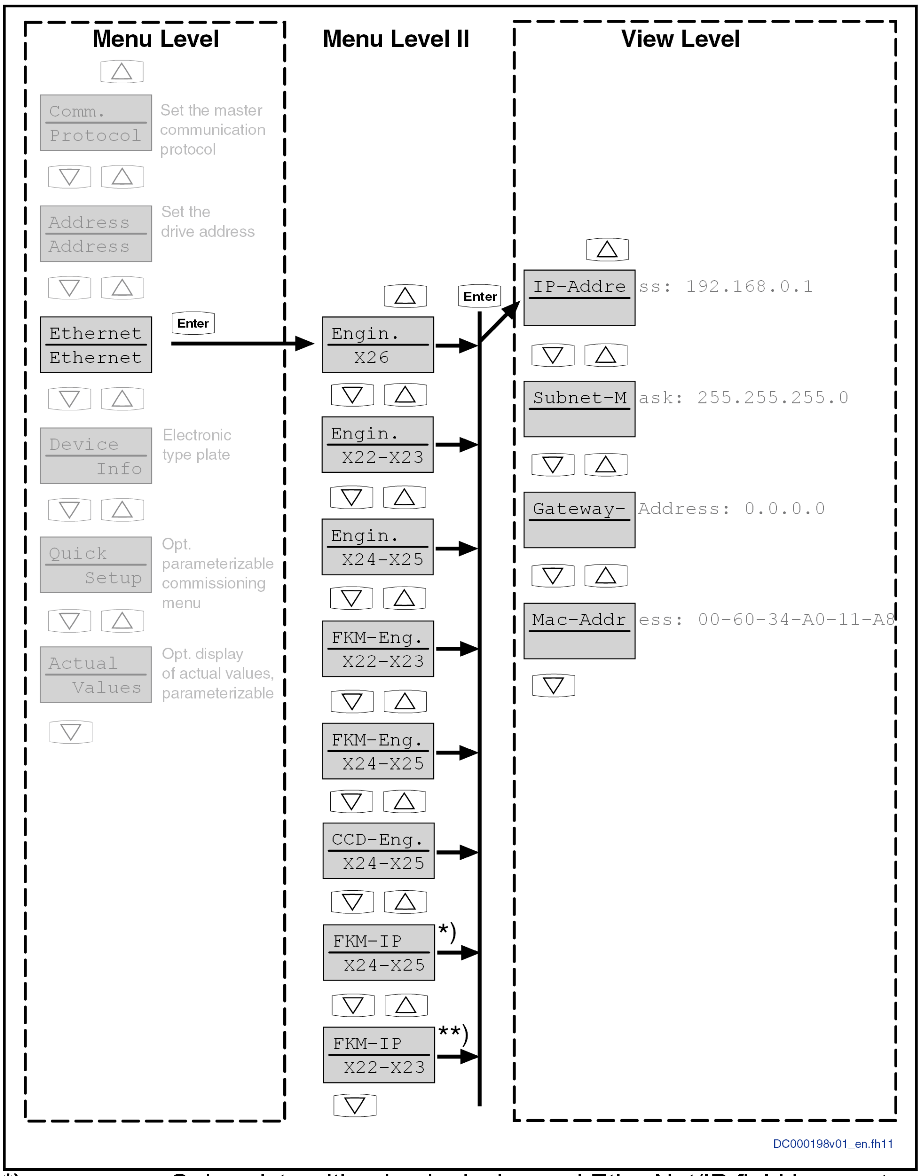
Ethernet

This menu entry contains the settings for the individual engineering interfaces.

The IP address, the subnet mask and the default gateway can be set. The physical (and unchangeable) MAC address can be seen here, too.

Depending on the hardware characteristic, more or less submenus are available on the Menu Level II.

Hardware	Available submenus		
IndraDrive Cs Basic Standard	FKM-Eng. X22-X23	-	-
IndraDrive Cs Basic incl. PROFIBUS or CANopen Interface	-	Engin. X22-X23	-
IndraDrive Cs Advanced incl. PROFIBUS or CANopen Interface	-	Engin. X26	CCD-Eng. X24-X25
IndraDrive Cs Advanced incl. MultiEthernet interface	FKM-Eng. X22-X23	Engin. X26	CCD-Eng. X24-X25
IndraDrive Cs Advanced without opt. master communication module	-	Engin. X26	CCD-Eng. X24-X25
IndraDrive Cs Economy sercos	FKM-Eng. X22-X23	-	-



*)	Only exists with a basis device and EtherNet/IP field bus protocol.
**)	Only exists with an Advanced device and EtherNet/IP field bus protocol.

Fig. 10-28: "Ethernet" Submenu

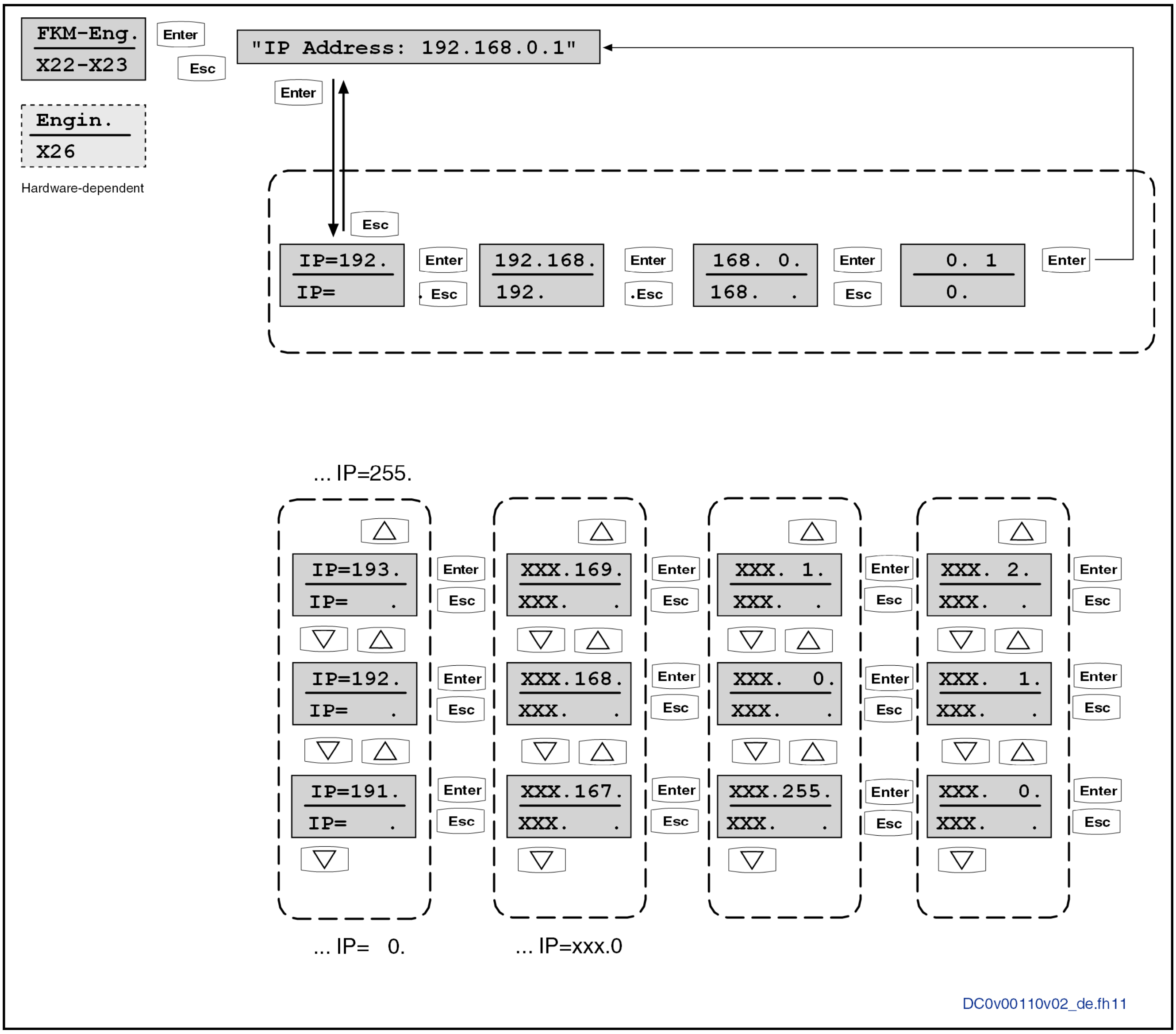


Fig. 10-29: Example for Setting the IP Address for "FKM-Eng. X22-X23"

Automatic assignment of the subnet mask

If the IP address is changed via the display, the subnet mask is automatically changed for 3 specific networks. The table below shows the dependencies:

IP address	Subnet mask
Class C network with: 192.x.x.x	255.255.255.0
Class B network with 172.x.x.x	255.255.0.0
Class A network with 10.x.x.x	255.0.0.0

If this setting is not desired, the subnet mask can be subsequently adjusted via the display.

Automatic activation of the IP addresses

If at least one setting is changed in the IP addresses, the command "C6100 Command Activate IP settings" is automatically started when the Menu Level II is exited via the "Esc" key and the modified IP settings are set valid.

Only those changes are set valid which had been previously confirmed in an Edit Level with the "Enter" key. The command is not executed, if no changes were made or if all changes were discarded by using the "Esc" key.

Comm. Protocol

Depending on the master communication hardware, this menu contains different elements. See Figure "Comm. Protocol" on page 1059.

The View Level at first displays the master communication protocol currently set. By pressing the Enter key again, the protocol can be changed in the case of the MultiEthernet option; otherwise, the master communication protocol can be activated/deactivated here.

If the drive is used as a stand-alone device without master communication connection, "not act." should be used as the master communication protocol.

The figure illustrates the structure of the menu for IndraDrive Cs Basic without master communication option.

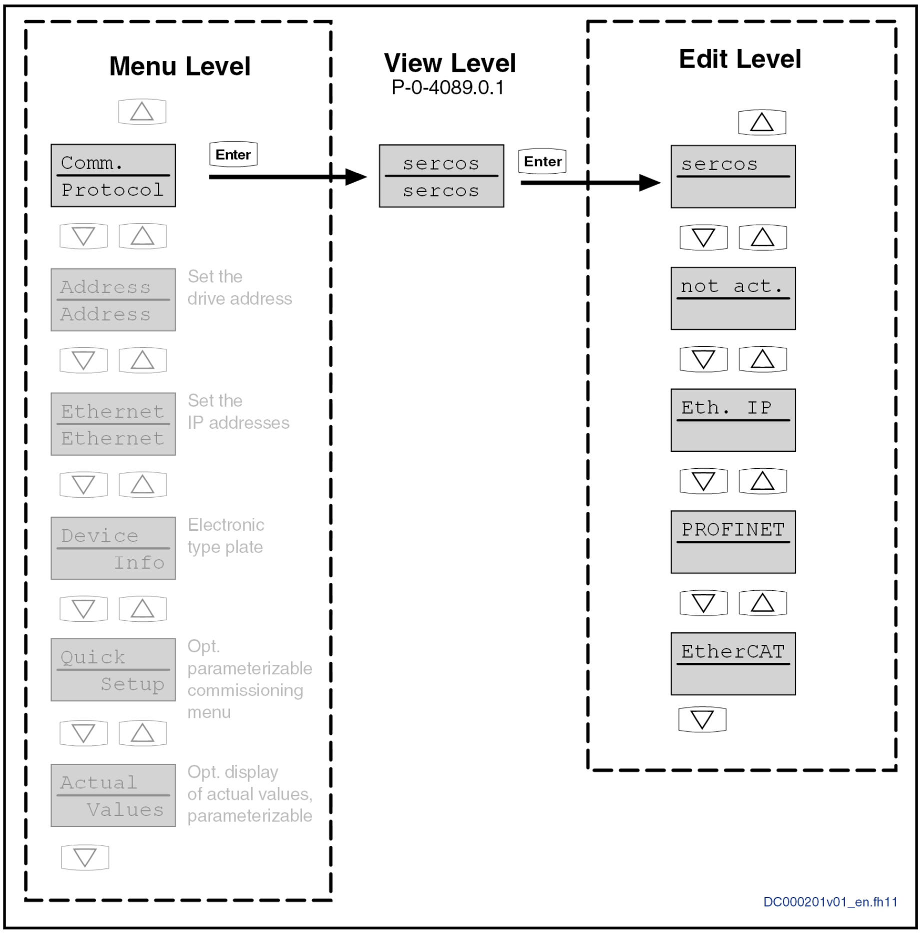


Fig. 10-30: Submenu of "Comm. Protocol" of IndraDrive Cs Basic in Standard Characteristic

Possible options on the Edit Level with different hardware:

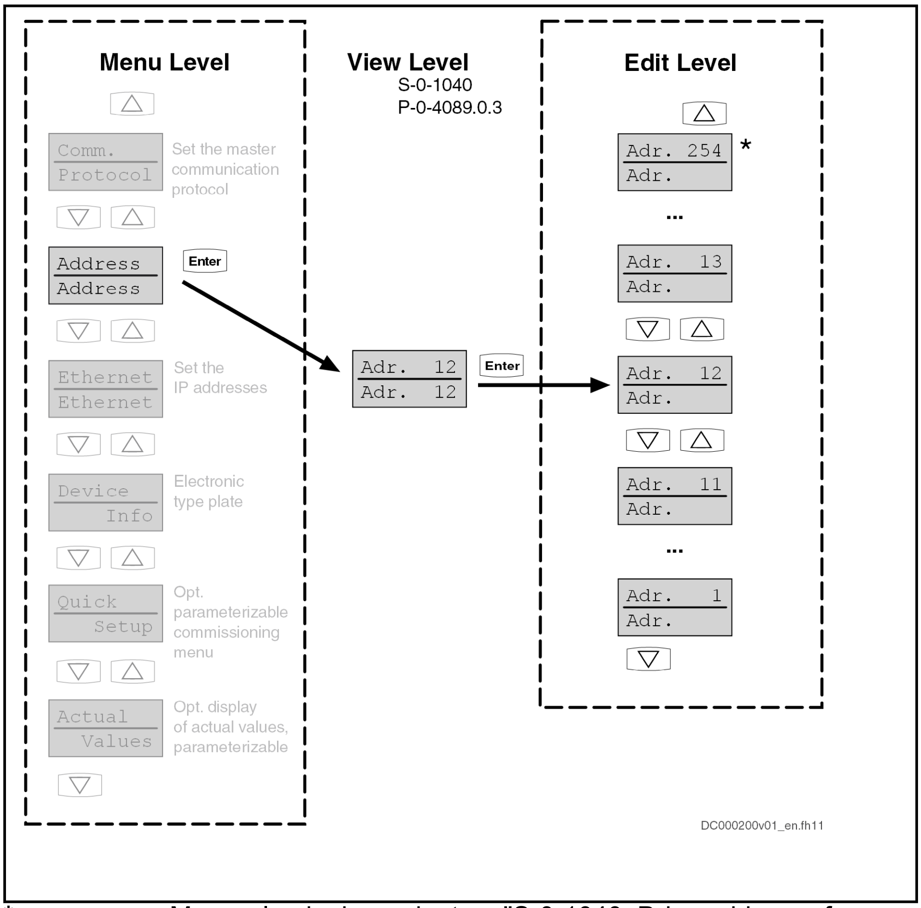
Hardware	Options						
IndraDrive Cs Basic/Advanced Standard	not act.	sercos	Eth. IP	EtherCAT	PROFINET	-	-
IndraDrive Cs Basic/Advanced incl. PROFIBUS Interface	not act.	-	-	-	-	PROFIBUS	-

Hardware	Options						
IndraDrive Cs Basic/Advanced incl. CANopen Interface	not act.	-	-	-	-	-	CANopen
IndraDrive Cs Economy S3*)	not act.	sercos	-	-	-	-	-

*) Name according to the type plate

Address

Under "Address", you can find the drive address currently set. Depending on the type of addressing, this is the "S-0-1040, Drive address of master communication" or the "P-0-4089.0.3, Device Address". This address is used by the higher-level controller for logical identification of the drive. In the case of an incorrect configuration, the control unit can thus recognize that there is a drive with a wrong configuration in the group.



* Max. value is dependent on "S-0-1040, Drive address of master communication", "P-0-4089.0.3, Device Address"

Fig. 10-31: Submenu for "address"

Device Info

Under "Device Info" you can find identification data, such as e.g. the application type and the firmware version. Hardware information, too, e.g. can be found in this menu, that includes type code, material number and serial number.

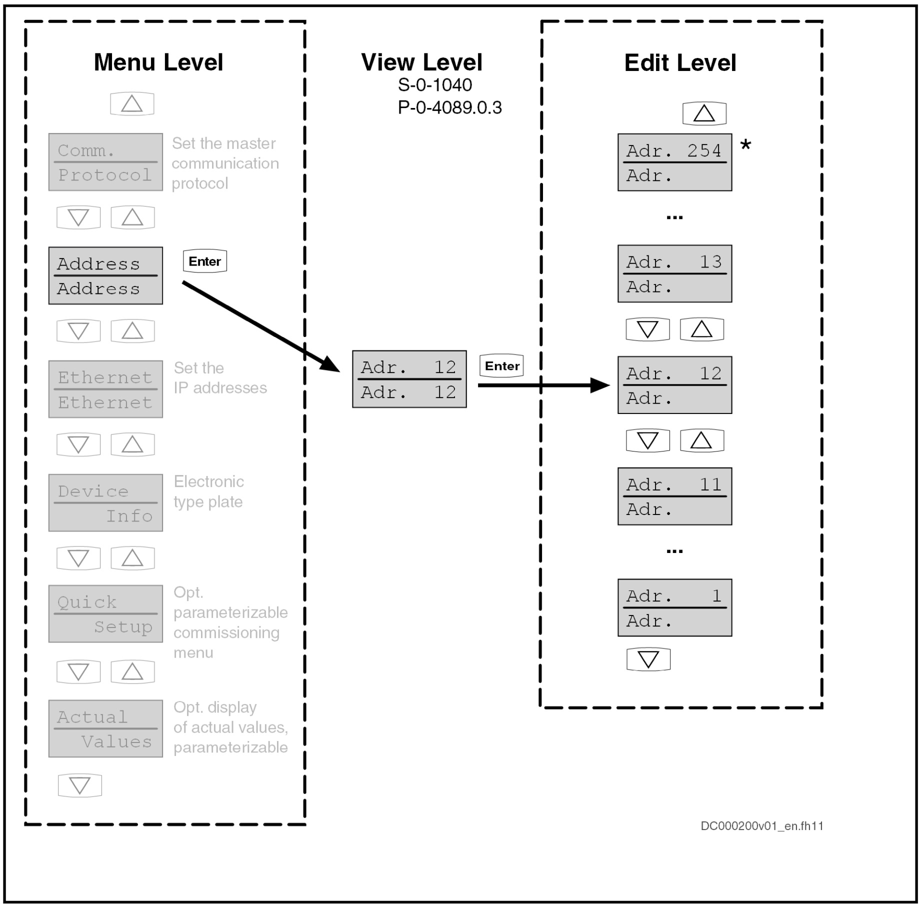


Fig. 10-32: Structure under "Device Info"

Assignment of the Entries in the "Device Info" Menu to the Parameters Used

Device variant	Menu	Entry	Parameter used
	-	FW revision	S-0-1300.0.9
IndraDrive Cs	Drive	Device Name	S-0-1300.0.4
		HW revision	S-0-1300.0.8
		Order Number	S-0-1300.0.11
		Serial Number	S-0-1300.0.12
	Motor	Device Name	S-0-1300.20.4
		HW revision	S-0-1300.20.8
		Order Number	S-0-1300.20.11
		Serial Number	S-0-1300.20.12

Device variant	Menu	Entry	Parameter used
double-axis device	Power Unit	Device Name	S-0-1300.0.4
		HW revision	S-0-1300.0.8
		Order Number	S-0-1300.0.11
		Serial Number	S-0-1300.0.12
	Control Unit	Device Name	S-0-1300.1.4
		HW revision	S-0-1300.1.8
		Order Number	S-0-1300.1.11
		Serial Number	S-0-1300.1.12
	Motor 1	Device Name	S-0-1300.20.4
		HW revision	S-0-1300.20.8
		Order Number	S-0-1300.20.11
		Serial Number	S-0-1300.20.12
	Motor 2	Device Name	S-0-1300.21.4
		HW revision	S-0-1300.21.8
		Order Number	S-0-1300.21.11
		Serial Number	S-0-1300.21.12
Indra Drive M	Power Unit	Device Name	S-0-1300.0.4
		HW revision	S-0-1300.0.8
		Order Number	S-0-1300.0.11
		Serial Number	S-0-1300.0.12
	Control Unit	Device Name	S-0-1300.1.4
		HW revision	S-0-1300.1.8
		Order Number	S-0-1300.1.11
		Serial Number	S-0-1300.1.12
	Motor 1	Device Name	S-0-1300.20.4
		HW revision	S-0-1300.20.8
		Order Number	S-0-1300.20.11
		Serial Number	S-0-1300.20.12

Tab. 10-9: Structure of Device Info Menu Depending on the Device

Pertinent Parameters:

S-0-1300.x.9, Software version

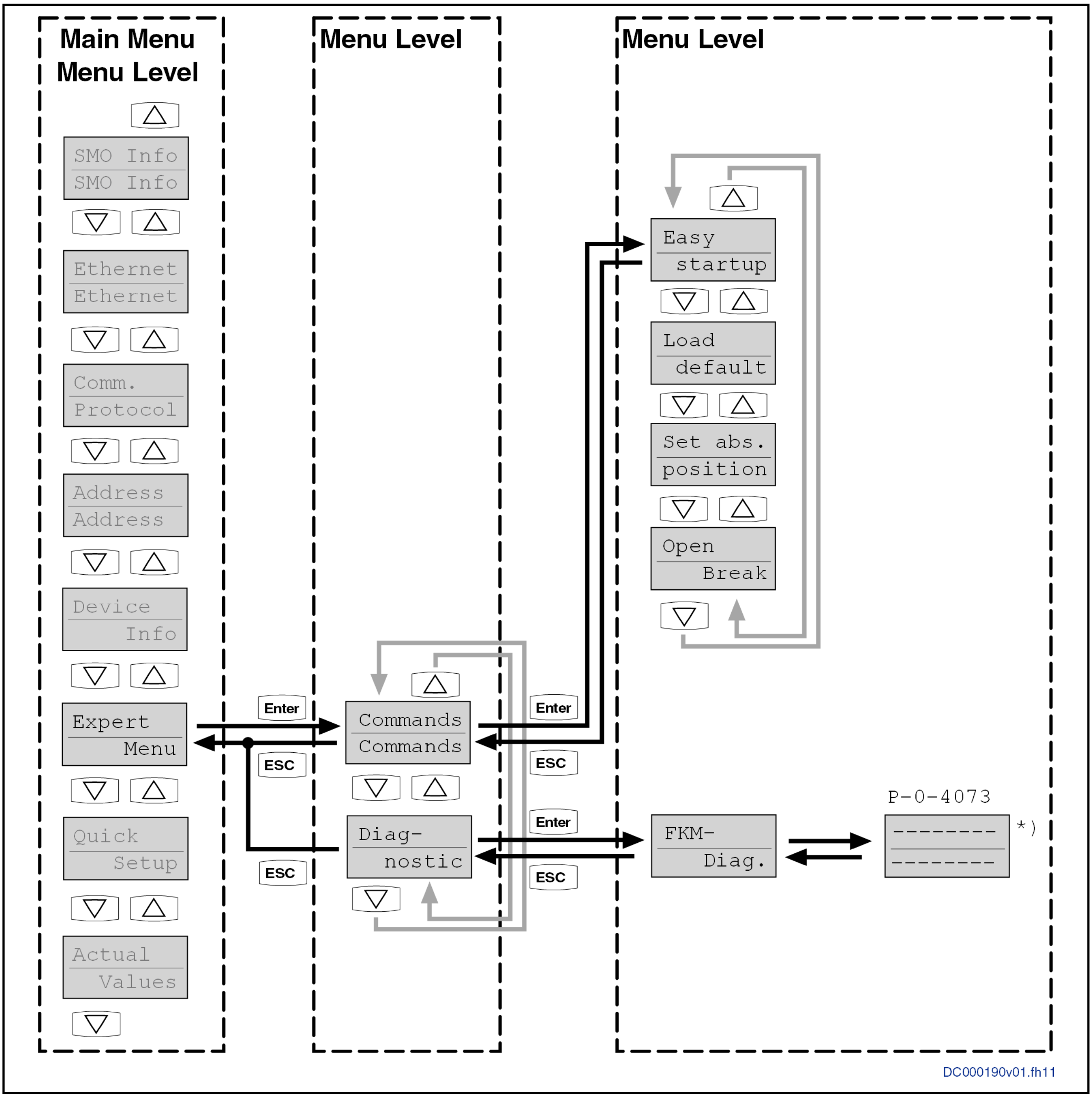
S-0-1300.x.4, Device Name

S-0-1300.x.8, Hardware version

S-0-1300.x.11, Order Number

S-0-1300.x.12, Serial Number

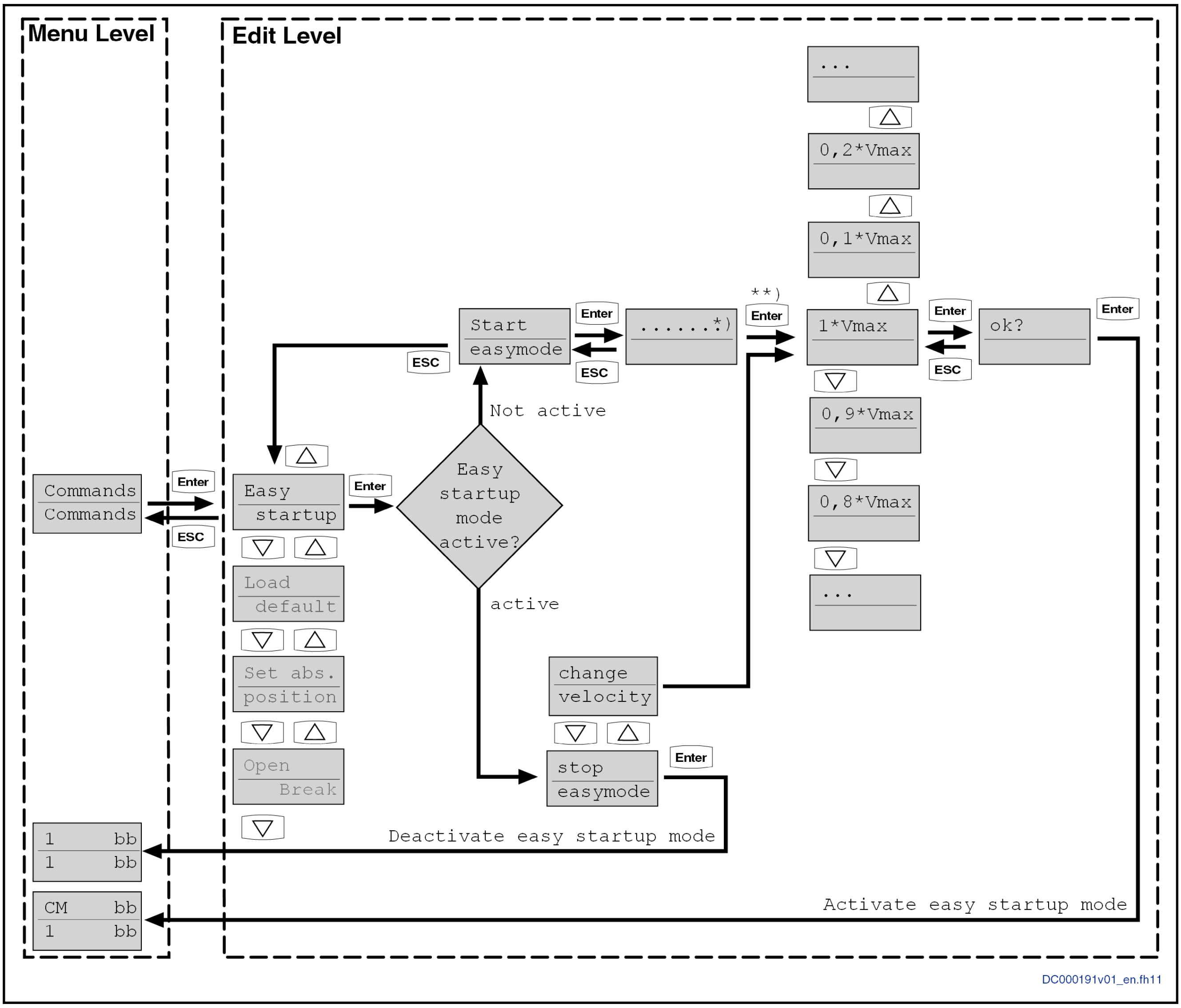
Expert Menu with Sub-Menu Commands and Diagnostics



*) The status of the field bus master communication is stored in plain text in this parameter. This diagnosis is dependent on the field bus in use and is based on the names used in the standard.

Fig. 10-33: DC000190_Aufbau_Expert_Menue_Commands_Diagnose_gti

Handling, Diagnostic and Service Functions



*) Display as continuous text: v control with Vmax=xxx rpm

**) "Enter" or at the end of the continuous text display

Fig. 10-34: DC000191_Ablauf_Easy_Startup_gti, DE

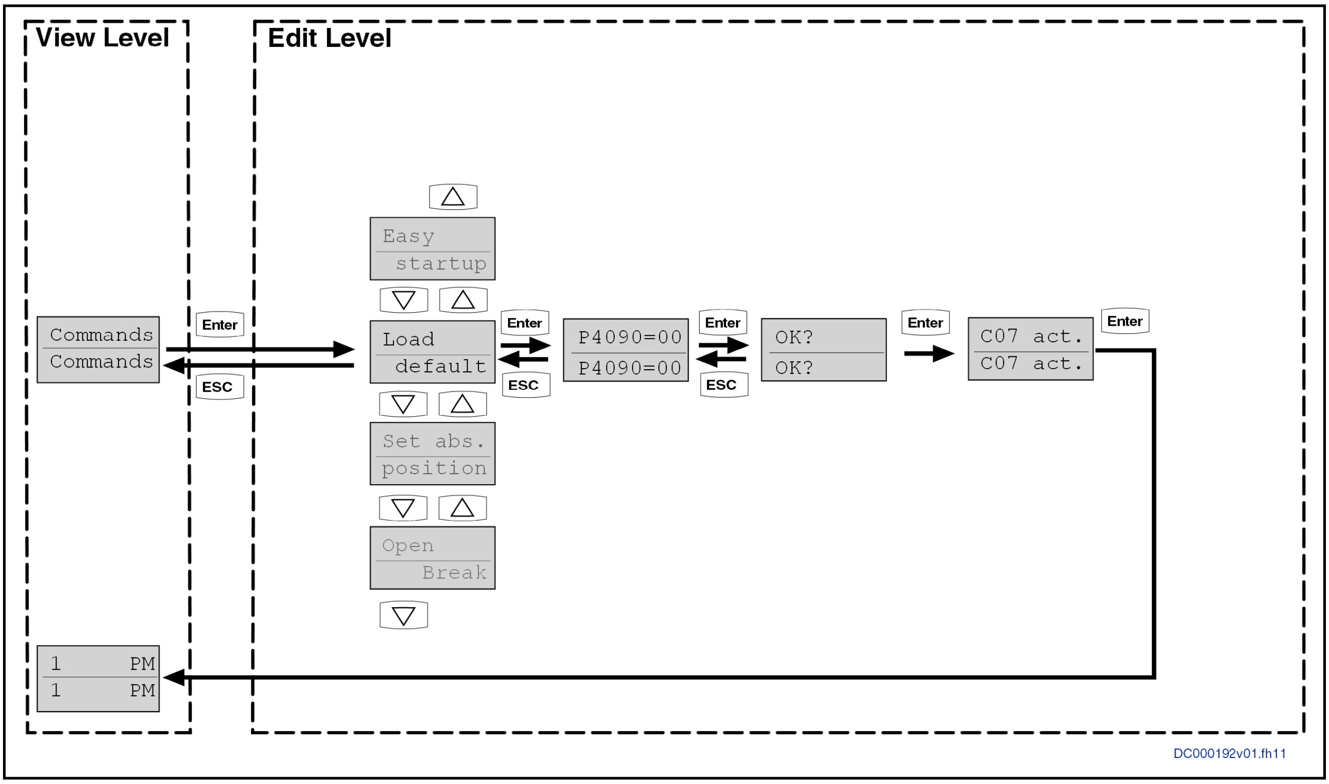


Fig. 10-35: DC000192_Ablauf_Basisparameter_laden_gti

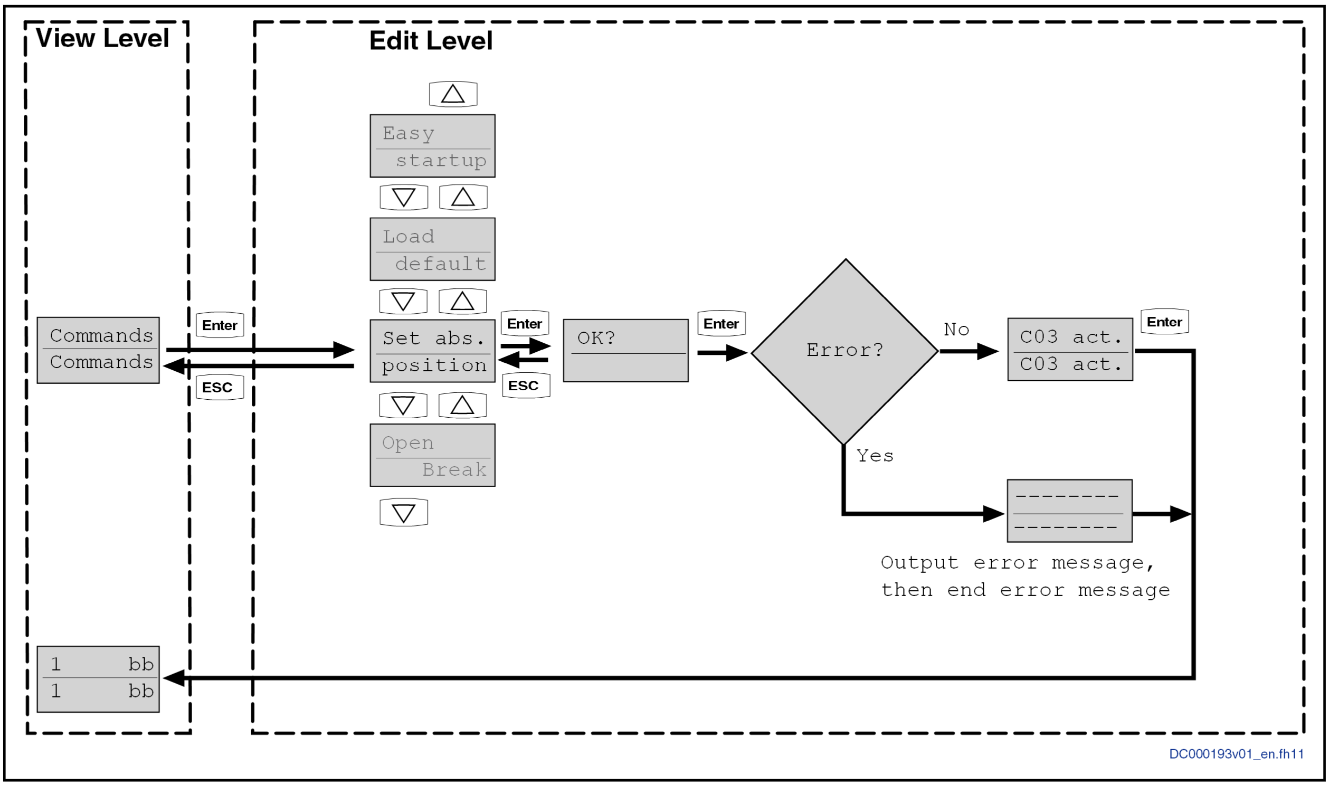


Fig. 10-36: DC000193_Ablauf_Absolutmass_setzen_gti, DE

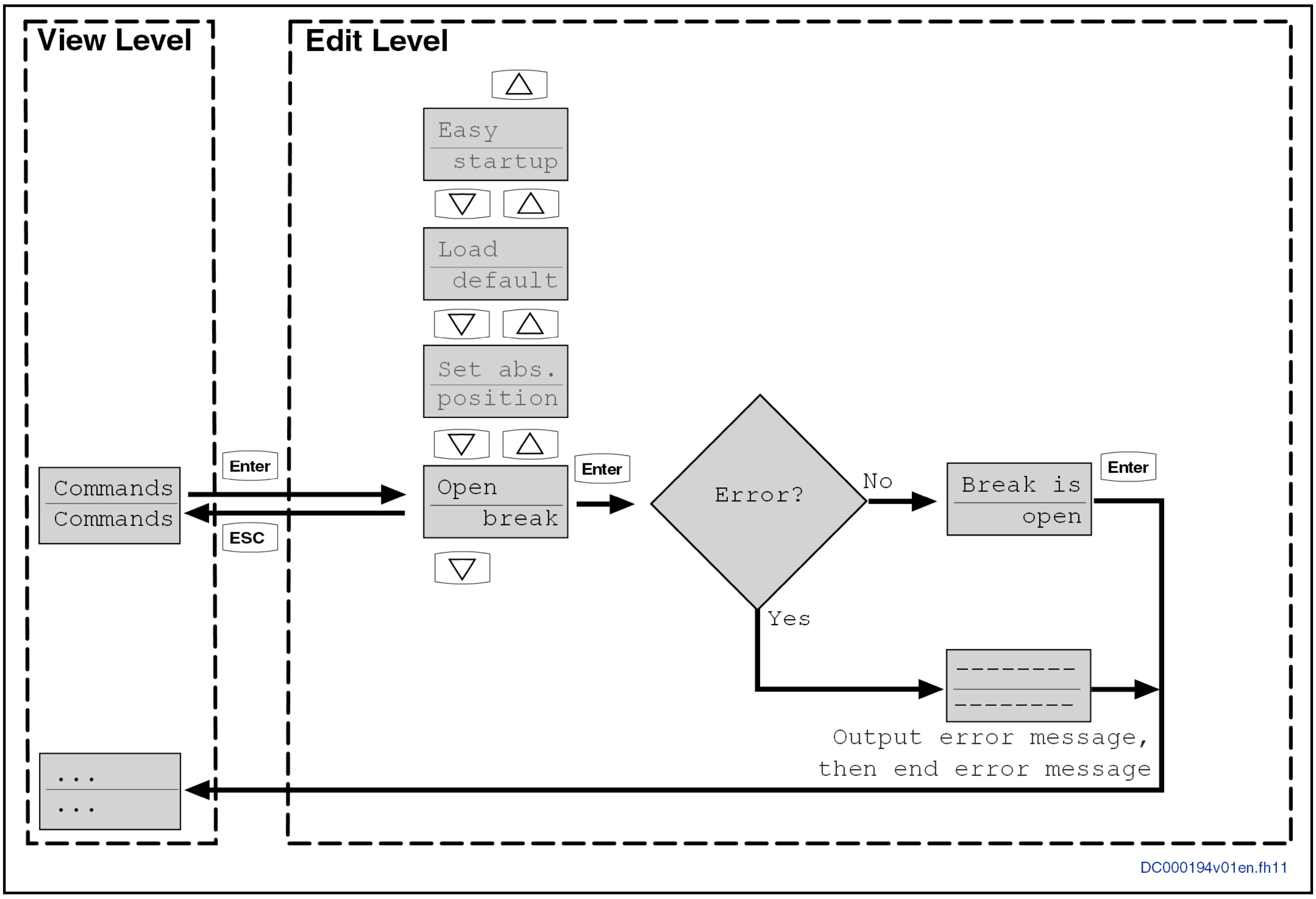


Fig. 10-37: DC000194_Ablauf_Bremse_oeffnen_gti

Quick Setup

"Quick Setup" is an optional sub-menu with entries parameterizable on the user-side. Each entry contains a scaled value directly connected to a parameter, see also "P-0-0680.0.1, Control panel: Config. list of changeable app. parameters".

Actual Values

"Actual Values" is an optional sub-menu with entries parameterizable on the user-side. Each entry contains a scaled value directly connected to a parameter, see also "P-0-0680.0.2, Ctrl panel: Config. list of app. parameters to be displayed".

10.6 Firmware Replacement

10.6.1 Brief Description

Basic Principles

Explanation of Terms

The following cases are distinguished for firmware replacement:

- **Release update**

  An old firmware release (e.g. MPB18**V06**) contained in the device is replaced by a new firmware release (e.g. MPB18**V10**).

- **Version upgrade**

  The old firmware version contained in the device is replaced by a new firmware version (example: MPB**17**V10 is replaced by MPB18V06).

☞ The following chapters regarding the release update and firmware upgrade exclusively apply to devices of the IndraDrive Cs type, as well as control sections (CSB02, CSH02, CDB02, CSE02) and IndraDrive Mi (KSM02, KMS02). The information does **not** apply to IndraDrive HCQ / HCT, but is described in the separate documentation "Rexroth IndraMotion MTX micro12VRS System Description" (DOK-MTXMIC-SYS*DES*V12-PR01-EN-P, mat. no. R911334369).

How to Replace the Firmware

Firmware for IndraDrive can be replaced using the following hardware and software:

- Computer with FireFox or Internet Explorer web browser or
- Computer with "IndraWorks" software or
- Computer with TFTP client
- IndraMotion Service Tool (IMST) or IndraDrive Service Tool (IDST) (as of MPx18V10)

☞ "IndraMotion Service Tool (IMST)" or "IndraDrive Service Tool (IDST)" allow accessing the drive system, e.g. for remote diagnostics. Besides, authorized users can handle different service cases with IMST or IDST, such as replacing drive components, loading parameters or updating/upgrading the drive firmware.

"IndraMotion Service Tool (IMST)" additionally analyzes drive systems connected via cross communication (CCD). Further information on "IndraMotion Service Tool (IMST)" and "IndraDrive Service Tool (IDST)" is described in the separate documentation „Rexroth IndraDrive Service Tools IMST/IDST" (DOK-IM*MLD-IMSTIDSTV13-RE**-EN-P; mat. no. R911342652).

☞ The "IndraWorks" commissioning software can be ordered from Rexroth.

The scope of supply of "IndraWorks" contains a documentation which describes the operation of the program.

To be Noticed

After every firmware replacement (release update and version upgrade), check the following parameters for validity:

- P-0-2003, Selection of functional packages
- P-0-4089.0.1, Master communication: Protocol

It might possibly be necessary to set them valid during the first run-up after the firmware replacement.

IndraDrive HCQ / IndraDrive HCT

The firmware replacement for "IndraDrive HCQ" / "IndraDrive HCT" is described in the documentation "Rexroth IndraMotion, MTX micro 12VRS, System Description" (DOK-MTXMIC-SYS*DES*V12-PR01-EN-P, material number R911334369).

Preparations and Conditions for Firmware Replacement

Preparing the Firmware Replacement

You have to make the following preparations for firmware replacement:

1. Drive controller must be on (24 V supply).
2. Drive controller **mustn't** be in operating mode (communication phase 4) (cf. P-0-0115).

3. It is recommended to save the backup parameters before replacing the firmware (see Functional Description "Loading, Storing and Saving Parameters").

General Notes on How to Carry Out Firmware Replacement

You have to observe the following points when carrying out the firmware replacement:

- For firmware replacement via IndraWorks or IndraMotion Service Tool (IMST) resp. IndraDrive Service Tool (IDST), Ethernet communication with the drive must be possible. (IMST and IDST are available as of MPx18V10.)
- Do not switch off the 24 V control voltage while replacing the firmware.
- The firmware replacement always must be carried out completely.

Communication Types

The engineering communication works in different ways, depending on the activated bus system (cf. P-0-4089.0.1). Make the settings and comply with the requirements in accordance with the bus system used. For further information, see "chapter TCP/IP Communication".

Via the programming module, the active IP settings can be viewed or adjusted, if necessary (see Functional Description "Standard Control Panel").

> ☞ After you have changed the IP settings, the device must be restarted for activating the settings. If several devices have been connected via the master communication bus, you have to make sure that an unequivocal IP address is assigned to each node.

IP Configuration in the Easy Menu

See Functional Description "Standard Control Panel"

IP Settings at the Computer

See Microsoft help, keyword "LAN connection"

10.6.2 Firmware Release Update

General Information

Before the firmware release update, it is recommended to save the backup parameters of the drive!

> ☞ If the firmware is replaced at a device activated in a safety-related way, this procedure must be recorded in the machine logbook, together with the axis identifier, configuration type data and parameterization type data.

Firmware Release Update with Computer

> ☞ When the safety technology options S3 or S4 are used, the system checks whether firmware and parameter set are compatible. This prevents the safety technology from being operated with an incompatible parameter set. Incompatible changes typically do not occur in the case of a release update. In the case of an incompatibility, it is possible to either
>
> - continue with the existing parameterization by reloading the originally available firmware, or
> - continue with the new firmware by means of initial commissioning (incl. loading of basic parameters for SMO contained therein)

1. Connect drive to computer (recommended: Cat5e Ethernet cables)

2. Load firmware

   There are three possibilities of performing a firmware release update using a computer:

   - By means of IndraWorks
   - With a TFTP client
   - Via the supplied web interface IMST or IDST.

     This option only applies to firmware updates of MPx18V10 and above; IMST and IDST are not available for older versions.

   1. *Firmware Download with IndraWorks*

      1.1 Call "IndraWorks".

      1.2 Load project for corresponding axis or create new project; to do this, address axis via Ethernet.

      1.3 Switch project "online".

      1.4 Select/highlight controller and call "Firmware Management" in context menu.

      A new window opens and firmware currently available in drive is displayed.

      1.5 Highlight new firmware (*.ibf file) in upper part of dialog and start firmware download via "Download" button.

      Firmware download runs automatically and all required firmware components are loaded to drive.

      1.6 After firmware download has been completed, close "Firmware Management" window.

   2. *Firmware Download Using a TFTP Client*

      2.1 Firmware update service is made available via a TFTP server. Command for sending the firmware is "put" command. The TFTP cent must transmit the file in the binary format.

☞ It is possible with any TFTP client supporting this command (e.g. Windows command line program "tftp.exe") to carry out a firmware release update **without IndraWorks**.

Example (with "Microsoft Windows consoles TFTP client"):

To carry out a firmware release update, only a "put" request is transmitted. Do not use an optional alternative name for the file on the target system. The IP address of IndraDrive must be specified as the target (the standard is 192.168.0.1): `tftp -i 192.168.0.1 put FWA-INDRV_-MPB-17V12-D5.ibf`

The parameter "-i" means that the file is to be transmitted in binary form.

See also Functional Description: "Firmware Download via TFTP Server"

   3. *Firmware Download with IMST/IDST (as of MPx18V10)*

      3.1 Enter IP address of IndraDrive in web browser

      3.2 Log in as service user at web interface

      3.3 In navigation tree on the left side select "Firmware Update" dialog in "Service" folder

3.4 Select new firmware by clicking "Search" button, firmware update is started by clicking download button

3. Restart drive

   At the end of the update, IndraWorks and IMST/IDST automatically provide the option to restart IndraDrive via the reboot command S-0-1350. As an alternative, IndraDrive can be restarted by means of control voltage reset

4. Put machine into ready-for-operation status again according to machine manufacturer's instructions.
5. Check functions of the drive.

10.6.3 Firmware Version Upgrade

General Information

When firmware in a drive controller is replaced by firmware of a **more recent version**, this is called firmware version upgrade (e.g., FWA-INDRV*-MPB-**16**V24-D5 replaced by FWA-INDRV*-MPB-**17**V12-D5).

☞ **Before** carrying out the firmware version upgrade, you must save all parameters (e.g., with "IndraWorks"). **After** firmware replacement, the parameters must be restored, because the command "C07_1 Load defaults procedure command (factory settings)" is carried out automatically. After the desired parameter file was loaded, the drive controller is ready for operation again.

Saving Parameter Values

Before firmware upgrade, all application-specific parameter values must be saved on a data carrier. The parameter backup can be carried out by means of:

- **Commissioning software "IndraWorks"**

  → Saving parameter values on external data carrier

- or -

- IndraMotion Service Tool (IMST) or IndraDrive Service Tool (IDST) (as of MPx18V10)

  → Saving parameter values on external data carrier

- or -

- **Control master**

  → Saving parameter values on master-side data carrier

Version Upgrade with "IndraWorks"

Requirements

The following requirements should have been fulfilled in order that carrying out the firmware version upgrade with "IndraWorks" makes sense:

- Existing Ethernet connection between PC and drive controller
- Current parameter setting of axis was saved.

When upgrading from MPB16VRS to MPB17VRS, for example, the error F8100 is sometimes generated during the drive controller's first run-up. This error can be cleared via the display and will not occur again during the next booting process.

Firmware Upgrade with "IndraWorks"

Carrying out the firmware version upgrade with "IndraWorks" requires the following steps:

1. **Load firmware**
   - 1.1 Call "IndraWorks".
   - 1.2 Load project for corresponding axis or create new project; to do this, address axis via Ethernet.
   - 1.3 Switch project "online".
   - 1.4 Select/highlight controller and call "Firmware Management" in context menu.

     A new window opens and firmware currently available in drive is displayed.
   - 1.5 Highlight new firmware (*.ibf file) in upper part of dialog and start firmware download via "Download" button.

     Firmware download runs automatically and all required firmware components are loaded to drive.
   - 1.6 After firmware download has been completed, close "Firmware Management" window.
   - 1.7 Reboot drive controller
2. **Put drive into ready-for-operation state**

   ⇒ Switch project "online".

   After project has been switched "online", a message sometimes signals that "IndraWorks" could not establish communication to drive via Ethernet interface, as drive-internal settings for Ethernet communication were reset.

   ⇒ In this case, reconfigure communication via button "Search for devices"!

   ⇒ As firmware in drive no longer complies with version stored in project, a corresponding message is displayed. Select desired option in dialog to make drive available in project again and allow reestablishing communication to device.

   ⇒ Manually set functional package and master communication protocol via corresponding parameters.

   ⇒ Activate command "C07_1 Load defaults procedure command (factory settings)". All buffered parameters are thereby set to their default values.
3. **Load parameter values**

   ⇒ Load parameter file which was saved.

   ⇒ Switch off drive and start it again so that the parameterization becomes active.
4. **Put machine into ready-for-operation state**

   ⇒ Put machine into ready-for-operation state again according to machine manufacturer's instructions.

   ⇒ Check functions of drive.

10.6.4 Possible Problems During Firmware Replacement

General Information

After an incomplete firmware update, the drive controller possibly is no longer operable.

Firmware replacement is carried out incompletely, if one of the following situations occurs during the sequence of firmware replacement:

- 24 V supply of control section is switched off
- Connection to drive is interrupted (e.g., defective interface cable)
- Crash of update software / of computer

If there isn't any valid firmware available in the control section, the loader is started. The text "LOADER active! IP address: 192.168.0.1" appears on the display in light writing. With the loader, it is possible to replace the firmware of the control section.

☞ Upon successful firmware replacement in the control section, a restart has to be carried out.

Firmware Replacement in Control Section in the Case of Error

The following steps are required for loading the firmware to the control section in the case of error:

1. Call "IndraWorks".
2. In menu, call firmware management under **Tools Drive ▸ Firmware Management.**

   A new window opens in which firmware file last used is displayed on PC.

3. Select "Download via Ethernet" tab.
4. Set IP address "192.168.0.1".
5. Highlight desired firmware (*.ibf file) and start firmware download via **Download** button.
6. Firmware download runs automatically and all required firmware components are loaded to drive.
7. After firmware download has been completed, close "Firmware Management" window.
8. Restart drive.

10.7 Optional Memory

10.7.1 Brief Description

Fields of Application

- Accessing file level via FTP server
- Using a web application via web server
- Expanded MLD project (4 MB of memory space)
- Extended retain data memory for MLD (31,725 bytes), no longer available as of MPx17V10
- Backup & Restore of the operating data
- MLD programs can use memory to store user data

Overview of Functions

The optional memory serves as a backup memory. If a memory card has been plugged when the device is booted, the card is checked for a valid partition. Besides, these folders are created as a standard, if they do not exist:

Folder	Significance
USER	Folder is at free disposal
PLC	Storage location of an MLD project and, if necessary, of the MLD retain data when replacing devices

Backup	Internal memory of the Backup & Restore function
Documentation	Presently not used; the user can employ it to file machine-specific documentation
Tools	Storage location for web application of Rexroth
Temp	Folder is at free disposal

Tab. 10-10: List of Automatically Created Folders

It is impossible to use a memory card plugged during operation. To use the memory card, the device must be restarted. This can be done, for example, via "S-0-1350, C6400 reboot command".

Features

- Use of a partition
- FAT-16 format
- Capacity limited to a max. of 2 GB
- Only Rexroth SD cards are allowed

Hardware Requirements

IndraDrive Cs Advanced

Pertinent Parameters

- P-0-1521 Programming module identifier
- P-0-4066 Card Identification Data

Pertinent Diagnostic Messages

- C6500 Archive device data
- C6600 Restore device data
- C6700 Update of device data
- F2101 File system structure error on the memory card
- F2120 Memory card could not be initialized

10.8 Replacing the Controller

10.8.1 Overview

A controller of the IndraDrive range consists of the components power section, control section and programming module / control panel (incl. firmware). The control section can be configured with additional components (e.g., optional safety technology module). The control section and power section are firmly connected; only Rexroth service engineers or especially trained users are allowed to replace individual components. The paragraphs below describe how to replace the complete controller.

☞ The controller must be replaced by a device of the identical type. Only in this way is it ensured that the originally configured functions can be used in unchanged form.

When devices with integrated safety technology are used, it is necessary to ensure by organizational measures, e.g. by a lockable control cabinet, that the device is exclusively replaced by an authorized person. It is also necessary to ensure that the replacement of devices is not carried out for several axes at the same time in order to avoid accidentally interchanging them.

A device which is intended for replacement and has already been in operation (thus is not in the factory-new condition as supplied), must be brought to the condition as supplied again ["load defaults procedure (factory settings)", command C0750] before it is used.

The figure below illustrates the basically required individual steps.

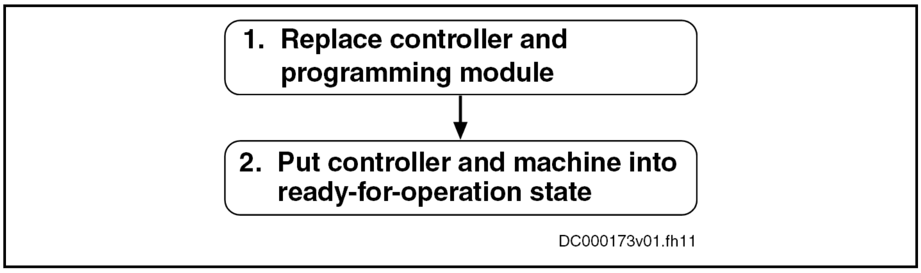


Fig. 10-38: Sequence of Controller Replacement

☞ "IndraMotion Service Tool (IMST)" or "IndraDrive Service Tool (IDST)" allow accessing the drive system, e.g. for remote diagnostics. Besides, authorized users can handle different service cases with IMST or IDST, such as replacing drive components, loading parameters or updating/upgrading the drive firmware.

"IndraMotion Service Tool (IMST)" additionally analyzes drive systems connected via cross communication (CCD). Further information on "IndraMotion Service Tool (IMST)" and "IndraDrive Service Tool (IDST)" is described in the separate documentation „Rexroth IndraDrive Service Tools IMST/IDST“ (DOK-IM*MLD-IMSTIDSTV13-RE**-EN-P; mat. no. R911342652).

10.8.2 How to Proceed when Replacing Controllers

Replacing Controller and Programming Module

1. Open the main switch
2. Make sure the main switch cannot be switched on again.
3. Make sure drive controller is de-energized.

   WARNING! Lethal electric shock by live parts with more than 50 V! Before working on live parts: De-energize installation and secure power switch against unintentional or unauthorized re-energization. Wait at least 30 minutes after switching off the supply voltages to allow discharging. Check whether voltage has fallen below 50 V before touching live parts!
4. Separate connection lines from the controller.
5. Dismount controller from the control cabinet.
6. Dismount programming module / control panel
   - With IndraDrive C/M/Cs: Unplug programming module / control panel from the defective device.
   - With IndraDrive Mi: Dismount programming module (X107) from the defective device, write down positions of the address selector switches S4 and S5 (the address selector switches are to be found under the connections X103.1 and X103.2).
7. Mount programming module / control panel
   - With IndraDrive C/M/Cs: Plug programming module / control panel of the defective device in the new controller.
   - With IndraDrive Mi:
     1. Set the address selector switches in the same way as for the defective device.
     2. Dismount cover from slot X107.

3. Plug programming module of the defective device in the replacement device.
4. Mount cover of slot X107.

   NOTE: Damage to the programming module caused by penetration of dirt or moisture. When mounting the cover of X107, make sure that the sealing ring is undamaged and fits correctly.

8. Mount new controller.

☞ The controller must be replaced by a device of the identical type. Only in this way is it ensured that the originally configured functions can be used in unchanged form.

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9. Connect device according to machine circuit diagram

Putting Controller and Machine Into Ready-For-Operation State

1. Restore control voltage.
2. Put machine into ready-for-operation state again according to the machine manufacturer's instructions.
3. Activate safety technology (only for active Safe Motion with S3/S4 option)

   With single-axis devices, the following message appears on the display of the control panel during the booting process:

   "Load new Safety?"

   With double-axis devices, the following message appears on the display of the control panel during the booting process:

   "**.1 Load new Safety?**" for Axis 1 or "**.2 Load new Safety?**" for Axis 2

   Pressing the "Enter" key at the control panel acknowledges the message. The safety technology parameters are now loaded from the control panel to memory of the optional safety technology module.

☞ IndraDrive Mi does not feature a control panel; this is why the parameter image of safety technology must be activated by executing the command "P-0-3231.0.3, C8300 SMO: Command Activate parameter image", e.g. by means of the IndraDrive Service Tool (IDST).

The error "F8330, SMO: Configuration data record has not been activated" generated during the booting process signals that the active image identifier on the programming module does not comply with the image identifier that was stored on the safety technology hardware. After the command C8300 was successfully executed, the error must be cleared by "clear error" (C0500). The command execution is described in the Functional Description of the firmware, see chapter "Command Processing".

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4. Check functions of the drive.
5. Check safety technology parameters (only for active Safe Motion with S3/S4 option)

   Completing the process, you must check with activated safety technology whether the correct safety technology parameters have been loaded for the drive.

The replacement of the device must be recorded in the machine logbook. For this purpose, the data of the following safety technology parameters must be documented accordingly and checked for correctness (they can be queried via the control panel in the "SMO Info" menu; for IndraDrive Mi, the data must be read by means of the IndraDrive Service Tool (IDST), for example, because IndraDrive Mi does not feature a control panel):

- P-0-3230, SMO: Password level
- P-0-3235.0.1, SMO: Active axis identifier
- P-0-3234.0.1, SMO: Configuration checksum
- P-0-3234.0.2, SMO: Operating hours at last change of configuration
- P-0-3234.0.3, SMO: Configuration change counter
- P-0-3234.0.4, SMO: Parameterization checksum
- P-0-3234.0.5, SMO: Operating hours at last change of parameterization
- P-0-3234.0.6, SMO: Parameterization change counter

10.8.3 Possible Problems During Controller Replacement

Display Defective or Programming Module Defective

If the programming module / the display is defective, the parameter values saved after initial commissioning must be loaded.

NOTICE

The parameter values saved after initial commissioning are not generally suited for reestablishing the operatability of the drive after a device has been replaced!

Check actual position values and active target position before setting drive enable!

When firmware and drive parameters are to be transmitted to the replacement controller, the required firmware and a parameter backup of the respective axis must be available.

1. Reestablish the control voltage supply of the controller.
2. Carry out firmware update, see also chapter "Firmware Replacement"
3. Via the "IndraWorks" commissioning tool or the control master, load the parameter file to the controller:
   - "IndraWorks" commissioning tool

     Load the parameter values saved after initial commissioning to the controller.
   - "IMST" or "IDST" service tool

     Load the parameter values saved after initial commissioning to the controller.
   - Control master

     Load the axis-specific parameter values [according to list parameters "S-0-0192, IDN-list of all backup operation data" and "P-0-0195, IDN list of retain data (replacement of devices)"] saved after initial commissioning.

☞ With active Safe Motion, the initial commissioning or serial commissioning of the controller is required after the programming module has been replaced!

☞ In the case of drives with absolute value encoder and modulo format, the position data reference must be established again after having loaded the parameter values saved after initial commissioning, even if the actual position values are signaled to be valid via the parameter "S-0-0403, Position feedback value status"!

10.9 Enabling of Functional Packages

10.9.1 Brief Description

The scope of functionality of the IndraDrive firmware can be scaled by the user. This allows adjusting the scope of firmware functions to the respective requirements and, if necessary, reducing its complexity.

The drive functionality is scaled by licensing (enabling) optional expansion packages that are available in addition to the standard base package of the respective IndraDrive firmware.

See also "Overview of Functions/Functional Packages"

Features

- Activated functional packages displayed in parameter "P-0-2004, Active functional packages"
- Firmware type designation in parameter "S-0-0030, Manufacturer version" dynamically adjusted to the active functional packages displayed in P-0-2004
- Functional packages activated/deactivated via parameter
- Count of operating hours counter at last change of access enable is stored

Pertinent Parameters

- S-0-0030, Manufacturer version
- S-0-1350, C6400 reboot command
- P-0-2002, Oper. hours of contr. sect. at change of functional packages
- P-0-2003, Selection of functional packages
- P-0-2004, Active functional packages

Pertinent Diagnostic Messages

- C0202 Parameter limit error (->S-0-0423)
- C0299 Configuration changed. Restart

10.9.2 Functional Description

Changing the Active Functional Package Selection

The functionality of the drive firmware is divided into several functional packages. By enabling certain packages, it can be adjusted to the requirements of the respective application.

Basically, there are the following possibilities of subsequent scaling of the drive functionality:

- **Reducing** the already licensed scope of functions in order to reduce the complexity of the firmware
- **Expanding** the scope of functions originally ordered (additional licensing)

☞ Non-licensed functional packages must not be used. Enabling functional packages which are not part of the originally ordered scope of functions requires additional licensing that is not free of charge! If you use a non-licensed function, any guarantee on the part of Rexroth will expire.

The count of the operating hours counter at the change of access enable for functional packages is stored in parameter P-0-2002. The Rexroth staff can therefore provide evidence of non-licensed drive functions that have been enabled.

Parameter P-0-2003 is available for selecting the functional packages; parameter P-0-2004 for displaying the activated packages.

The following assignment applies:

Bit No.	Name of package (Bit = 1 → Package has been selected)	Rules for selection via P-0-2003
0	Base package "open-loop"	- As an alternative to bit 1
1	Base package "closed-loop"	- As an alternative to bit 0
2	Not used	--
3	Not used	--
4	Expansion package "servo function" (SRV)	- As an alternative to bit 5 or 6 - Not with "open-loop"
5	Expansion package "synchronization" (SNC)	- As an alternative to bit 4 or 6
6	Expansion package "main spindle" (MSP)	- As an alternative to bit 4 or 5
7	Not used	--
8	Additional package "IndraMotion MLD Advanced" (MA)	- For MPC only - Only in conjunction with bit 1 (closed-loop) and bit 9 (IndraMotion MLD)
9	Additional package "IndraMotion MLD" (ML or TF)[1)]	- Not for MPE
10 to 31	Not used	--

Tab. 10-11: Selecting the Functional Packages via Parameter P-0-2003

☞ You can purchase the functional package option "ALL" and thereby license all three above-mentioned expansion packages (SRV, SNC, MSP). This allows you using any of these expansion packages.

Example

The following setting is required in P-0-2003 to enable the base package "closed loop" and the expansion package "servo function":

- Bit 1 = 1 for the base package "closed loop"
- Bit 4 = 1 for the expansion package "servo function"

→ P-0-2003 = 0x0012

These settings are displayed in parameter P-0-2004, in case parameter P-0-2003 is changed they are only displayed after repeated booting process.

The figure below illustrates the interaction of the parameters involved in enabling of functional packages.

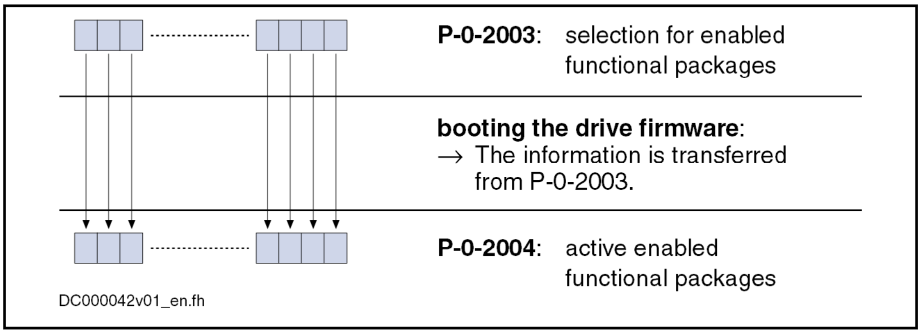


Fig. 10-39: Interaction of Parameters for Functional Package Selection

Every change of the selected functional packages is recorded via an entry of the current count of the operating hours counter in parameter "P-0-2002, Oper. hours of contr. sect. at change of functional packages".

☞ Rexroth can at any time provide evidence of non-licensed functional packages that have been subsequently enabled.

The table below shows the presently possible combinations for input in parameter "P-0-2003, Selection of functional packages". **Whether the respective combination can be used, depends on the available hardware design.**

Base package/expansion package(s)	Content of P-0-2003
Open-loop packages	
Open-loop **without expansion packages**	0x0000 0001
Open loop **with synchronization (SNC)**	0x0000 0021
Open-loop **with main spindle (MSP)**	0x0000 0041
Open-loop **with IndraMotion MLD (ML)**[1]	0x0000 0201
Open-loop **with synchronization (SNC) + IndraMotion MLD (ML)**[1]	0x0000 0221
Open-loop **with main spindle (MSP) + IndraMotion MLD (ML)**[1]	0x0000 0241
Closed-loop packages	
Closed-loop **without expansion packages**	0x0000 0002
Closed loop **with servo function (SRV)**	0x0000 0012
Closed loop **with synchronization (SNC)**	0x0000 0022
Closed loop with **main spindle (MSP)**	0x0000 0042
Closed-loop **with IndraMotion MLD (ML)**[1]	0x0000 0202
Closed-loop **with servo function (SRV) + IndraMotion MLD (ML)**[1]	0x0000 0212
Closed-loop **with synchronization (SNC) + IndraMotion MLD (ML)**[1]	0x0000 0222
Closed-loop **with main spindle (MSP) + IndraMotion MLD (ML)**[1]	0x0000 0242
Closed-loop **with IndraMotion MLD Advanced (MA)**[2]	0x0000 0302
Closed-loop **with servo function (SRV) + IndraMotion MLD Advanced (MA)**[2]	0x0000 0312
Closed-loop **with synchronization (SNC) + IndraMotion MLD Advanced (MA)**[2]	0x0000 0322
Closed-loop **with main spindle (MSP) + IndraMotion MLD Advanced (MA)**[2]	0x0000 0342

1) MLD design for MPB firmware has type designation "TF"
2) "MA" (IndraMotion MLD Advanced) also includes the functionality of the MLD design "ML"

Tab. 10-12: Possible Combinations of Functional Packages of MPx18 Firmware

☞ Changes in parameter "P-0-2003, Selection of functional packages" are only accepted by the drive after repeated booting process.

Reducing the Active Functional Packages

The user can at any time reduce the scope of functions of the firmware by deactivating individual functional packages. To do this, the bits assigned to the functional packages which are not required are reset in parameter "P-0-2003, Selection of functional packages".

Subsequent Expansion (Additional Licensing)

The required functions are normally licensed by ordering the IndraDrive firmware. At delivery, the licensed functions are indicated as firmware type on the type plate of the control section and in addition internally registered by Rexroth.

☞ Rexroth can at any time prove which scope of functions had been activated and thus licensed at delivery. If you use a non-licensed function, any guarantee on the part of Rexroth will expire!

In individual cases, it is possible to make an additional licensing, if you whish to enable other functions than the ones contained in the ordered and paid functionality. The procedure is described in the following section "Notes on Commissioning".

10.9.3 Notes on Commissioning

Condition as Supplied

When a drive is delivered, the licensed functional packages have been enabled. For package "ALL", the package "servo function" (SRV) has been enabled ex works.

☞ The firmware type printed on the firmware type plate has to comply with the content of parameter "S-0-0030, Manufacturer version" (or contain the package identifier "ALL").

The content of parameter S-0-0030 can be read via the standard control panel (see "Control Panels of the IndraDrive Controllers").

The following example of the firmware MPH17V06 shows the relation to the functional package "Closed-loop, Synchronization and IndraMotion":

Example

- Content of S-0-0030 → FWA-INDRV*-MPB17V06-MS-1-SNC-ML
- Imprint on type plate → FWA-INDRV*-MPB17V06-MS-1-SNC-ML

  - or (with complete licensing) -

  → FWA-INDRV*-MPB17V06-MS-1-ALL-ML

Reducing the Functionality

The drive functionality is scaled by selecting functional packages via an entry in parameter "P-0-2003, Selection of functional packages".

The scaling can be changed by directly writing data to the parameter via the master communication or the corresponding dialog in the "IndraWorks D" commissioning tool.

The time of change is registered by an entry in "P-0-2002, Oper. hours of contr. sect. at change of functional packages".

☞ A change in parameter P-0-2003 only takes effect after repeated booting process. The active functional packages are then displayed in parameter "P-0-2004, Active functional packages".

Additional Licensing (Expansion of Functionality)

If the firmware originally ordered and delivered does not contain all required functions, it is possible to subsequently enable further functional packages. This requires additional licensing that is not free of charge.

☞ For test purposes, it is possible to enable non-licensed functional packages via parameter P-0-2003 for a limited time (max. 2 weeks).

If you use a non-licensed functional package permanently, any guarantee on the part of Rexroth will expire!

How to Proceed for Additional Licensing

For additional licensing proceed as follows:

1. Enable desired functional packages in parameter P-0-2003
2. Reboot drive and check content of P-0-2004 (content must comply with that of P-0-2003!)
3. See parameter "S-0-0030, Manufacturer version" for firmware type and write it down; this parameter displays current firmware configuration defined via P-0-2003.
4. See "P-0-1511, Circuit board code control section" (list element 3) for serial number of control section and write it down
5. Send purchase order to Rexroth indicating serial number (from P-0-1511) and desired firmware configuration (from S-0-0030)
6. Receive adjusted firmware type plate from Rexroth to stick it on type plate of control section so that content of S-0-0030 complies with firmware description on type plate

If there hasn't any functional package been previously enabled by the customer, the additional licensing can start with step 4. In step 5, the desired new firmware configuration then cannot be read from S-0-0030, but has to be taken from the overview of firmware types (see "Firmware Types" in section "Overview of Functions/Functional Packages").

☞ For handling the purchase order, please contact your Rexroth sales representative!

Scope of Supply

The scope of supply consists of

- ordered new firmware type as a FWA file incl. parameter file as a file

  - and -

- adjusted firmware type plate (to stick on).

10.9.4 Verifying the Enabled Functional Packages

When the transition command "C0200 Exit parameterization level procedure command" is executed, a check is run to find out whether the value entered in parameter "P-0-2003, Selection of functional packages" corresponds to valid enabled packages. If not, the diagnostic command message C0202 is generated and the parameter IDN "P-0-2003, Selection of functional packages" entered in list parameter "S-0-0423, IDN-list of invalid data for parameterization levels".

See also diagnosis description "C0202 Parameter limit error (->S-0-0423)"

When the enabling of functional packages has been changed, you have to reboot the drive so that the change becomes active and is applied to parameter P-0-2004. When the transition command "C0200 Exit parameterization level procedure command" is executed, a check is run to find out whether the value entered in parameter P-0-2003 corresponds to the value in parameter P-0-2004. If there is a difference, the diagnostic command message "C0299 Configuration changed. Restart" is displayed.

See also diagnosis description "C0299 Configuration changed. Restart"

10.10 Extended Diagnostic Possibilities

10.10.1 Logbook Function

Brief Description

A logbook function is realized in the drive firmware in order to obtain a detailed diagnostic error message in the case of error. The information provided by the logbook function allows reproducing the internal firmware sequence, if required.

Pertinent Parameters

- P-0-0478, Logbook event
- P-0-0479, Logbook time stamp

Functional Description

The list parameters"P-0-0478, Logbook event" and "P-0-0479, Logbook time stamp" are organized as ring buffers and can contain 128 elements. The entries in these parameters are realized automatically by the controller subject to internal states. The entry in P-0-0478 marks the event (or the status); the time of the entry is stored in P-0-0479.

Content and Format of the Logbook Entries

The entries in parameter P-0-0478 are hexadecimal numbers with the following assignment:

- Bits 31 to 16 → Module code
- Bits 15 to 0 → Internal diagnosis key

The displayed values of this parameter can only be interpreted with internal knowledge of the drive firmware.

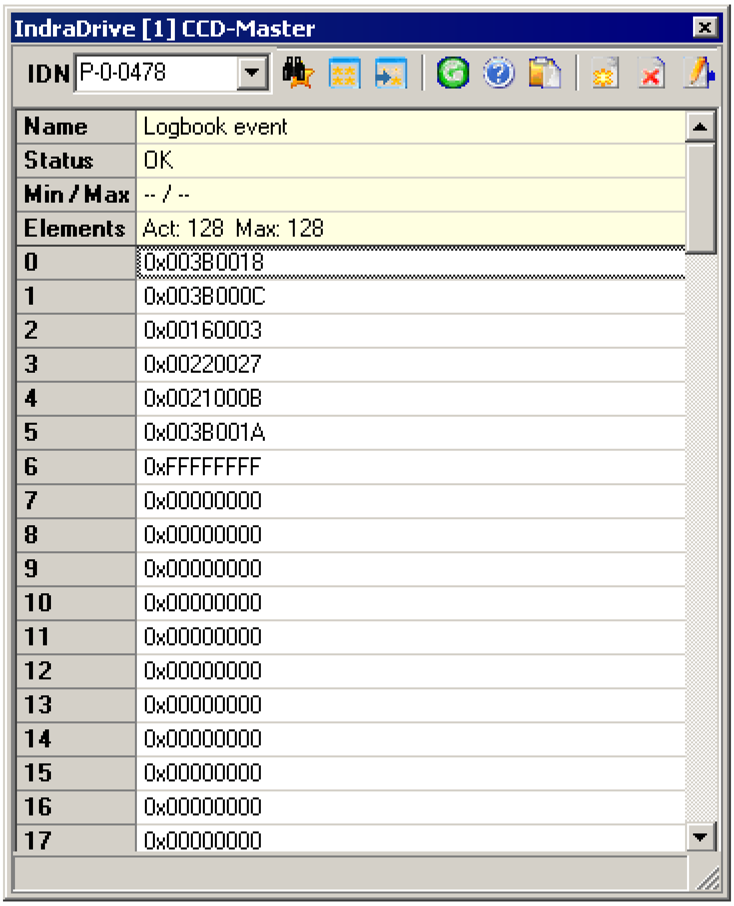


Fig. 10-40: Logbook Entries (Example)

☞ Each time the control section is switched on, "0xFFFFFFFF" is entered in P-0-0478 as a separator in order to mark the "new start".

The entries in P-0-0479 contain the operating hours of the control section in seconds at the time of the respective event.

Handling, Diagnostic and Service Functions

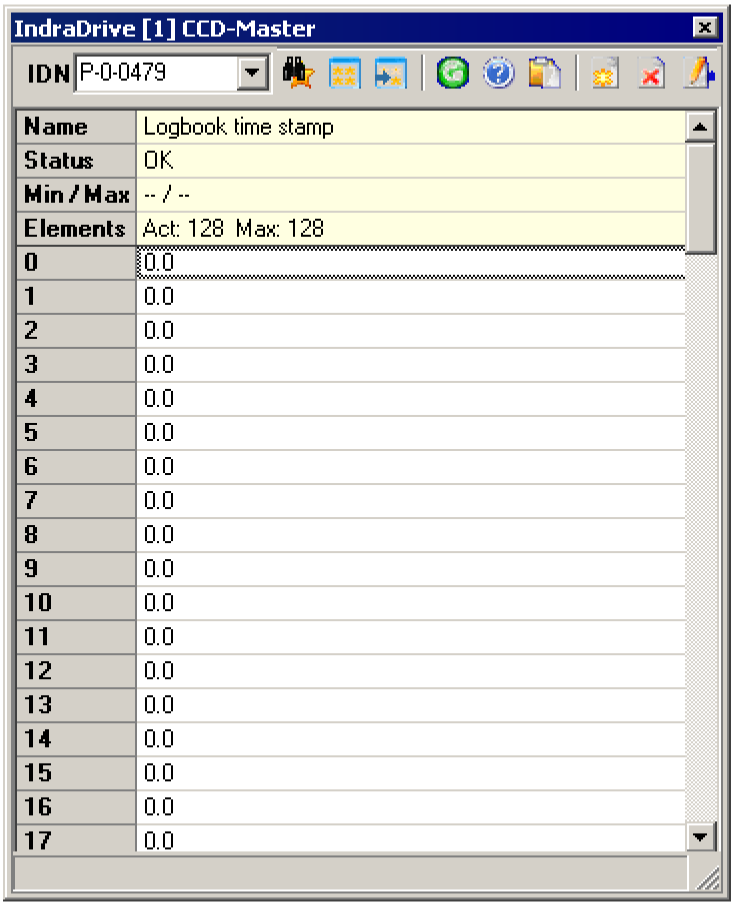


Fig. 10-41: Content of Parameter P-0-0479 (Example)

10.10.2 Patch Function

Brief Description

The patch function can be used for reading and writing any storage location (or internal variable) as a data object via the master communication, the analog output or the oscilloscope function.

In conjunction with the analog output or the oscilloscope function, this functionality can be used for locating errors.

The PLC patch function serves for diagnosis of internal signal states and internal data of the PLC by developers and instructed users.

☞ When using the patch display in the oscilloscope you have to take into account that first the patch address and then the oscilloscope signal is assigned. This must be repeated after every change in the patch address.

☞ As it is a **function for exclusive use by the development staff**, the patch display parameters P-0-0485 and P-0-0491 write-protected with the master password.

The configuration parameters of the patch function are **not stored in the flash**, but are lost when the drive is switched off.

Pertinent Parameters

General patch functions:

- P-0-0480, Patch function 1, source pointer
- P-0-0481, Patch function 1, attribute
- P-0-0482, Patch function 1, bit mask
- P-0-0483, Patch function 1, exponent
- P-0-0485, Patch function 1, display
- P-0-0486, Patch function 2, source pointer
- P-0-0487, Patch function 2, attribute
- P-0-0488, Patch function 2, bit mask
- P-0-0489, Patch function 2, exponent
- P-0-0491, Patch function 2, display

Functional Description of General Patch Function

Read Access (Displaying Internal Storage Locations/Signals)

The patch function allows transforming any storage location into a data object that can be read via the master communication. For this purpose, a storage location is specified via parameters "P-0-0480, Patch function 1, source pointer" and "P-0-0486, Patch function 2, source pointer". The access to this address is configured via the bits 0 to 2 of parameters "P-0-0481, Patch function 1, attribute" and "P-0-0487, Patch function 2, attribute". INT4 reads a 4-byte integer value starting from the source pointer, INT2/INT1 read 2 bytes or 1 byte accordingly. FLOAT8 reads an 8-byte floating-point value (DOUBLE), FLOAT4 reads 4 bytes accordingly (FLOAT).

Due to the processor architecture, the possible memory accesses are subject to certain restrictions. A 4-byte access, for example, is only allowed for storage locations the address of which can be divided by 4. The table below contains a complete overview of the allowed and prohibited modes of memory access.

☞ If you want to change the access mode via bits 0 to 2 of the patch attribute parameters (P-0-0481/P-0-0487), this is only possible if the patch source pointer that has just been set (P-0-0480/P-0-0486) allows the new access mode (see table).

	Possible access to source addresses that …		
Access as...	... can be divided by 4 (DWORD-aligned)	… can be divided by 2, but not by 4 (WORD-aligned)	... do not have any particular alignment (BYTE-aligned)
INT4	■	–	–
INT2	■	■	–
INT1	■	■	■
FLOAT8	■	–	–
FLOAT4	■	–	–

■ Access allowed
– Access prohibited

Tab. 10-13: Possible Access Modes of the Patch Function

The desired display format is set via bits 4 to 7 of the patch attribute parameters (P-0-0481/P-0-0487). This allows interpreting the value read as a decimal number with or without sign, as a hexadecimal number or as a binary number. When selecting "BOOL" as the display type, "1" is output when a value unequal zero was read, otherwise "0" is displayed.

If a storage location is read as integer and output in a non-float format, the value read is ANDed with the bit mask set via the patch bit mask parameters (P-0-0482/P-0-0488). The standard setting of this mask is "0xFFFFFFFF" so that the value read is not changed.

When a storage location is read as a float value and a non-float format is selected for display, the value read is multiplied with $10^{-exponent}$. This allows making an adjustment to the displayed value range (-2147483648 to 2147483647, value range of a "signed int"). The exponent can be set via parameters "P-0-0483, Patch function 1, exponent" or "P-0-0489, Patch function 2, exponent".

☞ If the value read and scaled with the exponent is outside the possible range of display, one of the extreme values is displayed. In this case, it is necessary to select a different exponent.

Write Access (Changing Internal Storage Locations/Signals)

In analogy to read access, it is possible to write any storage location. A bit mask possibly set (P-0-0482/P-0-0488) is taken into account (ANDed) as is a preset patch exponent (P-0-0483/P-0-0489).

☞ Please observe that in the "BOOL" display mode, it is impossible to write the storage location, because it is impossible to assign an unequivocal numeric value to the value "TRUE" (displayed as "1"). Any value unequal zero is interpreted as "TRUE".

NOTICE **Write access to even addresses in the INT1 mode can lead to undefined hardware behavior.**

As in the case of read access, odd addresses in the case of write access are only allowed in the INT1 mode. In contrast to read access, the write access is directly carried out as a byte access. You should therefore avoid activating addresses outside the DRAM in this way, because this can lead to undefined hardware behavior.

10.10.3 Value Generator in the Drive

Brief Description

Fields of Application

To evaluate the thermal load of drive controller and motor over a machine cycle, the total rms value of the output current of the output stage is the decisive characteristic value.

Overview of Functions

The drive cyclically generates the rms value of the output current of the output stage. Via a control bit, the beginning and the end of the cycle are defined.

Pertinent Parameters

- P-0-0610, Control word of current rms value generator
- P-0-0611, Current rms value

Pertinent Diagnostic Messages

None

Functional Description

The generation of the rms value is switched on and off via the control bit "P-0-0610, Control word of current rms value generator", bit 0. If the control bit is set, the rms value of the output current of the output stage is generated as follows:

1. Integration of the current square and recording of the current integration time
2. Generation of the quotient from the sum of the current square and the integration time

The rms value is thereby cyclically generated and the respective current value is displayed in "P-0-0611, Current rms value". Deleting the control bit stops the calculation and the last value generated is frozen. A rising edge of the control bit deletes the rms value and the generation is restarted.

Notes on Commissioning

Proceed as follows to determine the total current rms value at the output of the drive controller over a defined machine cycle:

1. Set control bit P-0-0610, bit 0, at the start of the cycle
2. Delete control bit P-0-0610, bit 0, at the end of the cycle

   The total current rms value over the defined machine cycle is displayed in P-0-0611. If the value is greater than the maximum allowed continuous current of the motor or controller, this machine cycle cannot be run continuously. Thermal overload of the motor or controller is to be expected.

10.11 Oscilloscope function

10.11.1 Brief Description

The oscilloscope function can be used to record drive-internal and external status variables (parameter contents). This function can be effectively used both for initial commissioning and debugging. Its functionality can be compared to that of a 4-channel oscilloscope.

The total scope of the oscilloscope function is divided into the following function blocks:

- Recording measured values

  It is possible to record 4 channels at the same time, the signals being selected by configuration of signal selection lists (IDN lists).
- Configuration (basic settings)

  The control/status block determines the basic functions (start/stop, time resolution, size of memory, operating mode). The current status (status diagram) of the oscilloscope is continuously transmitted to the master.
- Trigger function

  Besides extensive trigger functions, the drive provides the possibility of triggering at different signals and events in the drive.

Features

The oscilloscope function is characterized by the following features:

- Recording measured values

- 4 channels, each with a maximum of 8192 measured values
- Time resolution to be freely selected in steps of the position loop clock (see "Performance Data")
- Signal selection by indicating the IDN of the respective parameter
- Data of the SMO option Sx (S0, S4 and S5) can at maximum be updated and recorded in the cycle time of the SMO application cycle (t = 1 ms)

- Configuration (basic settings)
  - Multi-channel display in "IndraWorks Ds/D/MLD"
  - More than 100 different measuring and trigger signals (cf. P-0-0149)
  - Expanded oscilloscope function using patch function
- Trigger function
  - Trigger signal selection by indicating the parameter IDN
  - Internal trigger or external trigger
  - External trigger with trigger offset determination for synchronizing multiple-axis measurements
  - Unit of trigger level adjusting to trigger signal selection
  - Possibility of triggering at internal memory contents with patch signal
- Trend mode

  It is possible to switch from a single measurement (Single Shot) to a continuous measurement (trend mode).
  - Recording of up to 4 channels in a cyclic mode
  - Signal selection via the previous parameters
  - Values are administrated in a buffer memory and cyclically called
  - IndraWorks can read this buffer memory and display it continuously
  - Setting of time resolution and signal selection only in trend mode that has been switched off
  - Allowed time resolutions must be a multiple of 2 ms
  - Single Shot mode cannot be used in parallel

Pertinent Parameters

- P-0-0020, Oscilloscope: Operation mode
- P-0-0136, Oscilloscope: Manual trigger signal
- P-0-0279, Oscilloscope: Trend mode, time resolution
- P-0-0280, Oscilloscope: Trend mode, list of measured values

Control/status:

- P-0-0028, Oscilloscope: Control word
- P-0-0029, Oscilloscope: Status word
- P-0-0031, Oscilloscope: Time resolution
- P-0-0032, Oscilloscope: Size of memory
- P-0-0149, Oscilloscope: Signal selection list
- P-0-0150, Oscilloscope: Number of valid measured values

Measuring channels:

- P-0-0021, Oscilloscope: List of measured values 1
- P-0-0022, Oscilloscope: List of measured values 2
- P-0-0023, Oscilloscope: Signal selection 1
- P-0-0024, Oscilloscope: Signal selection 2
- P-0-0145, Oscilloscope: List of measured values 3
- P-0-0146, Oscilloscope: List of measured values 4
- P-0-0147,
- P-0-0148,

Trigger function:

- P-0-0025, Oscilloscope: Trigger mask
- P-0-0026, Oscilloscope: Trigger signal selection
- P-0-0027, Oscilloscope: Trigger level
- P-0-0030, Oscilloscope: Trigger edge
- P-0-0033, Oscilloscope: Number of measured values after trigger event
- P-0-0035, Oscilloscope: Trigger control offset
- P-0-0036, Oscilloscope: External trigger signal
- P-0-0037, Oscilloscope: Internal trigger signal

10.11.2 General Information on the Oscilloscope Function

Sequence of a Measurement (State Diagram)

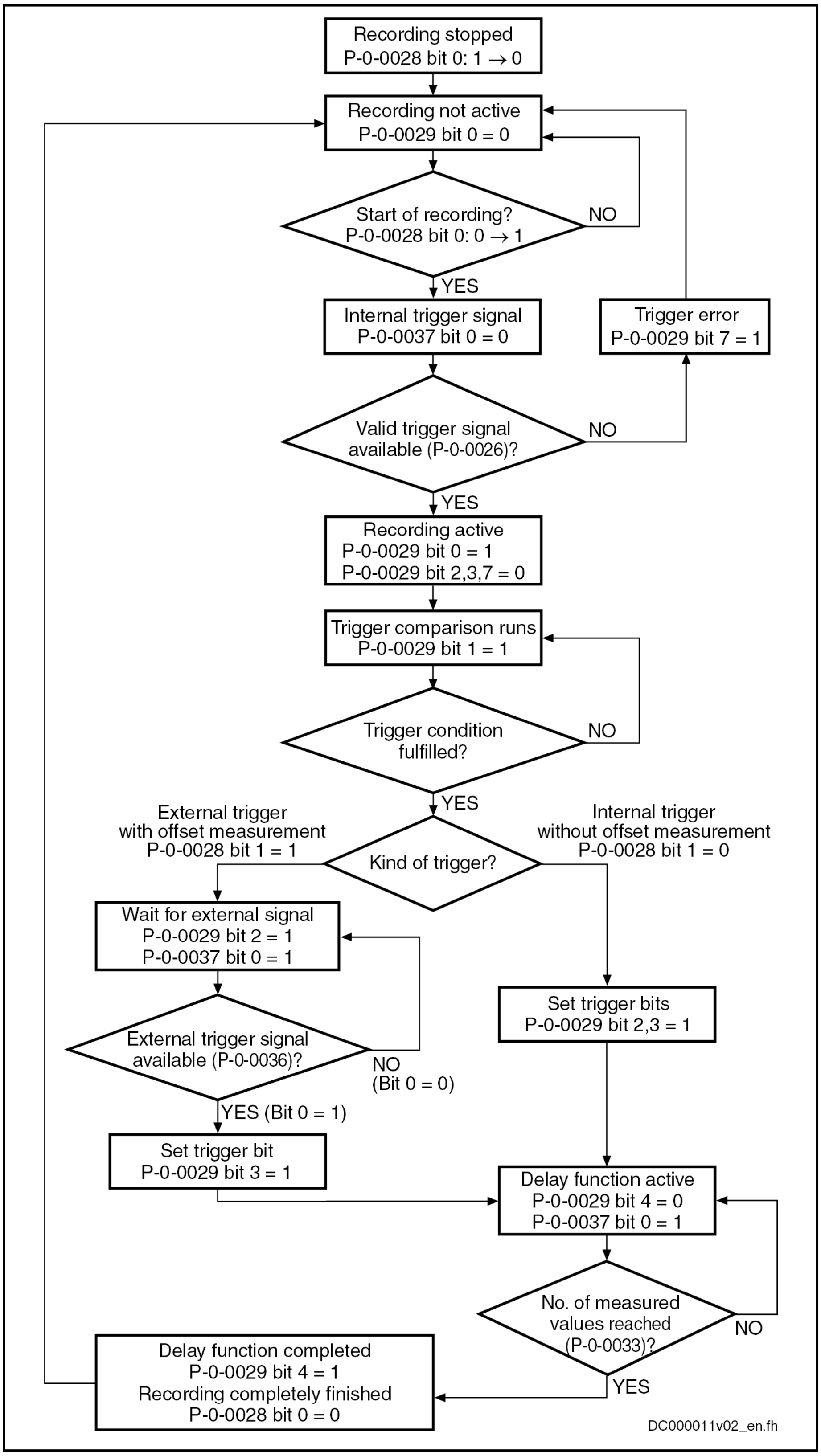


Fig. 10-42: State Diagram of Oscilloscope Function

Configuring the Measured Value Channels

A measured value channel is configured by inputting the IDN of the desired parameter in the respective signal selection parameter:

- P-0-0023, Oscilloscope: Signal selection 1
- P-0-0024, Oscilloscope: Signal selection 2
- P-0-0147,
- P-0-0148,

Signal Selection List (P-0-0149)

All IDNs contained in parameter "P-0-0149, Oscilloscope: Signal selection list" can be entered.

P-0-0149 contains all parameters that are suitable as trigger signal (P-0-0026) or measuring signal (P-0-0023, P-0-0024, P-0-0147, P-0-0148). By reading P-0-0149, the master can recognize the signals that can be recorded in the drive.

☞ At present, all cyclically configurable parameters (> 100) are contained in the list!

Example of Signal Selection

Example of the signal selection of the oscilloscope function:

- "S-0-0051, Position feedback value 1" is selected as signal to be recorded
- Position feedback 1 value (S-0-0051) is written to parameter "P-0-0023, Oscilloscope: Signal selection 1"

→ When the limiting conditions occur, position feedback value of axis 1 is recorded in the oscilloscope and transmitted to the master.

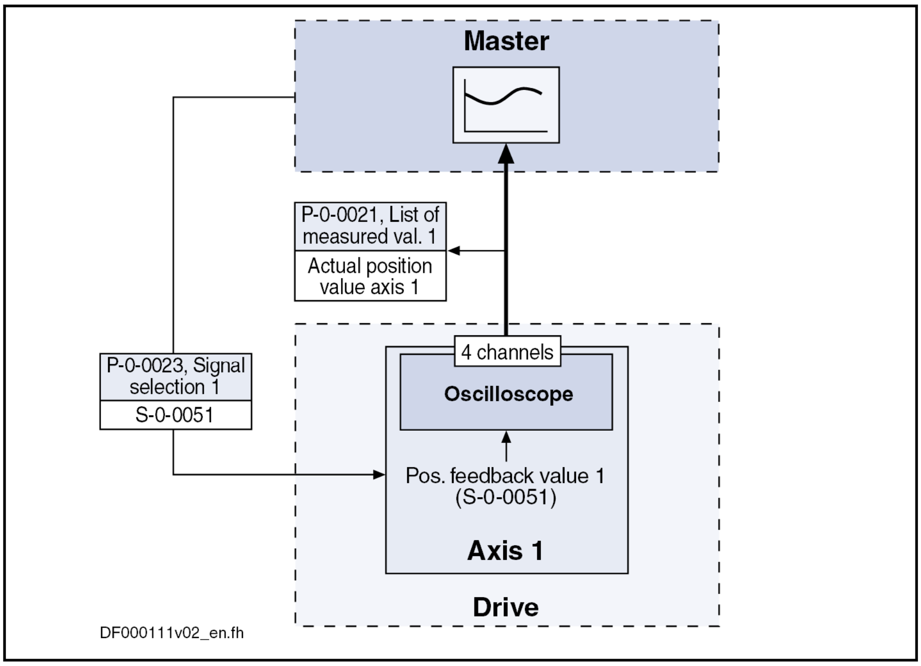


Fig. 10-43: Example of Signal Selection

Extended Oscilloscope Function (Patch Function)

Besides the recording of parameter contents via the oscilloscope function, the drive provides the possibility of recording any internal signal, i.e. memory address (patch function).

Using the patch function is only possible with information about the structure of the internal data memory; therefore, this function can be used effectively only by the developers of the IndraDrive firmware.

In order to record internal signals (memory address contents), "P-0-0485, Patch function 1, display" or "P-0-0491, Patch function 2, display" have to be configured in one of the signal selection parameters (P-0-0023, P-0-0024, P-0-0147, P-0-0148).

The patch function has to be parameterized before the assignment as trigger or measuring signal. After assignment in the signal selection, the address is copied from the patch function. This means that a subsequent change of the address only takes place when it is newly assigned to the signal parameter.

See also "Patch Function"

Activating the Oscilloscope Function

The oscilloscope function is activated/deactivated by means of parameter "P-0-0028, Oscilloscope: Control word".

P-0-0028, bit 0:

- Bit 0 = 1 → Starting a measurement
- Bit 0 = 0 → Stopping a measurement

Setting bit 0 in P-0-0028 activates the oscilloscope function, i.e. the recording of measured values of the selected signal starts. The oscilloscope function waits for the selected trigger edge or level to occur. At detection of a valid edge the measured values keep being written to the measured value memory until the number of measured values defined in "P-0-0033, Oscilloscope: Number of measured values after trigger event"has been reached (delay function).

With sercos master communication, start of signal recording and of trigger evaluation are delayed until the next feedback acquisition starting time T4 (S-0-0007 and S-0-1007).

This causes the recording data and the data in the AT telegram to be identical and several drives at one sercos bus to simultaneously start the recording within one sercos cycle.

After the defined number of measured values has been recorded, the bit "delay function completed" (bit 4) is set in parameter "P-0-0029, Oscilloscope: Status word". The recording is complete and automatically terminated. Bit 0 in parameter P-0-0028 is reset and the list of measured values can be read.

Depending on the parameterization of the size of memory, the time resolution, the number of measured values after trigger event and the point of time the trigger event occurs, the entire measured value memory for the current measurement is not always written.

This means that there may still be old measured values in the memory that are not valid for the current measurement!

10.11.3 Trigger function

Trigger Signal Selection

The drive provides extensive and flexible possibilities of triggering.

Triggering at Standard Signals

The trigger signal is selected in parameter "P-0-0026, Oscilloscope: Trigger signal selection" by directly inputting parameter IDNs. Only such IDNs are allowed that are contained in the list "P-0-0149, Oscilloscope: Signal selection list".

> ☞ If there is no valid trigger signal available when the oscilloscope function is activated, bit 7 for "trigger error" is set in parameter "P-0-0029, Oscilloscope: Status word".

"P-0-0026, Oscilloscope: Trigger signal selection" determines which signal is monitored with regard to the parameterized edge reversal or threshold value.

Triggering at Any Signal

Besides the triggering of parameter contents, the drive provides the possibility of recording any internal signal, i.e. memory address (patch function).

> ☞ Using the patch function is only possible with information about the structure of the internal data memory; therefore, this function can be used effectively only by the developers of the IndraDrive firmware.

Patch Function

In order to trigger at internal signals (memory address contents), "P-0-0485, Patch function 1, display" or "P-0-0491, Patch function 2, display" have to be configured in P-0-0026.

See also "Patch Function"

Internal or External Trigger

The type of trigger can be selected in parameter "P-0-0028, Oscilloscope: Control word".

P-0-0028, bit 1:

- Bit 1 = 0 → Internal trigger without offset measurement
- Bit 1 = 1 → External trigger with offset measurement

Trigger Event

The trigger event is the point of time at which trigger signal (P-0-0026) and trigger level (P-0-0027) are matching, taking the determined trigger edge into account (P-0-0030). When the trigger event occurs, the internal trigger is released.

Internal Trigger (without Offset Measurement)

When "internal trigger" is selected (P-0-0028; bit 1 = 0), the external trigger source (P-0-0036, bit 0) is not taken into account. Until the trigger event is reached, the current state of the comparison "signal/trigger level" is displayed in "P-0-0029, Oscilloscope: Status word".

When the trigger event has been reached, the bit "internal trigger event" is set in parameter "P-0-0029, Oscilloscope: Status word" and recording is continued until the defined number of measured values after trigger event (P-0-0033) has been reached. Only then is the bit "delay function completed" set (P-0-0029; bit 4). Setting this bit terminates the complete recording. Independent of the trigger source, the bit indicates the end of the recording.

When internal trigger source has been selected, the status bit "trigger function completed" (P-0-0029, bit 3) is set simultaneously with the bit for "internal trigger event" (P-0-0029, bit 2) (see State Diagram).

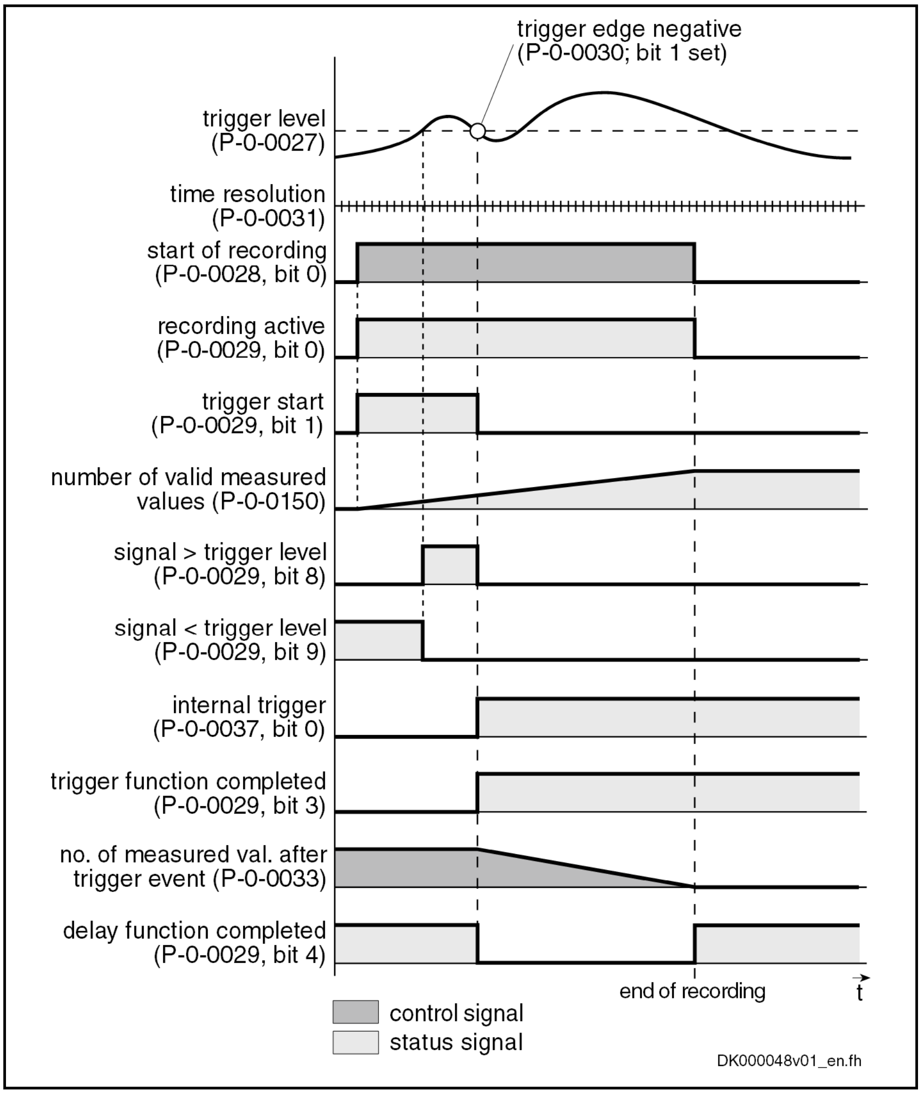


Fig. 10-44: Internal Trigger without Offset Measurement (P-0-0028; Bit 1 = 0)

☞ Parameterizing P-0-0036 (external trigger signal) in "P-0-0026, Oscilloscope: Trigger signal selection" allows triggering the internal trigger function by the external trigger input.

External Trigger with Offset Measurement

When the trigger type "external trigger with offset measurement" (P-0-0028; bit 1 = 1) has been selected, the internal and external trigger are used for the master axis.

When "external trigger" has been selected, the behavior, until the internal trigger event has been reached, corresponds to the behavior for the case when trigger source "internal trigger" has been selected. Until the external trigger signal occurs (P-0-0036; bit 0), the trigger offset between both trigger events is determined and displayed in P-0-0035. Then the bit "trigger function completed" (P-0-0029; bit 3) is set in the status word. The rest of the sequence is the same as in the case of internal trigger source without offset measurement.

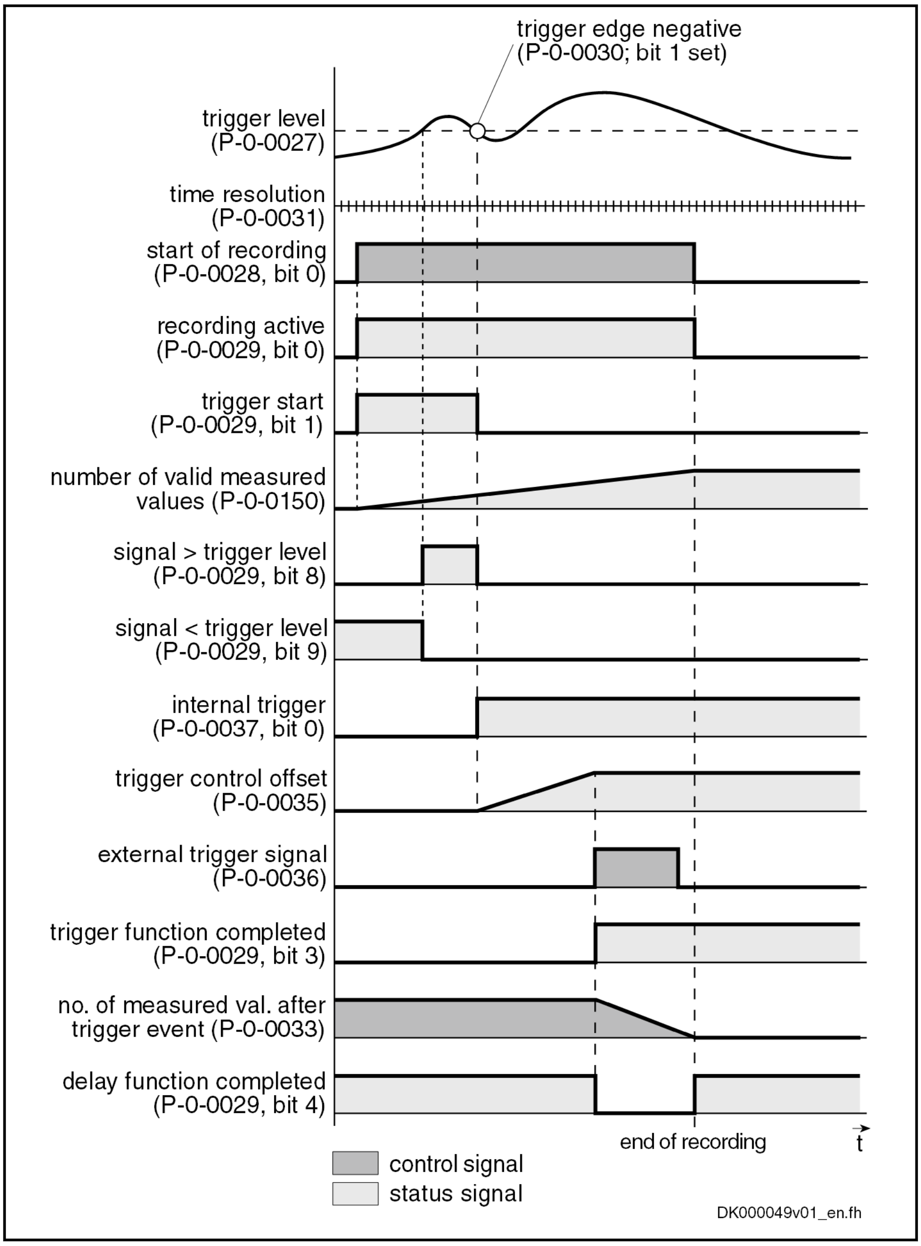


Fig. 10-45: External Trigger with Offset Measurement (P-0-0028; Bit 1 = 1)

The use of the external trigger source with trigger offset determination is described in section " Synchronizing the Measuring Signals of Several Axes" (see below).

Selection of Trigger Edges

Trigger Edge (P-0-0030)

In parameter "P-0-0030, Oscilloscope: Trigger edge" it is possible to set at which edge of the trigger signal the internal trigger is released. The following options are available:

- Triggering at the **positive** edge
- Triggering at the **negative** edge
- Triggering at **both** edges
- Triggering when trigger signal **equals** trigger level

Even if both edges are activated, the triggers are not released until the value goes above or falls below this value. The trigger is not released in the event of parity.

See Parameter Description "P-0-0030, Oscilloscope: Trigger edge"

Setting the Trigger Delay

Trigger Delay Function

Via "P-0-0033, Oscilloscope: Number of measured values after trigger event" it is possible to reach a trigger delay independent of the preset trigger source (external/internal). For this purpose, the number of measured values that is to be recorded after the respective trigger event is set in parameter P-0-0033.

It is also possible to record measured values before the trigger event occurs (trigger delay functions of an oscilloscope).

No data are recorded when entering "0" in P-0-0033 which lie after the trigger event, the trigger event is the last value in the list of measured values. No data are recorded when entering 0 in P-0-0032 which lie before the trigger event, the trigger event is the first value in the list of measured values. The trigger event is thus counted too. In other words, P-0-0033 has the value "0" or "1" the trigger event is the last value in the list of measured values.

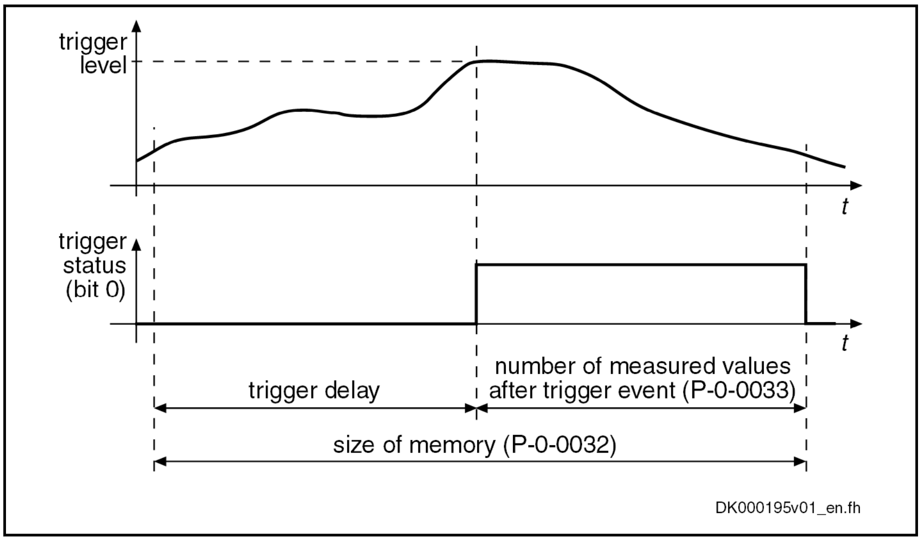


Fig. 10-46: Trigger Delay: Number of Measured Values After Trigger Event

Extended Trigger Functions

Trigger Mask (P-0-0025)

With Parameter "P-0-0025, Oscilloscope: Trigger mask", it is possible to trigger at certain events. For trigger signals with the display formats "Bin" and "Hex", it is possible to mask the trigger signal and the trigger level.

See Parameter Description "P-0-0025, Oscilloscope: Trigger mask"

Trigger Level (P-0-0027)

The trigger level can be freely set via parameter "P-0-0027, Oscilloscope: Trigger level", the attribute, unit, etc. being adjusted to the selected trigger signal.

See Parameter Description "P-0-0027, Oscilloscope: Trigger level"

10.11.4 Synchronizing the Measuring Signals of Several Axes

The parameter "P-0-0035, Oscilloscope: Trigger control offset" contains the number of measured values between the occurrence of the internal trigger event (P-0-0029; bit 2) and the external trigger event (P-0-0036; bit 0).

Trigger Control Offset (P-0-0035)

The transmission of the trigger event via the master causes a delay between the detection of the trigger event and the release of the trigger. This delay is measured by drive 1 (master drive) and stored in parameter "P-0-0035, Oscilloscope: Trigger control offset". A time-correct display of the signals of several drives can be guaranteed by taking this parameter into account for the visualization of the measured values.

☞ In principle, a slave drive can also be used as a triggering axis. This then acts as the master axis.

See also "Internal or External Trigger" above

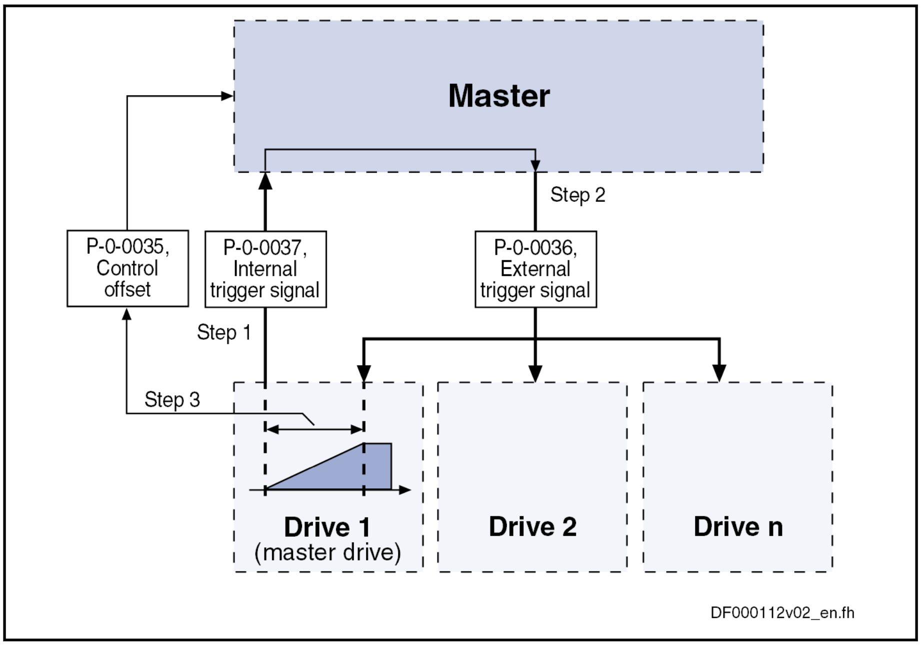


Fig. 10-47: Application for Trigger Source "External" with Determination of Trigger Offset

☞ The value in parameter P-0-0035 can be used by the master for synchronizing the measuring signals of several axes with the internal trigger event of the master axis.

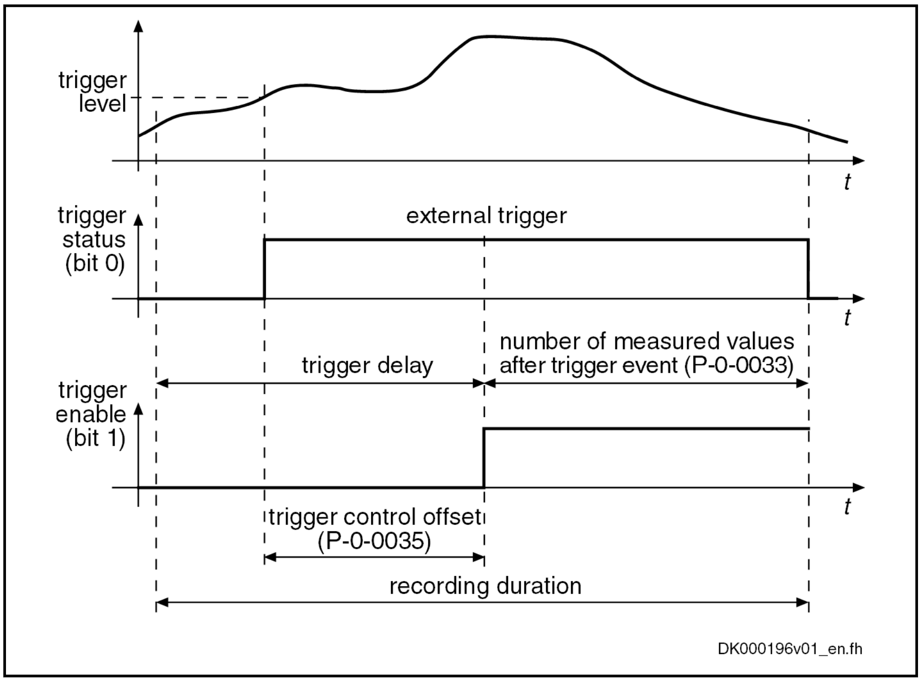


Fig. 10-48: Trigger Control Offset

Status of Internal Trigger (P-0-0037)

Upon successful comparison of trigger signal and trigger condition, bit 0 is set in parameter "P-0-0037, Oscilloscope: Internal trigger signal" (trigger status), but the trigger is not released. It is thereby possible for the master to signal the trigger event via the real-time status bits and real-time control bits to several drives at the same time and to release the trigger.

External Trigger Signal (P-0-0036)

"P-0-0036, Oscilloscope: External trigger signal" can be parameterized as real-time control information, both in the real-time channel of the interface and as hardware input. This allows triggering at external signals that are preset via

- the master communication

- or -

- an analog or digital input.

10.11.5 Parameterizing the Oscilloscope Function

Recording Duration

The recording duration is determined according to the following relationship:

$$t_A = (P\text{-}0\text{-}0031) \times (P\text{-}0\text{-}0032)$$

t_A	Recording duration (in µs)
P-0-0031	Oscilloscope: Time resolution
P-0-0032	Oscilloscope: Size of memory

Fig. 10-49: Determining the Recording Duration

Parameterizing the Selection of Measured Values

For the oscilloscope function, it is possible to select 4 signals that are defined by the IDNs of their respective parameters and assigned to the following parameters:

- P-0-0023, Oscilloscope: Signal selection 1
- P-0-0024, Oscilloscope: Signal selection 2
- P-0-0147,

- P-0-0148,

Only such parameter IDNs are allowed that are contained in the list parameter "P-0-0149, Oscilloscope: Signal selection list".

> ☞ The selected signal (parameter IDN) defines the unit of the data stored in the list of measured values.

Parameterizing the Trigger Function

See "Trigger Function" above

Parameterizing Time Resolution and Size of Memory

The recording range or the recording duration can be adjusted to the measurement requirements via the following parameters:

- P-0-0031, Oscilloscope: Time resolution
- P-0-0032, Oscilloscope: Size of memory

Size of Memory of Oscilloscope Function

The number of measured values is determined via "P-0-0032, Oscilloscope: Size of memory". A maximum of 8192 measured values per channel can be recorded.

Time Resolution of Oscilloscope Function

"P-0-0031, Oscilloscope: Time resolution" determines the time intervals in which measured values are recorded (sampling rate). It is possible to select the time resolution on the time base of the position controller clock ($T_{osci} = N \times T_{A\_position}$; N = 1, 2, 3, 4, …).

The position controller cycle time depends on the control performance. The control performance in turn depends on the hardware design of the controller and the setting in parameter P-0-0556.

What times can be reached can be taken from "performance data".

10.11.6 Diagnostic and Status Messages

Status of the Oscilloscope Function

Parameter "P-0-0029, Oscilloscope: Status word" displays the current status of the oscilloscope function.

P-0-0029 contains, for example, status information on:

- Start/end of recording
- Trigger function
- Status of trigger signal
- Delay function

> ℹ See also Parameter Description "P-0-0229, Oscilloscope: Status word"

Via parameter "P-0-0037, Oscilloscope: Internal trigger signal", the master is informed of the status of the internal trigger. This parameter can be parameterized as real-time status information, both in the real-time channel of the interface and as hardware output.

Displaying the Number of Valid Measured Values

After a measurement, the parameter "P-0-0150, Oscilloscope: Number of valid measured values" displays the number of detected measured values in the ring buffer. When the ring buffer has been completely filled with the length determined in parameter "P-0-0032, Oscilloscope: Size of memory", the size of memory is displayed in this parameter.

See also Parameter Description "P-0-0150, Oscilloscope: Number of valid measured values"

10.11.7 Trend Mode

Trend mode allows for recording of up to 4 channels in a cyclic mode. The values are administrated in a buffer memory and cyclically called. IndraWorks can read this memory and display it continuously This does not necessarily have to do with an equidistant measurement, it may happen that measured values are missing e.g. by a slow connection. These are shown in the graphical display.

To allow the trend mode to be used, the system time must be activated. This time basis is used to assign the corresponding measuring points uniformly to a point in time.

Setting of time resolution and signal selection can only taken place in trend mode that has been switched off Only times which are multiples of 2 ms are allowed as time resolutions. If another value is entered, this is rounded up. Signal selection via the previous parameters.

Trend mode is activated by setting P-0-0020, Bit 5. The mode of the "classic" oscilloscope cannot be used in parallel. Trend recording is then activated via P-0-0028, Bit 0. The trend also signals the activity in P-0-0029, Bit 0.

10.12 Options for Integrated Energy and Power Measurement

10.12.1 Brief Description

Fields of Application

Mounting energy costs increasingly require the project planning of automation systems to conform with energy efficiency. To discover energy saving potentials, it is of crucial significance to analyze the energy consumption of the individual system components. For this purpose, the IndraDrive system makes available specific energy and power values which allow analyzing and evaluating the energy consumption on the drive level.

As a standard, the IndraDrive system provides this function in its basic configuration. By using IndraDrive, installations in the industrial production automation can therefore benefit from this functionality, independently of their respective industrial sector and by deriving measures of increase in energy efficiency from the measured variables.

Overview of Functions

The figure below shows an overview of the energy and power values of the IndraDrive system for a single-axis system.

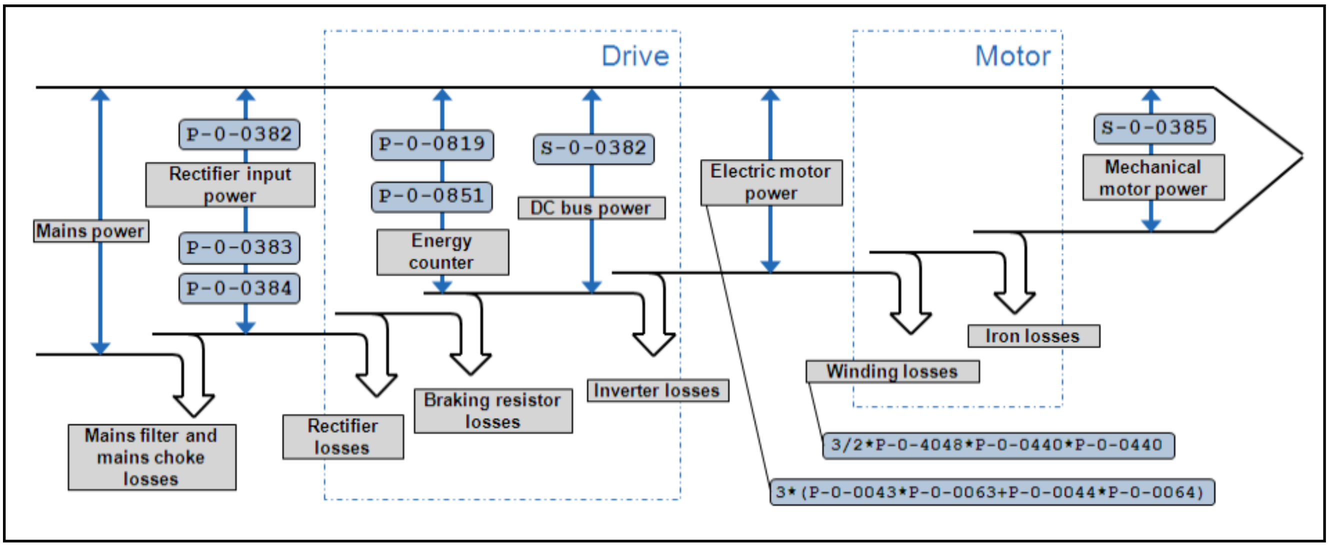


Fig. 10-50: Energy and Power Values of the IndraDrive System

We distinguish between

- axis-related values (S-0-0385, S-0-0382, P-0-0819, P-0-0851) and
- device-related values (P-0-0382, P-0-0383, P-0-0384).

The energy and power requirements of an individual axis can be determined by means of the above axis-related values. These parameters are available in each axis. Mains-side energy and power values are device-related and only available for converters. They can be used to determine the total power requirements of a drive system.

Features

- Determining the axis-specific power requirement
- Calculating the motor power dissipation
- Determining the total energy absorption of a drive system
- Drawing up a power balance of the drive system
- Discovering optimization potentials for saving energy
- Determining the maximum mains input current (HCS01.1E-W0054 only)
- Including the energy and power values in IndraWorks is possible
- Depicting dynamic power processes in the position controller cycle

Hardware and Software Requirements

The availability of the energy and power values depends on the hardware:

- Axis-related values are axis parameters and available for all IndraDrive devices: S-0-0385, S-0-0382, P-0-0851 and P-0-0819.
- Mains-side values are device parameters and therefore only available for converters: P-0-0382, P-0-0383 and P-0-0384. The significance of the displayed value depends on the topology and available sensors: Only converters without DC bus connection or converters which do not supply any other inverters via the DC bus, and the HCS01.1E-W0054 device, provide correct values. In all other cases, the mains-side values cannot be calculated due to the restricted sensor system. The displayed values are not correct. For an overview of the availability of the energy and power values depending on the hardware used, see chapter "Determining the Energy and Power Values".

☞ In order that the energy and power values are correctly displayed, it is obligatory to **activate** the **output stage compensation**. For this purpose, set bit 5 of parameter "P-0-0045, Control word of current controller".

Pertinent Parameters

- S-0-0040, Velocity feedback value
- S-0-0084, Torque/force feedback value
- S-0-0109, Motor peak current
- S-0-0110, Amplifier peak current
- S-0-0111, Motor current at standstill
- S-0-0380, DC bus voltage
- S-0-0381, DC bus current
- S-0-0382, DC bus power
- S-0-0383, Motor temperature
- S-0-0385, Motor power
- S-0-0533, Nominal torque/force of motor
- S-0-0534, Maximum torque/force of motor
- P-0-0043, Torque-generating current, actual value
- P-0-0044, Flux-generating current, actual value
- P-0-0045, Control word of current controller
- P-0-0051, Torque/force constant
- P-0-0063, Torque-generating voltage, actual value
- P-0-0064, Flux-generating voltage, actual value
- P-0-0065, Absolute voltage value, actual value
- P-0-0114, Undervoltage threshold
- P-0-0382, Mains power
- P-0-0383, Mains energy counter
- P-0-0384, Short-time mains energy counter
- P-0-0440, Actual output current value (absolute value)
- P-0-0450, Current torque/force constant
- P-0-0532, Premagnetization factor
- P-0-0556, Config word of axis controller
- P-0-0819, Energy counter
- P-0-0833, Braking resistor threshold
- P-0-0851, Short-time energy counter
- P-0-0853, Max. DC bus voltage, motor
- P-0-0860, Converter configuration
- P-0-4048, Stator resistance

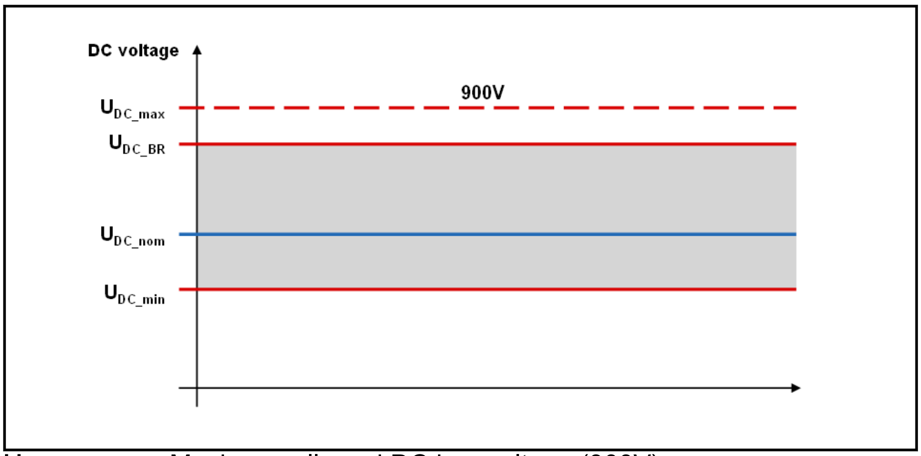
Pertinent Diagnostic Messages

None

10.12.2 Basic Principles

Tolerance Range of the DC Bus Voltage

The current value of the DC bus voltage is measured and displayed in "S-0-0380, DC bus voltage". Depending on the application, the DC bus voltage fluctuates; the following ranges must be distinguished:



U_{DC_max}	Maximum allowed DC bus voltage (900V)
U_{DC_BR}	Braking resistor switch-on threshold (default: HCS01.1E-*-02: 390V, HCS04.2: 765V, otherwise: 820V)
U_{DC_nom}	Nominal DC bus voltage (HMV-E / HCS: mains peak, HMV-R: 750V)
U_{DC_min}	Minimum allowed DC bus voltage (default: Three-phase: 75% of the mains peak, single-phase: 66% of the mains peak)

Fig. 10-51: Tolerance Range of the DC Bus Voltage

The tolerance range of the DC bus voltage in the running operation of an installation is within the limits U_{DC_min} and U_{DC_BR}. Short-term operation above the braking resistor switch-on threshold is basically possible, but must be avoided because the device risks to be destroyed. The braking resistance switch-on threshold can be sent via "P-0-0853, Max. DC bus voltage, motor" in order to protect motors from overvoltage. Below the minimum allowed DC bus voltage, it is not ensured that the DC bus power required by the process can be made available so that this range can exclusively be used for a defined error reaction in the case of mains failure. The voltage threshold is parameterizable via "P-0-0114, Undervoltage threshold".

Accuracy of the Torque Feedback Value

The accuracy of the torque/force feedback value is decisive for the correct calculation of the mechanical power of the motor. The torque/force feedback value is calculated as the product of the torque-generating current and the torque/force constant:

$$M = K_M \, I_q$$

K_M	Torque/force constant [Nm/A]
I_q	Torque-generating current [A]
M	Torque/force feedback value of motor [Nm]

Fig. 10-52: Calculating the Torque/Force Feedback Value of the Motor

The so-called torque/force constant is not a constant variable, but depends on the following factors:

- Manufacturing tolerances of the motor

- Active motor current (magnetic saturation effects)
- Winding and rotor temperatures

The IndraDrive firmware supports the correction of the torque/force constant by activating the function in "P-0-0556, Config word of axis controller", bit 11 (see chapter 8.6.5 "Correction of the Torque/Force Constant" on page 778). The current value is of the torque/force constant is displayed in parameter P-0-0450. The torque/force feedback value is calculated as follows:

$$M = S\text{-}0\text{-}0084 = P\text{-}0\text{-}0450 \times P\text{-}0\text{-}0043$$

M Motor torque [Nm]

Fig. 10-53: Parameter Formula: Calculating the Motor Torque

If the torque/force feedback value of the motor is to be determined by means of approximation for a certain working point of the motor, the following cases must be distinguished for the manual calculation of the torque/force constant:

- The torque/force constant for the cold motor (reference temperature 20°C) corresponds to the parameter "P-0-0051, Torque/force constant".
- The torque/force constant for the motor at operating temperature is the quotient from "S-0-0533, Nominal torque/force of motor" and "S-0-0111, Motor current at standstill" (based on the assumption that the lowest allowed cooling type is used).
- The minimum torque/force constant at the maximum motor load is the quotient from "S-0-0534, Maximum torque/force of motor" and "S-0-0109, Motor peak current".

☞ The firmware-side correction of the torque/force constant only works correctly when the above parameters have been parameterized with the corresponding motor-specific values. Using the wrong torque/force constant causes the mechanical motor power to be incorrectly calculated and thereby results in an invalid power balance of the overall system.

10.12.3 Determining Energy and Power Values

Overview

The energy analysis of the IndraDrive system is carried out on the basis of internal status variables of the drive which represent the chronological energy/power requirement. We distinguish the following energy/power values:

1. Energy and power values **directly** mapped by status variables of the drive,
2. Energy and power values that can be **indirectly** determined on the basis of status variables of the drive

The following table displays the device-dependent availability of the direct energy and power values.

Device	Axis Parameters				Device parameters		
	S-0-0385	S-0-0382	P-0-0819	S-0-0851	P-0-0382	P-0-0383	P-0-0384
Inverter (HMS, HMD, Mi) or Converter in inverter mode	■	■	■	■	–	–	–
HCS01.1E less than W0028	■	■	■	■	■	■	■

Device	Axis Parameters				Device parameters		
	S-0-0385	S-0-0382	P-0-0819	S-0-0851	P-0-0382	P-0-0383	P-0-0384
HCS01.1E-W0028	■	■	■	■	□	□	□
HCS01.1E-W0054 / HCP	■	■	■	■	■	■	■
HCQ/HCT	■	■	■	■	■	■	■
HCS02.1E-W0012	■	■	■	■	■	■	■
HCS02.1E larger than W0012	■	■	■	■	□	□	□
HCS03.1	■	■	■	■	□	□	□
HCS04.2	■	■	■	■	□	□	□

■ Parameter available
– Parameter not available
□ Parameter available; correct display with individual supply, not correct for DC bus voltage

Tab. 10-14: Device-Independent Overview of Energy and Power Values

Axis-Related Values (Axis Parameters)

Axis-related values are energy and power values are available for all IndraDrive devices. The parameters display the energy demand/power requirement of the individual axis. A controller can therefore determine the total energy consumption of a drive system independent of its topology by summing the corresponding parameter.

Mechanical Motor Power

To calculate the mechanical power it is necessary to distinguish between rotary and linear motors. A rotary motor has a shaft output proportional to the speed and torque:

$$P_{mech} = \omega M = \frac{2\pi}{60} nM$$

P_{mech} Mechanical power [W]
ω Angular frequency [rad/s]
M Torque [Nm]
n Speed [1/min]

Fig. 10-54: Mechanical Power of a Rotary Motor

For a linear motor, the mechanical power results as a product of velocity and force:

$$P_{mech} = \frac{10^{-3}}{60} vF$$

P_{mech} Mechanical power [W]
v Velocity [mm/min]
F Force along the direction of motion [N]

Fig. 10-55: Mechanical Power of a Linear Motor

The mechanical power of the motor is displayed in parameter "S-0-0385, Motor power". The calculation is made firmware-internally based on "S-0-0040, Velocity feedback value" and "S-0-0084, Torque/force feedback value".

The torque/force feedback value has a crucial significance for the precision of the mechanical power – therefore where possible, activate torque correction. For this purpose, set bit 11 of parameter P-0-0556 (see chapter "Accuracy of the Torque Feedback Value" on page 1103).

In open-loop operation and with asynchronous machines in the field weakening range, deviations of S-0-0385 of 20% are possible.

Motor Losses

The losses of an electrical drive can be divided into three groups:

- Copper/winding losses
- Iron losses (hysteresis and eddy-current losses)
- Friction losses

Up to now, it has only been possible to determine the copper losses by means of drive-internal parameters. They are proportional to the square of the rms value of the motor current:

$$P_{Cu}=3R_{corr}R_wI^2$$

P_{Cu}	Copper power dissipation of motor [W]
R_{corr}	Correction factor depending on winding temperature [--]
R_w	Winding resistance per phase at a winding temperature of 20 °C [Ω]
I	RMS value of motor current [A_{rms}]

Fig. 10-56: Copper Losses of an Electric Motor

The correction factor R_{corr} is calculated as follows, under the assumption of a linear dependance between winding resistance and winding temperature:

$$R_{corr}=1+\alpha_{20}(\theta_w-20°C)$$

R_{corr}	Correction factor depending on winding temperature [--]
α_{20}	Material-dependent temperature coefficient at 20°C (for copper: 0.0039) [1/°C]
θ_w	Winding temperature of motor [°C] (cf. S-0-0383)

Fig. 10-57: Temperature Dependance of the Winding Resistance

Using parameters, the motor losses are calculated as follows:

$$P_{Cu}=\frac{3}{2}\times R_{corr}\times P\text{-}0\text{-}4048\times P\text{-}0\text{-}0440\times P\text{-}0\text{-}0440$$

P_{Cu}	Copper power dissipation of motor [W]
R_{corr}	Correction factor depending on winding temperature [--]

Fig. 10-58: Parameter Formula: Copper Losses of Motor

In practical application, the resulting R_{corr}=1.41 (winding temperature: 125°C) is a useful value for calculating the copper losses.

Effective Electric Power

The effective electric power is calculated in the dq system in power-varying form and corresponds to the effective output power of the controller:

$$P_{el}=\frac{3}{2}\left(U_d I_d + U_q I_q\right)$$

P_{el} Electric power [W]
U_d Flux-generating voltage [V]
I_d Flux-generating current [A]
U_q Torque-generating voltage [V]
I_q Torque-generating current [A]

Fig. 10-59: Effective Electric Power

This is how to calculate the effective electric power by means of drive parameters:

$$P_{el}=3\times(P\text{-}0\text{-}0043\times P\text{-}0\text{-}0063+P\text{-}0\text{-}0044\times P\text{-}0\text{-}0064)$$

P_{el} Electric power [W]

Fig. 10-60: Parameter Formula: Effective Electric Power

Electric Apparent Power

The geometric sum of effective electric power and wattless power of the motor corresponds to the apparent power at the motor terminals. It is calculated as the product of motor terminal voltage and motor phase current:

$$S_{el}=\sqrt{3}UI$$

S_{el} Electric apparent power [VA]
U Terminal voltage (reference to conductor) [V]
I Motor phase current [A]

Fig. 10-61: Electric Apparent Power

To calculate the absolute value of the apparent power on the parameter level, use the following formula:

$$S_{el}=\sqrt{3}\times P\text{-}0\text{-}0065\times P\text{-}0\text{-}0440$$

S_{el} Electric apparent power [VA]

Fig. 10-62: Parameter Formula: Electric Apparent Power

DC Bus Power

The DC bus power is generally calculated as the product of DC bus voltage and DC bus current:

$$P_{DC}=U_{DC}I_{DC}$$

P_{DC} DC bus power [W]
U_{DC} DC bus voltage [V]
I_{DC} DC bus current [A]

Fig. 10-63: Calculating the DC Bus Power

As the DC bus current is not measured, the DC bus power in the drive cannot be determined according to the above formula. The power displayed in parameter "S-0-0382, DC bus power" corresponds to the DC bus output of the individual drive which is calculated on the basis of the effective electric power. A positive sign means that the drive works in motive form and draws energy from the DC bus, a negative sign identifies a drive working in regenerative form that feeds energy to the DC bus.

☞ The parameter S-0-0382 is firmware-internally filtered with 8ms, i.e. rapid changes in power are visible only in a limited way.

Energy Consumption of the Drive System

With its two energy counters P-0-0819, Energy counter and "P-0-0851, Short-time energy counter" the drive offers options for determining the energy consumption of an individual drive or a drive system. The energy counters differ with regard to their resolutions:

Parameter	Unit	Decimal places
P-0-0819	kWh	2
P-0-0851	Ws	0

Tab. 10-15: Energy Counter: Attributes

Consequently, P-0-0851 is used to assess the energy demand of machining cycles between a couple of seconds and several hours. The parameter is not stored and is zero when the device is switched on. The parameter P-0-0819 displays the energy consumption over a long period (several years or service life of the drive); it is stored when the device is switched off.

The energy counters are axis-related and display the energy an individual drive requires or generates. A positive sign means that energy is drawn from the DC bus, a negative sign means that energy is recovered to the DC bus by a drive working in regenerative form.

☞ The power dissipation converted into an internal or an external brake resistor is not included in the calculation of the energy counter. To reset an energy counter to zero, write zero to the corresponding parameter.

☞ In the case of a multi-axis system, the individual powers of all axes connected to the DC bus must be summed to determine the energy absorbed by the overall system. For this purpose, all available P-0-0819 or P-0-0851 must be summated.

Mains-Side Values (Device Parameters)

Mains-side energy and power values are only available for converters. The corresponding parameters are covered with a converter or inverter in inverter mode. The precision of values depends on the available sensor system (device-dependent) and topology (individual supply or DC bus voltage coupling).

Individual Supply

Converters without DC bus terminal (HCS01.1E-*-02, HCS02.1E-W0012) or converters that do not supply any further inverters via the DC bus voltage exclusively provide power for its integrated inverter section. The mains-side output power can be calculated on the basis of the axis-related DC bus continuous power taking into account brake resistor losses. The display in the parameters P-0-0382, P-0-0383 and P-0-0384 thus corresponds to the mains-side values in good proximity.

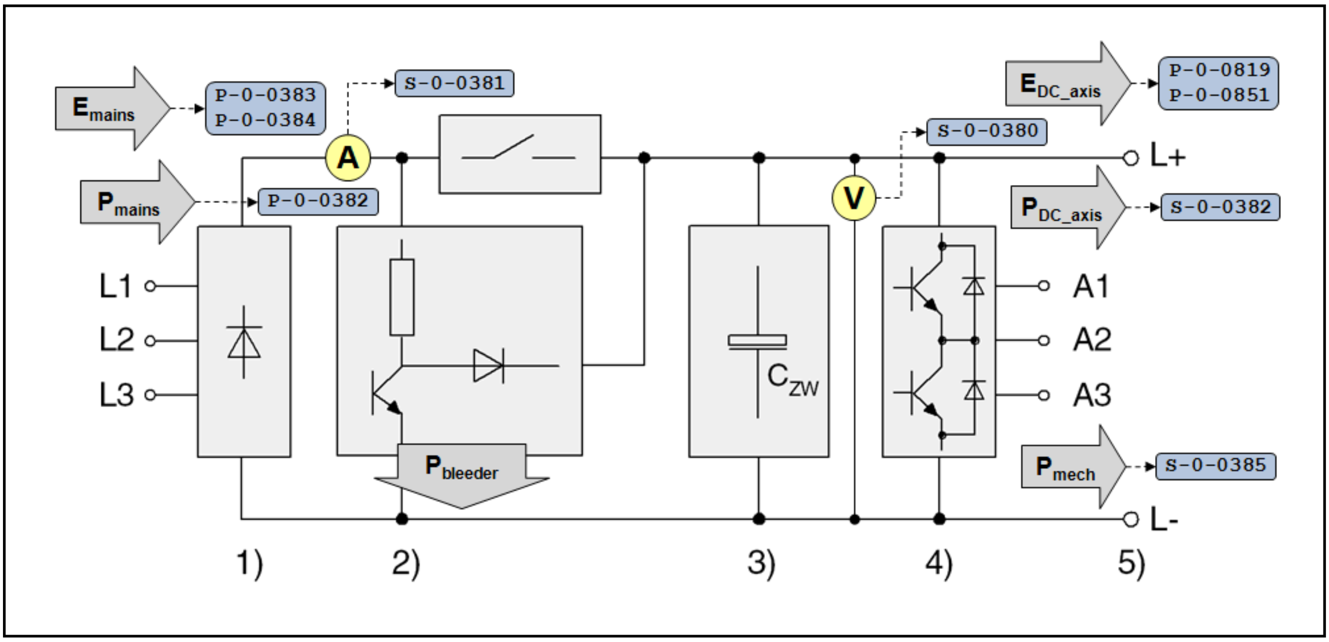
DC bus coupling

Converters without DC bus voltage measurement which supply additional inverters via the common DC bus voltage, provide power for their integrated inverter section and all other inverters. With this topology, it is not possible to calculate the mains-side power due to missing sensor systems. The display in the parameters P-0-0382, P-0-0383 and P-0-0384 corresponds to the energy/power values of the axis of the converter and thus does not correspond to the mains-side total energy demand/power.

☞ The display of mains-side energy/power values is not correct with the converter without a DC bus current measurement when DC bus voltage exists.

Converter with DC Bus Current Measurement

The HCS01.1E-W0054 device as an additional sensor technology provides DC bus current measurement which has been implemented on the hardware side in accordance with the diagram below. The DC bus current corresponds to the current at the rectifier output and is displayed in the parameter S-0-0381, DC bus current.



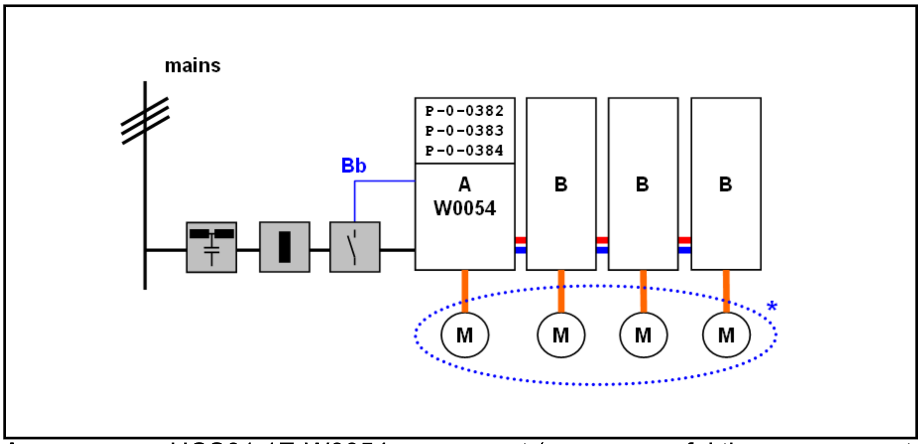
1)	Rectifier
2)	Braking resistor circuit; charging current limitation
3)	DC bus capacitance
4)	Inverter stage with output to motor
5)	DC bus connection
E_{mains}	Mains-side energy counter
P_{mains}	Mains-side input power
$P_{bleeder}$	Power dissipation of braking resistor
E_{DC_axis}	Energy counter of the local axis
P_{DC_axis}	DC bus power of the local axis
P_{mech}	Mechanical power of the local axis

Fig. 10-64: Electrical Design of HCS01.1E-W0054

In the case of central supply by means of HCS01.1E-W0054, there are the following additional diagnostic possibilities:

- Determining the mains-side peak current which in good approximation corresponds to the maximum value of S-0-0381, DC bus current.
- Determining the DC bus input power mapped in the parameter "P-0-0382, Mains power".
- Determining the total energy absorption of the system by means of the parameters "P-0-0383, Mains energy counter" and "P-0-0384, Short-time mains energy counter".

The overviews below shows the available energy and power values in the case of central supply by means of HCS01.1E-W0054:



A	HCS01.1E-W0054 component (more powerful than component B); connected to other components via DC bus
B	HCS01 component (less powerful than component A); connected to other components via DC bus
Bb	Bb relay contact wiring
*	Local axes of the components A and B; energy demand / power requirement of the respective axis available via S-0-0382, P-0-0819, P-0-0851.

Fig. 10-65: Energy and Power Values with Central Supply via HCS01.1E-W0054

10.12.4 Options for Increasing the Energy Efficiency

Energy-Optimized Supply Concept

The kind of supply concept of a drive system is to a great extent responsible for the system's energy efficiency. Energy saving potentials lie in the selection of the right components and their interconnection.

DC Bus Coupling with Central Supply and Group Supply

If a drive system consists of several drives working in motive and regenerative form, the DC bus coupling of the individual devices always must be implemented, if possible, as this results in the following advantages with regard to the energy efficiency:

- Efficient energy exchange via the common DC bus between drives working in regenerative and motive form. Losses will only occur in the output stage of the drive controller.
- No losses in the braking resistor in the case of optimum sizing.

For the DC bus coupling of the components, observe the following aspects:

- It must be possible to couple the individual components via the DC bus in accordance with the Project Planning Manual.
- Total continuous power and total maximum power of the DC-bus-coupled axis group must not exceed the continuous power or maximum power of the supplying device or the supplying devices.
- The travel profiles of the axes must be chronologically synchronized in such a way that the energy exchange via the DC bus is possible and makes sense. The simultaneous acceleration or deceleration of all drives must be avoided.
- The energy store in the DC bus must be dimensioned in such a way that the minimum DC bus voltage and braking resistor switch-on threshold are not reached. Only then is it possible to avoid undervoltage in the DC bus and energy loss in the braking resistor.

Using Regenerative Supply Units

If, due to the process, drives working in regenerative form cause high power peaks which cannot be absorbed by the energy store of the DC bus, it is possible and makes sense to use a regenerative supply unit. Regarding the energy efficiency, this provides the following advantages:

- No losses in the braking resistor.
- Drives working in regenerative form regenerate their energy via the DC bus to the mains. Losses will occur in the output stages of the drive controller and the supply unit.

Supply Units with Smart Energy Mode

Supply units with Smart Energy Mode limit the mains-side peak current to the 1.1-fold value of the nominal input current of the supply unit. This reduces the maximum power as compared to a supply unit without Smart Energy Mode. If a supply unit with Smart Energy Mode is used in an application with high power peaks in the DC bus, mains-side current peaks and mains pollution are clearly reduced as compared to the standard supply concept. Using the Smart Energy Mode provides the following advantages regarding the energy efficiency:

- Reduction of the power dissipation in mains choke and mains filter due to the reduction of the mains-side current peaks.
- Reduction of the power dissipation of the supply unit's output stage due to the reduction of the maximum current.
- No losses in the braking resistor.

Observe the following aspects when using a supply unit with Smart Energy Mode:

- The total continuous power of the DC-bus-coupled axis group must not exceed the continuous power of the supply unit.
- Positive power peaks above the power limitation of the supply unit must be made available by the energy store in the DC bus.
- Negative power peaks below the (negative) power limitation of the supply unit must be absorbed by the energy store in the DC bus.
- The tolerance range of the DC bus voltage depends on the mains voltage. The allowed minimum value is the mains peak, the allowed maximum value is the braking resistor switch-on threshold (see chapter "Tolerance Range of the DC Bus Voltage" on page 1103).

☞ The lower the mains voltage, the higher the maximum possible energy absorption by the DC bus at the same capacity of the energy store.

Energy Storage

In the case of DC-bus-coupled drive systems, energy storage takes place in the DC bus. We distinguish between

- electrical energy store (capacitance) and
- kinetic energy store (flywheel / Kinetic Buffer).

The storage technology must be selected in accordance with the application and basically depends on the amount of energy alternating between the process and the DC bus.

Electrical Energy Store (DC Bus Capacitance)

The electrolytic capacitors used for energy storage have the following properties:

- High power density
- Low energy density
- High efficiency (>95%)

- Easy handling: Direct coupling with the DC bus, no additional intelligence required

Due to the high power density, capacitors are suited to buffer short power peaks like they occur in dynamic applications by rapid acceleration and deceleration processes. Increase in energy in the DC bus causes the DC bus voltage to rise, decrease in energy causes the DC bus voltage to drop. This causes an energy difference in the DC bus which can be described as follows:

$$\Delta E_{DC} = \frac{1}{2} C \left(U_0^2 - U_1^2 \right)$$

ΔE_{DC}	Energy absorption or energy output of the DC bus capacitor [Ws]
C	Capacitance of the DC bus capacitor [F]
U_0	DC bus voltage before energy absorption or energy output [V]
U_1	DC bus voltage after energy absorption or energy output [V]

Fig. 10-66: Energy of DC Bus Capacitor

The maximum possible energy absorption or energy output depends on the current DC bus voltage U_0 and the tolerance range of the DC bus voltage. After the energy absorption or energy output process, the DC bus voltage U_1 must be within the tolerance range.

Capacitors are only suited with restrictions for storing great amounts of energy. The maximum allowed DC bus capacitance and the construction volume restrict the use of capacitors.

Kinetic Energy Store (Kinetic Buffer)

The kinetic energy store in the form of an additional motor with flywheel mass has the following properties:

- Good power density
- High energy density
- Good efficiency (depending on the motor, 90-95% are possible)
- Complex handling: Coupling with the DC bus via drive controller, additional intelligence required to control the motor, additional engineering effort

Due to its high energy density, the Kinetic Buffer is suited for storing great amounts of energy. Increase in energy in the DC bus causes the speed of the buffer drive to increase, decrease in energy causes the speed to decrease. This causes a difference in the rotational energy which can be calculated as follows:

$$\Delta E_{rot} = \frac{1}{2} J \left(\omega_0^2 - \omega_1^2 \right)$$

ΔE_{rot}	Energy absorption or energy output of the Kinetic Buffer [Ws]
J	Inertia of the flywheel mass of the Kinetic Buffer [kgm^2]
ω_0	Speed before energy absorption or energy output [rad/s]
ω_1	Speed after energy absorption or energy output [rad/s]

Fig. 10-67: Energy of Kinetic Buffer

The maximum possible energy absorption or energy output depends on the current speed ω_0 and the allowed speed range of the buffer drive. After the energy absorption or energy output process, the speed ω_1 must be within the allowed speed range of the motor.

If the control of the buffer drive has a highly dynamic response, the kinetic energy store can also be used to buffer short power peaks if the maximum power of the drive is accordingly high. Using a capacitor, however, is more energy-efficient.

Reducing the Magnetizing Current

When bit 2 has been set in "P-0-0045, Control word of current controller", the magnetizing current of an asynchronous motor can be reduced, independent of the load, via "P-0-0532, Premagnetization factor". Reducing the magnetizing current causes the total motor current to be reduced and thereby causes the winding losses to be reduced.

As reducing the magnetizing current causes performance losses, this type of optimization should only be used in applications in which the dynamic response plays a minor role.

> ☞ A value smaller than 100% delays the torque output at the motor shaft as compared to the command value.

Adjusting the Travel Profile

Adjusting the travel profile can affect the average working point of the drive. Indirectly, this allows optimizing the energy efficiency, because the power dissipation of the drive depends on its working point.

Acceleration Limitation Acceleration limitation causes less acceleration torque and thereby reduces the motor current. This results in an energetically more advantageous working point at reduced motor power dissipation, with the disadvantage of performance losses.

Jerk Limitation Jerk limitation causes the acceleration profile to be smoothed and thereby causes the current peaks to be reduced. Thus, the motor power dissipation is reduced and it is possible to save energy with minor performance losses.

> ☞ Both the acceleration limitation and the jerk limitation cause performance losses. In the latter case, the losses are clearly less so that jerk limitation must be preferred.

10.12.5 Energy Analysis by Means of IndraWorks

General Information

The IndraWorks Engineering Framework offers the possibility to analyze the energy and power requirements of the drive system graphically with its integrated oscilloscope function IndraDrive (see chapter 10.11 "Oscilloscope function" on page 1087).

IndraWorks Oscilloscope Settings

To compare, analyze and evaluate individual energy and power measurements, the following aspects must be observed for the handling of the oscilloscope:

- Use **identical configuration settings** for each measurement. This includes:
  - Identical time base
  - Identical size of memory
  - Identical trigger settings (trigger signal name, trigger level, PreTrigger, trigger edge)

- Save all measurements as a ".zip" (IndraWorks <= 11V06) or ".scope" (IndraWorks >= 12V02)
- To permit evaluation by means of external tools, subsequently renaming the zip file or scope file is not allowed

A comprehensive energy/power analysis of the drive system is only possible if the above points have been complied with.

Determining the Energy Demand of an Individual Drive

When recording using the oscilloscope function, a distinction must be made between direct and indirect energy energy/power values.

Direct Power Values

The following energy/power values can be directly recorded and subsequently analyzed:

- Axis Parameters
  – S-0-0382, DC bus power
  – S-0-0385, Motor power
  – P-0-0819, Energy counter
  – P-0-0851, Short-time energy counter
- Device parameters
  – P-0-0382, Mains power
  – P-0-0383, Mains energy counter
  – P-0-0384, Short-time mains energy counter

Indirect Power Values

To calculate energy/power values which are not directly mapped as parameters, the corresponding status variables required for calculation must be recorded:

- Calculate the copper power dissipation of the motor: The following status variables must be recorded:
  – P-0-0440, Actual output current value (absolute value)

  The calculation is carried out in accordance with fig. 10-58 "Parameter Formula: Copper Losses of Motor" on page 1106
- Calculate the effective electric power: The following status variables must be recorded:
  – P-0-0043, Torque-generating current, actual value
  – P-0-0044, Flux-generating current, actual value
  – P-0-0063, Torque-generating voltage, actual value
  – P-0-0064, Flux-generating voltage, actual value

  The calculation is carried out in accordance with fig. 10-60 "Parameter Formula: Effective Electric Power" on page 1107

The calculation itself must be carried out subsequently to the measurement by means of the oscilloscope function "Define Computation" button.

Determining the Total Energy Absorption of the Drive System

To determine the total energy absorption or total power consumption of the drive system, it is necessary to record status variables at several axes. Basically, there are two possible procedures:

1. Parallel recording of the signals at all axes using the multi-device measurement of the oscilloscope function, or
2. Sequential recording of the signals per axis using the single-device measurement of the oscilloscope function

The first procedure is preferable, because in this case all signals are recorded in time-synchronized form and time displacement between the individual signals is therefore excluded. In the case of sequential recording, the machine cycle to be recorded must be run again per individual device. Make sure that the machine cycle to be recorded is the same for all measurements and that the oscilloscope settings are identical (see chapter "IndraWorks Oscilloscope Settings" on page 1113).

Parallel Recording

For parallel recording of the signals of all axes, the following steps must be carried out:

1. Select multi-axis device measurement
2. Select trigger device
3. Adjust oscilloscope settings
4. Make signal selection
5. Carry out a measurement
6. If necessary, calculate indirect power values individually for each axis in accordance with "Indirect Power Values" on page 1114
7. Summation of the same energy/power values over all axes by means of "Define Computation → Addition"
8. Save measurement (calculations are saved, too)

Sequential Recording

For sequential recording of the signals, the following steps must be carried out **per axis**:

1. Select single-device measurement
2. **Check oscilloscope settings** (settings must be **identical** for each measurement)
3. Make signal selection
4. Carry out a measurement
5. If necessary, calculate indirect power values in accordance with "Indirect Power Values" on page 1114
6. Save measurement

When the measurement for each axis has been carried out successfully, the total energy/power value is calculated. For this purpose, open all measurements via "Oscilloscope → Append Signal Data". The summation of the corresponding values must be carried out via "Define Computation → Addition".

☞ If the individual signals are evaluated by means of an external tool, the calculations in IndraWorks are not required. In the case of sequential recording, make sure to have **identical oscilloscope settings** in each axis.

11 Engineering/Diagnosis Interfaces

11.1 Safety Instructions

⚠ WARNING **Dangerous movements! Danger to life, risk of injury, serious injury or property damage!**

- Keep free and clear of the ranges of motion of machines and moving machine parts.
- Prevent personnel from accidentally entering the machine's range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

11.2 IndraMotion Service Tool (IMST), IndraMotion Diagnostic Tool (IDST)

"IndraMotion Service Tool (IMST)" and "IndraMotion Diagnostic Tool (IDST)" are web-based applications that allow access to a drive system via an Ethernet connection.

Original Equipment Manufacturers (OEM), end users and customer advisors can access the drive system with the help of IMST or IDST, in order to carry out remote diagnoses for example. Besides, authorized users can handle different service cases with IMST or IDST, such as replacing drive components, loading parameters or updating/upgrading the drive firmware.

"IndraMotion Service Tool (IMST)" additionally analyzes drive systems connected via cross communication (CCD). Further information on "IndraMotion Service Tool (IMST)" and "IndraMotion Diagnostic Tool (IDST)" is described in the separate documentation „Rexroth IndraMotion, MLD 13VRS, Service Tool“ (DOK-IM*MLD-IMSTIDSTV13-RE**-EN-P; mat. no. R911342652).

11.3 TCP/IP Communication

11.3.1 Brief Description

☞ In the section "TCP/IP Communication", all necessary information for standard Ethernet communication is given. In addition to TCP/IP, communication via UDP/IP is also possible.

To prevent confusion with the master communication "EtherNet/IP™ interface", the designation "Ethernet communication" was not used here; instead, the term "IP communication" is used.

It is possible to communicate with an IndraDrive controller via standard Ethernet telegrams. These Ethernet telegrams contain TCP/IP or UDP/IP telegrams for application-side connection. For communication with the device, the CSMA/CD access method is applied. Interfaces over which TCP/IP communication is possible provide connection options. This can be an inactive port of the master communication card (e.g. sercos or EtherNet/IP™), a separate Engineering port (if present) or optionally an inactive port of the master communication interface of the CCD master.

Example of sercos Master Communication

For sercos, in addition to the time-controlled transmission of sercos-type Ethernet telegrams (MDT and AT), the Unified Communication Channel (UCC) exists, with which IP telegrams are transmitted in a specially reserved time slot.

Therefore, for sercos, another option for asynchronous data transmission is available in addition to the existing service channel, that is very well suitable for large data volumes due to the maximum lengths of useful data of approx. 1500 bytes.

Possible Applications

With the utilization of the TCP/IP communication in the drive, different application options are available, which are summarized in the following table.

Connection	Server application	Exemplary client applications
SIP protocol	Parameter access	IndraWorks Engineering with CCD master
SIP protocol	Parameter access	IndraWorks parameter application
TFTP	Firmware update service	Carrying out a firmware update
HTTP	Web server	Displaying the IndraMotionServiceTool
FTP	File server	File access to the optional memory card (only available, if optional memory card plugged during the booting process)

Tab. 11-1: Overview of the Possible Applications

Pertinent Parameters

- S-0-1019, Master comm. engineering over IP: MAC address
- S-0-1020, Master comm. engineering over IP: IP address
- S-0-1021, Master comm. engineering over IP: Network mask
- S-0-1022, Master comm. engineering over IP: Gateway address
- P-0-1044, Master comm. engineering over IP: Status IP communication
- P-0-1530, Engineering: MAC address
- P-0-1531, Engineering: IP address
- P-0-1532, Engineering: Network mask
- P-0-1533, Engineering: Gateway address
- P-0-1534, C6100 Command Activate IP settings
- P-0-1544, Engineering: Status IP communication
- P-0-1640, CCD: MAC address
- P-0-1641, CCD: IP address
- P-0-1642, CCD: Network mask
- P-0-1643, CCD: Gateway address
- P-0-4089.0.10, Master communication: MAC address device
- P-0-4089.0.13, Master communication: IP address
- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

Pertinent Diagnostic Messages

- C6101 Incorrect IP settings
- F2190 Incorrect Ethernet configuration

11.3.2 Functional Description

Basic Information on the Function

Components for TCP/IP Communication

A MultiEthernet master communication interface has been integrated into each device. IP communication is directly possible via this interface. Depending on the available hardware and the activated master communication, this interface is called "Engineering over IP" or "Engineering Port".

The interface is called "Engineering over IP" for:

- sercos
- EtherNet/IP™
- PROFINET® RT
- EtherCAT®

  With IndraWorks, it is possible to establish the connection in conjunction with TwinCAT via the ADS interface or the EoE profile.

☞ IndraDrive HCQ controllers and IndraDrive Cs Economy do not have a MultiEthernet master communication interface. Instead, a sercos master communication interface is used.

The interface is called "Engineering Port" for:

- Profibus DP

  For Profibus DP, an additional interface option is necessary and the X24/X25 interfaces can exclusively be used as engineering ports.
- Master communication not active

  If the master communication is deactivated, the X24/X25 interfaces can be used as engineering ports.

Connection Setup

For IP communication, at least the IP address and the network mask must be set in each drive.

Additionally, a gateway address can be set.

Interface	IP address	Network mask	Gateway address
Engineering over IP	S-0-1020	S-0-1021	S-0-1022
Engineering port	P-0-1531	P-0-1532	P-0-1533

Tab. 11-2: Parameters for Setting the IP Configuration

Changes become effective through restart of the drive or activation of the drive command "C6100 Command Activate IP settings" .

Structure of the IP Address

The IP address of a communication node always comprises of a network address (network ID) and a host address (host ID).

In a class C network (network mask 255.255.255.0), the network ID corresponds to the first three bytes of the IP address. The host ID is the fourth byte of the IP address.

Engineering/Diagnosis Interfaces

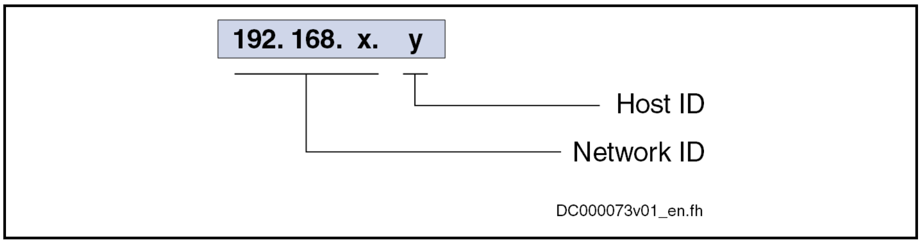


Fig. 11-1: Structure of the IP Address

For the address area of the IP communication with the drive, one "private" area should always be used. The defined areas of the following networks are available

- Class A networks (10.x.x.x),
- Class B networks (172.16.x.x) or
- Class C networks (192.168.x.x).

It is recommended to use the private class C networks (192.168.x.x) for the IP address area or as default setting.

Interface	IP address	Network mask	Gateway address
Engineering over IP	192.168.0.<master comm. address>	255.255.255.0	192.168.0.254
Engineering port	192.168.1.<master comm. address>	255.255.255.0	No default value

Tab. 11-3: Default Values of the IP Configuration

By means of "load basic parameters (factory settings)", the default values of the IP configuration are restored (see table).

The configuration for the IP communication can be maintained by making the corresponding selection in "load basic parameters".

With the option "without engineering interface", the settings for the engineering port remain unchanged. With the option "without master communication parameters", the settings for "engineering over IP" are not changed.

Automatic Settings

IP Address of the Master Communication Interface

This IP configuration is preset automatically:

- **IP address:** 192.168.0.<master comm. address>
- **Network mask:** 255.255.255.0
- **Gateway address:** 192.168.0.254

If required, the settings have to be changed accordingly. This can be done via an already active connection to the drive via the control unit or via "Easy Menu" of the programming module.

Manual Setting via "Easy Menu"

IndraDrive HCQ and IndraDrive HCT do not have a programming module. Thus, manual setting via "Easy Menu" is not possible.

The IP configuration can be changed and activated manually, directly at the device via the "Easy Menu" of the programming module in the **Ethernet** menu item.

☞ The settings are applied via the command C6100 or upon restart of the drive. The command C6100 is started automatically when exiting the menu via the ESC key.

IP Port List

The following table contains an overview of the IP ports used in the drive and their configurability.

Communication	Port	Protocol	Port configurable?
IndraWorks drive programming	5002	TCP	No
IndraWorks drive programming	35021	TCP	No
IndraLogic MLD programming system	1200	TCP	No
IndraLogic network variables	1202	UDP	Yes
EtherNet/IP™	44.818	TCP/UDP	No
EtherNet/IP™	2222	UDP	No
TFTP	69	UDP	No
TFTP - more ports dynamic	1023 et seq.	UDP	Yes
Telnet	23	TCP	No
Global port list "well known ports"	http://www.iana.org/assignments/port-numbers		

Tab. 11-4: IP Port List

11.4 S/IP Protocol

11.4.1 Brief Description

Fields of Application

S/IP allows easy access to all drive parameters.

Typical fields of application are:

- Communication with the drive for Engineering via IndraWorks
- Replacement for cyclic bus communication for controlling simple axis applications without real-time requirements, e.g. in positioning block mode or for drive-controlled positioning

Overview of Functions

Features

- TCP/IP-based protocol
- The protocol is focused on exchanging data; very little management is required.
- User-defined Busy-Timeout (time until drive sends a defined answer)
- User-defined Lease-Timeout (time after which the connection is released again if no new queries are made)
- Its own service for reading out all information of a parameter in a query
- Up to two connections possible simultaneously

Pertinent Diagnostic Messages

The following error messages have been defined, and the drive directly returns them in an individual service:

Name	Value in telegram	Significance
CONNECTION_ERROR	1	Error in establishing the connection
ABORTED	2	Procedure aborted
UNKNOWN_MESSAGE_TYPE	3	Message type in header is unknown
SERVICE_SPECIFIC	4	Service-specific error, e.g. "Operation data is write protected"

Tab. 11-5: S/IP Error Classes

11.4.2 Functional Description

General Information

S/IP is the abbreviation of sercos Internet Protocol.

The following section provides an overview of the services available in the S/IP protocol and explains the individual services. Sample requests and responses are presented in the "Notes on Commissioning".

A service always consists of a request and a response. The request is always sent from the client, the server (drive) can respond to a request with different responses. If the request can be processed and answered immediately, then the drive transmits the associated response to the request directly (generally, Service number response = Service number request + 1). If the drive is busy with another request, a busy response (service number: 68) can be transmitted. If the telegram was incorrectly formatted, if the service is not supported or if another error has occurred, an exception response (service number: 67) is returned.

Each telegram consists of a static part and a service-specific part. A package number can be issued in the static part to assign the response to the request. Furthermore, the service carried out with this telegram is specified.

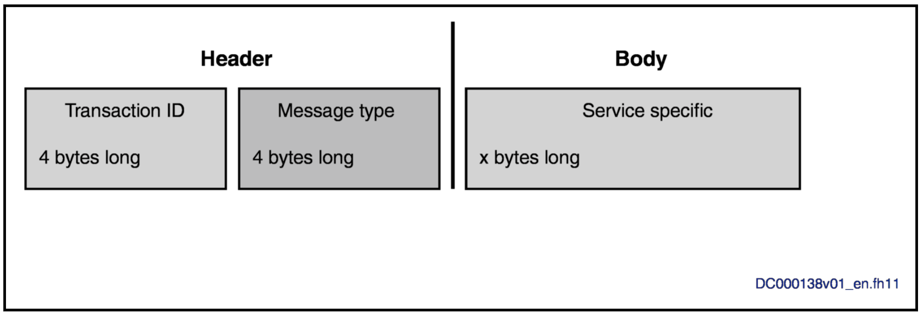


Fig. 11-2: Basic Structure of an S/IP Telegram

The header consists of 8 bytes:

- Bytes 1 - 4 form the "Transaction ID", an identification number that defines this request. This number is specified again with a response.
- Bytes 5 - 8 define the "Message Type". The Message Type is the service number (list of services supported by the drive, see below). As currently only services with a length of 1 byte are used, the low byte is relevant.

Variable Definitions

The "ReadEverything Response" and "ReadDescription Response" services transmit a 2-byte value in addition to the data, indicating which elements are valid in the response. This "ValidElements" value consists of the following:

Bit	Description
0x01	Data status is valid
0x02	Description and DescriptionLength are valid
0x04	Attribute is valid
0x08	Unit and UnitLength are valid
0x10	Minimum value is valid
0x20	Maximum valid is valid
0x40	Value and ValueLength are valid

Tab. 11-6: Valid Elements

The "ReadEverything Request", "ReadOnlyData Request", "ReadOnlyDescription Request", "ReadDataStatus Request", "WriteData Request" and "WriteDataBits Request" services require information about the parameters for which the action is to be performed.

A 4-byte value is transmitted to the drive for this purpose. The structure corresponds to the following scheme.

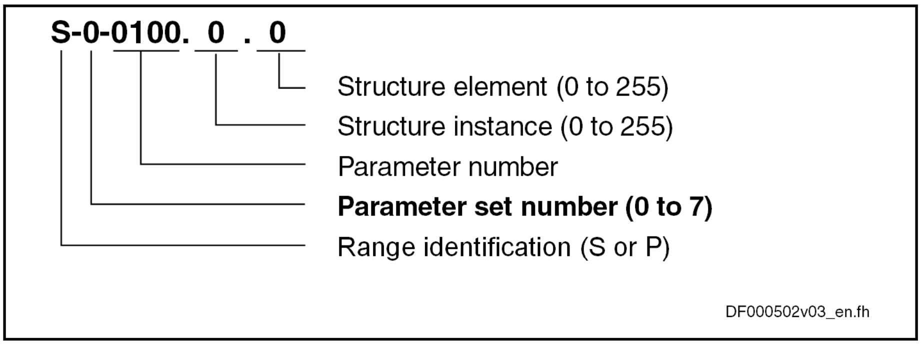


Fig. 11-3: Example of a 4-Byte IDN

Bit No.	Description		Value range	Notes
31-24	Parameter instance/structure instance (SI)		0-255	
23-16	Parameter element/ structure element (SE)	sercos-defined SE	0-127	defined by sercos (bit 15 = 0)
		product-specific SE	128-255	not in use
15	sercos-specified or product-specific IDN (S or P)	Standard IDN (S-0-nnnn)	0	SE (0-127), SI and parameter number are defined via sercos
		Product-specific IDN (P-0-nnnn)	1	Product-specific parameters
14-12	Parameter set		0-7	see also "Parameter Set Switching"
11-0	Parameter number		0-4095	

Tab. 11-7: Structure of the 4-Byte Value

Engineering/Diagnosis Interfaces

Supported Services

The following table provides an overview of the services supported by the drive and the associated "Message Types" for the request and response respectively.

Service name	Service number	
	Request	Response
Connect	63	64
Ping	65	66
Exception	-	67
Busy	-	68
ReadEverything	69	70
ReadOnlyData	71	72
ReadDescription	73	74
ReadDataStatus	87	88
WriteData	83	84
WriteDataBits	85	86
Nameplate	89	90

Tab. 11-8: Supported S/IP Services of IndraDrive

Connect

Request

Structure:

The Connect service connects the client to the drive. Message Type "63" is transmitted for this purpose. The so-called Busy Timeout and Lease Timeout times are also proposed by the client in this telegram.

- **Busy Timeout:** Indicates how much time may elapse before a response telegram to a request is received.
- **Lease Timeout:** Indicates after what time the drive automatically closes the connection if no new requests are received

It also specifies which protocol version of S/IP is used for communication. The drive supports specification 1.0 and accordingly the value "1" is to be transmitted in the "Version" field.

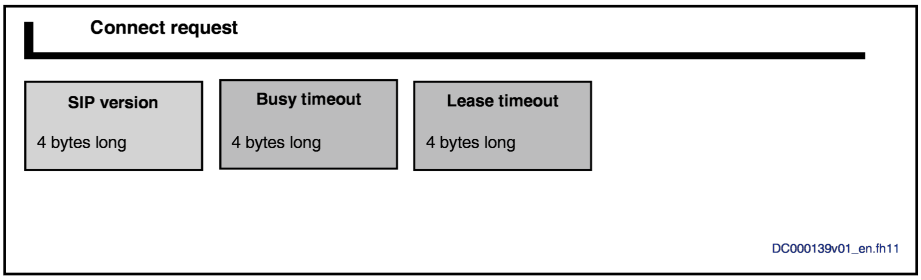


Fig. 11-4: Illustration of a Connect Request

Response

The Connect response is transmitted as a response to a Connect request, if the connection could be established successfully. The service is identified with service number "64" and provides information about the connection:

- Which Busy Timeout is actually used
- Which Lease Timeout is actually used

- Which protocol version is actually used
- An array of all the drive's supported services (requests)

Byte offset	Length (byte)	Name	Significance	Example
0	4	Version	Protocol version of the drive used	1
4	4	BusyTimeout	The drive's Busy Timeout used	500
8	4	LeaseTimeout	The drive's Lease Timeout used	15.000
12	4	NumberMessageTypes	Number of services that the drive supports	12
16	NumberMessageTypes * 4	MessageTypes	Array consisting of 4-byte values which contain the drive's available services	-

Tab. 11-9: Structure of Connect Response

Ping

Ping Request

The ping request is identified via service number "65". This is an empty telegram, that is to say the telegram contains 0 bytes of useful data. The service can be used to:

- Maintain the connection, as the drive rejects the connection at the end of Lease Timeout
- Measure the minimum time that a response requires from the drive

Ping Response

The Ping response is transmitted as a response to a Ping request. The telegram contains no useful data.

Busy & Exception

The "Busy" and "Exception" services are special services. These services can be transmitted as a response to any request.

Busy Response

The Busy response is transmitted if the response telegram cannot yet be transmitted by the end of the Busy Timeout. The Busy response does not contain any data. This response can virtually be suppressed by setting the Busy Timeout to higher values. However, high values do not guarantee that no Busy responses are transmitted.

Exception Response

The Exception response is transmitted if a general error has occurred in the communication. There are various possibilities to explain why an Exception response is transmitted.

ReadEverything

ReadEverything Request

The ReadEverything request is used to collectively request all data from a parameter. The service is identified via service number "69". The SlaveIndex and SlaveExtension are also needed for this purpose. The parameter that is to be read is also transmitted.

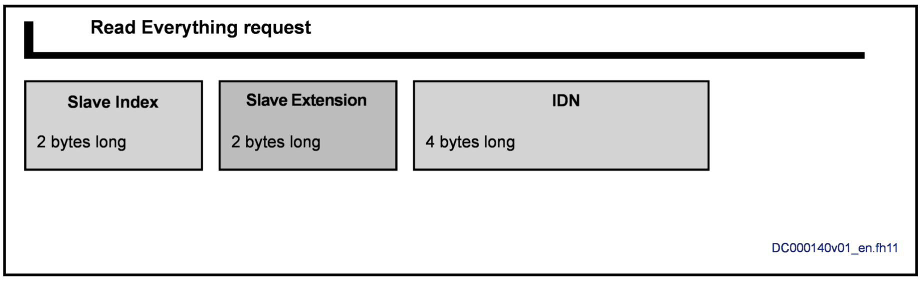


Fig. 11-5: Illustration of a ReadEverything Request

Byte offset	Length (byte)	Name	Significance	Example
0	2	SlaveIndex	Only relevant with Multi-Axis Devices (HCQ/HCT/CDB). 0: access to 1st axis 1: access to 2nd axis etc.	0
2	2	SlaveExtension	reserved - always 0	0
4	4	IDN	Parameter to be read	0x30

Tab. 11-10: Structure of ReadEverything Request

ReadEverything Response

The ReadEverything response contains the data for the "ReadEverything request". The service is identified via service number "70".

The following values are transmitted:

- Data Status
- Attribute
- Minimum value and maximum value
- Maximum length of the list in bytes (if list parameter)
- Current length of the data in the parameter in bytes
- Current length of the unit of the parameter in bytes
- Current length of the name in bytes
- Parameter data in binary format
- Parameter unit as a string
- Parameter name as a string

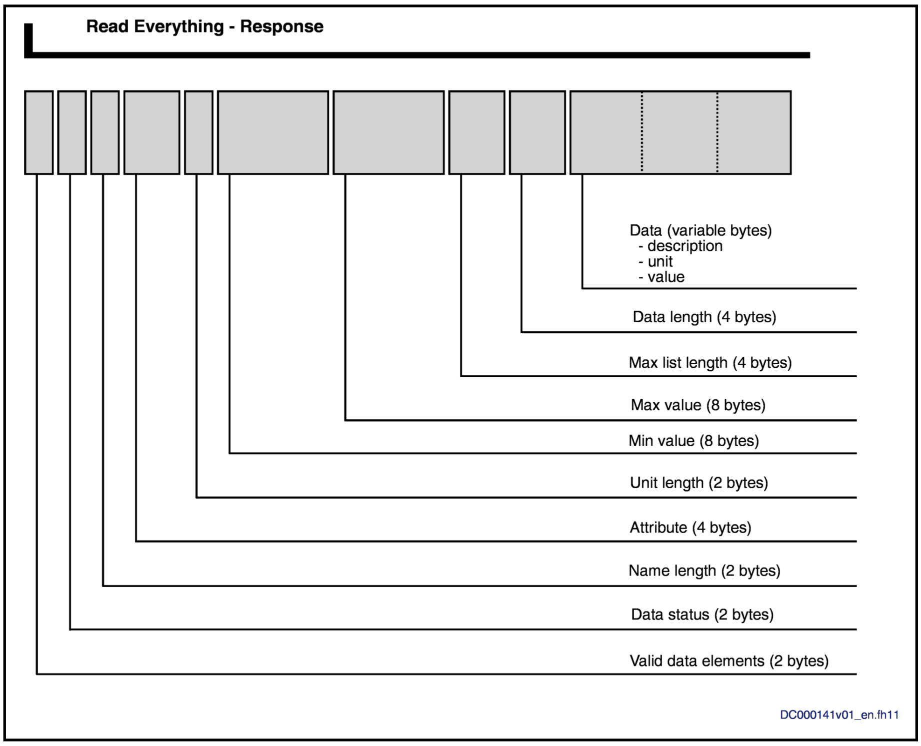


Fig. 11-6: Illustration of the ReadEverything Response

Byte offset	Length (byte)	Name	Significance	Example
0	2	ValidElements	Bit list in which the valid elements are coded	0b0000.0000.0100.1 1111
2	2	DataStatus	Data status of the parameter (valid/invalid) or command status for command parameters	1
4	2	NameLength	Length of the string which contains the name of the parameter in the language set in S-0-0265	0x20
6	4	Attributes	The attribute of the parameter contains information about decimal places, display format, maximum length, write protection and whether the parameter is a command parameter	0x77560000
10	2	UnitLength	Length of the string which contains the unit of the parameter (scaling-dependent)	6
12	8	Min	Lower input limit of this parameter	-
20	8	Max	Upper input limit of this parameter	-
28	4	MaxListLength	Maximum length of the list parameter in bytes (only valid with list parameters)	8196
32	4	DataLength	Current length of the parameter	38
36	NameLength	Name	Name of parameter	"Firmware version"
36 + NameLength	UnitLength	Unit	Unit of parameter	""
36 + NameLength + UnitLength	DataLength	Data	The value of the parameter	"FWA-INDRV****"

Tab. 11-11: Structure of ReadEverything Response

ReadOnlyData

ReadOnlyData Request

The "ReadOnlyData request" is used to read the data. The request for "ReadOnlyData" is identical to the "ReadEverything request", and service number "71" is transmitted in the header.

ReadOnlyData Response

The "ReadOnlyData response" is identified by service number "72". The following data are transmitted:

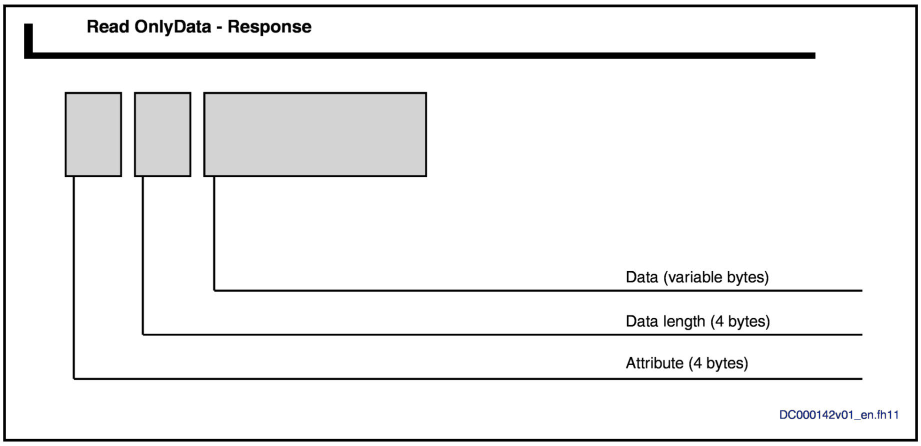


Fig. 11-7: Illustration of the ReadOnlyData Response

Byte offset	Length (byte)	Name	Significance	Example
0	4	Attributes	Attribute of parameter	0x77560000
4	4	Length	Length of the data field in bytes	2
4	Length	Data	The parameter data	0x1345

Tab. 11-12: Structure of ReadOnlyData Response

ReadDescription

ReadDescription Request The "ReadDescription request" is used to request all information about the parameter, with the exception of the operating data per se. The request for "ReadDescription" is completely identical to the "ReadEverything request", except that service number "73" is used.

ReadDescription Response The "ReadDescription response" is identified by service number "74". The following data are transmitted:

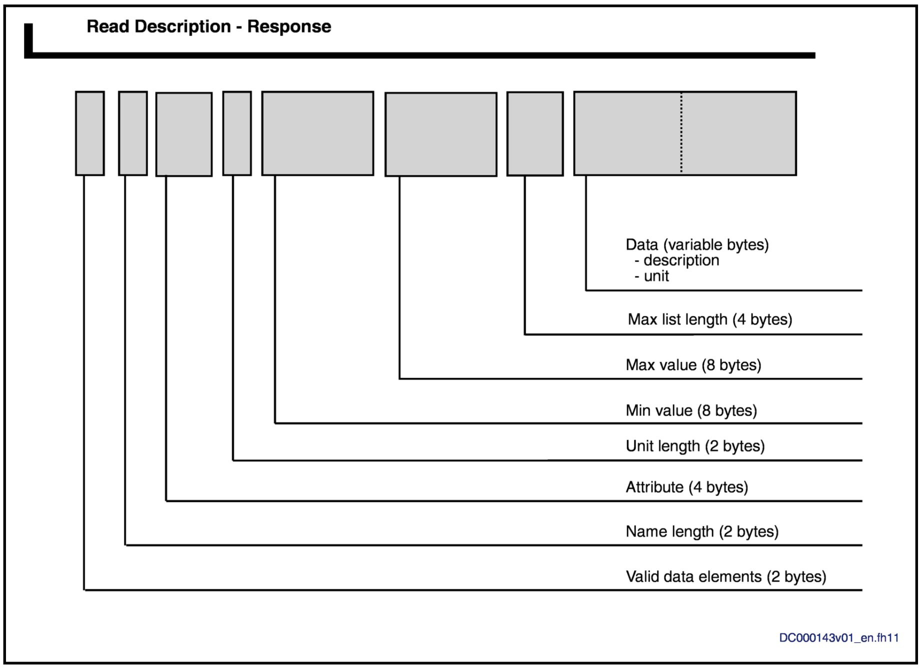


Fig. 11-8: Illustration of the ReadDescription Response

Byte offset	Length (byte)	Name	Significance	Example
0	2	ValidElements	Bit list in which the valid elements are coded	0b0000.0000.0100.11111
2	2	NameLength	Length of the string which contains the name of the parameter in the language set in S-0-0265	0x20
4	4	Attributes	The attribute of the parameter contains information about decimal places, display format, maximum length, write protection and whether the parameter is a command parameter	0x77560000
8	2	UnitLength	Length of the string which contains the unit of the parameter (scaling-dependent)	6
10	8	Min	Lower input limit of this parameter	-

Byte offset	Length (byte)	Name	Significance	Example
18	8	Max	Upper input limit of this parameter	-
22	4	MaxListLength	Maximum length of the list parameter in bytes (only valid with list parameters)	8196
26	4	DataLength	Current length of the parameter	38
30	NameLength	Name	Name of parameter	"Firmware version"
30 + Name-Length	UnitLength	Unit	Unit of parameter	""

Tab. 11-13: Structure of ReadDescription Response

ReadDataStatus

ReadDataStatus Request The "ReadDataStatus request" is used to read the data status directly. The request for "ReadDataStatus" is identical to the "ReadEverything request", and service number "87" is used.

ReadDataStatus Response The "ReadDataStatus response" is identified by service number "88". The following data are transmitted:

Byte offset	Length (byte)	Name	Significance	Example
0	2	DataStatus	Data status of the requested parameter	1

Tab. 11-14: Structure of ReadDataStatus Response

WriteData

WriteData Request The "WriteData request" is used to read the data. Service number "83" is used in this case.

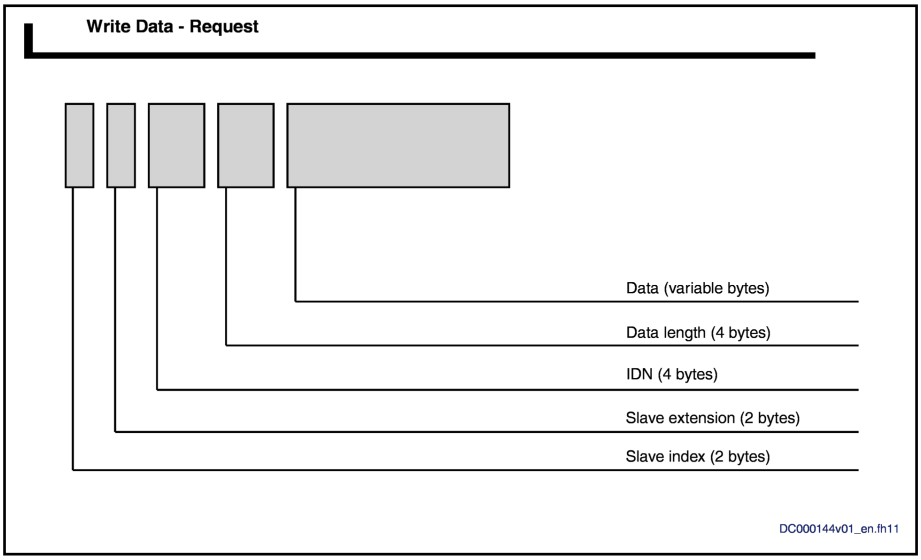


Fig. 11-9: Illustration of the WriteData Request

Byte offset	Length (byte)	Name	Significance	Example
0	2	SlaveIndex	reserved - always 0	0
2	2	SlaveExtension	reserved - always 0	0

Engineering/Diagnosis Interfaces

Byte offset	Length (byte)	Name	Significance	Example
4	4	IDN	Parameter to be read	0x30
4	4	DataLength	Length of transmitted data	2
8	DataLength	Data	The operating data to be transmitted	0x1234

Tab. 11-15: Structure of WriteData Request

WriteData Response

The "WriteData response" is identified by service number "84". No data are transmitted.

WriteDataBits

WriteDataBits Request

The "WriteDataBits request" is used to individually write individual bits of a parameter. The request for "WriteDataBits" is identified by service number "85".

Any number of bits of a parameter value can be written in a request. The bits written depend on the DataMask, which forms part of the request. It is therefore possible to change an individual bit at any position in the parameter or write all bits. The bits that are written must be selected at the corresponding position in the "DataMask". If bit 7 is to be written, bit 7 must be set to 1 in the "DataMask".

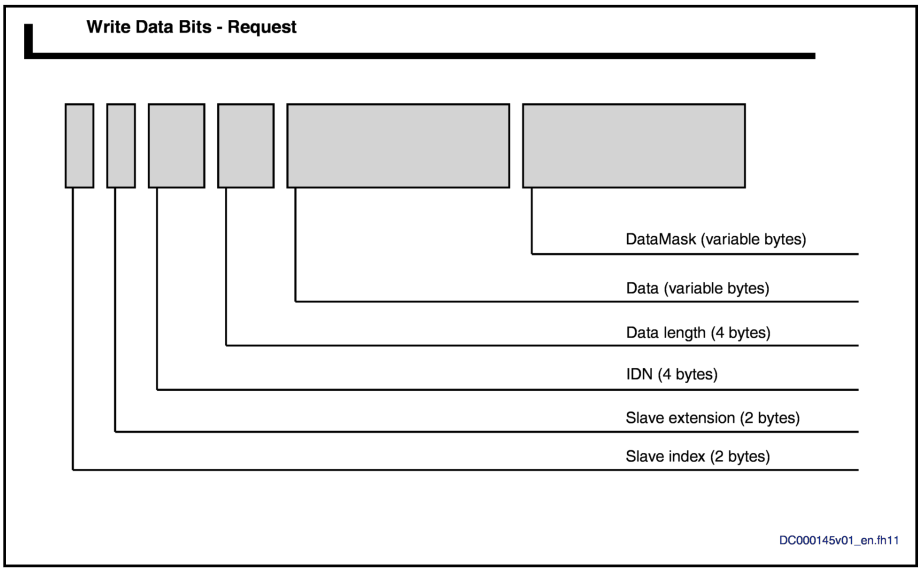


Fig. 11-10: Illustration of the WriteDataBits Request

Byte offset	Length (byte)	Name	Significance	Example
0	2	SlaveIndex	reserved - always 0	0
2	2	SlaveExtension	reserved - always 0	0
4	4	IDN	Parameter to be read	0x30
4	4	DataLength	Length of transmitted data	2
8	DataLength	Data	The operating data to be transmitted	0x1234
8 + DataLength	DataLength	DataMask	The bits to be updated	

Tab. 11-16: Structure of WriteDataBits Request

WriteDataBits Response

The "WriteDataBits response" is identified by service number "86". There aren't any useful data transmitted. In the event of an error, an "Exception response" is returned instead of the WriteData response.

Nameplate

Nameplate Request In preparation

Nameplate Response In preparation

11.5 Firmware Download via TFTP Server

11.5.1 Brief Description

Fields of Application

If a firmware download is to be carried out, a TFTP server is available for this purpose. This makes it possible to download new firmware to the device.

Overview of Functions

Identifying Firmware

A special "ReadRequest" can be used to identify firmware existing in the device. To do this, in the "ReadRequest" the string "Firmware" is transmitted.

The response telegram contains a data packet, the first four bytes of which are the control section circuit board code and the following content is the manufacturer version (cf. S-0-0030.0.0).

Firmware Download

The download procedure is started using a WriteRequest. To do this, the drive must be in PM. Here the "WriteRequest" also initiates the connection to the TFTP server.

Then "DataRequests" is used to download the firmware to the device. The device takes over various checks:

- Can the new firmware file be used with this device (compatibility check)?
- Was the correct quantity of data transmitted (data integrity check)?
- Was the firmware file transferred correctly and was it valid (validity check)?

Error Diagnostics

Any possible error that occurs during this procedure is returned via the ErrorFrame in the TFTP. The error text is available as a plain text.

Features

The TFTP server of an IndraDrive device has the following features:

- A TFTP connection does not know any authentication
- The following five packet types are present in a TFTP connection:
  - "ReadRequest" (reading of files from server/drive starts)
  - "WriteRequest" (writing of files from server/drive starts)
  - "Data" (data are transmitted)
  - "Acknowledge" (data packets are confirmed)
  - "Error" (any type of error message)
- Each data packet must be confirmed with "Acknowledge" before the next data packet is transmitted.

Pertinent Diagnostic Messages

Errors that occur are transmitted in plain text via "TFTP ErrorFrame" (see the description of diagnostic message: "Firmware Download")

11.6 File Handling via FTP via Ethernet

11.6.1 Brief Description

Base package of all firmware variants in **open-loop and closed-loop** characteristic

Via an integrated FTP server, IndraDrive devices with Ethernet communication can access the data of the optional memory card by means of FTP connection. This allows reading or writing data/directories on the memory card.

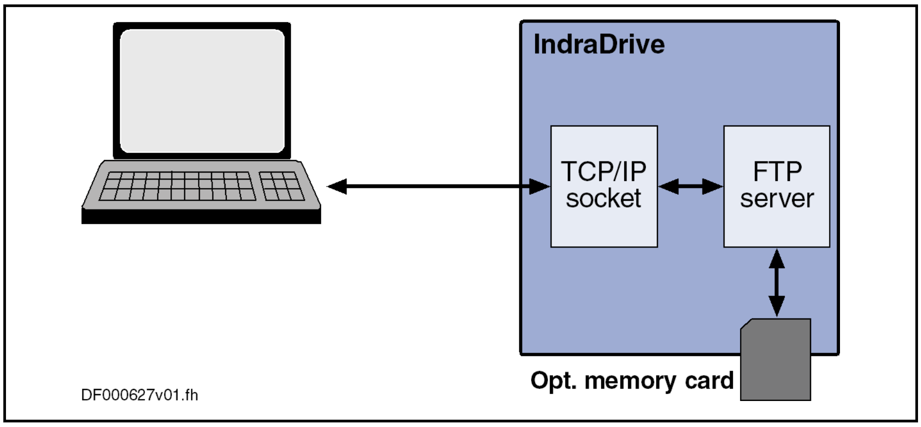


Fig. 11-11: Schematic Illustration of FTP File Handling

Features

The FTP server of an IndraDrive device has the following features:

- Two kinds of login to the FTP server:
  - Anonymous login (read-only data access)
  - User login (read and write access to data)
- A maximum of 2 simultaneous connections
- The effective transmission rate depends on processor load and current drive status

  The transmission rate is approx. 450 kbytes/s for download (STOR command) and 300 kbytes/s for upload (RETR command) with an active connection. If 2 FTP connections are simultaneously active (download or upload), the effective transmission rate is dramatically reduced in both directions.

Hardware Requirements

The following hardware requirements must have been fulfilled:

- IndraDrive Cs Advanced with Advanced display
- Memory card plugged before booting

If no memory card was recognized during the booting process, the parameter "P-0-4066, Card Identification Data" contains the value 0xFFFFFFFF.

Pertinent Parameters

- P-0-4066, Card Identification Data
- S-0-1020, Master comm. engineering over IP: IP address
- P-0-1531, Engineering: IP address
- P-0-1641, CCD: IP address

11.6.2 Functional Description

Connections

A maximum of 2 connections to the FTP server can be simultaneously established.

Establishing the Connection

After the drive has been booted, the FTP connection is not active yet. To establish the connection, log in to the FTP server using the correct IP address.

Terminating the Connection

When there is no more data traffic, the drive automatically terminates the FTP connection after 5 min. If the connection is to be maintained, the FTP command "NOOP" can be cyclically transmitted.

File Directories

The drive automatically creates the following directories should they not yet be present:

- USER
- BACKUP
- TOOLS
- PLC
- DOCUMENTATION
- TEMP

FTP Login

Each time the connection is established, you have to log in to the FTP server. IndraDrive supports two types of login, standard login and anonymous login.

Standard Login

For standard login to the FTP server, log in under the user name "boschrexroth" with the password "boschrexroth" (login according to Bosch Rexroth standard).

Upon successful standard login, you can access all files and directories of the memory card and carry out read access or write access.

After each login, the FTP server opens the "USER" directory of the memory card.

Anonymous Login

Anonymous login to the FTP server is possible, too. For this purpose, employ the user name "anonymous" and any e-mail address as a password (IndraDrive-specific login). With this type of login, you have read-only access to all data and directories of the memory card.

After each login, the FTP server opens the "USER" directory of the memory card. This is the area in which the user data were stored.

FTP Data Handling

File Date

Files created via FTP on the memory card, are created there as a new file. The time from parameter "P-0-0197, System time" is used as the file date; the minimum date used as start value is "01.01.00".

File Names

When choosing file names and directory names, observe the following rules and restrictions:

- File names may only contain the following characters:
  - !#$%&'()+-0123456789=?
  - ABCDEFGHIJKLMNOPQRSTUVWXYZ[]^_
  - abcdefghijklmnopqrstuvwxyz{}~
- Lowercase letters "a" to "z" are converted into uppercase letters "A" to "Z".
- Files must not start with ".".

- The lengths of file names (incl. file path) mustn't exceed 80 characters.

FTP Commands

The FTP server accepts the commands contained in the following table. If commands are entered via a user interface (e.g. FTP client), some different commands are used (e.g. "dir" instead of "LIST"). In these cases, the FTP client converts the commands, which the user entered, to the below-mentioned syntax.

Command syntax	Description
USER xxxx	Log in with user name xxxx
PASS xxxx	Enter password xxxx
TYPE x	Enter transmission type: x = "A" for ASCII; x = "I" for IMAGE (binary)
STOR xxxx	Store a file of name xxxx on a µSD card
RNFR xxxx RNTO yyyy	Rename file xxxx, new name yyyy
CWD xxxx	Change working directory to xxxx
SYST	Request system information from FTP server
CDUP	Change working directory, go one level "up"
QUIT	Terminate the connection
STRU F	Set data structure type to "File"
APPE xxxx	Append data to file xxxx or create file xxxx
LIST	Request directory structure from server
STAT	Request status message of current settings of TYPE, STRU and MODE
RMD xxxx	Delete directory xxxx
XRMD xxxx	Delete directory xxxx
ACCT xxxx	Change user ID to xxxx
PORT xxxx	Transmit port number of host for data transfer
MODE S	Set transfer mode to "Stream"
ABOR	Abort current transmission
NLST	Transmit a file list to client
HELP	Transmit a list of supported FTP commands to client
PWD	Show current working directory
XPWD	Show current working directory
MKD xxxx	Create directory xxxx
XMKD xxxx	Create directory xxxx
PASV	Open FTP server as "passive" connection
RETR xxxx	Transmit file xxxx to client
DELE xxxx	Delete file xxxx on server
NOOP	"No Operation"→ Can be transmitted periodically to maintain connection

Tab. 11-17: Function Commands for FTP Data Handling

12 Commissioning

12.1 Safety Instructions

⚠ WARNING **Dangerous movements! Danger to life, risk of injury, serious injury or property damage!**

- Keep free and clear of the ranges of motion of machines and moving machine parts.
- Prevent personnel from accidentally entering the machine's range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

12.2 Commissioning Motors

12.2.1 Checking the Installation/Assembly

Checking the Assembly

Check the assembly of the IndraDrive controllers and supply units as well as motors with regard to correct implementation, according to the data contained in respective Project Planning Manual.

Checking the Installation

Check the wiring of control cabinet and machine with regard to correct implementation, according to the data contained in the Project Planning Manual and the recommendations in the documentation "Electromagnetic Compatibility (EMC) in Drive and Control Systems".

12.2.2 Initial Commissioning/Serial Commissioning

Brief Description

The drive can be commissioned after assembly and installation have been correctly implemented.

Initial Commissioning

The initial commissioning of a drive differs from the commissioning of other identical drives (serial commissioning).

The initial commissioning is carried out in the following steps:

- Establishing the operatability of the drive (including the required measuring systems)
- Adjusting the drive behavior to the requirements of the application
- Adjusting the master communication interface between master and drive
- Integrating drive functionalities in the machine processes

In each of the mentioned steps, values of relevant parameters are adjusted to the requirements. The result of the initial commissioning is a drive the behavior of which is exactly adjusted to the axis. By storing the values of the initial commissioning in the form of a parameter set the drive behavior can be reproduced.

Serial Commissioning

For the commissioning of other identical axis drives on machines of the same type, the set of parameter values determined during the initial commissioning is loaded to the respective controller (serial commissioning). This allows

- exactly reproducing the drive behavior

- and -

- reducing the effort for further commissioning to a little adjustment work and, if necessary, search and elimination of assembly/installation errors.

Possibilities of Commissioning

As a matter of principle, commissioning can be carried out by means of

- the "IndraWorks Ds/D/MLD" commissioning tool by Rexroth which is connected to the drive via sercos interface, via an engineering interface, via Ethernet or a field bus,
- the control panel of the controller and digital and analog input signals,
- a control unit connected to the drive via a master communication interface.

Two-Step Commissioning

It is basically recommended to always carry out both the initial commissioning and the serial commissioning in two steps:

- 1st objective: Initial Start of the Motor
- 2nd objective: Providing drive functions for the machine axis

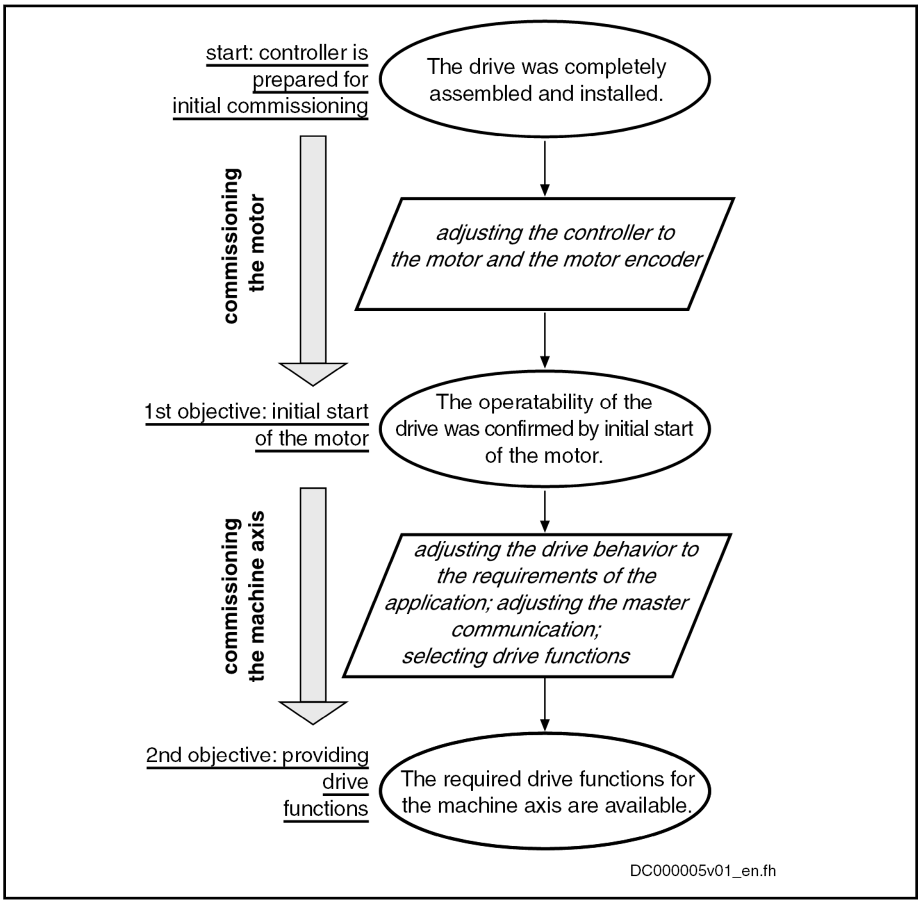


Fig. 12-1: Two-step drive commissioning (schematic)

In the first step, the two-step procedure ensures the operatability of the drive (1st objective during initial commissioning and serial commissioning). In the second step, the drive functions required for the machine axis and the drive's advantageous properties are individually adjusted to the machine axis in a reasonable order (2nd objective during initial commissioning) or the expected functional principle is checked (2nd objective during serial commissioning).

☞ As a matter of principle, it is advantageous to establish the operatability of a drive independent of a higher-level control system. The drive should therefore first be commissioned as a self-contained unit via "IndraWorks Ds/D/MLD" or in the "Easy-Startup" mode!

See the following sections:

- "Initial Start in "Easy Startup" Mode"
- "Initial Start with the Commissioning Tool"

Notes on Commissioning

Initial Start of the Motor

See "Initial Start in Easy Startup Mode"

See "Initial Start with the Commissioning Tool"

Providing Drive Functions

See "Commissioning Machine Axes"

Initial Commissioning

After initial commissioning has been carried out the defined application-specific parameter values have to be saved. The saved parameter values allow reproducing the drive behavior required at the respective machine axis.

☞ For saving the parameter values the drive provides parameter lists supporting the complete storage of the relevant parameter values.

By reloading the saved parameter values the initial state after initial commissioning can be established again for the axis drive!

See also "Parameters, Basics: Loading, Storing and Saving Parameters"

Reestablishing the Original Status

Attention: For drives with absolute encoders, it is necessary to reestablish the original status after initial commissioning!

NOTICE **Possible property damage for drives with absolute encoders caused by incorrect actual position value after repeated loading of parameter values saved according to S-0-0192!**

⇒ Save parameter values by means of accordingly modified IDN list of parameter S-0-0270 (see below)

For drives with absolute value encoder and modulo scaling, it is recommended to determine the parameter set for saving the parameter values after initial commissioning by means of a list of "S-0-0270, IDN-list of selected backup operation data" modified by the customer; when this is done, there cannot occur any actual position value error when the saved parameter values are loaded to the same axis drive again.

☞ This is only possible via a control master. "IndraWorks Ds/D/MLD" only work with the content of the list parameter S-0-0192!

In its initial state, the content of the list parameter S-0-0270 first corresponds to the list parameter S-0-0192 and should be modified as follows:

- Remove the IDNs P-0-0177 and P-0-0178

These parameters contain information on the current position data of the absolute encoders at the time of parameter backup. If the current data of P-0-0177 and P-0-0178 during the loading of the saved parameter values were overwritten with data referring to a different axis position current at the time of parameter backup, the actual position values would correspond to the other axis position! The actual position values would remain valid (S-0-0403, Position feedback value status), because it still is the same absolute value encoder.

☞ The incorrect actual position value generated in this case cannot be detected on the drive side because otherwise unjustified errors would be generated in service cases when devices are replaced!

See also "Notes on How to Replace the Devices"

☞ The list of S-0-0270 modified as described can also be used for saving and loading the parameter values of axes with relative measuring systems, because the parameters P-0-0177 and P-0-0178 in this case do not contain relevant information!

☞ The content, possibly modified, of the list parameter S-0-0270 is contained in parameter S-0-0192, too! This means that when the backup is made via parameter S-0-0192, the content of parameter S-0-0270 can be read from the stored list, in order to load only these individually selected parameter values!

Serial Commissioning

The serial commissioning of axis drives of machines of the same type is supported by the application-specific parameter set of the respective axis drive saved after initial commissioning.

During serial commissioning the saved parameter sets are loaded to the controllers of the respective axis drives of other machines of the same type. This allows easily reproducing the behavior of the drives of a "model machine"!

After the application-specific parameter set of an axis drive has been loaded only some more adjustments are required:

- Setting the communication parameters, e.g. drive address (see "Basic Functions of Master Communication: Setting the Axis Address"), Master Communication: IP address of master communication: Device name
- "Establishing position data reference" for axes with measuring systems that can be evaluated in absolute form (see "Establishing Position Data Reference: Establishing Position Data Reference for Absolute Measuring Systems")

See also "Parameters, Basics: Loading, Storing and Saving Parameters"

12.2.3 Initial Start in "Easy Startup" Mode

Brief Description

The so-called "easy startup mode" allows moving the drive without connected or active control unit (or master communication master) or external command value box. When using a Rexroth motor with encoder data memory, this is also possible without using a commissioning PC, because all motor and controller parameters are stored in the encoder data memory.

☞ The easy startup mode is therefore particularly suited for **initial commissioning** of individual axes, as well as for maintaining an **emergency mode** when the control unit has failed.

Features

- **Activation** of "easy startup" mode via:
  - Engineering interface or digital inputs
  - Control panel of drive controller
- Automatic **deactivation** of master communication interface (see P-0-4077, S-0-0134) and activation of "P-0-0120, Control word easy startup"
- Activation of **drive enable** (P-0-0120, bit 15) via:
  - The digital input assigned to drive enable (different according to hardware design, see default assignment under "Automatic Configuration of the Inputs")
  - Engineering interface when configuration of digital inputs for "easy startup" mode made before was removed
- Drive moves in "velocity control" mode with a parameterizable velocity command value (cf. P-0-1206) without external command value box
- Selection of **travel direction** (positive/negative) via digital input signals (see parameter "P-0-1200, Control word 1 velocity control")

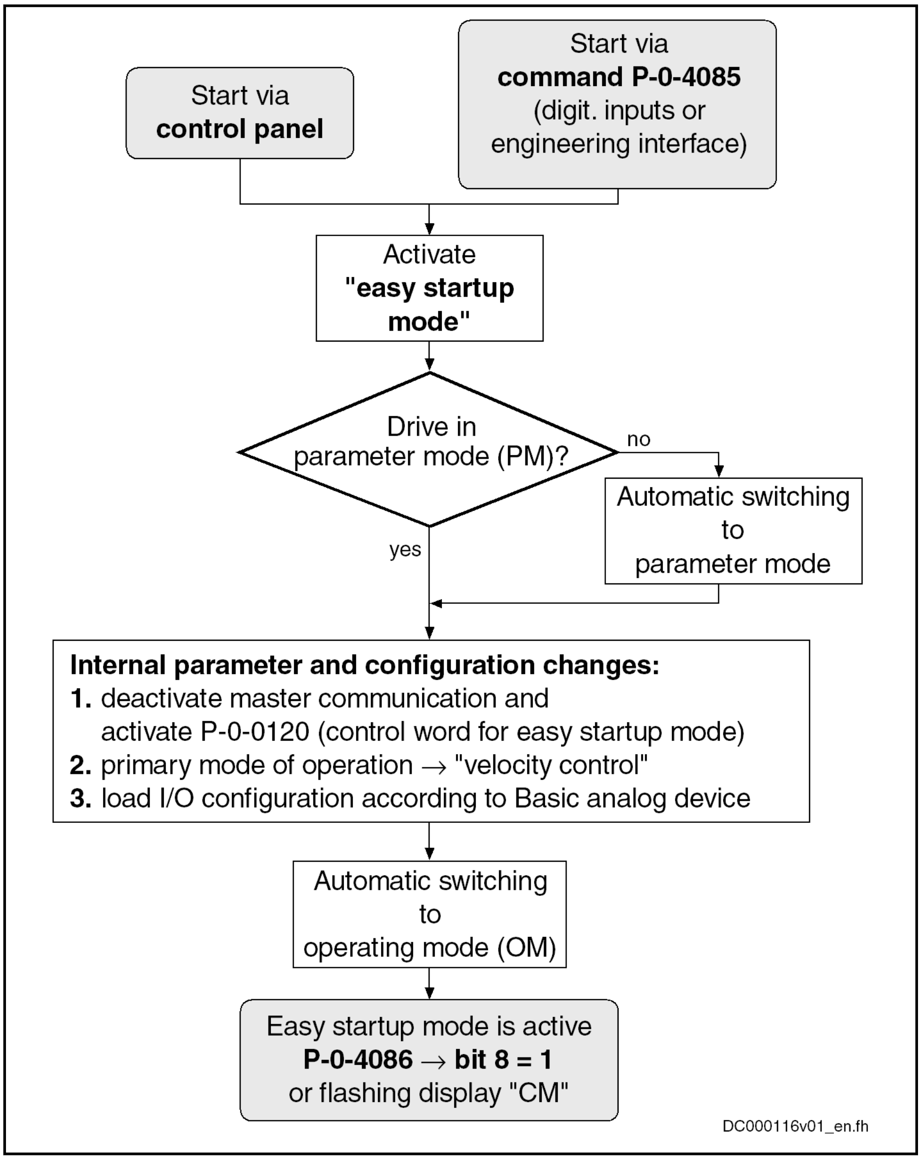


Fig. 12-2: Activating the "Easy Startup" Mode, Overview

Hardware Requirements

For the "easy startup" mode, the digital inputs at interface X31 must be wired as follows:

- X31/1 +24V for activating drive enable
- X31/6 +24V for activating the positive direction of rotation
- X31/7 +24V for activating the negative direction of rotation

Pertinent Parameters

- S-0-0032, Primary operation mode
- S-0-0091, Bipolar velocity limit value
- P-0-0120, Control word easy startup
- P-0-0300, Digital inputs, assignment list
- P-0-0301, Digital inputs, bit numbers
- P-0-1200, Control word 1 velocity control
- P-0-1206, Memory of velocity command values
- P-0-4085, C4700 Command Activate easy startup mode
- P-0-4086, Master communication status

Pertinent Diagnostic Messages

In the "easy startup" mode, additional simple diagnostic texts appear on the display of the control panel in "light writing":

- When the "easy startup" mode has been activated, the display switches between the drive address and the message "CM" (Commissioning Mode).
- During commissioning, the relevant messages appear on the display.

Functional Description

Requirements

The following requirements and conditions must have been fulfilled for using the "easy startup" mode:

- The wiring of the drive is complete and correct.
- There shouldn't any master communication have been activated.

  Attention: The "easy startup" mode switches off any possibly active master communication!
- The drive controller must be supplied with control voltage and it must be possible to switch power on.
- There mustn't any error message be present.

For Rexroth motors with encoder data memory, there is no commissioning PC required; otherwise the motor parameters have to be set during commissioning, if necessary with a PC.

General Information on How to Activate the Easy Startup Mode

The "easy startup" mode can be activated both in the parameter mode (phase 2) and in the operating mode (phase 4), by activating "P-0-4085, C4700 Command Activate easy startup mode".

> ☞ If the drive already is in the "easy startup" mode and this mode is activated again, the display reads "easymode active"!

The "easy startup" mode can be activated via:

- The control panel of the drive controller
- A digital input
- The engineering interface (Ethernet)

> ☞ By activating "P-0-4085, C4700 Command Activate easy startup mode", the drive automatically switches to the parameter mode and configures the "velocity control" mode with values from the memory of fixed command values (P-0-1206).

Activation via Control Panel

The figure below illustrates how the easy startup mode is activated via the control panel of the IndraDrive controllers:

Commissioning

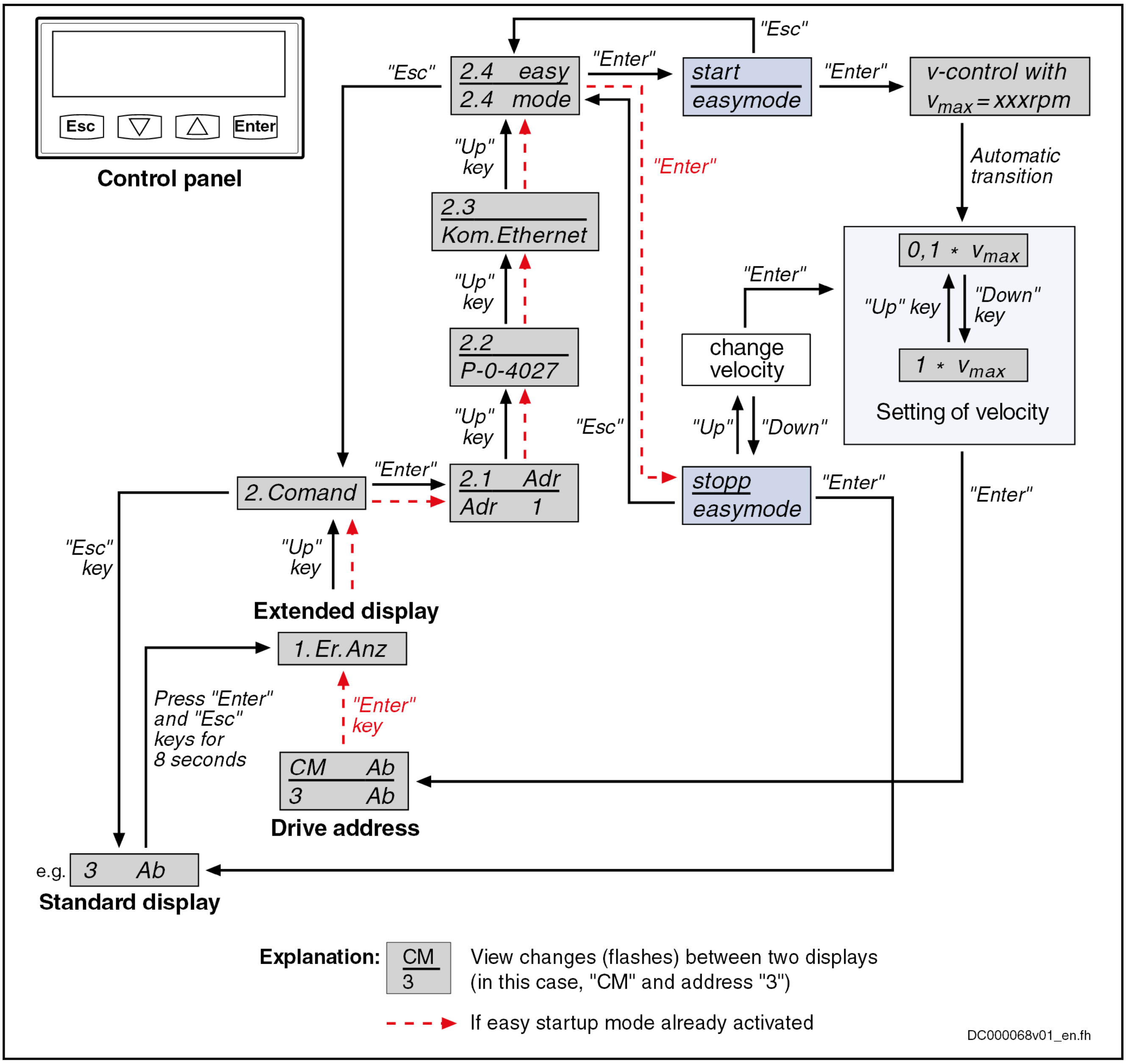


Fig. 12-3: Activating the Easy Startup Mode via the Control Panel

See also "Control Panels of the IndraDrive Controllers"

Activation via Digital Input

If the "easy startup" mode is activated via a digital input, bit 0 of parameter P-0-4085 has to be assigned to a digital input.

See "Digital Inputs/Outputs"

Activation via Engineering Interface

To activate the "easy startup" mode via the engineering interface, the parameter P-0-4085 must be written.

"P-0-4085, C4700 Command Activate easy startup mode" can also be directly written via the master communication (e.g. sercos or field bus), but in this way the master would deactivate itself!

Acknowledging the Active "Easy Startup" Mode

The active "easy startup" mode is acknowledged by:

- Setting bit 8 in "P-0-4086, Master communication status"

- Changing the display on the control panel between "CM" (Commissioning Mode) and the drive address

Automatic Configuration of the Inputs

For automatic configuration of the inputs, the following actions are performed:

- Deactivation of master communication interface and activation of drive enable in parameter "P-0-0120, Control word easy startup"
- Setting of operation mode "velocity control" with values from memory of fixed command values (P-0-1206)
- Assignment of the command velocity selected via the control panel (in percent) of "S-0-0091, Bipolar velocity limit value" to element 1 or element 2 of "P-0-1206, Memory of velocity command values" (with positive sign to element 1, with negative sign to element 2).
- Assignment of allocation of inputs

☞ The actual configuration of the inputs/outputs depends on the available digital inputs of the control section (see tables below).

☞ The automatic configuration of the inputs/outputs for the "easy startup" mode takes place **in volatile form**, i.e. any I/O configuration existing before is reestablished when the command is completed. This is not the case, if the I/O configuration was specifically (manually) changed with the command being active.

IndraDrive Cs			
Connection	Signal	Function	I/O assignment
X31_1	I_1	Drive enable	P-0-0120, Control word easy startup (bit 15)
X31_6	I_6	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 0)
X31_7	I_7	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 1)

Tab. 12-1: Automatic I/O Configuration for Easy Startup Mode with IndraDrive Cs

"Load Defaults Procedure (Factory Settings)" with Invalid Parameters Settings

After the "easy startup" mode has been activated, the drive normally is ready for operation ("bb" or "Ab" → communication phase 4). When the drive stops in communication phase 3 due to invalid parameter values, valid basic default values can be loaded via the control panel.

See also "Control Panels of the IndraDrive Controllers"

Controlling the Drive

According to master communication or setting of the device control, different control words take effect. Internally, however, all relevant control bits are always displayed in "P-0-0116, Device control: Control word".

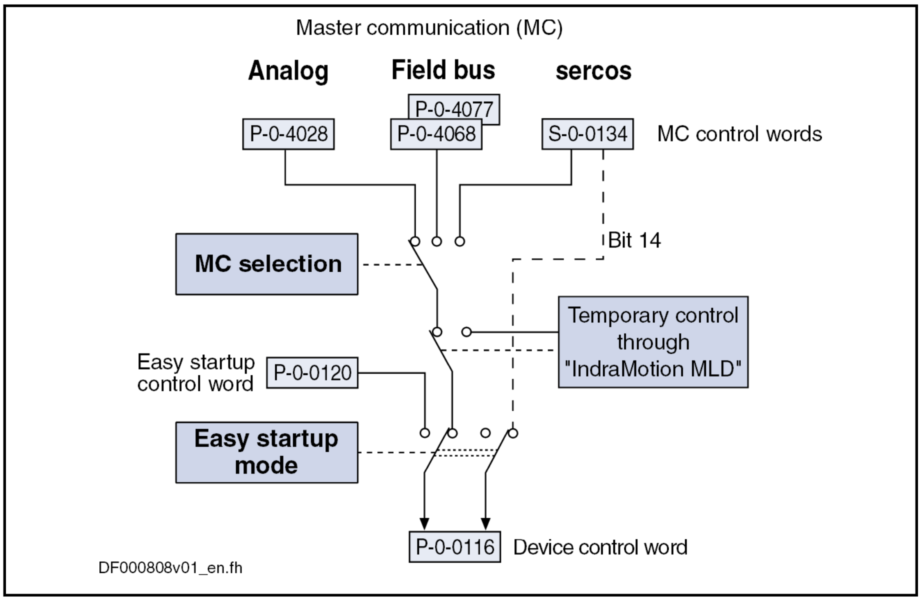


Fig. 12-4: Controlling the Drive in the "Easy Startup" Mode

> ☞ In the case of temporary control of the PLC, bit 14 (drive enable) is nevertheless taken from "S-0-0134, Master control word" for sercos interface! Only in the case of stand-alone "Motion Control" does the PLC also control bit 14. In the case of field buses, bit 14 is activated internally.
>
> See also "Profile Types (with Field Bus Interfaces)"

The control parameter "P-0-0120, Control word easy startup" active in the "easy startup" mode can be changed or influenced in the following ways:

- Via digital inputs, if they were accordingly configured before
- Via the engineering interface by directly writing P-0-0120

Exiting the "Easy Startup" Mode

After the "easy startup" mode has been exited, the drive controller is in its initial state again. All changes automatically made to the configuration were undone.

> ☞ Any manually changed I/O settings are not undone. The configuration of the digital inputs X31_1, X31_6 and X31_7 active before the activation of the command "P-0-4085, C4700 Command Activate easy startup mode" is only reestablished if the inputs were not (manually) changed during the command execution.

Notes on Commissioning

General Information

Invalid Commands

The commands for backup of working memory ("P-0-0120, Control word easy startup" and "C2400 Selectively backup working memory procedure command") should not be triggered in the "easy startup" mode, because otherwise the settings of the "easy startup" mode will be stored in the non-volatile memory and will be active again after the drive is switched on the next time!

Initial Commissioning

In the "easy startup" mode, initial commissioning of Rexroth motors with encoder data memory is easily done without the commissioning tool, as the required parameter settings for motor control and motor encoder are automatically made via the command "Load defaults procedure (motor-spec. controller values)".

For the "Load default values procedure", see "Default Settings in the Motor Encoder Data Memory (Motor-Spec. Controller Values)" under "Drive Control: Overview".

Initial commissioning of Rexroth motors without encoder data memory or of third-party motors in the "easy startup" mode is only possible in conjunction with an "IndraWorks Ds/D/MLD" commissioning tool, in order to load or enter the values for motor control parameters and motor encoder parameters. For synchronous motors with absolute measuring system, the commutation offset only has to be determined at initial commissioning. For synchronous motors with relative measuring system, the commutation offset is automatically determined every time drive enable is set for the first time after transition "PM → OM".

If for synchronous motors the commutation offset can only be determined by supplying current, this is only possible in the operating status "Ab" with active "easy startup" mode!

See "Initial Start with the Commissioning Tool"

NOTICE **Danger of property damage during initial start in "easy startup" mode caused by incorrect parameter values!**

⇒ For motors without encoder data memory, the required motor and controller parameters must be checked before initial start in the "easy startup" mode!

Recommissioning

In the "easy startup" mode, recommissioning (after initial commissioning having been carried out) of drives is possible without any problem, because the correct values of motor control parameters and motor encoder parameters are already available in the drive.

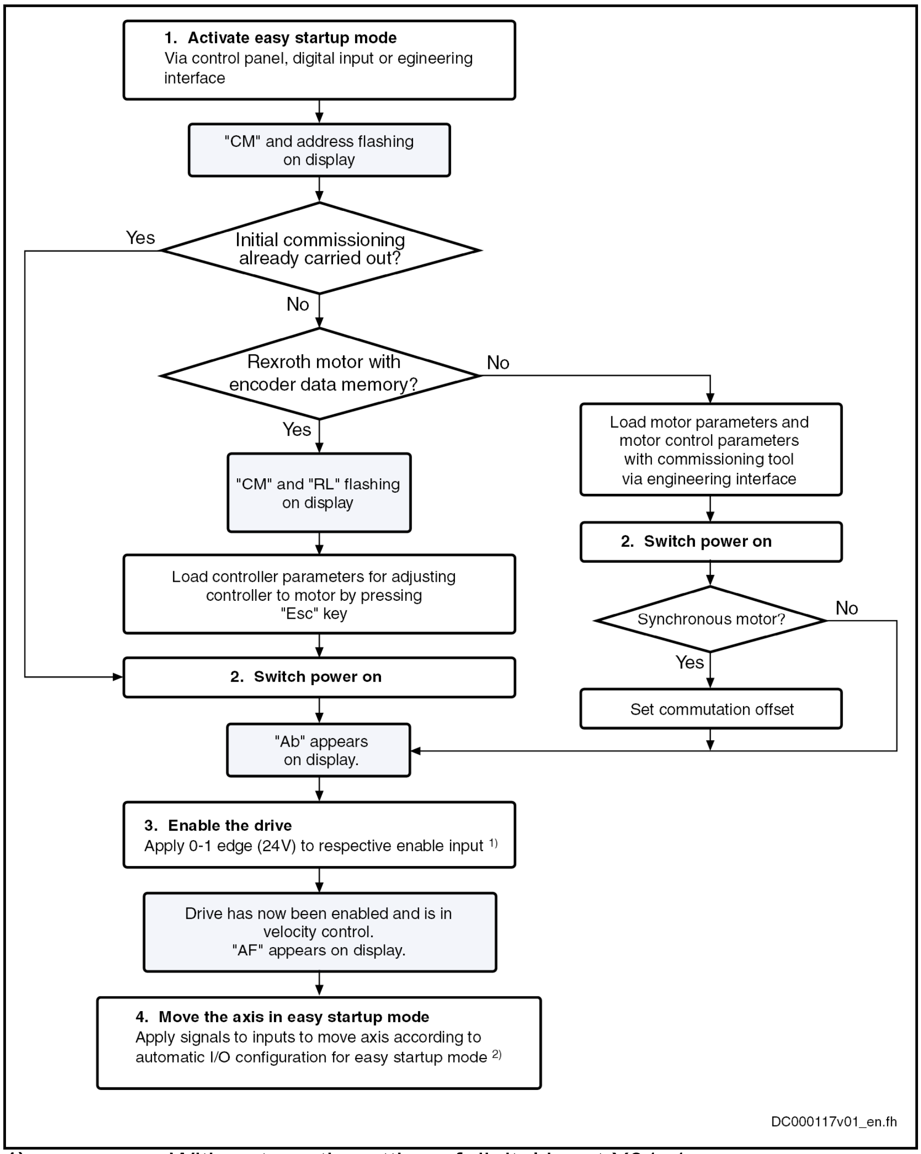
Only the commutation setting of synchronous motors with relative measuring system is automatically determined again every time drive enable is set for the first time after the "PM → OM" transition!

NOTICE **Property damage caused by errors when controlling motors!**

⇒ The digital input signals must be applied with due caution!

The figure below summarizes the commissioning sequence with the "easy startup" mode:

Commissioning



1) With automatic setting of digital input X31_1
2) With automatic setting of digital input X31_6 for positive rotational direction and X31_7 for negative rotational direction

Fig. 12-5: Commissioning Sequence with Easy Startup Mode

Commissioning with PC - Easy Startup Mode in IndraWorks

Navigation

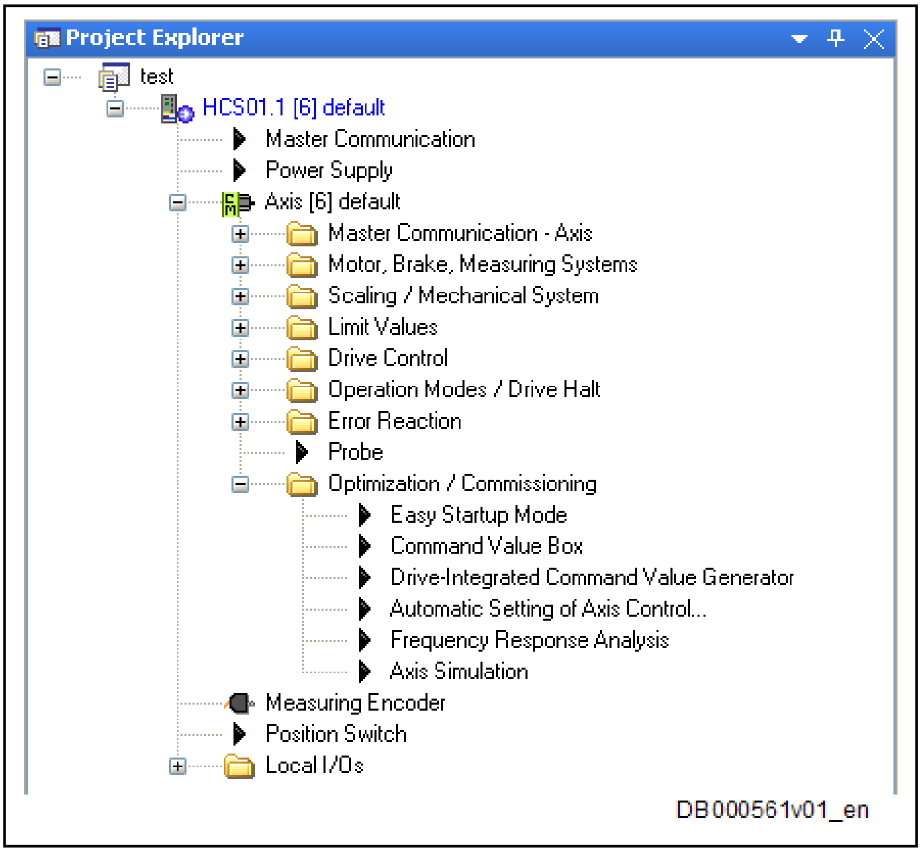


Fig. 12-6: Project Explorer in IndraWorks

To go to the easy startup mode, proceed as follows:

1. Device branch, e.g. HCS01.1 [6] default
2. Axis branch, e.g. Axis [6] default
3. Optimization / Commissioning branch
4. "Easy Startup" Mode menu

In addition, the project tree shows whether or not the drive is in the "easy startup" mode.

Commissioning

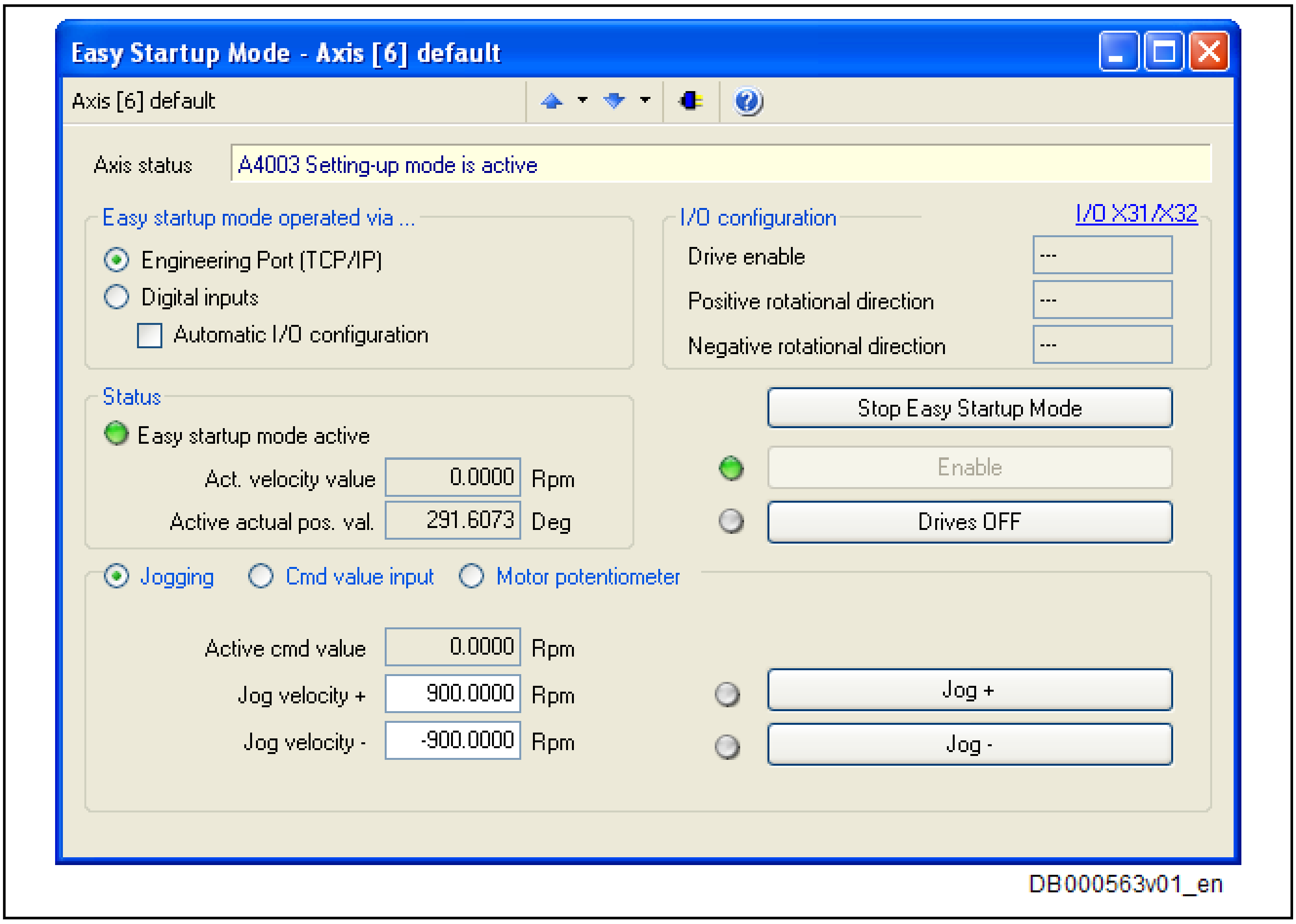


Fig. 12-7: Easy Startup Mode Dialog in IndraWorks

Handling

By means of the "Easy Startup" Mode dialog, it is possible to parameterize the "easy startup" mode and move the motor in a simple way.

1. Before using the "easy startup" mode, check whether drive has been correctly wired. Mains voltage must be available.

   NOTICE — **Devices for 3-phase mains connection (HCS01.1E-Wxxxx-A-03) must be connected to 3 phases. Otherwise, the error "F2818 Phase failure" will be generated when power is switched on.**

   For test runs, the phase monitoring can be deactivated. This is done via P-0-0860, bit 13.

2. Making presettings. For handling via IndraWorks, select "Easy startup mode operated via..." "Engineering Port (TCP/IP)" and enter "Jog velocity +" and "Jog velocity -". Start "easy startup" mode via the "Start Easy Startup Mode" button.

   - Drive goes to "bb" or "Ab", if power has already been applied
   - The "Start Easy Startup Mode" button changes to "Stop Easy Startup Mode"
   - In "Status" display group, "Easy startup mode active" software LED is activated and in green color.

- Drive display alternately shows axis number and "CM" for Commissioning Mode.

3. Switch power on

   Grayed out "Enable" button is activated, drive can be enabled.

4. Click "Enable" button; it is imperative that you observe and follow the instructions of use and take and the corresponding safety precautions.

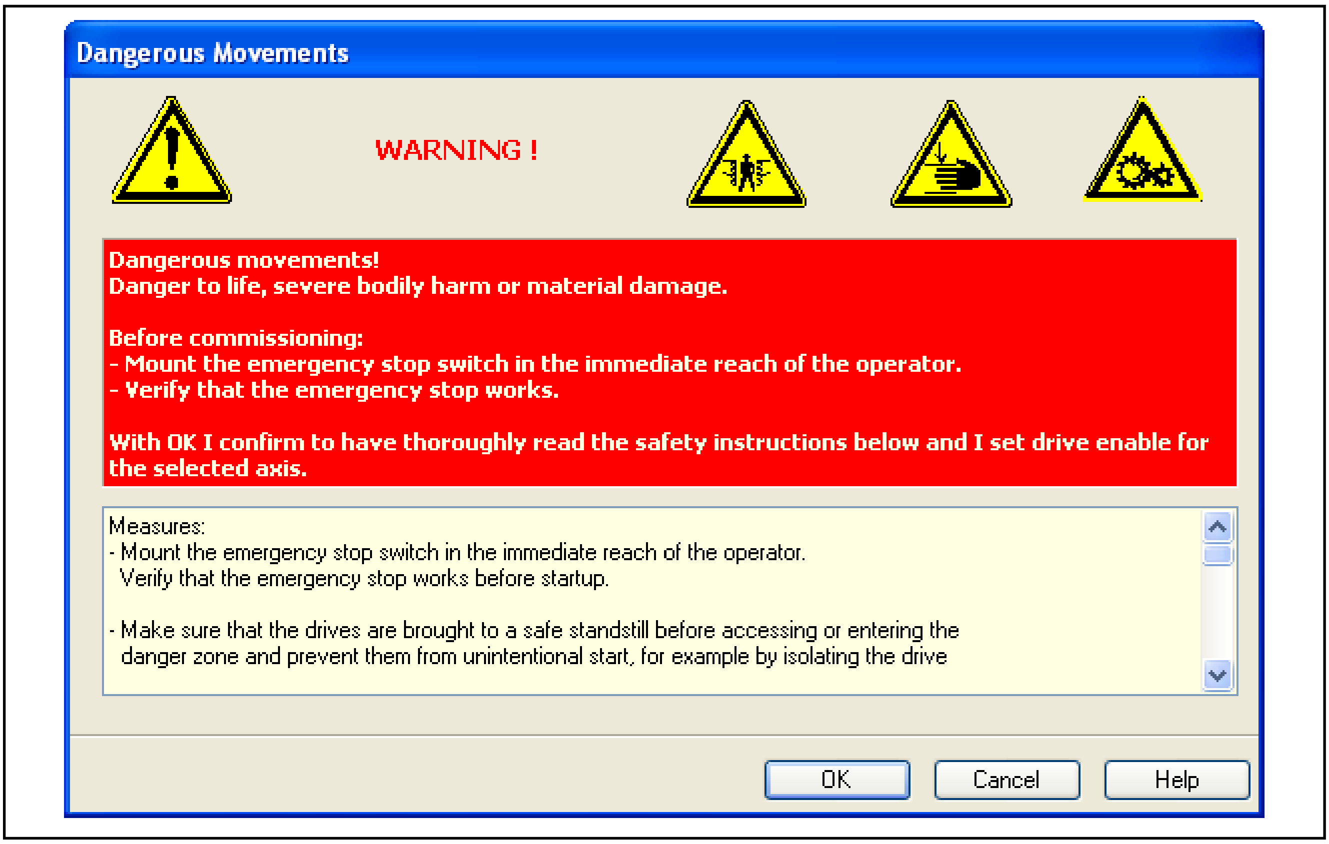


Fig. 12-8:

5. When is is ensured that the mentioned measures have been implemented, confirm dialog with "OK".
   - Diagnostic text on drive display goes to "AF"
   - "Axis status" text in dialog shows "A4003 Setting-up mode is active"
   - "Enable" button is grayed out again and status LED next to "Enable" button is in green color, "Drives OFF" button is activated.

6. By means of "Jog +" and "Jog -" buttons, drive can now be moved with entered velocity command values. Command value is active as long as corresponding button stays pressed.

   Drive moves according to command value input in velocity control

7. Upon successful test, drive can be switched off again. To do this, first remove enable signal, then exit easy startup mode and, if necessary, switch power off.

   Drive is in its initial state again.

12.2.4 Initial Start with the Commissioning Tool

Brief Description

Establishing the Operatability of the Drive

After complete and correct assembly and wiring of the drive or the drives it is advisable to establish the operatability. With drives of the IndraDrive range, this is very easily done means of initial start in the "easy startup" mode (velocity-controlled operation, master communication master not required) in conjunction with the Rexroth commissioning tool "IndraWorks Ds/D/MLD".

According to the available equipment, the initial commissioning of the motor is supported as follows:

- If there is **no** commissioning tool (e.g. PC) available, Rexroth motors with encoder data memory can be easily commissioned in the "easy startup" mode. The motor parameters and motor control parameters of these motors are automatically loaded from the data memory to the controller by switching control voltage on.
- IndraDrive: If a PC with Rexroth commissioning tool is available, the motor parameters and motor control parameters of motors without encoder data memory can be loaded from the internal database of the commissioning tool to the controller via the engineering interface. This allows initial commissioning in the "easy startup" mode for these motors, too.

Available Commissioning Tools

Rexroth provides the following commissioning tools (software) for drives:

- IndraDrive: IndraWorks Ds/D/MLD

IndraWorks Ds/D/MLD

"IndraWorks Ds/D/MLD" is a component of the "IndraWorks" software range which supports parameterization and commissioning of control units and drives by Rexroth.

The "IndraWorks Ds/D/MLD" commissioning tool provides the following options and advantages:

- The functions and features made available by the drive are structurally visualized, the respective parameter values are displayed in their functional context.
- Parameter values can be directly changed and thereby adjusted to the respective requirements.
- The parameter values available in the drive can be saved drive-externally as a group (parameter set), e.g. on the PC hard disk, and can be reloaded from the hard disk.
- Diagnostic messages and operating status messages are displayed in clearly arranged form.
- For the purpose of commissioning, commands can be started.
- Via the "easy startup" mode, IndraDrive devices can be commissioned and moved.

Functional Description

For the initial start of the motor, the following steps must be carried out:

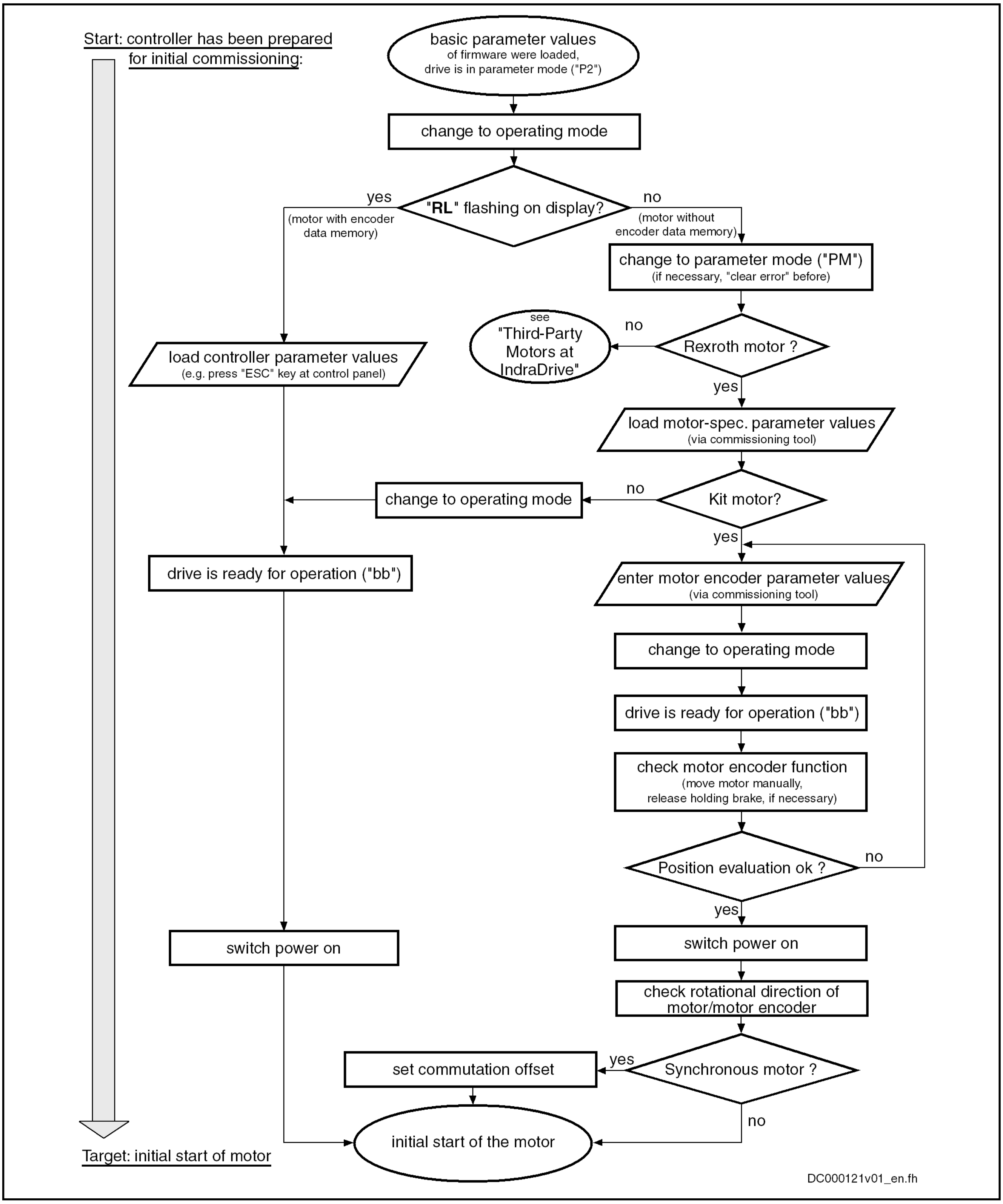


Fig. 12-9: Commissioning Steps for Initial Start of Rexroth Motors

Notes on Commissioning for Using "IndraWorks Ds/D/MLD"

For Rexroth motors without encoder data memory in conjunction with "IndraWorks Ds/D/MLD", the steps illustrated in the figure "Commissioning

Steps for Initial Start of Rexroth Motors" (see above) can only be carried out in "Easy startup" mode (initial start without active master communication)!

With "IndraWorks Ds/D/MLD" the values for the motor, motor control and motor encoder parameters, for motors without encoder data memory, can be loaded from the internal data base of the commissioning tool via the engineering interface of the controller.

For synchronous kit motors, commutation setting has to be carried out first (see "Commutation Setting"), the sequence this requires is supported by commands. If the motor has to be supplied with current in this case, the active "easy startup" mode is required!

See "Initial Start in "Easy Startup" Mode"

12.3 Commissioning Machine Axes

12.3.1 Procedure for Commissioning

The drive supports different commissioning procedures. The type of commissioning depends on the existing machine components (control, drive controllers, motor, mechanical system). Commissioning is made using one of the commissioning tools available.

Commissioning Procedure

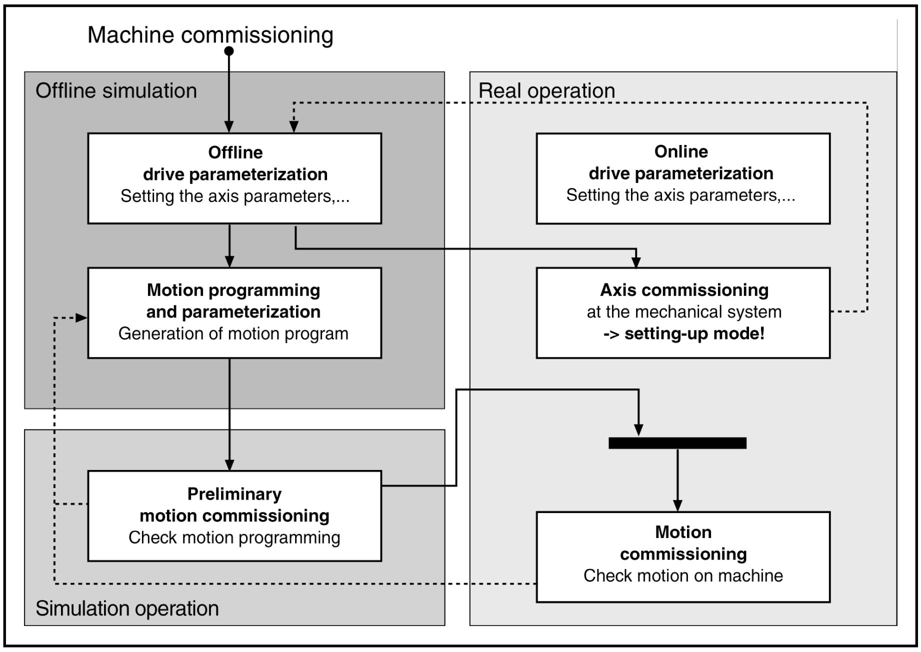


Fig. 12-10: Overview of Procedures for Commissioning

Real Operation

In real operation all necessary components are available. The parameterization of the drive controller is made online; then commissioning of the axis system can be made in setting-up mode. The commissioning of the machine is made by means of a control.

Offline Simulation

The offline simulation does not require any machine component. The parameterization of the drive controller is made offline. The parameters are applied to the drive controller during transition to real operation. The parameterization for a drive-internal control (MLD) can also be made offline, as well as creation of motion programs.

Simulation Mode

In simulation mode only the drive controller is required, parameterization is made online. With the axis simulation the velocity and actual position values are simulated, the drive can be operated in velocity- and position-controlled operation modes. A higher-level control unit can thus test its motion programs even without motor or mechanical system.

12.3.2 Overview and Practical Tips

Brief Description

Before commissioning machine axis-specific functions it is useful to make sure that the drive, consisting of controller, motor and motor encoder, is operational. The best way to do this is the initial start of the drive with the PC-based commissioning tool "IndraWorks Ds/D/MLD" by Rexroth (see "Initial Start with the Commissioning Tool").

The commissioning of machine axis-specific functions should also be carried out via "IndraWorks Ds/D/MLD", if possible. The advantage is that the correct sequence of an axis-specific function can be configured and ensured independent of the control unit. Further commissioning of the drive, with widely complete configuration, is then easier for the control unit.

Schematic Sequence

Commissioning procedure as a sequence of steps:

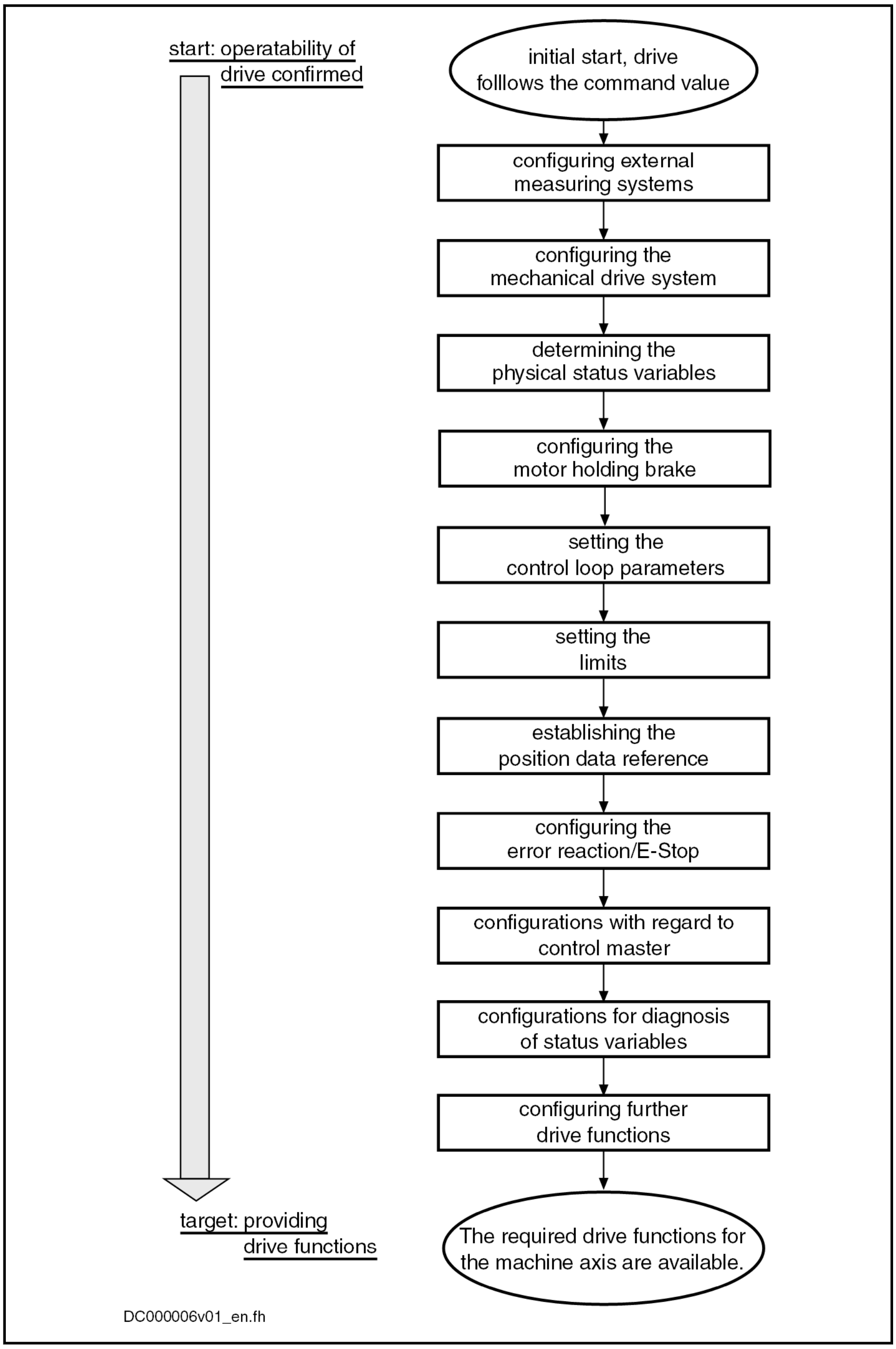


Fig. 12-11: Steps of Machine Axis-Related Commissioning

Notes on the Commissioning Steps

The subjects of the individual commissioning steps are treated in detail in different chapters of this firmware documentation. The information contained in the chapter is basically divided into:

- Brief Description
- Functional Description
- Notes on Commissioning

To explain the individual commissioning steps, we refer to the Notes on Commissioning for the respective subject, if possible.

Detailed information on the parameters is only contained in the separate documentation "Rexroth IndraDrive, Parameter Description" (reference list of all IndraDrive parameters).

Configuring the Measuring Systems

General Information Configure controller and encoder (set travel range, if necessary)

See "Notes on Commissioning" under "Basics on Measuring Systems, Resolution"

Relative Encoders Set initial position value; configure distance-coded measuring systems

See "Notes on Commissioning" under "Relative Measuring Systems"

Absolute Encoders Check whether absolute encoder evaluation is possible (depending on travel range), set initial position value

See "Notes on Commissioning" under "Absolute Measuring Systems"

Position Monitoring Set position monitors:

- Axis position monitor (position at time drive is switched on) for absolute encoders
- Position difference monitor of motor encoder and external encoder
- Configure spindle encoder monitor

See "Notes on Commissioning" under "Monitoring the Measuring Systems"

Configuring the Mechanical Axis System

Depending on the mechanical properties, make the following settings:

- Enter load gear ratio
- Enter feed constant
- Enter motor encoder gear ratio
- Enter gear ratio for external encoder

See "Notes on Commissioning" under "Mechanical Axis System and Arrangement of Measuring Systems"

Determining the Physical Status Variables

Make scaling settings for position, velocity, acceleration, torque/force and temperature data.

See "Notes on Commissioning" under "Scaling of Physical Data"

Configuring the Holding Brake

If the motor to be controlled is equipped with a holding brake or the controller has to control an external holding brake (for kit motors, if necessary), make the following settings:

- Enter maximum "drive off" delay time
- Enter holding brake data (external brake), if necessary
- Configure type, functional principle and monitor of brake in holding brake control word

See "Notes on Commissioning" under "Motor Holding Brake"

Setting the Control Loop Parameters

Set controller and filter parameters for the control loops:

- Velocity control loop
- Position control loop

See "Notes on Commissioning for Control Loop Setting" under "General Information on Closed-Loop Axis Control"

Setting the Limitations

The controller offers the possibility of limiting physical status variables of the drive. Depending on the application, limit values can be set for:

- Torque/force command value
- Velocity command value
- Position command values and actual position values

Limiting the Torque/Force Command Value

On the user side, limitations are available for:

- Maximum allowed torque/force (S-0-0092, P-0-0109)
- Motive and regenerative load at stationary velocity (S-0-0082, S-0-0083)

The limit values currently effective due to the user-side limit settings are displayed in:

- P-0-0444, Actual value peak torque limit
- P-0-0442, Actual value torque limit positive (stationary)
- P-0-0443, Actual value torque limit negative (stationary)

Current command values are displayed in:

- P-0-0049, Effective torque/force command value
- P-0-0038, Torque-generating current, command value

See description of the respective parameter in the separate documentation "Rexroth IndraDrive, Parameter Description"

Apart from the user-side limits, further limits take effect in the torque/force or current control loop:

- Absolute current limit values due to controller and motor
- Load-dependent (dynamic), thermal current limit values

See also "Current and Torque/Force Limitation"

Limiting the Actual Velocity Value

On the user-side, the "torque/force control" mode allows limitation of the actual velocity value to the lower value of

- 1.125 × Bipolar velocity limit value (S-0-0091)
  - and -
- maximum motor speed (S-0-0113)

.

See also "Torque/Force Control"

Limiting the Velocity Command Value

On the user side, the "velocity control" mode allows limitation of the velocity command value via

- bipolar velocity limit value (S-0-0091)

and in the "position control" mode the limitation of the

- position command value difference (to values of S-0-0091 and S-0-0113)

.

See also "Velocity Control" and "Position Control with Cyclic Command Value Input"

Limiting the Position

There are the following possibilities on the user side for limiting the position:

- limitation of actual position value (firmware "limit switch")
- Limitation of travel range of the axis (hardware limit switch)

See also "Limitations: Position Limitation/Travel Range Limit Switches"

Establishing the Position Data Reference

Measuring Systems to be Evaluated in Absolute Form

For measuring systems that can be evaluated in absolute form, the position data reference has to be established once during initial commissioning.

See "Notes on Commissioning" under "Establishing Position Data Reference for Absolute Measuring Systems"

Relative Measuring Systems

For relative measuring systems all settings have to be made in such a way that the position data reference can be established internally and automatically (after switching on the machine at a command of the control master to the respective axis drive).

See "Notes on Commissioning" under "Establishing Position Data Reference for Relative Measuring Systems"

Configuring the Error Reaction/E-Stop

The desired reaction of the drive to errors detected on the drive side has to be set.

See "Error Reactions"

The setting has to be made whether a drive is to carry out an E-Stop reaction at a hardware-side E-Stop signal and how the E-Stop reaction of the drive is to take place.

See "E-Stop Function"

Configurations with Regard to Control Unit (Master)

With regard to master-controlled drive operation the following settings are required:

- Presetting of operating modes (primary operation mode and secondary operation modes)

  See "General Information on the Operation Modes: Operation Mode Handling"
- Settings for the determined primary or secondary operation modes

  See description of the respective operation mode in chapter "Operation Modes"

With regard to the master communication interface used by the control master, you can make presettings for:

- sercos
- EtherCAT
- PROFINET
- EtherNet/IP
- PROFIBUS-DP
- CANopen
- Analog interface

See description of the Respective Master Communication Interface

Configurations for Diagnosis of Status Variables

If status variables of the drive are to be evaluated during operation, these status variables can be transmitted to the control master in different ways.

Diagnostic possibilities with sercos interface:

- Content of a parameter cyclically updated that can be cyclically transmitted and that contains the value of the respective status variable

  sercos interface
- Message in terms of whether a threshold value of the status variable was exceeded, via "S-0-0144, Signal status word"

  See "Control Options/Additional Functions: Configurable Signal Status Word"
- Drive-internal oscilloscope function

  See "Oscilloscope Function"

Diagnostic possibilities independent of the master communication interface:

- Analog output of the value of the respective status variable as voltage signal

  See "Analog outputs"
- Digital message in terms of whether a threshold value of the status variable was exceeded, by assigning bits from "S-0-0144, Signal status word"

  See "Digital Inputs/Outputs"

Configuring Further Drive Functions

Further configurable drive functions are:

- Drive Halt
- Friction torque compensation
- Detecting the marker position
- Spindle positioning
- Probe Function
- Digital Inputs/Outputs
- Analog Inputs
- Analog Outputs

See Description of the Respective Function

12.4 Axis Simulation

12.4.1 Brief Description

Contained in **base package** of variants **MPB, MPM and MPE** in **open-loop and closed-loop** characteristic.

The "simulation mode" function is made available for the function check of control units. It provides the possibility for the control unit to execute a program check without axis motion. For this purpose, only a drive control section is required of the drive, the power supply, motor and encoder are not used; therefore, the drive is directly ready for enabling ("AB") in the operating mode.

The function is carried out with the "Parking axis" command. For this purpose, the "permanently parked axis" function is activated with the parameter "P-0-0399, Configuration of simulation mode". The command and thereby the axis simulation are automatically started during the transition to the operating mode.

Pertinent Parameters

- P-0-0399, Configuration of simulation mode
- S-0-0448, Set absolute position control
- S-0-0139, C1600 Parking axis procedure command
- S-0-0147, Homing parameter

12.4.2 Functional Description

With bit 0 in "P-0-0399, Configuration of simulation mode", the "permanently parked axis" function is activated. The parameter can only be activated in the parameter mode (communication phase "P2" or "P3"). When switching to the operating mode takes place, the "parking axis" command is automatically started and the simulation mode becomes active. The simulation mode has the following effects:

- Current control switched off and PWM control
- Hardware monitoring of encoder is switched off
- Commands for brake control are disabled
- Switching to "AB" without power takes place
- "SA" and axis number are displayed alternately in the display of the operating panel
- "AB" or "AF" are displayed in the control panel and the operation mode is displayed in the diagnostic system

The simulation mode can only be terminated by switching off bit 0 in "P-0-0399, Configuration of simulation mode". This is only possible in the parameter mode.

Simulation Mode

A simulation encoder (motor encoder and external encoder) is defined; it adds up an actual position value from the command value of the velocity loop. It is thereby possible to use the operation modes with velocity control and position control. The axis runs with an ideal velocity loop, i.e. the command value input is applied to the actual value / mechanical system in (t = 0).

The "torque/force" mode is not simulated and therefore should not be used. This, too, applies to the "positive stop drive procedure" function. The torque limitation in the V-loop remains active, the values for the nominal torque and maximum torque are preset with exemplary values.

Simulation Encoder

An internal encoder type is defined for the simulation encoder. In an individual evaluation function, the encoder value is integrated from the velocity command value of the V-loop, further position processing thereafter remains unchanged. The simulation encoder cannot be directly selected in the parameter (P-0-0074/0075), it is only set internally.

The simulation encoder is defined as an encoder with 1024 lines (S-0-0116/0117), the multiplication (S-0-0256/0257) is calculated, as you know, with relation to the maximum travel range (S-0-0278).

The simulation encoder has been defined as an absolute encoder and can be homed with the "set absolute position" procedure. If the "homing" function is to be possible, too, "homing" must be allowed in "S-0-0448, Set absolute position control" and "homing without home switch", as well as "homing without reference mark", must be set in "S-0-0147, Homing parameter".

☞ The external encoder is only simulated, when the encoder type 2 [P-0-0075, Encoder type 2 (optional encoder)] has been set.

---

13 Service and support

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Our technology-oriented Competence Center in Lohr, Germany, is responsible for all your service-related queries for electric drive and controls.

Contact the **Service Helpdesk & Hotline** under:

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Fax:	+49 9352 18 4941
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Internet:	http://www.boschrexroth.com

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To be able to help you more quickly and efficiently, please have the following information ready:

- Detailed description of malfunction and circumstances resulting in the malfunction
- Type plate name of the affected products, in particular type codes and serial numbers
- Your contact data (phone and fax number as well as your email address)

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