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Rexroth
Bosch Group

Rexroth IndraDrive
Firmware for Drive Controllers
MPH-04, MPB-04, MPD-04

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Edition 02

Functional Description

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Firmware for Drive Controllers
MPH-04, MPB-04, MPD-04

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Table of Contents

Page

Table of Contents

Page

Table of Contents

Page

Table of Contents

Page

Page

Table of Contents

Page

Page

Table of Contents

Table of Contents

Page

Table of Contents

Table of Contents

Page

Table of Contents

Page

Table of Contents

Table of Contents

Page

Table of Contents

Page

Page

Page

Page

Table of Contents

Page

Table of Contents

Page

Page

1 System Overview

1.1 General Information

1.1.1 Overview of Drive Firmware

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:

- **MTH**: Drives for Machine Tool Applications With SERCOS interface (**Advanced** Performance and Functionality)
- **MPx**: Drives for General Automation (Incl. Machine Tool Applications) With SERCOS interface, PROFIBUS-DP, Parallel and Analog Interface (the variants of design are **MPH**, **MPB** and **MPD**; see below)

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

- **MT:** ""Machine Tool" → Drives for Machine Tool Applications With SERCOS interface
(drive profile according to SERCOS)
- **MP:** "Multi Purpose" → Drives for General Automation (Incl. Machine Tool Applications) With SERCOS interface, PROFIBUS-DP, as Well as Parallel and Analog Interface
(drive profile according to SERCOS)

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

- **H**: **Single-axis** firmware with **Advanced** performance and functionality
- **B**: **Single-axis** firmware with **Basic** performance and functionality
- **D**: **Double-axis** firmware with **Basic** performance and functionality

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This documentation describes the functionality of the following firmware types:

- **FWA-INDRV*-MPH-04VRS-D5**
- **FWA-INDRV*-MPB-04VRS-D5**
- **FWA-INDRV*-MPD-04VRS-D5**

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

Organization of the Firmware

For application-specific definition of 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. integrated safety technology, 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" .

1.1.2 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. Specific parameter values (operating data) are checked for validity by the drive firmware.

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)
- As a MultiMediaCard (MMC), optional

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 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.
- The MMC contains the drive firmware and the basic parameter sets.

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.

Storing of 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:

- MMC → copying the parameter values by command
- "IndraWorks D" commissioning tool → saving the parameter values on external data carrier
- Control master → saving the 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 of Parameter Values

Loading parameter values is required in the following cases:

- Initial commissioning of the motor (loading basic parameter values and motor-specific parameter values)
- Serial commissioning of machine axes at series machines (loading the values saved after initial commissioning)
- Restablishing a defined original status (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
- MMC → loading the parameter values by command
- "IndraWorks D" commissioning tool → loading the parameter values from 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.

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 parameters that can be written:

- Parameters that are write-protected as a standard, such as motor parameters, hardware code parameters, encoder parameters, error memory etc. ("administration parameters"). The values of these parameters guarantee 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 parameters that can be written and are not contained in the above-mentioned groups. They are not write-protected.

Kinds 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 can be written; "administration parameters" remain read-only.
- **Master password**

  All parameters that can be written, 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 or clear commands.

Each command is assigned to a parameter by means of which the execution of the command can be controlled. During the execution of the command 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 the parameter S-0-0025, IDN-list of all procedure commands.

Kinds of Commands

There are 3 different kinds of commands:

- **Drive control commands**
  – can cause automatic drive motion,
  – can be started only when drive enable has been set,
  – deactivate the active operating mode during its execution.
- **Monitor commands**
  – activate or deactivate monitors or functions in the drive.
- **Administration commands**
  – carry out administration tasks,
  – cannot be interrupted.

See also section "Command Processing"

Operating Modes

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

One of the four or eight (for SERCOS) operating 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
- "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 operating mode was activated.

☞ All implemented operating modes are stored in the "S-0-0292, List of all operating modes" parameter.

See also chapter "Operating Modes"

Warnings

Depending on the active operating mode and the parameter settings, many monitoring functions are carried out. If a status is detected that still allows correct operation but in case this status persists will cause an error to occur and therefore cause the drive to be automatically switched off, the drive firmware generates a warning message.

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

Classes of Warnings

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

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

The following classes of warnings are distinguished:

- **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 operating mode and the parameter settings, many monitoring functions are carried out. If a status is detected that affects or prevents correct operation the drive firmware generates an error message.

Error Classes

Errors are classified in different error classes. There are 6 error classes with different drive error reactions.

☞ 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
F9xxx	fatal system error
E-xxxx	fatal system error "processor exception"

Fig. 1-1: 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 not displayed at the control panel with a diagnostic message number of the "Fxxxx" pattern, but with a short text. Booting and firmware download errors are described in the separate documentation "Troubleshooting Guide" (description of diagnostic messages).

Error Reactions of the Drive

If the drive controller is in control and an error status 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 interface errors and non-fatal errors is determined 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 cleared automatically, but by the following action:

- Starting the command "S-0-0099, C0500 Reset class 1 diagnostics"

- or -

- Actuating the "Esc" key on the control panel

If the error status 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
- Input 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 +24Volt DC error") are not stored in the error memory.

The diagnostic message numbers in the error memory are mapped to the "P-0-0192, Diagnostic numbers of error memory" parameter and can be displayed by means of the control panel. By means of the "IndraWorks D" commissioning tool it is possible to display the diagnostic message numbers and the respective times at which the errors occurred.

1.1.3 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 are not always existing 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 functions.

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, Parameter Description".

The detailed description of the diagnostic messages, their causes and remedies is contained in the separate documentation "Rexroth IndraDrive, Troubleshooting Guide" (description of 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, Troubleshooting Guide" (description of 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 operating modes have a marker containing information on the availability of this functionality in the respective functional package of the firmware, e.g.:

Base package of all firmware variants

Fig. 1-2: Assignment to Functional Package

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 **design** single-axis, double-axis (multi-axis)
- Firmware **variant** e.g. MP**H**, MP**B**, MP**D**
- Firmware **version** e.g. MPH-**04**VRS
- Firmware **characteristic** open-loop/closed-loop
- Firmware **performance** Basic/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 for 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 documentations are additionally signaled by the "info icon", unless contained in a note, in a table or in brackets.

Reference Documentations

Firmware documentation:

- Parameter Description
  → DOK-INDRV*-GEN-**VRS**-PA**-EN-P; part no. R911297317
- Troubleshooting Guide (description of diagnostic messages)
  → DOK-INDRV*-GEN-**VRS**-WA**-EN-P; part no. R911297319
- Integrated Safety Technology
  → DOK-INDRV*-SI*-**VRS**-FK**-EN-P; part no. R911297838
- Rexroth IndraMotion MLD (Drive-Integrated PLC)
  → DOK-INDRV*-MLD-**VRS**-AW**-EN-P; part no. R911306084
- Firmware Version Notes
  → DOK-INDRV*-MP*-04VRS**-FV**-EN-P; part no. R911315487

Hardware documentation (Project Planning Manuals):

- Rexroth IndraDrive – Supply Units and Power Sections
  → DOK-INDRV*-HMV-S-D+HCS-PR**-EN-P; part no. R911318790
- Rexroth IndraDrive – Drive Controllers, Control Sections
  → DOK-INDRV*-CSH********-PR**-EN-P; part no. R911295012
- Rexroth IndraDrive – Drive System
  → DOK-INDRV*-SYSTEM*****-PR**-EN-P; part no. R911309636

☞ This list of hardware documentations only mentions those Project Planning Manuals to which the Functional Description of the firmware mainly refers.

Additional hardware descriptions are available; they are all listed in the introduction of the documentation "Rexroth IndraDrive – Drive System, Project Planning Manual".

1.2 Drive Controllers

1.2.1 Overview

Standard Design of the IndraDrive Controllers

As a standard, IndraDrive controllers consist of two hardware components:

- Power section
- Control section

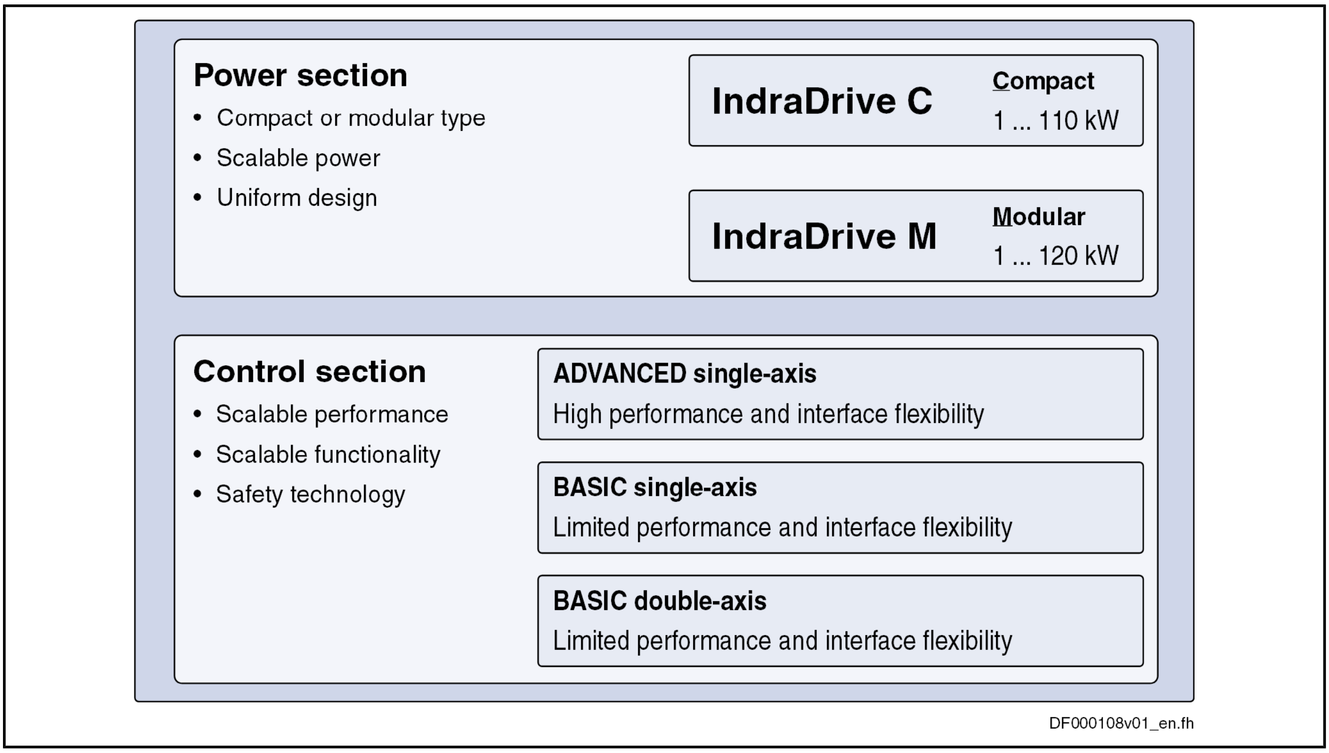


Fig. 1-3: Design of the IndraDrive Controllers

Power Section

The following are connected to the power section:

- Supply unit (DC bus voltage)
- 24 V control voltage
- Motor

Each of the two types of the control section is described in a separate documentation; e.g. "Supply Units and Power Sections, Project Planning Manual" (DOK-INDRV-HMS+HMD****-PR**-EN-P; part no.: R911318790).

Control Section

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 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; part no.: R911295012).

Special Design of the IndraDrive Controllers

Apart from the usual device design which consists of power section and control section, there are the following special designs:

- SERCOS analog converter (= control section + housing)
- IndraDrive Mi (with motor-integrated converter)

SERCOS Analog Converter

The so-called "SERCOS analog converter" is a control section housing with 24V supply but without output stage. An IndraDrive control section can be plugged in this housing.

The SERCOS analog converter is used to

- connect control units with SERCOS interface to components with analog interface

- and -

- convert SERCOS position command values to analog speed command values.

☞ With these possibilities of use, the SERCOS analog converter is suited for modernization of machines and installations. Drive controllers with analog command value input of the ANAX range can be controlled with IndraDrive; in this case IndraDrive acts as the gateway to the SERCOS control unit.

Realizing the SERCOS analog converter requires the following individual components:

- Housing for **HAC01.1-002** control sections
- Configurable control section with SERCOS master communication, e.g. BASIC UNIVERSAL double-axis **CDB01.1C-SE**-NNN-NNN-**MA1**-NNN-NN-S-NN-FW
- IndraDrive firmware **as of** version **MPx-04VRS**, e.g. FWA-INDRV*-**MPD-04VRS**-**-*-***-**

See also separate documentation "Rexroth IndraDrive – Drive System, Project Planning Manual" (DOK-INDRV*-SYSTEM*****-PR**-EN-P; part no.: R911309636)!

1.2.2 Power Sections

The following power sections for the standard design of IndraDrive controllers can be operated with the firmware **MPx-04VRS**:

IndraDrive M		IndraDrive C	
Single-axis power sections	**Double-axis power sections**	**Single-axis converters in 300mm type of constr.**	**Single-axis converters in 400mm type of constr.**
HMS01.1N-W… HMS02.1N-W…	HMD01.1N-W…	HCS02.1E-W…	HCS03.1E-W… HCS04.1E-W…

Fig.1-4: Power Sections for IndraDrive Firmware

1.2.3 Control Sections

Available Control Section Designs

The following control sections can be operated with the appropriate **MPx-04VRS** firmware variant:

- Configurable control sections:
  - ADVANCED (single-axis; types CSH01.1C-... and CSH01.2C-...)
  - BASIC UNIVERSAL (single-axis; type CSB01.1C-...)
  - BASIC UNIVERSAL double-axis (type CDB01.1C-...)
- Non-configurable control sections:
  - BASIC OPENLOOP (single-axis; type CSB01.1N-FC-...)
  - BASIC SERCOS (single-axis; type CSB01.1N-SE-...)
  - BASIC PROFIBUS (single-axis; type CSB01.1N-PB-...)
  - BASIC ANALOG (single-axis; type CSB01.1N-AN-...)

Supported Control Section Configurations

The configurable control sections differ with regard to the scope of their configurability. It basically depends on the control section type and the corresponding firmware variant.

The following overview contains the **theoretically possible configurations** of control sections as regards the support by the **MPx-04VRS** firmware. The abbreviations in the first column identify the configuration of control sections in the type designation.

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

	Control section type →	CSH01.1C CSH01.2C	CSB01.1C	CDB01.1C
	Firmware variant →	MPH-04VRS	MPB-04VRS	MPD-04VRS
Optional modules for master communication				
CO	CANopen/DeviceNet	■	■	–
ET	PROFINET (in preparation)	■	–	■
PB	PROFIBUS-DP	■	■	■
PL	Parallel interface	■	■	–
S3	SERCOS III	■	■	■
SE	SERCOS interface	■	■	■
Optional modules for encoder evaluation and I/O extension				
EN1	Encoder interface for HSF, resolver	■	■	■
EN2	Encoder interface for EnDat, 1Vpp sine and TTL signals	■	■	■
ENS	Encoder interface for MSK motors and HIPERFACE encoders	■	■	■
MA1	Analog I/O extension	■	■	■
MD1	Digital I/O extension	■	–	–
MD2	Digital I/O extension (with SSI interface)	■	–	–
MEM	Encoder emulation	■	■	■
Optional module for cross communication				
CCD 1)	Cross communication	■	–	–
Optional modules for safety technology				
L1	Starting lockout	■	■	■
S1	Safety technology	■	–	■

1) Only required for CCD master

Fig. 1-5: Supported Control Section Configurations

☞ The type codes of the individual designs of IndraDrive control sections and the respective assignment of possible optional modules to the slots are described in the separate documentation "Control Sections for Drive Controllers; Project Planning Manual" (DOK-INDRV*-CSH********-PR**-EN; part no.: R911295012).

1.3 Supported Motors and Measuring Systems

1.3.1 Supported Motors

The table below contains an overview of the Rexroth motors which can be operated at IndraDrive controllers.

Rexroth housing motors		Rexroth kit motors	
Synchronous	**Asynchronous**	**Synchronous**	**Asynchronous**
MSK (IndraDyn S)	MAD (IndraDyn A)	MLF (IndraDyn L)	1MB
MHD	MAF (IndraDyn A)	MBS (Standard)	
MKD	2AD	MBSxx2 (IndraDyn H)	
MKE	ADF	MBT (IndraDyn T)	
MSP	MAL	LSF	
SF (by Bosch)			

Fig. 1-6: Appropriate Rexroth motors for IndraDrive

1.3.2 Supported Measuring Systems

Motor Encoder and External Optional Encoders

In addition to the encoders integrated in the Rexroth motors, the IndraDrive firmware can evaluate the following measuring systems as motor encoders or as external optional control encoders:

- GDS or GDM encoders from Bosch Rexroth (single-turn or multi-turn type)
- Resolvers according to Rexroth signal specification (single-turn or multi-turn type)
- Encoders with sine signals and EnDat2.1 interface (1 Vpp)
- Encoders with sine signals (1 Vpp)
- Encoders with square-wave signals (TTL)
- Hall sensor box and encoder with sine signals (1 Vpp)
- Hall sensor box and encoder with square-wave signals (TTL)
- Encoders with sine signals and HIPERFACE interface (1 Vpp)

Measuring Encoder

For measuring purposes the firmware can evaluate the following measuring systems (measuring encoders, no control encoders):

- GDS or GDM encoders from Bosch Rexroth (single-turn or multi-turn type)
- Encoders with sine signals and EnDat2.1 interface (1 Vpp)
- Encoders with sine signals (1 Vpp)
- Encoders with square-wave signals (TTL)
- Encoders with sine signals and HIPERFACE interface (1 Vpp)
- Motor encoders of MSK, MHD, 2AD, ADF, MAD, MAF motors
- SSI encoders

☞ Resolvers cannot be evaluated as measuring encoders!

1.4 Overview of Master Communication

The following interfaces for master communication are available in the firmware **MPx-04VRS**:

- SERCOS interface
- SERCOS III
- PROFIBUS-DP
- CANopen interface
- DeviceNet interface
- Parallel interface (not for double-axis design MPD)
- Analog interface (not for double-axis design MPD)

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*-04VRS** drive firmware depends on

- the available control section and, if available, its 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

The control sections of the IndraDrive controllers have a maximum of 4 optional card slots and a master communication slot. Depending on the available optional cards, it is possible to activate certain functions (incl. corresponding parameters), e.g.:

- **Master communication**
- **Safety technology** (starting lockout, standard safety technology)
- **Analog I/O extension card**
- **Digital I/O extension card**

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

See also 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)

System Overview

– 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:

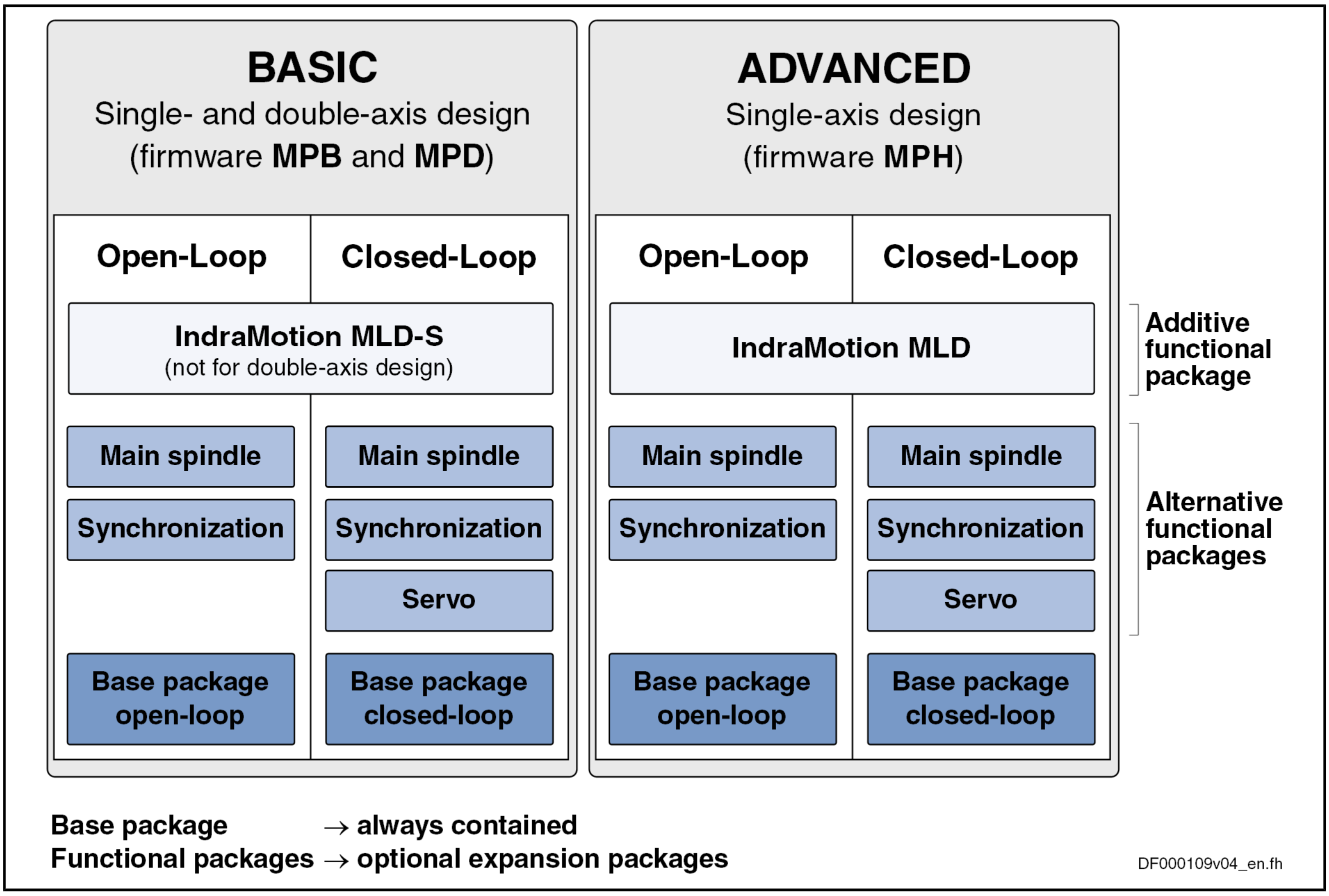


Fig. 1-7: Functional Packages of IndraDrive Firmware MPx04 Depending on Control Performance

☞ With Basic performance, the option "IndraMotion MLD-S" is not allowed for free programming!

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 firmware **FWA-INDRV*-MP*-04VRS** supports the functional packages listed below.

☞ Each of the listed packages is available in **Basic** 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 operating 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)! → **Alternative functional packages**

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.

Overview of Dependencies

The overview below illustrates how the individual functional packages are depending on the respective hardware and the firmware type:

System Overview

		Firmware variant →	MPB		MPD		MPH	
		Control section design →	**CSB01.1**		**CDB01.1**		**CSH01.1**	
		Control section range ↓	**OL**	**CL**	**OL**	**CL**	**OL**	**CL**
Base package	Basic functions		■	■	■	■	■	■
	Base package "open-loop"	BASIC	■	■	■	■	■	■
		ADVANCED	–	–	–	–	■	■
	Base package "closed-loop"	BASIC	■	■	■	■	■	■
		ADVANCED	–	–	–	–	■	■
Alternative functional packages	Servo function	BASIC	–	■	–	■	–	■
		ADVANCED	–	–	–	–	–	■
	Synchronization	BASIC	■	■	■	■	–	–
		ADVANCED	–	–	–	–	■	■
	Main spindle	BASIC	■	■	■	■	–	–
		ADVANCED	–	–	–	–	■	■
Additive functional package	IndraMotion MLD	BASIC	■ 1)	■ 1)	–	–	■	■
		ADVANCED	–	–	–	–	■	■

MPB Single-axis firmware with Basic performance
MPD Double-axis firmware with Basic performance
MPH Single-axis firmware with Advanced performance
OL Open-loop characteristic
CL Closed-loop characteristic
1) No free programming and only MLD-S

Fig. 1-8: Dependence of Functional Packages on Hardware and Firmware Variant

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*	-MP**B**-	04	VRS-	D5-	x-	xxx-	xx
Basic double-axis	FWA-INDRV*	-MP**D**-	04	VRS-	D5-	x-	xxx-	xx
Advanced single-axis	FWA-INDRV*	-MP**H**-	04	VRS-	D5-	x-	xxx-	xx

Fig. 1-9: 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
- **MPD** → Double-axis firmware with Basic performance
- **MPH** → Single-axis firmware with Advanced 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
- **TF** → IndraMotion MLD for using the technology functions (for MPB firmware)
- **ML** → IndraMotion MLD for free programming; incl. use of technology functions (for MPH firmware)

☞ Our sales representative 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
  - Analog output
  - 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
- Serial communication

Scope of Functions of Base Packages

Apart from the basic functions, there are other functions available in the base package of the firmware. Their scope depends on the firmware variant and its characteristic ("open-loop" or "closed-loop").

See "Supported Operating Modes" in section "Operating Modes: General Information"

See "Availability of the Extended Axis Functions"

See "Availability of the Optional Device Functions"

1.5.3 Alternative Functional Packages

General Information

Apart from the base packages that are always available, we offer optional expansion packages. Part of the expansion packages is the group of alternative functional packages; from this group only one package can be activated at a time (alternative activation).

At present, there are the following alternative expansion packages available:

- Expanded servo function
- Synchronization
- Main spindle function

Servo Function

Depending on the firmware variant and characteristic, the expansion package "servo function" has the following scope of functions, in addition to the functions available in the base package:

Firmware variant →	MPB (Basic single-axis)		MPD (Basic double-axis)		MPH (Advanced single-axis)	
Functions of the expansion package "servo function"	**OL**	**CL**	**OL**	**CL**	**OL**	**CL**
Relative return motion	–	■	–	■	–	■
Precision axis error correction	–	–	–	■	–	■
Temperature error correction	–	■	–	■	–	■
Quadrant error correction	–	■	–	■	–	■
Cogging torque compensation	–	–	–	■	–	■
Programmable position switch	–	■	–	■	–	■
Probe function	–	■ 1)	–	■ 1)	–	■ 1)
Set/shift coordinate system	–	■	–	■	–	■

OL Open-loop characteristic
CL Closed-loop characteristic
1) For Advanced single-axis 2 probes; for Basic single-axis only 1 probe; for Basic double-axis 2 probes per controller

Fig. 1-10: Overview Expansion Package "Servo Function"

☞ With "BASIC ..." hardware design, the probe input is only available for the control sections BASIC SERCOS, BASIC PROFIBUS and BASIC UNIVERSAL (CSB01.1***).

Synchronization

Depending on the firmware variant and characteristic, the expansion package "synchronization" has the following scope of functions, in addition to the functions available in the base package:

Firmware variant →	MPB		MPD		MPH	
Functions of the expansion package "synchronization"	**OL**	**CL**	**OL**	**CL**	**OL**	**CL**
Velocity synchronization	■	■	■	■	■	■
Phase synchronization	–	■	–	■	–	■
Electronic cam shaft	–	■	–	■	–	■
Electronic motion profile	–	■	–	■	–	■
Cogging torque compensation	–	–	–	■	–	■
Measuring wheel mode	–	■	–	■	–	■
Virtual master axis generator	■	■	■	■	■	■
Programmable position switch	–	■	–	■	–	■
Probe function	■ 1)2)	■ 1)	■ 1)2)	■ 1)	■ 2)	■ 1)
Measuring encoder	■ 3)	■ 3)	■	■	■	■

OL Open-loop characteristic
CL Closed-loop characteristic
1) For Advanced single-axis 2 probes; for Basic single-axis only 1 probe; for Basic double-axis 2 probes per controller
2) In parameter "S-0-0428, Probe, IDN list signal selection", the following signals are not available: S-0-0051, S-0-0052, P-0-0227
3) Only with control section BASIC UNIVERSAL
Fig. 1-11: Overview Expansion Package "Synchronization"

☞ With "BASIC ..." hardware design, the probe input is only available for the control sections BASIC SERCOS, BASIC PROFIBUS and BASIC UNIVERSAL (CSB01.1***).

Main Spindle Function

Depending on the firmware variant and characteristic, the expansion package "main spindle" has the following scope of functions, in addition to the functions available in the base package:

Firmware variant →	MPB		MPD		MPH	
Functions of the expansion package "main spindle"	**OL**	**CL**	**OL**	**CL**	**OL**	**CL**
Spindle positioning	–	■	–	■	–	■
Parameter set switching	■	■	–	–	■	■
Drive-controlled oscillation	■	■	–	–	■	■

OL Open-loop characteristic
CL Closed-loop characteristic
Fig. 1-12: Overview Expansion Package "Main Spindle"

1.5.4 Additive Functional Packages

General Information

The 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, there is the following additive functional package available:

- **IndraMotion MLD** (drive-integrated PLC and technology functions)

> The **drive-integrated safety technology** is a functionality only scalable by means of the hardware and is not part of the expansion packages that can be enabled!

IndraMotion MLD (Drive-Integrated PLC)

The expansion package "IndraMotion MLD" makes available the following scope of functions:

- **Integrated logic control** (type designation "ML")

  Standard PLC tasks

- **Integrated multi-axis/single-axis motion control** (type designation "ML")

  Motion function block according to PLCopen for single-axis positioning on local and remote axes and synchronization mode (synchronous running, cam shaft) → "low-level motion functions"

- **Basis for technology functions** (type designation "TF" or "ML")

  Examples: Following-on cutting devices, pick&place, process controller (register controller, winding computation, etc.), preventive maintenance, free function block combination

> The expansion package "IndraMotion MLD" is **not** available in conjunction with BASIC double-axis control sections (CDB-***)!

Apart from "Rexroth IndraMotion MLD", another variant of a freely programmable control unit, "Rexroth IndraMotion MLC", is available. Other freely programmable control units, e.g. "Rexroth IndraMotion MLP", are in preparation. The variants differ in functionality, performance and hardware platform.

The following hardware characteristics are distinguished:

- Drive-based PLC → IndraMotion MLD
- PC-based PLC → IndraMotion MLP (in preparation)
- Controller-based stand-alone PLC → IndraMotion MLC

The figure below illustrates the integration of "Rexroth IndraMotion MLD" in the automation platform "Rexroth IndraMotion":

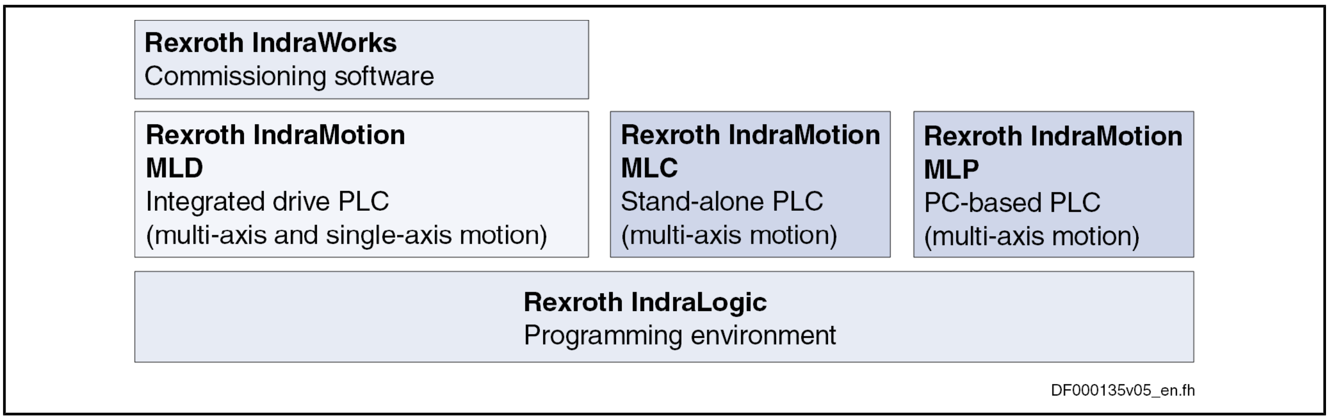


Fig.1-13: Overview "Rexroth IndraMotion"

> All "Rexroth IndraMotion" variants are operated and programmed with the same programming tool (Rexroth IndraLogic) so that the programs created with it are portable, if the requirements have been complied with (see "Guidelines for Programming with IndraLogic").

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 use of the optional safety technology modules **L1** or **S1** depending on the control section configuration.

The following safety function is supported in conjunction with the optional module "starting lockout" (safety module **L1**):

- Safety related starting lockout

The following safety functions are supported in conjunction with the optional module "safety technology I/O" or PROFIsafe in the different operating states (safety module **S1**):

- In **normal operation**
  - Safety related limited maximum velocity
  - Safety related limited absolute end position
- In **status "safety related halt"**
  - Safety related standstill
  - Safety related operational stop
  - Safety related drive interlock
- In **status "safety related motion"**
  - Safety related reduced speed
  - Safety related direction of motion
  - Safety related limited increment
  - Safety related limited absolute position
- **Auxiliary functions**
  - Safety related monitored stopping process
  - Safety related homing procedure
  - Safety related parking axis
- **Safety functions for "safety related feedback"**
  - Safety related diagnostic outputs
  - Safety related control of a door locking device (not with PROFIsafe)
  - Safety related inputs/outputs

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

  → Highest degree of control performance by high internal clock rates for the control loops and the signal processing of inputs/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 by reduced clock rates for the control loops and the signal processing of inputs/outputs or drive-integrated PLC (IndraMotion MLD)

Performance and Clock Rates

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

- Current loop clock $T_{A\_current}$
- Velocity loop clock $T_{A\_velocity}$
- Position loop 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).

Performance	$T_{A\_current}$	$T_{A\_velocity}$	$T_{A\_position}$	T_{MLD}	$T_{MastCom}$
Advanced	62,5/83,3/125	125	250	1000	250
Basic	62,5/83,3/125/250 1)	250	500	2000	500
Economy	125/250 1)	500	1000	2000	1000 2)

1) At 2kHz PWM
2) With half the number of cyclic data
Fig. 1-14: Clock Rates (in µs)

☞ The control performance is not equivalent to the control section design (Advanced or Basic), because it is determined by several factors (e.g. P-0-0556, bits 2 and 5).

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

- **Control section design** (CSH, CSB or CDB) and the corresponding drive **firmware** (MPH, MPB and MPD)
- **Activation of functional packages** (cf. P-0-2004)
- Performance level in "P-0-0556, Config word of axis controller" (bits 2 and 5)
- Switching frequency in "P-0-0001, Switching frequency of the power output stage"

See also "Principles of Drive Control: Overview of Axis Control (Closed-Loop Operation)"

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 clock frequencies).

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

Control section type/firmware	Functional packages	Performance level	f_{PWM} 1)	P-0-0556 Bit 2	P-0-0556 Bit 5	$T_{A\_current}$	$T_{A\_velocity}$	$T_{A\_position}$	T_{MLD}	$T_{MastCom}$
CSH01.1/ MPH	All	Basic	2 kHz 2)	0	0	250 µs	500 µs	500 µs	1000 µs	500 µs
		Basic	4 kHz	0	0	125 µs	250 µs	500 µs	1000 µs	500 µs
		Basic	8 kHz	0	0	125 µs	250 µs	500 µs	1000 µs	500 µs
		Basic	12 kHz	0	0	83.3 µs	250 µs	500 µs	1000 µs	500 µs
		Basic	16 kHz	0	0	62.5 µs	250 µs	500 µs	1000 µs	500 µs
		Advanced	4 kHz	1	0	125 µs	125 µs	250 µs	1000 µs	250 µs
		Advanced	8 kHz	1	0	62.5 µs	125 µs	250 µs	1000 µs	250 µs
		Advanced	16 kHz	1	0	62.5 µs	125 µs	250 µs	1000 µs	250 µs
CSB01.1/ MPB	All, except for "synchronization" and "IndraMotion"	Basic	2 kHz 2)	0	0	250 µs	250 µs	500 µs	--	500 µs
		Basic	4 kHz	0	0	125 µs	250 µs	500 µs	--	500 µs
		Basic	8 kHz	0	0	125 µs	250 µs	500 µs	--	500 µs
		Economy	2 kHz 2)	0	1	250 µs	500 µs	1000 µs	--	1000 µs 3)
		Economy	4 kHz	0	1	125 µs	500 µs	1000 µs	--	1000 µs 3)
		Economy	8 kHz	0	1	125 µs	500 µs	1000 µs	--	1000 µs 3)
	"Synchronization" and "IndraMotion"	Economy	2 kHz 2)	0	1	250 µs	500 µs	1000 µs	2000 µs	1000 µs 3)
		Economy	4 kHz	0	1	125 µs	500 µs	1000 µs	2000 µs	1000 µs 3)
		Economy	8 kHz	0	1	125 µs	500 µs	1000 µs	2000 µs	1000 µs 3)
CDB01.1/ MPD	All	Basic	4 kHz	0	0	125 µs	250 µs	500 µs	--	500 3) µs
		Basic	8 kHz	0	0	125 µs	250 µs	500 µs	--	500 3) µs

1) Switching frequency of the power output stage (can be set via P-0-0001)
2) Only with power section HCS04.1… and MAD/MAF
3) With half the number of cyclic data
P-0-0556 Config word of axis controller

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

1.6.3 Selecting Performance via Parameter P-0-0556

For certain applications it is necessary to use the same clock rates in all axes so that the slowest drive sets the clock. It is therefore possible to specifically reduce the performance via bit 2 and bit 5 of parameter "P-0-0556, Config word of axis controller".

- For **BASIC control sections** it is possible to select the performance levels "Basic" or "Economy" via bit 5 of P-0-0556.
- For **ADVANCED control sections** it is possible to select the performance levels "Advanced" or "Basic" via bit 2 of P-0-0556.

See also Parameter Description "P-0-0556, Config word of axis controller"

The effective clock rates of the active performance level are contained in the table "Performance depending on the control section design" in section "Control Section Design and Performance" (see above).

1.6.4 Restricted Performance With Certain Functional Packages

If you use extensive and complex functions, the internal clock rates for **BASIC control sections** (CSB with firmware MPB and CDB with firmware MPD) are automatically reduced. This applies to the use of the following functional packages:

- Drive-integrated PLC "IndraMotion MLD" (functional package "ML")
- Expansion package "synchronization" (functional package "SNC")

If you use one of these functional packages for BASIC control sections, the clock rates (position loop, velocity loop) are reduced to the lowest performance level "Economy"!

☞ For **ADVANCED control sections** (CSH with firmware MPH), the clock rates are not reduced depending on the functional packages that are used (reduction possible via P-0-0556).

☞ The effective clock rates of the active performance level are contained in the table "Performance depending on the control section design" in section "Control Section Design and Performance" (see above).

2 Important Directions for Use

2.1 Appropriate Use

2.1.1 Introduction

Rexroth products represent state-of-the-art developments and manufacturing. 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 the industrial environment 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, make sure that all the pre-requisites for an appropriate use of the products are satisfied:

- Personnel that in any way, shape or form uses our products must first read and understand the relevant safety instructions and be familiar with 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.
- Do not mount damaged or faulty products or use them in 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 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, making it possible for the motor to execute 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:

- 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 indicated technical data and specifications is defined as "inappropriate use".

Drive controllers must 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 must not be used in applications which have not been expressly authorized by Rexroth. Please carefully follow the specifications outlined in the general Safety Instructions!

3 Safety Instructions for Electric Drives and Controls

3.1 Safety Instructions - General Information

3.1.1 Using the Safety Instructions and Passing them on to Others

Do not attempt to install or commission this device without first reading all documentation provided with the product. Read and understand these safety instructions and all user documentation prior to working with the device. If you do not have the user documentation for the device, contact your responsible Bosch Rexroth sales representative. Ask for these documents to be sent immediately to the person or persons responsible for the safe operation of the device.

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

WARNING

Improper use of these devices, failure to follow the safety instructions in this document or tampering with the product, including disabling of safety devices, may result in material damage, bodily harm, electric shock or even death!

Observe the safety instructions!

3.1.2 How to Employ the Safety Instructions

Read these instructions before initial commissioning of the equipment in order to eliminate the risk of bodily harm and/or material damage. Follow these safety instructions at all times.

- Bosch Rexroth AG is not liable for damages resulting from failure to observe the warnings provided in this documentation.
- Read the operating, maintenance and safety instructions in your language before commissioning the machine. If you find that you cannot completely understand the documentation for your product, please ask your supplier to clarify.
- Proper and correct transport, storage, assembly and installation, as well as care in operation and maintenance, are prerequisites for optimal and safe operation of this device.
- Only assign trained and qualified persons to work with electrical installations:
  - Only persons who are trained and qualified for the use and operation of the device may work on this device or within its proximity. The persons are qualified if they have sufficient knowledge of the assembly, installation and operation of the product, as well as an understanding of all warnings and precautionary measures noted in these instructions.
  - Furthermore, they must be trained, instructed and qualified to switch electrical circuits and devices on and off in accordance with technical safety regulations, to ground them and to mark them according to the requirements of safe work practices. They must have adequate safety equipment and be trained in first aid.
- Only use spare parts and accessories approved by the manufacturer.

- Follow all safety regulations and requirements for the specific application as practiced in the country of use.
- The devices have been designed for installation in industrial machinery.
- The ambient conditions given in the product documentation must be observed.
- Only use safety-relevant applications that are clearly and explicitly approved in the Project Planning Manual. If this is not the case, they are excluded. Safety-relevant are all such applications which can cause danger to persons and material damage.
- The information given in the documentation of the product with regard to the use of the delivered components contains only examples of applications and suggestions.

  The machine and installation manufacturer must

  – make sure that the delivered components are suited for his individual application and check the information given in this documentation with regard to the use of the components,
  – make sure that his 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 permitted once it is sure that the machine or installation in which they are installed complies with the national regulations, safety specifications and standards of the application.
- Operation is only permitted 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 documentation (Project Planning Manuals of components and system).

  The machine or installation manufacturer is responsible for compliance with the limiting values as prescribed in the national regulations.
- Technical data, connection and installation conditions are specified in the product documentation and must be followed at all times.

National regulations which the user must take into account

- European countries: according to 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)

3.1.3 Explanation of Warning Symbols and Degrees of Hazard Seriousness

The safety instructions describe the following degrees of hazard seriousness. The degree of hazard seriousness informs about the consequences resulting from non-compliance with the safety instructions:

Warning symbol	Signal word	Degree of hazard seriousness acc. to ANSI Z 535.4-2002
	Danger	Death or severe bodily harm will occur.
	Warning	Death or severe bodily harm may occur.
	Caution	Minor or moderate bodily harm or material damage may occur.

Fig.3-1: Hazard classification (according to ANSI Z 535)

3.1.4 Hazards by Improper Use

DANGER

High electric voltage and high working current! Risk of death or severe bodily injury by electric shock!

Observe the safety instructions!

DANGER

Dangerous movements! Danger to life, severe bodily harm or material damage by unintentional motor movements!

Observe the safety instructions!

WARNING

High electric voltage because of incorrect connection! Risk of death or bodily injury by electric shock!

Observe the safety instructions!

WARNING

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

Observe the safety instructions!

CAUTION

Hot surfaces on device housing! Danger of injury! Danger of burns!

Observe the safety instructions!

CAUTION

Risk of injury by improper handling! Risk of bodily injury by bruising, shearing, cutting, hitting or improper handling of pressurized lines!

Observe the safety instructions!

CAUTION

Risk of injury by improper handling of batteries!

Observe the safety instructions!

3.2 Instructions with Regard to Specific Dangers

3.2.1 Protection Against Contact with Electrical Parts and Housings

☞ This section concerns devices and drive components with voltages of **more than 50 Volt**.

Contact with parts conducting voltages above 50 Volts can cause personal danger and electric shock. When operating electrical equipment, it is unavoidable that some parts of the devices conduct dangerous voltage.

DANGER

High electrical voltage! Danger to life, electric shock and severe bodily injury!

- Only those trained and qualified to work with or on electrical equipment are permitted to operate, maintain and repair this equipment.
- Follow general construction and safety regulations when working on power installations.
- Before switching on the device, the equipment grounding conductor must have been non-detachably connected to all electrical equipment in accordance with the connection diagram.
- Do not operate electrical equipment at any time, even for brief measurements or tests, if the equipment grounding conductor is not permanently connected to the mounting points of the components provided for this purpose.
- Before working with electrical parts with voltage potentials higher than 50 V, the device must be disconnected from the mains voltage or power supply unit. Provide a safeguard to prevent reconnection.
- With electrical drive and filter components, observe the following:

  Wait **30 minutes** after switching off power to allow capacitors to discharge before beginning to work. Measure the electric voltage on the capacitors before beginning to work to make sure that the equipment is safe to touch.
- Never touch the electrical connection points of a component while power is turned on. Do not remove or plug in connectors when the component has been powered.
- Install the covers and guards provided with the equipment properly before switching the device on. Before switching the equipment on, cover and safeguard live parts safely to prevent contact with those parts.
- A residual-current-operated circuit-breaker or r.c.d. cannot be used for electric drives! Indirect contact must be prevented by other means, for example, by an overcurrent protective device according to the relevant standards.
- Secure built-in devices from direct touching of electrical parts by providing an external housing, for example a control cabinet.

For electrical drive and filter components with voltages of **more than 50 volts**, observe the following additional safety instructions.

DANGER

High housing voltage and high leakage current! Risk of death or bodily injury by electric shock!

- Before switching on, the housings of all electrical equipment and motors must be connected or grounded with the equipment grounding conductor to the grounding points. This is also applicable before short tests.
- The equipment grounding conductor of the electrical equipment and the devices must be non-detachably and permanently connected to the power supply unit at all times. The leakage current is greater than 3.5 mA.
- Over the total length, use copper wire of a cross section of a minimum of 10 mm^2 for this equipment grounding connection!
- Before commissioning, also in trial runs, always attach the equipment grounding conductor or connect to the ground wire. Otherwise, high voltages may occur at the housing causing electric shock.

3.2.2 Protection Against Electric Shock by Protective Extra-Low Voltage

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

All connections and terminals with voltages between 5 and 50 volts at Rexroth products are PELV systems. [1)] It is therefore allowed to connect devices equipped with basic insulation (such as programming devices, PCs, notebooks, display units) to these connections and terminals.

WARNING

High electric voltage by incorrect connection! Risk of death or bodily injury by electric shock!

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. [2)]

3.2.3 Protection Against Dangerous Movements

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

- improper or wrong wiring of cable connections
- incorrect operation of the equipment components
- wrong input of parameters before operation
- malfunction of sensors, encoders and monitoring devices
- defective components
- software or firmware errors

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

1) *"Protective Extra-Low Voltage"*

2) *"Protective Extra-Low Voltage"*

The monitoring in the drive components will normally be sufficient to avoid faulty operation in the connected drives. Regarding personal safety, especially the danger of bodily harm and material 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.

DANGER

Dangerous movements! Danger to life, risk of injury, severe bodily harm or material damage!

- Ensure personal safety by means of qualified and tested higher-level monitoring devices or measures integrated in the installation.

  These measures have to be provided for by the user according to the specific conditions within the installation and a hazard and fault analysis. The safety regulations applicable for the installation have to be taken into consideration. Unintended machine motion or other malfunction is possible if safety devices are disabled, bypassed or not activated.

To avoid accidents, bodily harm and/or material damage:

- Keep free and clear of the machine's range of motion and moving parts. Possible measures to prevent people from accidentally entering the machine's range of motion:
  - use safety fences
  - use safety guards
  - use protective coverings
  - install light curtains or light barriers
- Fences and coverings must be strong enough to resist maximum possible momentum.
- Mount the emergency stop switch in the immediate reach of the operator. Verify that the emergency stop works before startup. Don't operate the device if the emergency stop is not working.
- Isolate the drive power connection by means of an emergency stop circuit or use a safety related starting lockout to prevent unintentional start.
- Make sure that the drives are brought to a 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 equilibration of the vertical axes.
- The standard equipment motor brake or an external brake controlled directly by the drive controller are **not sufficient to guarantee personal safety**!
- Disconnect electrical power to the equipment using a master switch and secure the switch against reconnection 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 electronics circuits and supply leads. If the use of such devices cannot be avoided, verify the system and the installation for possible malfunctions in all possible positions of normal use before initial startup. If necessary, perform a special electromagnetic compatibility (EMC) test on the installation.

3.2.4 Protection Against Magnetic and Electromagnetic Fields During Operation and Mounting

Magnetic and electromagnetic fields generated by current-carrying conductors and permanent magnets in motors represent a serious personal danger to those with heart pacemakers, metal implants and hearing aids.

WARNING

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

- Persons with heart pacemakers and metal implants are not permitted to enter following areas:
  - Areas in which electrical equipment and parts are mounted, being operated or commissioned.
  - Areas in which parts of motors with permanent magnets are being stored, repaired or mounted.
- If it is necessary for somebody with a pacemaker to enter such an area, a doctor must be consulted prior to doing so. The noise immunity of present or future implanted heart pacemakers differs greatly so 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. Otherwise health hazards may occur.

3.2.5 Protection Against Contact with Hot Parts

CAUTION

Hot surfaces at motor housings, on drive controllers or chokes! Danger of injury! Danger of burns!

- Do not touch surfaces of device housings and chokes in the proximity of heat sources! Danger of burns!
- Do not touch housing surfaces of motors! Danger of burns!
- According to the operating conditions, temperatures can be **higher than 60 °C**, 140°F during or after operation.
- Before accessing motors after having switched them off, let them cool down for a sufficiently long time. Cooling down can require **up to 140 minutes**! Roughly estimated, the time required for cooling down is five times the thermal time constant specified in the Technical Data.
- After switching drive controllers or chokes 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, the manufacturer of the end product, machine or installation, according to the respective safety regulations, has to take measures to avoid injuries caused by burns in the end application. These measures can be, for example: warnings, guards (shielding or barrier), technical documentation.

3.2.6 Protection During Handling and Mounting

In unfavorable conditions, handling and mounting certain parts and components in an improper way can cause injuries.

CAUTION

Risk of injury by improper handling! Bodily injury by bruising, shearing, cutting, hitting!

- Observe the general construction and safety regulations on handling and mounting.
- Use suitable devices for mounting and transport.
- Avoid jamming and bruising by appropriate measures.
- Always use suitable tools. Use special tools if specified.
- Use lifting equipment and tools in the correct manner.
- If necessary, use suitable protective equipment (for example safety goggles, safety shoes, safety gloves).
- Do not stand under hanging loads.
- Immediately clean up any spilled liquids because of the danger of skidding.

3.2.7 Battery Safety

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

CAUTION

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 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 electrical parts installed in the devices.
- Only use the battery types specified by the manufacturer.

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 separate from other waste. Observe the local regulations in the country of assembly.

3.2.8 Protection Against Pressurized Systems

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

CAUTION

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 (for example safety goggles, safety shoes, safety gloves).
- Immediately clean up any spilled liquids from the floor.

☞ Environmental protection and disposal! The agents used to operate the product might not be economically friendly. Dispose of ecologically harmful agents separately from other waste. Observe the local regulations in the country of assembly.

4 Master Communication

4.1 Basic Functions of Master Communication

4.1.1 Brief Description

General Information

The basic functions of master communication for IndraDrive devices apply to SERCOS interface, SERCOS III, field bus interface, parallel and analog interface.

Features

All variants of master communication supported by IndraDrive have the following functional features in common:

- **Address assignment**

  → Communication address to be freely parameterized (via master communication, serial and control panel) via parameter "P-0-4025, Drive address of master communication"
- **Command processing**

  → Drive commands to be externally activated (via master communication, serial and 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-0-0014, S-0-0135).
  - 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 operating mode (OM) and parameter mode (PM).
- **Extended possibilities of control**
  - Signal control word (S-0-0145) and signal status word (S-0-0144)
  - Multiplex channel

  See section "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 1 procedure command
- S-0-0422, C0200 Exit parameterization level procedure command
- S-0-0423, IDN-list of invalid op. data for parameterization level
- S-0-0424, Status parameterization level
- P-0-4086, Master communication status
- P-0-4088, Master communication, configuration

Operating Mode Parameters

- S-0-0032, Primary mode of operation
- 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

Device-Specific Control and Status Words

- S-0-0099, C0500 Reset class 1 diagnostics
- S-0-0144, Signal status word
- S-0-0145, Signal control word
- P-0-0115, Device control: status word
- P-0-0116, Device control: control word
- P-0-4028, Device control word

SERCOS-Specific Parameters

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

- S-0-0021, IDN list of invalid operating data for communication phase 2
- S-0-0022, IDN list of invalid operating data for communication phase 3
- S-0-0127, C0100 Communication phase 3 transition check
- S-0-0128, C5200 Communication phase 4 transition check
- S-0-0134, Master control word
- S-0-0135, Drive status word

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

- S-0-1134, SERCOS III: Master control word
- S-0-1135, SERCOS III: Drive status word

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 Parallel/Analog Interface

For the parallel/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

4.1.2 Setting the Axis Address

Overview

Each drive is identified by its own address.

☞ Multiple addressing is not allowed; i.e. an address number may only be assigned once in the drive group!

The drive address can be set in the following ways:

- Directly writing the parameter "P-0-4025, Drive address of master communication" via the master communication

- or -

- Changing the content of "P-0-4025, Drive address of master communication" via the control panel (see below)

☞ The address entered in parameter "P-0-4025, Drive address of master communication" takes effect during the transition from P0 → P1. This address is displayed in parameter "P-0-4031, Overview of device addresses".

Condition as Supplied In the condition as supplied the address "99" has been set.

Address Setting via Standard Control Panel

The drive address for IndraDrive controllers can be set via the standard control panel at the front of the device.

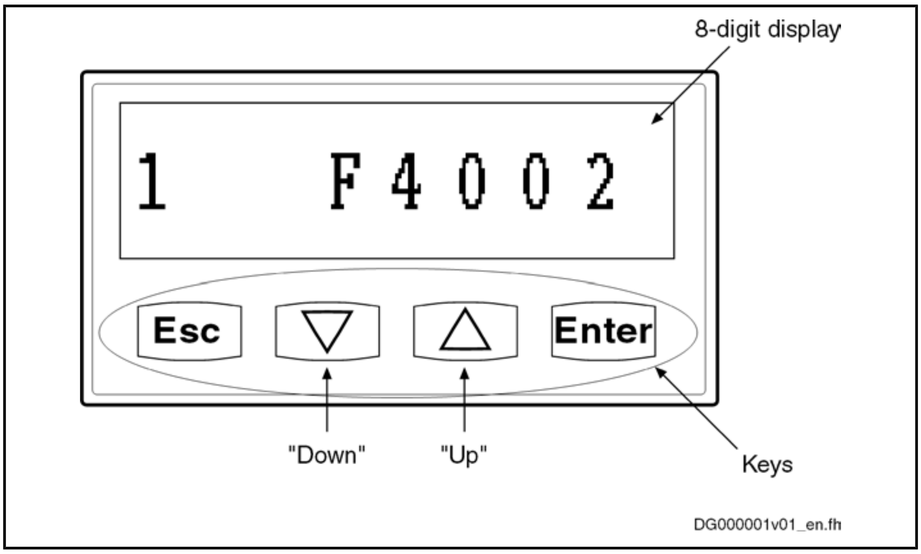


Fig.4-1: Standard Control Panel (Example of Display)

The address is set via the control panel as follows:

1. Change to "Commands/settings" mode

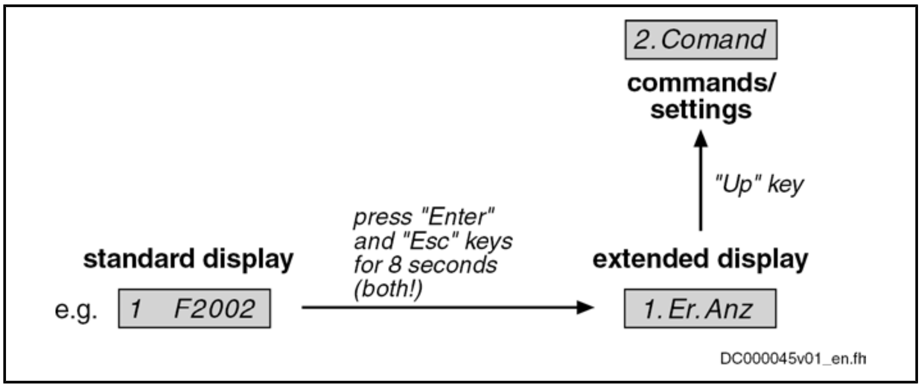


Fig.4-2: Activating the "Commands/Settings" Mode

2. Select element "2.1 drive address" by means of "Up/Down" key, then confirm by means of "Enter" key
3. Set drive address by means of "Up/Down" keys, then confirm by means of "Enter" key
   - First set **tens digit**

     → The display reads "2.1.1 drive address"
   - Then set **units digit**

     → The display reads "2.1.2 drive address"

☞ The tens or units digit is accepted by pressing the "Enter" key. To return press the "Esc" key.

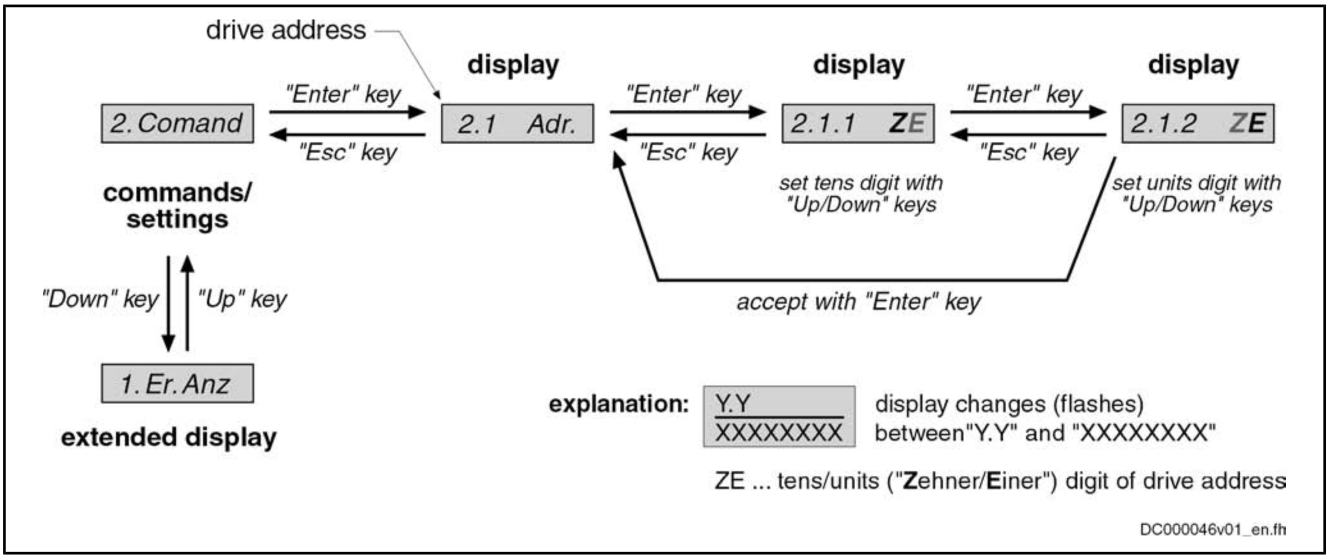


Fig.4-3: Selecting and Setting the Drive Address

Address Setting via Parameter Access

The drive address can also be set by writing the parameter "P-0-4025, Drive address of master communication". This is particularly interesting if you administrate the axis data in centralized form in the control unit and want to set the address from the control unit when replacing devices.

See also "Notes on How to Replace the Devices"

The address written to parameter "P-0-4025, Drive address of master communication" will only take effect after repeated booting process or, in the case of SERCOS devices, after the transition from P-1 → P1.

4.1.3 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 the parameter "S-0-0025, IDN-list of all procedure commands".

Kinds of Commands

We distinguish 3 kinds of commands:

- **Drive control commands**
  - Can cause automatic drive motion
  - Can only be started when drive enable has been set
  - Deactivate the active operating mode during its execution
- **Monitor commands**
  - Activate or deactivate monitorings or functions in the drive
- **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 or 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.

CAUTION

Damage to the internal memory (flash) caused by cyclic command execution (write access 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 access. For this reason, you should make sure that such write access is not carried out too often.

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. parameter S-0-0099 in the case of command C0500) via serial interface of master communication

- or -

- A 0-1 edge when the command was assigned to a digital input

  See also the following sections:

  – "Configurable Signal Control Word"

  – "Parallel Interface"

  – "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 status of the command execution. The current status 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 status "in process (0x7)" 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 master communication.

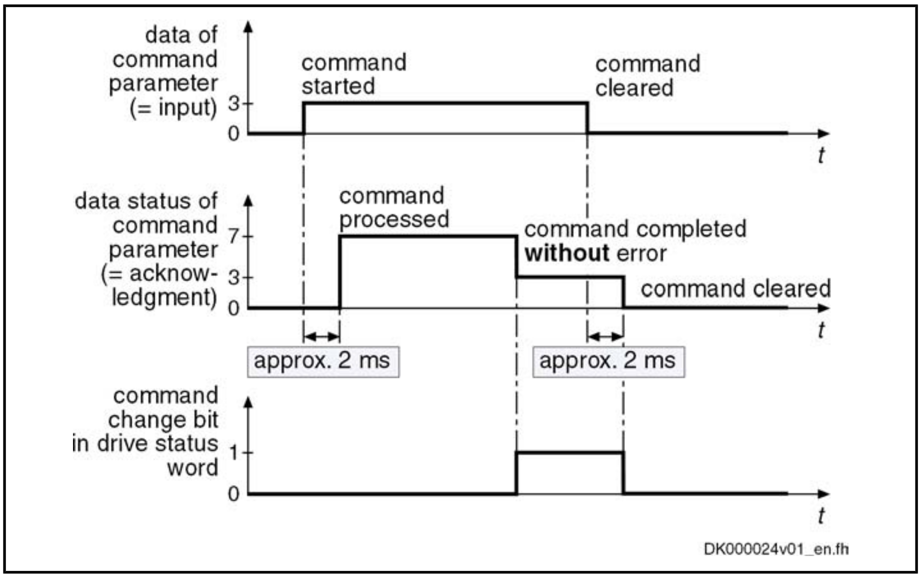


Fig.4-4: Input, Acknowledgment and Command Change Bit in the Case of Correct Execution

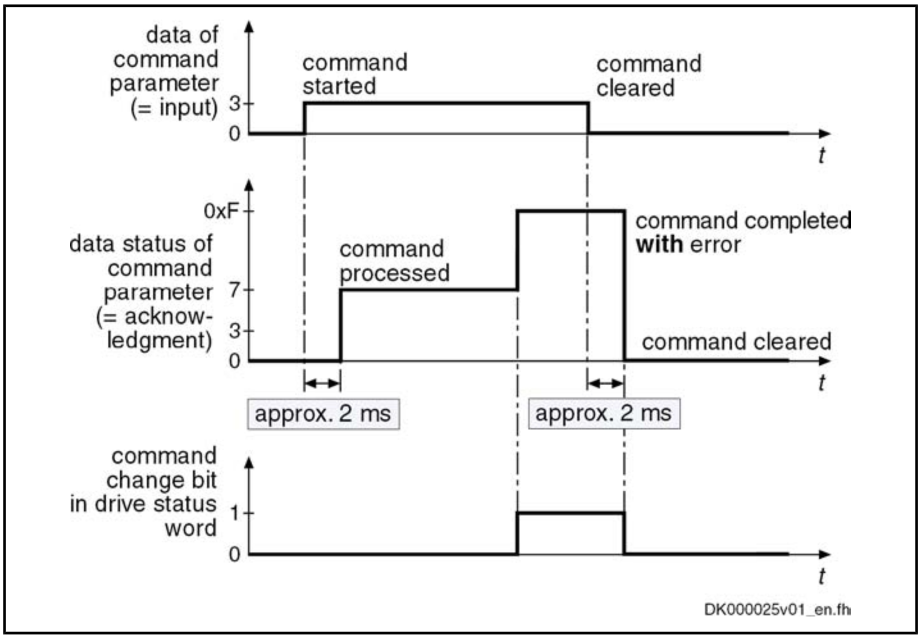


Fig.4-5: Input, Acknowledgment and Command Change Bit in the Case of Incorrect Execution

4.1.4 Device Control and State Machines

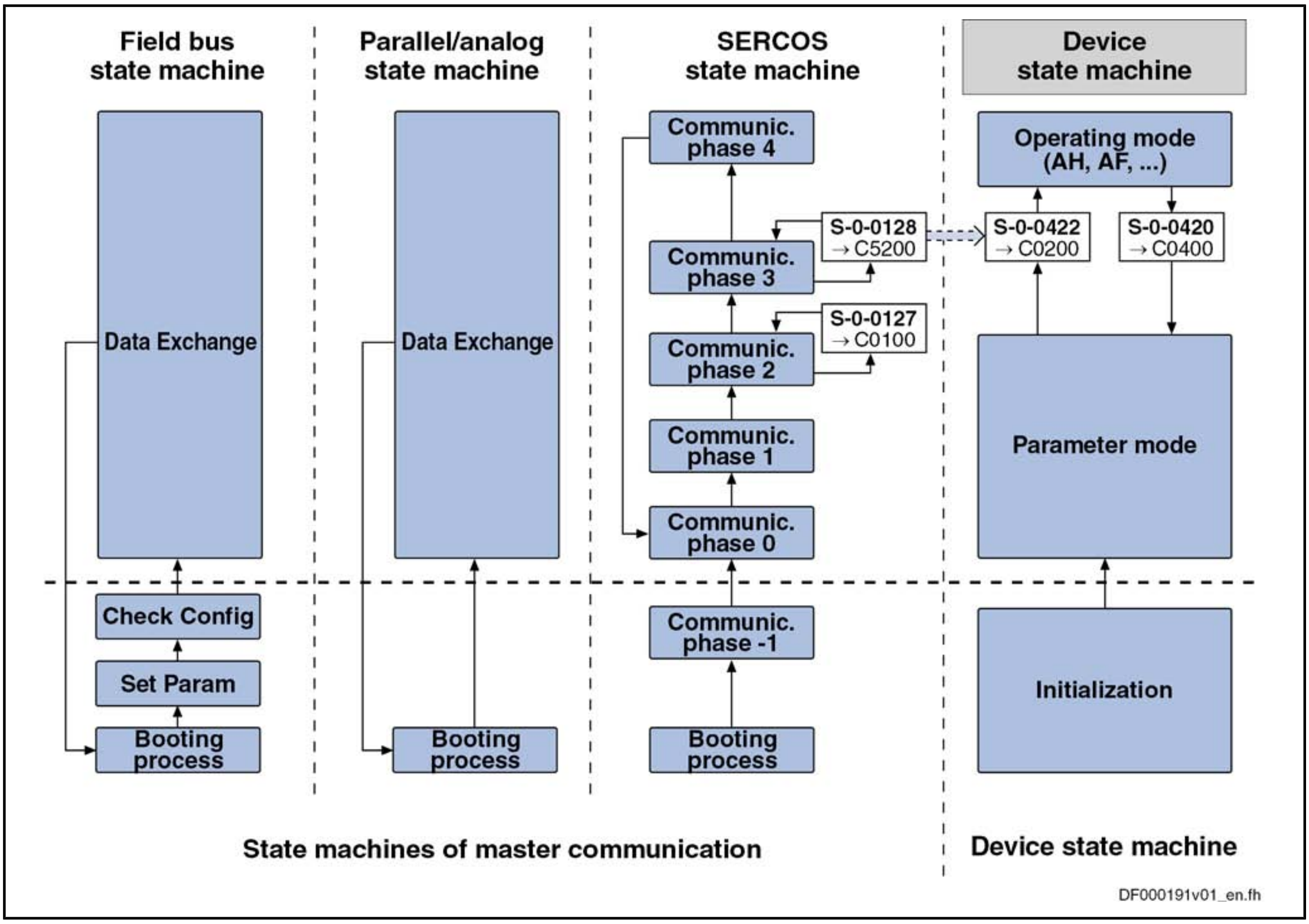
Overview

The drive status (e.g. Drive Halt, drive error) represents a specific internal and external drive behavior. The drive status can be exited by defined events (e.g. drive commands, switching of operating modes). Corresponding status transitions are assigned to the events. The status 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
Fig.4-6:	*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 1 procedure command
- S-0-0422, C0200 Exit parameterization level procedure command

Observe the following aspects for switching:

- Switching is generally possible by direct execution of 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 "SERCOS 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.
- In the case of master communication other than SERCOS interface, the device-internal state machine changes to the operating mode after the booting process.

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

State Machine of Master Communication

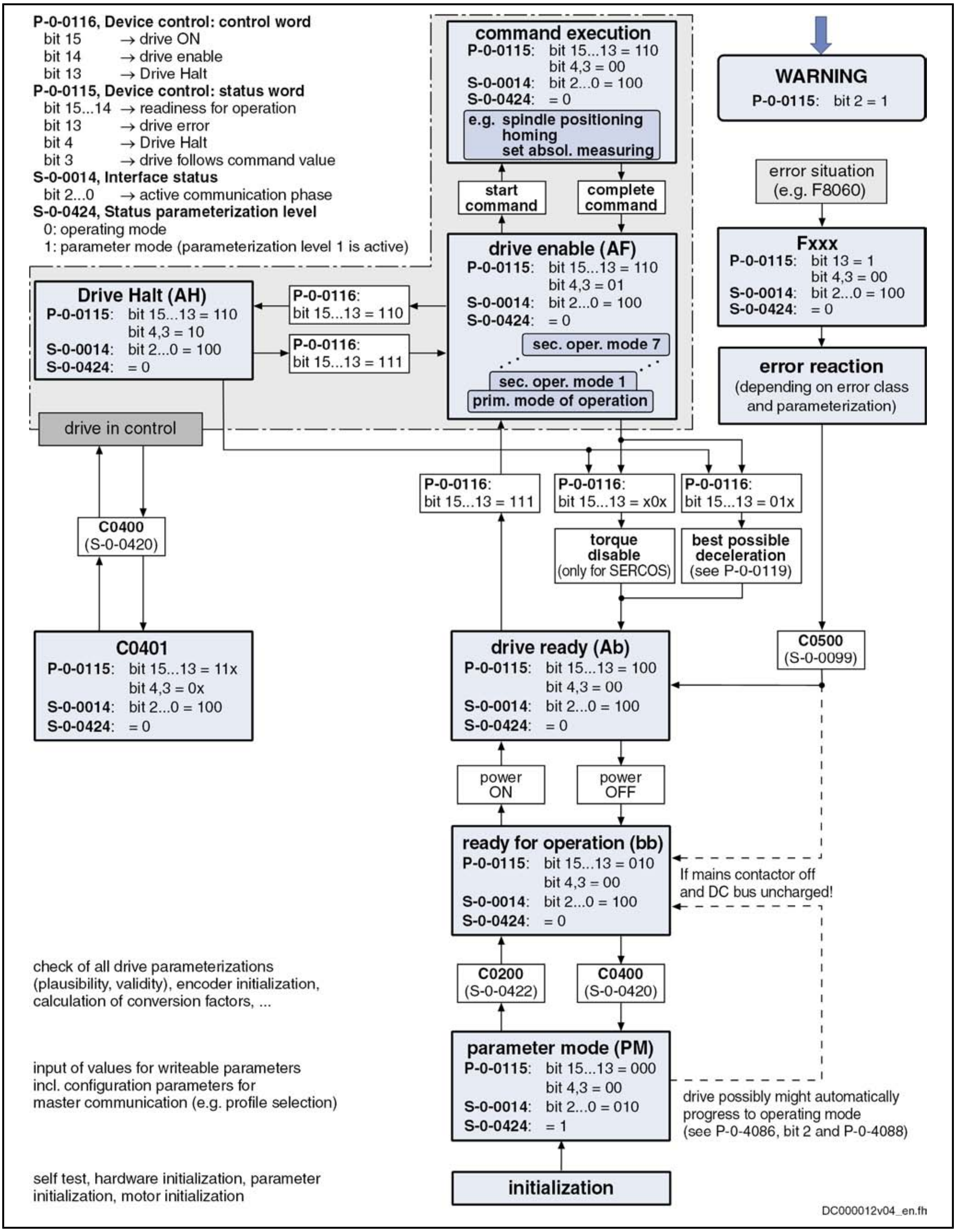


Fig.4-7: Device Control (General State Machine)

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

- SERCOS state machine
- Field bus state machine
- Parallel/analog 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:

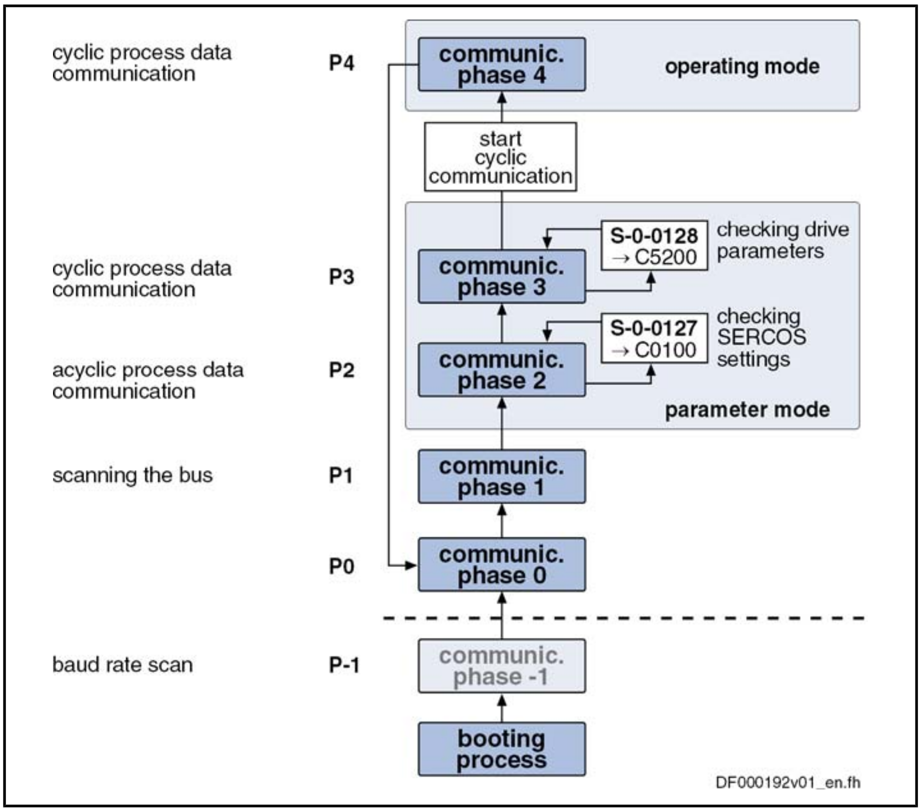


Fig.4-8: State Machine of the Communication Phases of the Drive According to SERCOS Specification

See also "SERCOS interface"

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

Field Bus State Machine

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

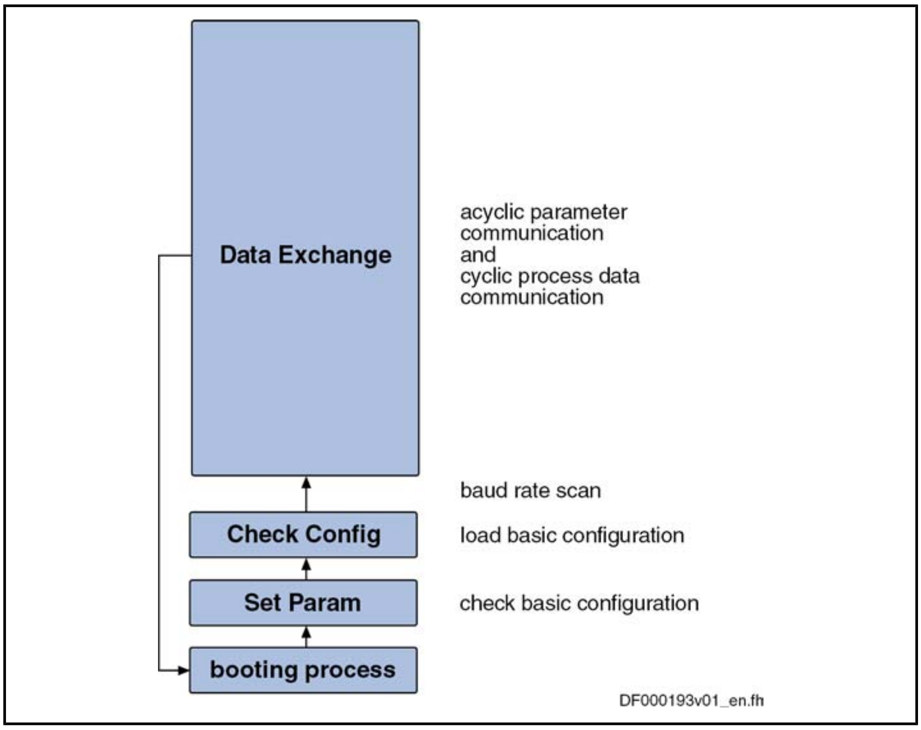


Fig.4-9: State Machine for Field Bus Interfaces

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 operating 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**: After it is switched on, the drive goes to phase -1 and carries out a baud rate scan. As soon as the drive receives valid SERCOS telegrams from the master, it changes to phase 0.
- **P0**: The master checks the SERCOS ring by sending synchronization telegrams. During phase 0, communication between master and drive isn't possible yet.
- **P1**: When the ring is closed, the master changes to phase 1 and scans the slaves. In addition, it checks the configuration of the ring.
- **P2**: In phase 2, the complete drive parameterization can be carried out.

  The following kinds 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 operating 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, ...)

☞ According to SERCOS specification, the parameter mode is divided 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 phase switch to phase 4.

- **P4**: In phase 4, the so-called "operating mode", only the cyclic data can be changed, the configuration parameters cannot. The switch 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 has to 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 status "Data Exchange", apart from the basic initialization. In the status "Data Exchange", we distinguish the following device states:

- Parameter mode
- Operating mode

Communication Phases for Parallel or Analog Interface

Basically, the same communication phases apply to devices with **analog or parallel interface** and to devices with field bus 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:

- SERCOS interface:
  - S-0-0134, Master control word
  - S-0-0135, Drive status word
- SERCOS III:
  - S-0-1134, Master control word
  - S-0-1135, Drive status word
- Field bus interface (e.g. PROFIBUS, CANopen, DeviceNet):
  - 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/parallel 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:

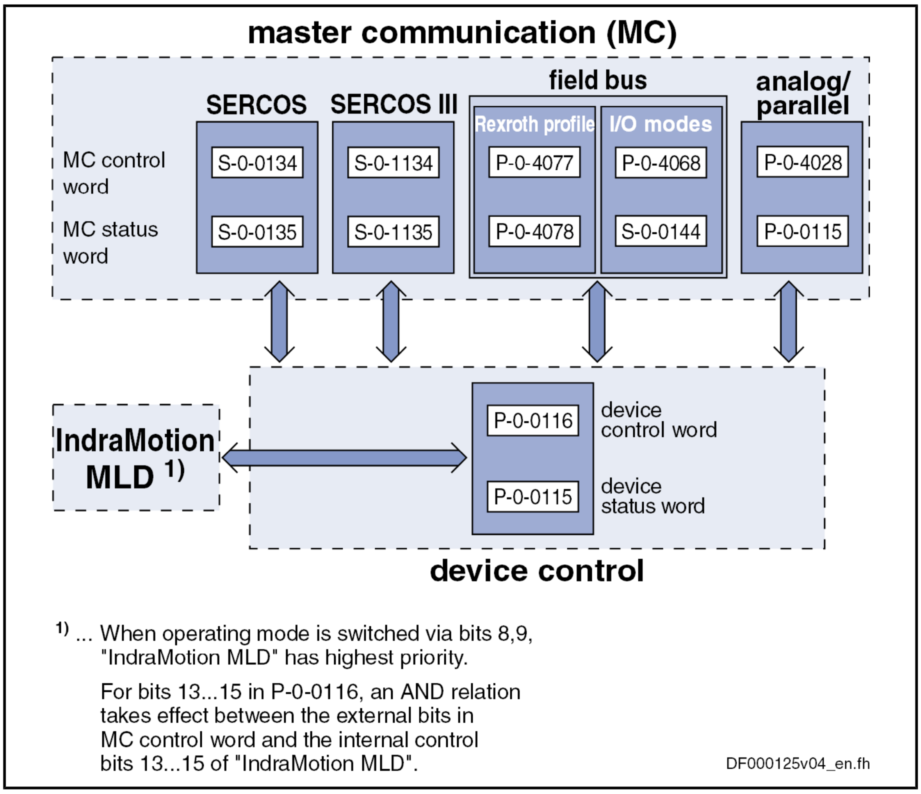


Fig.4-10: Interaction of the Available Control and Status Words

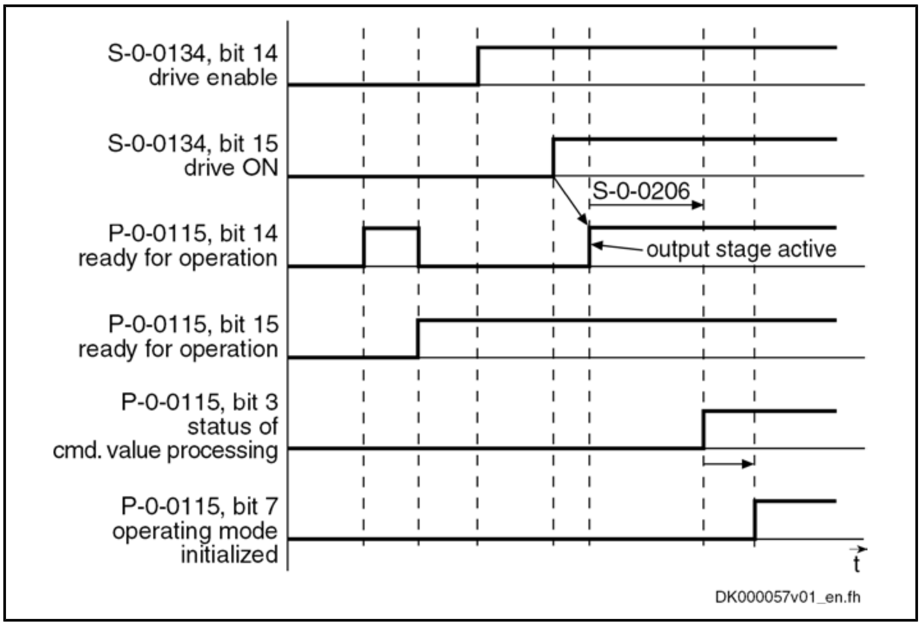
See also separate documentation "IndraMotion MLD".

The internal control and status words can only be directly reached via the PLC integrated in the drive (functional package "IndraMotion MLD" as optional expansion). If this function has not been activated, it is always the specific control and status words that are accessed via the master communication. But it is always possible to read the parameters P-0-0115 and P-0-0116 in order to obtain information on the internal device status.

Timing Diagrams for Device Control

The control bits in parameter "S-0-0134, Master control word" are input externally via the master communication (the following examples apply to SERCOS)!

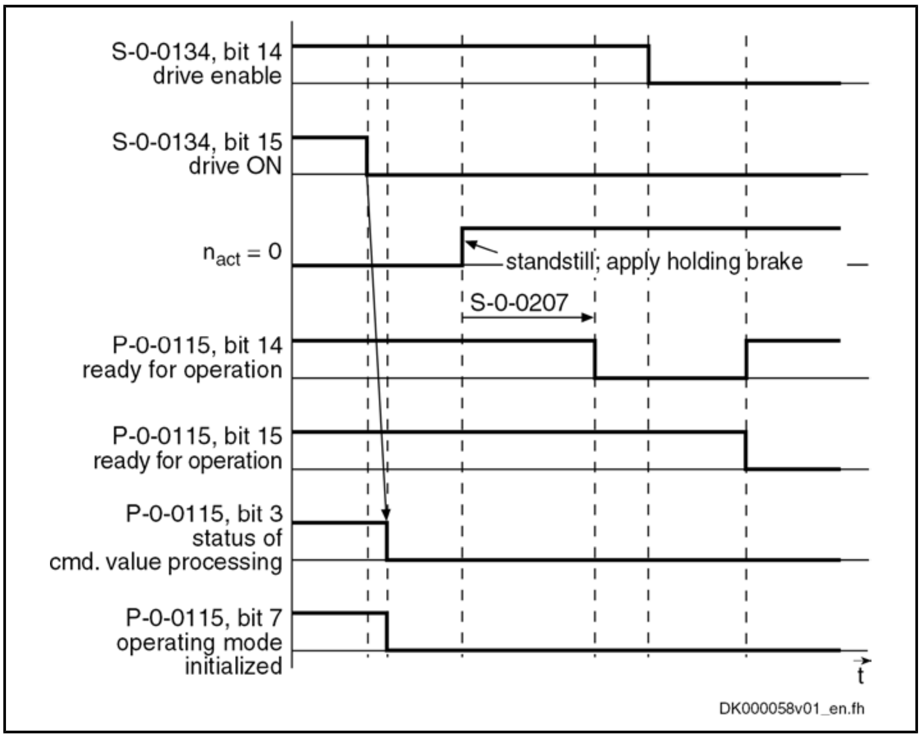
Bit Sequence During Switch-On Process



S-0-0206 Drive on delay time

Fig.4-11: Bit Sequence During Switch-On Process

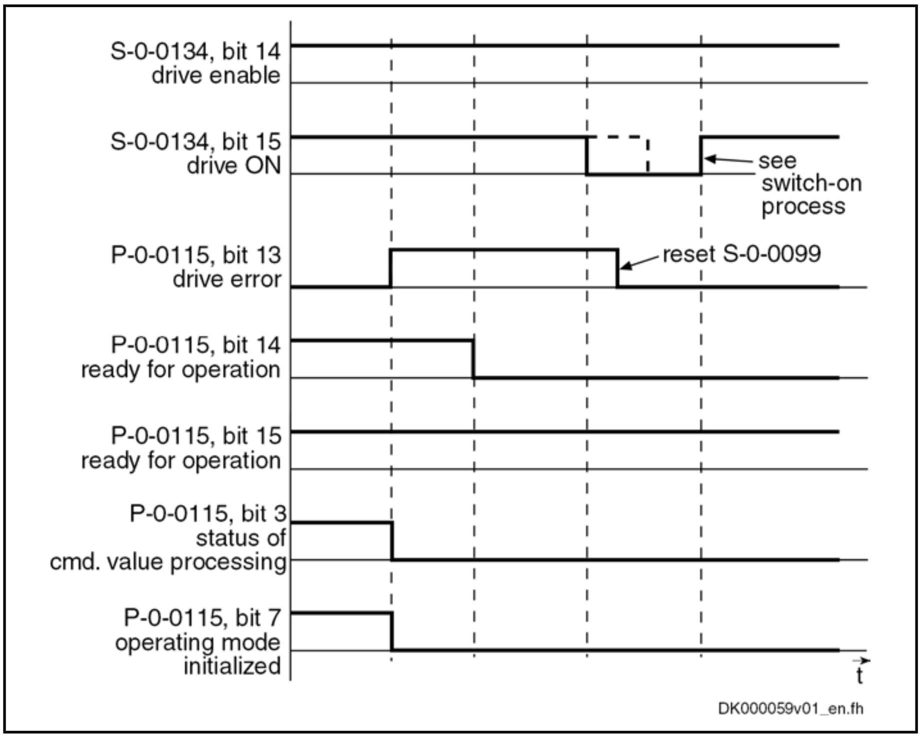
Bit Sequence During Switch-Off Process



S-0-0207 Drive off delay time

Fig.4-12: Bit Sequence During Switch-Off Process

Bit Sequence During Error Reaction



S-0-0099 C0500 Reset class 1 diagnostics

Fig.4-13: Bit Sequence During Error Reaction

Bit Sequence During Change of Operating Modes

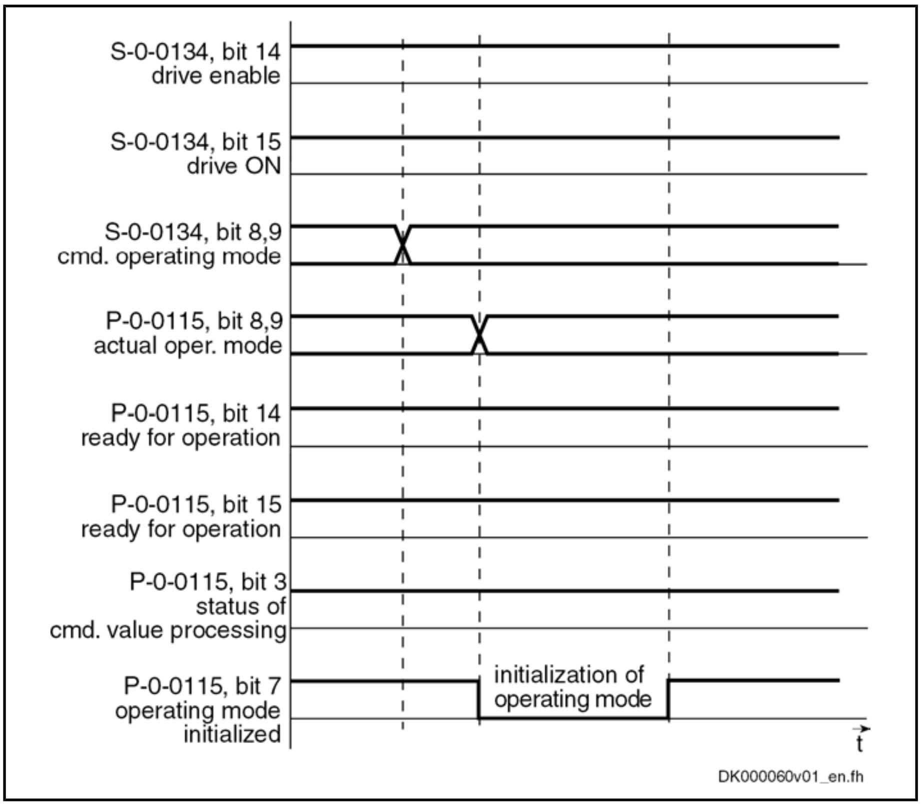


Fig.4-14: Bit Sequence During Change of Operating Modes

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 1 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-0-0422) is automatically called during the execution of command C5200 (S-0-0128). This is why a 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" is generated. The IDNs of the faulty parameters are listed in parameter "S-0-0021, IDN list of invalid operating data for communication phase 2". These parameters have to be set valid by writing correct values to them.
  – C0101 Invalid parameters (->S-0-0021)
- Checking device configuration
  – C0132 Invalid settings for controller cycle times
- 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.
  – 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
- If necessary, checking timing parameters for SERCOS communication in phases 3 and 4 for validity and compliance with requirements
  – C0108 Time slot parameter > Sercos cycle time
  – C0109 Position of data record in MDT (S-0-0009) even
  – C0110 Length of MDT (S-0-0010) odd
  – C0111 ID9 + Record length - 1 > length MDT (S-0-0010)
  – 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)
  – C0115 T2 too small
  – C0116 T3 (S-0-0008) within MDT (S-0-0089 + S-0-0010)
  – C0139 T2 (S-0-0089) + length MDT (S-0-0010) > TScyc (S-0-0002)
- Limit value check of communication parameters and system

- C0102 Limit error in parameter (-> S-0-0021)
- C0103 Parameter conversion error (-> S-0-0021)
- C0131 Switching to phase 3 impossible

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 Functional package selection changed. Restart

    → Drive has to 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: 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 is 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 encoder 3
  - 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
  - C0260 Incremental enc. emulator resol. cannot be displayed
- Initializing integrated safety technology
  - C0254 Configuration error PROFIsafe
  - C0255 Safety command for system init. incorrect
  - C0256 Safety technology configuration error
  - C0257 No encoder assigned to slot 1
- Limit value check
  - C0202 Parameter limit error (->S-0-0423)
  - C0203 Parameter calculation error (->S-0-0423)
- General system checks
  - C0245 Operating mode configuration (->S-0-0423) not allowed
- Initializing fine interpolator
  - C0258 Error in relation TNcyc (S-0-0001) to fine interpol.
- Initializing digital inputs/outputs
  - C0246 Trav. range lim. switch not ass. to dig. input
  - C0247 Dig. output already assigned to another axis
  - C0248 Dig. input assigned differently to axes
  - C0249 Digital I/Os: bit number too high
- 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

4.2 Control Options/Additional Functions

4.2.1 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.

☞ The bits in the signal control word are processed in every interface cycle at the point of time defined in parameter "S-0-0008, Command value valid time (T3)".

Examples of Use This functionality can be used, for example,

- for freely configuring the digital inputs
- for setting-up mode via digital inputs
- for setting bits in drive parameters and for starting commands via the cyclic channel (master communication)

☞ For SERCOS and field bus interface 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 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 the signal control word

Notes on Commissioning of the Signal Control Word

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

Configuring the IDNs In parameter "S-0-0027, Configuration list 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".

> If this list remains empty, bit 0 of the mentioned parameters is automatically influenced. Otherwise the bit that is to be assigned to the target parameter is entered in this list.

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 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.
- If the parameter assigned is parameter "S-0-0346, Positioning control word", a positive edge in the respective bit of the control word causes toggling of parameter S-0-0346.

> 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-0-1134, SERCOS-III: 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 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 the signal control word", the error message "0x7008 Invalid data" is generated.

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

4.2.2 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 important status information of the drive for the control unit.

> The bits in the signal status word are configured in every master communication cycle at the point of time defined in parameter "S-0-0007, Feedback acquisition starting time (T4)".

Pertinent Parameters

- S-0-0026, Configuration list 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 of the Signal Status Word

Configuring the IDNs

In parameter "S-0-0026, Configuration list signal status word", the IDNs of those parameters are indicated that contain the original bits (sources). The parameters that can be entered in the configuration list are listed in parameter "S-0-0398, IDN list of configurable data in the 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 signal status word" is copied to the signal status word has to be determined in "S-0-0328, Assign list signal status word".

☞ If this list remains empty, bit 0 of the mentioned parameters is automatically copied. Otherwise, the bit to be taken from the source parameter is specified in the list.

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

Fig.4-15: Example of configuration of 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 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 control bits which are not contained in parameter "S-0-1135, SERCOS-III: drive status". 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 signal status word", the following check is 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 function 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!

4.2.3 Multiplex Channel

Brief Description

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

☞ To be able to use the "multiplex channel" mechanism it is necessary to use master communication via SERCOS or field bus (e.g. PROFIBUS-DP) and configure the multiplex parameters in the cyclic real-time channel.

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 with a cycle time of "T_{scyc} x number of multiplex data" by incrementing the addressing index (S-0-0368)
- To achieve operating mode dependent configuration of the cyclic data by index switching in case the operating mode is changed.

☞ When IndraMotion MLC is used, the multiplex channel is used for communication between MLC and drive and therefore cannot be freely used any more!

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: Cmd value -1
- S-0-0450 Data container A: Cmd value -2

  - to -

  S-0-0456 Data container A: Cmd value -8

Parameters for actual value channel:

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

  - to -

  S-0-0486 Data container A: Actual 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

- C0238 Order cycl. command value configuration incorrect
- C0151 IDN for command value data container not allowed
- C0152 IDN for actual value data container not allowed
- 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-0-0188, List of configurable data in the cycl. cmd value data channel
- S-0-0187, List of configurable data in the cycl. actual value data channel

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

☞ 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 actual values).

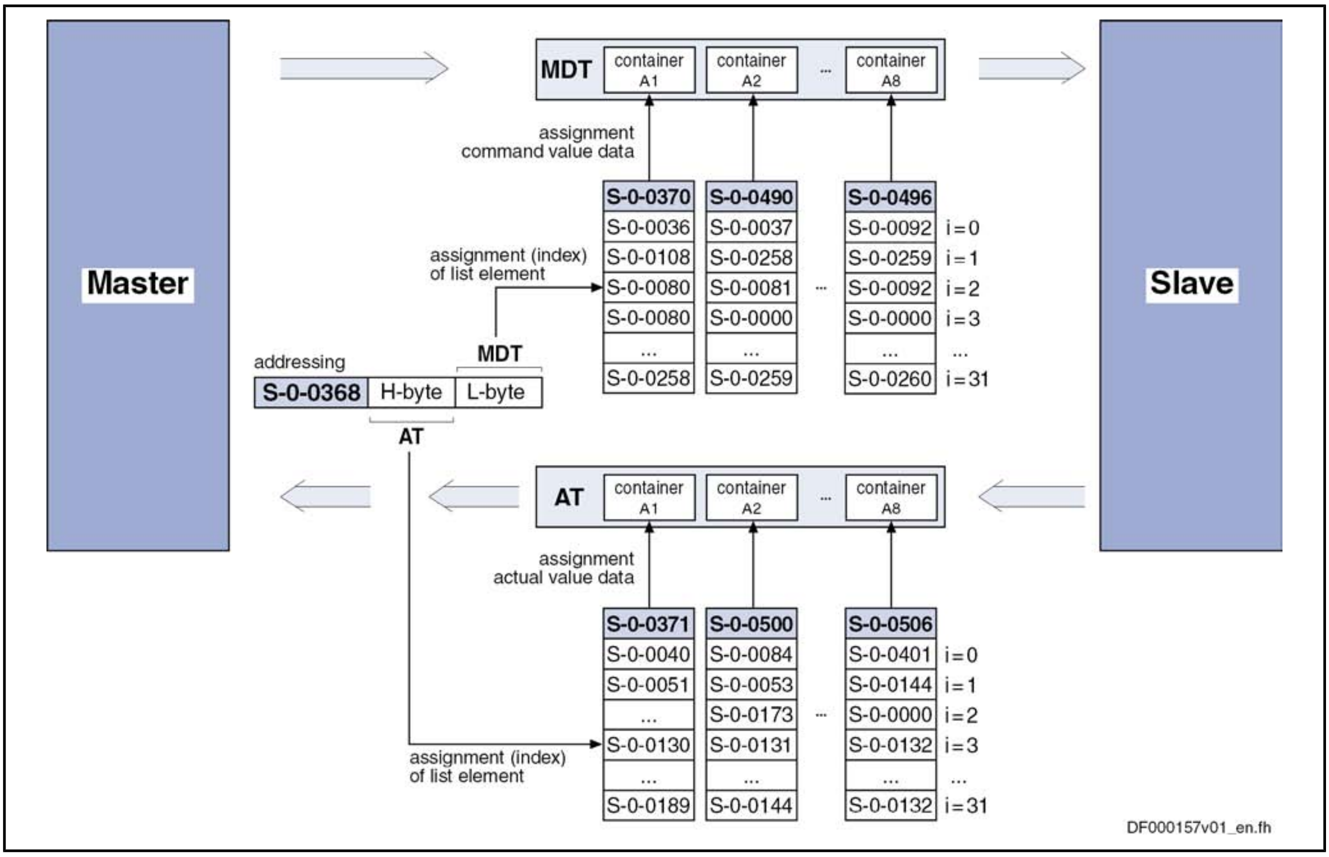
The following assignment applies to S-0-0368:

- 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 bits 0...4 (for MDT) and bits 8...12 (for AT) are used for addressing via parameter S-0-0368. The other bits are ignored. This is why no value greater 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: configuration list feedback value-1
S-0-0500	Data container A: configuration list feedback value-2
S-0-0506	Data container A: configuration list feedback value-8

Fig.4-16: 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:

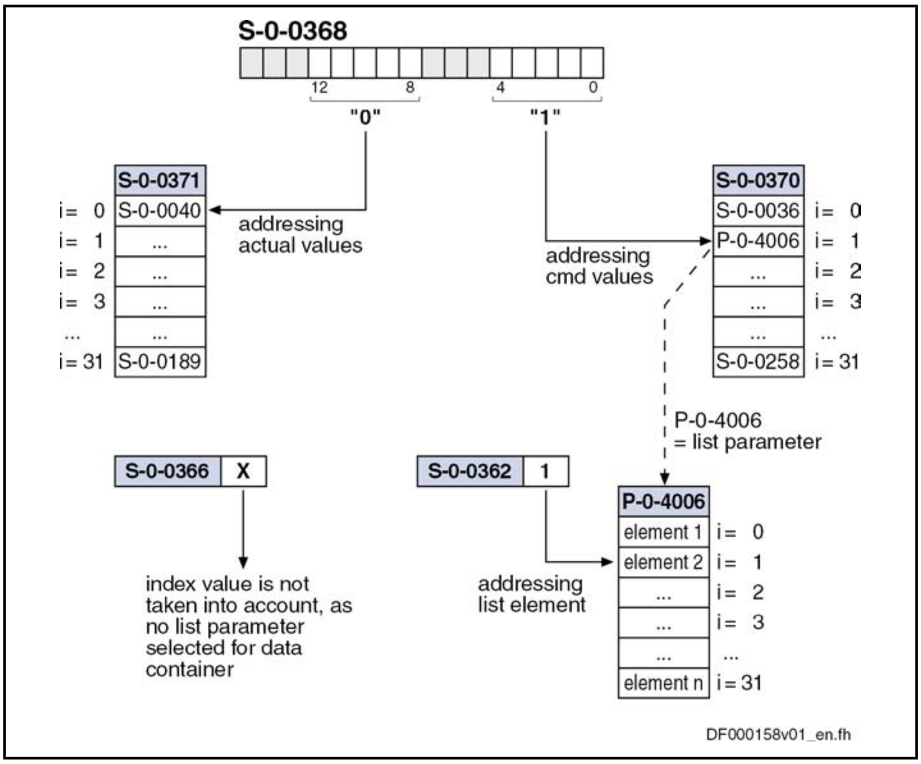
- S-0-0362 Data container A: list index command values

  → 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: configuration list feedback value-1
P-0-4006	Positioning block target position

Fig.4-17: 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 parameter:

- **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 to which the content (data) of "Data container A: feedback value-x" (S-0-0364, …) is to be written we also distinguish between single and list parameter:

- **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 actual 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, Config. list of the master data telegram".

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 IDN contained in the configuration lists are existing and the corresponding parameters can be cyclically configured.

This is why a check is run at the execution of command "S-0-0127, C0100 Communication phase 3 transition check" in order 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 are not existing or 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 are not existing or 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

The drive during the runtime 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.

4.3 Profile Types (With Field Bus Interfaces)

4.3.1 Supported Profile Types

Overview

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

- I/O mode positioning
- I/O mode preset velocity
- Freely configurable mode (Rexroth profile type)

The tables below contain an overview of the most important properties and features of these 3 profile types:

I/O mode positioning			
Content of "P-0-4084, Profile type"	**Master communication**	**Field bus or drive operating mode**	**Features**
0xFF82	PROFIBUS CANopen DeviceNet	I/O mode positioning (positioning block mode, encoder 1, lagless)	- up to 64 positioning blocks can be controlled via field bus - apart from control 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 function "configurable signal status word"

Fig.4-18: Profile type "I/O mode positioning"

Master Communication

I/O mode preset velocity			
Content of "P-0-4084, Profile type"	**Master communication**	**Field bus or drive operating mode**	**Features**
0xFF92	PROFIBUS CANopen DeviceNet	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 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 function "configurable signal status word"

Fig.4-19: Profile type "I/O mode preset velocity"

Freely configurable mode			
Content of "P-0-4084, Profile type"	**Master communication**	**Field bus or drive operating mode**	**Features**
0xFFFE	PROFIBUS CANopen DeviceNet	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 operating mode selection - control word and status word have a Rexroth-specific structure - selection suited for operation with analog command values in commissioning phase
0xFFFD	like profile 0xFFFE, but reduced field bus control word (relevant for MLD applications, for example)		

Fig.4-20: Profile type "freely configurable mode"

Pertinent Parameters

- S-0-0026, Configuration list 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 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 channel
- P-0-4081, Field bus: Config. list of cyclic command value data channel
- P-0-4082, Field bus: Length cyclic actual value data channel
- P-0-4083, Field bus: Length of the parameter channel
- P-0-4084, Field bus: Profile Type

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 operating mode (S-0-0032, S-0-0033, S-0-0034, S-0-0035),
- the drive states and their transitions (state machine of Rexroth 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 status (e.g. Drive Halt, drive error, ...) represents a specific internal and external behavior. The status can be exited by defined events (e.g. drive commands, switching of operating modes, ...). Corresponding status transitions are assigned to the events. The interaction of control and status bits and the status transitions are called state machine.

Abbreviations

- **i16**: 16-bit variable with sign (1 word) in Intel format
- **i32**: 32-bit variable with sign (2 words) in Intel format
- **u16**: 16-bit variable without sign (1 word) in Intel format
- **u32**: 32-bit variable without sign (2 words) in Intel format
- **ZKL1**: Class 1 diagnostics
- **ZKL2**: Class 2 diagnostics

4.3.2 I/O Mode (Positioning and Preset Velocity)

Brief Description

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

- I/O mode positioning (functionality similar to parallel interface)
- I/O mode preset velocity (e.g. for open-loop applications)

General Features

The I/O mode has the following features:

- Optional parameter channel via "P-0-4083, Field bus: Length of the parameter channel" (maximum 8 words) can be activated, if required.

  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 channel"
  – **Slave → master** (drive)

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

Fig.4-21: Structure of the real-time channel for the I/O modes

Features of "I/O Mode Positioning"

Specific features of "I/O mode positioning":

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

Features of "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 operating 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):

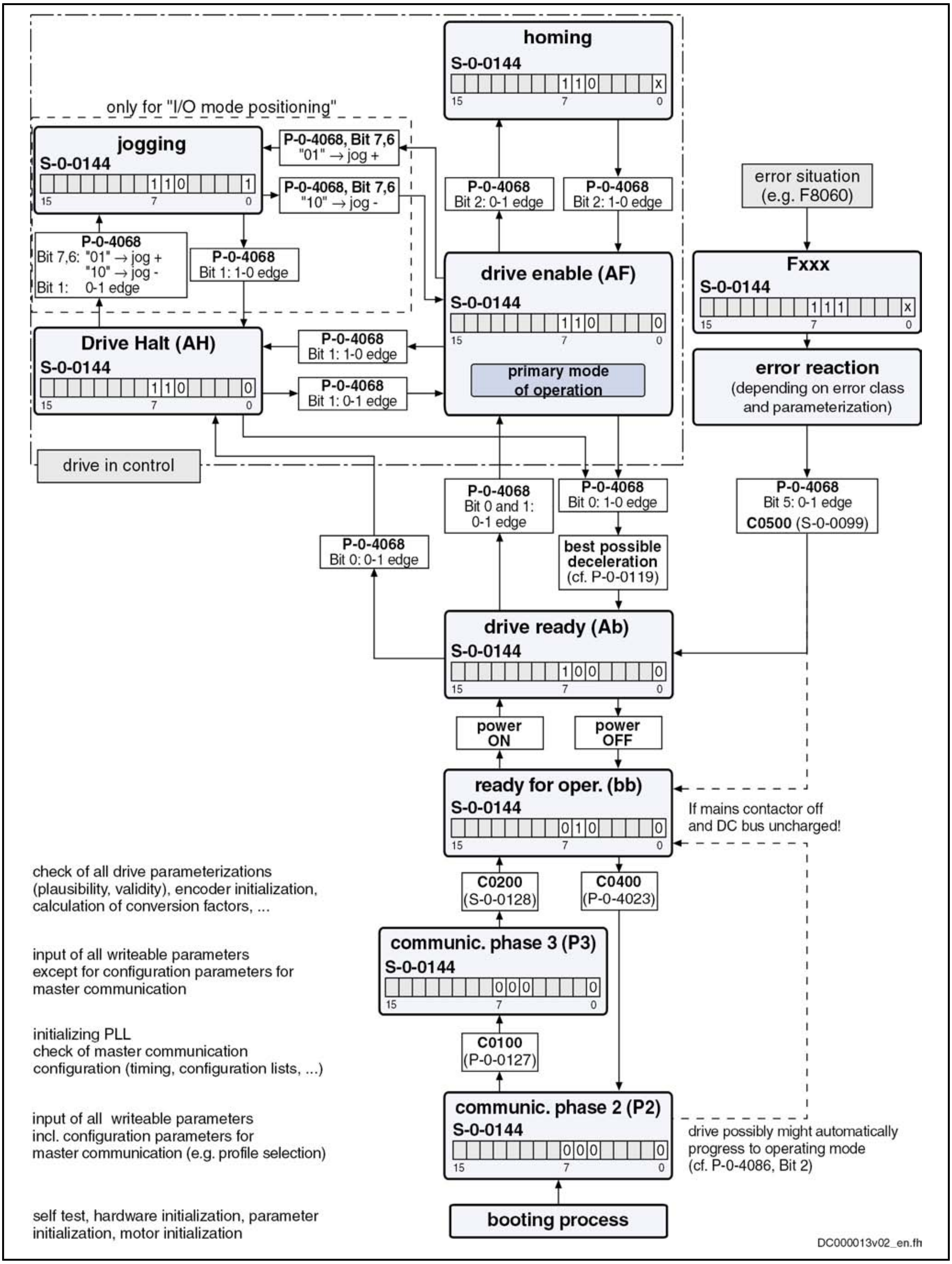


Fig.4-22: Device control of variants of I/O mode (state machine)

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

DANGER

Automatic restart after bus failure!

In the case of bus failure (message "F4009" or "E4005"), an error reaction must be carried out in the control unit, too, to prevent automatic restart after the bus has been reestablished. This means that 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") should be reset in the control unit in the case of bus failure.

Field Bus Control Word in I/O Mode

The bits in parameter "P-0-4068 Field bus: control word IO" are permanently defined by Bosch Rexroth and cannot be changed by the user. 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	Assignment	Significance
0	active operating 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)

Bit	Assignment	Significance
13…8	positioning block acknowledgment	P-0-4051, Positioning block acknowledgment
15…14	not assigned	

Fig.4-23: Default assignment of parameter "S-0-0144, signal status word" for "I/O mode positioning" (P-0-4084 = 0xFF82)

Bit	Assignment	Significance
0	status of ramp-function generator	**1:** run-up stop active (P-0-1210, bit 1)
1	status of ramp-function generator	**1:** acceleration active (P-0-1210, bit 2)
2	status of ramp-function generator	**1:** deceleration active (P-0-1210, bit 3)
3	in motion	**1:** message "n_act = 0" (S-0-0331, bit 0)
4	status 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	status of ramp-function generator	**1:** cmd value within masking window (P-0-1210, bit 4)
9	status of ramp-function generator	**1:** V-ramp within masking window (P-0-1210, bit 5)
15…10	not assigned	

Fig.4-24: 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.

i 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 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.
- Only "P-0-4068 Field bus: Control word IO" and "S-0-0144, Signal status word" are transmitted in the real-time channel.

Features/Settings with Free Configuration or Expansion

There are the following possibilities 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 channel" and "P-0-4081, Field bus: Config. list of cyclic command value data channel".
- The content of "S-0-0144, Signal status word" can be freely parameterized via "S-0-0026, Configuration list 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 signal control word" and "S-0-0329, Assign list signal control word".

4.3.3 Freely Configurable Mode (Rexroth 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 includes the utilization of a specific control 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 of the bits in the parameters "P-0-4077 Field bus: Control word" and "P-0-4078, Field bus: Staus word" can only be used in connection with special operational modes.
- This profile type allows using the entire drive functionality (e.g. velocity synchronization, drive-controlled positioning, ...).
- The primary mode of operation and the secondary operating modes can be freely determined in the parameters S-0-0032, S-0-0033 etc.
- The operating 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").

☞ One of the parameters "P-0-4077, Field bus: control word" or "P-0-4078, Field bus: status word" must always be contained in the first digit of 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 channel" and "P-0-4080, Field bus: config list of cyclic actual value data channel" 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

Data direction	Word1	Format
slave → master	P-0-4078, Field bus: status word	u16 (1 word)
	optional command values	according to selection

Fig.4-25: Structure of the real-time channel in the freely configurable mode

☞ The IDN of the parameters of the cyclic configurable command and actual values are contained in "S-0-0188 List of configurable data in the cycl. command value data channel" and "S-0-0187, List of configurable data in the cycl. actual value data channel".

Data direction	Word1	Word2	...	Word_n
master → slave	P-0-4077	cmd value 1	...	
slave → master	P-0-4078	actual value 1	...	

Fig.4-26: Content and order of data in real-time channel in the freely configurable mode

State Machine in Freely Configurable Mode (Rexroth Profile Type)

Each field bus drive of Bosch Rexroth, independent of the command communication interface, is equipped with a uniform "state machine". In connection with this, the parameters "P-0-4077 Field bus: control word" and "P-0-4078, Field bus: status word" require a consistent structure.

ⓘ 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):

Master Communication

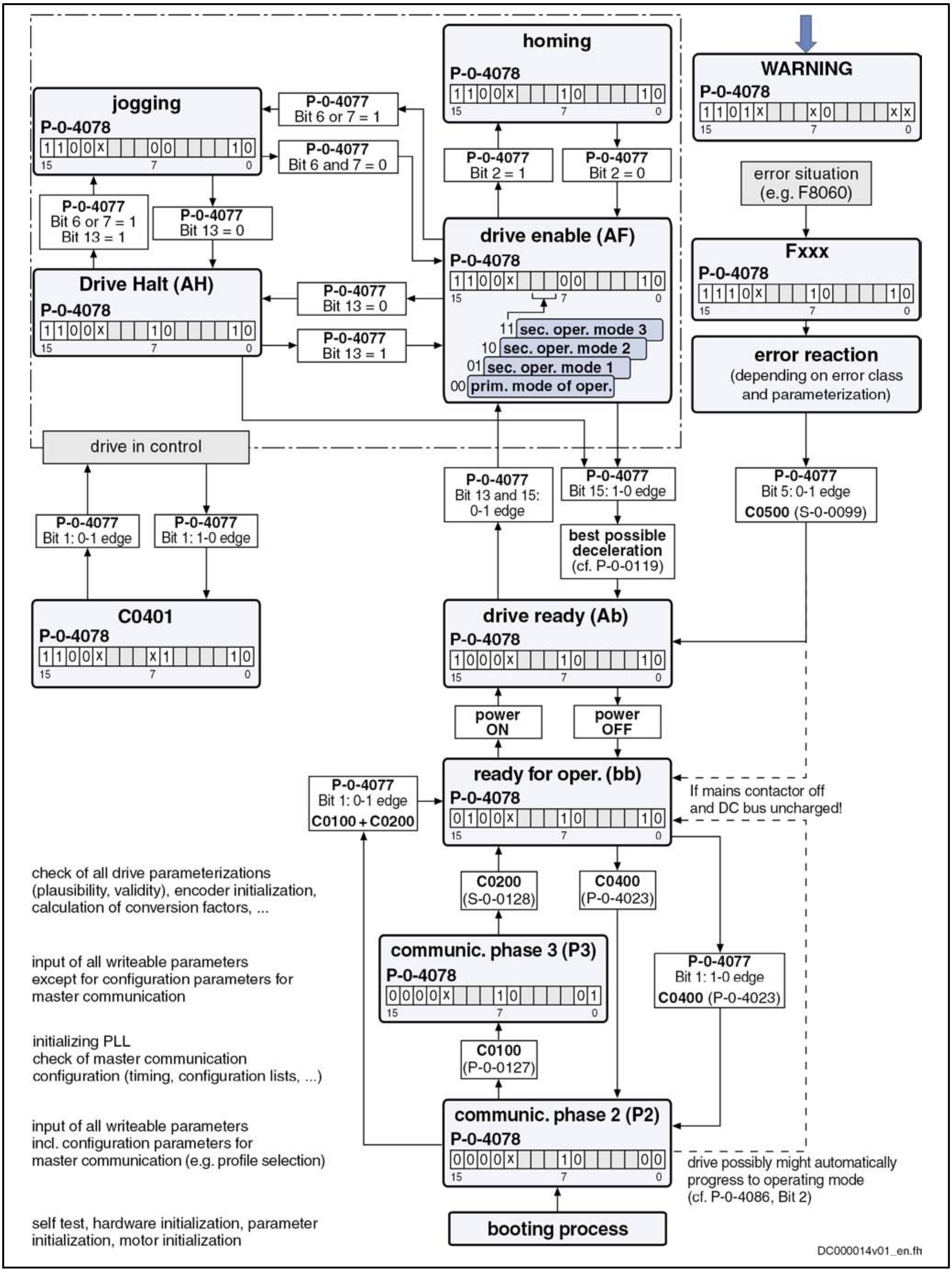


Fig.4-27: Device control in the freely configurable mode (state machine)

DANGER

Automatic restart after bus failure!

In the case of bus failure (message "F4009" or "E4005"), an error reaction must be carried out in the control unit, too, to prevent automatic restart after the bus has been reestablished. This means that 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") should be reset in the control unit in the case of bus failure.

Field Bus Control Word and Field Bus Status Word

For this profile type the field bus control word and status word are preset by Bosch 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"

The two parameters "P-0-0116, Device control: control word" and "P-0-0115, Device control: status word" are only used for diagnostic purposes in field bus drives. 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 mode of operation in parameter S-0-0032 (see also description of the operating mode "Velocity Control").
- Via the field bus, the content of parameter "S-0-0036, Velocity command value" is cyclically transmitted in the command value data channel and the contents of "S-0-0040, Velocity feedback value", "S-0-0051, Position feedback 1 value" 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 (Rexroth Profile Type)"). Some of the bits in the parameters "P-0-4077 Field bus: control word" and "P-0-4078, Field bus: status word" are not relefant for this configuration (or operating 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 position data configured in parameter "P-0-4081 Field bus: config list cyclic command value dat channel" are transmitted from master to drive; from drive to master the data configured in parameter "P-0-4080 Field bus: config. list of cyclic actual value data channel" are transmitted.

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 1 value	i32 (2 words)
	S-0-0390, Diagnostic message number	u32 (2 words)

Fig.4-28: 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)

Fig.4-29: 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 mode of operation in parameter S-0-0032 (see also description of the operating mode "Drive-Internal Interpolation").
- Via the field bus, the contents of the parameters "S-0-0258, Target position" and "S-0-0259, Positioning Velocity", as well as "S-0-0051, Position feedback 1 value" 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 (Rexroth Profile Type)"). Some of the bits in the parameters "P-0-4077 Field bus: Control word" and "P-0-4078, Field bus: Status word" are not relefant for this configuration (or operating 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 position data configured in parameter "P-0-4081 Field bus: config list cyclic command value dat channel" are transmitted from master to drive; from drive to master the position data configured in parameter "P-0-4080 Field bus: config. list of cyclic actual value data channel" are transmitted.

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 1 value	i32 (2 words)
	S-0-0040, Velocity feedback value	i32 (2 words)
	S-0-0390, Diagnostic message number	u32 (2 words)

Fig.4-30: 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)

Fig.4-31: 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 mode of operation in parameter S-0-0032 (see also description of the operating mode "Drive-controlled positioning").
- The Rexroth-specific definitions for the field bus control and status words are applying (see also section "Freely Configurable Mode (Rexroth Profile Type)").
- Through configuration of the contents of "S-0-0282 Positioning command value" as a cyclic command value, the bits 0,3,4 can be used in "P-0-4077 Field bus: Control word" in order to switch directly between relative and absolute positioning (functionally compatible for 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 position data configured in parameter "P-0-4081 Field bus: config list cyclic command value dat channel" are transmitted from master to drive; from drive to master the position data configured in parameter "P-0-4080 Field bus: config. list of cyclic actual value data channel" are transmitted.

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

Fig.4-32: 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)

Fig.4-33: 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.
- This allows, among other things, starting commands contained in parameter "S-0-0399, IDN list of configurable data in the 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 mode of operation".
- 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 position data configured in parameter "P-0-4081 Field bus: config list cyclic command value dat channel" are transmitted from master to drive; from drive to master the position data configured in parameter "P-0-4080 Field bus: config. list of cyclic actual value data channel" are transmitted.

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)
slave → master	P-0-4078, Field bus: Status word	u16 (1 word)
	S-0-0051, Position feedback 1 value	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)

Fig.4-34: 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

Fig.4-35: 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"

4.4 SERCOS interface

4.4.1 Brief Description

General Features

- Cyclical data exchange of command and actual values in equal time intervals
- Data transfer via fiber optic cables; except for converter in motor (in this case, copper conductor)
- Service channel for parameterization and diagnosis
- Free configuration of telegram contents
- Synchronization between time command value takes effect and measurement starting time of the actual values for all drives on a ring
- Overall synchronization of all connected drives to the control unit

Firmware-Specific Features

- Cycle time: Min. 250/500 µs, max. 65 ms (multiples of position clock 250 µs or 500 µs can be set)
- SERCOS compatibility class C
- Baud rate: Optionally 2, 4, 8 or 16 MBaud
- Automatic baud rate detection; active baud rate displayed in a parameter
- Transmission power can be set via indication of transmission length (setting via control panel)
- Max. number of configurable data in the MDT: 48 bytes
- Max. number of configurable data in the AT: 48 bytes

The number of configurable bytes in the MDT/AT 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 24 bytes

SERCOS cycle time > position cycle time → max. length 48 bytes

For more detailed information, see SERCOS specification.

Pertinent Parameters

- S-0-0001, NC cycle time (TNcyc)
- S-0-0002, SERCOS cycle time (TScyc)
- S-0-0003, Minimum AT transmit starting time (T1min)
- S-0-0004, Transmit/receive transition time (TATMT)
- S-0-0005, Minimum feedback acquisition time (T4min)
- S-0-0006, AT Transmission starting time (T1)

- S-0-0007, Feedback acquisition starting time (T4)
- S-0-0008, Command valid time (T3)
- S-0-0009, Position of data record in MDT
- S-0-0010, Length of master data telegram
- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0016, Configuration list of AT
- S-0-0024, Config. list of the master data telegram
- S-0-0028, MST error counter
- S-0-0029, MDT error counter
- S-0-0088, Receive to receive recovery time (TMTSY)
- S-0-0089, MDT Transmit starting time (T2)
- S-0-0090, Command value proceeding time (TMTSG)
- S-0-0096, Slave arrangement (SLKN)
- 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-0-0143, Sercos interface version
- 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
- P-0-4027, Transmission length SERCOS interface
- P-0-4029, Diagnostic report SCSB module
- P-0-4087, Baud rate SERCOS interface

Pertinent Diagnostic Messages

- 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
- C0109 Position of data record in MDT (S-0-0009) even
- C0110 Length of MDT (S-0-0010) odd
- C0111 ID9 + Record length - 1 > length MDT (S-0-0010)
- C0112 TNcyc (S-0-0001) or TScyc (S-0-0002) error

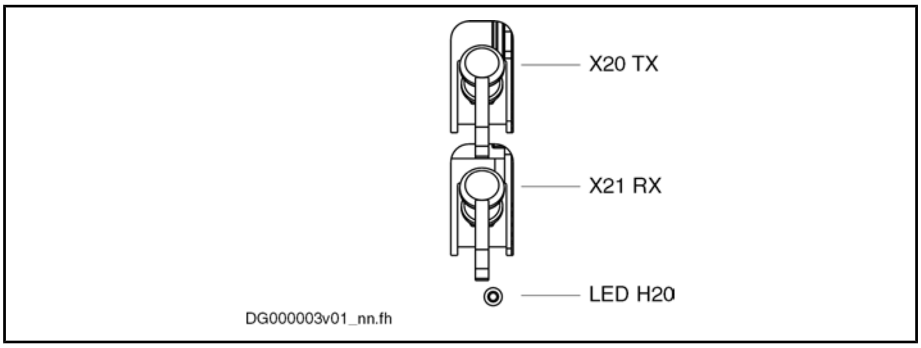
- C0113 Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error
- C0114 T4 > TScyc (S-0-0002) - T4min (S-0-0005)
- C0115 T2 too small
- C0116 T3 (S-0-0008) within MDT (S-0-0089 + S-0-0010)
- C0139 T2 (S-0-0089) + length MDT (S-0-0010) > TScyc (S-0-0002)
- F4001 Double MST failure shutdown
- F4002 Double MDT failure shutdown
- F4003 Invalid communication phase shutdown
- F4004 Error during phase progression
- F4005 Error during phase regression
- F4006 Phase switching without ready signal

4.4.2 Commissioning the SERCOS interface

Steps of Commissioning

To commission the interface, you basically have to carry out the following steps:

- Connect the fiber optic cables
- Set the drive address
- Set the transmission length (transmitting power)
- Check the distortion indicators



X20 TX Optical output (transmitter)
X21 RX Optical input (receiver)
H20 Distortion indicator LED
Fig.4-36: SERCOS interface

Settings of the SERCOS interface

For settings or display for communication via SERCOS interface, the following parameters are available:

- P-0-4025, Drive address of master communication
- P-0-4027, Transmission length SERCOS interface
- P-0-4087, Baud rate SERCOS interface

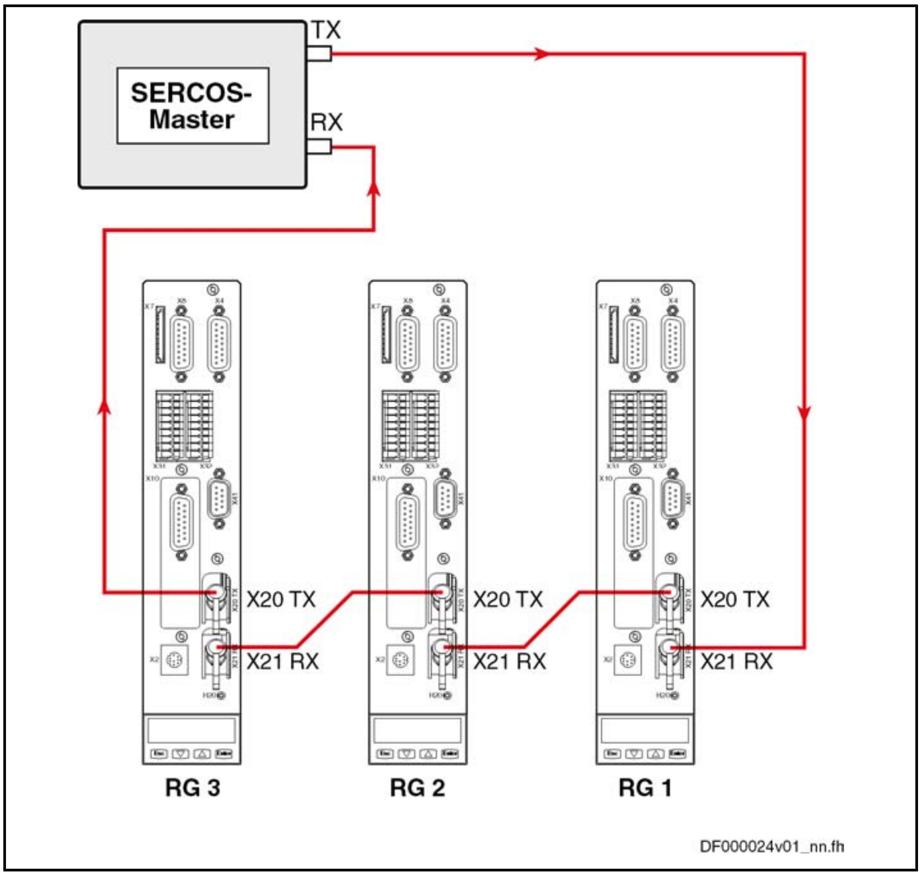
For information on these parameters, see the following sections!

☞ The settings must be made via the SERCOS ring before communication is built up.

Connecting the Fiber Optic Cables

The connection between the master (control unit) and the drive controllers is established with fiber optic cables.

To do this, it is necessary to set up a ring structure according to SERCOS interface (IEC 1491).



RG Controller

Fig.4-37: Connecting the Fiber Optic Cables (Example)

The fiber optic cable ring starts and ends at the SERCOS master (control unit).

The optical output of the master is connected to the optical input of the first drive (X21). The output of this drive (X20) is connected to the input of the next drive etc.

The output of the last drive is connected to the optical input of the master.

Setting the Drive Address

The drive address is set in parameter "P-0-4025, Drive address of master communication" (instead of the address selector switch which was used before). A drive address set or changed in this parameter is only activated at the next change of communication phase from "0" to "1".

The drive address is independent of the order of drive connections via the fiber optic cables.

Setting the Transmission Length (Transmitting Power) of the SERCOS interface

The length of the fiber optic cable connected to X20 (TX) is entered in parameter "P-0-4027, Transmission length SERCOS interface".

Depending on the entered fiber optic cable length, the required optical transmitting power of the light source is automatically set. The controller classifies the entered length in one of four ranges.

Ranges of length for the connected fiber optic cable:

- Up to 15 m

- 15 m to 30 m
- 30 m to 45 m
- More than 45 m and glass fiber

Transmission Rate of the SERCOS interface

The transmission rate is preset by the master, automatically recognized by the drive, set accordingly and displayed in the parameter "P-0-4087, Baud rate SERCOS interface".

☞ Baud rates of 2, 4, 8 and 16 MBaud are supported.

Using the Distortion Indicator "H20"

Checking the Optic Signal Level

After the drive address has been set, it is necessary to check whether the optic signal levels available at every node are sufficient, i.e. whether the receiver is neither underloaded nor overloaded. The optic signal level is checked by means of the distortion indicator at the front of the controllers (LED "H20").

The distortion indicator LED normally stays dark.

To check the optic signal level, the distortion indicators of all drives in the ring are checked in signal flow direction, starting from the transmitter output of the master (control unit) (see figure in section "Connecting the Fiber Optic Cables").

Check the distortion indicators in the "direction of the light", i. e. at first, check the first drive in the ring. If its distortion indicator is dark, go to the next drive. Do this up to the last drive and then at the master (control unit).

☞ The distortion indicator must not be lit nor glow!

The distortion indicator "H20" will be lit in the following cases:

- Fiber optic cable leading to the preceding drive is defective
- Transmission rate is not supported
- Transmission length (transmitting power) is incorrectly set

What to do when the distortion indicator is lit:

Check the Fiber Optic Cable

Check the fiber optic cable and its connectors from the physical predecessor in the ring to the affected drive (see below).

Check the Transmission Rate

Compare the transmission rate of the master to the supported baud rates of the drive.

Check the Transmission Length

At the physical predecessor of the affected drive, check the transmission length (length of the fiber optic cable at the optical output X20) set in parameter "P-0-4027, Transmission length SERCOS interface".

Checking the Fiber Optic Cables

The fiber optic cable may be defective, if the preset transmission rate is supported and the transmission lengths were correctly set, but communication nevertheless is not established. In this case, the "H20" distortion indicator will be lit.

The reason for a defective fiber optic cable can be mechanical damage or bad assembly (connector mounting, ...).

Sometimes it is possible to recognize a defective fiber optic cable by the fact that hardly any light comes out at its end or that the optical fiber was "drawn back" into the connector (check the "face of the connector"). Further checks of the fiber optic cable cannot be carried out with simple means.

Defective fiber optic cables must be replaced.

4.4.3 Cyclic Data Transfer

General Information

To synchronize the drives in a ring, the master synchronization telegram (MST) is sent at the beginning of every SERCOS cycle. The only information the MST contains is the communication phase preset by the master.

The content of master data telegram (MDT) and drive telegram (AT = Antriebstelegramm) can be configured.

Once per SERCOS cycle time, a collective master data telegram for all drives is sent from the control unit to the drives. The master data telegram contains the master control word, the service channel and a configurable data block. This data block mostly contains the command and limit values the control unit wants to transmit to the drive to operate the corresponding operating mode. The content of this data block can be configured by means of the telegram settings.

The master data telegram is received by all drives in the ring at the same time.

In addition, a separate drive telegram is sent once per SERCOS cycle time from every drive to the control unit. The drive telegram contains the drive status word, sections of the service channel and a configurable data block. This data block mostly contains the actual and status values the control unit needs from the drive to operate the corresponding operating mode.

Master Control Word

The master control word is part of the master data telegram. The master control word contains all important control information for the drives, such as:

- Drive on
- Drive enable
- Drive Halt
- Interpolator clock
- Command operating mode
- Real-time control bits 1 and 2
- Control information for the service channel

☞ The master control word is mapped to parameter S-0-0134. The exact structure of this parameter is described in the separate Parameter Description.

See Parameter Description "S-0-0134, Master control word"

The master control word is cyclically transmitted to the drive with every master data telegram in the SERCOS clock (see "S-0-0002, SERCOS cycle time (TScyc)"). For diagnostic purposes, the master control word can be read via parameter "S-0-0134, Master control word".

Drive Enable

The drive is activated by a positive edge of the drive enable signal. In the case of drive controllers with SERCOS interface, the drive enable signal corresponds to bit 15 in the master control word of the master data telegram (MDT).

The controller enable signal is accepted, i.e. the drive switches from its de-energized status to its energized status, when the following conditions have been fulfilled:

- SERCOS interface ready for operation (communication phase 4)
- No drive error
- Power section switched on

In this status the display of the drive reads "Ab", the diagnostic message via parameter S-0-0095 is "A0012 Control and power sections ready for operation".

When drive enable signal is set, the display changes to "AF", the diagnostic message then shows the activated mode of operation (e.g. "A0101 Velocity control").

Drive Halt

The "Drive Halt" signal is status-controlled and active when the signal = 0 V. The input signal is mapped to the master control word bit 13.

Drive Status Word

The drive status word is part of the drive telegram (AT). It contains all important status information from the drive, such as:

- Readiness for operation of control and power sections
- Drive errors
- Change bits class 2 and 3 diagnostics
- Current operating mode
- Real-time status bits 1 and 2
- Status information for the service channel

☞ The drive status word is mapped to parameter S-0-0135. The exact structure of this parameter is described in the separate Parameter Description.

See Parameter Description "S-0-0135, Drive status word"

The drive status word is cyclically transmitted to the control unit with every drive telegram in the SERCOS clock (see Parameter description "S-0-0002, SERCOS cycle time (TScyc)"). For diagnostic purposes, the drive status word can be read via parameter "S-0-0135, Drive status word".

Acknowledging Drive Enable

The drive acknowledges the drive enable setting in the drive status word of the drive telegram. Bits 14 and 15 change from "10" (control and power section ready for operation, torque-free) to "11" (in operation, under torque) after drive enable is activated and has been accepted.

The time that passes between the setting of drive enable and its acknowledgment is needed by the drive to establish its complete readiness for operation. For example, in the case of asynchronous motors this time is used to magnetize the motor.

If drive enable is disabled, the drive performs the reaction parameterized by parameter "P-0-0119, Best possible deceleration". In this case, too, time passes between the resetting and acknowledgment of the reset. This time depends on

- the setting of parameter P-0-0119,
- the existence of a motor brake and its parameterization,
- the velocity of the axis at the time drive enable is reset.

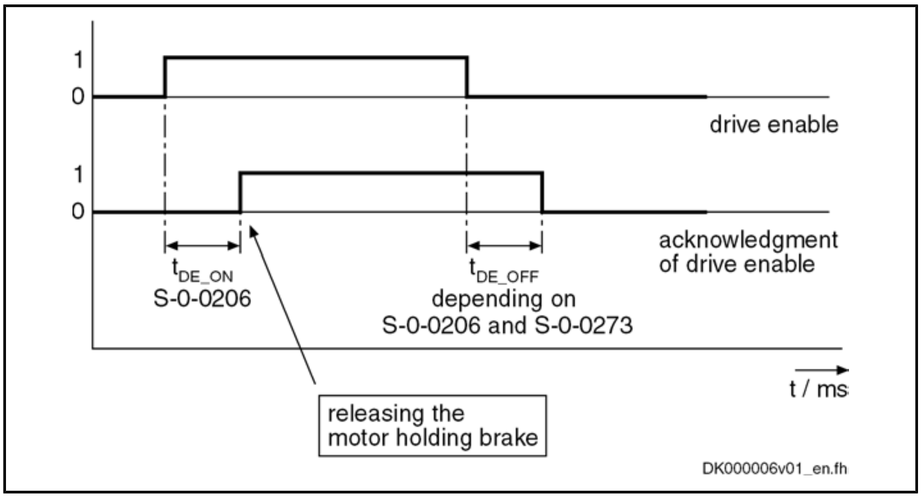


Fig.4-38: Acknowledging Drive Enable (DE)

Typical values for t_{DE_ON} (S-0-0206) are about 8 ms for synchronous motors or 300 ms for asynchronous motors.

☞ During the t_{DE_ON} time, the command value set by the control unit should be such that the command velocity is zero. Releasing the possibly available motor holding brake only takes place at the time drive enable is acknowledged (positive edge of "drive enable acknowledge")!

4.4.4 Transmission of Non-Cyclical Data

Non-cyclical data are parameters that are not transmitted cyclically, but via the service channel. The service channel is therefore used for parameterization and diagnosis.

The transmission via the service channel is done in sections in the MDT and AT, and per transmitted element can last several SERCOS cycles.

4.4.5 Interface Errors and Diagnostic Possibilities

Possible Error Messages

If conditions are detected in the drive that no longer allow the correct operation of the interface, or if incorrect preset values are detected during the initialization phase, the drive reacts by going back to communication phase 0. No more drive telegrams will be sent, the drive automatically carries out the programmed error reaction (see Parameter Description "P-0-0119, Best possible deceleration") and waits for the reinitialization of the SERCOS ring by the master.

Possible error messages could be:

- F4001 Double MST failure shutdown
- F4002 Double MDT failure shutdown
- F4003 Invalid communication phase shutdown
- F4004 Error during phase progression
- F4005 Error during phase regression
- F4006 Phase switching without ready signal

Diagnostic Parameters for Interface Status

The parameter "S-0-0014, Interface status" is used to diagnose existing interface errors and the current communication phase.

Error Counter for Telegram Failures

The drive checks every received master synchronization and master data telegram for

- the correct receive time,
- the assigned telegram length,
- the correct CRC checksum.

The failure of a telegram is registered by incrementing an error counter. For this purpose, the parameters "S-0-0028, MST error counter" and "S-0-0029, MDT error counter" are used.

The content of parameter S-0-0028 is cleared when switching from communication phase 2 to 3, the content of parameter S-0-0029 is cleared when switching from communication phase 3 to 4.

4.4.6 Real-Time Control Bits and Real-Time Status Bits

Brief Description

The master control word and the drive status word contain 2 configurable real-time bits each. To configure these binary signals there are the following parameters:

- 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-0-0398, IDN list of configurable data in signal status word
- S-0-0399, IDN list of configurable data in the signal control word
- 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

These parameters contain the information of which parameter bit 0 (LSB) is mapped to the corresponding real-time status bit and therefore is sent cyclically to the master, or to which parameters the real-time control bits are mapped.

Notes on Commissioning

Selection List S-0-0399

Only parameters contained in the list parameter "S-0-0399, IDN list of configurable data in signal control word" can be assigned to the parameters S-0-0301 or S-0-0303 (allocation of real-time control bit 1 or 2). Assigning command parameters that are possibly contained in the list parameter S-0-0399, however, is not possible!

> ☞ The real-time control bits are processed in every interface cycle at the point of time defined in parameter "S-0-0008, Command value valid time (T3)".

Selection List S-0-0398

Only parameters contained in the list parameter "S-0-0398, IDN list of configurable data in signal status word" can be assigned to the parameters S-0-0305 or S-0-0307 (allocation of real-time status bit 1 or 2).

> ☞ The real-time status bits are configured in every master communication cycle at the point of time defined in parameter "S-0-0007, Feedback acquisition starting time (T4)".

4.5 SERCOS III

4.5.1 Brief Description

It is possible to operate IndraDrive controllers with a SERCOS III interface as master communication module. This requires the control section with the optional module "SERCOS III" (S3). Via this optional module, it is possible to exchange real-time data with a SERCOS III master.

The following communication channels are distinguished:

- **Cyclic data channel** (MDT, AT)

  → Data container for cyclic transmission of useful data (**process data**) in real time
- **Acyclic data channel** (service channel)

  → Data container for acyclic transmission of useful data (**service data**)

General Features

- Transmission rate 100 Mbit/s
- Cyclical data exchange of command and actual values in equal time intervals
- Data transmission via Ethernet cable (CAT5-copper)
- Service channel for parameterization and diagnosis
- Free configuration of telegram contents
- Synchronization between time command value takes effect and measurement starting time of the actual values for all drives on a ring
- Overall synchronization of all connected drives to the master

Firmware-Specific Features

- Cycle time: Min. 250/500 µs, max. 65 ms (multiples of position clock 250 µs or 500 µs can be set)
- SERCOS compatibility class C
- Max. number of configurable data in the MDT: 48 bytes
- Max. number of configurable data in the AT: 48 bytes

☞ The number of configurable bytes in the MDT/AT 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 24 bytes

SERCOS cycle time > position cycle time → max. length 48 bytes

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Hardware Requirements

The optional module with SERCOS III interface is available for the following configurable control sections:

- Single-axis BASIC UNIVERSAL (CSB01.1C)
- Single-axis ADVANCED (CSH01.1C)

Pertinent Parameters

Specific parameters for SERCOS III communication:

- S-0-1001, SERCOS III: NC cycle time (TNcyc)
- S-0-1002, SERCOS III: SERCOS cycle time (TScyc)
- S-0-1005, SERCOS III: Minimum feedback acquisition time (T5)
- S-0-1006, SERCOS III: AT transmission starting time (T1)
- S-0-1007, SERCOS III: Feedback acquisition starting time (T4)
- S-0-1008, SERCOS III: Command value valid time (T3)

- S-0-1009, SERCOS III: RTC offset in MDT
- S-0-1010, SERCOS III: MDT lengths
- S-0-1011, SERCOS III: RTC offset in AT
- S-0-1012, SERCOS III: AT lengths
- S-0-1013, SERCOS III: SVC offset in MDT
- S-0-1014, SERCOS III: SVC offset in AT
- S-0-1015, SERCOS III: ring delay
- S-0-1016, SERCOS III: slave delay (SYNCCNT-P, SYNCCNT-S)
- S-0-1017, SERCOS III: IP channel transmission starting time
- S-0-1018, SERCOS III: SYNC delay (P-Count, S-Count)
- S-0-1019, Master communication: MAC address
- S-0-1020, Master communication: IP address
- S-0-1021, Master communication: network mask
- S-0-1022, Master communication: gateway address
- S-0-1023, SERCOS III: SYNC jitter
- S-0-1024, SERCOS III: ring control
- S-0-1025, SERCOS III: ring status
- S-0-1026, SERCOS III: hardware code
- S-0-1028, SERCOS III: MST error counter
- S-0-1029, SERCOS III: MDT error counter
- S-0-1030, SERCOS III: AT error counter
- S-0-1031, SERCOS III: signal assignment
- S-0-1095, SERCOS III: diagnostic message
- S-0-1134, SERCOS III: Master control word
- S-0-1135, SERCOS III: Drive status word

Additional pertinent parameters according to "SERCOS interface":

- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0016, Configuration list of AT
- S-0-0024, Config. list of the master data telegram
- S-0-0096, Slave arrangement (SLKN)
- S-0-0097, Mask class 2 diagnostics
- S-0-0098, Mask class 3 diagnostics
- S-0-0143, Sercos interface version
- 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

- 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
- C0109 Position of data record in MDT (S-0-0009) even
- C0110 Length of MDT (S-0-0010) odd
- C0111 ID9 + Record length - 1 > length MDT (S-0-0010)
- 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)
- C0115 T2 too small
- C0116 T3 (S-0-0008) within MDT (S-0-0089 + S-0-0010)
- C0139 T2 (S-0-0089) + length MDT (S-0-0010) > TScyc (S-0-0002)
- F4001 Double MST failure shutdown
- F4002 Double MDT failure shutdown
- F4003 Invalid communication phase shutdown
- F4004 Error during phase progression
- F4005 Error during phase regression
- F4006 Phase switching without ready signal
- F4017 S III: incorrect sequence during phase switch

☞ To get a more detailed description of the SERCOS III interface and information on its possibilities of use with MPx04 firmware, please contact your Bosch Rexroth sales representative!

4.6 PROFIBUS-DP

4.6.1 Brief Description

It is possible to operate IndraDrive controllers with a PROFIBUS interface as master communication module. Via this module it is possible to exchange real-time data with a PROFIBUS-DP master.

The following communication channels are distinguished:

- **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 devided into

  – One (optional) device-sepecific **parameter channel** for reading and writing of all parameters via PROFIBUS-DP.

    Note: This parameter channel does not fulfill "real-time properties"!

  – One (optional) **safety** related, axis-specific **process data channel** (PROFIsafe), which enables the transmission of safety relevant signals, depending on the firmware and hardware (see also section "Integrated Safety Technology"),

– One axis-specific **process data channel** (real-time channel) that contains fixed, selected information that can be directly interpreted by the receiver.

- **Acyclic data channel** (DPV1 parameter communication)

  The following are supported:

  – One class-1 connection

  – Two class-2 connections

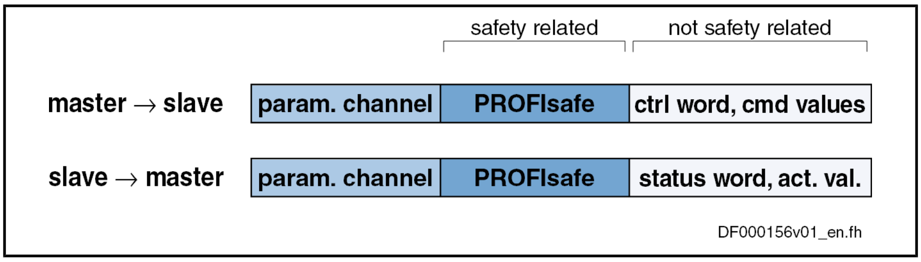


Fig.4-39: Overview of cyclic data channel

To simplify field bus communication Bosch Rexroth makes available function blocks for different programmable logic controllers (PLCs). The principles applied can be easily used for other field bus masters.

Features

The slafe PROFIBUS-DP circuit with master communication module PL 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)
- Additional optional parameter channel in the cyclic channel with up to 16 bytes (8 words)
- Monitoring of the cyclical 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)
- Parameter acccess with DPV1-class-1-services
  – DDLM_Initiate (establishement 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
- Supported field bus profiles:
  - 0xFF82: I/O mode "positioning" with configurable real-time data
  - 0xFF92: I/O mode "preset velocity" with configurable real-time data
  - 0xFFFE: freely configurable mode
- Access to all device parameters according to PROFIdrive specification

Hardware Requirements

Using the master communication "PROFIBUS-DP" requires the following control section design:

- Single-axis BASIC PROFIBUS (not configurable) (CSB01.1N-PB)

In addition, communication via "PROFIBUS-DP" is possible for with the following configurable control setions, if they are equipped with the optional module "PB":

- Single-axis BASIC UNIVERSAL (CSB01.1C)
- Single-axis ADVANCED (CSH01.1C)
- Double-axis BASIC UNIVERSAL (CDB01.1C)

Pertinent Parameters

Communication Parameters

Specific parameters for communication via PROFIBUS-DP:

- P-0-3290, PROFIsafe: F_Destination_Address
- P-0-4069, Field bus: Module diagnosis

Parameters for general communication via field bus interfaces:

- P-0-4073, Field bus: Diagnosis
- P-0-4074, Field bus: Data format
- P-0-4075, Field bus: Watchdog
- P-0-4076, Field bus: Cycle time (Tcyc)
- P-0-4079, Field bus: Baud rate

Profile type parameters

Apart from mere communication parameters, we use parameters in conjunction with the profile types.

See "Profile Types (with Field Bus Interfaces)"

Parameters for extended communication

We use additional parameters for extended communication.

See following sections:

- "Configurable Signal Control Word"
- "Configurable Signal Status Word"
- " Multiplex Channel"

Pertinent Diagnostic Messages

- C0154 Field bus: IDN for cycl. command values not configurable
- C0155 Field bus: Length for cycl. command values exceeded
- C0156 Field bus: IDN for cycl. actual values not configurable
- C0157 Field bus: Length for cycl. actual values exceeded
- C0158 Field bus: Tcyc (P-0-4076) incorrect
- C0159 Field bus: P-0-4077 is missing for cycl. command values

- F4009 Bus failure
- F4012 Incorrect I/O length

4.6.2 Configuring the PROFIBUS-DP Slave

Device Data Sheet for IndraDrive

Like every other PROFIBUS slave, IndraDrive controllers have to be configured in the field bus master. This requires the corresponding device data sheet "**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 (GSD) for IndraDrive controllers supports all hardware types and enabling of functional packages.

IndraDrive controllers assign their data to four modules (for single-axis devices), seven modules (for double-axis devices) of up to 25 modules for devices operated via CCD group (1CCD master + 7CCD slaves), which possibly have to be configured. Each drive in the CCD group has an F-module, one input module and one output module:

- Module 1: Parameter channel
- Module 2: F-module axis 0 (optional for PROFIsafe)
- Module 3: Inputs axis 0
- Module 4: Outputs axis 0
- Module 5: F-module axis 1 (optional for PROFIsafe, double-asis devices or devices operated at the CCD group)
- Module 6: Inputs axis 1 (only for double-axis devices or devices operated at the CCD group)
- Module 7: Outputs axis 1 (only for double-axis devices or devices operated at the CCD group)
- Module X: F-module asis X (optional for FROFIsafe, according to number of CCD drives)
- Module Y: Inputs axix X (according to number of CCD drives)
- Module Z: Outputs axix X (according to number of CCD drives)

The default configuration stored in the device data sheet "Input 1 Word" and "Output 1 Word" (single-asis devic) without safety technology and without parameter channel. For configurators that are supporting the GSD version 03 or higher this default configuration is automatically set. For IndraDrive this setting is active after the load defaults procedure.

The device data sheet also contains the IDN assigned to the IndraDrive controller by the PROFIBUS User Oganization :

- **Ident. no. 107 hex**

☞ During the installation of IndraWorks D the device data sheet is stored in the "Indramat\DeviceDataSheets" directory.

Module 1: Parameter Channel

The module 1 is marked with "ParamCh" and of the input/output module type. If no parameter channel is required, the module "ParamCh not used" has to be selected. For a parameter channel with the standard length of 5 words the module "ParamCh 5 Words" has to be included.

☞ The standard length provides the optimum between the required I/O length and transmission rate. If possible, it should always be selected for the parameter channel. The function blocks available for IndraDrive use this length, too.

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 valuse/actual values. This allows parameter download from the master after a device was replaced.

☞ This active setting is displayed in bytes in parameter "P-0-4083 Field bus: length of parameter channel".

Module 2: F-Module

The (optional) module 2 is used to configure a safety related process data channel (with the corresponding hardware and enabling of functional packages). When the optional module is not used, the blank module "F-module not used" has to be assignet to it.

Module 3: Inputs

In module 3 the length of the input data in words is set. The module identifier is "Input". For successful data exchange the length that was set has to equal the value in parameter "P-0-4082 Field bus: length of cyclic actual value data channel" which indicates the length in bytes.

☞ If the configuration of the master does not correspond with the one of the IndraDrive controller, the IndraDrive device will generate the error message "F4012 Incorrect I/O length".

Module 4: Outputs

Module 4 corresponds to module 3 but defines the outputs. The module identifier is "Output". The length of the output data that was set has to correspond with the value of parameter "P-0-4071 Field bus: Length cyclic command value data channel".

☞ If the configuration of the master does not correspond with the one of the IndraDrive controller, the IndraDrive device will generate the error message "F4012 Incorrect I/O length".

Modules 5 to 7

The modules 5 to 7 are provided for double-axis devices or for 5 to 25 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.

Configuring the Process Data Channel

Standard Process Data Channel (Not Safety Related)

The user can freely configure the cyclical data in the standard process data channel according to the process requirements.

☞ For the profile types "freely configurable mode" (P-0-4084 = 0xFFFE) or "I/O mode" (P-0-4084 = 0xFF82) there is a default configuration that the user can change at any time.

See also "Profile Types (with Field Bus Interfaces)"

Configuration List Cyclic Command Value Data Channel

In parameter "P-0-4080, Field bus: config list of cyclic actual value data channel" the structure and therefore the number of words and their assigned objects (indices) for the process input data (slave → master) are mapped. The master can use this configuration in order to localize the individual real-time data in the field bus.

Configuration List Cyclic Command Value Data Channel

In parameter "P-0-4081, Field bus: config list of cyclic command valud data channel" the structure of the process output data (master → slave) is mapped. This enables the read-out via the parameter channel of the current structure and thus the assignements in the field bus.

> ☞ It is possible to configure up to 15 real-time parameters (incl. control or status word) on the bus in each data direction.

PROFIsafe Proces Data Channel (Safety Related)

The safety related channel is configured in the master using the safety module (F-module 2 or module 5). The drive automatically recognizes the control configuration during the run-up (→ "CeckConfig").

> ☞ Drive operated via the CCD group do not support PROFIsafe. In this case, use the blank module "F-Modul not used".

As a result thereof the individual modules (module 2 and modules 5) have to be supported, too!

> ☞ In order to use the safety-related channel in the drive, a value unequal zero has to be set in parameter "P-0-3290, PROFIsafe: F_Destination_Address". This activates the safety related process data channel (PROFIsafe) and deactivates the safety inputs/outputs on the optional safety technology card (except for input for safety related homing procedure).

Per direction of transmission the safety related process data channel contains 2 bytes useful data (safety-technology control and status word) and 4 bytes header for backing up the transmission of useful data.

> ☞ The control word gets to parameter "P-0-3212, Safety technology signal control word, channel1" in inverted form; the status word corresponds to the content of parameter "P-0-3214, Safety technology signal status word, channel 1".
>
> See also Parameter Description P-0-3212 and P-0-3214

Lenght of the Process Data Channel (Real-Time Data Channel)

Standard Process Data Channel (Not Safety Related)

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 circuit allows flexible configuration of the process data channel, the length of the process data channel is thereby changing accordingly.

> ☞ The length currently effective is contained in the parameters "P-0-4082, Field bus: length of cyclic actual value data channel" and "P-0-4071, Field bus: length 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 configruation lists "P-0-4080, Field bus: config list of cyclic actual value data channel" and/or "P-0-4081, Field bus: config list of cyclic command value data channel" and is contained in the following parameters:

- P-0-4071, Field bus: Length cyclic command value data channel (master → slave)
- P-0-4082, Field bus: Length cyclic actual value data channel (slave → master)

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.

Note that a change in the length of the process data channel also requires a change in the master configruation. The length of the process data channel that was set has to be in accordance with the projected length in the master. Otherwise, the error messate "F4012 Incorrect I/O length" is generated.

PROFIsafe Proces Data Channel (Safety Related)

The length of this safety rlated process data channel cannot be modified! There are always 2 bytes available for useful data and 4 bytes header for data backup.

4.6.3 Cyclic Communication via Process Data Channel

Communication Cycle Time

Cyclic communication via the process data channel takes place in the so-called communication cycle (cf. "P-0-4076, Field bus: cycle time (Tcyc)"). The possible number of cyclic data depends on the setting of parameter P-0-4076.

Min. cycle time	Max. number of process data / setting P-0-4076	Notes
0,5 ms (T_{A_pos})	16 bytes → P-4076 = 0,5 ms 32 bytes → P-4076 = 1 ms 48 bytes → P-4076 > 1 ms	additionally a maximum of 16 bytes parameter channel for PROFIBUS

Fig.4-40: Number of cyclic data depending on P-0-4076

Valid values for P-0-4076: 0,5 ms, 1 ms, 2 ms, 3 ms, 4 ms, 5 ms, …

When the safety related channel (PROFIsafe) is used, the minimum allowed cycle time is limited to 2 ms!

Axis-Specific Process Data Channel

Fig.4-41: Position of the not safety related 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 communicaiton is not suited for synchronous operating modes such as "position control with cyclic command value input", but only for positioning modes and the "velocity control" mode.

In the drive only a limited number of cyclic data can be processed (Basic: 32 bytes; Advanced: 40 bytes).

☞ 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 have to be configured in the parameter mode. The section "Configuring the PROFIBUS-DP Slave" " describes how the cyclic data are configured.

Safety Related, Axis-Specific Process Data Channel (PROFIsafe)

General Information

☞ Using the safety related process data channel (PROFIsafe) requires the hardware option "S1" for safety technology and the corresponding firmware version (as of MPx-03VRS)!

Fig.4-42: Position of the safety related process data channel (PROFIsafe) in the cyclic data channel

☞ When the safety related channel (PROFIsafe) is used, the minimum allowed cycle time is limited to 2 ms!

The internal processing of the command values and actual values is carried out synchronously with the control clock. The safety related channel allows selecting the integrated safety functions via Profibus or transmitting the corresponding feedback signals (acknowledgements).

The available safety functions and mechanisms are described in the Functional and Application Description on integrated safety technology.

See separate documentation "Rexroth IndraDrive - Integrated Safety Technology"

☞ A check (→ safety related transmission) is carried out for the cyclically transmitted, safety related command values (2 bytes) and they are stored in volatile form.

PROFIsafe Configuration

☞ Drive operated via the CCD group do not support PROFIsafe. In this case, use the blank module "F-Modul not used".

Configuration of IndraDrive PROFIsafe is activated by entering the PROFIsafe destination address in parameter "P-0-3290, PROFIsafe: F_Destination_Address". Entering the value "0" deactivates PROFIsafe.

When PROFIsafe has been activated, the value from the control unit configuration must be applied to parameter "P-0-3291, PROFIsafe: F_Source_Address".

The PROFIsafe parameters which have to be set via the PLC configuration are displayed in parameter "P-0-3292 PROFIsafe: F_Parameters"

Configruation of the Control Unit

To use PROFIsafe in the drive you have to include the PROFIsafe modules in the control unit configuration according to the required functionality. The follwoing PROFIsafe modules (F-modules) are available for this purpose:

- **F-Modul not used**

  This axis does not exchange any data via PROFIsae. PROFIsafe must be deactivated for the axis (P-0-3290 = 0).

- **F-Modul I/O**

  16 safety related control bits (P-0-3216) are transmitted to the drive in inverted form. The drive transmits 16 safety related status bist (P-0-3214 of channel 1, channel 2 must supply the same value). The "Destination Address" set in the PLC configuration must be entered in parameter P-0-3290.

- **F-Modul I/O Cmd**

  This module is provided for future expansions. In addition to the status and control bits, a safety related command value of type "Integer 32" is transmitted. The "Destination Address" set in the PLC configuration must be entered in parameter P-0-3290.

- **F-Modul I/O Real**

  Apart from the safety related status/control bits, this module transmits as safety relatd actual value of type "Integer 32". For formware version MPx04 this value exclusively is the safety related actual position value (S-0-0051, controlled by P-0-3280). The "Destination Address" set in the PLC configuration must be entered in parameter P-0-3290.

- **F-Modul I/O Cmd Real**

  This module is provided for future expansions. Both the safety related status/control bits and the safety related command value as well as the safety related actual value are transmitted. The "Destination Address" set in the PLC configuration must be entered in parameter P-0-3290.

See separate documentation "Rexroth IndraDrive - Integrated Safety Technology"

Parameter Channel in the Cyclic Channel (Device-Specific)

Fig.4-43: Position of the parameter channel in the cyclic data channel

Since it must be possible to parameterize the drive via the field bus, a configurable parameter channel was implemented in the cyclic channel of the IndraDrive the length of which can be set to 4...16 bytes. The parameter channel consits of a control or status word and up to a maximum of 7 words for data.

☞ The parameter channel is always at the beginning of the cyclical data channel. The length of the parameter channel is configured in the master and taken over by the drive to parameter "P-0-4083, Field bus: length of the parameter channel".

Structure of the Parameter Channel:

- Control word: 2 bytes
- Data: 2 to 14 bytes

Object Directory for PROFIBUS-DP via the Parameter Channel

For PROFIBUS-DP there wasn't any object directory defined. Acyclic access to drive parameters in only possible via the parameter channel.

In order to make cyclic parameter access as easy as possible (without SIS telegrams), objects were assigned to drive parameters.

The data of an object are accessed via:

- Index
- Subindex

Generating Law for Object Index

- Index = 0x2000 + IDN (S-0-XXXX) → **S-parameters**
- Index = 0x2000 + IDN (S-0-XXXX) → **P-parameters**

Generating Law for Object Subindex

Example 1: accessing data of S-0-0051

- Index = 0x2000 + IDN (S-0-0051) = 0x2000 + 51 = 0x2033
- Subindex = 7, since access to data desired

Example 2: accessing data of P-0-0051

- Index = 0x3000 + IDN (P-0-0051) = 0x3000 + 51 = 0x3033
- Subindex = 7, since access to data desired

Structure of Control Word in Parameter Channel

The control word is sent from the master to the slave. Its width is 16 bits and the individual bits have the following significance:

15	14	13	12	11 … 8	7 … 0
res	G	L	T	FL	GL

res reserved (always 0)
G no basic setting
L load bit
T toggle bit
FL length of user data in fragment (4 bits)
GL length of data still to be transmitted including the data in the current fragment (8 bits)

Fig.4-44: Structure of control word in parameter channel

Structure of Status Word in Parameter Channel

The status word is sent from the slave to the master. Its width is 16 bits and the individual bits have the following significance:

15	14	13	12	11 … 8	7 … 0
res	F	L	T	FL	GL

res reserved (always 0)
F error
L load bit
T toggle bit
FL length of user data in fragment (4 bits)
GL length of data still to be transmitted including the data in the current fragment (8 bits)

Fig.4-45: Structure of status word in parameter channel

Configuration of the Parameter Channel

The parameter channel is made up of:

- Control word / status word
- User data

Withoug considering a fragmentation or an error, the parameter channel when **writing a parameter** is made up of:

	Control word	Index	Subindex	Data
M → S	2 bytes	2 bytes	2 bytes	max. 80 bytes
	Status word			
S → M	2 bytes			

Fig.4-46: Parameter channel when writing a parameter channel

Withoug considering a fragmentation, the parameter channel when **reading a parameter** is made up of:

	Control word	Index	Subindex	
M → S	2 bytes	2 bytes	2 bytes	
	Status word	**Data**		
S → M	2 bytes	max. 80 bytes		

Fig.4-47: Parameter channel when reading a parameter channel

Basic Setting

The control unit defines the basic setting and the drive responds with the identifier (2 bytes) of the supported parameter channel format; in this case with 01V00.

	Control word / status word						User data							
	Res	G/F	L	T	FL	GL	B2	B3	B4	B5	B6	B7	B8	B9
M → S	0	1	1	0/1	0	0	-	-	-	-	-	-	-	-
S → M	0	0	1	0/1	2	2	01h	00h	-	-	-	-	-	-

Fig.4-48: Basic setting for parameter channel

Non-Fragmented Reading

The control unit reads the operating data of parameter S-0-0057. It is a double word, fragmentation thereof is not necessary.

The value is 100.

Parameter mapping:

- Index = 2039h
- Subindex = 7h

	Control word / status word						User data							
	Res	G/F	L	T	FL	GL	B2	B3	B4	B5	B6	B7	B8	B9
M → S	0	1	1	1/0	4	4	20h	39h	00h	07h	-	-	-	-
S → M	0	0	1	1/0	4	4	00h	00h	00h	64h	-	-	-	-

Fig.4-49: Non-fragmented reading

Non-Fragmented Writing Without Error

The control unit writes a new operating data to parameter S-0-0057. It is a double word, fragmentation therefore is not necessary.

Teh value is 200. The drive returns an acknowledgement that mirrors the length.

Parameter mapping:

- Index = 2039h
- Subindex = 7h

	Control word / status word						User data							
	Res	G/F	L	T	FL	GL	B2	B3	B4	B5	B6	B7	B8	B9
M → S	0	1	1	0/1	8	8	20h	39h	00h	07h	00h	00h	00h	C8h
S → M	0	0	1	0/1	0	0	-	-	-	-	-	-	-	-

Fig.4-50: Non-fragmented writing without error message

Non-Fragmented Writing With Error Message

The control unit writes a new operating data to parameter P-0-0032.

The value is "8193" and above the allowed maximum. The drive returns an error message, in this case 7007h.

Parameter mapping:

- Index = 3020h
- Subindex = 7h

	Control word / status word						User data							
	Res	G/F	L	T	FL	GL	B2	B3	B4	B5	B6	B7	B8	B9
M → S	0	1	1	0/1	6	6	30h	20h	00h	07h	20h	01h	-	-
S → M	0	1	1	0/1	2	2	70h	07h	-	-	-	-	-	-

Fig.4-51: Non-fragmented writing with error message

Fragmented Reading

The control unit reads the operating data of parameter S-0-0016. It is a list of words. In the example below it contains 40 (28h), 51 (33h), 53 (36h), 84 (54h), 95 (5F), 130 (82h) and 131 (83h). First the list pointer (subindex 10) is set to zero.

Parameter mapping:

- Index = 2010h
- Subindex = 11h → 17 → 7 elements

	Control word / status word						User data							
	Res	G/F	L	T	FL	GL	B2	B3	B4	B5	B6	B7	B8	B9
M → S	0	1	1	1/0	8	8	20h	10h	00h	0Ah	00h	00h	00h	00h
S → M	0	0	1	1/0	0	0	-	-	-	-	-	-	-	-
M → S	0	1	1	0/1	4	4	20h	10h	00h	11h	-	-	-	-
S → M	0	0	0	0/1	8	14	00h	28h	00h	33h	00h	36h	00h	54h
M → S	0	1	1	1/0	0	6	-	-	-	-	-	-	-	-
S → M	0	0	1	1/0	6	6	00h	5Fh	00h	82h	00h	83h	-	-

Fig.4-52: Fragmented reading

Fragmented Writing

The control unit writes data to parameter P-0-4006. It is a list of double words. In the example below it is to contain 100 (64h), 200 (C8h), 300 (12Ch), 400 (190h), 500 (1F4) and 600 (258h). First the list pointer (subindex 10) is set to zero.

Parameter mapping:

- Index = 3FA6h
- Subindex = 10h → 16 → 6 elements

length: 4 byte header + (6 x 4 byte of data) = 28 byte

	Control word / status word						**User data**							
	Res	G/F	L	T	FL	GL	B2	B3	B4	B5	B6	B7	B8	B9
M → S	0	1	1	0/1	8	8	3Fh	A6h	00h	0Ah	00h	00h	00h	00h
S → M	0	0	1	0/1	0	0	-	-	-	-	-	-	-	-
M → S	0	1	0	1/0	8	28	3Fh	A6h	00h	10h	00h	00h	00h	64h
S → M	0	0	1	1/0	0	20	-	-	-	-	-	-	-	-
M → S	0	1	0	0/1	8	20	00h	00h	00h	C8h	00h	00h	01h	2Ch
	0	0	1	0/1	0	12	-	-	-	-	-	-	-	-
	0	1	0	1/0	8	12	00h	00h	01h	90h	00h	00h	01h	F4h
	0	0	1	1/0	0	4	-	-	-	-	-	-	-	-
	0	1	1	0/1	4	4	00h	00h	02h	58h	-	-	-	-
S → M	0	0	1	0/1	0	0	-	-	-	-	-	-	-	-

Fig.4-53: Fragmented writing

Requesting the Next Fragment

For requesting the next fragment of a fragmented transmission it is necessary to calculate GL with the data received from the control word / status word:

$$GL_{SEND} = GL_{RECEPTION} - FL_{RECEPTION}$$

GL length of data still to be transmitted including the data in the current fragment (8 bits)

FL length of user data in fragment (4 bits)

Fig.4-54: GL calculation

4.6.4 Acyclic Parameter Access (PROFIdrive via DPV1)

General Information

As of firmware version MPx-03VRS the field bus independent parameter access via DPV1 is no longer supported, but access according to **PROFIdrive**. The following has been taken as a basis:

- PROFIdrive → Profile Drive Technology version 3.1 / Nov. 2002
- PROFIBUS → Profile Order-No. 3.172

☞ This modification does not have any effect on the parameter channel!

Overview of Acyclic Communication

DP-Master Class-1

An acyclic communication relationship of type MSAC_C1 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 type MSAC_C2 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)

Parameter Exchange via DPV1 Services

The parameter exchange descrived below is executed via DPV1 telegram frame. The following sequence is run:

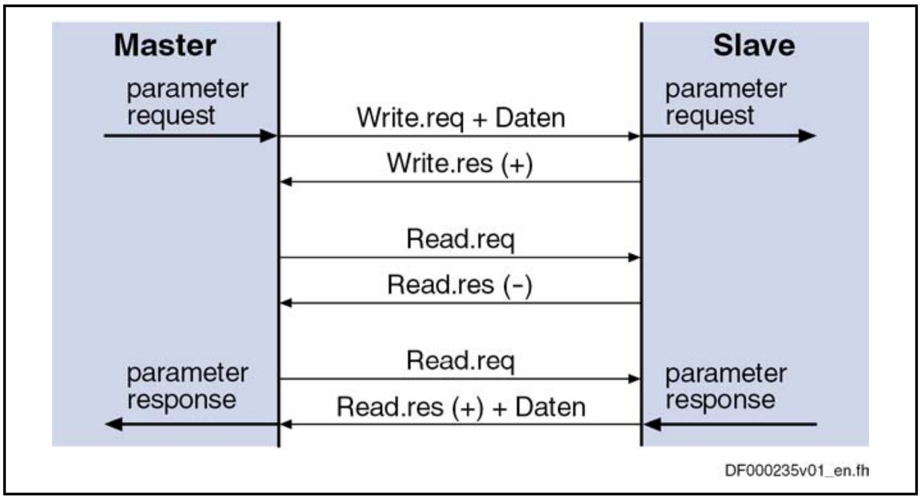


Fig.4-55: Sequence of the parameter exchange via DPV1 services

The individual parameters are accessed with the services "request parameter" or "change parameter".

Request Parameter

Request header	request reference 1 to 255	request ID 1 = request parameter
	Axis	number of parameters
Parameter address	attribute	number of elements
	parameter number	
	Subindex	

Fig.4-56: PROFIdrive-request parameter via DPV1

Response header	request reference mirrored 1 to 255	response ID 1 = positive acknowledgement 129 = negative acknowledge-ment
	axis mirrored	number of parameters
Parameter value(s)	Format	number of values
	value(s) or error value	
	...	

Fig.4-57: PROFIdrive-parameter response

Change Parameter

Request header	request reference 1 to 255	request ID 2 = change parameter
	Axis	number of parameters

Parameter address	attribute	number of elements
	parameter number	
	Subindex	
Parameter value(s)	Format	number of values
	value(s)	
	...	

Fig.4-58: PROFIdrive-request parameter via DPV1

Response header	request reference mirrored 1 to 255	response ID 2 = positive acknowledgement 130 = negative acknowledgement
	axis mirrored	number of parameters

Fig.4-59: DPV1-parameter response

Parameter Structure

A parameter structure is accessed via a 16-bit index and a 16-bit subindex.

Each parameter has the following attributes:

- "Parameter Value"
- "Parameter Description"
- "Parameter Text"
- "Manufacturer Specific"

☞ The attribute valid for access is indicated in the header of the request.

Index The index corresponds to the SERCOS IDN:

SERCOS-IDN	Index (hex)	Index (dec)
S-0-0001 to S-0-4095	0x0001 to 0x0FFF	1 to 4095
S-1-0001 to S-1-4095	0x1001 to 0x1FFF	4097 to 8191
S-2-0001 to S-2-4095	0x2001 to 0x2FFF	8193 to 12287
S-3-0001 to S-3-4095	0x3001 to 0x3FFF	12289 to 16383
S-4-0001 to S-4-4095	0x4001 to 0x4FFF	16385 to 20479
S-5-0001 to S-5-4095	0x5001 to 0x5FFF	20481 to 24575
S-6-0001 to S-6-4095	0x6001 to 0x6FFF	24577 to 28671
S-7-0001 to S-7-4095	0x7001 to 0x7FFF	28672 to 32767
P-0-0001 to P-0-4095	0x8001 to 0x8FFF	32769 to 36863
P-1-0001 to P-1-4095	0x9001 to 0x9FFF	36865 to 40959
P-2-0001 to P-2-4095	0xA001 to 0xAFFF	40961 to 45055
P-3-0001 to P-3-4095	0xB001 to 0xBFFF	45057 to 49151
P-4-0001 to P-4-4095	0xC001 to 0xCFFF	49153 to 53247
P-5-0001 to P-5-4095	0xD001 to 0xDFFF	53249 to 57343

SERCOS-IDN	Index (hex)	Index (dec)
P-6-0001 to P-6-4095	0xE001 to 0xEFFF	57345 to 61439
P-7-0001 to P-7-4095	0xF001 to 0xFFFF	61441 to 65535

Fig.4-60: Rlationship between SERCOS-parameter, -IDN and Index

Subindex The subindex is the element number. Its significance depends on the attribute.

Parameter Value (0x10) Access to the parameter value takes place in the attribute "Parameter Value". For single parameters or commands there is only subindex 0 existing. In the case of lists, the sub-index ranges from 0 to "list length - 1". All elements are of the same data type.

Parameter Description (0x20) The description of the parameter via the attribute "Parameter Description" is devided into different elements which are accessed by means of the subindex:

- **Complete description** (0)

  → Complete description (subindex 1 to 12, always with a length of 46 bytes)
- **Identifier** (1)

  → 16-bit value for the basic description of the parameter with the following significance of the individual bits (if set).
  - Bit 0 to 7 → data type
  - Bit 8 → "Standardiz. Factor" + "Variable Attibut" irrelevant
  - Bit 9 → parameter write protected
  - Bit 10 → parameter text available
  - Bit 11 → reserved (always 0)
  - Bit 12 → parameter value does not correspond to default value
  - Bit 13 → parameter can only be reset, cannot be used
  - Bit 14 → list parameter
  - Bit 15 → reserved (always 0)
- **Number of array elements or length of string** (2)

  → 16-bit value with number of list elements or length of string

  In the case of a string, each character is assigned to a sub-index. **Only element of the description that might possibly be changed!**
- **Standardization factor** (3)

  → 32-bit floating point number by means of which it is possible to calculate the physical value from the parameter value (number for IndraDrive normally is a power of ten)
- **Variable attribut** (4)

  → Two 8-bit values for determining the unit and its prefix

  The standard value is 0x00FE, as not all of the units used for IndraDrive can be mapped.
- **Reserved** (5)

  → 32-bit reserved data
- **Name** (6)

  → Name of the parameter with maximum number of 16 characters

  As the IndraDrive parameter names normally are longer, the SERCOS IDN is stored as string (e.g. "S-0-0158").
- **Low limit** (7)

  → Minimum possible parameter value

If this parameter value does not exist for IndraDrive, the lower value range limit of the data type is entered.

- **High limit** (8)

  → Maximum possible parameter value

  If this parameter value does not exist for IndraDrive, the upper value range limit of the data type is entered.

- **Reserved** (9)

  → 16-bit reserved data

- **ID extension** (10)

  → 16-bit reserved data

- **PZD reference parameter** (11)

  → 16-bit value with number or the reference parameter

  If there is no reference parameter, the value "0" is entered.

- **PZD normalization** (12)

  → 16-bit value with additional information on normalization:

  – Bits 0 to 5 → Normalization bit 0 to 31

  – Bits 6 to 14 → reserved

  – Bit 15 → Normalization valid

Parameter Text (0x30) The attribute "Parameter Text" is not supported.

Manufacturer Specific (0x80) In the attribute "Manufacturer Specific" there is such information stored that cannot be mapped to standard elements of PROFIdrive:

- **Complete structure** (0)

  → All elements of this structure (a total of 84 bytes)

- **Maximum number of elements** (1)

  → 32-bit value with maximum possible number of elements

  In the case of single-parameters and command, this value always is "1".

- **Parameter name** (2)

  → 64-byte string with the characters of the parameter name

  Zero is written to unused characters after the end of the name.

- **SERCOS attribute** (3)

  → 32 bits of the SERCOS attribute

- **Unit** (4)

  → 16-byte string with the characters of the unit

  Zero is written to unused characters after the end of the unit.

Error Codes

Error No.	Significance	Extended information
0x00	parameter not available (previously 0x1001)	0
0x01	parameter cannot be written (previously 0x7004)	subindex
0x02	value outside of limit values (previously 0x7006/0x7007)	subindex
0x03	sub-index not available	subindex

Error No.	Significance	Extended information
0x04	list access to single parameter	0
0x05	access with incorrect data type (previously 0x7002/0x7003)	0
0x07	write access to write-protected element	subindex
0x0B	access not possible due to operating status (previously 0x7005)	0
0x0F	no parameter text available	0
0x15	response data too long for telegram	0
0x17	error in format	0
0x18	writing beyond end of list	0
0x19	access to nonexistend axis	0
0x65	manufacturer-specific error code	SIS error code

Fig.4-61: Error codes at acyclic parameter access

Data Types

Data type	Code	SERCOS type
Integer 16	0x03	decimal number with sign 1)
Integer 32	0x04	decimal number with sign 1)
Unsigned 16	0x06	binary, IDN, decimal number without sign 1), hexadecimal, command
Unsigned 32	0x07	decimal number without sign 1), hexadecimal
Floating Point	0x08	
Visible String	0x09	text
Error code	0x44	

1) depending on bits 16 and 17 of SERCOS attribute

Fig.4-62: Data types at acyclic parameter access

4.6.5 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).

☞ The input "0" in parameter "P-0-4081, Field bus: watchdog" means that the watchdog monitoring function has been 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

Ths status 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 status "Data_Exchange". This means that the real-time data are exchanged between IndraDrive device and master.

Parameter for Field Bus Diagnostic 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 significance:

Text	Significance
"OFFLINE"	Initialization value of the diagnostic message
"Power-On"	A PROFIBUS-DP card 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.
"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.

Fig.4-63: Significance 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 significance:

Error code	Significance
0x0082	number of all transmitted data is too low, i.e. less than 4 bytes
0x0083	number 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 sent although there are still data to be transmitted
0x008D	length of data that are still to be transmitted indicated in the control word is incorrect

Fig.4-64: Overview parameter channel errors

DPV1 Errors

The table below contains an overview of the possible DPV1 error messages and their significance:

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 more 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
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

Fig.4-65: Overview DPV1 errors

Parameter Access Errors

The table below contains an overview of the possible parameter access errors and their significance; 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)

Error No. (hex)	Significance
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	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	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 set number
0x9004	invalid data block number
0x9005	Data element number invalid
0x9006	error in R/W flag
0x9007	invalid character in the data

Fig.4-66: Overview parameter access errors

4.7 CANopen Interface

4.7.1 Brief Description

It is possible to operate IndraDrive controllers with a CANopen interface as master communication module. This requires the control section with the optional module "CANopen/DeviceNet" (CO). 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** (PDO)

  The field bus provides data containers in which useful data can be cyclically transmitted in real time (process data objects).

- **Acyclic data channel** (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 (in addition, 100 kbit/s is supported)
- Configurable cyclic data up to 12 parameters (incl. field bus control word and field bus status word) in both data directions (max. 24 bytes or 12 words)
- Multiplex channel permanently configured in one PDO pair
- Functional compatibility with EcoDrive functions through profile selection (I/O mode)
- Node monitoring (heartbeat 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:

- Single-axis BASIC UNIVERSAL (CSB01.1C)
- Single-axis ADVANCED (CSH01.1C)

Pertinent Parameters

Communication parameters

Specific parameters for CANopen communication:

- P-0-3610, CANopen: Heartbeat 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-0-4076, Field bus: cycle time (Tcyc)
- P-0-4079, Field bus: baud rate

Profile type parameters

Apart from mere communication parameters, we use parameters in conjunction with the profile types.

See "Profile Types (with Field Bus Interfaces)"

Parameters for extended communication

We use additional parameters for extended communication.

See following sections:

- "Configurable Signal Control Word"
- "Configurable Signal Status Word"
- " Multiplex Channel"

Pertinent Diagnostic Messages

- F4009 Bus failure
- F4012 Incorrect I/O length

☞ To get a more detailed description of the CANopen interface and information on its possibilities of use with MPx04 firmware, please contact your Bosch Rexroth sales representative!

4.8 DeviceNet Interface

4.8.1 Brief Description

It is possible to operate IndraDrive controllers with a DeviceNet interface as master communication module. This requires the control section with the optional module "CANopen/DeviceNet" (CO). Via this optional module, it is possible to exchange real-time data with a DeviceNet master. The drive supports the protocol "DeviceNet" according to ODVA version 2.0.

We distinguish the following communication channels:

- **Cyclic data channel** (polled I/O)

  The field bus provides data containers in which useful data can be cyclically transmitted in real time.
- **Acyclic data channel** (Explicit Message)

  The field bus provides an object directory of the device. The objects can be acyclically read and, if allowed, can be written.

☞ The process data are always transmitted via "polled I/O".

To achieve the highest possible system flexibility, all parameters of the drive are accessible via objects. With DeviceNet, these objects can be addressed through class, instance and attribute. Some of these objects can be assigned to the "polled I/O" 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

- DeviceNet interface completely galvanically decoupled
- "Open Pluggable Connector" according to specification 2.0 (Phoenix COMBICON connector)
- "DeviceNet Generic Device" according to specification ODVA 2.0
- Easy configuration by implementing "Group 2 only Server"
- All data rates supported:
  - 125 kbit/s (up to a distance of 500 m)
  - 250 kbit/s (up to a distance of 250 m)
  - 500 kbit/s (up to a distance of 100 m)

- Freely configurable process data channel (max. 24 words, max. 15 IDN) in both data directions via drive parameters P-0-4080 and P-0-4081
- Monitoring of the process data channel (watchdog function)
- All parameters of the drive can be acyclically read via "Explicit Message" and, if allowed, can be written
- 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: module status and network status)

Hardware Requirements

The optional module with DeviceNet interface is available for the following configurable control sections:

- Single-axis BASIC UNIVERSAL (CSB01.1C)
- Single-axis ADVANCED (CSH01.1C)

Pertinent Parameters

Communication parameters

Parameters for general field bus communication (incl. DeviceNet):

- 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: cycle time (Tcyc)
- P-0-4079, Field bus: baud rate

Profile type parameters

Apart from mere communication parameters, we use parameters in conjunction with the profile types.

See "Profile Types (with Field Bus Interfaces)"

Parameters for extended communication

We use additional parameters for extended communication.

See following sections:

- "Configurable Signal Control Word"
- "Configurable Signal Status Word"
- " Multiplex Channel"

Pertinent Diagnostic Messages

- F4009 Bus failure
- F4012 Incorrect I/O length

4.8.2 Configuration DeviceNet Slave

EDS File

For each DeviceNet device it is necessary to have an EDS file (*.EDS) which contains the data required for operating the device on the field bus. This file, when configuring the bus master, is required for each node.

The EDS file for IndraDrive is an ASCII file with the name "IndraDrive_DVN.EDS".

Setting the Node Address of the Slave

The address determines the priority of data sent by of the slave, with the lowest address having the highest priority. Usually, the master has the highest priority and therefore the lowest address. Each DeviceNet node has to transmit data on the bus unequivocally assigned to it. According to the DeviceNet specification, this requires a slave address (MAC ID) that is unequivocal for the whole bus.

This address is set in parameter "P-0-4025, Drive address of master communication".

According to ODVA 2.0, the address can be set within the range of 1 to 63.

The node address of the slave in parameter P-0-4025 can only be changed, when the 24V supply voltage of the DeviceNet interface (Sense bus) has been switched off!

See also section "Setting the Axis Address"

Baud Rate Search/Baud Rate Input

The baud rate used by the DeviceNet field bus is set in parameter "P-0-4079, Field bus: baud rate" (in kBaud). Possible baud rates are 125 kBaud, 250 kBaud and 500 kBaud.

Baud Rate Search

The automatic baud rate search is activated by writing the value "0" to parameter P-0-4079 or by the command "load defaults procedure". The search is carried out directly after switch-on. The LEDs "module status" (H4) and "network status" (H5) are switched off. The parameter "P-0-4073, Field bus: diagnostic message" displays "BAUD SEARCH" as status. Baud rates which were found by baud rate search are displayed as negative numbers in parameter P-0-4079. The baud rate which was found is at the same time the start value for repeated baud rate search after the control section has been switched on again.

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 deactivate the baud rate search after having switched on.

☞ With low bus load, the baud rate search might possibly fail. The baud rate should therefore be set to a fixed value, if possible.

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.

These parameters are set via the commissioning tool "IndraWorks D".

☞ Changes in the settings are only applied by reinitializing the DeviceNet card (switching 24V bus voltage off), or by restarting the drive.

4.8.3 Specifying the DeviceNet Interface

The module uses the "Predefined Master/Slave Connection Set" and works as Group-2-Only Server.

The implemented DeviceNet object directory contains the objects "Identity Object" (class 1), "Message Router Object" (class 2), "DevicNet Object" (class 3), "Assembly Object" (class 4), "Connection Object" (class 5), as well as a vendor-specific object (class 100), which are obligatory for a Generic Device.

Addressing takes place with 8-bit values for class and attribute and 16-bit values for the instance.

4.8.4 Cyclic Communication via Process Data Channel (Polled I/O)

The cyclic channel (polled I/O) is generated by parameterization of "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 DeviceNet level, a static Output Assembly Object (class 4, instance 101) and a static Input Assembly Object (class 4, instance 102) are transmitted in the cyclic channel.

4.8.5 Acyclic Parameter Access (Explicit Message)

Addressing the Objects

For DeviceNet communication the objects are addressed according to the following scheme:

Class → instance → attribute

Class All parameters of the drive are mapped to the manufacturer-specific class 100.

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

Fig.4-67: Structure of the IDN

Attribute The attribute number depends on the format of the drive parameter.

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 IDN	T[8]
2	Name	Parameter name	T[60]
3	Attribute	Display mode of the parameter	L
4	Unit	Parameter unit	T[12]
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

Fig.4-68: 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 data which is processed at the next access to element 7	L
11	Action for 1 list element	W/L/T
12	Action for 2 list elements	W/L/T
13	Action for 3 list elements	W/L/T
14	Action for 4 list elements	W/L/T
15	Action for 5 list elements	W/L/T
16	Action for 6 list elements	W/L/T
17	Action for 7 list elements	W/L/T
18	Action for 8 list elements	W/L/T
19	Action for 9 list elements	W/L/T
20	Action for 10 list elements	W/L/T

Fig.4-69: 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. With access to parameter texts, the number of attributes is the value "9".

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 number of data of the parameter (attribute 8). The real size is stored in the actual number 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 it points to zero, the first element is accessed. To simplify access 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. 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 Parameter P-0-0072 has 18 list elements and is to be read:

- Read: class 100, instance 8048h, attribute 9h = 12h (actual length)
- Write: class 100, instance 8048h, attribute Ah = 0h (list pointer)
- Read: class 100, instance 8048h, attribute Bh = element 0
  → List pointer now automatically pointing to 1
- Read: class 100, instance 8048h, attribute 14h = elements 1 to 10
  → List pointer now automatically pointing to 11
- Read: class 100, instance 8048h, attribute Ch = elements 11, 12
  → List pointer now automatically pointing to 13
- Read: class 100, instance 8048h, attribute Fh = elements 13 to 17
  → List pointer now automatically pointing to 18 (12h)
- Read: class 100, instance 8048h, attribute Ah = 12h (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 at parameter access, the additional error code provides hints at the cause of the error.

Error number (hex)	Significance
0x02	Parameter transmitted too short
0x03	Parameter transmitted too long
0x04	Parameter cannot be changed
0x05	Parameter is write-protected at this time
0x06	Value is smaller than minimum input value
0x07	Value is greater than maximum input value
0x08	Incorrect value
0x09	Parameter is password-protected
0x0A	Parameter write-protected, as cyclically configured in MDT
0x0B	Invalid indirect addressing

Error number (hex)	Significance
0x0C	Parameter is write protected at this time, due to other settings (parameter, operation mode, drive enable...)
0x10	Procedure command already active
0x11	Procedure command not interruptible
0x12	Procedure command at this time not executable (e.g., in this phase procedure command cannot be activated)
0x13	Procedure command not executable (invalid or false parameters)

Fig.4-70: Error Codes and Their Significances at Parameter Access

4.8.6 Notes on Commissioning

Commissioning the DeviceNet interface requires the following individual steps:

1. Before switching drive on, set switch above bus connector to "DVN". After that you can switch drive on.
2. To set address (see also "Setting the Axis Address") it is advantageous not yet to connect DeviceNet connector to drive. In this case, drive always is in status in which address may be changed.
3. 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.
4. Configure cyclic data (see also section "Profile Types (with Field Bus Interfaces)").

☞ The communication parameters "P-0-4025, Drive address or master communication" and "P-0-4079, Field bus: baud rate" can only be changed, when the 24V supply voltage of the DeviceNet interface (Sense bus) has been switched off. The parameter "P-0-4075, Field bus: watchdog" is for display only and corresponds to the 4-fold "Expected Packet Rate" set by the DeviceNet master.

4.8.7 Diagnostic Messages and Monitoring Functions

Diagnostic LED

There are two LEDs at the front of the optional module CO; with master communication "DeviceNet" their displays have the significances described below.

LED Display "Module Status" (H4)

The LED display "module status" (H4) displays the status of the "DeviceNet Identity Object":

Behavior of LED "H4"	Significance/status
LED off	No control voltage available
LED flashes green/red	Device self test active
LED flashes green	Device "Standby"
LED permanently lit green	Device "Operational"

Behavior of LED "H4"	Significance/status
LED flashes red	Device "Major Recoverable Fault"
LED permanently lit red	Device "Major Unrecoverable Fault"

Fig.4-71: Behavior and Significance of Module Status LED

LED Display "Network Status" (H5)

The LED display "network status" (H5) displays the network status of the DeviceNet master communication:

Behavior of LED "H5"	Significance/status
LED off	Device "Offline"
LED flashes green	"Online" but no connection to master
LED permanently lit green	"Online" and connection to master
LED flashes red	Polled I/O connection "Timed Out"
LED permanently lit red	Critical connection error

Fig.4-72: Behavior and Significance of Network Status LED

DeviceNet - Diagnostic Messages

In parameter "P-0-4073, Field bus: diagnostic message", the current status of the DeviceNet master communication is displayed:

Diagnostic message	Significance
BAUD SEARCH	Automatic baud rate search is active.
DEVICE_SELF_TESTING	Automatic self test is active.
OPERATIONAL	"Operational", no connection to master
POLLED IO	"Operational" and connection to master, real-time data are processed.
POLLED IO IDLE	"Operational" and connection to master, real-time data are **not** processed.
RECOVERABLE_FAULT	A recoverable error is present.
UNRECOVERABLE_FAULT	An **unrecoverable** error is present.

Fig.4-73: Overview of Diagnostic Messages for DeviceNet Communication

In case an unrecoverable error occurs and its cause can be determined, one of the following possible error messages is displayed in parameter P-0-4073 instead of "UNRECOVERABLE_FAULT":

Diagnostic message	Significance
DUP_MAC_ERROR	Duplicate MAC Check error
RX_QUEUE_OVERRUN	Overflow of Rx queue
TX_QUEUE_OVERRUN	Overflow of Tx queue
IO_SEND_ERROR	Error when transmitting the cyclic data
CAN_BUS_OFF	CAN controller in status "BUS-OFF"
CAN_OVERRUN	Overflow in CAN controller
BUS_POWER_FAIL	24V error

Fig.4-74: Specific Error Messages in Status "UNRECOVERABLE_FAULT"

IndraDrive - Diagnostic Error Messages

IndraDrive's diagnostic error messages and their significances in conjunction with DeviceNet master communication:

- **F4009 Bus failure** → Within the "field bus watchdog time" there hadn't any polled I/O telegram been received.

  Note: The "field bus watchdog time" corresponds to the fourfold "Expected Packet Rate" set by the DeviceNet master.
- **F4012 Incorrect I/O length** → The length of the configured cyclic data of master does not match data length of slave.

  Note: This situation can arise when the configuration of parameter "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." is changed in running bus operation. The established polled I/O connection persists. The received cyclic data, however, are not accepted by IndraDrive. The configuration of the cyclic data also has to be adjusted in the master and the bus has to be started again to allow clearing the diagnostic error message F4012 which is present.

4.9 Parallel Interface

4.9.1 Brief Description

It is possible to operate IndraDrive controllers with a parallel interface as master communication module. This requires the control section design with the optional module "parallel interface (PL)", with 16 digital inputs and 16 digital outputs.

Features

- Free configuration of the total of 16 digital inputs by means of the signal control word function (see S-0-0145)
- Free configuration of the total of 16 digital outputs by means of the signal status word function (see S-0-0144)

Hardware Requirements

The optional module with parallel interface is available for the following configurable control sections:

- Single-axis BASIC UNIVERSAL (CSB01.1C)
- Single-axis ADVANCED (CSH01.1C)

Pertinent Parameters

- S-0-0026, Configuration list signal status word
- S-0-0027, Configuration list signal control word
- S-0-0144, Signal status word
- S-0-0145, Signal control word
- S-0-0328, Assign list signal status word
- S-0-0329, Assign list signal control word
- S-0-0346, Positioning control word
- S-0-0398, IDN list of configurable data in signal status word
- S-0-0399, IDN list of configurable data in the signal control word
- S-0-0437, Positioning status word
- P-0-0115, Device control: Status word
- P-0-0116, Device control: Control word
- P-0-4026, Positioning block selection
- P-0-4028, Device control word

- P-0-4060, Positioning block control word
- P-0-4061, Positioning block status word

Pertinent Diagnostic Messages

- F2044 External power supply X15 error

4.9.2 Functional Description

Controlling the Brake

Drive Enable

Activating the drive requires a positive edge of the "drive enable" signal.

☞ The "drive enable" signal is mapped to parameter "P-0-4028, Device control word".

See also "Device Control and State Machines"

The enable signal is accepted, i.e. the drive switches from its de-energized status to its energized status, when the following conditions have been fulfilled:

- There mustn't be any drive error present.
- The drive must be in 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 status 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".
- The signal "Ready" in parameter "P-0-0115, Device control: Status word" must be set (P-0-0115, bit 1 = 1).

"Drive Halt" Signal

When drive enable is set and the "Drive Halt" signal is active (P-0-4028, 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 the "Drive Halt" signal is then deactivated (P-0-4028, bit 13 = 1),

- the display of the control panel changes to "AF" and
- the diagnostic drive message then is A0206, A0207, A0210 or A0211 (positioning block mode) and thereby signals the activation of the operating mode.

☞ The "Drive Halt" signal is status-controlled and active when the signal = 0 V.

Clear Error

A positive edge at the "clear error" input starts the command for error clearing. By default setting the command for error clearing "C0500 Reset class 1 diagnostics, error reset" has been assigned to a digital input on the parallel interface.

☞ By activating the command for error clearing all drive errors are cleared!

Configurable Digital Inputs

Cycle Time

The signal control word for IndraDrive devices is cyclically generated or cyclically transmitted to the I/O module:

- Cycle time "Advanced" → T = 250 µs
- Cycle time "Basic" → T = 500 µs

☞ The digital inputs of the parallel interface are mapped to those of parameter "S-0-0145, Signal control word".

Bit number in signal control word	Digital input of the parallel interface
0	X15, pin 1
1	X15, pin 20
2	X15, pin 2
3	X15, pin 21
4	X15, pin 3
5	X15, pin 22
6	X15, pin 4
7	X15, pin 23
8	X15, pin 5
9	X15, pin 24
10	X15, pin 6
11	X15, pin 25
12	X15, pin 7
13	X15, pin 26
14	X15, pin 8
15	X15, pin 27

Fig.4-75: Assignment of signal control word to digital inputs

See also "Configurable Signal Control Word"

☞ The connector pin assignment is described in the separate documentation "Control Sections for Drive Controllers, Project Planning Manual" in the "I/O Extensions" section.

Configurable Digital Outputs

Cycle Time The signal status word for IndraDrive devices is cyclically generated or cyclically transmitted to the I/O module:

- Cycle time "Advanced" → T = 250 µs
- Cycle time "Basic" → T = 500 µs

☞ The bits of parameter "S-0-0144, Signal status word" are mapped to the digital outputs of the parallel interface.

Bit number in signal status word	Digital output of the parallel interface
0	X15, pin 28
1	X15, pin 10
2	X15, pin 29
3	X15, pin 11
4	X15, pin 12

Bit number in signal status word	Digital output of the parallel interface
5	X15, pin 31
6	X15, pin 13
7	X15, pin 32
8	X15, pin 33
9	X15, pin 15
10	X15, pin 34
11	X15, pin 16
12	X15, pin 17
13	X15, pin 36
14	X15, pin 18
15	X15, pin 37

Fig.4-76: Assignment of signal status word to digital outputs

See also "Configurable Signal Status Word"

☞ The connector pin assignment is described in the separate documentation "Control Sections for Drive Controllers, Project Planning Manual" in the "I/O Extensions" section.

4.9.3 Notes on Commissioning/Parameterization

Positioning Block Mode with Parallel Interface

See also operating mode "Positioning Block Mode"

☞ With the device configuration "parallel interface (PL)", the signal control word and the signal status word are configured accordingly when the command "load basic parameters" is executed.

Positioning Block Selection, Start Signal

With a positive edge (0 → 1) at the strobe input (bit 0 of "P-0-4060, Positioning control word"), a positioning block is selected and started. The inputs for the positioning block selection are mapped to parameter "P-0-4026, Positioning block selection".

Block Selection Acknowledgement, "In-Pos" Message

The block selection in parameter P-0-4051 is acknowledged as soon as the positioning block has been started. The "In-Pos" message is simultaneously updated.

Jogging Inputs

Selecting the jogging inputs causes an internal switching to the "drive-controlled positioning" mode. The two jogging inputs are mapped to parameter "S-0-0346, Positioning control word" (bit 1 and bit 2) and the jogging direction is thereby determined.

☞ The jogging inputs are used, among other things, for operational stop (positioning stop; cf. S-0-0346).

Examples of control of the jogging inputs

S-0-0346, Positioning control word:

- Bit 2, 1 = 01 → Jog +
- Bit 2, 1 = 10 → Jog -

- Bit 2, 1 = 11 → Positioning stop

Bit number in signal control word	Configured parameter	Function/significance
0	P-0-4026, bit 0	positioning block selection
1	P-0-4026, bit 1	positioning block selection
2	P-0-4026, bit 2	positioning block selection
3	P-0-4026, bit 3	positioning block selection
4	P-0-4026, bit 4	positioning block selection
5	P-0-4026, bit 5	positioning block selection
6	P-0-4060, bit 0	acceptance of positioning block
7	S-0-0148, bit 0	homing command (C0600)
8	S-0-0346, bit 1	jogging +
9	S-0-0346, bit 2	jogging -
10	P-0-4028, bit15	device control word (AF)
11	P-0-4028, bit13	device control word (AH)
12	S-0-0099, bit 0	command for error clearing (C0500)
13	--	not assigned
14	--	not assigned
15	--	not assigned

Fig.4-77: Default configuration for positioning block mode via digital inputs

Bit number in signal status word	Configured parameter	Function/significance
0	P-0-0115, bit 1	status of device control "ready"
1	S-0-0059, bit 0	position switch point
2	S-0-0403, bit 0	status reference encoder
3	S-0-0331, bit 0	n_{act} = 0
4	P-0-4061, bit 1	status "end position reached"
5	P-0-0115, bit 2	status of device control "warning"
6	S-0-0437, bit 12	status "jog mode active"
7	S-0-0437, bit 3	status "interpolator stopped"
8	P-0-4051, bit 0	positioning block acknowledgment
9	P-0-4051, bit 1	positioning block acknowledgment
10	P-0-4051, bit 2	positioning block acknowledgment
11	P-0-4051, bit 3	positioning block acknowledgment
12	P-0-4051, bit 4	positioning block acknowledgment
13	P-0-4051, bit 5	positioning block acknowledgment

Bit number in signal status word	Configured parameter	Function/significance
14	P-0-4051, bit 6	positioning block acknowledgment
15	P-0-4051, bit 7	positioning block acknowledgment

Fig.4-78: Default configuration for positioning block mode via digital outputs

Change of Operating Mode via Parallel Interface

To change the operating mode, bits 8 and 9 of parameter "P-0-4028, Device control word" have to be assigned to the digital inputs. By setting the inputs, the bits for operating mode selection (primary mode of operation and secondary operating modes) are then set.

Main Spindle Drive with Analog Interface and Parallel Interface

In the case of main spindle drives, operating states that are important for the working cycle have to be transmitted to the master so that it can process or advance the command blocks in accordance with the process and in a fail-safe way.

The "position spindle" command allows aligning the spindle for tool change without the control master having to leave the "velocity control" mode mainly used for spindles.

In the case of master communication with analog interface, the required messages have to be made available to the master via the digital outputs. The "position spindle" command has to be started via a digital input. To do this, the command parameters are assigned to a digital input, the main spindle messages are assigned to the digital outputs.

The following commands are relevant for main spindle drives:

- C0900 Position spindle command (S-0-0152)
- C0600 Drive-controlled homing procedure command (S-0-0148)

Bit number in signal control word	Configured parameter	Function/significance
0	--	
1	S-0-0152, bit 0	position spindle command (C0900)
2 … 6	--	
7	S-0-0148, bit 0	homing command (C0600)
8, 9	--	
10	P-0-4028, bit15	device control word (AF)
11	P-0-4028, bit13	device control word (AH)
12	S-0-0099, bit 0	command for error clearing (C0500)
13 … 15	--	

Fig.4-79: Example of configuration for main spindle drive via digital inputs

The following messages are relevant for main spindle drives:

- Speed reached ("S-0-0330, Message 'n_actual = n_command'")
- Spindle has stopped ("S-0-0331, Status 'n_feedback = 0'")
- Speed value has fallen below threshold ("S-0-0332, Message 'nactual < nx'")

- In target position during spindle positioning ("S-0-0336, Message In position")
- Torque limit value reached ("S-0-0334, Message 'T >= Tlimit'")
- Torque threshold exceeded ("S-0-0333, Message 'T >= Tx'")
- Speed threshold exceeded ("S-0-0335, Message 'n command > n limit'")
- Power threshold exceeded ("S-0-0337, Message 'P >= Px'")

See also descriptions of the respective parameters in the separate documentation "Rexroth IndraDrive, Parameter Description"

Bit number in signal status word	Configured parameter	Function/significance
0	P-0-0115, bit 1	status of device control "ready"
1	S-0-0330, bit 0	n_actual = n_command
2	S-0-0403, bit 0	status reference encoder
3	S-0-0331, bit 0	n_feedback = 0
4	S-0-0332, bit 0	nactual < nx
5	P-0-0115, bit 2	status of device control "warning"
6	S-0-0333, bit 0	T ≥ Tx
7	S-0-0334, bit 0	T ≥ Tlimit
8	S-0-0335, bit 0	n command > n limit
9	S-0-0336, bit 0	In_Position
10	S-0-0337, bit 0	P ≥ Px
11 … 15	--	

Fig.4-80: Example of configuration for main spindle messages via digital outputs

See also section "Spindle Positioning"

4.9.4 Diagnostic and Status Messages

Monitoring the Digital Inputs/Outputs

For the parallel interface different kinds of errors are monitored at the inputs and outputs or ports. The following error situations can be detected:

- Undervoltage of 24 V supply
- Incorrect polarity of the supply of a port
- Overload of an output
- Short circuit of an output

There is only the collective message "F2044 External power supply X15 error" for the above-mentioned errors of the parallel interface.

4.10 Analog Interface

4.10.1 Brief Description

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").

In conjunction with encoder emulation (SSI or incremental encoder), the position control loop can be closed in a higher-level control unit. The drive provides the possibility of, for example, emulating the actual position value for evaluation in the control unit.

The figures below illustrate the structure of drive solutions with analog interface and open-loop or closed-loop operation.

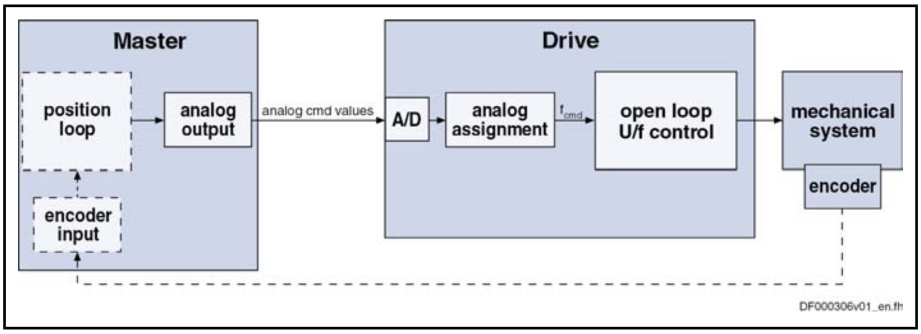


Fig.4-81: Open-Loop Operation With Analog Interface (With Optional Position Feedback to Open-Loop Control)

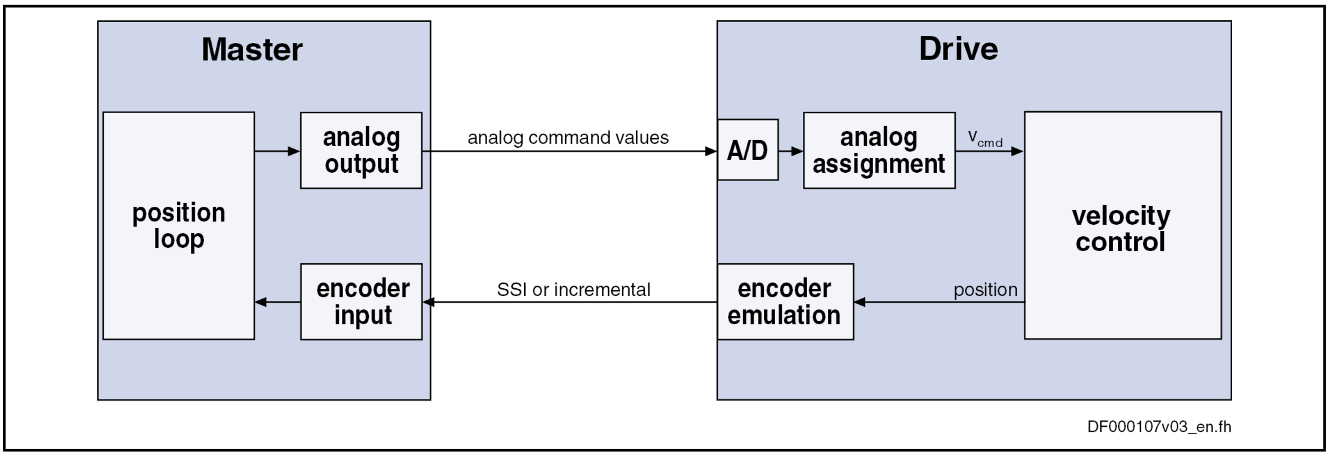


Fig.4-82: Closed-Loop Operation With Analog Interface (With Analog Command Value Input and SSI Emulation)

This section describes the basic functions of the analog interface and contains notes on commissioning and parameterization. The individual functions used, "analog inputs" and "encoder emulation", are described in separate chapters.

See also "Encoder Emulation"

See also "Analog Inputs"

Features

The analog interface is an interface for master communication with analog command values and digital I/Os (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 loop 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 loop clock $T_{position}$
  – Assignment channel B → assignment in clock of 2 ms

Features of **encoder emulation**:

- Freely configurable incremental encoder and SSI emulation of the different position values in the drive (actual position value, position command value...) load- or motor-related via position scaling (S-0-0076)

Features of **absolute encoder emulation**:

- Adjustable relationship via command "set absolute measuring" (C0300)
- Resolution to be set, only binary resolution (incr./motor rev. or mm)
- Power failure bit available

Features of **incremental encoder emulation**:

- Emulation of the reference pulse
- Reference pulse offset to be set; dead time compensation
- Resolution to be set (incr./motor rev. or mm)
- Monitoring of the maximum frequency

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:
    – Signals "drive enable" and "Drive Halt"
    – 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

☞ For the BASIC ANALOG control section, the analog inputs and the hardware for encoder emulation have already been integrated on the control section. The ADVANCED and BASIC UNIVERSAL control sections require optional add-on cards for analog I/Os (MA1) and encoder emulation (MEM).

Hardware Requirements

The optional module with analog interface is available for the following control sections:

- Single-axis ADVANCED (configurable) (CSH01.1C)
- Single-axis BASIC UNIVERSAL (configurable) (CSB01.1C)
- Single-axis BASIC ANALOG (not configurable) (CSB01.1N-AN)
- Double-axis BASIC UNIVERSAL (CDB01.1C)

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 I/Os, assignment list
- P-0-0301, Digital I/Os, bit numbers

- P-0-0302, Digital I/Os, direction
- P-0-0303, Digital I/Os, status display
- P-0-0304, Digital I/Os, outputs

Analog inputs:

- P-0-0208, Analog input 5
- P-0-0209, Analog input 6
- P-0-0210, Analog input 1
- P-0-0211, Analog input 2
- 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, scaling per 10V full scale
- P-0-0215, Analog input, assignment A, signal value at 0V
- 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, Analog input, maximum value for adjust
- P-0-0220, C2800 Analog input adjust command
- P-0-0228, Analog input 3
- P-0-0229, Analog input 4
- P-0-0231, Analog input 2, time constant input filter
- P-0-0232, Analog input 3, time constant input filter
- P-0-0233, Analog input 4, time constant input filter
- P-0-0234, Analog input 5, time constant input filter
- P-0-0235, Analog input 6, time constant input filter
- P-0-0236, Analog input, assignment B, target parameter
- P-0-0237, Analog input, assignment B, scaling per 10V full scale
- P-0-0238, Analog input, assignment B, signal value at 0V
- P-0-0239, Analog input, assignment B, dead zone
- P-0-3901, Adjust values of control section
- P-0-3904, Adjust values analog I/O interface 3-4

Encoder emulation:

- P-0-0900, Encoder emulation signal selection list
- P-0-0901, Encoder emulation signal selection
- P-0-0902, Encoder emulation control parameter
- P-0-0903, Encoder emulation resolution
- P-0-0904, Encoder emulation zero pulse offset

4.10.2 Functional Description

Control

With the analog interface, the drive is controlled via the digital inputs of the control section. Via the list parameter "P-0-0300, Digital I/Os, assignment list", the pins of the connectors X31, X32, X33 and X11 at the control section are assigned to drive parameters. Depending on the control section design, there is a default assignment of the pins of these terminal strips. The preset default assignment can be modified according to the application-specific requirements.

See Parameter Description "P-0-0300, Digital I/Os, assignment list"

As a matter of principle, using an ADVANCED control section with analog interface requires manual configuration of the digital I/Os.

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 "Drive Controllers, Control Sections; 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 status to its energized status, when the following conditions have been fulfilled:

- There mustn't be any drive error present.
- The drive must be in 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 status 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 the "Drive Halt" signal is then 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 operating mode (see description of the respective diagnostic message in the separate documentation "Troubleshooting Guide (description of diagnostic messages)")

The "Drive Halt" signal is status-controlled and active when the signal = 0 V.

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 I/Os, assignment list"
- In parameter "P-0-0301, Digital I/Os, bit numbers", set bit 0 for the element of S-0-0099

- In parameter "P-0-0302, Digital I/Os, direction", set the data direction for the element of S-0-0099 to input (value "0")

See also "Digital Inputs/Outputs"

☞ All drive errors are cleared by activating the command for error clearing!

Analog Command Value Input

The number of analog inputs, which differs according to control section, is used to input the analog command value.

For IndraDrive devices, the analog inputs are cyclically sampled and evaluated:

- Assignment channel A works in position loop clock (see "Performance Data")
- Assignment channel B works in 2-ms clock

See "Analog Inputs"

Emulation of Position Value

In order to close the position control loop via the master, it is necessary to transmit the axis position to the master. This is done by means of encoder emulation (incremental or SSI).

See "Encoder Emulation"

4.10.3 Notes on Commissioning/Parameterization

Encoder Emulation

In spite of its high degree of functionality and performance, the encoder emulation available for IndraDrive devices is subject to some systematic restrictions.

See "Encoder Emulation"

☞ If the higher-level master and the drive have not been synchronized, beat effects can occur during sampling due to the different clock-pulse rates. Bosch Rexroth therefore recommends not to use the analog interface in high end applications, but in these cases use digital interfaces, such as SERCOS interface.

Analog Inputs

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. Bosch Rexroth therefore recommends not to use the analog interface in high end applications, but in these cases use digital interfaces, such as SERCOS interface.

Main Spindle Drive With Analog Interface and Parallel Interface

In the case of main spindle drives, operating states that are important for the working cycle have to be transmitted to the master so that it can process or advance the command blocks in accordance with the process and in a fail-safe way.

The "position spindle" command allows aligning the spindle for tool change without the master having to leave the "velocity control" mode mainly used for spindles.

In the case of master communication with analog interface, the required messages have to be made available to the master via the digital outputs. The "position spindle" command has to be started via a digital input. For this purpose, the main spindle messages are assigned to the digital outputs, the command parameter to a digital input.

Messages The following messages are relevant for main spindle drives:

- Speed reached ("S-0-0330, Message 'n_actual = n_command'")
- Spindle has stopped ("S-0-0331, Status 'n_feedback = 0'")
- Speed value has fallen below threshold ("S-0-0332, Message 'nactual < nx'")
- In target position during spindle positioning ("S-0-0336, Message In position")
- Torque limit value reached ("S-0-0334, Message 'T >= Tlimit'")
- Torque threshold exceeded ("S-0-0333, Message 'T >= Tx'")
- Speed threshold exceeded ("S-0-0335, Message 'n command > n limit'")
- Power threshold exceeded ("S-0-0337, Message 'P >= Px'")

See also descriptions of the respective parameters in the separate documentation "Parameter Description"

Bit in signal status word	Configured parameter	Configured bit in parameter	Function/significance
1	S-0-0330	0	n_actual = n_command
2	S-0-0331	0	n_feedback = 0
3	S-0-0332	0	nactual < nx
4	S-0-0333	0	T ≥ Tx
5	S-0-0334	0	T ≥ Tlimit
6	S-0-0335	0	n command > n limit
7	S-0-0336	0	In_Position
8	S-0-0337	0	P ≥ Px
9	--	--	
10	--	--	
11	--	--	
12	--	--	
13	--	--	
14	--	--	
15	--	--	

Fig.4-83: Example of Configuration for Main Spindle Messages via Digital Outputs

Command The following command is relevant for main spindle drives:

- C0900 Position spindle command (S-0-0152)

Bit in signal control word	Configured parameter	Configured bit in parameter	Function/significance
1	S-0-0152	0	Spindle positioning
2	--	--	
…	…	…	
15	--	--	

Fig.4-84: Example of Configuration for Main Spindle Command via Digital Inputs

See also "Spindle Positioning"

4.10.4 Diagnostic and Status Messages

Information on General Drive Status

In parameter "P-0-0115, Device control: status word", all important status bits of the state machine of the drive are mapped. Reading and interpreting parameter P-0-0115 provides information on the current status 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 assignment to the internal drive parameters. The following applies:

- Digital inputs/outputs of the control module are mapped to parameter "P-0-0303, Digital I/Os, inputs"
- Analog inputs values are displayed in the following parameters:
  - P-0-0208, Analog input 5
  - P-0-0209, Analog input 6
  - P-0-0210, Analog input 1
  - P-0-0211, Analog input 2
  - P-0-0228, Analog input 3
  - P-0-0229, Analog input 4

See also "Diagnostic and Status Messages" in the following sections:

- "Digital Inputs/Outputs"
- "Analog Inputs"
- "Encoder Emulation"

5 Motor, Mechanical Axis System, Measuring Systems

5.1 General Information on Operation of Motors With IndraDrive

5.1.1 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 contact and 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!

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-0-4014, Type of construction of motor
- P-0-4048, Stator resistance

Asynchronous motor parameters:

- P-0-0532, Premagnetization factor
- P-0-4004, Magnetizing current

Field-weakening range parameters:

- P-0-0533, Flux loop proportional gain
- P-0-0534, Flux 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
- Default control loop parameters

5.1.2 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, Temperature sensor characteristic

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.

For this purpose, there are the following prerequisites:

- Motor has a built-in temperature sensor
- Motor-specific parameter values in firmware-side motor temperature model are active

- Ambient temperature is in allowed range

The motor is protected against thermal overload by

- monitoring motor temperature by means of sensor
  - and -
- limiting motor current by means of temperature model.

Monitoring the motor temperature by means of sensor is the most reliable way of protecting the motor against inadmissible temperature rise. Limiting the motor current by means of the temperature model assumes thermal requirements not guaranteed in reality in the "case of failure"!

☞ Limitation of the motor current by means of the 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". Standard sensor types are characterized by a characteristic number; a characteristic stored in the firmware is assigned to this number.

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 status	Motor temperature...	Message and reaction
Thermal range not allowed, temperature sensor possibly not connected.	... for 30 s ≤ -20°C	**Error:** F2021 Motor temperature monitor defective **Reaction:** Motor is immediately shut down (error reaction which was set) and switched off!
		Only with Sensor **KTY84**: **Warning:** E2021 Motor temperature outside of measuring range **Reaction:** No specific reaction!
Allowed thermal range	... < value of S-0-0201	No specific message or reaction!

Thermal status	Motor temperature...	Message and 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 **Reaction:** No specific reaction!
Upper limit of allowed thermal range reached!	... ≥ value of S-0-0204	**Error:** F2019 Motor overtemperature shutdown **Reaction:** Motor is immediately shut down (error reaction which was set) and switched off!
Only with Sensor **KTY84**: Short circuit or conductor break detected		Only with Sensor **KTY84**: **Error:** F2021 Motor temperature monitor defective **Reaction:** Motor is immediately shut down (error reaction which was set) and switched off!

Fig.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!

☞ The motors MHD, MKD, LSF, MBS and MKE have temperature sensors with switching characteristic. They are not suited for measuring the temperature and only used to switch off the motor in the case of overtemperature.

The message and shutdown threshold have been permanently set and **cannot** be set via the parameters S-0-0201 and S-0-0204!

Third-Party Motors

Third-party motors may include temperature sensors that do not correspond to the standard type sensors. This information is given to the controller via the parameter "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, Temperature sensor characteristic".

Third-party motors without built-in temperature sensor can also be operated with IndraDrive controllers, but they are only protected against thermal overload by the firmware-side motor temperature model! The temperature monitor has to be switched off in the mentioned case, because otherwise the controller demands a temperature sensor to be connected.

See also "Third-Party Motors at IndraDrive Controllers"

Notes on Commissioning

Relevant Parameters

For the following parameters, it is necessary to replace the default value by an adjusted value during commissioning.

Rexroth motors with the characteristic temperature sensor number "1" (MHD, MKD, LSF, MBS motors) or "4" (MKE motors):

→ No parameter settings regarding the temperature sensor required!

Rexroth motors with the characteristic temperature sensor number "2", "3" or "5" (2AD, ADF, 1MB, MAD, MAF or SF motors):

- S-0-0201, Motor warning temperature

Third-party motors with the characteristic temperature sensor number "2", "3" or "5":

- S-0-0201, Motor warning temperature
- S-0-0204, Motor shutdown temperature
- P-0-0512, Temperature sensor

Third-party motors with the characteristic temperature sensor number "100":

- S-0-0201, Motor warning temperature
- S-0-0204, Motor shutdown temperature
- P-0-0512, Temperature sensor
- P-0-0513, Temperature sensor characteristic

☞ The value in parameter S-0-0201 has to 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 this 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 number "1" or "4"):

- S-0-0383, Motor temperature

5.2 Rexroth Motors

5.2.1 Basics on Rexroth Motors

Classification

Bosch Rexroth's "Electric Drives and Controls" technology field 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 delivered with the motor. They can be easily loaded to the

controller, however, from a data base in the "IndraWorks D" 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.

Thermal Motor Monitoring

Rexroth motors are thermally monitored by the controller and protected against overheating. To do this 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.

☞ Rexroth motors, by motor parameters made available and temperature evaluation adjusted in an optimum way, 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 measuring system. The individual motor series have different measuring systems which allows offering cost-efficient motors depending on the application.

The following measuring systems are used:

- HSF ("high-resolution servo feedback"), single- or multi-turn type
- Resolver, single- or multi-turn type

Together with Rexroth kit motors it is possible to use different encoder systems:

- Encoder with sine signals and EnDat interface, 1Vpp, Heidenhain standard
- Encoder with sine signals, 1Vpp, Heidenhain standard
- Encoder with square-wave signals, TTL, Heidenhain standard
- Hall sensor box and encoder with sine signals, 1Vpp, Heidenhain standard (only for Rexroth linear kit motors)
- Hall sensor box and encoder with square-wave signals, TTL, Heidenhain standard (only for Rexroth linear kit motors)

5.2.2 Rexroth Housing Motors

Rexroth Housing Motors With Encoder Data Memory

Motor Lines

The following Rexroth housing motors are equipped with an encoder data memory:

- MSK, MHD, MKE, MKD, KSM
- MAD, MAF

☞ The Bosch motor with the type designation "SF..." that can be controlled with IndraDrive controllers is equipped with an encoder data memory, too. As regards commissioning and parameters, SF motors have the same behavior as Rexroth housing motors with encoder data memory!

Brief Description

See section "Basics on Rexroth Motors"

Pertinent Parameters

The encoder data memory, amongst others, contains the parameters listed below.

Motor parameters:

- P-0-2109, Motor peak current, encoder memory
- P-0-2111, Motor current at standstill, encoder memory
- P-0-2113, Maximum velocity of motor, encoder memory
- P-0-2141, Motor type, encoder memory
- P-0-3002, Number of pole pairs/pole pair distance, encoder memory
- P-0-3003, Rotor inertia, encoder memory
- P-0-3005, Torque/force constant, encoder memory
- P-0-3007, Stator resistance, encoder memory
- P-0-3008, Commutation offset, encoder memory
- P-0-3050, Motor inductance, encoder memory

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

Only for resolvers as absolute encoders (multi-turn resolvers):

- P-0-1003, Pulse wire encoder offset 1, encoder memory
- P-0-1004, Pulse wire encoder status 1, encoder memory

Parameter for motor holding brake (if available):

- P-0-3010, Torque of motor holding brake, encoder memory

Default control loop parameters:

- P-0-2100, Velocity loop proportional gain, encoder memory
- P-0-2101, Velocity loop integral-action time, encoder memory
- P-0-2104, Position loop Kv-factor, encoder memory
- P-0-2106, Current loop proportional gain 1, encoder memory
- P-0-2107, Current loop integral-action time 1, encoder memory
- P-0-3004, Speed controller smoothing time constant, encoder memory

At a command, default control loop parameters can be loaded to the controller. They are useful starting values for further control loop optimization.

Pertinent Diagnostic Messages

- C07_0 Load defaults procedure com. (load controller param.)
- 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

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 controller when the drive is switched on.

At the initial commissioning of a drive, the error message "F2008 RL The motor type has changed." will appear. 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. Default control loop parameter values for this motor are thereby loaded.

☞ Depending on the setting in "P-0-4090, Index for C07 Load defaults procedure", the following parameter values are loaded with the "load defaults procedure" command (S-0-0262):

- Default control loop parameter values (default setting)

- Basic parameter values (default parameter set) of the firmware

---

In the case of motors with integrated holding brake, the type of motor holding brake and the activation of the brake control is automatically set in "P-0-0525, Holding brake control word".

In the case of motors with several cooling type variants (MHD, MKD), the load data can be referred to the cooling type realized by entering the corresponding value in "P-0-0640, Cooling type".

Recommissioning

When the machine is repaired, 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 type parameter 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 connection 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 type parameter are loaded

  → C07_0 Load defaults procedure com. (load controller param.)
- 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 Lines

The following Rexroth housing motors do not have an encoder data memory:

- 2AD, ADF, MAL

Brief Description

See section "Basics on Rexroth Motors"

Pertinent Parameters

The parameters mentioned under "Basics on the Motors to be Controlled" are used for these motors.

Functional Description

Application-Dependent Motor Parameters for Asynchronous Motors

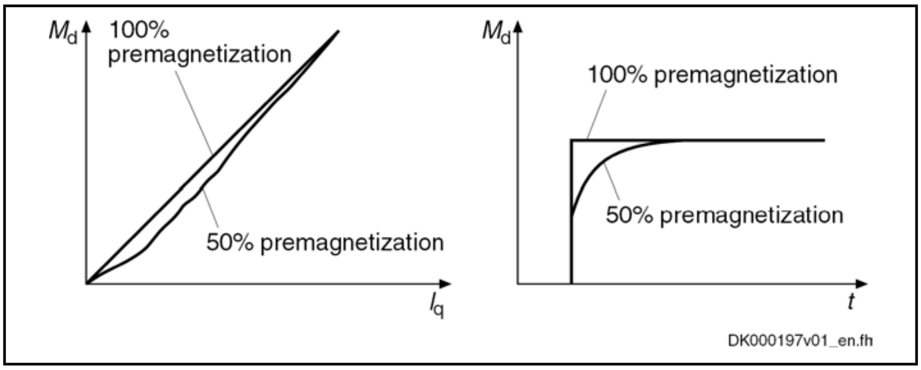
The Rexroth motors without encoder data memory, 2AD, ADF, MAD and MAF lines, are asynchronous motors. Therefore, a value adjusted to the application has to be written to the parameter "P-0-0532, Premagnetization factor".

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.5-2: Setting the Effective Magnetizing Current for Asynchronous Motors

The magnetizing current value determined for Rexroth motors by the manufacturer guarantees 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.



Md Torque at the motor shaft
Iq Torque-generating component of the motor current
Fig.5-3: Influence of the Premagnetization Factor on the Torque

Notes on Commissioning

Parameter Values Made Available

In the case of Rexroth motors without encoder data memory, the motor-specific parameter values made available, such as

- motor parameters
- parameters of the measuring system
- parameters of the motor holding brake
- temperature sensor parameters

can either be input manually by means of a list (e.g. via the control terminal) or loaded via the "IndraWorks D" commissioning tool from a data base.

Setting the Premagnetization Factor

The following table contains the recommended setting for the parameter "P-0-0532, Premagnetization factor", depending on the application.

Application	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

Fig.5-4: 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 Rexroth asynchronous motors (2AD, ADF, 1MB, MAD, MAF), published by Rexroth, refer to a premagnetization of 100%.

With lower values, you have to expect deviation from these data!

5.2.3 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
- Bearing

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 manufactured according to the "asynchronous motor" or "synchronous motor" functional principles. 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 "synchronous motor" functional principle:

- LSF and MLF linear motors
- MBS and MBT rotary motors

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 the use of 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:

- **Calculation method** for relative motor encoder when using the Hall sensor box

  → Distance measurement, currentless (only possible for Rexroth linear kit motors)
- **Measuring method** for motor encoders that can be evaluated in absolute form

  → Distance measurement, currentless (only possible for Rexroth linear 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!

Description of the method for commutation setting, see "Drive Control: Commutation Setting"

Rexroth Kit Motors, Asynchronous

Brief Description

The following Rexroth kit motors are manufactured according to the "asynchronous motor" functional principle:

- 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 and as an absolute encoder! Avoid using encoders with square-wave signals!

The parameters mentioned under "Basics on the Motors to be Controlled" are used for these motors.

Notes on Commissioning

Parameter Values Made Available

For commissioning the motor-specific parameter values made available by Rexroth, such as

- motor parameters and
- temperature sensor parameters

can either be input manually by means of a list (e.g. via the control terminal) or loaded via the "IndraWorks D" commissioning tool from a data base.

Premagnetization Factor

A value adjusted to the application has to be written only to the parameter "P-0-0532, Premagnetization factor".

See section "Rexroth Housing Motors without Encoder Data Memory"

5.3 Third-Party Motors at IndraDrive Controllers

5.3.1 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 Design 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.

See documentation "Rexroth IndraDrive – Drive System, Project Planning Manual" (DOK-INDRV*-SYSTEM*****-PR**-EN-P; part no.: R911309636)!

How to Commission?

The motor parameter values have to be determined first (see section "Determining the Parameter Values for Motor and Motor Control"). The parameter values of motor control are calculated by command internally in the firmware.

It is advisable to document the determined motor parameter values in the forms contained in the section "Forms for Parameter Values".

5.3.2 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.

5.3.3 Determining the Parameter Values of Third-Party Motors

General Information on How to Determine the Parameter Values

As Bosch 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 the following commands:

- **C3200 Command Calculate motor data**

  → For asynchronous motors, drive-internal calculation of the values for the motor control parameters from the data on the type plate

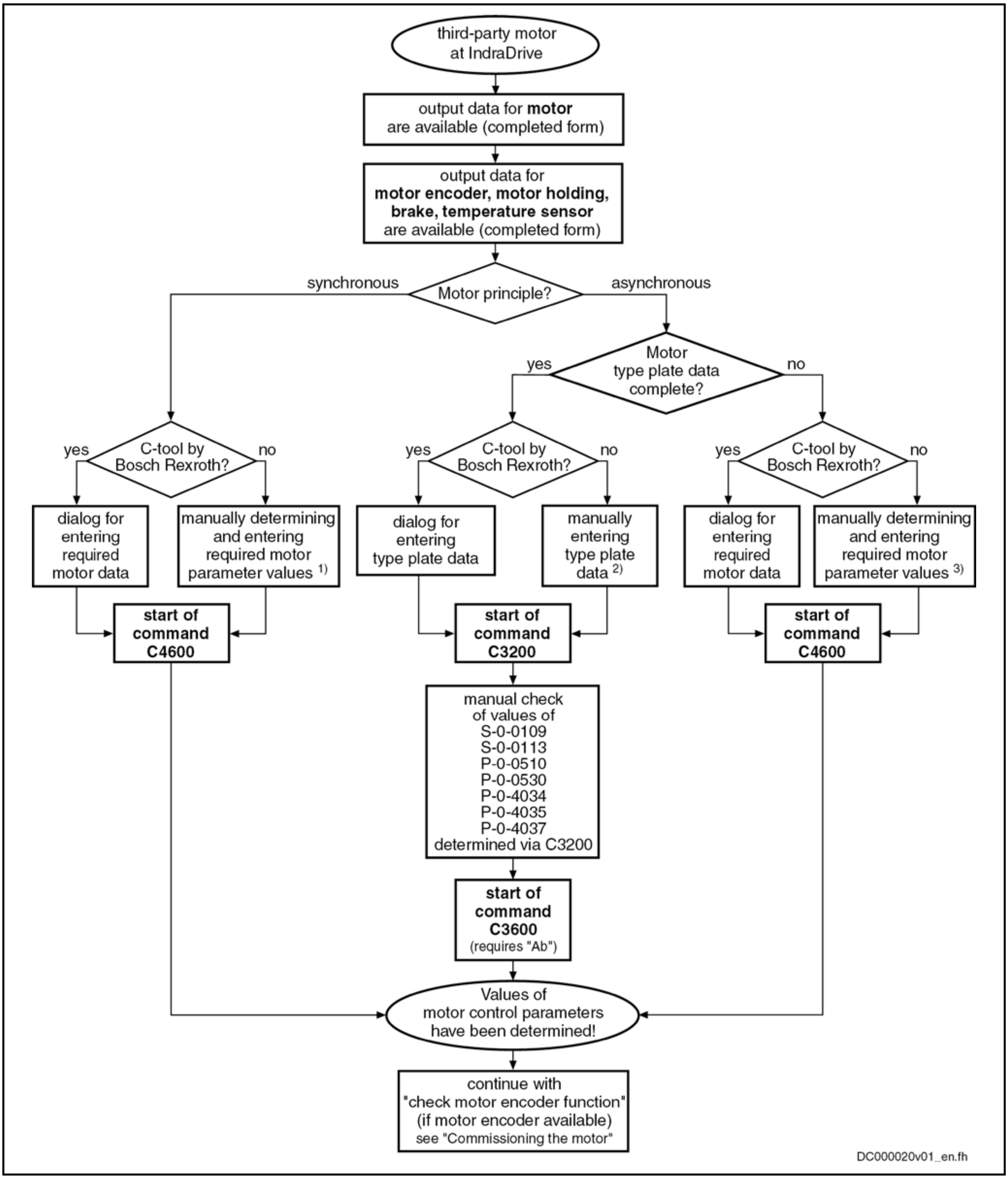
- **C3600 Command Motor data identification**

  → For asynchronous motors, drive-internal optimization of the motor control parameter values calculated by means of the command C3200

- **C4600 Command Calculate motor control parameters**

  → Calculating the motor control parameter values from the motor-specific data for synchronous motors and, if necessary, also for asynchronous motors (after manual input of motor-specific data in addition to the data from the type plate)

The specific motor data have to 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 D)
Fig.5-5:	*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)

On the basis of the motor-specific data made available by the manufacturer, you have to determine the motor parameter values for synchronous third-party motors. For asynchronous motors, the values can be determined in an external way, apart from the drive-internal way via the commands C3200 and C3600.

How to Proceed Without "IndraWorks D"

The collection of the motor parameter values to be determined is supported by the forms "Motor Parameters for Synchronous Motors" or "Motor Parameters for Asynchronous Motors" .

How to Proceed With "IndraWorks D"

If you use the commissioning tool "IndraWorks D", the values of 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 determined by means of the corresponding dialog, stored in a file and then loaded to the controller.

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 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 indicated in parameter "S-0-0109, Motor peak current".

For asynchronous motors, there usually isn't any value indicated 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 limitation according to the following relationships for thermal reasons:

$$\text{Rotary motors} \quad (\text{S-0-0109}) = f \times I_N$$

$$\text{Linear motors} \quad (\text{S-0-0109}) = f \times I_d$$

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.5-6: 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).

$$\text{Rotary synchronous motors } (S\text{-}0\text{-}0111) = I_N$$
$$\text{Linear synchronous motors } (S\text{-}0\text{-}0111) = I_d$$

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.5-7: Calculating the Value of Parameter S-0-0111 for Synchronous Motors

$$\text{Rotary asynchronous motors } (S\text{-}0\text{-}0111) = I_N \times \cos\varphi$$

S-0-0111	Motor current at standstill (rms value)
I_N	Rated current (rms value, acc. to motor data)
cos φ	Power factor

Fig.5-8: 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:

$$\text{Rotary synchronous motors } (P\text{-}0\text{-}0051) = \frac{M_N}{I_N}$$
$$\text{Linear synchronous motors } (P\text{-}0\text{-}0051) = \frac{F_N}{I_d}$$

P-0-0051	Torque/force constant (in Nm/Arms for rotary motors; in N/Arms for linear motors)
M_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.5-9: Calculating the Value of Parameter P-0-0051 for Synchronous Motors

$$\text{Rotary asynchronous motors } (P\text{-}0\text{-}0051) = \frac{M_N}{I_N \times \cos\varphi}$$

P-0-0051	Torque/force constant (in Nm/Arms for rotary motors; in N/Arms for linear motors)
M_N	Rated torque (acc. to motor data)
I_N	Rated current (rms value, acc. to motor data)
cos φ	Power factor

Fig.5-10: Calculating the Value of Parameter P-0-0051 for Asynchronous Motors

Stator Resistance

Calculating the value for 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.5-11: Calculating the Value of Parameter P-0-4048

☞ By menu prompt via dialogs, the commissioning tool "IndraWorks D" supports the input of the motor parameter values of third-party motors by means of the forms "Manufacturer-Side Data of Synchronous Motors" or "Manufacturer-Side Data of Asynchronous Motors" completed by the motor manufacturer!

Manual Input of Motor Parameter Values for Synchronous Motors

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" mustn't 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.5-12: 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.5-13: 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

$$(P\text{-}0\text{-}4005) = -\left[2 \times (S\text{-}0\text{-}0111)\right]$$

P-0-4005	Flux-generating current, limit value
S-0-0109	Motor peak current
S-0-0111	Motor current at standstill

Fig.5-14: Calculating the value of parameter P-0-4005 (The value with the smaller absolute value has to be entered with negative sign in parameter P-0-4005.)

☞ By menu prompt via dialogs, the commissioning tool "IndraWorks D" 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!

Manual Input of Motor Parameter Values for Asynchronous Motors

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.5-15: 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:

$$(P\text{-}0\text{-}4004) = \sqrt{1 - (\cos\varphi)^2} \times I_N$$

P-0-4004	Magnetizing current (rms value in A)
I_N	Rated current of the motor (rms value in A)
$\cos\varphi$	Power factor at rated load

Fig.5-16: 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

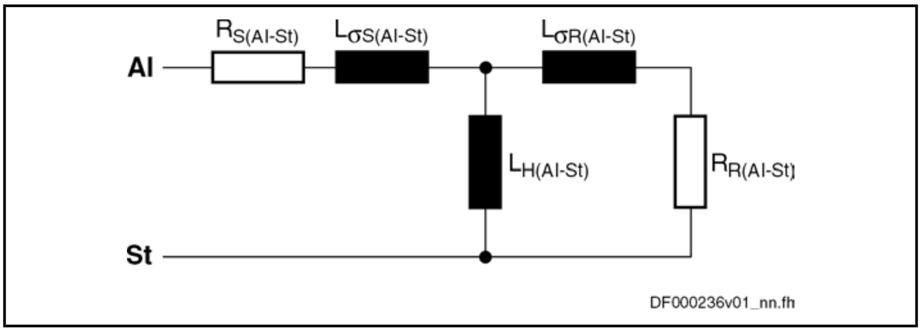
The values for the parameters P-0-4039, P-0-4040, P-0-4041 refer to the single-phase equivalent circuit diagram of asynchronous motors with star point reference (see below).

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.5-17: Values of Parameter 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.5-18: 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 values 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:

$$(P\text{-}0\text{-}4043) = \frac{L_{\sigma S(Al\text{-}St)} + L_{H(Al\text{-}St)}}{R_{R(Al\text{-}St)}} = \frac{(P\text{-}0\text{-}4040) + (P\text{-}0\text{-}4041)}{R_{R(Al\text{-}St)}}$$

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.5-19: Calculating the Value of Parameter P-0-4043 by Means of Approximation

☞ By menu prompt via dialogs, the commissioning tool "IndraWorks D" 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!

5.3.4 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)	M_N / F_N	Nm / N	
Rated current	I_N	A_{eff}	
Rated speed or rated velocity 1)	n_N / v_N	min^{-1} / m/min	
Rated voltage	U_N	V_{eff}	
Continuous current at standstill 1)	I_d	A_{eff}	
Inertia or mass	J / m	_	
Rated force 1)	F_N	N	
Allowed maximum current (magn. saturation effects?)	I_{max}	A_{eff} (yes/no)	
Maximum torque or maximum force 1)	M_{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	$\hat{u}_{max\_zul.}$	$V_{pp/2}$	
Allowed rate of rise of voltage	$du/dt_{zul.}$	kV/µs	
Cooling type (without/with blower, liquid cooling)	--	--	
Thermal time constant of motor	T_{Motor}	min	See "Limitations"
Thermal time constant of winding	$T_{Wicklung}$	s	See "Limitations"
Thermal short-time overload of winding	$k_{Überlast}$	--	See "Limitations"
Type of construction of motor (rotary/linear)	--	--	
Type of winding (distributed winding/toothed winding)	--	--	
Winding body material (iron/ironless)	--	--	

1) Only for linear motor

Fig.5-20: Motor Data of Synchronous Motors

☞ Take form "Manufacturer-Side Data of Motor Temperature Sensor, Motor Encoder and Motor Holding Brake" into account, too!

Name	Date	Signature

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	M_N	Nm	
Rated current 1)	I_N	A_{eff}	
Power factor 1)	cos φ	--	
Magnetizing current	I_{Mag}	A_{eff}	
Rated speed 1)	n_N	min^{-1}	
Rated frequency 1)	f_N	Hz	
Rated voltage 1)	U_N	V_{eff}	
Inertia	J	_	
Maximum speed	n_{max}	min^{-1}	
Number of pole pairs	PPZ	--	
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	
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	$\hat{u}_{max\_zul.}$	$V_{pp/2}$	
Allowed rate of rise of voltage	$du/dt_{zul.}$	kV/µs	
Cooling type (without/with blower, liquid cooling)	--	--	
Thermal time constant of motor	T_{Motor}	min	See "Limitations"
Thermal time constant of winding	$T_{Wicklung}$	s	See "Limitations"
Thermal short-time overload of winding	$k_{Überlast}$	--	See "Limitations"
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

Fig.5-21: Motor Data of Asynchronous Motors

☞ Take form "Manufacturer-Side Data of Motor Temperature Sensor, Motor Encoder and Motor Holding Brake" into account, too!

Name Date Signature

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?	

Fig.5-22: Data of Temperature Sensor

Motor encoder data (if available)

Kind/standard?	
Signal amplitude?	
Signal shape?	
Cycles/revolution? Division period/µm?	
Manufacturer?	
Type of construction?	

Fig.5-23: Data of Motor Encoder

Data of motor holding brake (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	

Fig.5-24: Data of Motor Holding Brake

Name Date Signature

5.3.5 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)".

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 / moved mass		(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

Fig.5-25: Motor Parameters for Synchronous Motors

Form "Motor Parameters for Asynchronous Motors"

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 / moved mass		(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

Fig.5-26: 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 description in the section "Determining the Motor Parameter Values for Manual Input (for Command C4600)" .

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	Feedback 1 Resolution		
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		

Fig.5-27: Parameters for Temperature Monitoring, Motor Encoder and Holding Brake

5.3.6 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 commissioning tool "IndraWorks D" simplifies the commissioning of third-party motors.

See also "Commissioning the Motor"

Basic Commissioning Steps for Third-Party Motors

The commissioning of a third-party motor (synchronous and asynchronous motors) starts with the following basic steps:

1. First check whether third-party motor has been connected according to manufacturer's specification.
2. Enter type designation of third-party motor in parameter "S-0-0141, Motor type". For closed-loop operation (obligatory for synchronous motors, optional for asynchronous motors), settings for motor encoder have to be made in corresponding parameters:
   - S-0-0116, Feedback 1 resolution
   - S-0-0277, Position feedback 1 type

- P-0-0074, Encoder type 1 (motor encoder)

3. Settings for motor temperature sensor and motor temperature model have to be made in 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
4. 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
- Specific prompts of the comfort control panel (optional equipment of the control section) 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. Manufacturer-side motor data have to be entered in motor parameters or converted by means of completed form "Manufacturer-Side Data of Synchronous Motors" (see "Determining the Parameter Values of Third-Party Motors"). All required motor parameters are listed in form "Motor Parameters for Synchronous Motors" (data can already be entered in communication phase "P2").

   Note: If you use the commissioning tool "IndraWorks D", the values of the motor parameters, after the motor-specific data have been input (via dialog), are determined, stored in a file and then loaded to the controller.
2. Then "P-0-0566, C4600 Command Calculate motor control parameters" has to be started for calculating values of motor control parameters.
3. After having successfully completed command execution, values of motor control parameters have been calculated and stored. Initial commissioning for initial start of motor can be continued with "check motor encoder function".

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

☞ Before the initial start it is obligatory to set the commutation offset for synchronous third-party motors. Only with correctly set commutation offset is the motor operational and safe to operate!

See also "Commutation Setting"

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 status "ready for power output" ("Ab"); then start command.

   Note: The command C3600 may only be started when the motor is in standstill. This is monitored by a possibly available motor encoder. If there is no motor encoder available and the motor is not in standstill at the start of the command, the results can be invalidated!
4. Depending on whether a motor encoder is used, initial commissioning for initial start of motor can be continued with "check motor encoder function" (in closed-loop operation) or with "setting the kind of motor control" (in open-loop operation).

   See "Commissioning Motors: Initial Start With the Commissioning Tool"
5. 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

5.4 Motor Holding Brake

5.4.1 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.

☞ 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 controls 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 holding 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. Voltage 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 mustn't 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 has to be controlled separately.

☞ The optionally available holding brakes of Rexroth motors can be directly controlled via the 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 motor holding brake
- P-0-0543, C3800 Command Apply motor 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 holding) and self-holding (electrically releasing) motor holding brakes. The controller is informed of the brake type via the respective bit in parameter "P-0-0525, Holding brake control word".

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 on this delay via "S-0-0206, Drive on delay time".

In order to avoid wear of the brake the command value acceptance is blocked within this delay. Only then does the controller signal to the control unit, by means of a bit in the respective status word (e.g. "S-0-0135, Drive status word" for SERCOS), that it is ready to move.

See also "Basic Functions of Master Communication: Device Control and State Machines"

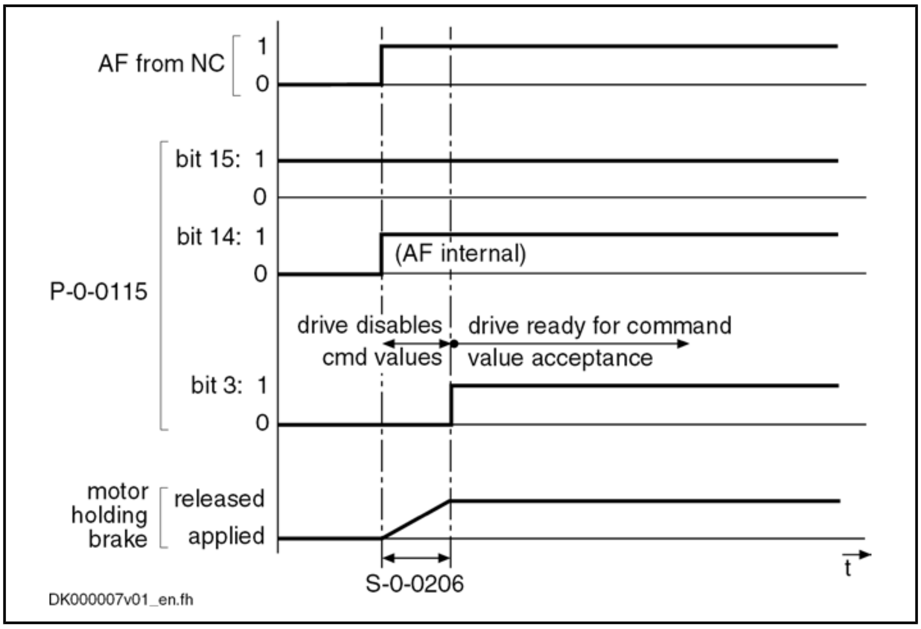


Fig.5-28: Time response when releasing the holding brake

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 on this delay via "S-0-0207, Drive off delay time".

In order to avoid, for example, that a non-equilibrated vertical axis in standstill does not move down due to weight force, "AF" (drive enable) is internally reset by this delay 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 on 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 in order 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" or "return motion" 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 drive 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 for minimizing 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 parameter "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" (in the case of "return motion" error reaction)

See also "Error Reactions"

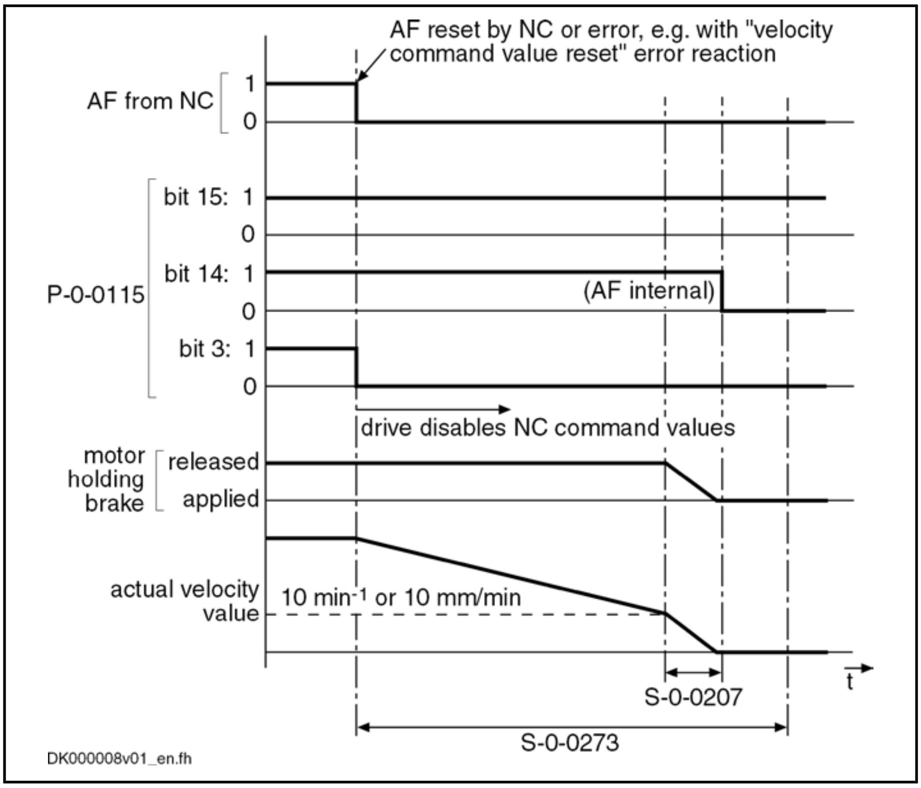


Fig.5-29: Holding brake control with error situation 1 and braking time < S-0-0273 (error reaction "velocity command value reset")

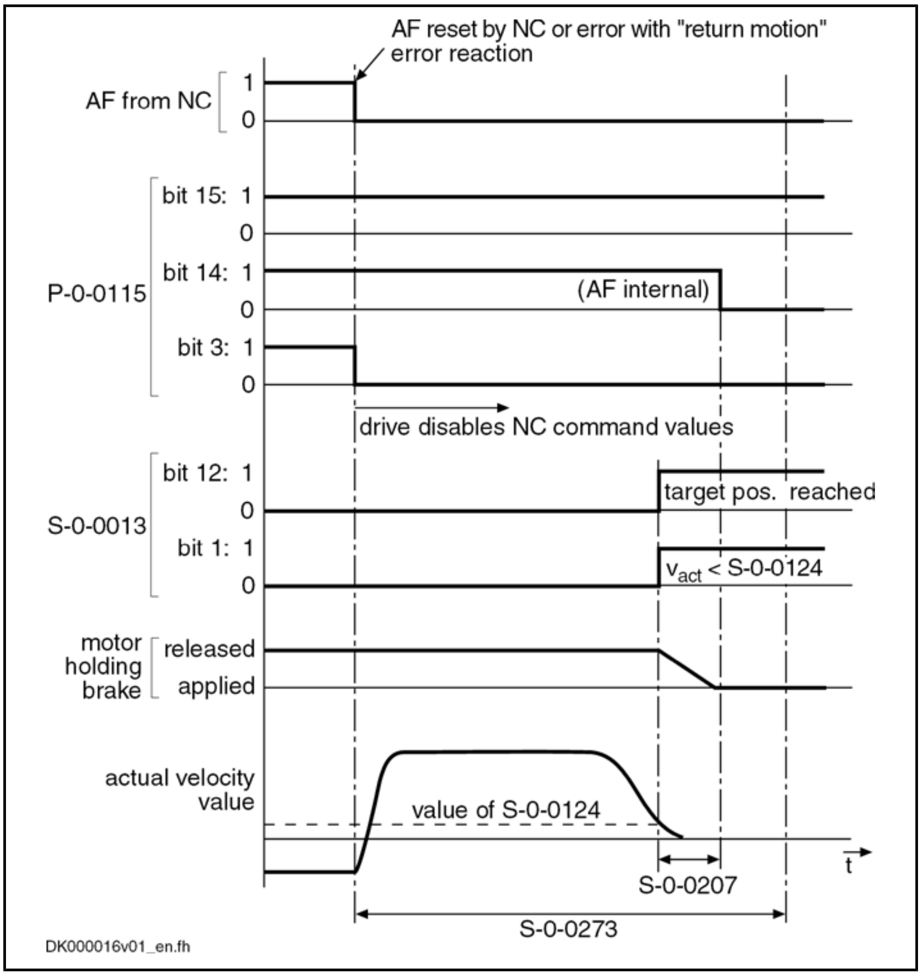


Fig.5-30: Holding brake control with error situation 1 and braking time < S-0-0273 (error reaction "return motion")

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):

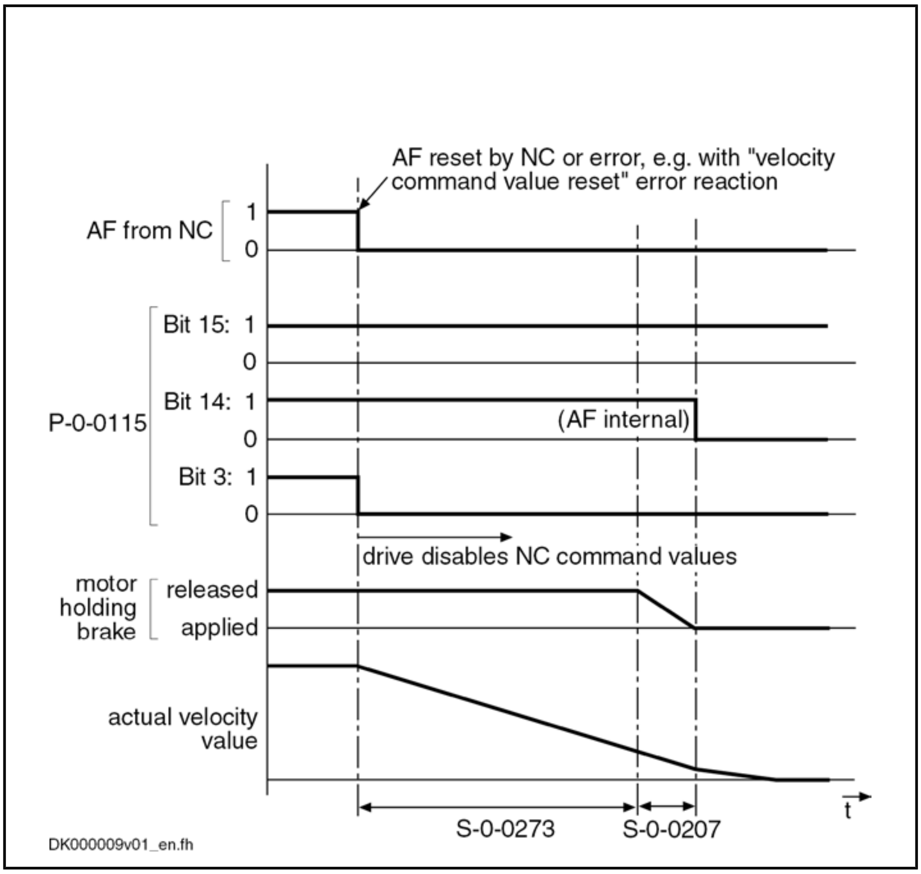


Fig.5-31: Holding brake control with error situation 1 and braking time > S-0-0273 for servo drives

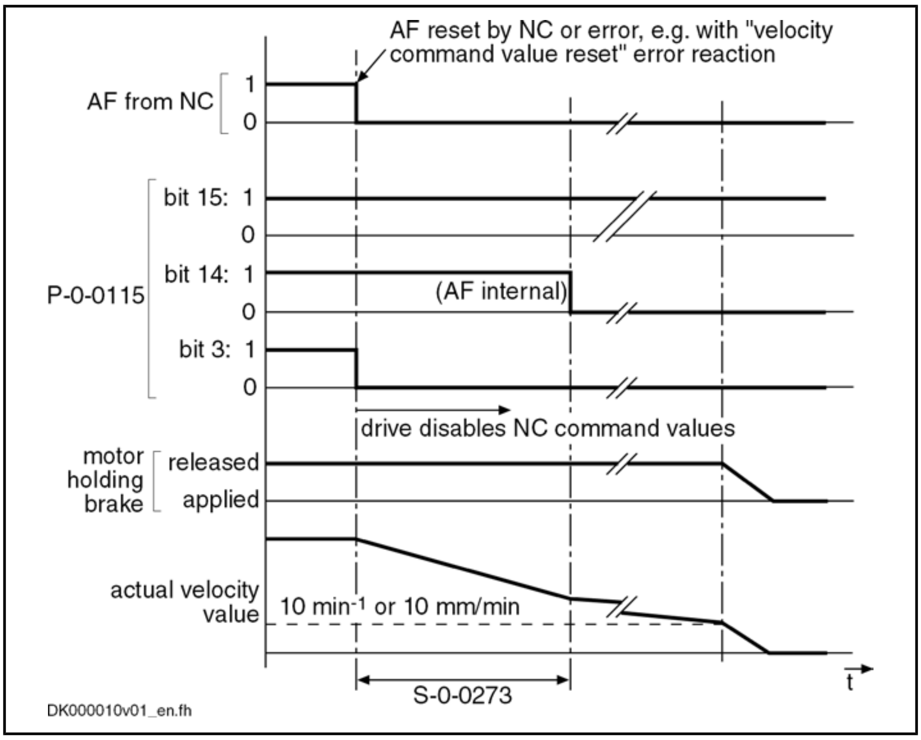


Fig.5-32: Holding brake control with error situation 1 and braking time > S-0-0273 for main drives

If the "return motion" error reaction has not yet been completed after the time set in S-0-0273, it is aborted:

- In the case of servo drives, the holding brake is applied. The internal drive enable is switched off with the delay of "drive off delay time".
- In the case of main drives, the internal drive enable is switched off immediately. The drive coasts to stop. After the velocity has fallen below the minimum value, the holding brake is applied.

Holding Brake Control with Error Situation 2

In the case of error situation 2, the drive becomes torque- 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).

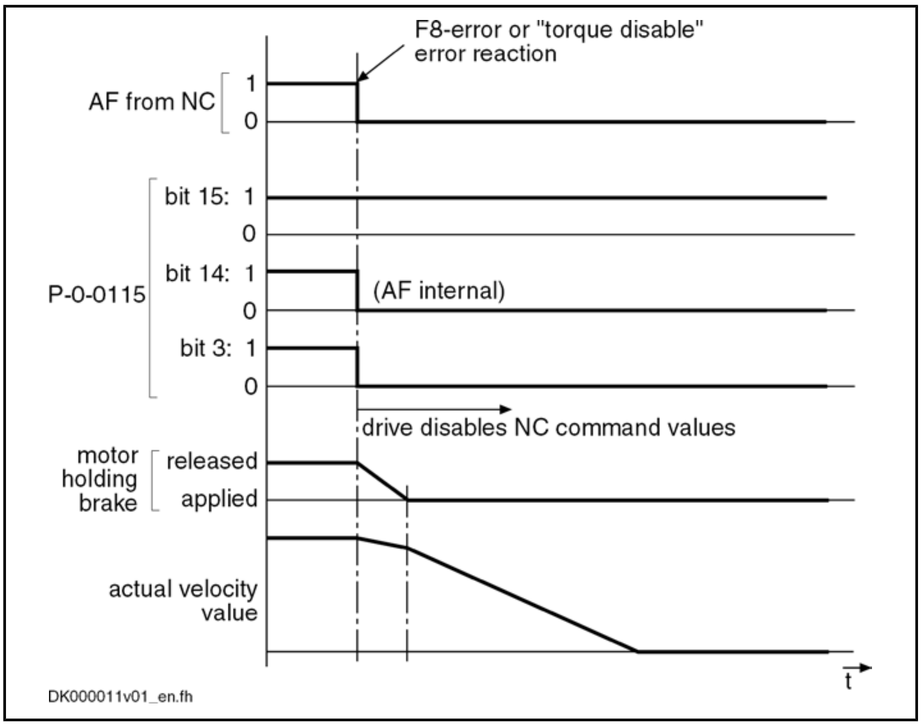


Fig.5-33: Holding brake control with error situation 2 for servo drives

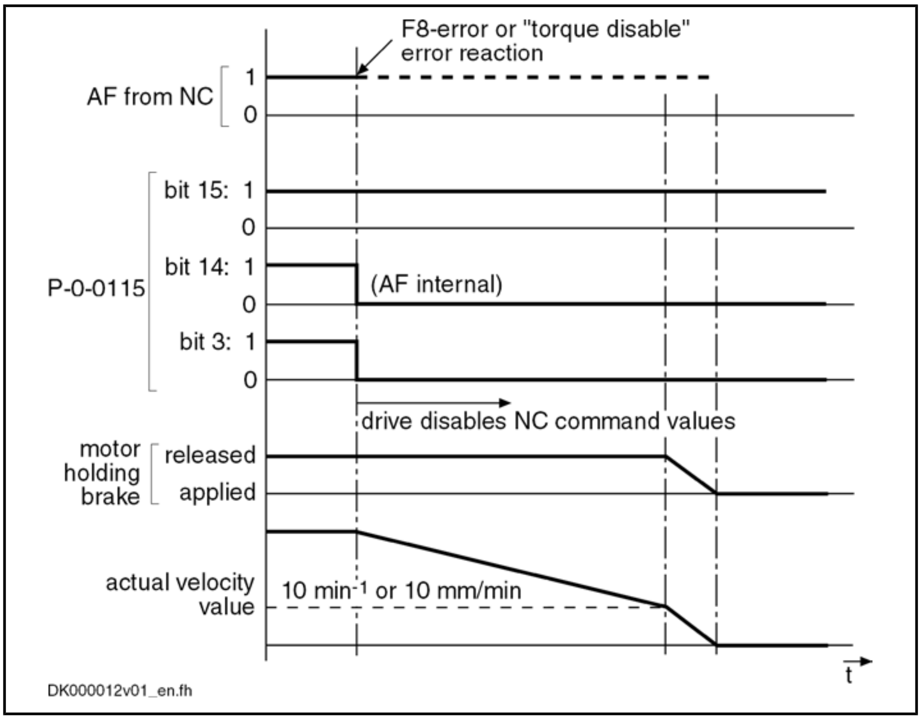


Fig.5-34: Holding brake control with error situation 2 for main drives

Command "Release Holding Brake"

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 motor holding brake". This command, however, first has to be enabled by the respective bit in "P-0-0525, Holding brake control word"!

CAUTION

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".

Command "Apply Holding Brake"

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, C2000 Command Apply motor holding brake"!

CAUTION

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 Brake check command"!

Influence of Drive Enable on Command "Apply Motor 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!

CAUTION

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

☞ The holding brake data are ...

- ... entered automatically when switching the drive on, in the case of Rexroth motors **with** encoder data memory!
- ... entered automatically only when loading the motor-specific parameter values from the data base of the "IndraWorks D" commissioning tool, in the case of Rexroth motors **without** encoder data memory!

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.

Command "Release Holding Brake"

The control unit can release the holding brake by means of the following command:

- P-0-0542, C2000 Command Release motor holding brake

CAUTION

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!

Command "Apply Holding Brake"

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 motor holding brake

CAUTION

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 Brake 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

Errors
- F6024 Maximum braking time exceeded

Command Errors
- C2001 Command not enabled

5.4.2 Function Check of Motor Holding Brake, Drive-Controlled

Brief Description

If the brake 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 and recording the monitoring intervals:

- Automatically each time drive enable is set and reset
- Depending on the situation at a command of the control master

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.

In the case of corrosion, the effectiveness of the holding brake can be rees- tablished 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 Brake check command
- P-0-0544, C3900 Command Brake resurfacing
- P-0-0545, Test torque for releasing motor holding brake
- P-0-0546, Starting torque for releasing motor holding brake
- P-0-0547, Nominal load of holding system
- P-0-0549, Oper. hours control section at last successful brake check
- P-0-0550, Time interval brake check

Pertinent Diagnostic Messages
- C2100 Brake check command
- C2101 Brake check only possible with drive enable
- C2103 Brake torque too low
- C2104 Command execution impossible
- C2105 Load of holding system > test torque
- C2106 Test torque of holding system not reached
- C3900 Command Brake resurfacing
- C3901 Resurfacing of brake only possible with drive enable
- C3902 Error during resurfacing of brake
- C3903 Command execution impossible
- E2069 Brake torque too low
- E3115 Prewarning, end of brake check time interval
- F2069 Error when releasing the motor holding brake
- F3115 Error, 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 a routine:

- Automatically each time drive enable is set and reset

- or -

- Depending on the situation, by "P-0-0541, C2100 Brake check command"

If the holding brake is all right the drive is operational after the routine is over. If the brake torque is too low the controller outputs the respective message.

The relevant bits for the desired kind of brake monitoring have to be set in "P-0-0525, Holding brake control word".

Automatic Monitoring

The automatic brake monitoring function is started when "AF" (drive enable) is set. After the time required for releasing the holding brake the motor generates a torque or a force; this sets the motor slightly in motion if the status of the holding brake is without error. The maximum value of this torque or force is determined during initial commissioning and entered in parameter "P-0-0545, Test torque for releasing motor holding brake" (described in the Notes on Commissioning for function check of holding brake).

If the test was successful, the drive starts operations.

If the motor does not move during this check, the error message "F2069 Error when releasing the motor holding brake" is output; the drive switches off.

When "AF" (drive enable) is reset by the master the holding torque of the brake is checked. After the holding brake was applied, a torque or force is generated that mustn't yet set the motor in motion if the status of the holding brake is correct. The value of this torque or force can be entered in parameter "P-0-0547, Nominal load of holding system". This value, too, is determined during initial commissioning (described in the Notes on Commissioning for function check of holding brake).

If the motor does not move during this check, the brake has the specified or required holding torque.

If the motor moves during this check, the diagnostic message "E2069 Brake torque too low" is output and drive enable is internally reset.

The warning E2069 is triggered in the case of the following motor motion:

- Rotary motors: >2 dgr
- Linear motors: Pole pair distance (in mm)/180 → P-0-0018/180

CAUTION

Possible property damage caused by vertical axis moving down!

⇒ Take constructional precautions!

Command "Brake Check"

At the start of "P-0-0541, C2100 Brake check command", the drive must be in "AF" (drive enable).

The routine corresponds to that of automatic monitoring (see above).

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 brake 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 Error, brake check time interval exceeded" is generated.

The warning E3115 disappears automatically when the brake check is successfully carried out within 15 min after the message had been generated. The brake check is carried out, for example, by starting "C2100 Brake check command" or, if automatic brake check was set, 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 Brake check command". 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 section at last successful brake 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, at the latest 15 min after drive enable had been set.

☞ 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 dimensioning and testing!

Reestablishing the Holding Brake Torque

For reestablishing the brake torque, "C3900 Command 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!

CAUTION

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

Command "Brake Check"

The control unit can activate the brake check by means of a command:

- P-0-0541, C2100 Brake check command

CAUTION

Property damage caused by drive-controlled axis movements during brake check!

⇒ Before starting the command, move the axis to a noncritical position!

Automatic Brake Check

The "brake check" function can also take place automatically, every time drive enable is set and reset. The function is activated via the respective bit in parameter

- P-0-0525, Holding brake control word.

Presetting the Brake Check

Check for brake released:

The status "holding brake released" 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 motor holding brake.

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 motor holding brake.

If the value "0" is entered in parameter P-0-0545 (or it 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 value can be preset in parameter

- P-0-0547, Nominal load of holding system.

The criterion for which the check is to be carried out is decisive for determining an appropriate value for P-0-0547:

- 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"

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"!

☞ 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 enter the demanded test torque or test force in parameter P-0-0547!

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"! If the "increased holding torque" is lower than the value of parameter P-0-0540, the tolerance range for detection of holding brake wear is increased which increases the service life of the holding brake!

Criterion "Brake Check Time Interval"

The criterion "brake check time interval" 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 brake check".

Command "Brake Resurfacing"

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 Brake resurfacing

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

Warnings

- E2069 Brake torque too low

Errors

- F2069 Error when releasing the motor holding brake

Command Errors

- C2101 Brake check only possible with drive enable
- C2103 Brake torque too low
- C2104 Command execution impossible
- C2105 Load of holding system > test torque
- C2106 Test torque of holding system not reached
- C3901 Resurfacing of brake only possible with drive enable
- C3902 Error during resurfacing of brake
- C3903 Command execution impossible

5.5 Measuring Systems

5.5.1 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 status 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 measuring system and time-derivation

- Position control loop

  → Actual value by evaluating the position measuring 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 Measuring

For acquiring the actual values of the velocity and position control loop there are position measuring 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 Measuring Systems

Position measuring 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)

- or -

- Absolute encoders (absolute value encoders).

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") after each time the drive is 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 each time the drive is switched on the correct actual position value is immediately available with 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)
- The absolute encoder precision
- The digitalization quality of the 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 three 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. It must be equipped with the encoder input appropriate for the encoder.

See also separate documentation "Drive Controllers, Control Sections; Project Planning Manual"

The following points apply to the parameters P-0-0077 and P-0-0078:

- In the case of motors with encoder data memory (MHD, MKD, MKE), the value for parameter P-0-0077 is automatically set correctly.
- In the case of motors without encoder data memory (2AD, ADF, rotary and linear 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 has to be set manually, too.

Pertinent Parameters

- S-0-0051, Position feedback 1 value
- S-0-0053, Position feedback 2 value
- S-0-0115, Position feedback 2 type
- S-0-0116, Feedback 1 resolution
- S-0-0117, Feedback 2 resolution
- 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 indicated by the manufacturer of the encoder.

Resolution (Division Periods)

The resolution of the measuring system (division periods) is entered in the following parameters:

- S-0-0116, Feedback 1 resolution
- S-0-0117, Feedback 2 resolution

Generally, the following applies:

→ **Feedback 1** means "motor encoder"

→ **Feedback 2** means "external or optional encoder"

The value of S-0-0116 or S-0-0117 can mean:

- In the case of rotary motor encoders or external rotary encoders, the number of division periods or cycles per encoder revolution (DP/rev)
- 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 resolvers as motor encoders or external resolver encoders, the number of pole pairs of the resolver

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).

In the case of Rexroth housing motors (MHD, MKD, MKE, 2AD, ADF, MAD, MAF) and linear motors with EnDat encoder, the correct value is automatically written to parameter S-0-0116!

Maximum 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)!

$$\text{Motor encoder (rotary)} \quad (\text{S-0-0116}) \times 2^{15}$$
$$\text{External encoder (rotary)} \quad (\text{S-0-0117}) \times 2^{15}$$

S-0-0116 Feedback 1 Resolution
S-0-0117 Feedback 2 Resolution
Fig.5-35: Maximum possible resolution of rotary 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 Feedback 1 Resolution
S-0-0117 Feedback 2 Resolution
Fig.5-36: Maximum possible resolution of linear encoders

Depending on the type of motion of the encoder, the "maximum encoder resolution after digitalization" is output 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 "±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:

Internal Encoder Resolution, Rotary Encoders

Motor encoder (rotary) (S-0-0116) × (S-0-0256)

External encoder (rotary) (S-0-0117) × (S-0-0257)

Auxiliary calculation and internal limiation:

$$(S\text{-}0\text{-}0256) = \frac{2^{30} \times c_{\_axis\_G1}}{(S\text{-}0\text{-}0116) \times (S\text{-}0\text{-}0278)} \leq 2^n \qquad n \leq 15 \text{ (in round numbers)}$$

$$(S\text{-}0\text{-}0257) = \frac{2^{30} \times c_{\_axis\_G2}}{(S\text{-}0\text{-}0117) \times (S\text{-}0\text{-}0278)} \leq 2^n \qquad n \leq 15 \text{ (in round numbers)}$$

S-0-0116	Feedback 1 Resolution
S-0-0256	Multiplication 1
S-0-0117	Feedback 2 Resolution
S-0-0257	Multiplication 2
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.5-37: Drive-internal resolution of rotary encoders

Internal Encoder Resolution, Linear 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:

$$(S\text{-}0\text{-}0256) = \frac{2^{30} \times (S\text{-}0\text{-}0116)}{(S\text{-}0\text{-}0278)} \leq 2^n \qquad n \leq 15 \text{ (in round numbers)}$$

$$(S\text{-}0\text{-}0257) = \frac{2^{30} \times (S\text{-}0\text{-}0117)}{(S\text{-}0\text{-}0278)} \leq 2^n \quad \text{(load reference)} \qquad n \leq 15 \text{ (in round numbers}$$

$$(S\text{-}0\text{-}0257) = \frac{2^{30} \times (S\text{-}0\text{-}0117)}{(S\text{-}0\text{-}0278) \times c_{\_bef\_M}} \leq 2^n \quad \text{(motor reference)} \qquad n \leq 15 \text{ (in round numbers}$$

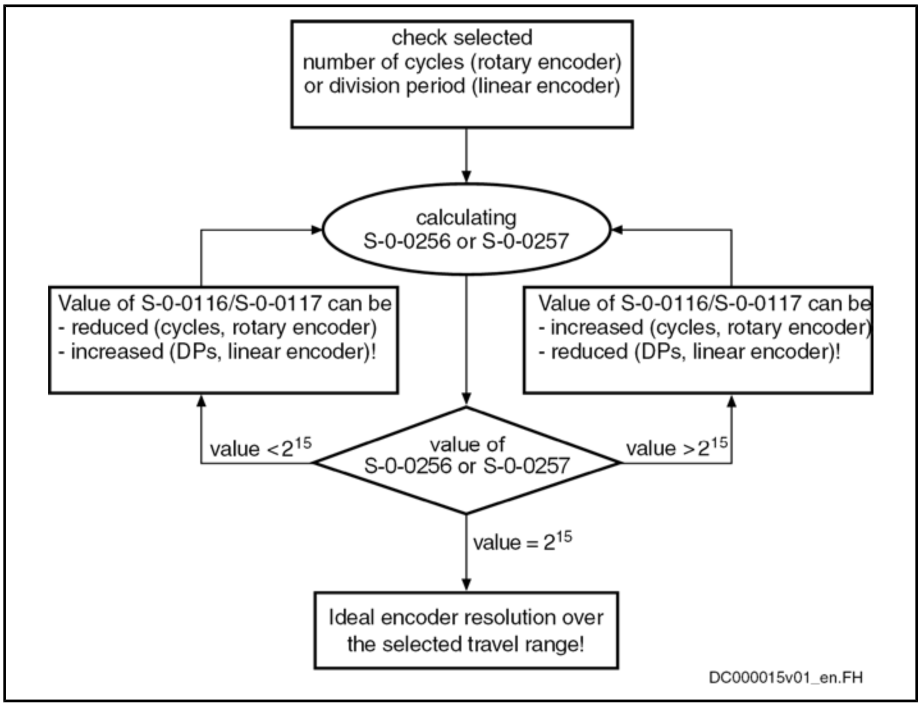
S-0-0116	Feedback 1 Resolution
S-0-0256	Multiplication 1
S-0-0117	Feedback 2 Resolution
S-0-0257	Multiplication 2
S-0-0278	Maximum travel range (± travel range)
$c_{\_bef\_M}$	infeed length / motor revolution

Fig.5-38: Drive-internal resolution of linear encoders

☞ Internally, the multiplication (S-0-0256 and S-0-0257) is automatically determined taking the value of parameter S-0-0278 into consideration.

Encoder Dimensioning

The multiplication values (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", characterize the encoder dimensioning.



S-0-0116 Feedback 1 Resolution
S-0-0117 Feedback 2 Resolution
Fig.5-39: Checking the selected resolution and determining the ideal resolution for 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 "$\geq 2^{15}$", 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
$n_{(S\text{-}0\text{-}0278)}$ number of motor revolutions for (S-0-0278)
S-0-0278 Maximum travel range (± travel range!)
Fig.5-40: 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.5-41: Drive-internal resolution of the position data for linear motors

Real Resolution of Rotary 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 encoder.

Real Resolution of Linear Encoders

The higher value from drive-internal encoder resolution and "maximum encoder resolution after digitalization" is the real resolution of the position data of a linear 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!

Notes on Commissioning

Configuring the Controller

The optional interfaces have to be assigned to the encoder connection in the following parameters:

- P-0-0077, Assignment motor encoder->optional slot
- P-0-0078, Assignment optional encoder ->optional slot

☞ In the case of motors with encoder data memory (MHD, MKD, MKE), the correct value is automatically written to parameter P-0-0077!

Configuring the Encoder

Set the motor encoder type:

- P-0-0074, Encoder type 1 (motor encoder)

Set the encoder type of the optional encoder:

- P-0-0075, Encoder type 2 (optional encoder)

Set the resolution (number of lines, division period) of the motor encoder:

- S-0-0116, Feedback 1 resolution

Set the resolution (number of lines, division period) of the optional encoder:

- S-0-0117, Feedback 2 resolution

Set the kind of encoder and the rotational direction of the motor encoder:

- S-0-0277, Position feedback 1 type

Set the kind of encoder and the rotational direction of the optional encoder:

- S-0-0115, Position feedback 2 type

☞ In the case of Rexroth housing motors (MHD, MKD, MKE, 2AD, ADF, MAD, MAF), the correct value is automatically written to the parameters P-0-0074, S-0-0116 and S-0-0277; in the case of linear motors with EnDat encoder, the correct value is automatically written to the parameters P-0-0074 and S-0-0116.

Setting the Travel Range

Enter the travel range of the axis:

- S-0-0278, Maximum travel range

Information on Position Evaluation

Current actual position value of the motor encoder:

- S-0-0051, Position feedback 1 value

Current actual position value of the optional encoder:

- S-0-0053, Position feedback 2 value

Position status of the connected encoders:

- S-0-0403, Position feedback value status

Multiplication of the motor encoder:

- S-0-0256, Multiplication 1 (motor encoder)

Multiplication of the optional encoder:

- S-0-0257, Multiplication 2 (optional encoder)

Resolution of the position data in the drive:

- P-0-0129, Internal position data format

☞ When the parameter S-0-0256 and, if available, S-0-0257 have the value "32768", the encoder evaluation is ideal. When the value is lower, the parameter S-0-0278 has to be checked for correct travel range input!

5.5.2 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. This allows, for example, detecting 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 status.

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: incorrect encoder signals.
- 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 Encoder 1: incorrect encoder signals (can be deleted in phase2)

Functional Description

IndraDrive controllers can evaluate signals of the following encoder types:

- Sine encoder 1 V_{pp} (Heidenhain standard)
- Resolver encoder (Rexroth standard)
- Square-wave encoder 5V TTL (Heidenhain standard)

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:

$$0{,}2 \times U_{A,B\_nom} \leq \sqrt{U_A^2 + U_B^2} \leq 1{,}5 \times U_{A,B\_nom}$$

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.5-42: 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 Encoder 1: incorrect encoder signals (can be deleted in phase2)
- F2042 Encoder 2: incorrect encoder signals.

The drive then reacts with the error reaction that has been set.

Signal Monitoring for Resolver Encoders

Monitoring the analog resolver encoder signals with carrier frequency is only possible by the calculated analysis of digitized values:

$$0{,}5 \times U_{A,B\_nom} \leq \sqrt{U_A^{\,2} + U_B^{\,2}} \leq 1{,}2 \times U_{A,B\_nom}$$

$$U_{A,B\_nom} = U_{out\_Resolver} \times \ddot{u}_{Resolver}$$

U_{A,B_nom}	nominal amplitude value of the resolver tracks
U_A	amplitude of resolver track A
U_B	amplitude of resolver track B
$U_{out\_Resolver}$	controller output voltage for resolver supply
$\ddot{u}_{Resolver}$	gear ratio of the resolver

Fig.5-43: Allowed voltage range for the signal amplitudes of resolvers

☞ The resolver data and resolver voltage supply data are contained in the Project Planning Manuals for motors and controllers!

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!

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 fixed 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!

Monitoring Mechanical Transfer Elements

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 error message "F2036 Excessive position feedback difference" is generated. This monitoring function is active as of communication phase 4 and can be deactivated, too!

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. The drive then switches off with the error message "F2046 Max. signal frequency of encoder 2 exceeded".

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):

$$f_{out} = \frac{TP \times n_{max}}{60000 \frac{s}{min}}$$

f_{out}	encoder output frequency of encoder in kHz
TP	number of lines of encoder per revolution
n_{max}	maximum speed of spindle in 1/min

Fig.5-44: 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
1	GDS/GDM encoder (Rexroth standard)	70 kHz
2	incremental encoder with sine signals (signal specification of Heidenhain)	200 kHz
3	resolver encoder with encoder data memory	2 kHz
4	encoder with HIPERFACE interface from Stegmann	200kHz
5	incremental encoder with square-wave signals (signal specification of Heidenhain)	500 kHz
8	encoder with EnDat interface from Heidenhain	200 kHz

Fig.5-45: Maximum frequency for troublefree encoder evaluation

When the maximum encoder output frequency reaches or exceeds the maximum frequency stored in the firmware, it makes sense to deactivate the spindle encoder monitor.

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 "Drive Controllers, Control Sections; Project Planning Manual").

Notes on Commissioning

See also Notes on Commissioning in section "Basics on Measuring Systems, Resolution"

Setting the Axis Position Monitor (Only with Absolute Encoder)

If monitoring the axis position is desired when the drive is switched on the values for the monitoring window have to be entered:

- P-0-0095, Absolute encoder monitoring window for motor encoder
- P-0-0096, Absolute encoder monitoring window for opt. 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".

Setting the Position Difference Monitor

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, 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. Determine the occurred maximum value of the actual position value difference by means of the display parameter "P-0-0391, Actual position value difference encoder1 - encoder2".
3. Multiply this value with a safety factor (recommendad: 2-fold value) and enter it in parameter "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".

Configuring the Spindle Encoder Monitor

When using an optional encoder at a spindle you should first determine, during the initial commissioning procedure, whether the maximum input frequency of the respective encoder input is exceeded at maximum speed. To do this, accelerate the spindle to maximum speed.

To prevent the drive from switching off, while in operation, with the error message "F2046 Max. signal frequency of encoder 2 exceeded", you should deactivate the spindle encoder monitor. Therefor enter the respective value in the parameter

- P-0-0185, Control word of encoder 2 (optional encoder).

Diagnostic Messages

If the position deviation of a motor encoder or external encoder with absolute position data reference exceeds the value in P-0-0095 or P-0-0096 between the points of time the control voltage is switched off and on again, the drive generates the error message

- F2074 Actual pos. value 1 outside absolute encoder window

- or -

- F2075 Actual pos. value 2 outside absolute encoder window

The value in P-0-0095 or P-0-0096 has to be unequal zero; the value "0" deactivates the monitor!

When the actual position value difference of motor encoder and external encoder (P-0-0391) exceeds the value of S-0-0391, the drive generates the error message

- F2036 Excessive position feedback difference.

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 the encoder signal frequency of the external encoder exceeds the maximum value stored in the firmware (see above), the drive generates the error message "F2046 Max. signal frequency of encoder 2 exceeded".

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 Encoder 1: incorrect encoder signals (can be deleted in phase2)

- or -

- F2042 Encoder 2: Incorrect encoder signals.

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"

5.5.3 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 -

- absolute encoders (absolute value encoders)

if they have the required signal specification.

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 measuring system. The individual motor series have different measuring systems which allows offering cost-efficient motors depending on the application.

The following measuring systems are used:

- HSF ("high-resolution servo feedback"), single- or multi-turn type for MHD, MAD, MAF, 2AD, ADF motors
- HIPERFACE encoder (only such types authorized by Rexroth) for MSK motors
- Resolver, single- or multi-turn type for MKD, MKE motors

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:

- EnDat linear encoders (Heidenhain) for linear motors or linear axes
- Rotary EnDat encoders (Heidenhain) or Rexroth single-turn or Rexroth multi-turn encoders 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 to motor or mechanical axis system, it is necessary to determine the position offset between encoder and axis zero point (see also "Establishing the Position Data Reference") once at the initial commissioning. establishing position data reference for absolute measuring systems").

Hardware Requirements

For the signal specification of third-party encoders for position and homing signals with regard to amplitude and phase angle, see the "Drive Controllers, Control Sections; Project Planning Manual" documentation.

☞ Rexroth encoders correspond to 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!

Controlling 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 "P-0-0012, C0300 Command Set absolute measuring"). 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 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 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 not "in reference".	0b … 000

P-0-0019 Initial position value (can be defined by user)

Fig.5-46: 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 or 7 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)	External encoder(S-0-0115)	Motor encoder (S-0-0051)	External encoder(S-0-0053)	Notes on the commissioning status	Current position status (S-0-0403)
active	active	**original position** of motor encoder	**original position** of external encoder	Initial commissioning not yet carried out, none of the encoders has "reference".	0b … 000
		absolute value motor encoder	absolute value motor encoder	During the initial commissioning only the motor encoder was set "in reference".	0b … 01x
		absolute value ext. encoder	absolute value ext. encoder	During the initial commissioning only the external encoder was set "in reference".	0b … 10x
		absolute value motor encoder	absolute value ext. encoder	During the initial commissioning both encoders were set "in reference".	0b … 111
active	inactive	**original position** of motor encoder	**original position** of motor encoder	Initial commissioning not yet carried out, motor encoder not "in reference".	0b … 000
		absolute value motor encoder	absolute value motor encoder	Initial commissioning was carried out, the motor encoder was set "in reference".	0b … 01x
active	not possible	**original position** of motor encoder	**original position** of motor encoder	Initial commissioning not yet carried out, none of the encoders has "reference".	0b … 000
		absolute value motor encoder	absolute value motor encoder	During the initial commissioning only the motor encoder was set "in reference".	0b … 10x
inactive	active	**original position** of external encoder	**original position** of external encoder	Initial commissioning not yet 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 "in reference".	0b … 010x

Absolute evaluation		Actual position values when switching on			
Motor encoder(S-0-0277)	External encoder(S-0-0115)	Motor encoder (S-0-0051)	External encoder(S-0-0053)	Notes on the commissioning status	Current position status (S-0-0403)
not possible	active	**original position** of external encoder	**original position** of external encoder	Initial commissioning not yet 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 "in reference".	0b … 10x
inactive	inactive	P-0-0019	P-0-0019		0b … 000

P-0-0019 Initial position value (can be defined by user)

Fig.5-47: 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" have to 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!

5.5.4 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 bore 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:

- Move 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

For the signal specification for position and homing signals with regard to amplitude and phase angle, see the "Drive Controllers, Control Sections; Project Planning Manual" documentation.

Pertinent Parameters

- S-0-0115, Position feedback 2 type
- S-0-0116, Feedback 1 resolution
- S-0-0117, Feedback 2 resolution
- S-0-0165, Distance-coded reference offset A
- S-0-0166, Distance-coded reference offset B
- S-0-0277, Position feedback 1 type
- 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			Current position status (S-0-0403, bit 0..2)
Motor Encoder	External encoder	Motor encoder (S-0-0051)	External encoder (S-0-0053)	Notes on the operating status	
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 motor encoder	absolute value 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 motor encoder	absolute value ext. encoder	Axis was homed via motor encoder and external encoder.	0b … 111

P-0-0019 Initial position value

Fig.5-48: 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.

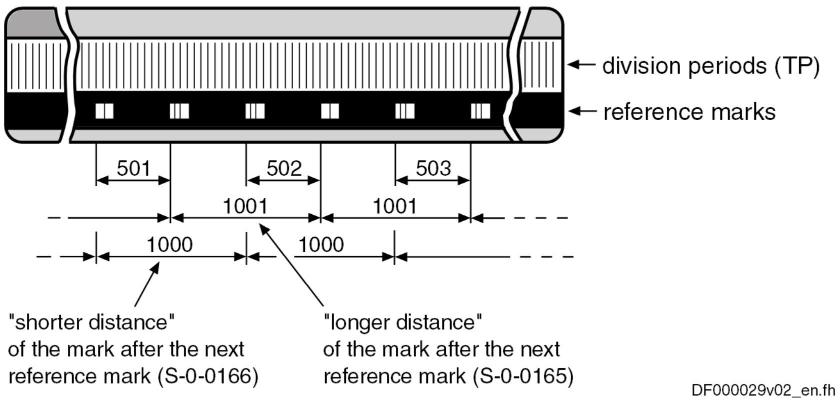
Reference Marks, Not Distance-Coded

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").

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 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.5-49:	*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 offset A" and "distance-coded reference offset B" have to be indicated by the manufacturer!

Determining the "Distance-Coded Reference Offset A"

If the value of "distance-coded reference offset A" is not directly indicated 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 reference point is indicated in the data sheet of the encoder:

Linear Encoders

General $$\text{S-0-0165} = \frac{x_{\text{ref}} + n \times \text{TP}}{\text{TP}}$$

Motor encoder $$\text{S-0-0165} = \frac{x_{\text{ref}} + n \times (\text{S-0-0116})}{(\text{S-0-0116})}$$

External encoder $$\text{S-0-0165} = \frac{x_{\text{ref}} + n \times (\text{S-0-0117})}{(\text{S-0-0117})}$$

S-0-0165	Distance-coded reference offset A (in number of DP)
x_{ref}	Travel distance for establishing the absolute reference point (in mm)
n	Number of DP of the distance difference (longer-shorter distance)
TP	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.5-50:	*Determining the value for the "longer distance" of the distance-coded reference marks with a relative linear encoder*

Rotary Encoders

$$\text{General} \quad \text{S-0-0165} = \frac{N_{cyc} \times \varphi_{ref}}{360°} + z$$

$$\text{Motor encoder} \quad \text{S-0-0165} = \frac{(\text{S-0-0116}) \times \varphi_{ref}}{360°} + z$$

$$\text{External encoder} \quad \text{S-0-0165} = \frac{(\text{S-0-0117}) \times \varphi_{ref}}{360°} + z$$

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.5-51: Determining the value for the "longer distance" of the distance-coded reference marks with a relative rotary encoder

Determining the "Distance-Coded Reference Offset B"

If the value of "distance-coded reference offset B" is not directly indicated 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 indicated in the data sheet of the encoder:

Linear Encoders

$$\text{General} \quad \text{S-0-0166} = \frac{x_{ref}}{TP}$$

$$\text{Motor encoder} \quad \text{S-0-0166} = \frac{x_{ref}}{(\text{S-0-0116})}$$

$$\text{External encoder} \quad \text{S-0-0166} = \frac{x_{ref}}{(\text{S-0-0117})}$$

S-0-0166	Distance-coded reference offset B (in number of DP)
x_{ref}	Travel distance for establishing the absolute reference point (in mm)
TP	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.5-52: Determining the value for the "shorter distance" of the distance-coded reference marks with a relative linear encoder

Rotary Encoders

$$\text{General} \quad \text{S-0-0166} = \frac{N_{cyc} \times \varphi_{ref}}{360°}$$

$$\text{Motor encoder} \quad \text{S-0-0166} = \frac{(\text{S-0-0116}) \times \varphi_{ref}}{360°}$$

$$\text{External encoder} \quad \text{S-0-0166} = \frac{(\text{S-0-0117}) \times \varphi_{ref}}{360°}$$

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.5-53: 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" have to 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 Establishing the Position Data Reference

5.6.1 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 it is necessary to move to a defined axis position and the actual position value is set to an axis-related value in a defined position

(exception: For relative encoders with distance-coded reference marks movement is only required via 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 command "NC-controlled homing" and for searching the reference point or dedicated point of the axis has to 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

Encoder Types Supported

IndraDrive controllers can evaluate a multitude of standard position encoders. 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 kind 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 (motor encoder)
- S-0-0115, Position feedback 2 type (external encoder)

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 measuring" 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"

Status Check of Position Data Reference

The current status 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 value of the respective position status bit of which encoder 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 motor encoder	absolute value 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 motor encoder	absolute value ext. encoder	Position data reference established for motor encoder and external encoder.
relative/ absolute	relative/ absolute	0b … 000	See "Absolute Measuring Systems" or "Relative Measuring Systems"		Position data reference was established neither for motor encoder nor for external encoder.

Fig.5-54: 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 (motor encoder)
- 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 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.

5.6.2 Establishing Position Data Reference for Absolute Measuring Systems (Set Absolute Measuring)

Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.5-55: Assignment to functional firmware package

See also 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 is automatically established by the drive by starting the "set absolute measuring" command.

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

- "set absolute measuring"

- or -

- "drive-controlled homing procedure".

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!).

Command "Set Absolute Measuring"

It is recommended to start the "set absolute measuring" 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 measuring" can also be executed with active drive.

Command "Drive-Controlled Homing Procedure"

When the command "drive-controlled homing procedure" (without previous start of "set absolute measuring") is started, the drive automatically moves the axis to a dedicated position, defined by a home switch and/or the zero position of the absolute encoder, and at this position establishes the position data reference.

For absolute encoders, the command "drive-controlled homing procedure" can be advantageously used after loss of position data reference after:

- encoder replacement in conjunction with a home switch,
- 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 Measuring"

By starting the command "set absolute measuring", 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 measuring" are realized via parameter settings.

Assigning the Axis-Related Actual Position Value with "Drive-Controlled Homing"

By starting the command "drive-controlled homing procedure", 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 "drive-controlled homing" are realized via parameter settings (see information on "Drive-Controlled Homing Procedure" in section "Establishing Position Data Reference for Relative Measuring Systems").

Pertinent Parameters

- S-0-0052, Reference distance 1
- S-0-0054, Reference distance 2
- P-0-0012, C0300 Command Set absolute measuring
- P-0-0177, Absolute encoder buffer 1 (motor encoder)
- P-0-0178, Absolute encoder buffer 2 (optional encoder)
- P-0-0612, Control word for setting absolute measuring
- P-0-1002, Absolute encoder offset 1, encoder memory

- P-0-1012, Absolute encoder offset 2, encoder memory

Pertinent Diagnostic Messages

- C0300 Command Set absolute measuring
- C0301 Measuring system unavailable
- C0302 Absolute evaluation of measuring system impossible
- C0303 Absolute encoder offset cannot be saved

Functional Description

Command "Drive-Controlled Homing Procedure" with Absolute Measuring Systems

The command "drive-controlled homing procedure" 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").

☞ The function "Drive-Controlled Homing Procedure" is described in section "Establishing Position Data Reference for Relative Measuring Systems".

Application Aspect, Requirement

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 "P-0-0612, Control word for setting absolute measuring".

Absolute Offset

When "C0600 Drive-controlled homing procedure command" was successfully completed, an absolute offset value could be determined. 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.

Command "Set Absolute Measuring"

Reference Position

By starting the command "set absolute measuring", 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 measuring" 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 1 value
S-0-0052 Reference distance 1
S-0-0053 Position feedback 2 value
S-0-0054 Reference distance 2
Fig.5-56: Actual position values after "set absolute measuring"

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 "P-0-0612, Control word for setting absolute measuring", the encoder for which the "set absolute measuring" 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 measuring", 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 Measuring"

The "set absolute measuring" command can be activated in the following operating states:

- Drive is ready for operation, but not active ("AB")
- Drive is active in position control ("AF")
- Drive is active and in "Drive Halt" ("AH")

Sequence of "Set Absolute Measuring"

When the "set absolute measuring" command is started, the reference of the selected encoder is cleared first (S-0-0403).

...with Inactive Drive ("AB") or in "Drive Halt (AH)"

After the reference was cleared, the new actual position value (S-0-0051/S-0-0053), with inactive drive ("AB" or "bb") and with drive in "Drive Halt (AH)", is set according to the preselected dedicated position (see formula "Actual position values after "set absolute measuring""). The new position reference takes immediate effect.

...with Drive Enable ("AF")

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 "Actual position values after "set absolute measuring"").

- 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 "Actual position values after "set absolute measuring"") 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 operating mode. After the master cleared the "drive-controlled homing procedure" command, the drive goes to master-controlled operation again.

...After Position Reference Has Been Established

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 measuring" command has to be cleared by the master!

Motor, Mechanical Axis System, Measuring Systems

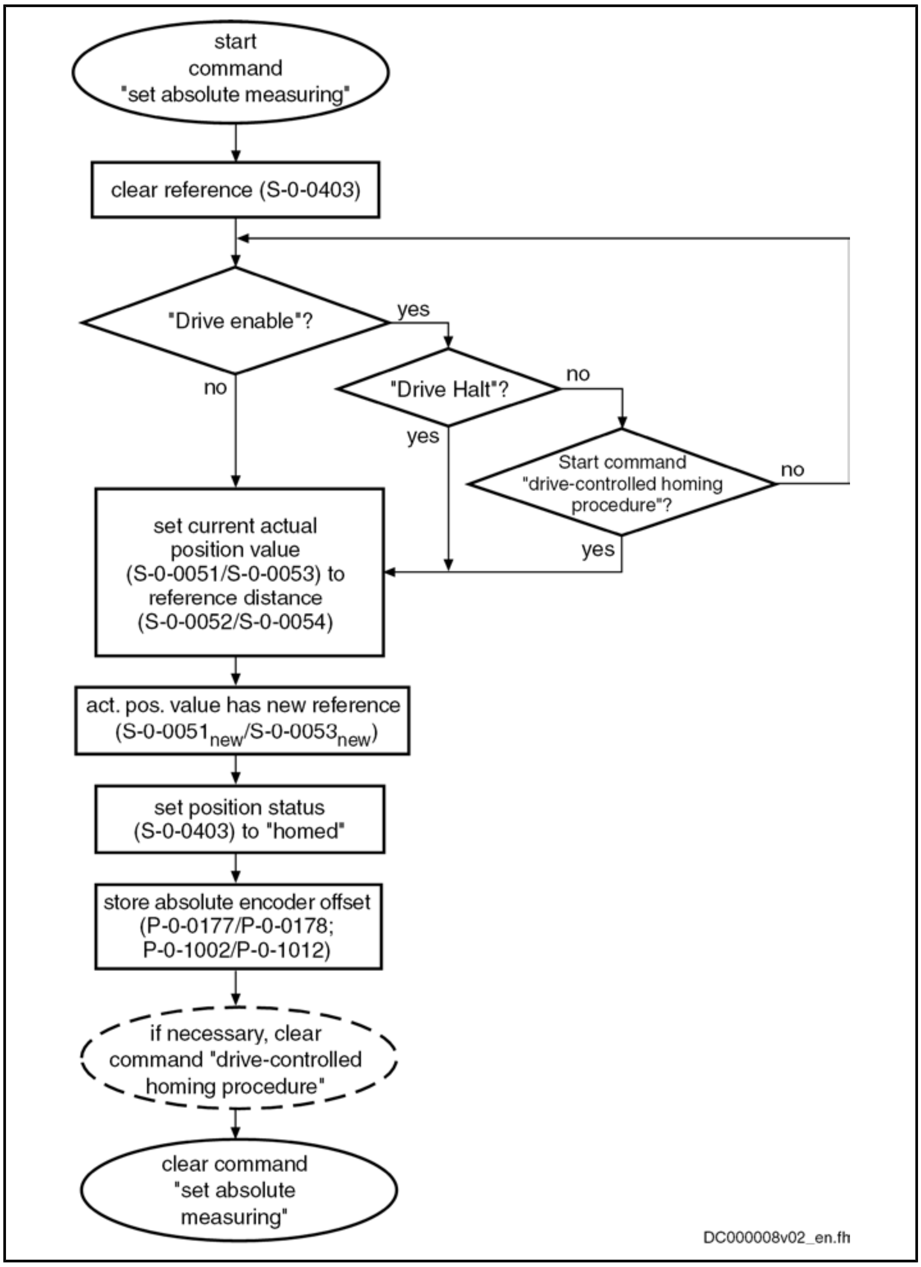


Fig.5-57: Sequence of "set absolute measuring" command execution

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

Make the presetting for "set absolute measuring" by determining the encoder for "set absolute measuring" in "P-0-0612, Control word for setting absolute measuring". Also set in this parameter whether the execution of "S-0-0148, C0600 Drive-controlled homing procedure command" is to be possible with absolute measuring system.

See Notes on Commissioning for "Drive-Controlled Homing Procedure" in section "Establishing Position Data Reference for Relative Measuring Systems"

Starting "Set Absolute Measuring"

Start the command "P-0-0012, C0300 Command Set absolute measuring".

See also "Command Processing"

Starting "Drive-Controlled Homing Procedure" If Necessary

If "set absolute measuring" 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 status "Drive Halt" (AH) to switch the actual position value. Removing drive enable (inactive drive), too, causes the actual position value to be switched (see fig. "Sequence of "set absolute measuring" command execution").

See also "Command Processing"

Checking Whether Position Data Reference was Established

The respective bit of "S-0-0403, Position feedback value status" displays whether the encoder selected via S-0-0612 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 measuring" 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 measuring" is carried out via command "drive-controlled homing procedure".

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 has to be established again!

5.6.3 Establishing Position Data Reference for Relative Measuring Systems (Homing)

Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.5-58: Assignment to functional firmware package

See also section "General Information on Establishing the Position Data Reference"

Actual Position Value of Relative Measuring Systems when Switching On

After the drive is 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 reference 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 serial 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 section "General Information on Establishing the Position Data Reference"

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, Jerk limit bipolar
- 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 feedback 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:

- P-0-0090, Travel range limit parameter
- P-0-0222, Travel range limit 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, Message '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
- C0604 Homing of absolute encoder not possible
- C0606 Reference mark not detected
- C0607 Home switch input not assigned

Diagnostic messages for NC-controlled homing:

- C4302 Distance home switch - reference mark erroneous
- C4304 Homing of absolute encoder not possible
- C4306 Reference mark not detected
- C4307 Home switch 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 HSF or resolvers. These measuring systems have an absolute position measuring range of one encoder revolution or parts of one encoder revolution (resolver) 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 of Rexroth motors of the MHD, MKD, MKE, MSK, MSH, MAD and MAF lines

  – GDS measuring system from Bosch Rexroth

  – Single-turn encoder from Heidenhain (with EnDat 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 can be required.
- For encoders of group 4, the axis as a maximum has to move over the double reference mark distance (see below "Motion Range for Homing Encoders with Distance-Coded Reference Marks").

> ☞ 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.

Relative encoder of ...	Number of reference mark signals occurring over the travel range			
	One signal		Several signals	
	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

AD additional device

Fig.5-59: 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.

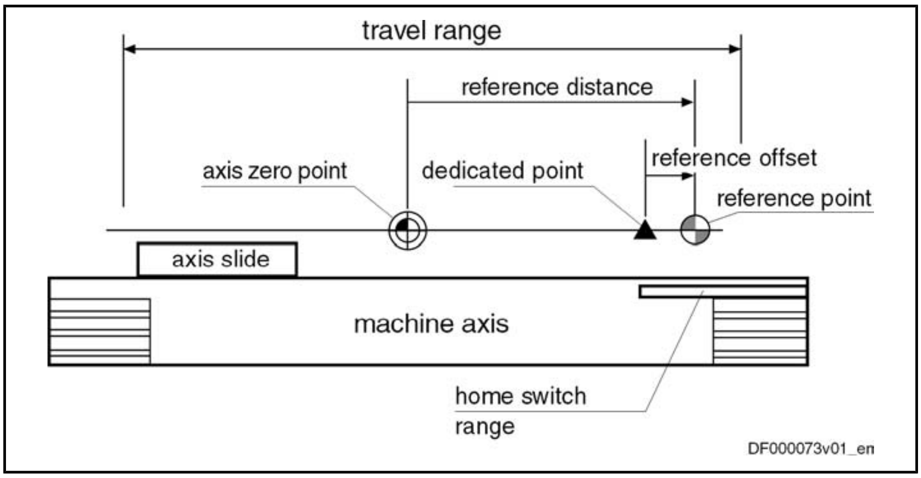


Fig.5-60: Example of positions of axis zero point, dedicated point and reference point for encoders of groups 1, 2, 3

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-0-0150, 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.

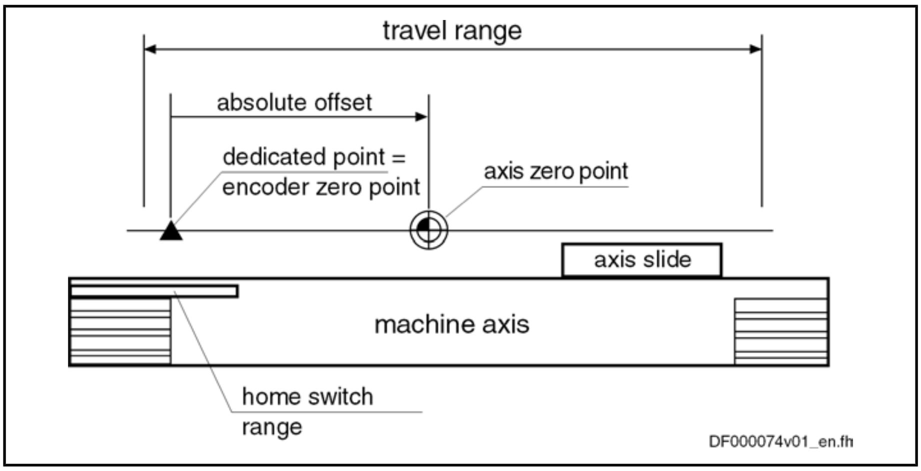


Fig.5-61: Example of positions of axis zero point and dedicated point for encoders of group 4

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:

$$\text{Motor encoder} \quad s_{\text{RefMarks}} = \text{S-0-0165} \times \text{S-0-0116}$$

$$\text{External encoder} \quad s_{\text{RefMarks}} = \text{S-0-0165} \times \text{S-0-0117}$$

s_{RefMarks}	distance of neighboring reference marks
S-0-0165	Distance-coded reference offset A
S-0-0116	Feedback 1 Resolution
S-0-0117	Feedback 2 Resolution

Fig.5-62: Distance of neighboring reference marks of linear encoders with distance-coded reference marks

Motor, Mechanical Axis System, Measuring Systems

Reference Mark Distance of Rotary Encoders

$$\text{Motor encoder} \quad s_{RefMarks} = \frac{\text{S-0-0165} \times 360°}{\text{S-0-0116}}$$

$$\text{External encoder} \quad s_{RefMarks} = \frac{\text{S-0-0165} \times 360°}{\text{S-0-0117}}$$

$s_{RefMarks}$	distance of neighboring reference marks
S-0-0165	Distance-coded reference offset A
S-0-0116	Feedback 1 Resolution
S-0-0117	Feedback 2 Resolution

Fig.5-63: 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 option "stop" was selected in parameter S-0-0147:

$$\text{Linear scaling} \quad s_{Ref\_max} = s_{Ref\_1} + s_{RefMarks} + \frac{v^2}{2 \times a}$$

$$\text{Rotary scaling} \quad s_{Ref\_max} = s_{Ref\_1} + s_{RefMarks} + \frac{\omega^2}{2 \times \alpha}$$

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.5-64: 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 -

- to 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:

$$\text{Linear scaling} \quad s_{Ref\_max} = 2 \times s_{RefMarks} + \frac{v^2}{2 \times a}$$

$$\text{Rotary scaling} \quad s_{Ref\_max} = 2 \times s_{RefMarks} + \frac{\omega^2}{2 \times \alpha}$$

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.5-65: 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 has to be mounted at the end of axis of the dedicated point their signals have to 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 status "activated" (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 "Recommendation for axis-side additional devices (AD) for determining the dedicated point"), a home switch can be used, for drive-controlled homing, as axis-side additional device for selecting a reference mark.

For using the NC-controlled homing an axis-side home switch is obligatory!

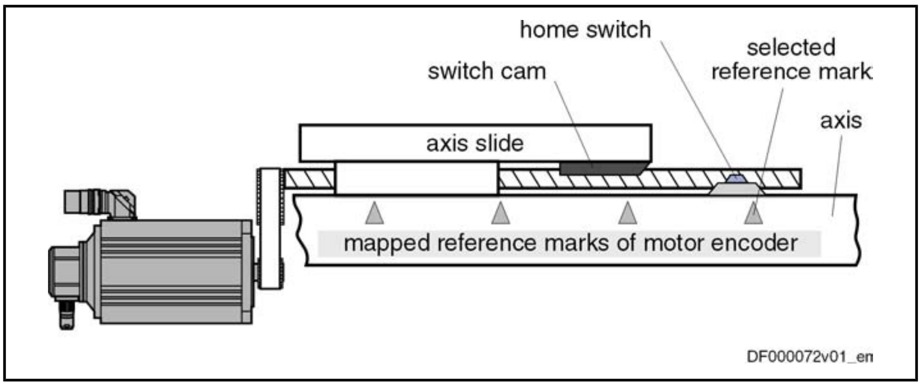


Fig.5-66: Selecting a reference mark via home switch in the case of a linear axis

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

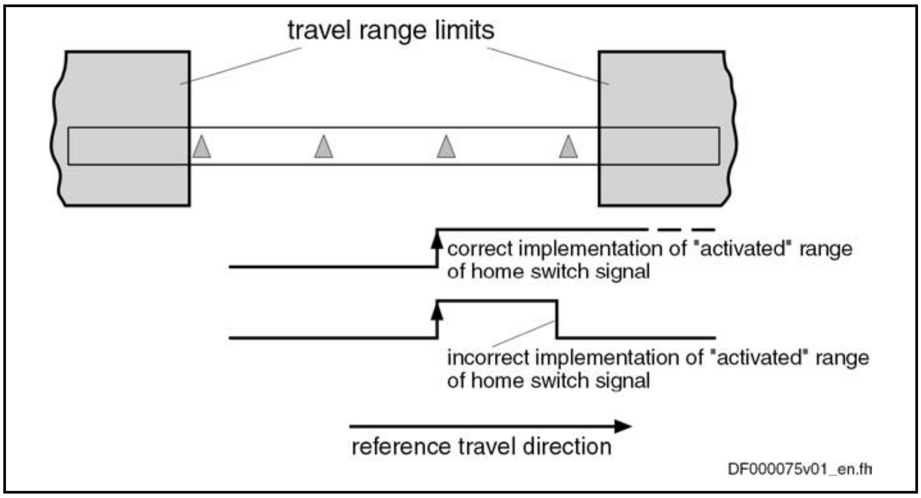


Fig.5-67: Arranging the home switch with regard to travel range limits in the case of linear axes

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:

$$x_{\mathrm{RS\_VbLimit}} \geq x_{\mathrm{RefMarks}} + \frac{v^2}{2 \times a}$$

$x_{RS\_VbLimit}$	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.5-68: 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 status 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 status of the home switch.

Determined edge evaluation (S-0-0147)	Signal status 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
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 is not activated, then reversal of motion; search for dedicated point after positive signal edge was detected

Fig.5-69: 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 status 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

Fig.5-70: 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 status 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 "Recommendation for axis-side additional devices (AD) for determining the dedicated point").

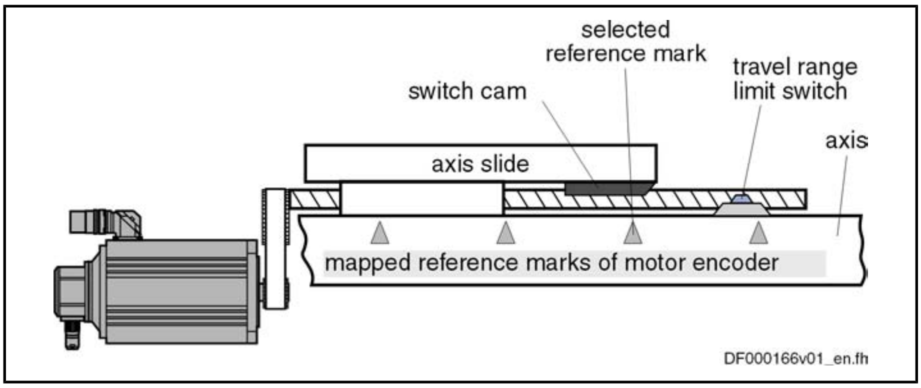


Fig.5-71: Selecting a reference mark via travel range limit switch

After the start of drive-controlled homing (command C0600), the axis is moved in 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 status 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 status 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

Fig.5-72: 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 status 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

Fig.5-73: 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 status of the respective travel range limit switch is displayed in parameter "P-0-0222, Travel range limit 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 "Recommendation for axis-side additional devices (AD) for determining the dedicated point").

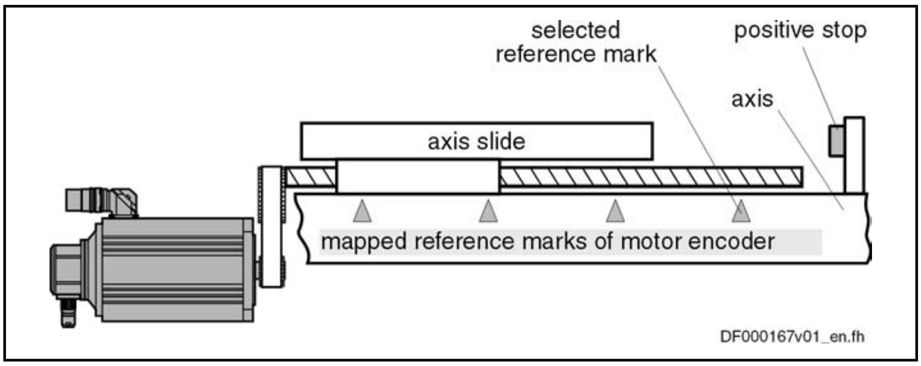


Fig.5-74: Selecting a reference mark via positive stop at the end of the axis

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 bits 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!

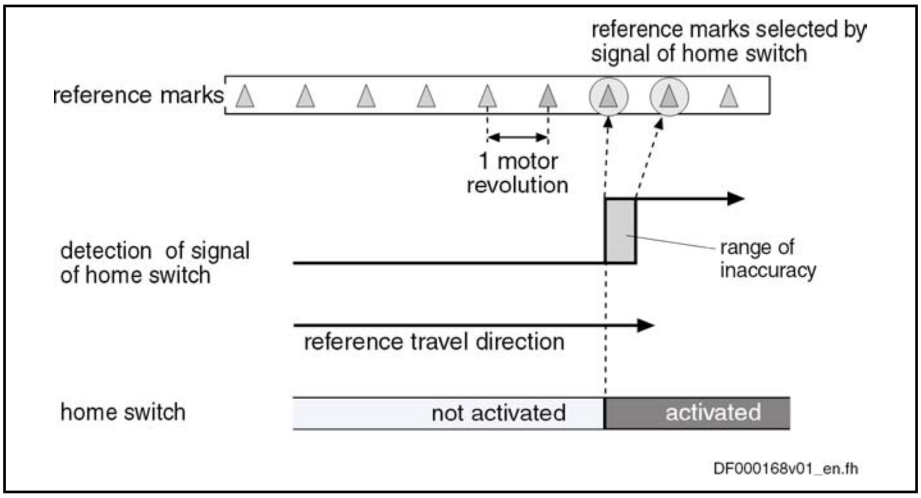


Fig.5-75: Ambiguous detection of reference marks in range of inaccuracy of home switch detection

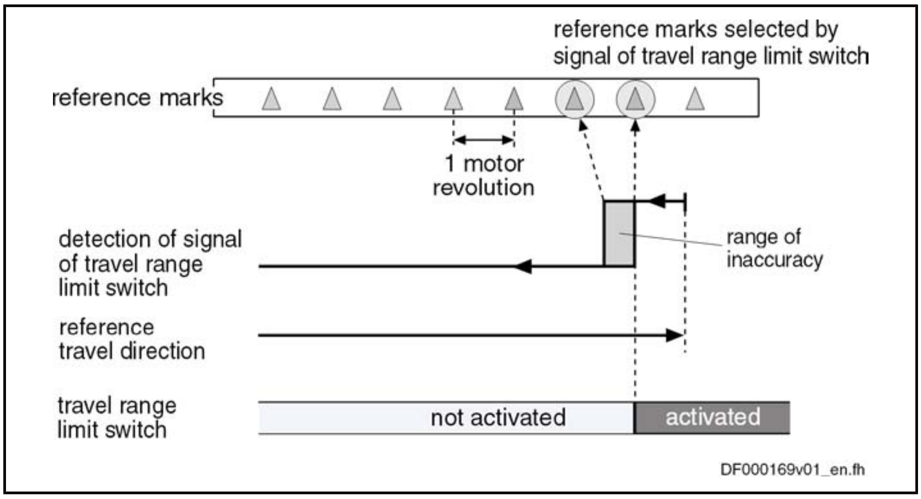


Fig.5-76: Ambiguous detection of reference marks in range of inaccuracy of travel range limit switch or positive stop detection

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" is 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	--

Fig.5-77: Data regarding the distance between switch edge or positive stop detection and reference mark

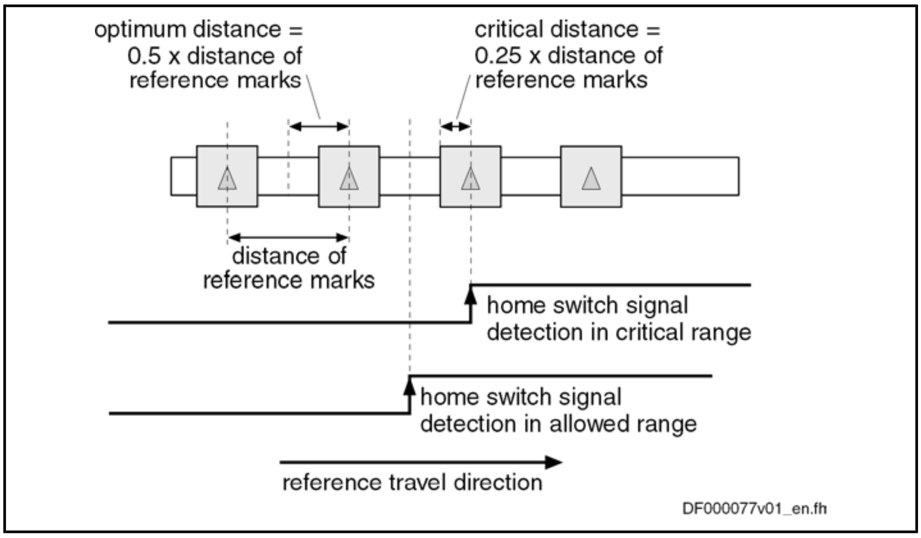


Fig.5-78: Critical and optimum distance of switch edge and reference mark in the case of the home switch

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 of the MHD, MKD, MKE, MSK, MSH, MAD and MAF lines the optimum distance is automatically calculated internally. The value for P-0-0153 has to be left in its default status!

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 "Parameter Description"

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.

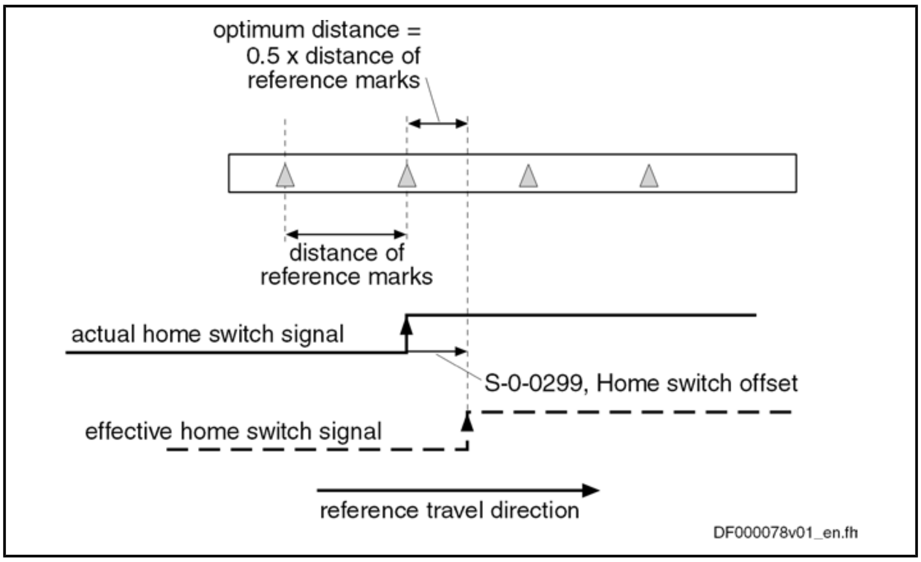


Fig.5-79: Operating principle of parameter S-0-0299 in the case of home switch signal

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!

Drive-Controlled Homing Procedure

General Information

Basic Sequence of "Search for Dedicated Point"

After activation of "S-0-0148, C0600 Drive controlled homing procedure command", 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 section "General Information on Establishing the Position Data Reference"

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 also 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!

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, Jerk limit bipolar".

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".

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:

- "Stop"

  → Non-target-oriented immediate braking motion that possibly is of shorter duration

- or -

- "Positioning"

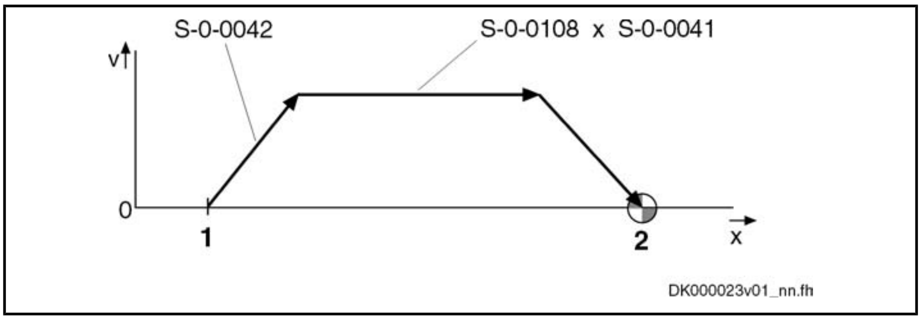
  → Target-oriented motion to the reference point (axis-related value in parameter "S-0-0052, Reference distance 1" or "S-0-0054, Reference distance 2"), if the reference point is within the allowed travel range

- 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.5-80: 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 in the Case of 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.

NC-Controlled Homing Procedure

General Information

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 operating 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 Procedure"

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 has to 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 reference 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 C4600.

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 1 value

- or -

- S-0-0053, Position feedback 2 value.

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 section "General Information on Establishing the Position Data Reference"

Notes on Commissioning

Notes on Commissioning, General

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 torque/force threshold for detection of blocking in parameter "S-0-0092, Bipolar torque/force limit value" resp. "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).

WARNING

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 "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 "Hold" 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.

Notes on Commissioning for "Drive-Controlled Homing Procedure"

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 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)

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 parameters below 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 (e.g. 10 rpm)
   - S-0-0042, Homing acceleration (e.g. 10 rad/s²)
4. Execute "C0600 Drive-controlled homing procedure command" (S-0-0148), if drive in "AF".

CAUTION

Property damage caused by step change of actual position value!

⇒ By clearing the command, the original operating 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 1 value" or "S-0-0053, Position feedback 2 value" 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 status 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 of the encoder selected in S-0-0147, this too has to be determined in parameter S-0-0147. The position can be preset via "S-0-0052, Reference distance 1" or "S-0-0054, Reference distance 2".

CAUTION

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!

Notes on Commissioning for Drive-Controlled Homing with Relative Encoders 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".

CAUTION

Property damage caused by step change of actual position value!

⇒ By clearing the command, the original operating 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 1 value" or "S-0-0053, Position feedback 2 value" 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 the command "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 End of 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 End of Homing Procedure

If the axis, after the dedicated point was detected, is to position to the reference point of the encoder selected in S-0-0147, this too has to be determined 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.

CAUTION

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 status 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.

Note on Commissioning for "NC-Controlled Homing Procedure"

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 parameter "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

☞ 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!

Search 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 1 value
- S-0-0053, Position feedback 2 value.

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 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
- C0604 Homing of absolute encoder not possible
- C0606 Reference mark not detected
- C0607 Home switch input not assigned

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 of absolute encoder not possible
- C4306 Reference mark not detected
- C4307 Home switch input not assigned

5.6.4 Shifting the Position Data Reference for Absolute and Relative Measuring Systems (Shift Coordinate System Procedure)

Brief Description

Expansion package **servo function** (order code **SRV**) of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.5-81: Assignment to functional firmware package

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

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 status 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 Command Set absolute measuring" oder "C0600 Command Drive-controlled homing procedure") is established after the actual position values have been shifted (value in parameter "S-0-0283, Current coordinate offset" unequal "0"), the current offset of the coordinate system is cleared and in parameter S-0-0283 the value "0" is displayed.

"Set Coordinate System Procedure" 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 function "A0010 Drive HALT".

ℹ See also Troubleshooting Guide for "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 Procedure" 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, Coordinates of 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!

CAUTION

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 Procedure"

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) has to 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. But first read "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"!

After that 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, Coordinates of 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!

5.6.5 Detecting the Marker Position

Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.5-82: Assignment to functional firmware package

The "get marker position" function, that is activated via the respective command, can be used for:

- Checking the correct detection of the reference mark of an incremental measuring system

- or -

- Determining the position of the reference mark in case the homing procedure is carried out by the control master. In this case, the coordinate system is switched in the master with the position information of the reference mark.

☞ 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 carried out:

- 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 operating 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 movement 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 measuring 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 and
- if required, position control loop.

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 driven motor shaft and machine axis it can 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 play 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:

- HSF encoders for MHD, 2AD and ADF motors of high precision requirements
- Resolver encoders for MKD and MKE motors for lower precision requirements

They are optionally available as

- Relative measuring system ("single-turn motor encoder")

- or -

- Absolute measuring system ("multi-turn motor encoders", 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 Encoders

Rexroth kit motors are delivered 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:

- GDS/GDM encoders from Rexroth (rotary single-turn or multi-turn encoders with housing and shaft)
- Incremental encoder with sine signals (compatible with signal specification of Heidenhain)
- Combined encoder of incremental encoder with sine signals (compatible with signal specification of Heidenhain) and "Hall sensor box SHL01.1" (Rexroth-compatible signal specification)
- Encoder with EnDat interface from Heidenhain
- Incremental encoder with square-wave signals (compatible with signal specification of Heidenhain)
- Combined encoder of incremental encoder with square-wave signals (compatible with signal specification of Heidenhain) and "Hall sensor box SHL01.1" (Rexroth-compatible signal specification)

☞ 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. The combined encoders are an exception; they can only be used for Rexroth synchronous linear motors (see also "Rexroth Kit Motors, Synchronous")!

☞ For synchronous kit motors or synchronous third-party motors it is recommended that you use a measuring system, which can be evaluated in absolute form, as a motor encoder so that you have to determine the commutation offset of the motor only once (during initial commissioning) (see also "Absolute Measuring Systems").

Motor Encoder with Gear

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!

External Encoders at Machine Axes

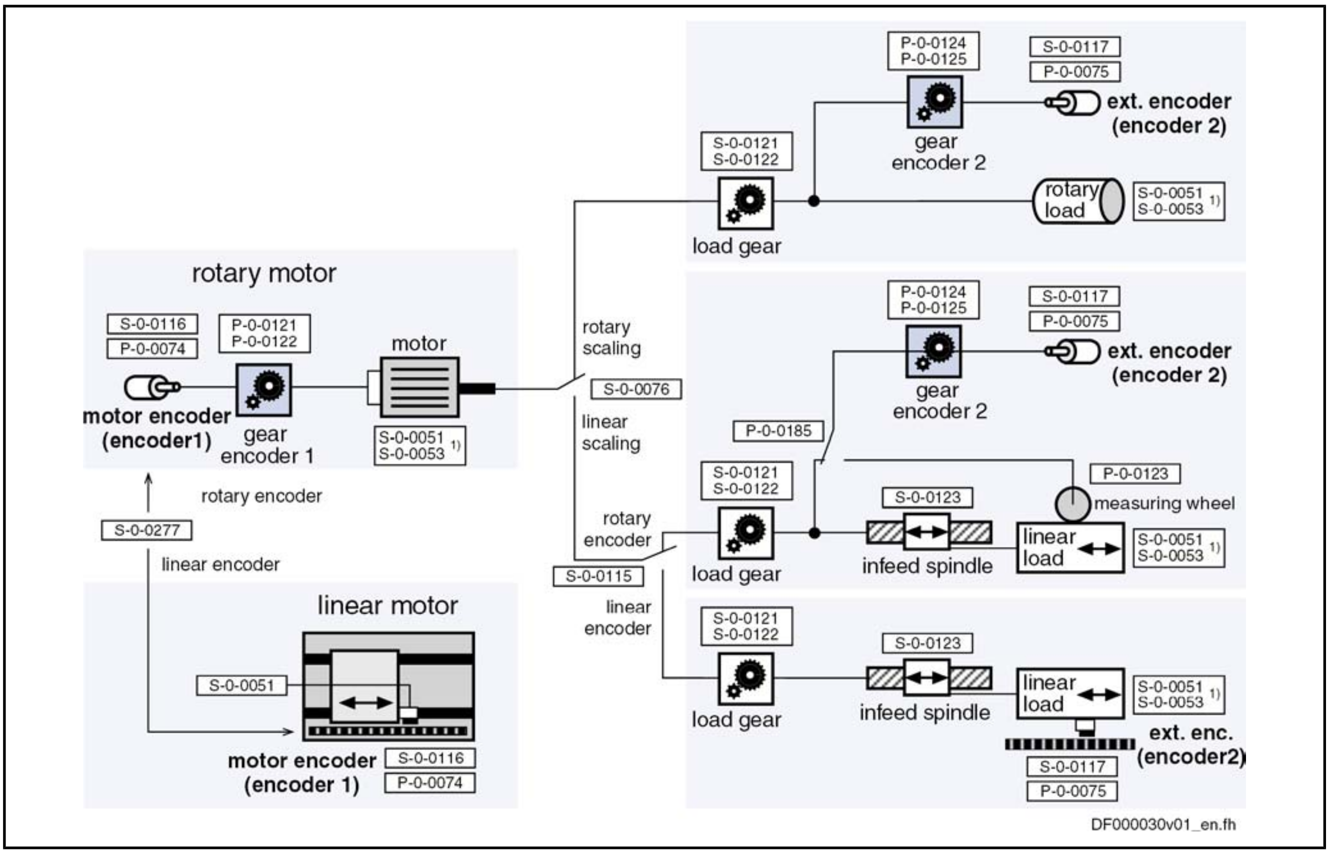
IndraDrive controllers can evaluate the following measuring systems as external encoders:

- GDS/GDM encoders from Rexroth (rotary single-turn or multi-turn encoders with housing and shaft)
- Incremental encoder with sine signals (compatible with signal specification of Heidenhain)
- Encoder with EnDat interface from Heidenhain

- Incremental encoder 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	Feedback 1 Resolution
S-0-0117	Feedback 2 Resolution
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.5-83: Overview of arrangement possibilities of mechanical drive system and measuring systems

Hardware Requirements

For connecting the measuring systems to the controller there are 3 optional interfaces available. By writing data to 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. The interface must be equipped with the appropriate encoder input for the encoder (see also documentation "Control Sections for Drive Controllers; Project Planning Manual")!

Pertinent Parameters

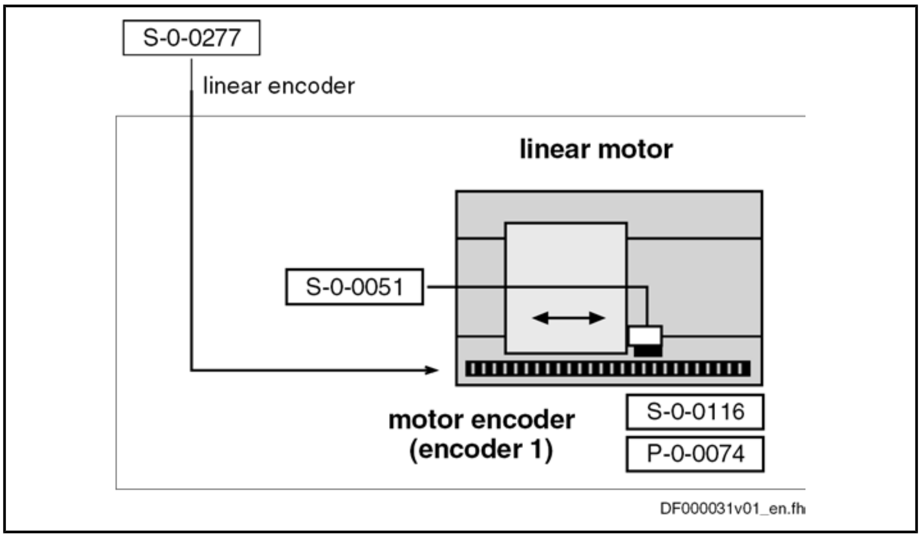
- S-0-0115, Position feedback 2 type
- S-0-0121, Input revolutions of load gear
- S-0-0122, Output revolutions of load gear
- S-0-0123, Feed constant
- S-0-0277, Position feedback 1 type
- P-0-0121, Gear 1 motor-side (motor encoder)
- P-0-0122, Gear 1 encoder-side (motor encoder)
- P-0-0123, Feed constant 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, the encoder 1 gear parameters are inactive, the actual position value reference (parameter "S-0-0076, Position data scaling type") has to be set to "with respect to the motor" 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!

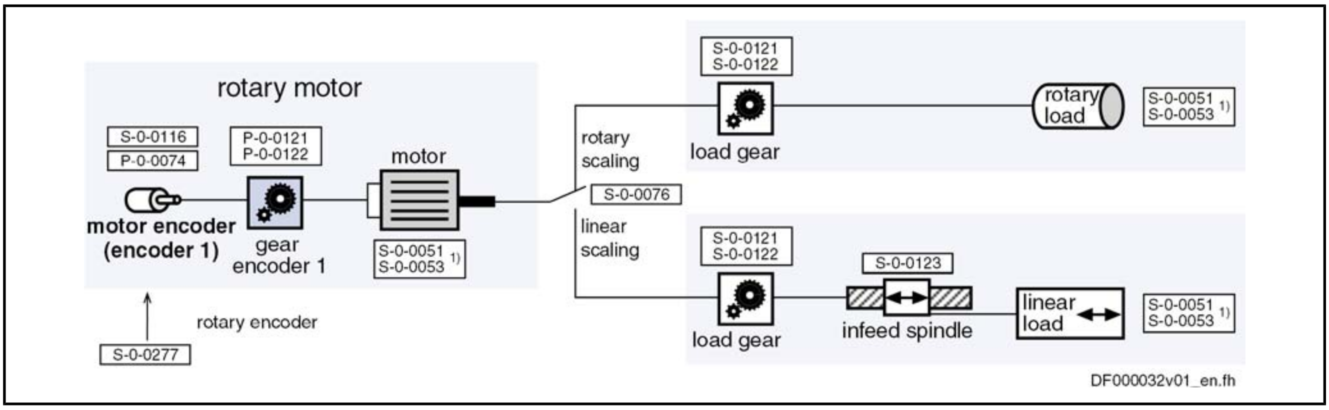


S-0-0051 Position feedback 1 value
S-0-0116 Feedback 1 Resolution
S-0-0277 Position feedback 1 type
P-0-0074 Encoder type 1 (motor encoder)
Fig.5-84: Motor encoder arrangement for drive with linear motor

When "rotary motor encoder" is 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 gear; Rexroth housing motors have a direct motor 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 1 value
S-0-0053	Position feedback 2 value
S-0-0076	Position data scaling type
S-0-0116	Feedback 1 Resolution
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)

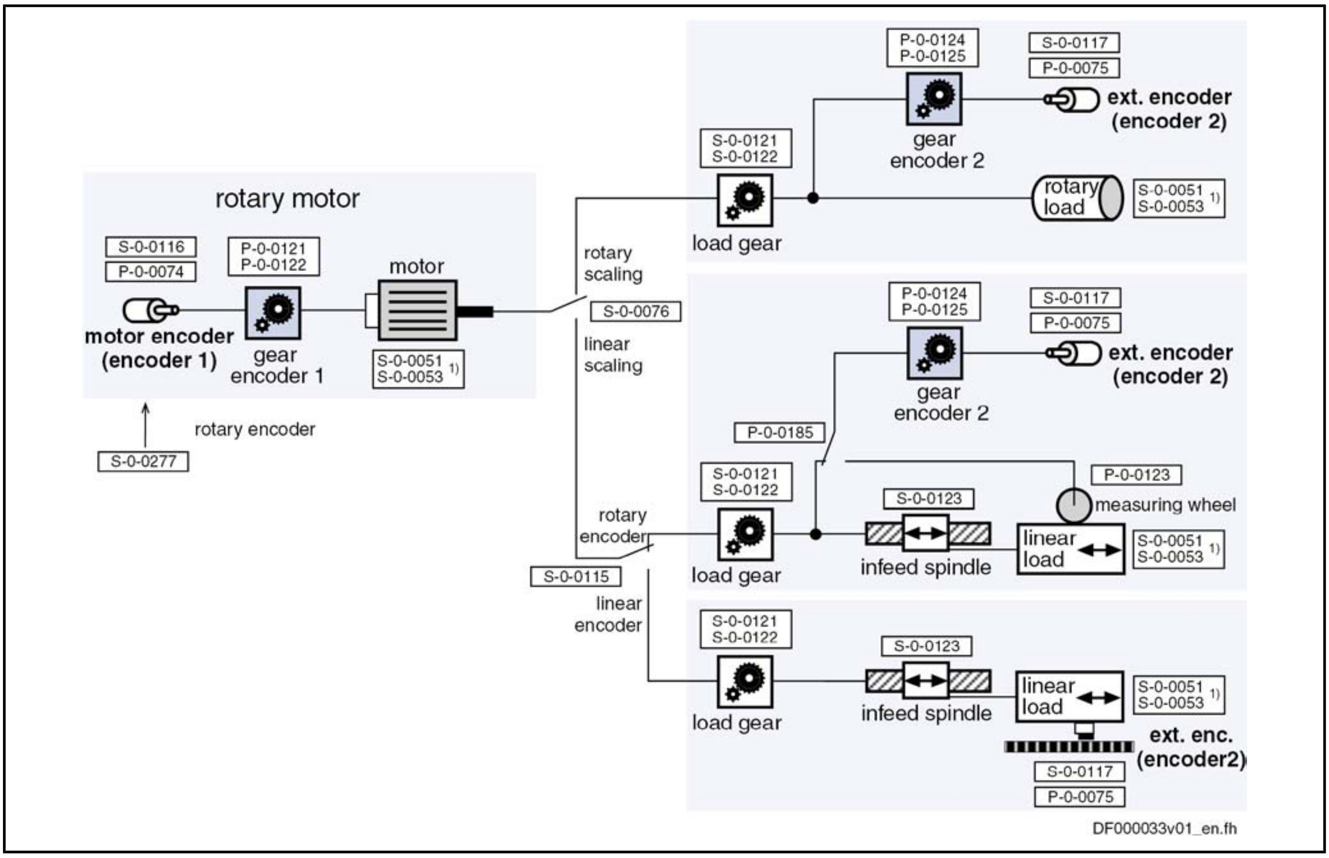
Fig.5-85: Possible drive arrangements with rotary motor (without external encoder)

External Encoder

In the case of 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 gear.
- A linear external encoder determines the actual position value directly at the linear load.

For drives with linear motor, it is impossible to connect an external encoder!



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	Feedback 1 Resolution
S-0-0117	Feedback 2 Resolution
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.5-86: 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" have to be observed, too!

Basic Settings

Set encoder type "linear" or "rotary":

- S-0-0277, Position feedback 1 type

Enter encoder type, hardware assignment and resolution:

- S-0-0116, Feedback 1 resolution
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0077, Assignment motor encoder->optional slot

Settings for Rotary Motors

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 Encoders

Set encoder type "linear" or "rotary":

- 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, Feedback 2 resolution

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 on 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. But physical data can also be exchanged in the control-internal format, i.e. without specific reference to physical units. To do this, 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.

In the case of axes with limited travel range (e.g. linear axes), the current axis position within the controller-side value range can be unequivocally displayed (see "Basics on Measuring Systems, Resolution").

In the case of axes with 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 position data
- S-0-0078, Linear position data scaling exponent position data
- 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	with unit "m"	with 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

Fig.5-87: Overview: preferred scalings for position data and velocity data

	Preferred scaling			
	Linear	Linear	Rotary	Ramp time
Physical data	with unit "m"	with unit "inch"	unit "rad"	unit "s"
acceleration data	0.000 in/s²	0.00001 inch/s²	0.001 rad/s²	0.001 s
jerk data	0.000000 in/s³	0.00001 inch/s³	0.001 rad/s³	0.001 s²

Fig.5-88: 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.5-89: 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
Fig.5-90: 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
Fig.5-91: Values of scaling parameters and decimal places of velocity data determined by preferred scaling

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
Fig.5-92: 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 also 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	$LSB = \text{unit}^{1)} \times \text{scaling factor}^{1)} \times 10^{SE}$
position data, rotary	$LSB = \dfrac{360}{\text{rotational pos. resolution}^{2)}} \times \text{unit}^{2)}$
velocity data	$LSB = \dfrac{\text{unit (position data)}}{TU} \times \text{scaling factor} \times 10^{SE}$
acceleration data (linear, rotary)	$LSB = \dfrac{\text{unit (position data)}}{TU^{2}} \times \text{scaling factor} \times 10^{SE}$
acceleration data (ramp time scaling)	$LSB = \dfrac{\text{S-0-0446}}{\text{scaling factor} \times 10^{SE}}$
jerk data	$LSB = \dfrac{\text{unit (position data)}}{TU^{3}} \times \text{scaling factor} \times 10^{SE}$

1) With scaling factor ≠ 1 the unit is no longer indicated as in parameter 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 unit of time

S-0-0446 ramp reference velocity for acceleration data

Fig.5-93: 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 position data
- S-0-0078, Linear position data scaling exponent position data
- 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 only possible to select preferred scaling (predefined scaling)!

Physical value	Preferred scaling		
	Linear	Rotary	Percentage-based
torque	--	0.01 Nm or 0.1 inlbf	0,1%
force	1 N or 0.1 lbf	--	0,1%

Fig.5-94: 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.

As individually defined scaling is impossible for torque/force data, the following parameters have fixed values corresponding to preferred scaling:

- S-0-0093, Torque/force data scaling factor and
- S-0-0094, Torque/force data scaling exponent

Temperature Data

For temperature data only the following units can be selected:

- Degree Celsius (°C)
- Fahrenheit (F)

For temperature data is it only possible to select preferred scaling (predefined scaling)!

Physical value	Preferred scaling	
	Celsius	Fahrenheit
Temperature	0.1 °C	0.1 F

Fig.5-95: 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").

To do this, 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)

Motor, Mechanical Axis System, Measuring Systems

- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)

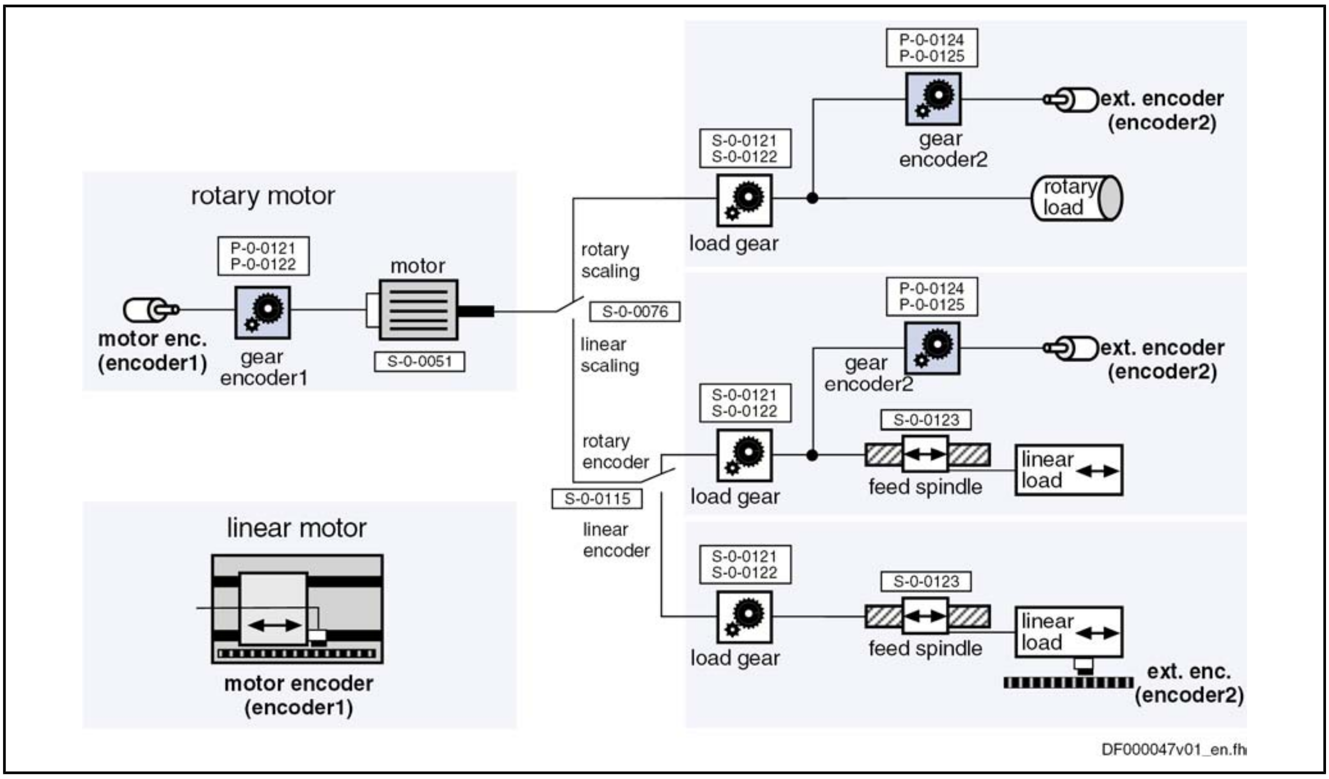


Fig.5-96: Mechanical transfer elements between motor, encoders and load

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

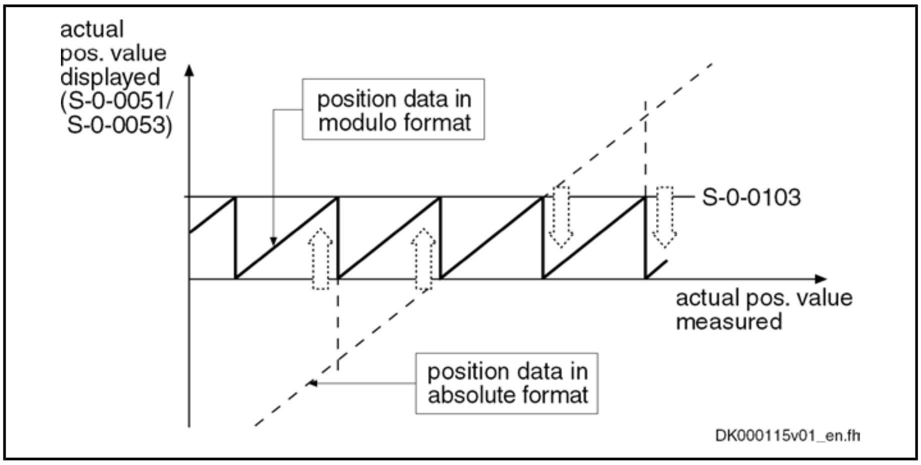
Via the respective bit of parameter "S-0-0076, Position data scaling type", it is possible to select, for the position data format, between two formats:

- 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; operating 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 parameter "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 1 value
S-0-0053	Position feedback 2 value
S-0-0103	Modulo value
Fig.5-97:	*Actual position value for axis motion with constant velocity for absolute and modulo format*

Modulo Format - Requirements

The "modulo format" selection 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, the following restrictions and conditions have to be observed and complied with:

- 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.5-98:	*Allowed maximum velocity for modulo format*

WARNING

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, Absolute encoder range of optional encoder")! The actual position value after switching on can otherwise be incorrect! This, however, cannot be diagnosed on the controller side!

WARNING

Possible property damage caused by errors when controlling motors and moving parts!

⇒ Block the mechanical system with drive switched off by self-holding holding brake or self-locking gear!

See also "Absolute Measuring Systems"

- The following conditions have to 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 Feedback 1 Resolution
S-0-0117 Feedback 2 Resolution
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

Fig.5-99: Conditions for modulo scaling and rotary position reference

☞ Rotary modulo scaling is impossible for linear external encoder!

- 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 Linear position data scaling position data
S-0-0078 Linear position data scaling position data
S-0-0103 Modulo value
S-0-0116 Feedback 1 Resolution
S-0-0117 Feedback 2 Resolution
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

Fig.5-100: Conditions for modulo scaling and linear position reference

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☞ Linear modulo scaling is impossible for 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 unit of time, if necessary
- 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 has to 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 parameter "S-0-0278, Maximum travel range"!

WARNING

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 parameter "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 position data
- S-0-0078, Linear position data scaling exponent position data

\- 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:

- C0101 Invalid parameters (->S-0-0021)
- C0102 Limit error in parameter (-> S-0-0021)
- C0103 Parameter conversion error (-> S-0-0021)
- C0122 Incorr. parameteriz. of motor enc. (mechanical system)
- C0123 Modulo value for motor encoder cannot be displayed
- C0127 Incorr. parameteriz. of opt. enc. (mechanical system)
- C0128 Modulo value for optional encoder cannot be displayed
- C0140 Rotary scaling not allowed

Example of Scaling Settings

There are many possibilities 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	---	possible
rotary	available/not available	available	rotary	no	---	linear	possible
rotary	available	not available	rotary	rotary	rotary	rotary	possible
rotary	available/not available	available	rotary	rotary	rotary	---	possible
rotary	available/not available	available	rotary	rotary	---	linear	possible
rotary	available/not available	available	rotary	linear	rotary	---	possible
rotary	available/not available	available	rotary	linear	---	linear	possible
linear	not available	not available	linear	---	---	linear	not possible

Fig.5-101: Useful scaling type settings depending on mechanical drive system and measuring systems

6 Drive Control

6.1 Overview of Drive Control

6.1.1 Basic Principles and Terms

The IndraDrive firmware supports the following two basic principles of drive control:

- **Open-loop axis control** (U/f control)

  → Open-loop-controlled operation without encoder information
- **Closed-loop axis 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!

The overview below shows the assignment and the possible applications of the different methods of control:

Operating mode / command value adjustment	Control mode	Functional principle of motor	Encoder available	Required base package	Notes
U/f control with command value adjustment of the velocity control	Voltage-controlled operation	Asynchronous	Yes	Closed-loop	--
			No	Open-loop	--
Torque/force control	Field-oriented current control	Asynchronous	Yes	Closed-loop	--
			No	Open-loop	--
		Synchronous	Yes	Closed-loop	--
			No	--	Function not available
Velocity control / velocity synchronization	Velocity control	Asynchronous	Yes	Closed-loop	--
			No	Open-loop	--
		Synchronous	Yes	Closed-loop	--
			No	--	Function not available
Position control, drive-controlled positioning, positioning block mode, phase synchronization, electronic cam shaft	Position control	Asynchronous	Yes	Closed-loop	--
			No	--	Function not available
		Synchronous	Yes	Closed-loop	--
			No	--	Function not available

Fig.6-1: Overview of Methods of Control and Applications

For scaling the drive firmware, we distinguish between the functional base packages with "open-loop" and "closed-loop" characteristic; in this case, however, the meaning is not identical to how the terms are used in conjunction with drive control!

See also section "Overview of Functions/Functional Packages"

6.1.2 Principles of Drive Control

Overview of Open-Loop Axis Control

Open-loop axis control allows open-loop-controlled operation of the drive without motor encoder (U/f control).

The primary mode of operation "velocity control" is configured, but only the command value processing specific to this operating mode takes effect. Closed-loop control (position and velocity) and functions and operating modes depending thereof are not possible.

See "Voltage-Controlled Open-Loop Operation (U/f Control)"

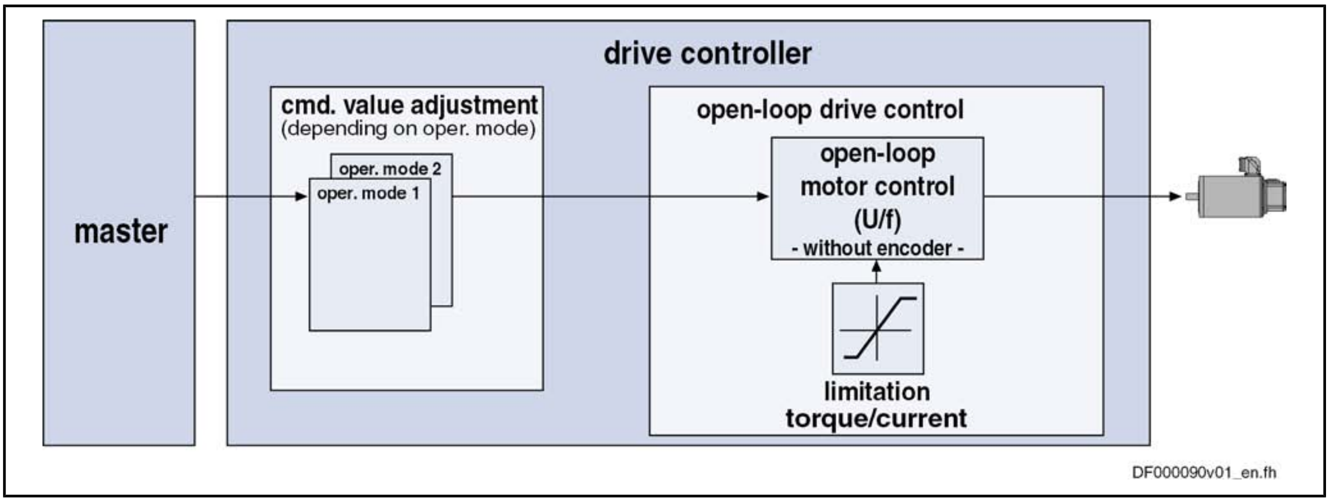


Fig.6-2: Principle of Drive Control (Open-Loop Operation)

See also section "Closed-Loop Axis Control (Closed-Loop Operation)"

See also 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 allows closed-loop-controlled operation of the drive; we distinguish between two principles of drive control:

- **Operation with encoder**

  The velocity control loop and the position control loop are closed by means of the encoder feedback so that the following operating modes are supported by field-oriented current control with encoder feedback:

  - Velocity control
  - Position control with cyclic command value input
  - Positioning modes (e.g. drive-controlled positioning)
  - Synchronization modes

- **Operation without encoder**

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 section "Field-Oriented Current Control"

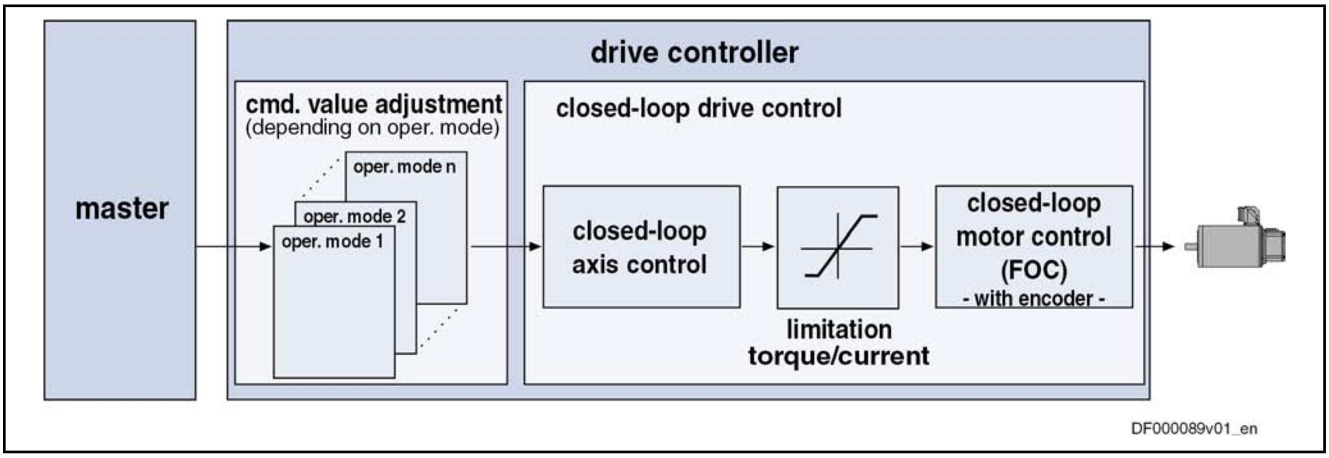


Fig.6-3: Principle of Drive Control (Closed-Loop Operation)

See also section "Open-Loop Axis Control (Open-Loop Operation)"

See also section "Overview of Functions/Functional Packages"

6.1.3 Control Loop Structure

General Information

The drive controller has a so-called cascade structure, i.e. the individual loops (position, velocity and current) are interconnected in cascaded form. Depending on the active operating 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

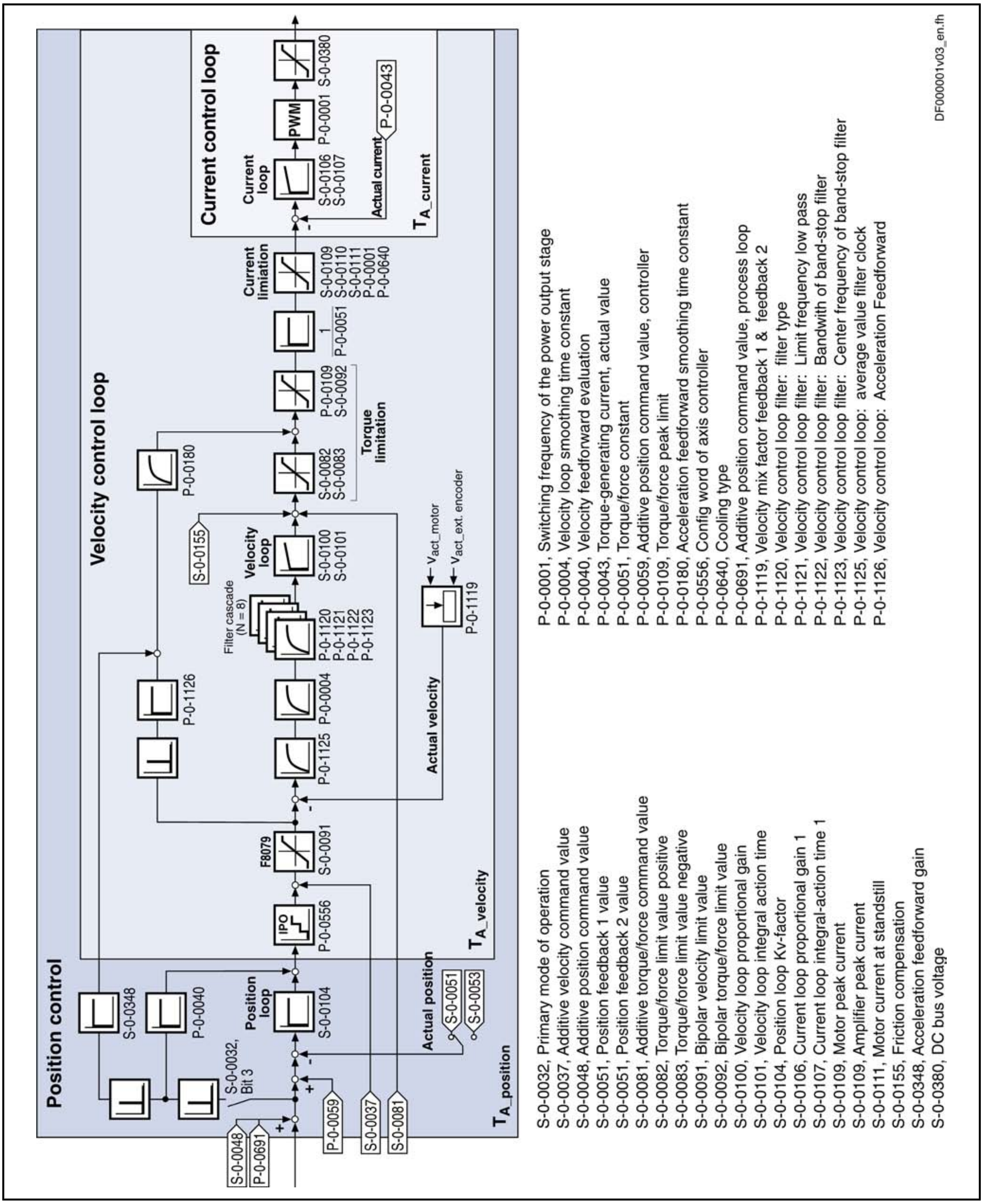
For the following position control modes, the position control loop, apart from the current and velocity control loops, is closed internally (in the drive):

- Position control with cyclic command value input
- Drive-internal interpolation
- Drive-controlled positioning

See also description of the respective operating 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).

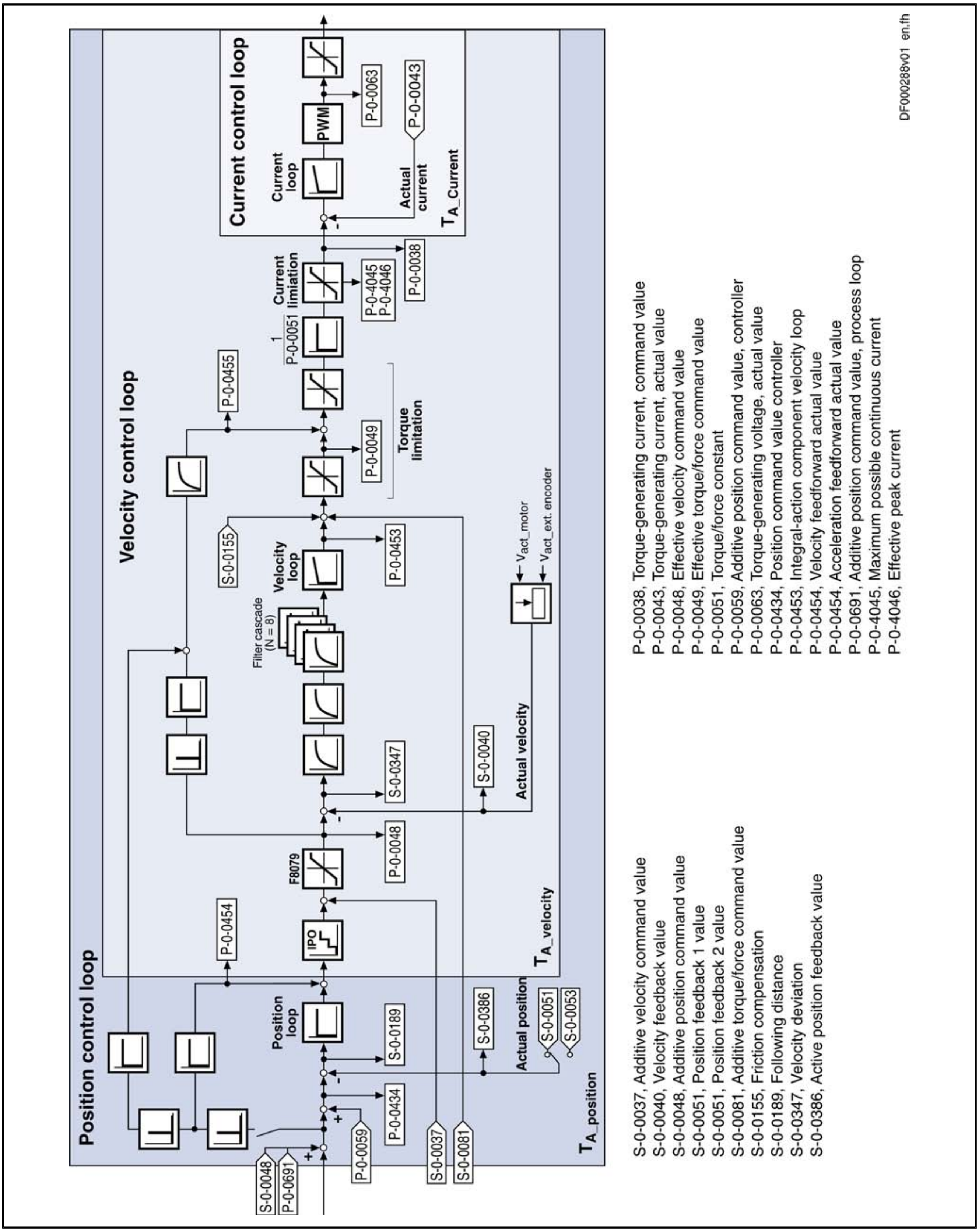
Control Loop Structure With Setting Parameters



T_A Sampling times (see table in the chapter "Features of the Control Loops")

Fig.6-4: Overall Structure of the Control Loops With Points at Which the Setting Parameters Take Effect

Control Loop Structure With Display Parameters



T_A Sampling times (see table in the chapter "Features of the Control Loops")

Fig.6-5: Overall Structure of the Control Loops With Display Parameters

6.1.4 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:

- Control section design (CSH, CSB or CDB)
- Activation of the functional packages
- P-0-0001, Switching frequency of the power output stage
- P-0-0556, Config word of axis controller (bits 2 and 5)

Depending on these factors, the following cycle and switching times can be achieved:

	ADVANCED control sections	BASIC control sections
PWM switching frequency	Max. 16 kHz	Max. 8 kHz
Current loop clock ($T_{A\_current}$)	62.5 µs	125 µs
Velocity loop clock ($T_{A\_velocity}$)	125 µs	250 µs
Position loop clock ($T_{A\_position}$)	250 µs	500 µs

Fig.6-6: Cycle and Switching Times to be Achieved With IndraDrive

☞ All performance data are listed under "System Overview: Performance Data".

Current Loop

The current loop is characterized by the following features:

- PI loop for 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 Loop

The velocity loop is characterized by the following features:

- Standardization of the output value at the velocity loop 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
- Possibility of extending the filter options for filtering resonance frequencies (4 filters of 2nd degree available; settings via parameters P-0-1120, P-0-1121, P-0-1122 and P-0-1123)
- Limitation of acceleration in velocity control by setting in parameter "S-0-0138, Bipolar acceleration limit value"

Position Loop

The position loop is characterized by the following features:

- Jerk limitation can be set in operating mode "cyclic position control" in parameter "S-0-0349, Jerk limit bipolar"; filter degree of smoothing filter (moving average) can be set in parameter "P-0-0042, Current position command average value filter order"
- Velocity feedforward (degree of feedforward) can be set in parameter "P-0-0040, Velocity feedforward evaluation" (0% ... 100%)
- Input value for parameter "S-0-0348, Acceleration feedforward gain"
  - Inertia in kg*m^2 (for rotary motors)

  - or -

  - Mass in kg (for linear motors)

6.1.5 General Notes on Commissioning and Application

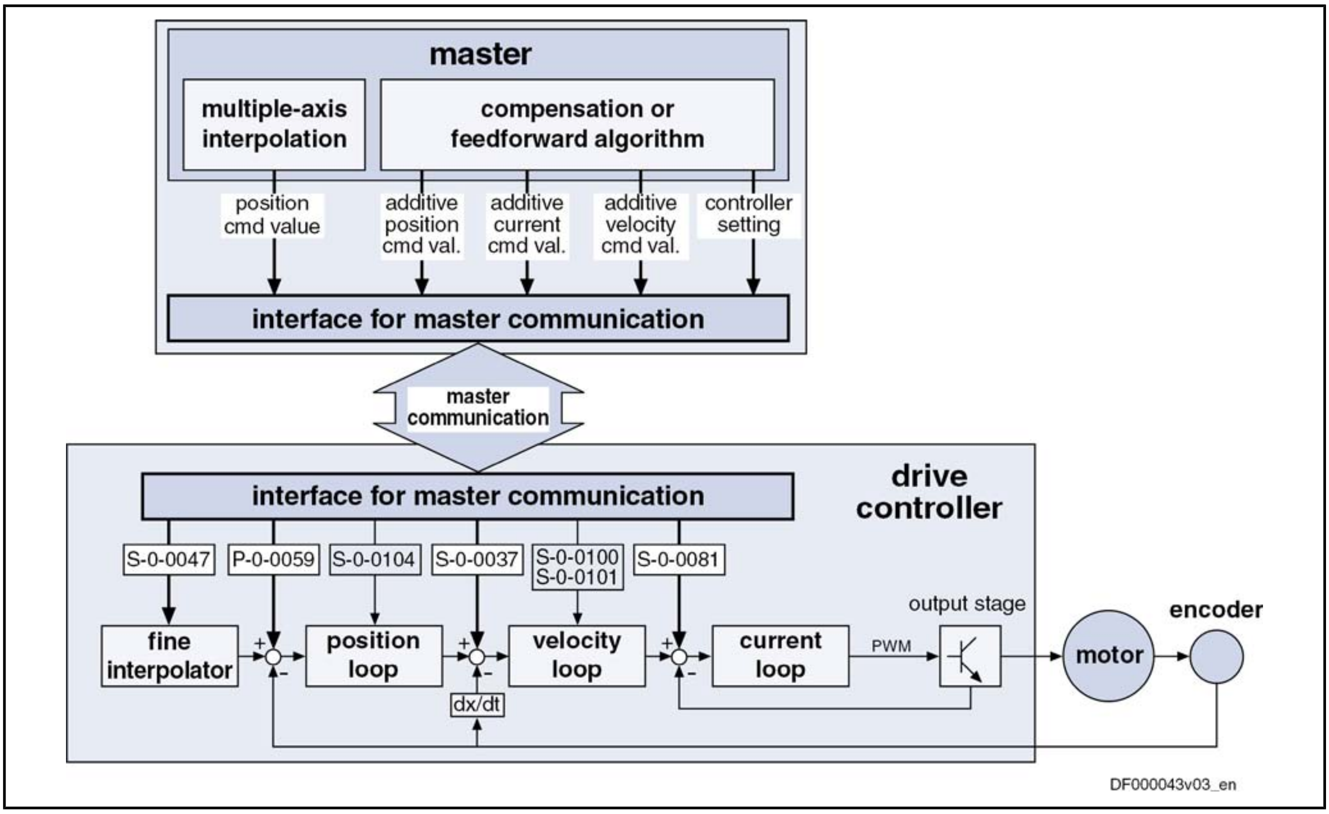
Additive Command Values and Possibilities of Accessing Outer Control Loops

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 operating mode, the following parameters are available to do this:

Operating mode	S-0-0081	S-0-0037	P-0-0059	S-0-0048
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 shaft	■	■	--	■

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
Fig.6-7: Overview of the Additive Command Values Depending on the Operating Mode

In closed-loop operation, it is possible to access the outer control loops from a higher-level operating 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.6-8: Structural Overview Including Access Options (Example of Operating Mode "Position Control With Cyclic Command Value Input")

Notes on Commissioning of the 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, MHD, MKD and MKE lines), optimizing the current loop is not required because the corresponding 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 data base via the "IndraWorks D" 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 loop (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) 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, stiffness 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 loop, 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")

Command "Load Defaults Procedure"

For all Rexroth motors of the lines with motor encoder data memory (e.g. MHD, MKD, 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 defaults procedure" command (S-0-0262).

There are two ways to activate the parameter "S-0-0262, C07_x Load defaults procedure command":

- 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" button 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".

During the load defaults 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 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, during the load defaults procedure, the following control loop parameters are set to their firmware-side default values, although there haven't any default values been stored for them in the motor data memory:

- S-0-0348, Acceleration feedforward gain
- P-0-1125, Velocity control loop: average value filter clock

☞ 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.

6.2 Motor Control

6.2.1 General Information on Motor Control

Open-Loop/Closed-Loop Operation

The IndraDrive firmware supports the following two basic principles of motor control:

- **Motor control** (U/f control) in **open-loop operation**

  → Open-loop-controlled operation without encoder information
- **Motor control** in **closed-loop operation**
  - **With** encoder feedback

    → Closed-loop-controlled operation (position, velocity and current)
  - **Without** encoder feedback

    → Closed-loop-controlled operation with motor model (velocity and current)

Via bit 14 and bit 15 of parameter "P-0-0045, Control word of current controller", the method of motor control is selected.

See also section "Overview of Drive Control"

Cycle Times and PWM Frequencies

Depending on the firmware variant (MPH, MPD or MPB) and the respective control section (CSH01.1, CDB01.1, CSB01.1), there are the following possible cycle times and PWM frequencies:

$T_{A\_current}$	P-0-0001	FWA variant	P-0-0556, bit 2	Performance
62.5 µs	16000	MPH	0	Basic
83.3 µs	12000	MPH	0	Basic
125 µs	8000	MPH MPB MPD	0	Basic
125 µs	4000	MPH MPB MPD	0	Basic
250 µs	2000 [1)]	MPH MPB	0	Basic
62.5 µs	16000	MPH	1	Advanced
83.3 µs	12000	MPH	1	Advanced

$T_{A\_current}$	P-0-0001	FWA variant	P-0-0556, bit 2	Performance
62.5 µs	8000	MPH	1	Advanced
125 µs	4000	MPH	1	Advanced

$T_{A\_current}$ Sampling time of current loop
P-0-0001 Switching frequency of the power output stage (in Hz)
P-0-0556 Config word of axis controller
1) Only with power section HCS04.1… and MAD/MAF
Fig.6-9: Cycle Times and Switching Frequencies That Can be Set

☞ Via bit 2 and bit 5 of parameter "P-0-0556, Config word of axis controller", it is possible to select the performance levels depending on the control section design.

See "Performance Data"

6.2.2 Voltage-Controlled Open-Loop Operation (U/f Control)

Brief Description

The drive function "voltage-controlled open-loop operation of asynchronous motors without encoder in U/f control" is made available in the base package "open-loop" in the "velocity control" mode. When the expansion package "synchronization" has been enabled, the operating mode "velocity synchronization with real/virtual master axis" is additionally available.

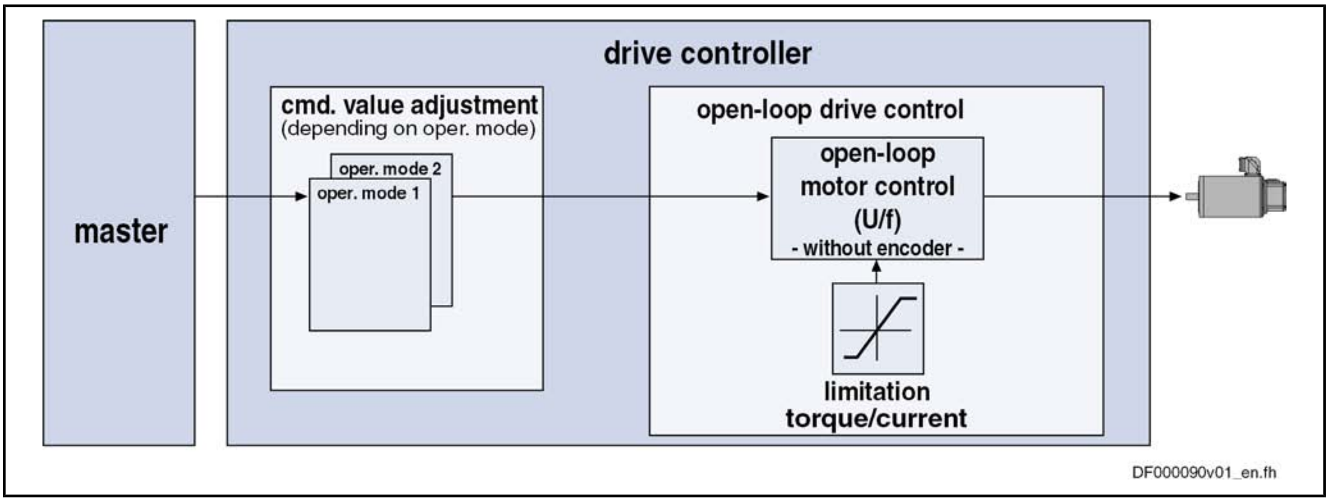


Fig.6-10: Principle of U/f Control

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 loop** (PI loop 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 **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)
- **Current limitation loop** to protect the output stage of the drive controller, as well as limitation to the effective peak current
- **Velocity search mode** of a coasting machine after switching drive enable on (can be set for the preset rotational direction or both rotational directions)
- User-side **torque/force limitation** via enabled stall protection loop

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-0-4036, Rated motor speed
- P-0-4046, Effective peak current

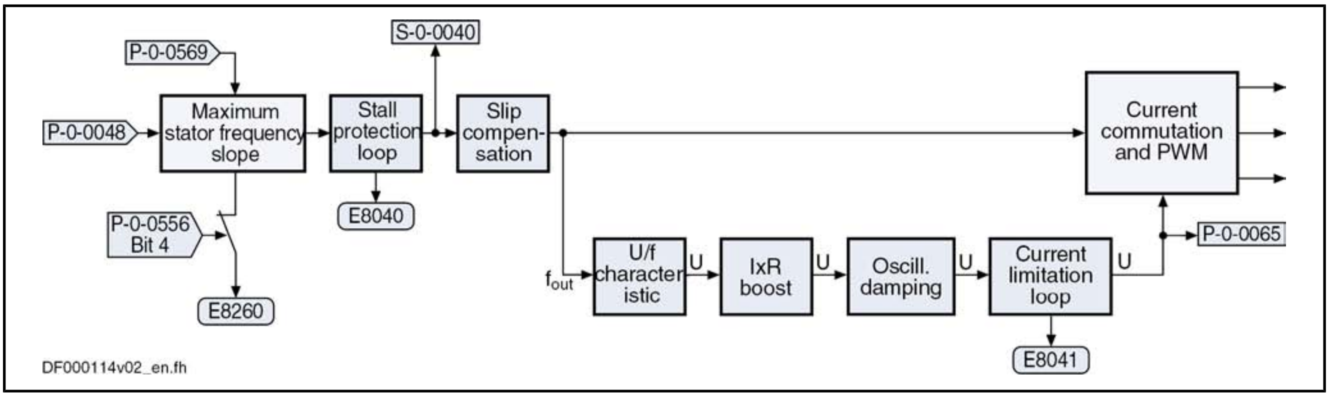
Pertinent Diagnostic Messages

- 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 U/f control:



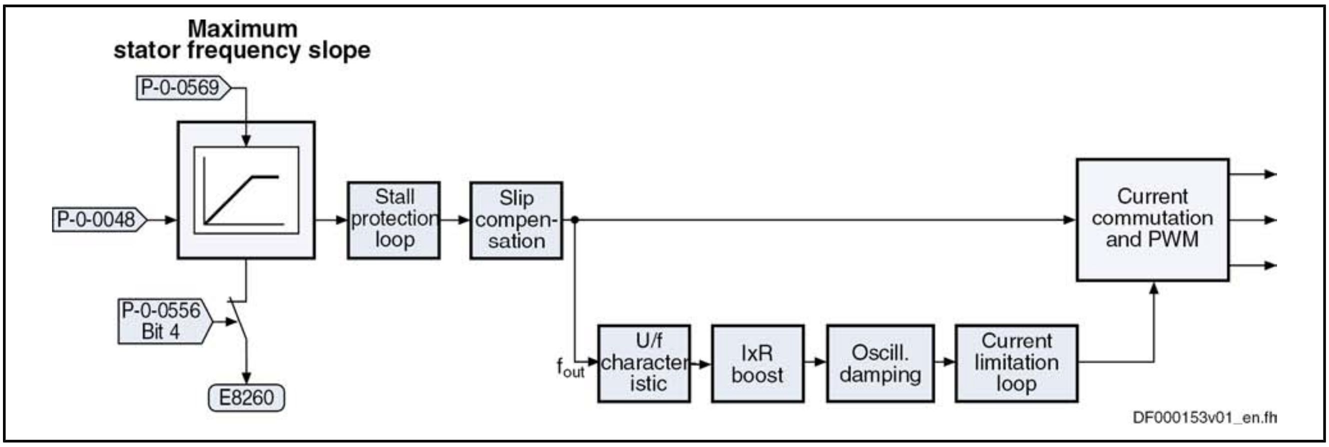
S-0-0040 Velocity feedback value
P-0-0048 Effective velocity command value
P-0-0065 Absolute voltage value, actual value
P-0-0556 Config word of axis controller
P-0-0569 Maximum stator frequency slope
Fig.6-11: Overview of Functions of U/f Control

Maximum Stator Frequency Slope

The maximum change of velocity with which the drive can follow the command values is determined by the motor and the sampling time of the stall protection loop. The limit value can be set in parameter "P-0-0569, Maximum stator frequency slope". When the acceleration capacity has been 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



P-0-0048 Effective velocity command value
P-0-0556 Config word of axis controller
P-0-0569 Maximum stator frequency slope
Fig.6-12: Core Function "Maximum Stator Frequency Slope"

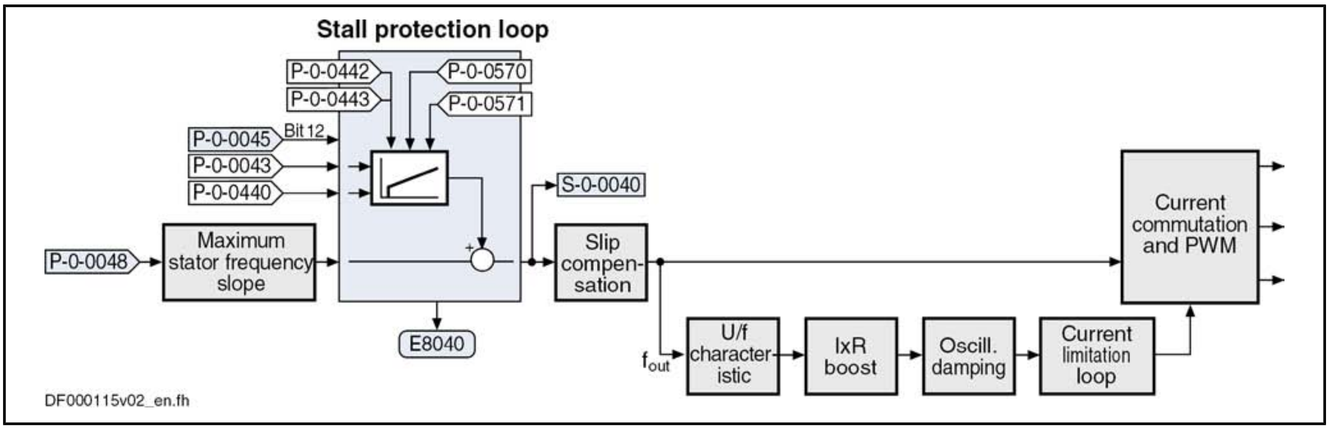
Stall Protection Loop

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 loop.

The stall protection loop is enabled via bit 12 of parameter "P-0-0045, Control word of current controller":

- Bit 12 = 1 → stall protection loop enabled
- Bit 12 = 0 → stall protection loop switched off

☞ The default setting in bit 12 of P-0-0045 is "1" (stall protection loop enabled).



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 loop proportional gain
P-0-0571	Stall protection loop integral action time

Fig.6-13: Core Function "Stall Protection Loop"

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)".

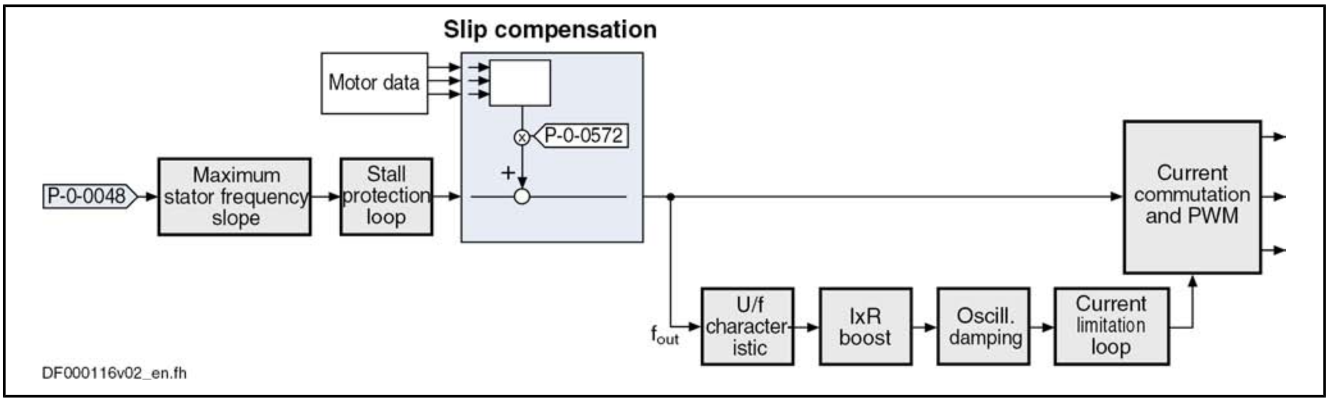
The stall protection loop is set via the following parameters:

- 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 loop 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.



P-0-0048 Effective velocity command value
P-0-0572 Slip compensation factor
Fig.6-14: Core Function "Slip Compensation"

The output signal of the stall protection loop 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.

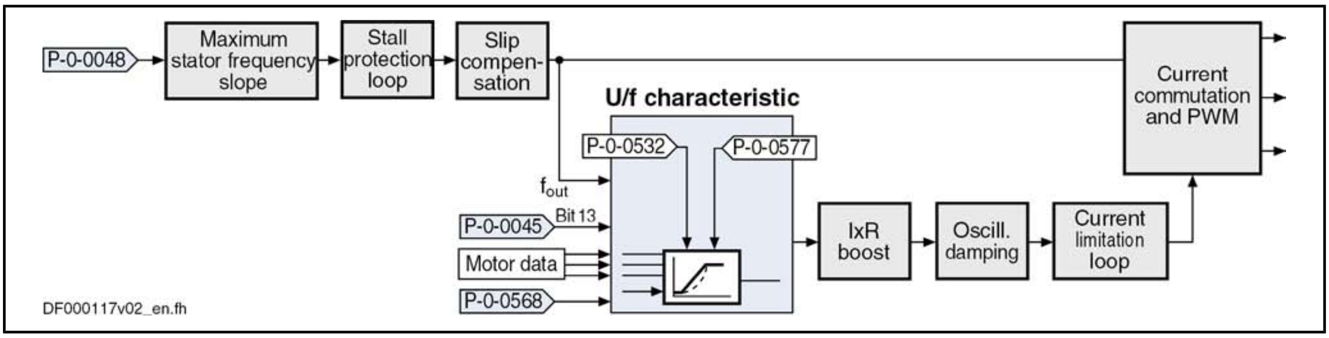
U/f Characteristic

In the "U/f characteristic" 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).



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
Fig.6-15: Core Function "U/f Characteristic"

The output signal of the slip compensation is used as the input value for the 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.

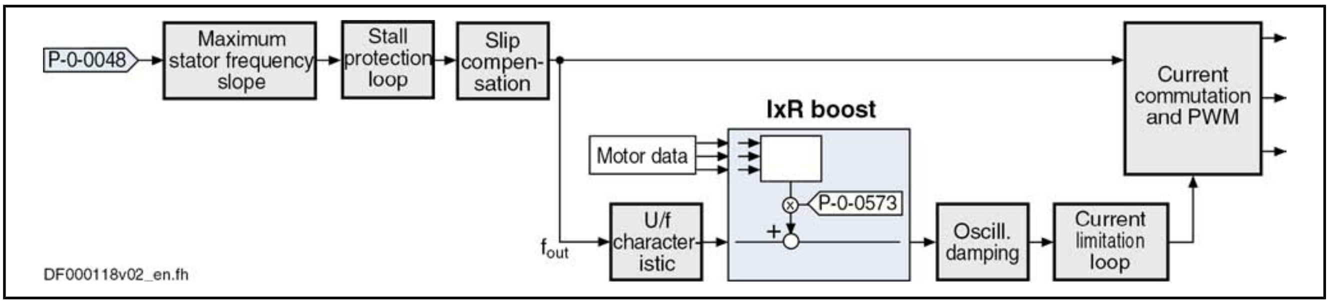
☞ The value "0.00%" in parameter P-0-0577 corresponds to the linear characteristic.

By means of parameter "P-0-0532, Premagnetization factor", it is possible to make a subsequent trimming of the machine's magnetization. This parameter 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.

☞ With a value of "0.00%" in parameter P-0-0573, the feedforward is switched off.

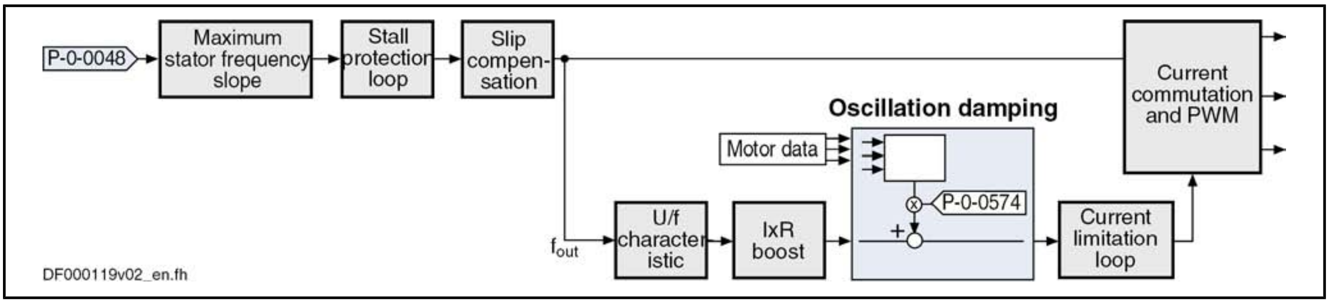


P-0-0048 Effective velocity command value
P-0-0573 IxR boost factor
Fig.6-16: Core Function "IxR Boost"

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.

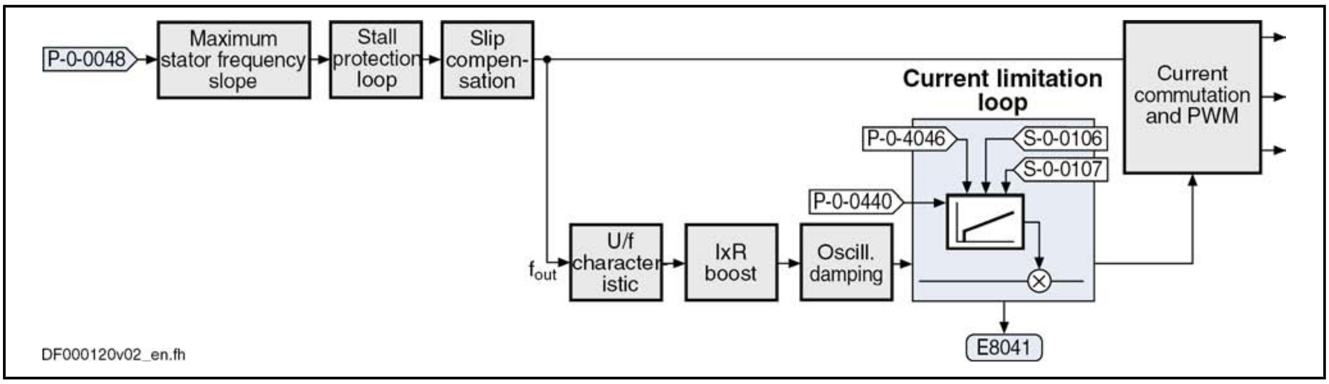


P-0-0048 Effective velocity command value
P-0-0574 Oscillation damping factor
Fig.6-17: Core Function "Oscillation Damping"

Current Limitation Loop

It is the task of the current limitation loop 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 loop only becomes active, if the enabled stall protection loop by changing the working point cannot reduce the drive load.



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
Fig.6-18: Core Function "Current Limitation Loop"

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".

Diagnostic and Status Messages

Monitoring the Stator Frequency

The limit value for the maximum change of 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 Loop

The activation of the stall protection loop is displayed in parameter "P-0-0046, Status word of current controller" (bit 12: stall protection loop):

- Bit 12 = 1 → stall protection loop active

  In addition, the diagnostic message "E8040 Torque/force actual value limit active" is generated.
- Bit 12 = 0 → stall protection loop not active

Status of Current Limitation Loop

The activation of the current limitation loop is displayed in parameter "P-0-0046, Status word of current controller" (bit 13: current limitation loop):

- Bit 13 = 1 → current limitation loop active

  In addition, the diagnostic message "E8041 Current limit active" is generated.
- Bit 13 = 0 → current limitation loop 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

6.2.3 Field-Oriented Current Control (FOC Control)

Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.6-19: Assignment to Functional Firmware Package

The current loop was preset for all motors by Bosch Rexroth and the parameter values have been stored in the motor encoder data memory or in the commissioning tool (IndraWorks D, DriveTop).

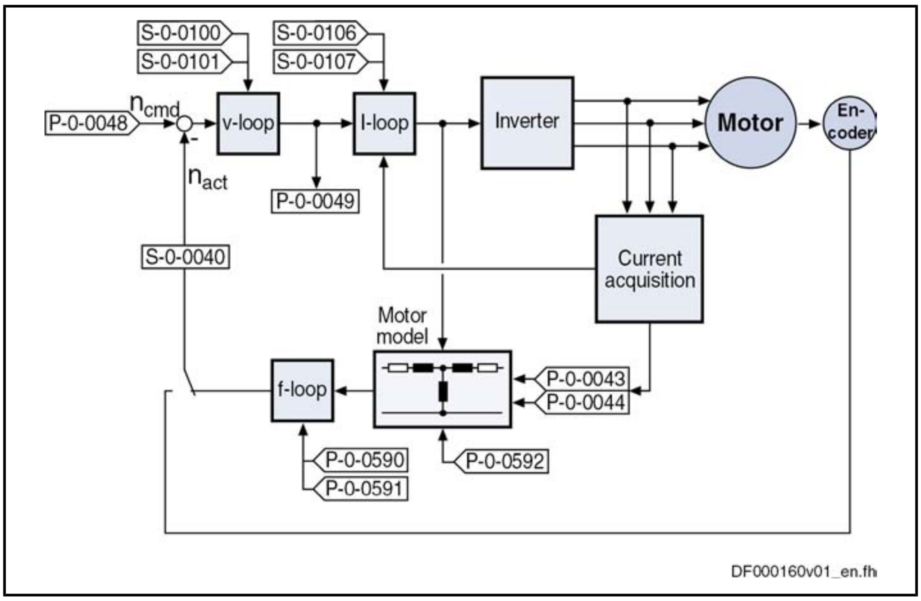
For notes on how to commission the current loop for third-party motors, see "Third-Party Motors at IndraDrive Controllers"!

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 loop for I_d
- I_q (torque-generating current) → PI loop for I_q

The figure below illustrates the principle of field-oriented current control for operation with motor encoder or with motor model:



v-loop Velocity loop
I-loop Current loop
f-loop Frequency loop

Fig.6-20: Simplified Schematic Diagram for Field-Oriented Current Control With Higher-Level Velocity Control

Sensorless Current Control

As of firmware version MPx04, field-oriented current control is also available without encoder feedback in the base packages "open-loop" and "closed-loop" with Advanced performance.

Sensorless field-oriented current control can only be used for asynchronous motors. For this purpose, it is necessary to calculate a motor model the parameter values of which are determined via the drive-internal setting of motor parameters and motor control parameters.

See section "Automatic Setting of Motor 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 loop for operation in the field weakening range
- Activation of the optimum current loop proportional gain value, depending on the current PWM frequency during the load defaults procedure

Features of Synchronous Motor Control

In the case of **synchronous motors**, field-oriented current control additionally has the following features:

- Only available for closed-loop operation with encoder
- 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 loop for correcting the flux feedforward
  – Flux loop 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 loop 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 loop setting:

- P-0-0533, Voltage loop proportional gain
- 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

Frequency control for asynchronous motors (in sensorless operation):

- P-0-0590, Motor model frequency loop proportional gain
- P-0-0591, Motor model frequency loop integral action time
- P-0-0592, Motor model adjust factor

Power monitoring:

- S-0-0158, Power threshold Px
- S-0-0337, Message 'P >= Px'
- S-0-0382, DC bus power

Encoder monitoring (in operation with encoder):

- P-0-0520, Error threshold for encoder monitoring

Display parameters:

- S-0-0380, DC bus voltage
- P-0-0043, Torque-generating current, actual value
- P-0-0044, Flux-generating current, actual value
- 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

- E8025 Overvoltage in power section
- E8028 Overcurrent in power section
- F2077 Current measurement trim wrong
- F8023 Error mechanical link of encoder 1
- F8060 Overcurrent in power section

General Function of Field-Oriented Current Control

Torque/Force Control

In contrast to the functional principle used in the "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 open-loop control of torque/force takes place, the torque or the force being directly connected with the torque-/force-generating current via the torque/force constant.

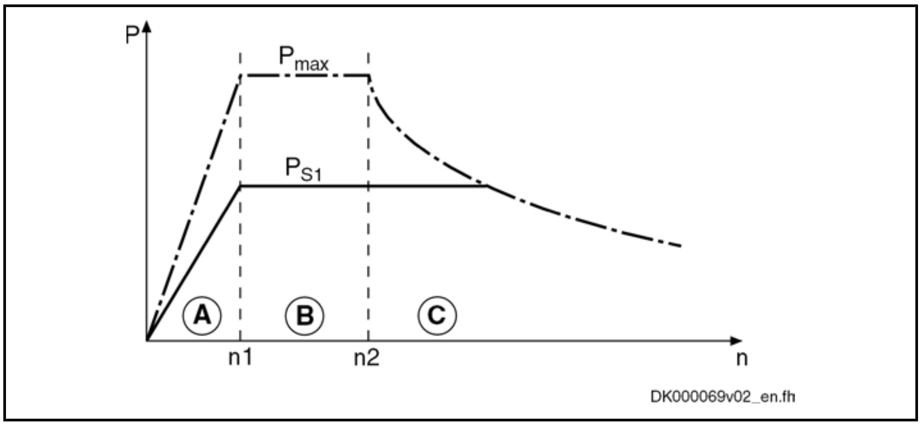
In the case of asynchronous motors, the torque constant is corrected according to the active rotor flux:

$$M_i = K_M \times I_q$$

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.6-21:	*Three Working Ranges of the Speed Range*

Basic Speed Range

The basic speed range is characterized by constant torque and fixed 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 loop.

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 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 operating modes. The figure below illustrates the control loop structure and the points at which the individual parameters take effect for a synchronous machine.

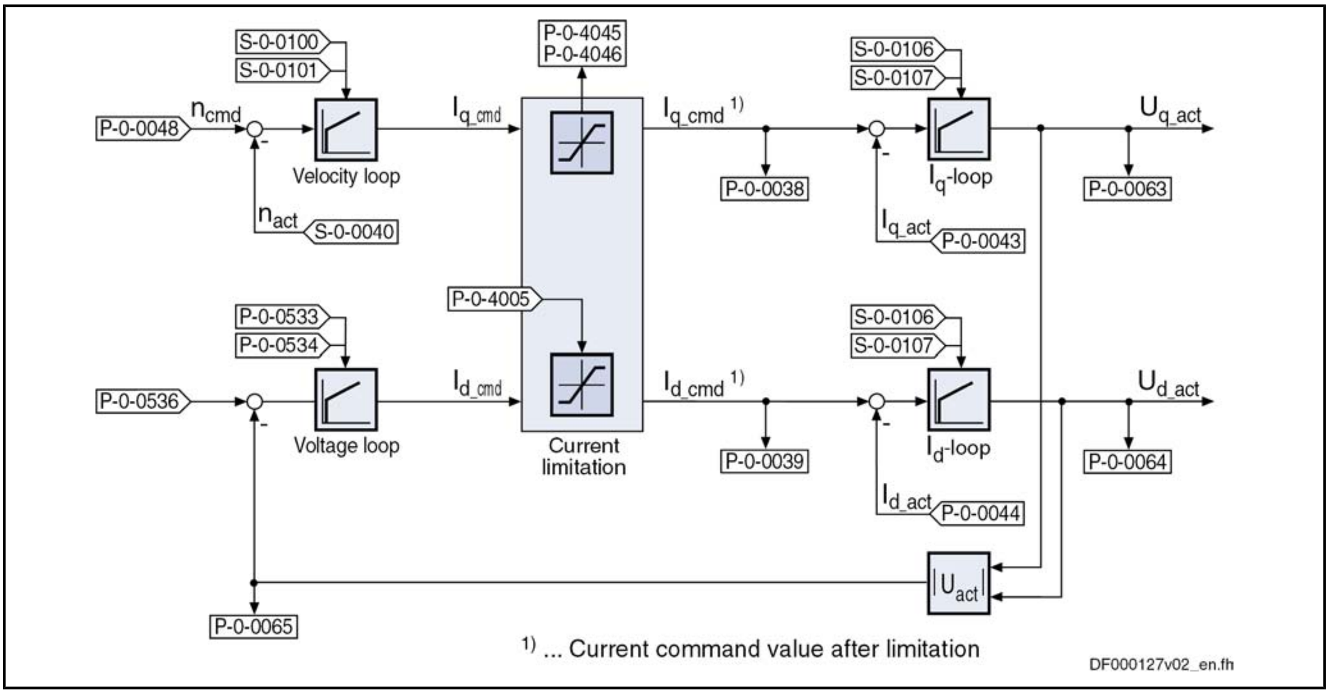


Fig.6-22: Simplified Schematic Diagram of the Current Control Loop for a Synchronous Machine

Voltage Loop for Synchronous Motors

For field control (or voltage control), a voltage loop designed as a PI loop is used that can be set via the following parameters:

- P-0-0533, Voltage loop proportional gain
- P-0-0534, Voltage loop integral action time

☞ The command value of the voltage loop is preset by parameter "P-0-0536, Maximum motor voltage".

The voltage loop becomes active when the current loop 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 loop is the command value for the field-generating component of the subsequent current loop (see figure above).

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 and q axes, 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)

☞ Utilization of the reluctance effect allows increasing the available torque in the basic speed range.

Field-Oriented Current Control of an Asynchronous Machine

☞ As of firmware version MPx04, field-oriented current control for asynchronous motors is also possible without motor encoder (with open-loop base package)!

Field-oriented control of the asynchronous machine differs from control of the synchronous machine in the additional function blocks "flux feedforward" and "flux loop incl. field model".

For field-oriented current control of an asynchronous machine, we distinguish the following characteristics:

- Current control with motor encoder for measuring the rotor angle
- Sensorless current control with motor model for determining the rotor angle

☞ In both cases, the motor velocity is displayed in parameter "S-0-0040, Velocity feedback value" and used as feedback for a velocity loop!

The figure below illustrates the control loop structure (incl. motor model and frequency loop) for both characteristics of field-oriented current control (with/without motor encoder):

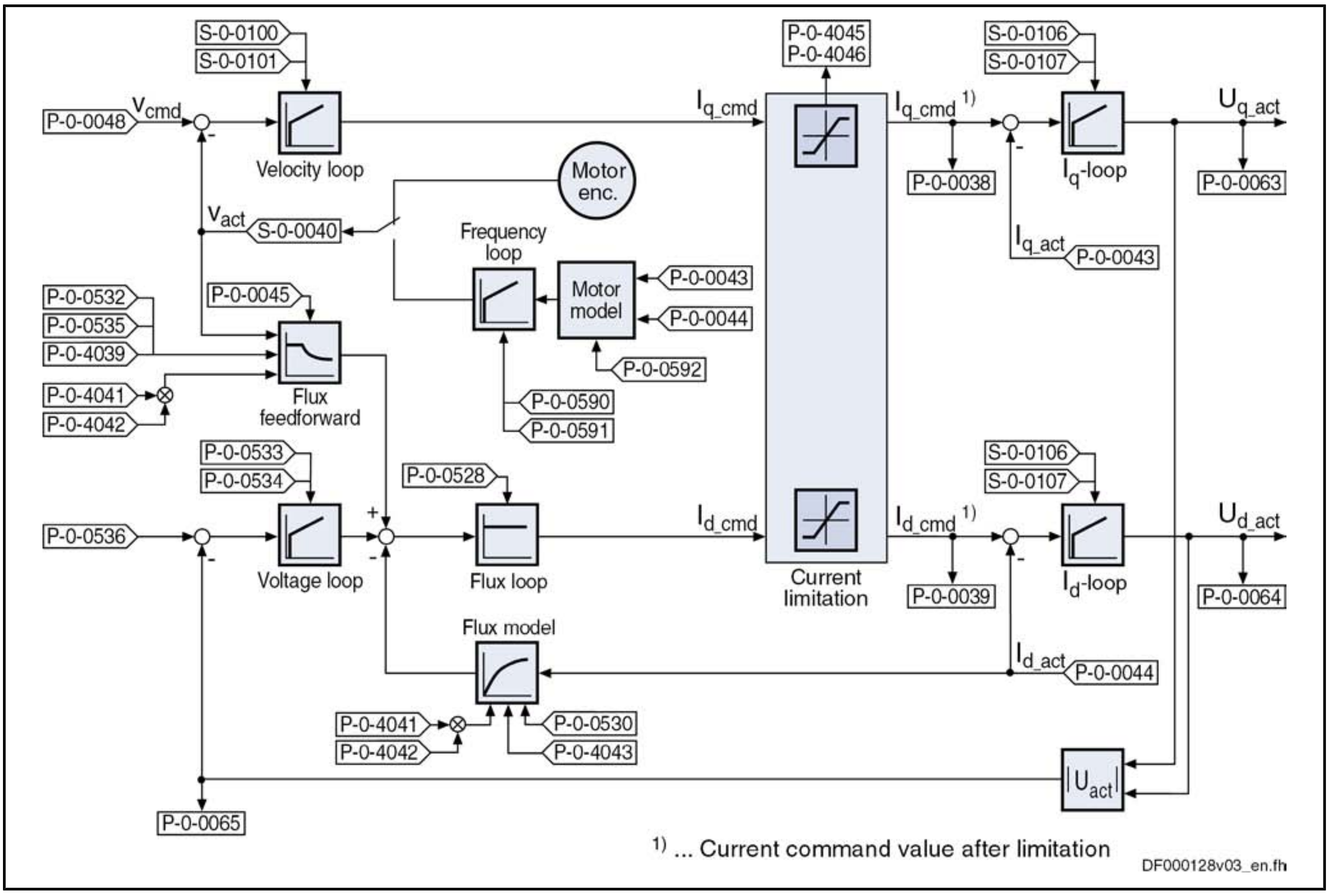


Fig.6-23: Simplified Schematic Diagram of the Current Control Loop for an Asynchronous Machine (With and Without Motor Encoder)

The following description first explains the functions (control loops) that take effect in operation without and with encoder, then the additional functions in sensorless operation (motor model, frequency loop).

Flux Feedforward and Flux 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 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 loop (see below) and additionally determines the torque constants and the behavior of the slip frequency of the asynchronous machine required for generating the torque.

Voltage Loop

The voltage loop works as a PI loop and in the absolute value limits the voltage output by the current loop to a maximum value. The setting is made via the following parameters:

- P-0-0533, Voltage loop proportional gain
- 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 loop interferes in a corrective way in the output value of the flux feedforward.

Flux Loop

The flux loop works as a P-loop with command value feedforward. It compares the actual value from the rotor flux model to the command value from flux feedforward and voltage loop 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 parameter "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" data base.

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 parameter "P-0-0529, Scaling of stall current limit" (in percent).

> When operating a motor without field weakening (generally in the case of linear asynchronous motors), it is only the effective magnetizing current that is applied as 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.

In operation without motor encoder, the rotor flux angle is determined by means of a motor model that cyclically takes all input and output values of the current loop into account.

> Apart from the missing motor encoder, sensorless field-oriented control differs from control with encoder in the additionally required motor model with subsequent frequency loop.

Motor Model

The motor model corresponds to a complete equivalent circuit diagram of the connected asynchronous motor taking motor inductances, resistances and time constants into account.

> The required values of the motor parameters and motor control parameters are automatically determined by means of the type plate data via command start.
>
> See section "Automatic Setting of Motor Control"

In the case of drive enable ("AF"), the motor model calculates the motor current and rotor flux in field-oriented vector representation, cyclically in the current loop clock (see section "General Information on Motor Control").

In order to compensate deviation of the model compared to the real motor, the model is corrected according to the measured current values and the correction factor is displayed in parameter "P-0-0592, Motor model adjust factor".

Frequency Loop

By means of the deviation between motor model and measured currents, the so-called "frequency loop" determines the current rotational frequency of the motor shaft of the asynchronous motor. The result of the frequency loop is entered in parameter "S-0-0040, Velocity feedback value" and used as feedback value for the velocity loop.

The frequency loop is a PI loop with the following values:

- P-0-0590, Motor model frequency loop proportional gain
- P-0-0591, Motor model frequency loop integral action time

Notes on Commissioning

☞ The current loop was preset for all motors by Bosch Rexroth and normally does not have to be adjusted.

Current Loop

The current loop for the torque- or force-generating current (I_q) designed as a PI loop 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 loop.

Availability of the parameter settings for the current loop:

- 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 sections "Automatic Setting of Motor Control" and "Third-Party Motors at IndraDrive Controllers").

See also "Commissioning the Motor"

Inductance Characteristic

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 loop gain for higher currents. This function is activated by setting bit 12 in parameter "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 loop 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 parameter P-0-4002 are factors which refer to the value in parameter "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 parameter P-0-4003 are factors which refer to the value in parameter "S-0-0111, Motor current at standstill".

The current values I_q of the characteristic are resulting by multiplication with this value.

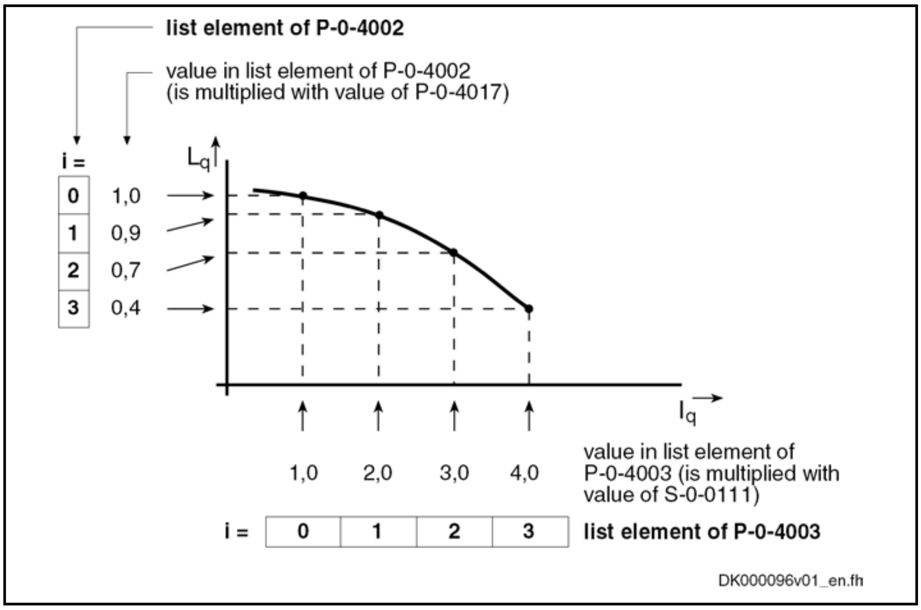


Fig.6-24: Interaction of the Parameters for Defining the Inductance Characteristic (With Exemplary Values)

Flux Feedforward

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.

☞ For reducing magnetization, a value between 50% and 100% can be set in parameter "P-0-0532, Premagnetization factor".

In addition, magnetization can be influenced via bit 2 in parameter "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 parameter P-0-0532

The value in parameter "P-0-0535, Motor voltage at no load" is used as limit value for 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 parameter P-0-0535.

Flux Model

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 parameter "P-0-0530, Slip increase".

☞ The factor in parameter P-0-0530 has to be set depending on the motor cooling type!

Voltage Loop (Flux Loop)

The voltage loop designed as a PI loop (flux loop) can be set via the following parameters:

- P-0-0533, Voltage loop proportional gain
- P-0-0534, Voltage loop integral action time

☞ The voltage loop is only active when bit 0 has been set (field weakening operation active) in the current loop control word (P-0-0045).

The command value of the voltage loop is set via the parameter "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 parameter P-0-0536.

Activating Field Weakening and Slip Increase

In addition to the parameterization of the voltage loop, 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.
- According to the motor cooling type, a different factor can be set in parameter "P-0-0530, Slip increase".

Activating Sensorless Operation

Sensorless field-oriented motor control can be activated via bits 14 and 15 of "P-0-0045, Control word of current controller".

☞ If a "closed-loop" functional package has been activated, the motor encoder has to be deactivated.

→ P-0-0074, Encoder type 1 (motor encoder) = 0

Determining Motor Model Parameters in Sensorless Operation

In order to use sensorless field-oriented motor control, the parameters of the motor model must have been correctly set. This is achieved with drive-internal determination and setting of the motor control parameters by activating the corresponding commands.

See section "Automatic Setting of Motor Control"

☞ The power section is switched on automatically!

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 parameter "S-0-0337, Message 'P >= Px'".
- S-0-0337, Message '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 parameter "S-0-0013, Class 3 diagnostics".

Display Values and Diagnostic Values

- The DC bus voltage is measured in the current loop clock and displayed in parameter "S-0-0380, DC bus voltage".
- The effective electric power produced by the controller (taking the inverter losses into account) is displayed in parameter "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 parameter "S-0-0158, Power threshold Px" is exceeded, bit 0 is set in parameter "S-0-0337, Message 'P >= Px'" and bit 7 in class 3 diagnostics.

- The measured value of the torque-generating current (I_q) detected in the current loop clock is displayed in parameter "P-0-0043, Torque-generating current, actual value".
- The measured value of the flux-generating current (I_d) detected in the current loop clock is displayed in parameter "P-0-0044, Flux-generating current, actual value".
- Parameter "P-0-0046, Status word of current controller" displays the status of the current loop.

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.
- C0251 Error during synchronization to master communication

  → The synchronization of drive control to the bus interface (SERCOS, PROFIBUS, Interbus …) failed during progression to the operating mode.
- 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 loop 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 loop is temporarily switched off to protect the motor (avoiding demagnetization).
- F2067 Synchronization to master communication incorrect

  → The synchronization of drive control to the bus interface (SERCOS, PROFIBUS, Interbus …) failed during operation.
- F2077 Current measurement trim wrong

  → During zero adjust of the current measurement, a deviation outside of the tolerance range occurred (hardware defect).

6.2.4 Automatic Setting of Motor Control

Brief Description

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.6-25: Assignment to Functional Firmware Package

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 loop, voltage loop, current loop, ...) 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 controller in different ways.

Motors by Bosch Rexroth

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 ("Load Defaults Procedure")")

- For motors **without motor encoder data memory**:
  - Parameters loaded via the commissioning tool "IndraWorks D" from the motor data base (DriveBase)

    - or -
  - Individual parameters manually written via the serial interface 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 for asynchronous motors

     Note: Appropriate start values already have to be available!
  2. Calculating the values of the motor control parameters
- C4600 Command Calculate motor control parameters

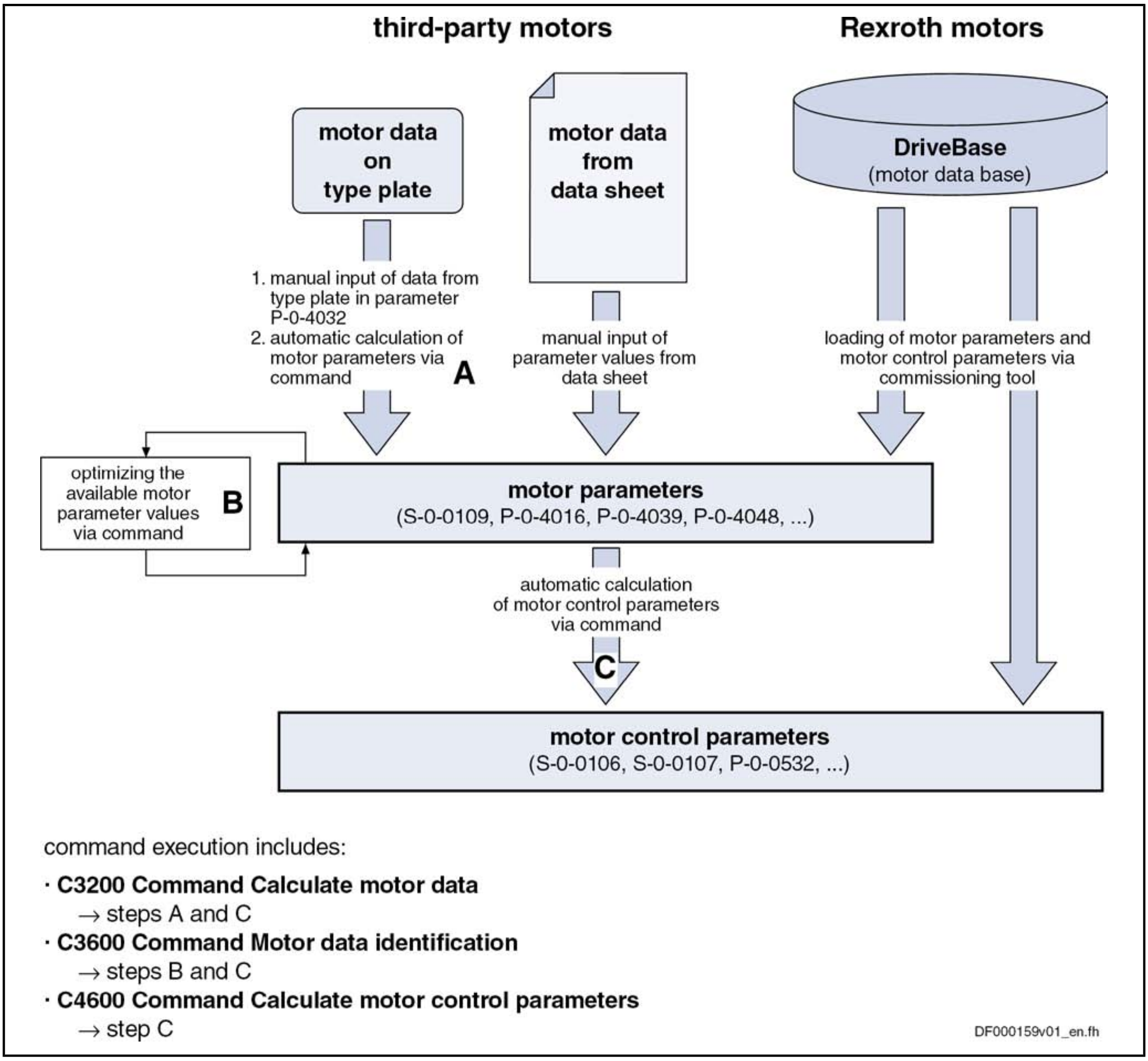
  Calculating the values of the motor control parameters from the motor parameters for synchronous motors and, if necessary, for asynchronous motors (after manual input of motor data in motor parameters)

☞ Basically, the prerequisite is the form "Manufacturer-Side Data of Synchronous Motors" or "Manufacturer-Side Data of Asynchronous Motors" in the section "Third-Party Motors at IndraDrive Controllers", to be completed by the motor manufacturer!

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:

Drive Control



P-0-4032 Motor type plate data

Fig.6-26: 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 loop are required.

See "Closed-Loop Axis Control (Closed-Loop Operation)"

See "Notes on Commissioning" in 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
- C3203 Incorrect input for voltage
- C3202 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
- 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
- C3605 Motor turning
- C3606 Type of construction of motor not allowed
- C4600 Command Calculate motor control parameters
- C4601 Error when writing parameters

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
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

Motor parameters	
Synchronous motor	**Asynchronous motor**
	P-0-4042, Characteristic of motor magnetizing inductance
	P-0-4043, Rotor time constant

Fig.6-27: 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 (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

Fig.6-28: Overview of Motor Control Parameters for Synchronous and Asynchronous Motors and Voltage-Controlled Operation (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, Voltage loop proportional gain	P-0-0533, Voltage loop proportional gain
P-0-0534, Voltage loop integral action time	P-0-0534, Voltage loop integral action time
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
	P-0-0590, Motor model frequency loop proportional gain

Motor control parameters for field-oriented current control (FOC)	
Synchronous motor	**Asynchronous motor**
	P-0-0591, Motor model frequency loop integral action time
	P-0-0592, Motor model adjust factor

Fig.6-29: Overview of Motor Control Parameters for Synchronous and Asynchronous Motors and Field-Oriented Current Control (FOC)

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 the parameter "P-0-4032, Motor type plate data".

See description of parameter "P-0-4032, Motor type plate data"

The command C3200 can only be used for asynchronous motors and can only be activated in communication phases "P2" or "P3"!

The figure below illustrates the scope of functions of the command C3200:

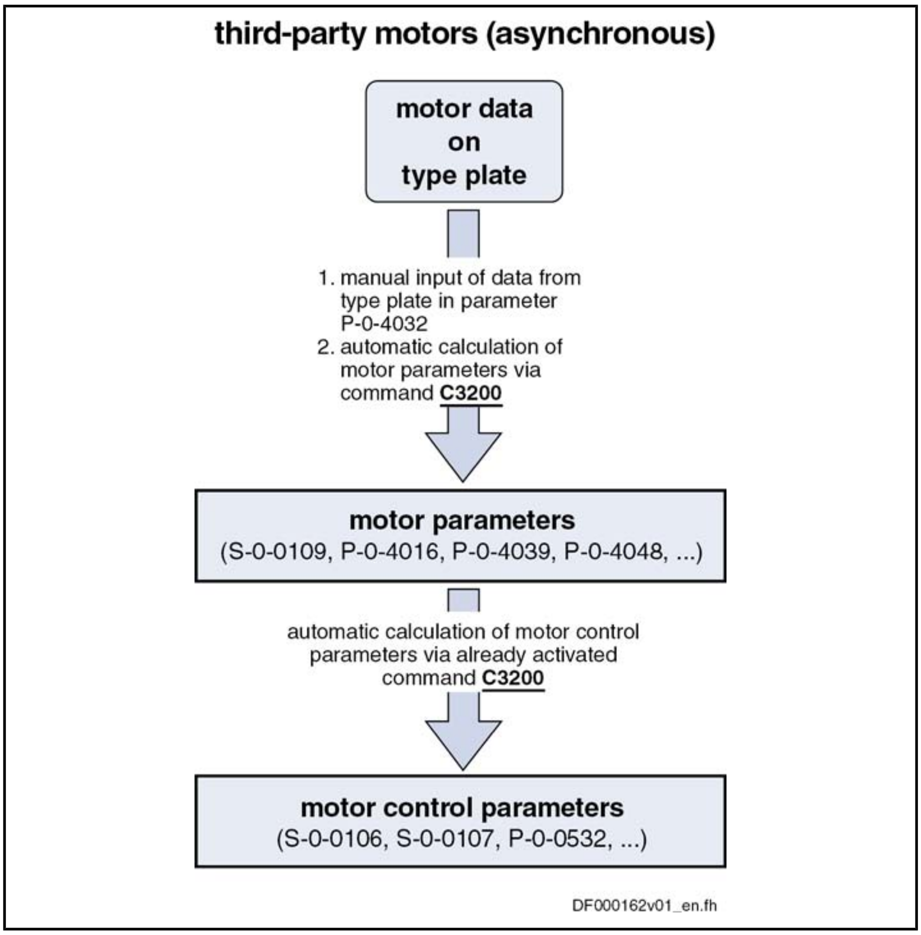


Fig.6-30: Functions of "C3200 Command Calculate Motor Data"

> 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 (for synchronous and asynchronous motors)
  - Specific motor parameters for asynchronous motors
- Motor control parameters
  - Motor control parameters for voltage-controlled operation (U/f) of sensorless asynchronous motors
  - Motor control parameters for field-oriented current control (FOC) of synchronous and asynchronous motors

Notes on Operating Principle

As regards the operating principle of the command C3200, observe the following points:

- Input in parameter 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 used for asynchronous motors and can only be activated in the operating mode (communication phase "P4")!

The figure below illustrates the scope of functions of the command C3600:

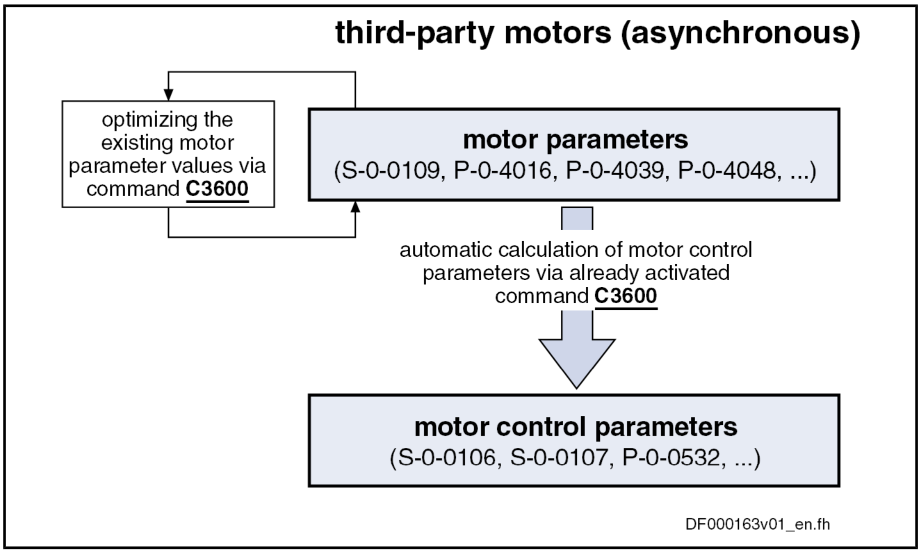


Fig.6-31: Functions of "C3600 Command Motor Data Identification"

Requirements

To execute the command C3600, the following requirements must have been fulfilled:

- Manual input of motor data from type plate in parameter "P-0-4032, Motor type plate data" and then execution of "C3200 Command Calculate motor data"

  - or -

- Manual input of all motor data in the motor parameters according to manufacturer's specification in completed motor data form

Procedure

In status "ready for power output" ("Ab"), current and voltage test signals are transmitted to the motor with the execution of command C3600. In this way, the motor parameters for asynchronous motors (see above) are checked and, if necessary, optimized.

A possibly available holding brake continues remaining in the status of control, as existing in the operating status "Ab".

After having successfully completed the command execution, the motor and motor control parameters have been optimized and stored.

The following parameters have been recalculated:

- Motor control parameters for voltage-controlled operation (U/f) of sensorless asynchronous motors
- Motor control parameters for field-oriented current control (FOC) of synchronous and asynchronous motors

Notes on Operating Principle

As regards the operating principle of the command C3600, observe the following points:

- Motor motion is not required; the motor holding brake possibly applied at "Ab" remains applied. The motor does not generate torque. With little friction and inertial mass, little motion can however occur!
- 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" below) for asynchronous motors, it is possible via "C4600 Command Calculate motor

Drive Control

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:

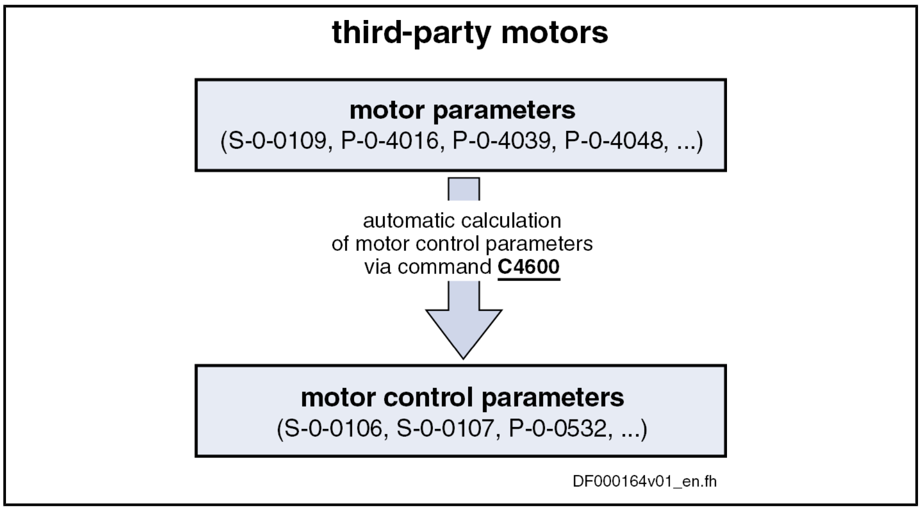


Fig.6-32: Function of "C4600 Command Calculate Motor Control Parameters"

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").
- For **asynchronous third-party motors**, the command C4600 is only useful, if the motor control parameters are to be generated from specific, manually input motor parameters (e.g. from equivalent circuit diagram data, see "Third-Party Motors at IndraDrive Controllers").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.

Notes on Operating Principle

As regards the operating principle of the command C4600, observe the following points:

- 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 manufac-turer	Motor design	Motor type	Encoder data memory	Motor parameters	Motor control parameters
Bosch Rexroth	Housing	MHD, MKD, MKE, MSK, SF, MAD, MAF	Yes	A	A
		2AD, ADF, MSD	No	M/D	M/D
	Kit	1MB, MBS, MBT, MBW, LSF, MLF, MBSxx2 (high speed)	No	M/D	M/D

Motor connected to controller				Parameter values made available	
Motor manufacturer	Motor design	Motor type	Encoder data memory	Motor parameters	Motor control parameters
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

Fig.6-33: Making Available Values for Motor Parameters and Motor Control Parameters

Rexroth Motors

For Rexroth motors, both the motor and motor control parameters are optimized by the manufacturer via the encoder data memory of the motor encoder or, for motors without encoder memory, via the commissioning tool.

For Rexroth motors it is not required to determine the motor or motor control parameters! The commands C3200, C3600 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!

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 data base of the commissioning tool, but are determined via command by the controller after manual input of the type plate data and motor parameter values (see "Third-Party Motors at IndraDrive Controllers").

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 descriptions of diagnostic messages in the separate documentation "Troubleshooting Guide (description of diagnostic messages)"

6.3 Open-Loop Axis Control (Open-Loop Operation)

6.3.1 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 U/f control.

The method of open-loop/closed-loop motor control can be selected via bit 14 of parameter "P-0-0045, Control word of current controller".

See also section "Motor Control"

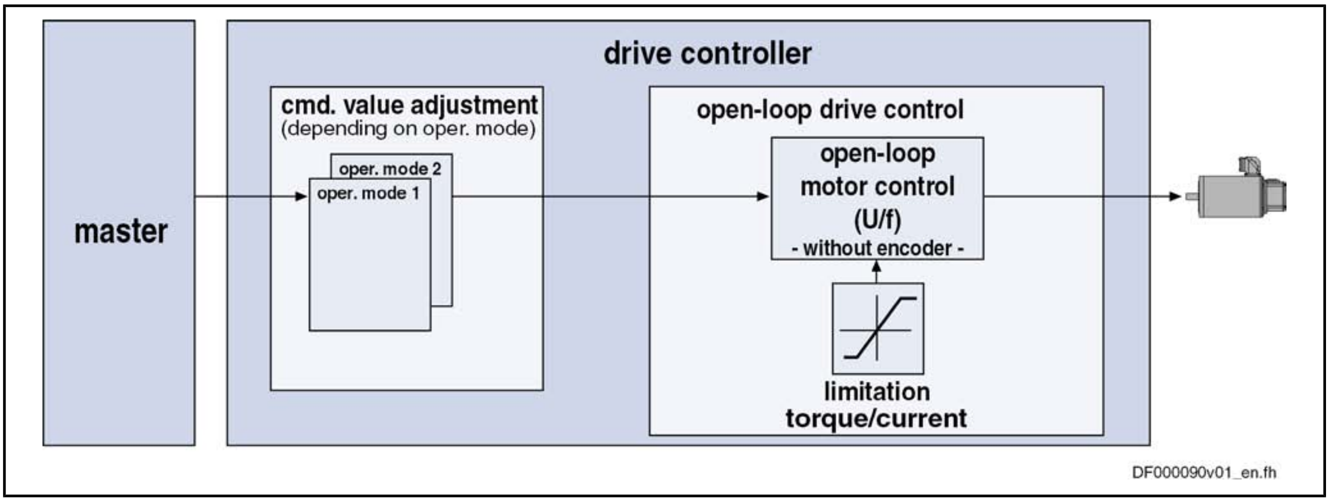


Fig.6-34: Principle of Drive Control in Open-Loop Operation

Features

The 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 loop** (PI loop 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 **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 loop** 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, Status word of axis controller
- P-0-0556, Config word of axis controller

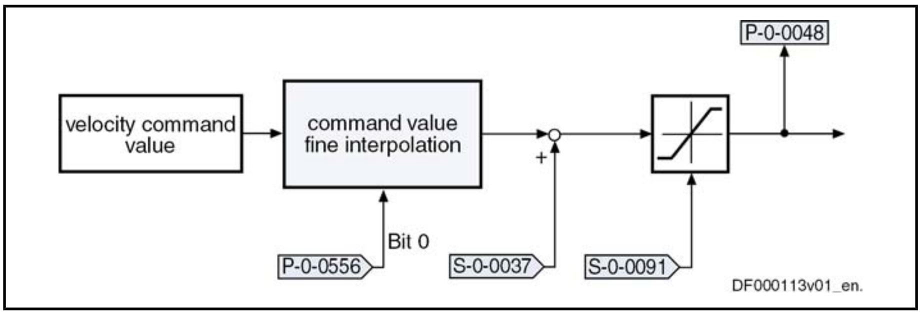
Pertinent Diagnostic Messages

- F8079 Velocity limit value S-0-0091 exceeded

6.3.2 Functional Description

Fine Interpolator

When the drive is running in open-loop operation (open-loop U/f control), the preset velocity command value can be smoothed by a fine interpolator via 2 steps.



S-0-0037 Additive velocity command value
S-0-0091 Bipolar velocity limit value
P-0-0048 Effective velocity command value
P-0-0556 Config word of axis controller
Fig.6-35: Fine Interpolation of the Velocity Command Value

☞ The fine interpolator can be activated via bit 0 of parameter "P-0-0556, Config word of axis controller".

Units of the Processed Data

The physical data for 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

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 Operation".

6.3.3 Diagnostic and Status Messages

Monitoring the Velocity Limit Value

The actual velocity value, internally generated via the stall protection loop is monitored for the limit value of 1.125 * S-0-0091 (bipolar velocity limit value). When this value is exceeded, the following error message is generated:

- F8079 Velocity limit value S-0-0091 exceeded

6.4 Closed-Loop Axis Control (Closed-Loop Operation)

6.4.1 General Information on Closed-Loop Axis Control

Control Loop Structure

The drive controller has a so-called cascade structure, i.e. the individual loops (position, velocity and current) are interconnected. Depending on the operating mode there are different control loop structures with different points of input and paths of the command values. Depending on the active mode of operation, 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 illustrated in the two graphics 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 standardisations and structural changes have been carried out.

Performance (Controller Cycle Times)

The internal controller cycle times (current, velocity and position) depend on the following conditions and parameters:

- Version of the control section (CSH, CSB or CDB)
- Activation of the functional packages
- P-0-0001, Switching frequency of the power output stage
- P-0-0556, Config word of axis controller (bits 2 and 5)

In accordance with these factors, the following cycle and switching times can be obtained:

	ADVANCED control sections	BASIC control sections
PWM switching frequency	max. 16 kHz	max. 8 kHz
current loop clock ($T_{A\_current}$)	62.5 µs	125 µs
velocity loop clock ($T_{A\_velocity}$)	125 µs	250 µs
position loop clock ($T_{A\_position}$)	250 µs	500 µs

Fig.6-36: Cycle and switching times that can be reached at IndraDrive

☞ All data about performance are summarized in the section "Performance Data".

Position Loop

- Jerk limitation in the "cyclic position control" mode by introducing the S-0-0349, Jerk limit bipolar parameter. The filtering degree of the smoothing filter (moving average value) can be set in the parameter "P-0-0042, Current position command average value filter order".
- Velocity feedforward, i.e. degree of feedforward, to be set in the parameter "P-0-0040, Velocity feedforward evaluation" (0% ... 100%)
- Input value for the parameter "S-0-0348, Acceleration feedforward gain" can be the respective inertia in kg*m^2 (for rotary motors) or the mass in kg (for linear motors).

Velocity Loop

- Standardization of the output value at the velocity loop to Newton (N) or Nowton meter (Nm). Therefore, depending on the motor type, the following unit is obtained for the parameter S-0-0100 in IndraDrive:
- Rotary motor → Nm * s/rad
- Linear motor → N * min/mm
- Possibility of extending the filter options for filtering the resonance frequencies. 4 filters of 2nd order are available, that can be set via the parameters P-0-1120, P-0-1121, P-0-1122 and P-0-1123.
- Limitation of the acceleration in the velocity loop through settings in the parameter "S-0-0138, Bipolar acceleration limit value"

Possibilities of Access to Included Control Loops

For operation in a higher-level mode of operation, it is possible to access an included control loop. Depending on the basic mode of operation, the following parameters are available:

In position control:

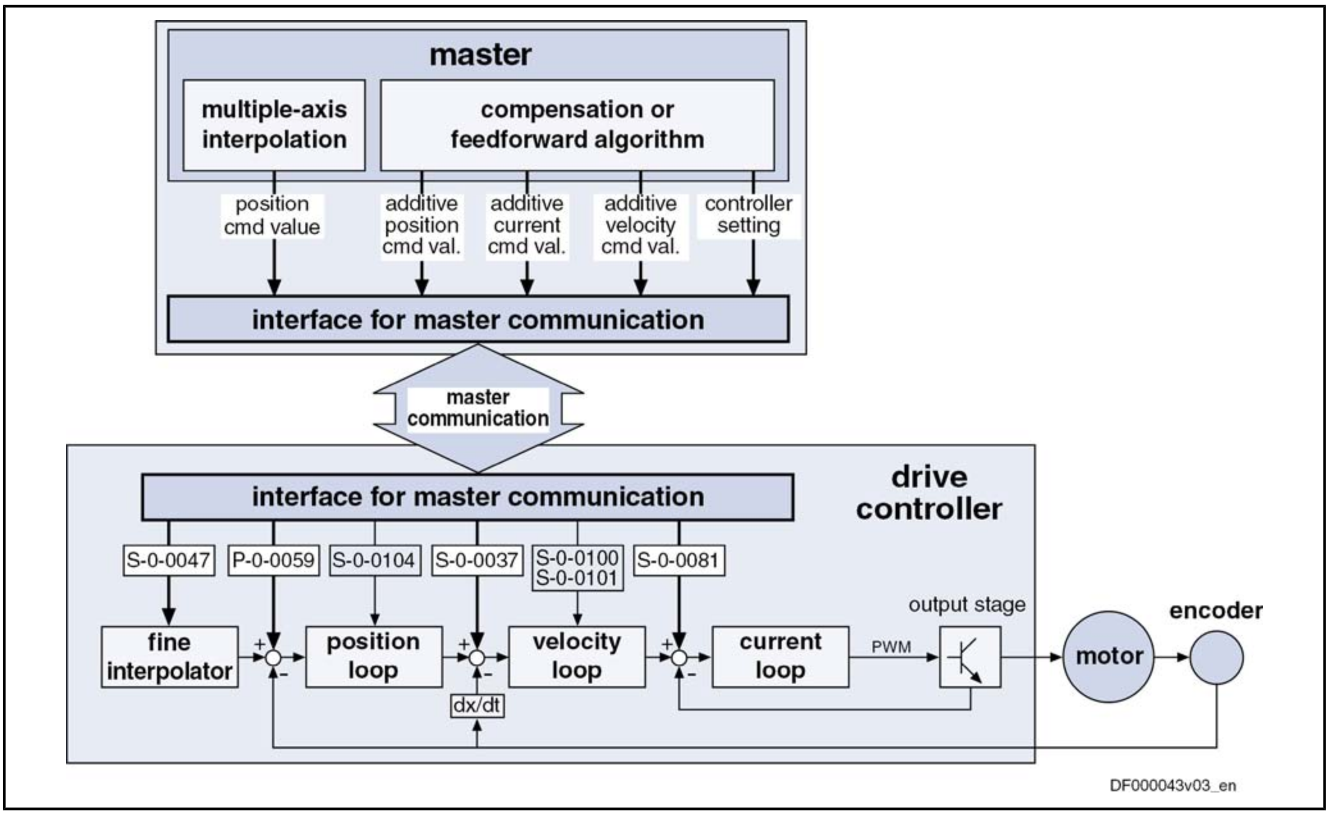
- P-0-0059, Additive position command value, controller
- S-0-0037, Additive velocity command value
- S-0-0081, Additive torque/force command value

In velocity control:

- S-0-0037, Additive velocity command value
- S-0-0081, Additive torque/force command value

In current control:

- S-0-0081, Additive torque/force command value



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.6-37: Structural overview with access options

Command Value Processing Depending on Operating Mode

Position Control

For the following modes of operation, 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
- Drive-controlled positioning

See also description of the respective mode of operation

Velocity Control In the "velocity control" mode of operation, the velocity control loop is closed in the drive, in addition to the current control loop.

See also "Velocity Control"

torque/force control The "torque/force control" mode of operation is not a control of the torque or the force in the actual sense but a 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 settings of the control loop in a digital drive controller are of decisive importance for the features of the servo axis.

For optimizing the control loop, utilization-specific control parameters are available for all digital Rexroth drives.

Order for the Manual Setting of the Control Loop Due to the cascade structure of the control loops it is required to parameterize them bottom-up. Therefore, the following order for the settings of the control loops is obtained:

1. **Current control loop**

   For **Rexroth motors with motor encoder data memory** (for the ranges MHD, MKD and MKE) the optimization of the current loop 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 obtained from a central motor data base by means of the commissioning tool "IndraWorks D" .

   The commissioning of **third-party motors** (including control loop settings) is described in this documentation in the respective chapters on third-party motors (see "Third-Party Motors at IndraDrive Controllers").

2. **Velocity control loop**

   The settings of the velocity controller (S-0-0100 and S-0-0101) including the respective filters (P-0-0004 and P-0-1120, P-0-1121, P-0-1122, P-0-1123) depend on the motor parameters, on the one hand (inertia and torque/force constant) and very strongly depend on the mechanical properties, on the other hand (degree of load inertia or mass, friction, stiffness of the connection, ...). Therefore, manual or automatic optimization is often necessary.

3. **Position control loop**

   In general, the position control loop must only be adapted to the dynamics of the outer velocity controller and the type of preset command values (jerk, acceleration and interpolation procedure).

Default Settings in the Motor Encoder Data Memory ("Load Defaults Procedure")

Command "Load Defaults Procedure" The basic settings for the controllers of all Bosch Rexroth motors of the ranges with motor encoder data memory (e.g. MHD, MKD MKE, MSK and possibly MAD and MAF) are saved and can be loaded into the drive by executing the command "Load defaults procedure" (S-0-0262).

There are two ways to activate the "S-0-0262, C07_x Load defaults procedure" command parameter:

- Automatic activation when the drive is run up, by recognising that the motor type has changed (compare parameter S-0-0141). Then the display reads "RL" and by pressing the key "Esc" on the operation panel, the command "load default procedure" is started internally, in case it has not been de-activated in "P-0-0556, Config word of axis controller".
- Starting of the commant by writing the parameter S-0-0262 with "11b".

See also "Loading, Storing and Saving Parameters"

☞ In order to start the command "Load default procedure", the parameter "P-0-4090, Configuration for loading default values" must contain the value "0" (default setting).

At the loading default procedure the following control loop parameters will be set to the optimized default values 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, Speed loop smoothing time constant

☞ The default settings for the current control loop (comp. S-0-0106 and S-0-0107) are automatically adjusted to the currently parameterized PWM frequency (comp. P-0-0001) and the performance settings (comp. P-0-0556) !

In addition, during loading default procedure, the following control loop parameters are set to their firmware default values, although there are no default values stored in the motor data memory:

- S-0-0348, Acceleration feedforward gain
- P-0-1125, Velocity control loop: average value filter clock

☞ In most cases, the controller settings stored in the motor encoder data memory lead to useful and stable control loop settings. In exceptional cases, however, it may be necessary to make the settings with regard to the specific application.

6.4.2 Automatic Setting of Closed-Loop Axis Control

Brief Description

To facilitate drive parameterization, the IndraDrive firmware provides automatic control loop setting in closed-loop operation. By means of the parameters "P-0-0163, Damping factor for autom. controller adjust" and "P-0-0164, Application for autom. controller adjust", the result of the control loop setting (obtained control loop dynamics) can be influenced.

☞ To carry out the automatic control loop setting, it is necessary to move the drive. The velocity and position control loops are optimized.

Features

- Definition of a travel range for movement control for the automatic control loop setting by
  – Absolute travel limits

- or -

– Entering a travel distance based on the current actual position

- Use of drive-internal interpolation and its parameters
- Possible settings in "P-0-0165, Selection for autom. controller adjust" for:
  – Velocity loop
  – Position loop
  – Acceleration feedforward
  – Determination of the load inertia
  – Determination of the maximum acceleration
  – Oscillation movement / unipolar movement
  – Absolute travel limits / relative movement around start position

Pertinent Parameters

- P-0-0162, C1800 Command Automatic control loop adjust
- P-0-0163, Damping factor for autom. controller adjust
- P-0-0164, Application for autom. controller adjust
- P-0-0165, Selection for autom. controller adjust
- P-0-0166, Lower limit for autom. controller adjust
- P-0-0167, Upper limit for autom. controller adjust
- P-0-0168, Maximum acceleration to be parameterized
- P-0-0169, Travel distance for autom. controller adjust

Pertinent Diagnostic Messages

- C1800 Command for automatic control loop setting
- C1801 Start only possible for drive enable
- C1802 No useful motor feedback data
- C1803 Error in determination of the mass inertia
- C1804 Automatic controller setting failed
- C1805 Travel range invalid
- C1806 Travel range exceeded
- C1807 Determining travel range only via travel distance
- E2047 Interpolation velocity = 0
- E2048 Interpolation acceleration = 0
- E2049 Positioning Velocity >= S-0-0091
- E2055 Feedrate override
  S-0-0108 = 0
- F2039 Maximum acceleration exceeded

Prerequisites for Starting the Automatic Control Loop Setting

CAUTION

Property damage and/or personal injury caused by drive motion!

During the execution of the command "C1800 Command automatic control loop setting", the drive moves automatically, i. e. without external command values.

⇒ Check and make sure that the E-Stop circuit and the travel range limit switches are working.

Defining the Travel Range

As the axis is moved for identifying and setting the control loop, it is necessary to define an allowed travel range. There are basically two possibilities for defining the range within which the axis may move during the automatic control loop setting:

- Definition of a travel range by entering limit values in the parameters P-0-0166 and P-0-0167

  - or -

- Definition of a travel range by parameterizing "P-0-0169, Travel distance for autom. controller adjust" (required for modulo axes)

☞ The mode for travel range definition is selected in parameter "P-0-0165, Selection for autom. controller adjust" (bit 15).

Determining Travel Range Limits

If bit 15 of P-0-0165 has not been set (value "0"), the allowed travel range is defined by means of

- the lower limit position (P-0-0166)

  - and -

- the upper limit position (P-0-0167).

The value of "P-0-0169, Travel distance for autom. controller adjust" results from these two limit values.

Entering a Travel Range

If bit 15 of P-0-0165 has been set (value "1"), the allowed travel range is defined by means of

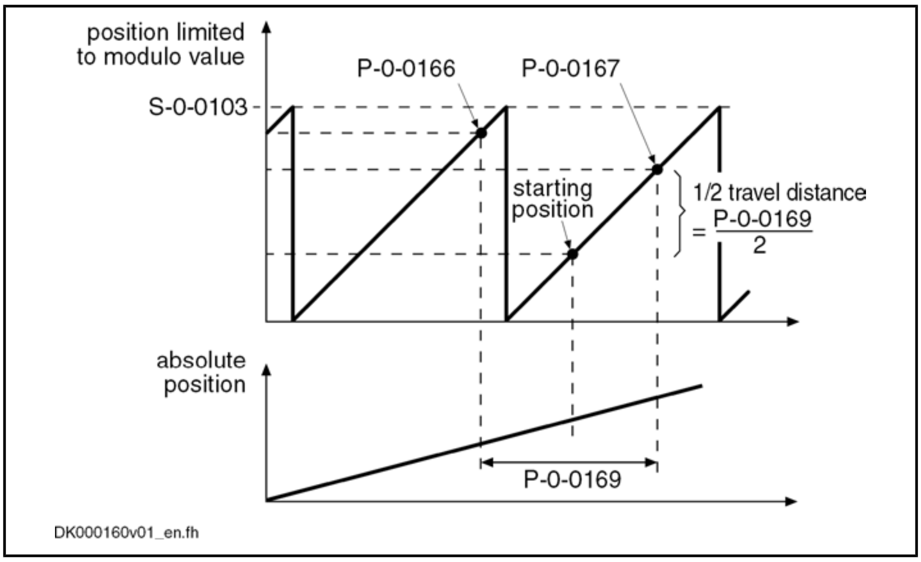
- P-0-0169, Travel distance for autom. controller adjust

  - and -

- start position (actual position) at the start of the command.

The resulting limit values for the travel distance are:

- Lower limit: P-0-0166 = start position – 0.5 * travel distance (P-0-0169)
- Upper limit: P-0-0167 = start position + 0.5 * travel distance (P-0-0169)



S-0-0103	Modulo value
P-0-0166	Lower limit for autom. controller adjust
P-0-0167	Upper limit for autom. controller adjust
P-0-0169	Travel distance for autom. controller adjust

Fig.6-38: Travel Range for Automatic Control Loop Setting With Modulo Scaling

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☞ The monitoring of the defined travel range is only effective during the execution of the command "automatic control loop setting"!

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.

Drive Enable and Drive Start

An oscillation for automatic control loop setting is only carried out when the following requirements have been fulfilled:

- **Drive enable** is present
- **Drive start** has been set

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.

- P-0-0163, Damping factor for autom. controller adjust

  → Selection of the desired control loop dynamics
- P-0-0164, Application for autom. controller adjust

  → Consideration of the mechanical properties for the controller optimization
- P-0-0165, Selection for autom. controller adjust

  → Selection of the functionality (modes) of the automatic control loop setting

Time Flow of Automatic Control Loop Setting

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. Determine total and extrinsic inertia by evaluating acceleration and deceleration processes
3. Calculate and activate controller parameters in the drive in consideration of "P-0-0163, Damping factor for autom. controller adjust" and "P-0-0164, Application for autom. controller adjust"
4. Check velocity control loop and correct controller parameters, if need be, until desired behavior occurs (depends on dynamics programmed)
5. Check position control loop and correct controller parameters, if need be, until desired aperiodic behavior in position control loop occurs
6. Wait for possible restart or end of command

   During this step the drive is idle (velocity = 0) and the display reads "C1800".

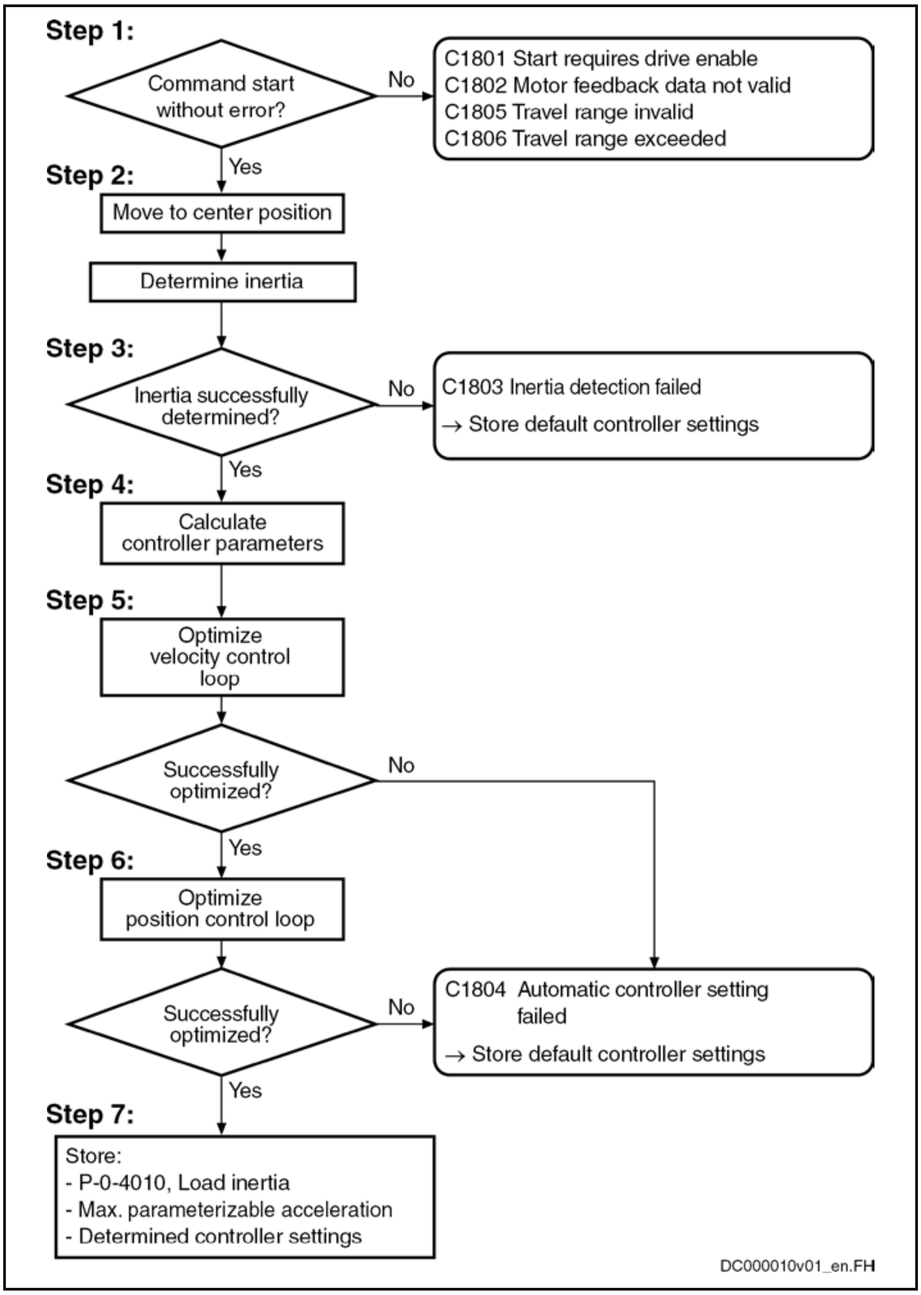


Fig.6-39: Steps of Automatic Control Loop Setting

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 Defaults Procedure")"

Selection Parameter for Automatic Control Loop Setting

Via "P-0-0165, Selection for autom. controller adjust", it is possible, by selecting the corresponding bit, to activate (bit = 1) or deactivate (bit = 0) the respective subfunction of the automatic control loop setting. The result of the automatic control loop setting depends on the selection made in P-0-0165.

See Parameter description "P-0-0165, Selection for autom. controller adjust"

Possible results of the automatic control loop setting (with respective bit set in P-0-0165):

- **Bit 1** → Setting of velocity control loop (cf. S-0-0100, S-0-0101, P-0-0004, P-0-1120 ...)
- **Bit 2** → Setting of position control loop (cf. S-0-0104)
- **Bit 4** → Setting of load inertia (reduced to motor shaft) and input in parameter P-0-4010
- **Bit 6** → Determination of maximum drive acceleration and input in parameter P-0-0168
- **Bit 3** → Determination of acceleration feedforward

As the result of the automatic control loop setting, the value for acceleration feedforward is calculated according to the formula below and entered in parameter S-0-0348:

S-0-0348 = (P-0-4010) + (P-0-0510)

Fig.6-40: Calculating the Acceleration Feedforward

Notes on Commissioning

CAUTION

The execution of the automatic control loop setting is connected with a drive motion!

⇒ Select the travel range defined with the parameters 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 command "automatic control loop setting" must be made prior to command start.

Starting the Automatic Control Loop Setting

The automatic control loop setting is started by writing the binary numeric value "3" (11b) to parameter "P-0-0162, C1800 Command Automatic control loop adjust" (command start).

Triggering a Motion

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 adjust", but the axis won't move.

Triggering the Motion by Starting the Command C1800

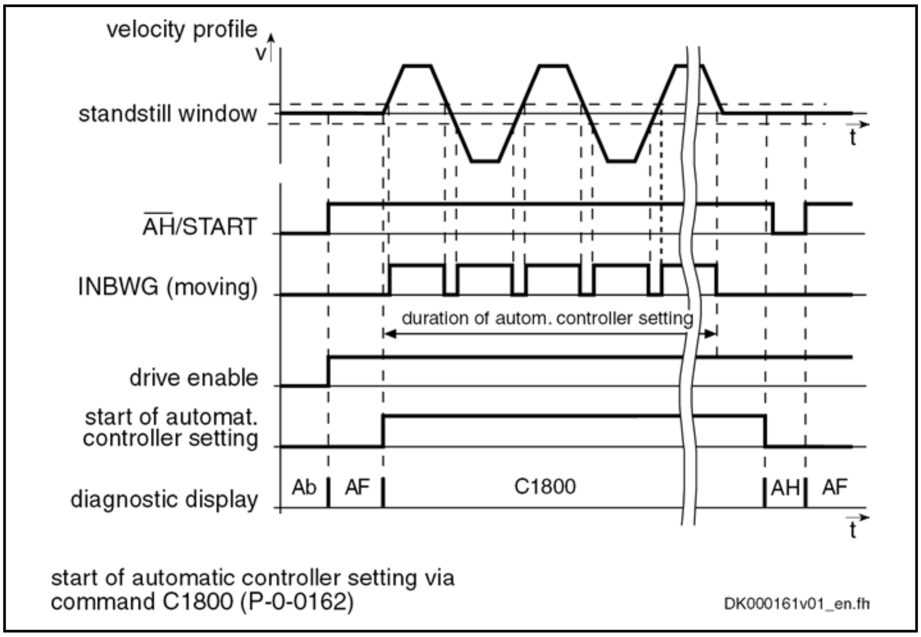


Fig.6-41: Signal Flow Chart for Motion by Command Start

Triggering the Motion by "Drive Start"

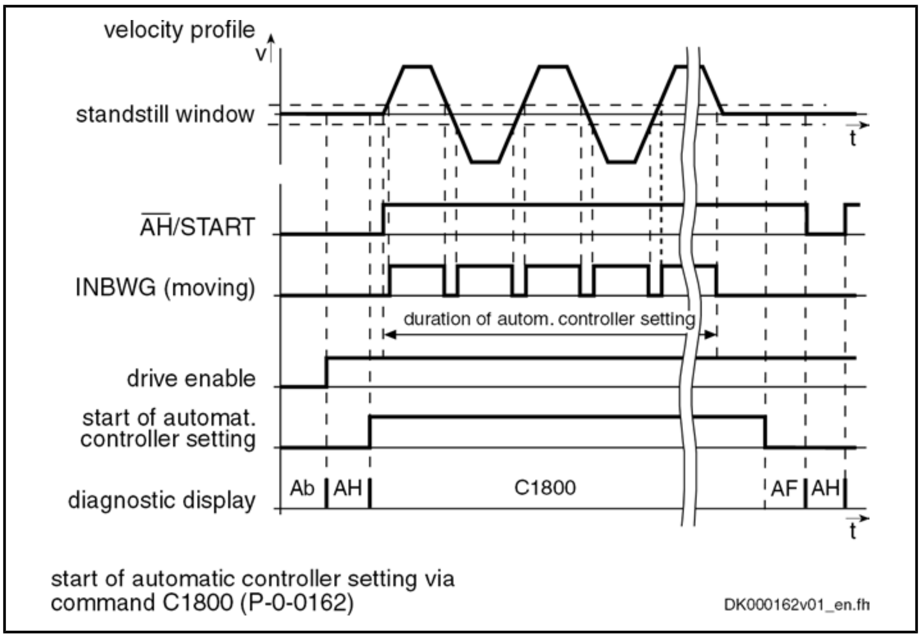


Fig.6-42: Signal Flow Chart for Motion by "Drive Start"

Interrupting the Command by "Drive Halt"

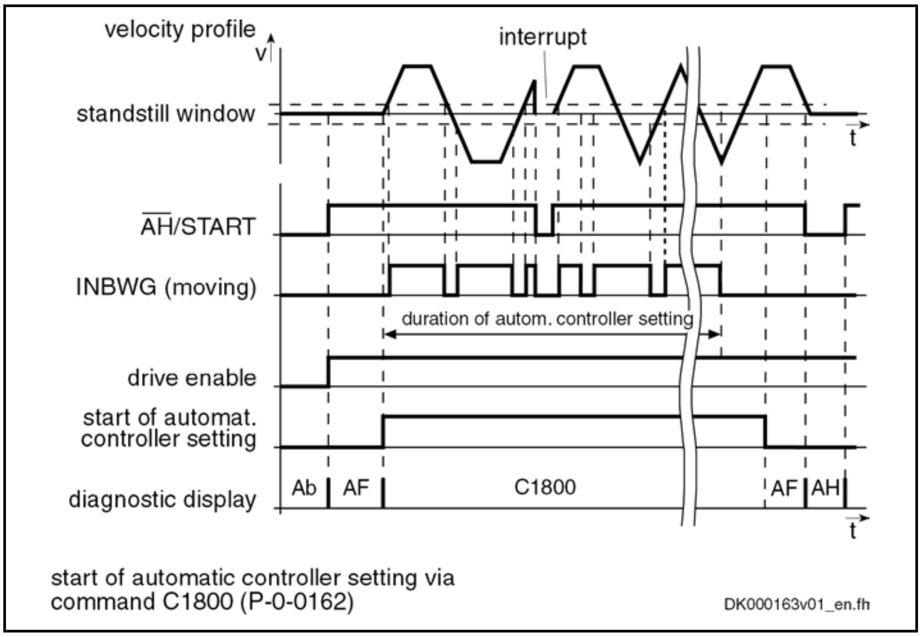


Fig.6-43: Signal Flow Chart for Interruption by "Drive Halt"

A repeated run with possibly changed settings can be carried out in two ways:

- By removing and then re-applying drive enable or start signal ("drive start")

- By completing and then restarting command C1800

Diagnostic Messages and Monitoring Functions

Checking the Defined Travel Range

When the travel range is defined, it is checked for useful values. In the case of error, the following command error messages can be generated:

- If the defined travel range is less than 2 motor revolutions, the error message "C1805 Travel range invalid" is displayed, because the correct execution of the command requires a minimum travel range.
- If the axis is not within the defined travel range at command start, the error message "C1806 Travel range exceeded" is displayed.

Drive Enable Missing

If drive enable is missing at command start, the error message "C1801 Start requires drive enable" is generated.

Monitoring of Mass Inertia Determination

In order to ensure correct setting of the controller parameters, the required determination of the mass inertia is monitored. Incorrect determination of the mass inertia would lead to incorrect controller settings and is therefore signaled by the error message "C1803 Inertia detection failed". This error message is generated when the values set in the following parameters are too low:

- S-0-0092, Bipolar torque/force limit value

  The maximum motor torque effective during the automatic control loop setting can be influenced via parameter S-0-0092. It is thereby possible to limit the torque to prevent wear of the mechanical system.
- S-0-0108, Feedrate override

  By means of the feedrate override, the velocity can be influenced via the analog channel (potentiometer) during the automatic control loop setting.
- S-0-0259, Positioning Velocity

This parameter defines the velocity effective during the automatic control loop setting.

- S-0-0260, Positioning Acceleration

  In this parameter, set the acceleration effective during the automatic control loop setting.

> The command error C1803 can occur due to the above-mentioned points, but also due to a too high degree of inertia. In this case, the entire drive dimensioning has to be checked, if necessary.

6.4.3 Velocity Loop (Including the Respective 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 controlled-loop operation (current and velocity) can be carried with encoder for all types of motors and for asynchronous motors also without encoders.

> The selection of the type of motor control is carried out by means of the parameter "P-0-0045, Control word of current controller" (Bit 14, 15)

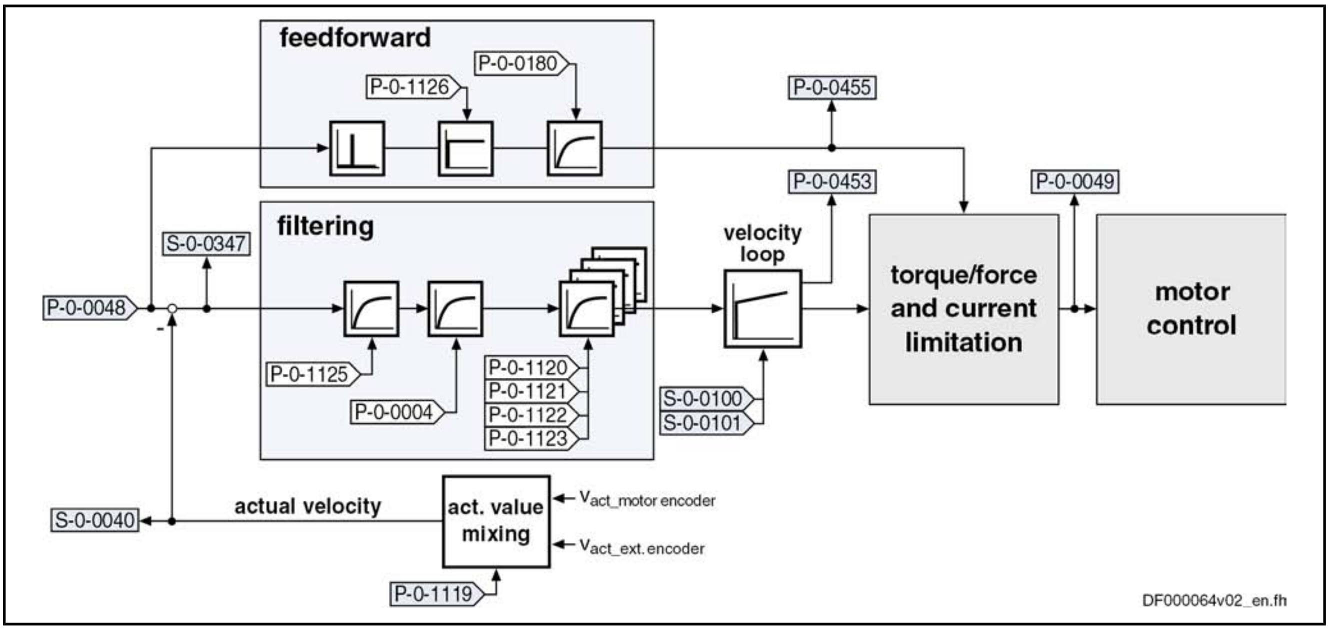


Fig.6-44: Structure of the velocity loop

> The following description is restricted to the velocity loop including the respective options of filtration and feedforward. The processing of the velocity command value is described within the operating mode"Velocity Control" section.

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

- Executing the function "load defaults procedure" once

  - or -

- Manual optimization (see description below)

  - or -

- Automatic parameterization of the axis controller (see "Automatic Setting of Axis Control ").

- Depending on the set control performance, for the velocity loop the cycle time of $T_{A\_velocity}$ is calculated with (see "Performance Data").
- Possibility of mixing the velocities of motor encoder and optional encoder
- 4 freely configurable filters of 2nd order (e.g. band-stop filters) for filtering resonance frequencies
- Moving average filter of the control loop deviation for a maximum of 16 controller clocks (as a feedback filter, in the case of low-resolution motor measuring systems)
- Low-pass filter to attenuate interference frequencies, to be set via parameter P-0-0004 (VZ1)
- Fine interpolation of the command values of the position loop (can be switched on by P-0-0556, Bit 0)
- Monitoring of the velocity control loop (can be switched off by 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-0-0091, 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-0-0347, Velocity deviation
- P-0-0004, Speed 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-0-0451, Process torque/force value
- P-0-0555, Status word of axis controller
- 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 low pass
- P-0-1122, Velocity control loop filter: Bandwith of band-stop filter
- P-0-1123, Velocity control loop filter: Center frequency of band-stop filter
- P-0-1125, Velocity control loop: average value filter clock
- P-0-1126, Velocity control loop: Acceleration Feedforward

- P-0-2100, Velocity loop proportional gain, encoder memory
- P-0-2101, Velocity loop integral-action time, encoder memory
- P-0-3004, Speed controller smoothing time constant, encoder memory

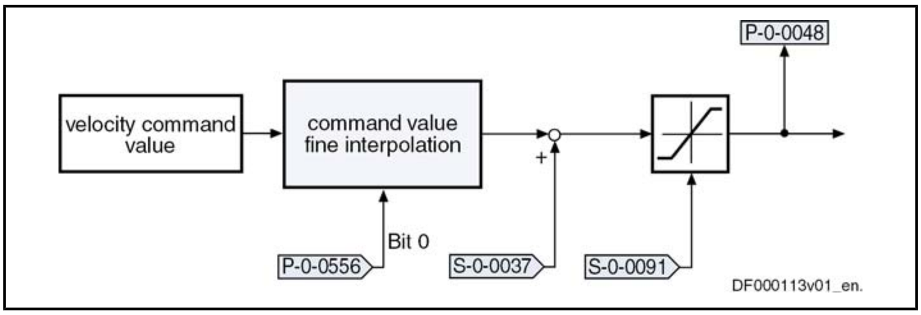
Pertinent Diagnostic Messages

- E2059 Velocity command value limit active
- E8260 Torque/force command value limit active
- F8078 Speed loop error

Functional Description

Fine Interpolator

The preset velocity command value can be smoothed through a fine interpolator via 2 steps. This is reasonable e.g. for cyclic position control with especially large position command value jumps (great cycle times, comp. S-0-0001 and S-0-0002).



S-0-0037 Additive velocity command value
S-0-0091 Bipolar velocity limit value
P-0-0048 Effective velocity command value
P-0-0556 Config word of axis controller
Fig.6-45: Fine interpolation of the velocity command value

> ☞ The fine interpolator is switched on in the default setting. It can be activated via bit 0 of parameter "P-0-0556, Config word of axis controller".

Units of the Processed Data

The physical data for the velocity control loop 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

Velocity Loop

The velocity loop designed as a PI loop 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 motors and the connected mechanical system.

- For Rexroth motors with motor data memory (e.g. the motor range IndraDyn S) a default controller setting that is suitable for the 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 are strongly dependant on loads, especially for kit motors.

See also "Velocity controller: Notes on Commissioning"

Velocity Mix Factor

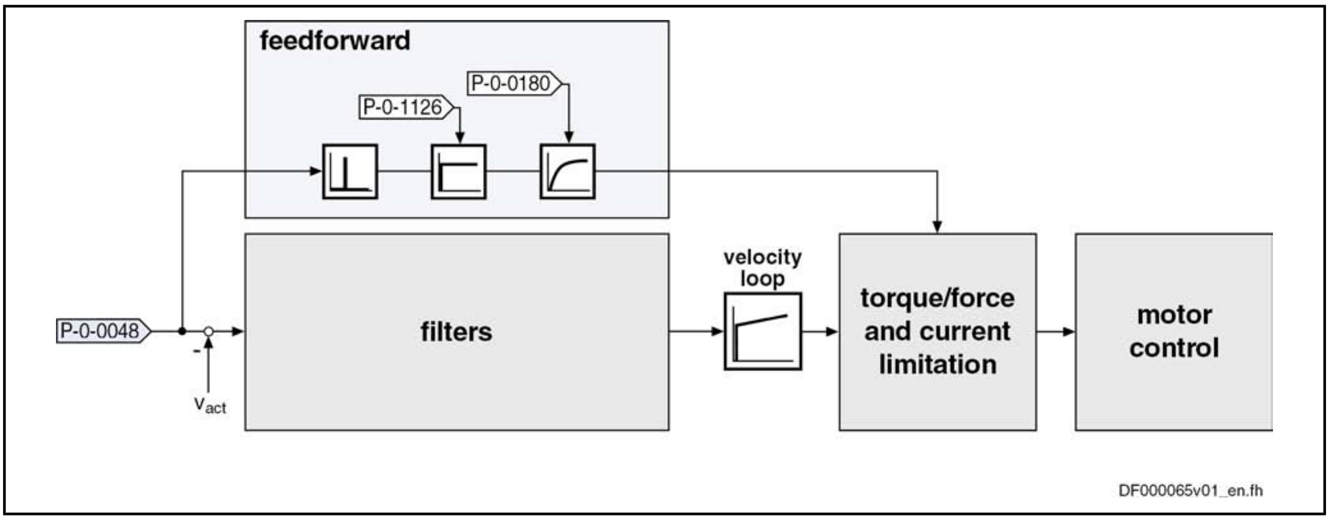
In the velocity control loop, for the utilization of a load-side encoder, there is the possibility of calculating the velocity value utilized for the control from a "mix factor" (see description of the parameter P-0-1119) that consists of the velocity values of the motor encoder and of the load-side encoder (see also Figure "Structure of the velocity loop").

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 in the case of connected load.

Acceleration Feedforward

In the velocity control loop there is the additional possibility of configuring the velocity loop in the control performance more dynamically through utilization of the so-named 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 loop will then only be required for correcting disturbances.

The following graphic 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.6-46: Acceleration feedforward in the velocity control loop

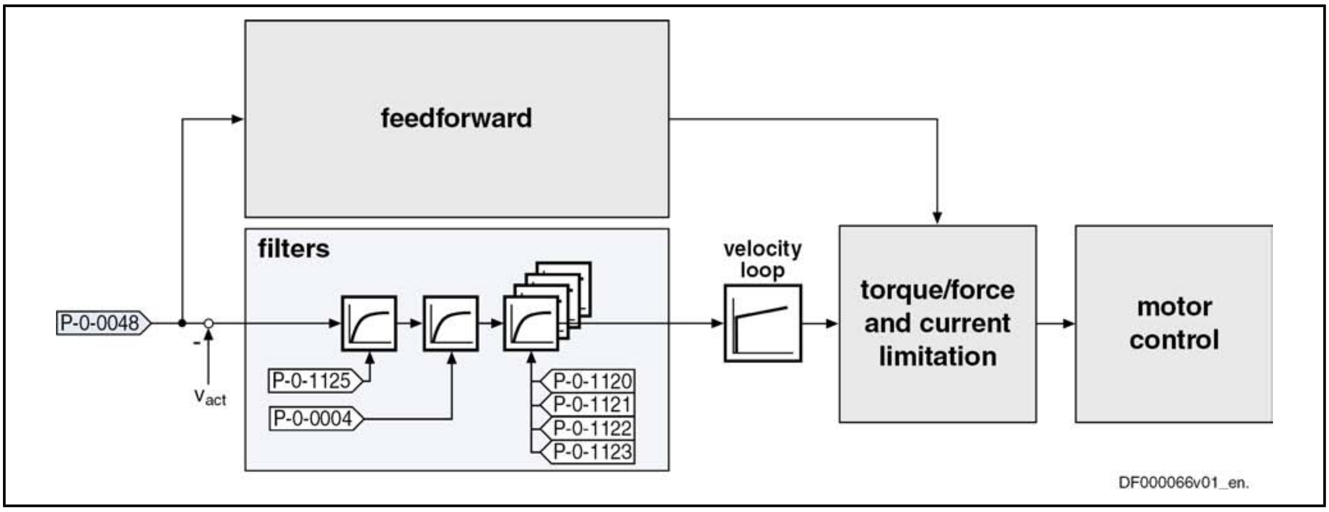
This type of feedforward can be advantageous for very large mass inertia and/or low encoder resolution.

Filter Options

The following filers are available in the velocity control loop:

- Four individually configurable filters of 2nd order (low pass, band-stop filter...)
- One low pass of 1st order (PT1-element)
- One average value filter

The graphic below illustrates the position of the filter in the overall control loop:



P-0-0004 Speed loop 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 low pass
P-0-1122 Velocity control loop filter: Bandwith of band-stop filter
P-0-1123 Velocity control loop filter: Center frequency of band-stop filter
P-0-1125 Velocity control loop: average value filter clock

Fig.6-47: 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:

- Limits the rigid connection of the mechanical system to the motor shaft

  → Resonances in the range of 100 Hz … 1000 Hz are possible (according to rigidness of the connection and to the mass ratio)
- Gear backlash
- Faulty connection of the load-side encoder

  → Resonances in the range of 1 kHz … 2 kHz are possible (according to connection 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 rejection 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 band-stop filters enable a suppression of resonance frequencies in the **frequency range from 100 Hz up to max. 4000 Hz** (advanced performance).

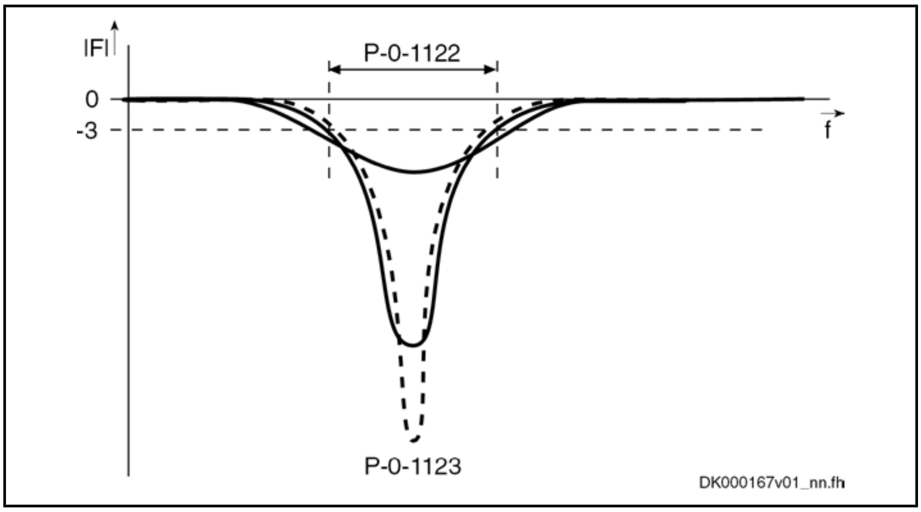
The upper limit depends on the velocity loop cycle time TAn (sampling theorem).

With the suppression of the mechanical resonance frequencies both the dynamics of the torque control loop and the dynamics of the position control loop can be improved by far more than with the control without the application of the rejection filters. This leads to improved movement according to conture and smaller cycle times for positioning processes with sufficient distance to the stability limit.

Explanation of the Filter Function

Both center frequency and band width can be set for the 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!



IFI	Value of the transmission function (in dB)
P-0-1122	Velocity control loop filter: Bandwith of band-stop filter
P-0-1123	Velocity control loop filter: Center frequency of band-stop filter

Fig.6-48: Amplitude characteristic of a band-stop filter depending on the bandwidth (qualitative)

Filtering by Means of a Multiple Smoothing Filter

The optimization of the control loop by means of a rejection filter does not always lead to a sufficient improvement of the control quality. 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 the parameter "P-0-1120, Velocity control loop filter: filter type" must be set to the value "1" or "0" respectively (see parameter description 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 the parameter "P-0-1121, Velocity control loop filter: Limit frequency low pass".

Together with the PT1-filter (Parameter "P-0-0004, Speed loop smoothing time constant") at the velocity loop 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

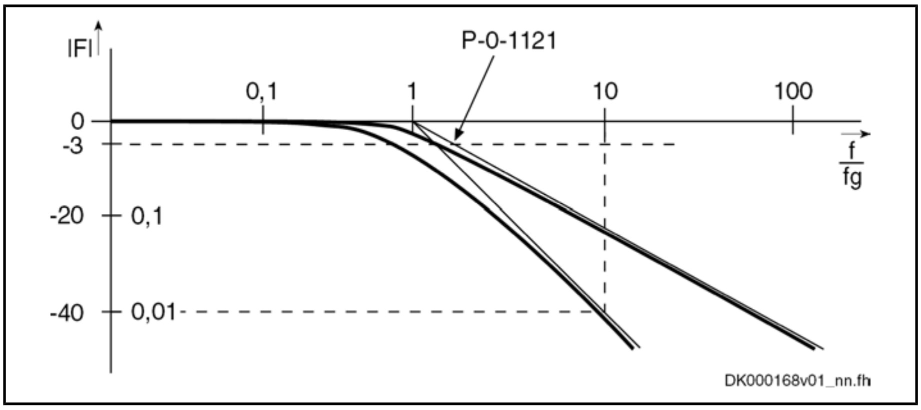
  → Attenuation of 20 dB/decade
- P-0-1121, Velocity control loop filter: Limit frequency low pass

  → 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.

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!"



IFI Value of the transmission function (in dB)
P-0-1121 Velocity control loop filter: Limit frequency low pass
Fig.6-49: Amplitude characteristic of a PT1 and a PT2 filter

Notes on Commissioning

Preparations for the Settings of the Velocity Loop

In order to be able to execute the settings of the velocity loop, 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 operation mode "velocity control" must be selected.

Start Settings

For the parameterization of the controller the start settings must be executed as illustrated 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, Speed loop smoothing time constant

  → Minimum input value → Filter is switched off

  → P-0-0004 = 125 µs (Advanced performance)

  → P-0-0004 = 250 µs (Basic performance)

  → P-0-0004 = 500 µs (Economy performance)

  See also "Performance Data"
- P-0-1120, Velocity control loop filter: Filter type

  → For a value "0000" → Filter is switched off

☞ When determining the velocity loop 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:

Determination of the Critical Proportional Gain

1. Have the drive moving with a low velocity after switching on the drive enable.
   - Linear motor → 1000 … 2000 mm/min
   - Rotary motor → 10 … 20 rpm
2. Increase the value in the parameter "S-0-0100, Velocity loop proportional gain" until an instable ratio (continuous oscillation) occurs.
3. The frequency of the oscillation must be recorded by oscilloscoping the actual value (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, Smoothing time constant" until the oscillation is reduced. Subsequently, increase the value in the parameter "S-0-0100, Velocity loop proportional gain" futher, until an oscillation occurs anew (instability).
4. Decrease the value in the parameter "S-0-0100, Velocity loop proportional gain" until the continuous oscillation ceases automatically.

   The value detected by this process is referred to as the "critical velocity loop proportional gain".

☞ By utilization of the filter cascade (P-0-1120, P-0-1121, P-0-1122, P-0-1123) a PT4-filtering can be activated.

Determination of the Critical Integral Action Time

To determine the "critical integral action time" proceed as follows:

1. Setting of the parameter "S-0-0100, Velocity loop proportional gain" = 0,5 × "critical proportional gain".
2. Reduce the value in the parameter "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 the parameter "S-0-0101, Velocity loop integral action time" until the continuous oscillation ceases automatically. The value detected by this process is referred to as the "critical integral action time". Here, common values range between 5 to 20 ms.

Calculation of 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 loop:

$$\text{S-0-0100} = \frac{(\text{P-0-0510}) + (\text{P-0-4010})}{T_s \times \boldsymbol{\alpha}} \times \frac{1}{60 \times 1000} \qquad (\text{in } \frac{\text{N} \times \text{min}}{\text{mm}})$$

S-0-0100	Velocity loop 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.6-50: Calculation of the value for the proportional gain of the velocity loop for linear motors

$$S\text{-}0\text{-}0100 = \frac{(P\text{-}0\text{-}0510) + (P\text{-}0\text{-}4010)}{T_s \times \alpha} \quad (\text{in } \frac{Nm}{rad})$$

S-0-0100 Velocity loop 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.6-51: Calculation of the value for the proportional gain of the velocity loop for rotary motors

$$S\text{-}0\text{-}0100_{IndraDrive} = P\text{-}0\text{-}0051 \times S\text{-}0\text{-}0100_{EcoDrive} \quad (\text{in } \frac{N \times min}{mm};\ \text{in } \frac{Nm}{rad})$$

S-0-0100 Velocity loop proportional gain
P-0-0051 Torque/force constant

Fig.6-52: 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
- Safe reproduction of the properties in serial machines

In the following table some of the most frequent modes of application and the respective characteristics of the control loop settings are illustrated.

Mode of application	Speed loop proportional gain	Speed loop 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

Fig.6-53: Features of the controller settings

Parameterization of the Band-Stop Filters

The parameterization of the band-stop filters is carried out by means of the following parameters:

- P-0-1120, Velocity control loop filter: Filter type
- P-0-1122, Velocity control loop filter: Bandwith of band-stop filter
- P-0-1123, Velocity control 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 for the setting of the band-stop filter:

1. First set the rejection filters inactive.

2. In the parameter "P-0-1120, Velocity control loop filter: Filter type" the following values must be entered:

   - 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

Determine Resonance Frequency

The following procedure is recommended for determining the resonance frequency:

1. Use the oscilloscope function of the drive in order to display the actual velocity value. This value can be read directly by means of a fast fourier transformation (FFT) at the frequency response. For this, the utilization of the commissioning tool "IndraWorks D" is required.
2. In reversing duty increase the value in parameter "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 feature (alternatively with external oscilloscope) and analyze it with regard to clearly distinctive frequencies. When using the internal oscilloscope feature, the resonance frequency can be directly read via the "IndraWorks D" commissioning tool by means of the frequency display.
4. Set the drive inable and optimize the velocity 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. In the parameter "P-0-1123, Velocity control loop filter: Center frequency of band-stop filter" the frequency that emerged most noticable must be entered in Hz.

   In the parameter "P-0-1122, Velocity control loop filter: Band width band-stop filter" a minimum band width must be entered (e.g. 25 Hz).

   ⇒ Re-record the previous step response!

   If the step response shows less overshooting and shorter period of oscillation:

7. Check whether additional improvement occurs for an increase of the value in the parameter " P-0-1122, Velocity control loop filter: Bandwidth band-stop filter" or whether additional improvement occurs for modification of the value in the parameter "P-0-1123, Velocity control loop filter: Center frequency of band-stop filter".

   If the step response shows the same behavior:

8. Check the determined resonance frequency; if need be, considerably change the value in the parameter "P-0-1122, Velocity control loop filter: Bandwidth band-stop filter".
9. Re-optimize the velocity loop by means of the pre-optimized values in the parameters "P-0-1122, Velocity control loop filter: Bandwidth of band-stop filter and "P-0-1123, Velocity control loop filter: Center frequency of band-stop filter".
10. If necessary, carry out another optimization procedure for parameters 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 substraction, from the effective velocity command value (P-0-0048) and the current actual velocity value (S-0-0040).

Acceleration Torque/Force

The acceleration torque is determined from the total inertia (P-0-0510 + P-0-4010) calculated from the automatic control loop setting and the value in the parameter "S-0-0164, Actual acceleration value 1" and is displayed in the parameter "P-0-0451, Actual acceleration torque / force".

Process Torque/Force

From the current total torque in the parameter "S-0-0084, Torque/force feedback value" and the determined "P-0-0451, Acceleration torque / force feedback value" the current process torque is determined and indicated in the parameter "P-0-0452, Process torque / force feedback value".

Limitation of the Current Command Value (E8260)

The output signal of the velocity loop 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 in the parameters 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 the parameter "P-0-0555, Status word of axis controller".

Speed Loop Error (F8078)

The correct function of the velocity loop is monitored in the drive to avoid the so-called "runaway effect". Possible causes for errors are:

- Incorrect commutation angle
- Interchanged motor connection

In case of an error the drive is immediately switched torque-free and the error message "F8078 Speed loop error" is generated.

See also Troubleshooting Guide for "F8078 Speed loop error"

6.4.4 Position Loop (With Respective Feedforward Functions and Actual Value Adjustment)

Brief Description

The following section only describes the position loop with the respective feedforward possibilities (velocity and acceleration feedforward).

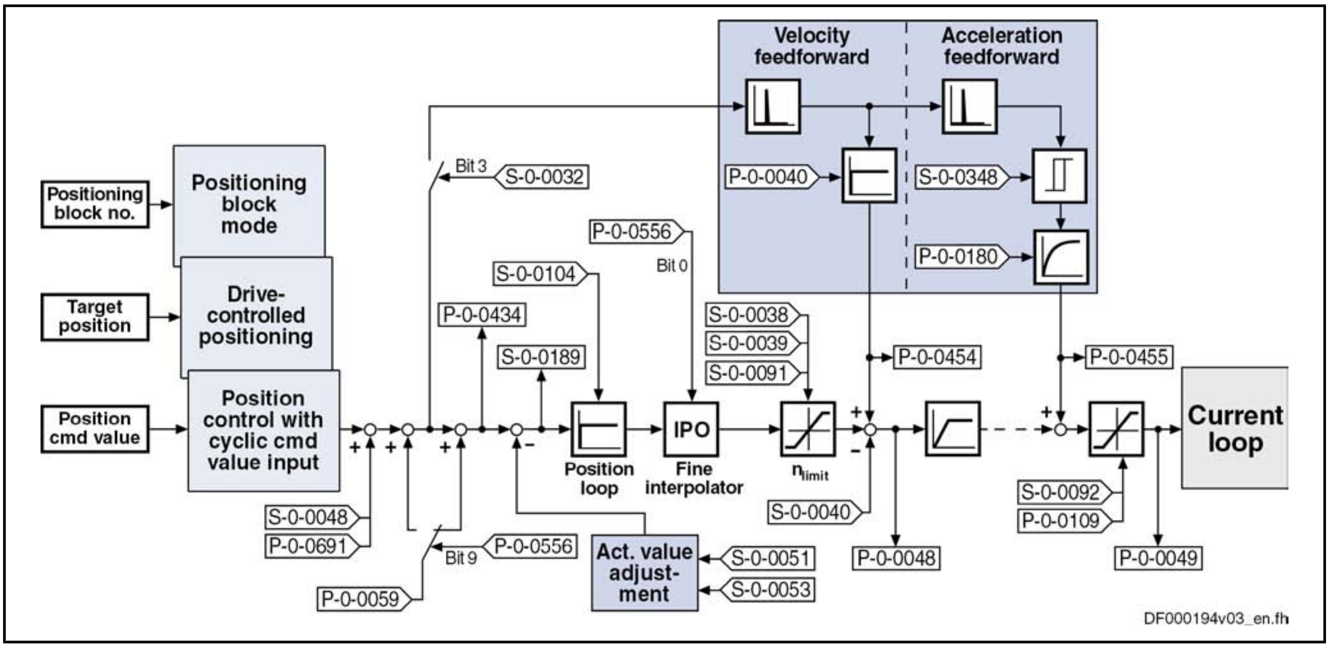


Fig.6-54: Structure of the Position Loop

☞ 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 loop, 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 loop calculations (see "Performance Data").
- With lag error or lagless, i.e. with velocity feedforward
- Model monitor 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 mode of operation

  → 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 1 value
- S-0-0053, Position feedback 2 value
- 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, Control word of axis controller
- S-0-0521, Status word of position loop
- 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 controller
- P-0-0454, Velocity feedforward actual value
- P-0-0454, 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 loop 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. For this purpose, set bit 9 of parameter "P-0-0556, Config word of axis controller".

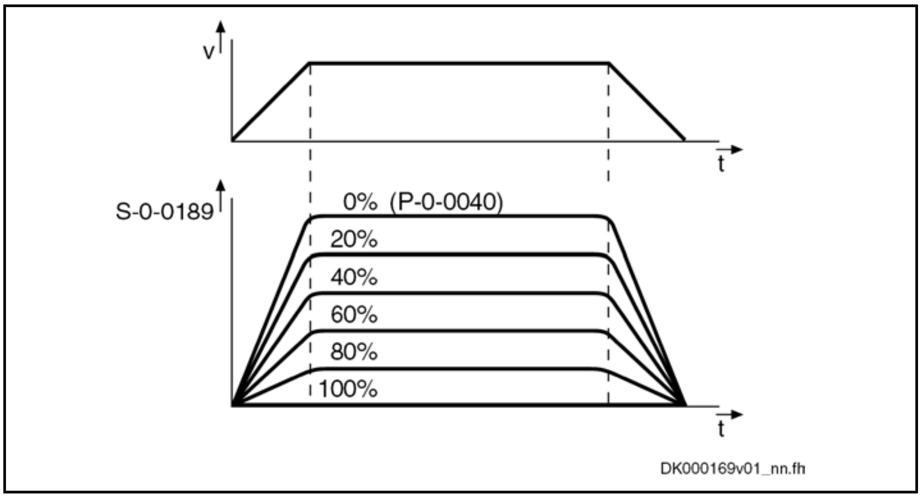
Acceleration Feedforward

In order 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 parameter S-0-0348:

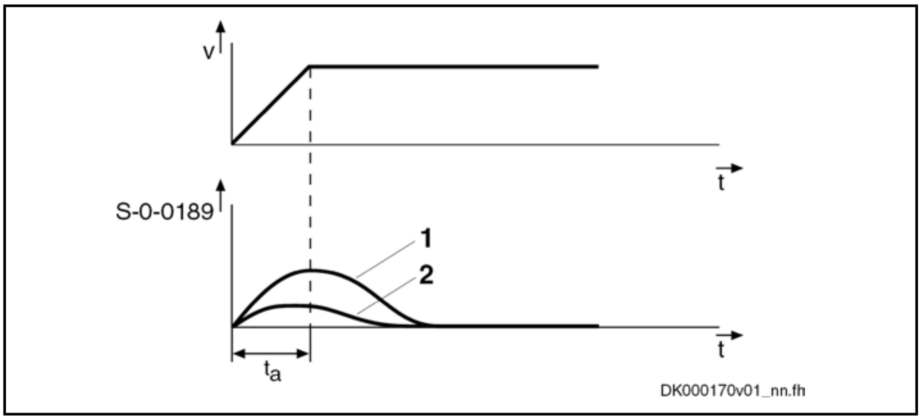
- Linear motor → total mass (motor + load) in kg
- Rotary motor → total mass inertia (motor + load) in kgm^2

☞ Adjust the input value in the parameter S-0-0348 in dependency of the respective local mechanical system!

The illustrations below exemplify the operating principle of the respective feedforward procedure.



S-0-0189 Following distance
P-0-0040 Velocity feedforward evaluation
Fig.6-55: Operating Principle of the Velocity Feedforward



1 Without acceleration feedforward
2 With acceleration feedforward
t_a Acceleration phase
S-0-0189 Following distance
Fig.6-56: Operating Principle of Acceleration Feedforward (With P-0-0040 = 100%)

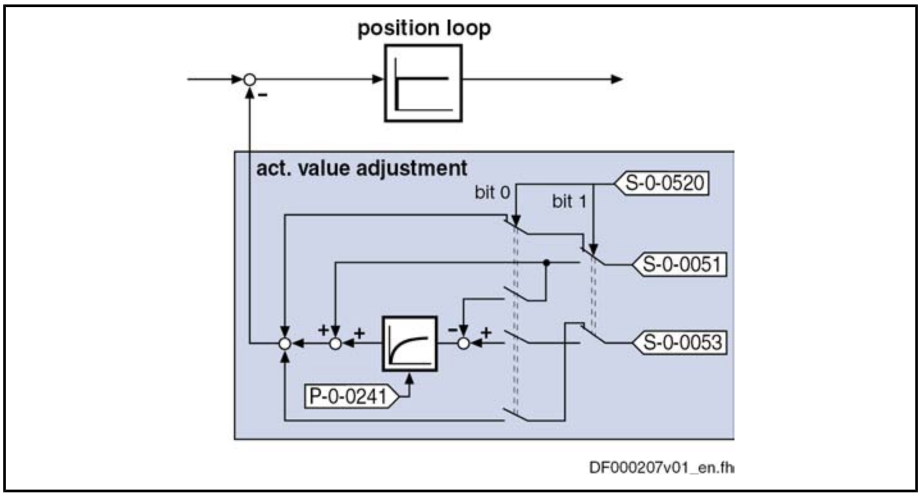
Making the Actual Position Value Available

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 slip occurs between motor encoder and external encoder (see also "Measuring Wheel Mode") or if there is only little stiffness available.



S-0-0051 Position feedback 1 value
S-0-0053 Position feedback 2 value
S-0-0520 Control word of axis controller
P-0-0241 Actual pos. smoothing time constant for hybrid pos. control
Fig.6-57: Generating the Hybrid Actual Position Value

The generation of the hybrid actual position value is configured in the parameter "S-0-0520, Control word of axis controller", its use for control tasks is activated in the same parameter.

To be noticed:

- By the value "0" in parameter "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 the parameters 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 **mustn't** have been activated as measuring wheel encoder in parameter "P-0-0185, Control word of encoder 2 (optional encoder)"!

Notes on Commissioning

The cascade structure of the loops requires the optimization of the position loop to be only carried out after all outer control loops (velocity and current) have been optimized, because in the case of a cascade loop structure the dynamic response of the outer control loops limits the dynamic response of the higher-level control loops.

Determining the Critical Position Loop Kv-Factor

To determine the critical position loop 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 parameter "S-0-0104, Position loop Kv-factor" until instable behavior (continuous oscillation) occurs.

3. Reduce parameter S-0-0104 until continuous oscillation decreases automatically.

   The value thus determined is the so-called "critical position loop Kv-factor".

Characteristics of the Control Loop Setting

From the determined critical Kv-factor (see above), it is possible to derive a control loop 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 loop normally is checked by optimizing the lag error. To do this, 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 control loop 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 parameter "P-0-0185, Control word of encoder 2 (optional encoder)". Configure the hybrid actual position value in parameter "S-0-0520, Control word of axis controller".

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 parameter "S-0-0520, Control word of axis controller"

  - and -
- position-controlled operating mode of the drive.

Deactivating the Hybrid Actual Position Value

The option "hybrid actual position value" 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 parameter "S-0-0520, Control word of axis controller"
- Switching to communication phase P2 or parameter mode
- Switching the drive off

Setting the Jerk Attenuation for the Hybrid Actual Position Value

Abrubt position differences between motor encoder and optional encoder can be attenuated by inputting a value greater than zero in parameter "P-0-0241, Actual pos. smoothing time constant for hybrid pos. control".

☞ The value "0" in parameter 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 parameter P-0-0241 and move axis at low velocity and little acceleration.
2. Increase infeed 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 loop:

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 real actual position value permanently exceeds the value of parameter "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 parameter "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 parameter "P-0-0391, Actual position value difference encoder1 - encoder2"!

The following limitation is carried out in the position loop:

Limiting the Velocity Command Value

- The output of the position loop (P-0-0048) is limited to a maximum absolute velocity value. The output signal of the position loop 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"

6.5 Commutation Setting

6.5.1 Basics on Commutation Setting

Brief Description

The following Rexroth kit motors are manufactured according to the functional principle "synchronous motor":

- Linear motors LSF, MLF
- Rotary motors MBS and MBT

As the motor is assembled in the machine, stator, rotor and measuring system cannot be put together by the manufacturer. The customer will make the electric-magnetic-mechanical allocation of the synchronous motor on site by determining and setting the commutation offset.

Measuring Systems for Synchronous Rexroth Motors

Absolute measuring systems should ideally be used for synchronous Rexroth kit motors. The advantage in this case is the absolute position detection of the rotor 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. This is realized by the commutation offset stored at initial commissioning.

For some applications it is necessary to use relative measuring systems, because the available length of absolute measuring systems is limited, for example. The disadvantage in this case is that absolute detection of the rotor position is impossible. It is therefore necessary, after each time the drive is switched on again or after having changed the communication phase from "P2" to "P4" ("bb" or "Ab"), to set the commutation offset again. For linear motors, this disadvantage can be removed by using the Hall sensor box SHL01.1, because with regard to commutation setting the relative motor encoder then behaves like an absolute measuring system.

☞ If you use a relative motor encoder, using the Hall sensor box SHL01.1 is absolutely recommended for linear motors! In this way, you achieve highest safety with regard to correct motor function and compliance with the power data!

Measuring Systems for Synchronous Third-Party Motors

Concerning operationally reliable drives with synchronous third-party motors and IndraDrive controllers, there are, with regard to the selected measuring system, the same principles applying as to synchronous Rexroth kit motors (see above); the Hall sensor box SHL, however, cannot be used for linear third-party motors!

Overview of the Synchronous Motors to be Used for Motor Measuring Systems

Motor measuring system	Synchronous Rexroth kit motor (rotary, linear)	Synchronous Rexroth kit motor (linear) with SHL01.1	Synchronous third-party motor
Absolute	+	--	+
Relative	o	+	o

+ Advantageous combination
o Combination possible, initial commissioning might possibly require especially trained staff
-- Combination not useful

Fig.6-58: Possible Combinations of Motor Measuring System and Synchronous Motors for Which Commutation Setting is Required

☞ The measuring system should be realized with high resolution and as a motor encoder to be evaluated in absolute form. If it is necessary to use a relative measuring system, you should avoid using encoders with square-wave signals!

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!

See also "Absolute Measuring Systems" and "Mechanical Axis System and Arrangement of Measuring Systems"

Pertinent Parameters

Apart from the motor parameters (see overview of parameters in "Basics on the Motors to be Controlled"), there are further parameters available for commutation setting:

- P-0-0506, Voltage amplitude for angle acquisition
- P-0-0507, Test frequency for angle acquisition
- P-0-0508, Commutation offset
- P-0-0517, Commutation: required harmonics component

- P-0-0518, C5600 Command subsequent optimization of commutation offset
- P-0-0521, Effective commutation offset
- P-0-0522, Control word for commutation setting
- P-0-0523, Commutation setting measured value
- P-0-0524, C1200 Commutation offset setting command
- P-0-3008, Commutation offset, encoder memory

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.
- 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
- 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 adjust
- 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

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 Hall sensor box (distance measurement, currentless → only possible with Rexroth linear kit motors, see documentation "Hall Sensor Box SHL01.1")
- **Measuring method**

→ For motor encoder that can be evaluated in absolute form (distance measurement, currentless → only possible with Rexroth linear 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 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 construction 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

Recommendations for selecting the determination method:

		Determination method			
		Calculation method (with Hall sensor box)	**Measuring method**	**Saturation method**	**Sine-wave method**
Motor type	**Measuring system used →**	**Relative, linear**	**Absolute, linear**	**Absolute/relative**	**Absolute/relative**
MSS		--	--	+	o
MSSxx2x (high speed)		--	--	o	+
MST		--	--	+	o
LSF		+	+	+	o
MLF		+	+	+	o

+ Recommended method
o Method not recommended
-- Method not possible

Fig.6-59: 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	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. 15% compared to the optimum value (autom. detection 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. 15%!

Applications of synchronous motors	Restrictions for saturation method
Drives that can be in motion during the determination of the commutation offset, e.g. coasting spindles, printing roller drives etc.	Saturation method only possible for motors in standstill!
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)!

Fig.6-60: 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 little friction!
Linear axes in Gantry arrangement	Only balanced (e.g. horizontal) axes with little friction! In addition, both drives have to carry out sequential commutation settings, "AF" in this case mustn't be active at the other drive!
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"!

Fig.6-61: Typical Applications and Restrictions for Sine-Wave Method

Significance of Commutation Offset

A synchronous motor can only generate the torque or the force specified according to motor data, when the commutation offset is correct. If the value for the commutation offset is incorrect, lower action of torque/force is to be expected; a highly incorrect value implies the danger of the motor having a "runaway effect".

Therefore, the parameter "P-0-0521, Effective commutation offset" as a matter of principle is write-protected. For initial commissioning, however, it is advantageous to allow writing parameter P-0-0521 in order to optimize the value, if necessary. An "initial commissioning mode" can be activated for this purpose (see "P-0-0522, Control word for commutation setting"). During the initial commissioning of the motor, you have to determine the commutation offset value with due diligence.

☞ For synchronous Rexroth motors with integrated motor encoder (MSK, MHD, MKD, 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.

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 and each time the drive has been switched on (recommissioned)

☞ Deviating values when determined again (recommissioning with relative motor encoder) can occur, this can cause deviating drive behavior (remedy: "Optimum Commutation Offset With Regard to Reference Point", see below)!

Notes on Commissioning

Initial Commissioning

Commutation Offset During Initial Commissioning of Synchronous Motor

Determining the commutation offset during the initial commissioning of a synchronous motor is of particular relevance. For this purpose, there are different methods available or applicable for determining the commutation offset, depending on motor and position measuring system (motor encoder). In addition, the effectiveness of the determined value should be checked and, if necessary, optimized.

The overview below illustrates the procedure for selecting the appropriate method of commutation offset determination for synchronous motors and the determination of a value for "P-0-0508, Commutation offset" within the scope of initial commissioning.

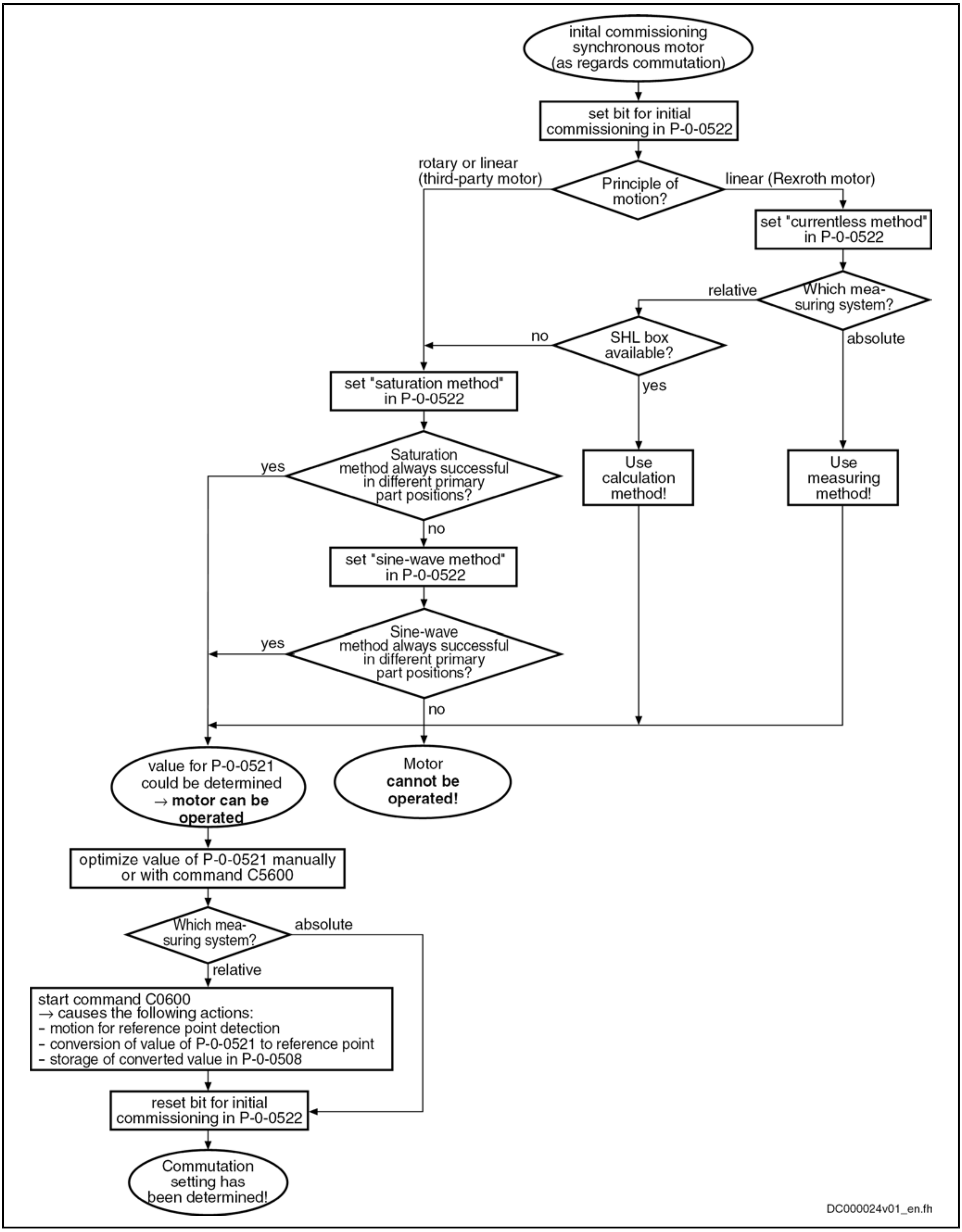


Fig.6-62: Selecting the Method for Determining Commutation Offset During Initial Commissioning of Synchronous Motor

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.

$$(\text{P-0-0521})_m = (\text{P-0-0521})_a \pm 256$$

m Manually
a Automatically determined

Fig.6-63: Range of Values for Optimizing the Commutation Offset

CAUTION

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

⇒ Before manually optimizing the commutation offset, move the axis to a noncritical position!

Automatically Optimizing the Offset Value

The value determined for "P-0-0521, Effective commutation offset" can be automatically optimized. This is done by starting "P-0-0518, C5600 Command subsequent optimization of commutation offset". For this purpose, 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

Fig.6-64: 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 improvement of 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.

It is always recommended to execute "C5600 Command subsequent optimization of commutation offset", when there isn't any of the restrictions which are mentioned for the sine-wave method (see above)!

CAUTION

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 measuring system (motor encoder) and with initial commissioning mode activated, the value determined and, if necessary, optimized during initial commissioning is converted to the reference point by a homing procedure (start of command C0600) and stored in parameter "P-0-0508, Commutation offset".

Recommissioning a Synchronous Motor

Readiness for operation of a synchronous motor is given after switch-on (putting into operation after initial commissioning already taken place), when the controller has stored or determined a commutation offset value for this motor.

Synchronous Motors With Absolute Measuring System

Immediate readiness for operation is generally given for absolute motor measuring systems and for linear Rexroth motors with relative measuring system and SHL box. The commutation offset value (P-0-0508) stored in the controller or in the measuring system during initial commissioning is activated by applying it to parameter "P-0-0521, Effective commutation offset".

Synchronous Motors With Relative Measuring System

For relative motor measuring systems (exception: linear Rexroth motor with relative measuring system and SHL box), 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 automatically done by a method with current (for overview of methods see above "Overview of Methods for Determining the Commutation Offset"). The value is stored in parameter P-0-0521 and refers to the current position of the axis.

Optimum Commutation Offset With Regard to Reference Point

When drive-controlled homing (command C0600) is now started due to the relative measuring system, the value of P-0-0521 is converted to the reference point position when the reference point is passed. This converted value is compared to the optimum commutation offset value determined during initial commissioning and stored in P-0-0508.

If the comparison results in "positive validation", the value of P-0-0508 is applied as effective commutation offset value in parameter P-0-0521 ("fine adjustment" of the commutation offset). If validation is negative, the value in P-0-0508 is probably incorrect (e.g. inverted value). The error message "F2032 Validation error during commutation fine adjust" is output and the drive switches off.

☞ If fine adjustment of the commutation offset is not desired, it can be deactivated via P-0-0508 = 0 or P-0-3008 = 0 (can be written in communication phase "P2"). This causes the automatically determined value to remain effective!

☞ For synchronous motors with relative measuring system, the torque or force development of the motor is reproduced with reference to the initial commissioning situation by using the commutation offset value relating to the reference point ("optimum commutation offset with regard to reference point")!

Drive Control

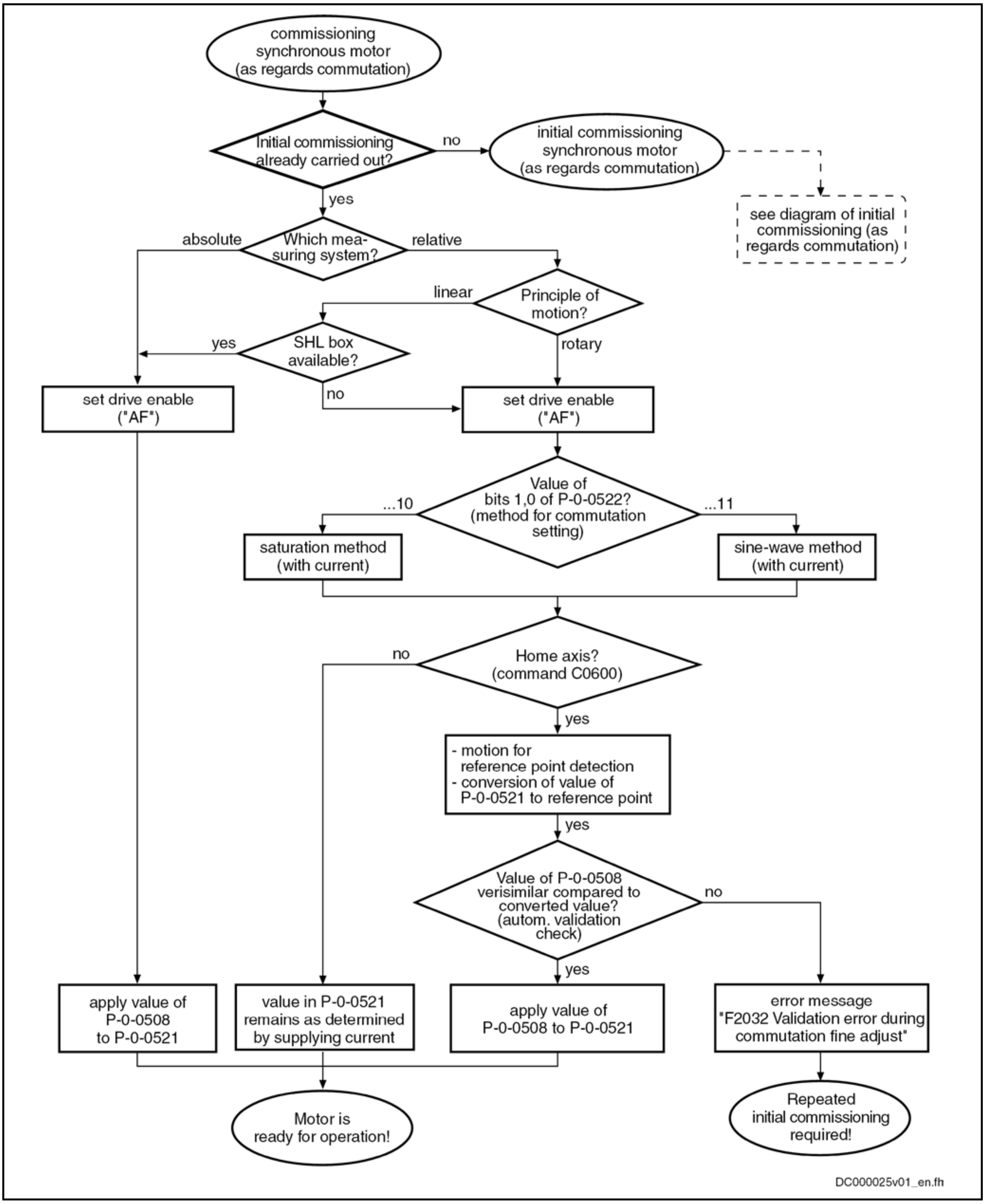


Fig.6-65: Establishing Readiness for Operation of a Synchronous Motor for Recommissioning

6.5.2 Commutation Setting for Rexroth Motors MLF, LSF

Brief Description

Linear Rexroth kit motors of the MLF and LSF lines are manufactured according to the functional principle "synchronous motor". For kit motors, the motor components stator, rotor and measuring system are finally assembled on the customer side in the machine.

With Absolute Motor Encoder

The electric-magnetic-mechanical allocation of the synchronous motor therefore can only be made on site by determining and setting the commutation offset. This is done once during initial commissioning of the motor, if it has been equipped with a motor encoder to be evaluated in absolute form.

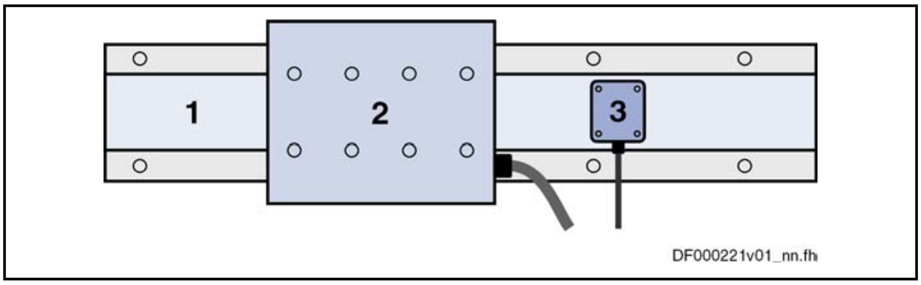
With Relative Motor Encoder

When a relative motor encoder is used, it is necessary to determine the commutation offset again each time after the drive was switched off.

Deviating commutation offset values when determined again (recommissioning with relative motor encoder) can occur, this can cause deviating drive behavior. To avoid this, it is recommended that you use the Hall sensor box SHL01.1 which was developed for linear Rexroth motors.

Hall Sensor Box SHL01.1

The Hall sensor box SHL01.1 is an absolute measuring system within one pole pair distance of linear Rexroth motors. Via the signals of the Hall sensors, the controller detects the position of the motor windings compared to the magnetic field of the motor; therefore, the commutation setting is only required during initial commissioning. When the drive is recommissioned, the correct commutation offset is already available at drive enable ("AF").



1 secondary part
2 primary part
3 Hall sensor box SHL
Fig.6-66: Linear Rexroth motor with Hall sensor box SHL

For information on mounting and connection see the documentation on Hall sensor box SHL01.1.

Functional Description

Commutation Offset With Relative Motor Encoder and Hall Sensor Box SHL

When using a linear Rexroth motor with relative measuring system as motor encoder and using the Hall sensor box SHL, the value for the 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 determined once during initial commissioning (for further information see documentation on Hall sensor box SHL01.1).

Commutation Offset With Absolute Motor Encoder, Measuring Method

The measuring method for determining the commutation offset can only be used for linear Rexroth motors with linear motor encoder that can be evaluated in absolute form (e.g. EnDat 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.

☞ For rotary synchronous Rexroth kit motors, the commutation offset can only be determined with methods with current (saturation 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 measurement and geometric motor data (see separate motor documentation for "Rexroth IndraDyn L").

After the determined value was entered in parameter P-0-0523, the command parameter "P-0-0524, C1200 Commutation offset setting command" has to be activated. The controller now calculates the value of the required commutation offset which is displayed in parameter "P-0-0521, Effective commutation offset".

Notes on Commissioning

Requirements

When using a Hall sensor box or the measuring method, the following settings must be made in parameter "P-0-0522, Control word for commutation setting" for initial commissioning:

- Method for determining the commutation offset → "without current"
- Initial commissioning mode → "active"

The drive must be in status "A0013 Ready for power on" ("bb").

Using the Hall Sensor Box SHL

When using the Hall sensor box SHL, carry out the following steps for commissioning:

1. Determine value for "P-0-0508, Commutation offset" according to documentation on Hall sensor box SHL01.1 and enter it in parameter "P-0-0521, Effective commutation offset".

   Note: It is recommended that you optimize the determined commutation offset value. 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").
2. Then reset command C5600 and set initial commissioning mode to "inactive" again in parameter P-0-0522.

Measuring Method with Absolute Motor Encoder

For the measuring method with absolute motor encoder, carry out the following steps for commissioning:

1. Enter value for relative position of primary part compared to secondary part in parameter "P-0-0523, Commutation setting measured value" (for how to determine this value see separate motor documentation "Rexroth IndraDyn L").

   Note: The position of the primary part or the slide mustn't change any more after the required distance measurements!
2. Activate command parameter "P-0-0524, C1200 Commutation offset setting command".
3. Controller enters value determined for commutation offset in parameter "P-0-0521, Effective commutation offset" and parameters "P-0-0508,

Commutation offset" and "P-0-3008, Commutation offset, encoder memory" apply this value.

Note: It is recommended that you optimize the determined commutation offset value. 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").

4. Then reset command C5600 and set initial commissioning mode to "inactive" again in parameter P-0-0522.

6.5.3 Saturation Method

Brief Description

For rotary synchronous Rexroth kit motors, IndraDrive controllers only provide methods with current to determine the commutation offset. The saturation method is one of these methods; when it is used, motor standstill is necessary. A possibly available holding brake should remain applied!

☞ For synchronous Rexroth motors with integrated motor encoder (MSK, MHD, MKD, 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 can also be used for linear synchronous Rexroth kit motors, if they have only been equipped with a relative measuring system (without Hall sensor box SHL), and for motors with an absolute measuring system for which distance measurement at the axis is impossible due to the mounting.

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.

When the requirements have been fulfilled, the saturation method can be used both for initial commissioning and for recommissioning.

☞ The restrictions to be observed when using the saturation method are described in the "Basics on Commutation Setting"section. This section outlines the different methods which can be used for determining the commutation offset.

Functional Description

Application-Related Aspect

The saturation method for determining the commutation offset can be used for all types of synchronous motors. It provides the advantage that distance measurement is not required. Stator and rotor of the motor can be inaccessibly installed in the machine. In the case of the saturation method, the commutation offset is determined with current supplied. The controller sets drive enable automatically for the duration of the measurement.

Method

By a test signal, the voltage and frequency of which require 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 parameter P-0-0506 at the start of "P-0-0524, C1200 Commutation offset setting command". The detected motor-specific value for P-0-0506 is stored and used for commutation setting for further operations.

☞ If the test current does not cause any magnetic saturation effect in the motor, the command C1200 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. in the case of 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. in the case of command error C1218), measures as described for "C1218 Automatic commutation: current too low" in the Troubleshooting Guide should be carried out!

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!

Notes on Commissioning

Saturation Method for Synchronous Motors with Absolute Measuring System

In the case of synchronous kit motors with absolute measuring system, the saturation method is **only started by a command at the initial commissioning** and the determined commutation offset value is stored in the controller or in the encoder data memory. In addition, the value can be manually or automatically optimized during initial commissioning.

Sequence of the Saturation Method

Sequence of the saturation method for synchronous motors with absolute measuring system:

1. In "P-0-0522, Control word for commutation setting" activate:
   - Initial commissioning mode

     - and -
   - Saturation method
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 value "0" in parameter "P-0-0506, Amplitude for angle acquisition"
3. Switch drive to operating mode ("AB"); start saturation method by "P-0-0524, C1200 Commutation offset setting command".
4. 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 in the case of absolute measuring systems:
   - P-0-0508, Commutation offset
   - P-0-0521, Effective commutation offset
   - P-0-3008, Commutation offset, encoder memory (if available)

The execution of the command is now completed, it can be reset. The drive now is operational.

Note: It is recommended that you optimize the determined commutation offset value. 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").

5. In "P-0-0522, Control word for commutation setting", deactivate initial commissioning mode via respective bit. Value in P-0-0508 resp. P-0-3008 is now read-only.

Each time the drive is switched on again or the measuring system is initialized, the value stored in the parameters P-0-0508 resp. P-0-3008 is applied to parameter P-0-0521 and becomes effective as the commutation offset value.

Saturation Method for Synchronous Motors with Incremental Measuring System

In the case of synchronous kit motors with incremental measuring system, the saturation method is automatically started when setting drive enable after the drive is switched on or after every initialization of the measuring system. The drive is operational only after the commutation offset has been successfully determined!

☞ The force development of the motor is guaranteed in a reproducible way when, at the homing of the axis, the optimized commutation offset value stored during initial commissioning becomes effective ("optimum commutation offset with regard to reference point")!

Sequence of the Saturation Method

Sequence of the saturation method for initial commissioning of synchronous motors with incremental measuring system:

1. In "P-0-0522, Control word for commutation setting" activate:
   - Initial commissioning mode

     - and -
   - Saturation method
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 value "0" in parameter "P-0-0506, Amplitude for angle acquisition"
3. Switch drive to operating mode ("AB"); start saturation method by "P-0-0524, C1200 Commutation offset setting command".
4. After the current was supplied and the commutation offset value has been successfully determined, this 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.

   Note: The motor-specific values for P-0-0506 and P-0-0507 should be checked for their safe function, independent of the position. To do this, 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 error message "F8013" (current too low)

  → Increase voltage (P-0-0506), reduce frequency (P-0-0507)
- With error message "F8014" (overcurrent)

  → Reduce voltage (P-0-0506), increase frequency (P-0-0507)

If the error message "F8013" 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 "F8013 Automatic commutation: Current too low" in the Troubleshooting Guide!

Recommendation: It is recommended that you optimize the determined commutation offset value. 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").

5. Now switch drive to parameter mode (P2). After switching back to operating mode, set "AF" and test function of drive. This automatically starts determination of commutation offset with stored parameters (P-0-506, P-0-0507, P-0-517). Motor is supplied with current and commutation offset determined again.

   Test 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!

   Note: If inadmissible values are generated for "P-0-0521, Effective commutation offset" and therefore the message "F8078 Speed loop error" appears, although there wasn't any error signaled during commutation offset determination, increase the value of parameter "P-0-0517, Commutation: required harmonics component"!
6. Now start "S-0-0148, C0600 Drive-controlled homing procedure command". By this command, due to active initial commissioning mode, value of P-0-0521 referring to an arbitrary position is converted to position of home point and stored in "P-0-0508, Commutation offset" and "P-0-3008, Commutation offset, encoder memory" (if available).
7. In "P-0-0522, Control word for commutation setting", deactivate initial commissioning mode via respective bit! Value in P-0-0508 resp. P-0-3008 is now read-only.

Recommissioning of synchronous motors after initial commissioning took place is the same for the methods with current. For detailed information see section "Basics on Commutation Setting".

☞ "Optimum commutation setting with regard to reference point" is generally recommended for relative measuring systems!

6.5.4 Sine-Wave Method

Brief Description

For synchronous motors, IndraDrive controllers, in addition to the saturation method, provide the sine-wave method, also with current, to determine the commutation offset. When this method is used, unrestricted movement of axis is required. The axis must be able to move easily and freely!

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.

When the requirements have been fulfilled, the sine-wave method is suited to only a limited extent for initial commissioning and for recommissioning.

☞ The restrictions to be observed when using the sine-wave method are described in the "Basics on Commutation Setting"section. This section outlines the different methods which can be used for determining the commutation offset.

Functional Description

Application-Related Aspect

The sine-wave method for determining the commutation offset can be used for all types of synchronous motors. However, it should only be used if the saturation method cannot be used for determining the commutation offset.

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!

☞ Observe the restrictions for the sine-wave method (see table "Typical applications and restrictions for sine-wave method" in section "Basics on Commutation Setting")!

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 for the sine-wave method is +/- 45mech/PPN for rotary motors and 1/2 pole pare distance for 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 parameter 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 further operations.

Notes on Commissioning

Sine-Wave Method for Synchronous Motors with Absolute Measuring System

In the case of synchronous kit motors with absolute measuring system, the sine-wave method is **only started by a command at the initial commissioning** and the determined commutation offset value is stored in the controller or in the encoder data memory. In addition, the value can be manually or automatically optimized during initial commissioning.

Sequence of Sine-Wave Method

Sequence of the sine-wave method for synchronous motors with absolute measuring system:

1. In "P-0-0522, Control word for commutation setting" activate:
   - Initial commissioning mode

     - and -
   - Sine-wave method

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 value "0" in "P-0-0506, Amplitude for angle acquisition"
3. Switch drive to operating mode ("AB"); start sine-wave method via "P-0-0524, C1200 Commutation offset setting command".
4. 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 in the case of absolute measuring systems:
   - P-0-0508, Commutation offset
   - P-0-0521, Effective commutation offset
   - P-0-3008, Commutation offset, encoder memory (if available)

   The execution of the command is now completed, it can be reset. The drive now is operational.

   Note: It is recommended that you optimize the determined commutation offset value. This can be done automatically by activating "C5600 Command subsequent optimization of commutation offset" (see section "Basics on commutation setting").
5. In "P-0-0522, Control word for commutation setting", deactivate initial commissioning mode via respective bit. Value in P-0-0508 resp. P-0-3008 is now read-only.

Each time the drive is switched on again or the measuring system is initialized, the value stored in the parameters P-0-0508 resp. P-0-3008 is applied to parameter P-0-0521 and becomes effective as the commutation offset value.

Sine-Wave Method for Synchronous Motors with Incremental Measuring System

For synchronous kit motors with incremental measuring system, the sine-wave method is automatically started when drive enable is set after the drive was switched on or after changing from communication phase "P2" to "P4" ("bb" or "Ab"). The drive is operational only after the commutation offset has been successfully determined!

☞ The force development of the motor is only guaranteed in a reproducible way when, at the homing of the axis, the value stored during initial commissioning with relation to the reference point becomes effective as commutation offset!

Sequence of Sine-Wave Method

Sequence of the sine-wave method for initial commissioning of synchronous motors with incremental measuring system:

1. In "P-0-0522, Control word for commutation setting", activate in communication phase "P2" (parameter mode):
   - Initial commissioning mode

     - and -
   - Sine-wave method
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 value "0" in "P-0-0506, Amplitude for angle acquisition"
3. Switch drive to operating mode ("AB"); start sine-wave method via "P-0-0524, C1200 Commutation offset setting command".

4. After the current was supplied and the commutation offset value has been successfully determined, this value is stored 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.

   Note: If the drive does not find any 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: It is recommended that you optimize the determined commutation offset value. This can be done automatically by activating "C5600 Command subsequent optimization of commutation offset" (see section "Basics on commutation setting").
5. Now start "S-0-0148, C0600 Drive-controlled homing procedure command". By this command, due to active initial commissioning mode, value of P-0-0521 referring to an arbitrary position is converted to position of home point and stored in "P-0-0508, Commutation offset" and "P-0-3008, Commutation offset, encoder memory" (if available).
6. In "P-0-0522, Control word for commutation setting", deactivate initial commissioning mode via respective bit! Value in P-0-0508 resp. P-0-3008 is now read-only.

Recommissioning of synchronous motors after initial commissioning took place is the same for the methods with current. For detailed information see the "Basics on Commutation Setting" section.

☞ "Optimum commutation setting with regard to reference point" is generally recommended for relative measuring systems!

6.6 Limitations

6.6.1 Overview of Limitations

Limitations in Open-Loop Operation (U/f Operation)

To protect the device or motor, the following parameterizable limitations have been implemented in open-loop operation:

- Current and torque limitation
  - Current limitation
  - Torque/force limitation
  - Stall protection loop for current limitation
  - Current limitation loop
- Position limitation
  - Travel range limit switches
  - Software limit switches

Limitations in Closed-Loop Operation

To protect the device or motor, the following parameterizable limitations have been implemented in closed-loop operation:

- Current and torque limitation
  - Current limitation
  - Torque/force limitation
- Velocity limitation
- Position limitation
  - Travel range limit switches
  - Software limit switches

6.6.2 Current and Torque Limitation (Open-Loop)

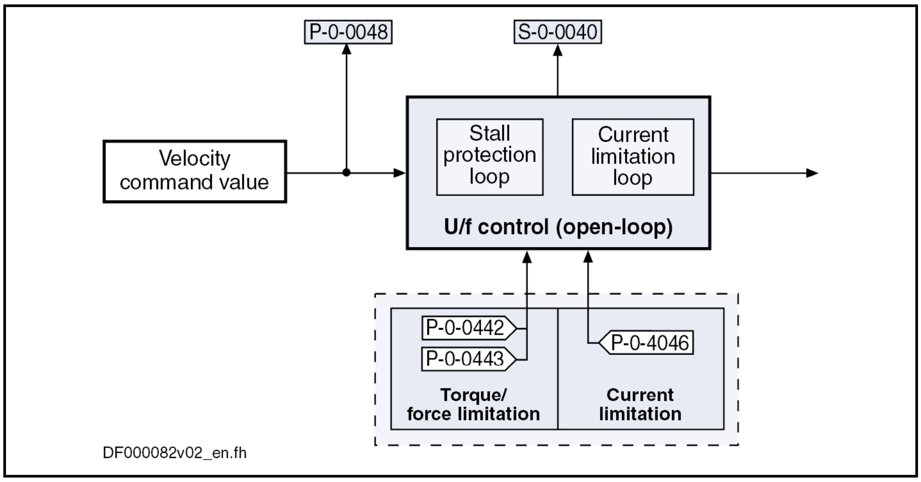
Brief Description

In open-loop operation, there is a current limitation and a torque/force limitation available in the drive. Both limitations take effect independently of each other.

See also section "Current and Torque Limitation (Closed-Loop)"

Other possibilities of current and torque limitation in open-loop operation:

- Limitation of the available peak current or torque by dynamic controller and motor protection equipment with current limitation loops
- User-side limitation of the available torque or force via stall protection loop



S-0-0040	Velocity feedback value
P-0-0048	Effective velocity command value
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.6-67: Principle of Current and Torque Limitation (Open-Loop)

Operating Principle of Stall Current Loop and Current Limitation Loop

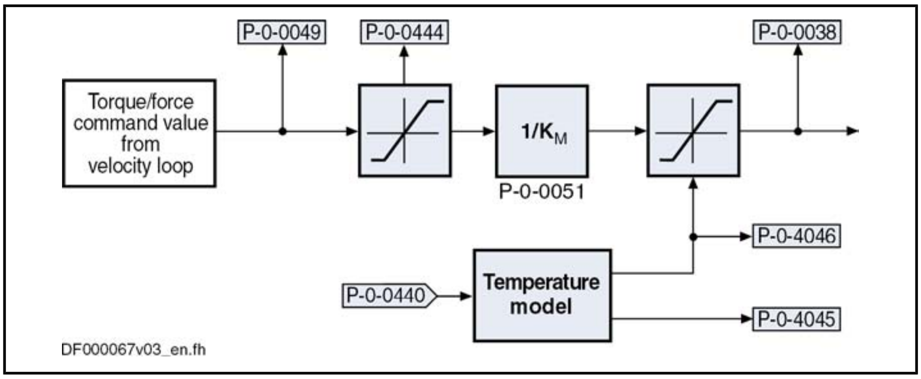
See "Functional Description: Stall Protection Loop" in section "Motor Control: Voltage-Controlled Operation (Open-Loop)"

See "Functional Description: Current Limitation Loop" in section "Motor Control: Voltage-Controlled Operation (Open-Loop)"

6.6.3 Current and Torque Limitation (Closed-Loop)

Brief Description

In closed-loop operation, there is a current limitation and a torque/force limitation available in the drive. Both limitations take effect independently of each other.



P-0-0038	Torque-generating current, command value
P-0-0049	Effective torque/force command value
P-0-0051	Torque/force constant
P-0-0440	Actual output current value (absolute value)
P-0-0444	Actual value peak torque limit
P-0-4045	Maximum possible continuous current
P-0-4046	Effective peak current

Fig.6-68: Principle of Current and Torque Limitation (Closed-Loop)

Features

- Separate limitation of current and torque/force (separated via "P-0-0051, Torque/force constant")
- Unipolar limits for torque/force (S-0-0082, S-0-0083)
- Absolute current limitation by minimum value of "S-0-0110, Amplifier peak current" and "S-0-0109, Motor peak current"
- Dynamic current limitation:
  - For currents above the 1.15.-fold motor current at standstill
  - Based on the amplifier temperature model (E8057/E2061)
  - Stall protection for asynchronous motors
- Display parameter "P-0-0440, Actual output current value (absolute value)"
- Separate status word for torque/force limitation (P-0-0445)
- Resulting limitations displayed in:
  - P-0-0444, Actual value peak torque limit
  - P-0-4046, Effective peak current
  - P-0-4045, Maximum possible continuous current (depending on PWM frequency and amplifier type)
- Current command values displayed in:
  - P-0-0049, Effective torque/force command value
  - P-0-0038, Torque-generating current, command value
- "Total actual current value" as parameter
- Process torque is displayed

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, Overload warning
- 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-0-0640, 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
- 8057 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.

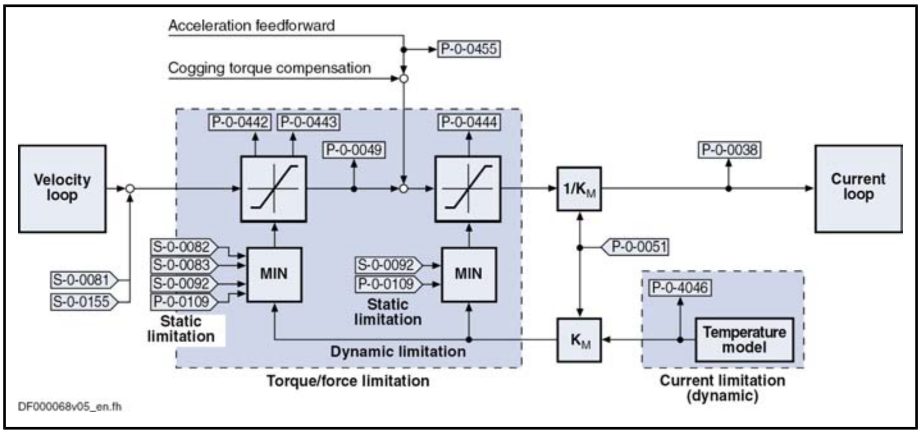
Parameters for bipolar limits:

- 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 figure below illustrates the functional principle:



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-0-0155	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

Fig.6-69: Principle of Torque/Force Limitation

Properties

The basic properties of torque/force limitation:

- 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.
- The torque/force limit value effective at the output of the limitation is displayed in parameter "P-0-0444, Actual value peak torque limit".

Current Limitation

☞ The current limitation cannot be parameterized by the user, but is automatically configured by the drive to protect the motor and the amplifier.

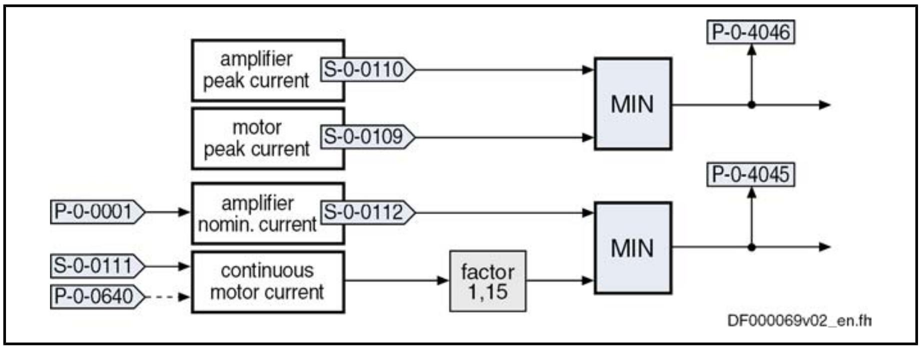
We basically distinguish the following principles of current limitation:

- **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

Calculating the maximum values for continuous current and peak current:

Drive Control



P-0-0001 Switching frequency of the power output stage
P-0-0640 Cooling type
P-0-4045 Maximum possible continuous current
P-0-4046 Effective peak current
Fig.6-70: Generating the Maximum Values for Continuous Current and Peak Current

Maximum Possible Continuous Current

The maximum possible continuous current (P-0-4045) can be the 1.15- fold value of the motor current at standstill. As a result, the motors theoretically can be continuously operated with the 1.15-fold current at standstill, if the continuous current of the controller (power section) allows it.

☞ Overload protection in peak load and short-time operation (KB = "Kurzzeitbetrieb") is realized by the temperature model of the motor and additionally by the temperature sensor included in the motor.

Effective Peak Current

According to the thermal load of the motor or drive controller, the effective peak current (P-0-4046) is subject to a dynamic current limitation. The theoretical maximum value for "P-0-4046, Effective peak current" results from the minimum of S-0-0109 and S-0-0110 (see fig. above "Generating the Maximum Values for Continuous Current and Peak Current").

Dynamic Peak Current Limitation

In the case of dynamic peak current limitation, we distinguish 2 types due to the influencing factors:

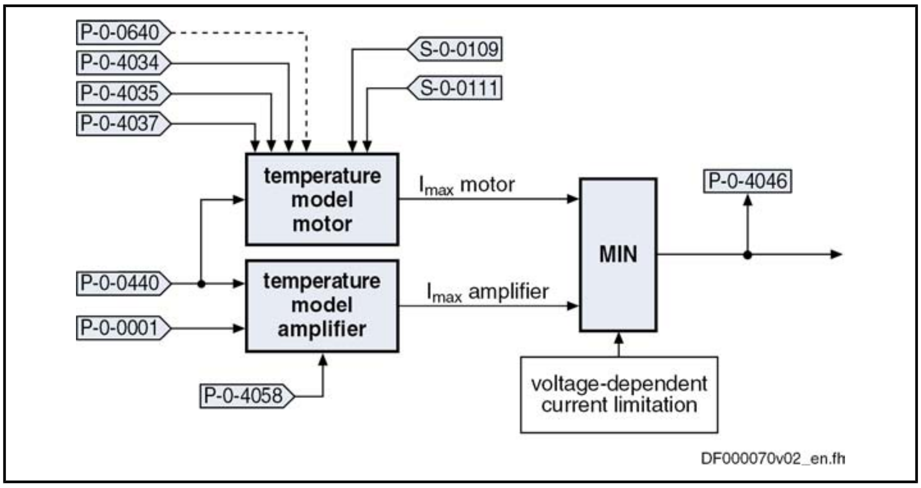
- **Limitation of amplifier current**

  It is used to protect the drive controller. An amplifier temperature model based on the amplifier type data is therefor stored in the controller.

☞ 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 protection of the motor with peak load and short-time overload operation. A motor temperature model based on the motor current data is therefor stored in the controller.



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
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.6-71: Generating the Dynamic Peak Current Limit Value (Temperature Model)

Properties

The basic properties of dynamic current limitation:

- The value taking effect is always the lowest value resulting from motor current or amplifier current limitation.
- The maximum possible continuous current is displayed in P-0-4045, the effective peak current in P-0-4046.
- The command value of the current after limitation is displayed in parameter P-0-0038.

Maximum Peak Current

If the drive controller was sufficiently dimensioned, the effective peak current (P-0-4046) can as a maximum reach the peak current of the motor (S-0-0109), because its value is the upper limit for the motor temperature model.

Maximum Duration for the Peak Current

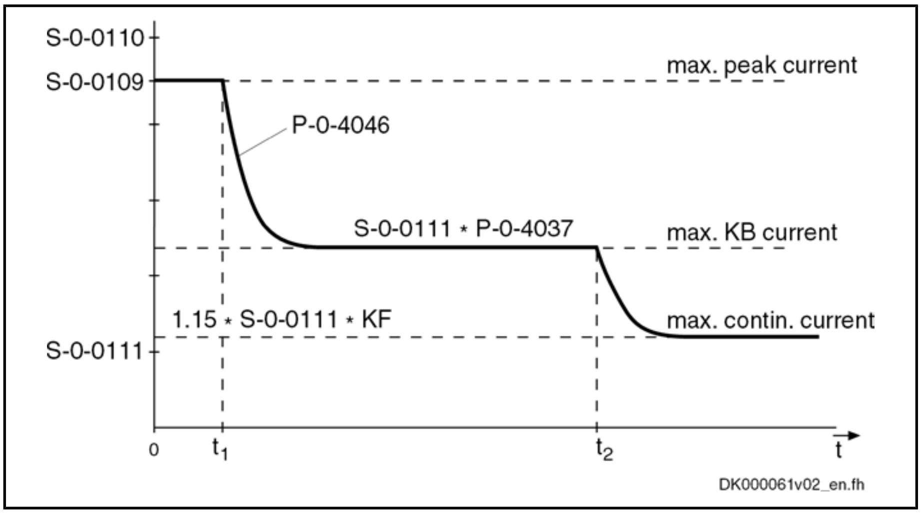
The maximum possible peak current can be made available for the time t_1 (see fig. below "Time Response of the Effective Peak Current") [e.g. a maximum of 400 ms at switching frequency 4kHz].

☞ According to load cycle or with higher switching frequency and the thermal load involved, the time t_1 is reduced.

Time Dependency of Effective Peak Current

If the peak current is required for a longer period than t_1, the value of "P-0-4046, Effective peak current" is reduced accordingly, at the most to the value preset in "P-0-4045, Maximum possible continuous current".

Drive Control



S-0-0109	Motor peak current
S-0-0110	Amplifier peak current
S-0-0111	Motor current at standstill
P-0-4045	Maximum possible continuous current
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.6-72: Time Response of the Effective Peak Current (at Full Motor Load, if the Motor Temperature Model is the Effective Limitation)

$$t_1 = -\ln\left[1-\left(\frac{(P\text{-}0\text{-}4037) \times (S\text{-}0\text{-}0111)}{I_{L1}}\right)^2\right] \times (P\text{-}0\text{-}4034)$$

$$t_2 = -\ln\left[1-\left(\frac{1{,}15 \times KF \times (S\text{-}0\text{-}0111)}{I_{L2}}\right)^2\right] \times \frac{(P\text{-}0\text{-}4035)}{KF}$$

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 < IL2 < 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.6-73: Calculating the Duration for the Effective Peak Current (See Above)

The duration t_1 depends on:

- The motor-controller combination
- The thermal preloading of the drive
- The load cycle

☞ 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 (2AD, ADF, MAD, MAF, MBT, MBS, LSF, MLF) and for non-ventilated motors MHD, MSK, MKD, MKE
- 1.5 → For ventilation (only MHD, MSK, MKD, MKE)
- 1.9 → For liquid cooling (only MHD, MSK, MKD, MKE)

☞ The physical data of motor-controller combinations can be retrieved via the selection list program "DriveSelect" (Intranet).

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.

Unipolar Torque Limitation

Bipolar torque/force limits are generally determined to protect the mechanical system, because this allows defining the allowed stress of the mechanical components (e.g. gear, coupling). The limit values to be entered therefore depend on the mechanical axis system.

Bipolar Torque Limitation

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 bus or assigned to an analog input.

☞ The parameter "P-0-0109, Torque/force peak limit" is used to determine the absolute limit and therefore always has to be defined by means of the mechanical limits.

Diagnostic and Status Messages

For diagnostic purposes, the status of all partial limits is mapped to a status word for torque/force limitation and current limitation (see 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
- 8057 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

6.6.4 Velocity Limitation

Brief Description

A unipolar velocity limitation was implemented in the drive that allows limiting the velocity command value to a positive and negative threshold freely definable and differing with regard to the absolute value.

Features

- Unipolar velocity limit values (S-0-0038, S-0-0039)
- Cyclically configurable, bipolar velocity limit value (S-0-0091)

Pertinent Parameters

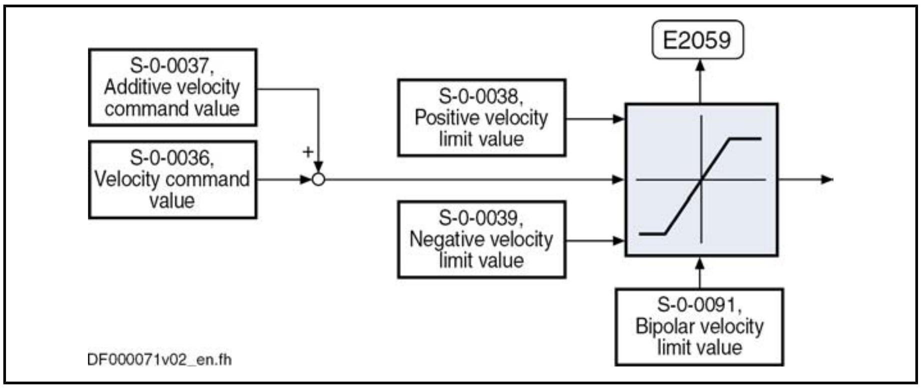
- S-0-0036, Velocity command value
- S-0-0037, Additive velocity command value
- S-0-0038, Positive velocity limit value
- S-0-0039, Negative velocity limit value
- S-0-0091, Bipolar velocity limit value

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.6-74: 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** → Resulting from the minimum value of "S-0-0091, Bipolar velocity limit value" and "S-0-0039, Negative velocity limit value"
- **Upper (positive) limit** → Resulting from the minimum value of "S-0-0091, Bipolar velocity limit value" and "S-0-0038, Positive velocity limit value"

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 the parameters S-0-0038 and S-0-0039 is "0". These two 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 warning "E2059" is displayed.
- E2063 Velocity command value > limit value

  The parameter "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 parameter "S-0-0040, Velocity feedback value" is monitored. When it exceeds the 1.125-fold effective positive or negative velocity limit, the error message "F8079" is generated.

6.6.5 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
- P-0-0090, Travel range limit parameter
- P-0-0222, Travel range limit 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
- F6029 Positive travel limit exceeded
- F6030 Negative travel 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, it is possible to connect and monitor 2 travel range limit switches (Limit+, Limit-) that can be connected to the digital inputs on 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

Monitoring for exceeding the travel range limit switches is only carried out when the monitor was activated via bit 1 of "P-0-0090, Travel range limit parameter".

Reaction when Exceeding Travel Range

The drive reaction to exceeding the travel range can be determined via bit 2 of "P-0-0090, Travel range limit parameter".

Exceeding Travel Range as an Error

When "0" is entered in bit 2 of parameter P-0-0090, 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 parameter P-0-0090, 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.
- 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. Checking the command values depends on the active operating mode (see below "Notes on commissioning").

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 is always carried out as quickly as possible with maximum allowed torque/force.

Position Limit Values (Software Limit Switches)

Parameters for Position Limit Values

To define the travel range via position limit values, the following parameters are available:

- S-0-0049, Positive position limit value
- S-0-0050, Negative position limit value

☞ The position limit values are polled every 2 ms so that the assigned 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 monitor:

- The position data reference of the drive must have been established (i.e. the encoder system of the active operating mode must be in reference). The status bit in parameter "S-0-0403, Position feedback value status" then is "1".
- Monitoring of the position limit values was activated in parameter "S-0-0055, Position polarities" (bit 4 = 1).

Reference Point for Position Limit Value Monitoring

When 2 measuring systems are used the drive, for position limit value monitoring, automatically refers to the measuring system that has been homed.

☞ When 2 measuring systems are used and both systems are in reference, the encoder selected in parameter 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 operating 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 parameter "P-0-0090, Travel range limit parameter".

Exceeding Position Limit Values as an Error

When "0" is entered in bit 2 of parameter P-0-0090, 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 parameter P-0-0090, 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.
- 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. Checking the command values depends on the active operating mode (see below "Notes on Commissioning").

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 is always carried out as quickly as possible with 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 hasn't 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).

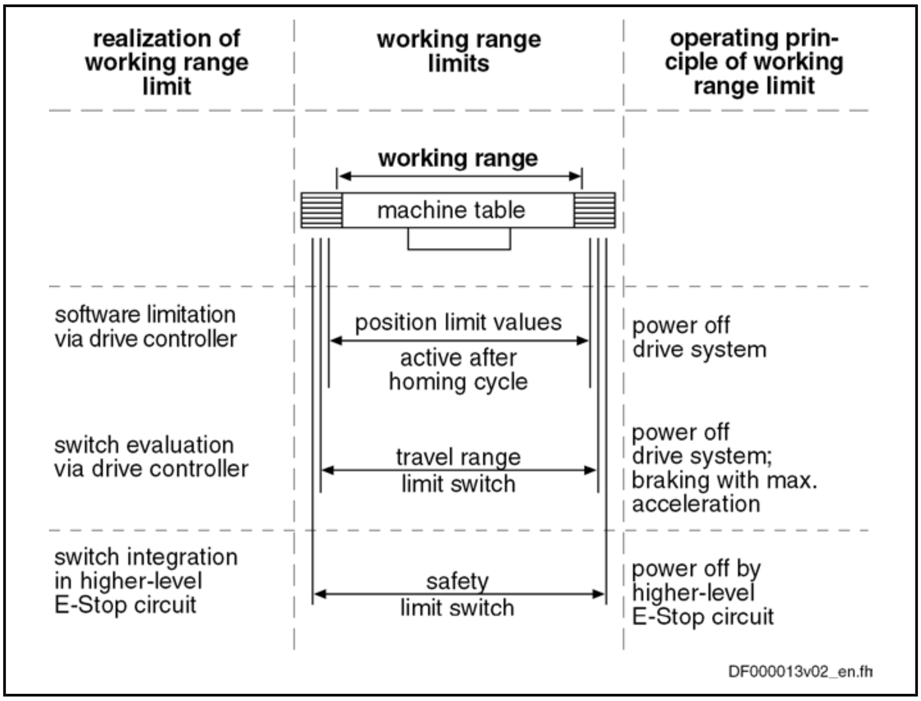


Fig.6-75: Realizations and operating principles of working range limitations

☞ 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 parameter "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 "P-0-0090, 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 and N/C)

Via bit 0 of "P-0-0090, 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. if 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. Checking the command values depends on the active operating mode.

The following applies:

Operating mode	Command value check
torque control	polarity of the torque/force command value (S-0-0080)
all operating modes with drive-internal velocity control	polarity of the internal velocity command value
all operating modes with drive-internal position control	polarity of the velocity resulting from the preset position command value

Fig.6-76: 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 "P-0-0090, Travel range limit parameter" (bit 2):

Handling	Display	Diagnosis
as error (bit 2 = 0)	F6029	F6029 Positive travel limit exceeded
	F6030	F6030 Negative travel limit exceeded
as warning (bit 2 = 1)	E8029	E8029 Positive position limit exceeded
	E8030	E8030 Negative position limit exceeded

Fig.6-77: Diagnostic messages when position limit values exceeded

E2053 Target Position out of Travel Range

When "drive-internal interpolation" is used as active operating 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 parameter "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 "P-0-0090, Travel range limit parameter" (bit 2):

Handling	Display	Diagnosis
as 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 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

Fig.6-78: 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 inputs":

- Bit 0 → Status of positive limit switch (Limit+)
- Bit 1 → Status of negative limit switch (Limit-)

See also Parameter Description "P-0-0222, Travel range limit inputs"

Connecting the Travel Range Limit Switches

See "Digital Inputs/Outputs"

See separate documentation "Control Sections for Drive Controllers - Project Planning Manual"

6.7 Power Supply

6.7.1 Possibilities of Power Supply for IndraDrive

Brief Description

For IndraDrive devices we basically distinguish two lines:

- Modular line, consisting of supply unit and modular inverter (IndraDrive M)
- Non-modular line, so-called converter devices, including power supply and inverter (IndraDrive C)

The power supply of the motors controlled via inverter is realized by a direct voltage power bus (DC bus). In the case of the modular line, this bus is supplied by the supply unit connected to the mains. Converters are supplied by the mains connection via the integrated supply unit.

Pertinent Parameters

- S-0-0380, DC bus voltage
- P-0-0114, Undervoltage threshold
- P-0-0118, Power supply, configuration
- 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-0-0810, Minimum mains crest value
- P-0-0815, Nominal mains voltage crest value
- P-0-0816, Amplifier temperature 2
- P-0-0819, Energy counter
- P-0-0833, Braking resistor threshold
- P-0-0844, Braking resistor load
- 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
- E2802 HW control of braking resistor

- E2810 Drive system not ready for operation
- E2814 Undervoltage in mains
- E2816 Undervoltage in power section
- E2818 Phase failure
- E2819 Mains failure
- E2820 Braking resistor overload prewarning
- E2829 Not ready for power on
- E8025 Overvoltage in power section
- E8028 Overcurrent in power section
- 8057 Device overload, current limit active
- E8058 Drive system not ready for operation
- F2026 Undervoltage in power section
- F2086 Error supply module
- F2087 Module group communication error
- F2814 Undervoltage in mains
- F2816 Softstart fault power supply unit
- F2817 Overvoltage in power section
- 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
- F2833 Ground fault in motor line
- F2834 Contactor control error
- F2836 DC bus balancing monitor error
- F2840 Error supply shutdown
- F2860 Overcurrent in mains-side power section
- F8838 Overcurrent external braking resistor

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 separate documentation "Rexroth IndraDrive – Drive System, Project Planning Manual" (DOK-INDRV*-SYSTEM*****-PR**-EN-P; Part no.: R911309635) .

Central Supply The figures below illustrates the principle of central supply:

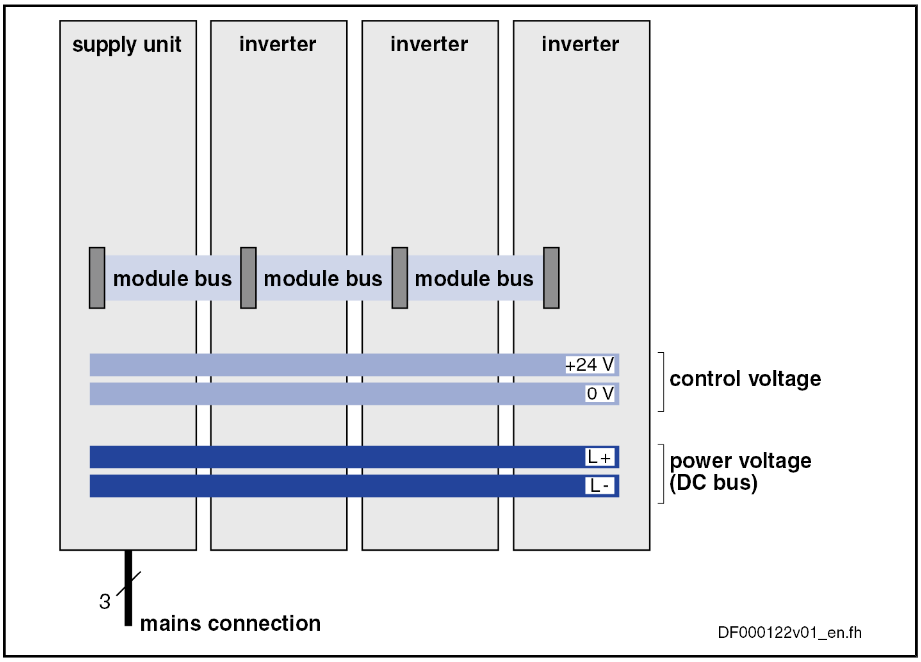


Fig.6-79: Mains supply via supply unit

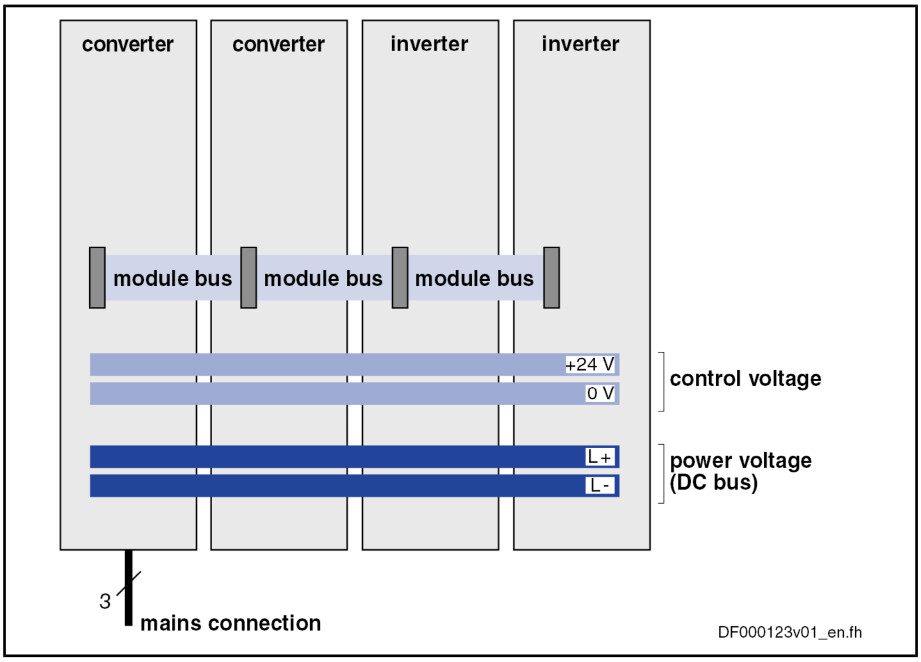


Fig.6-80: Mains supply via converter

Group Supply

The figure below illustrates the principle of group supply:

Drive Control

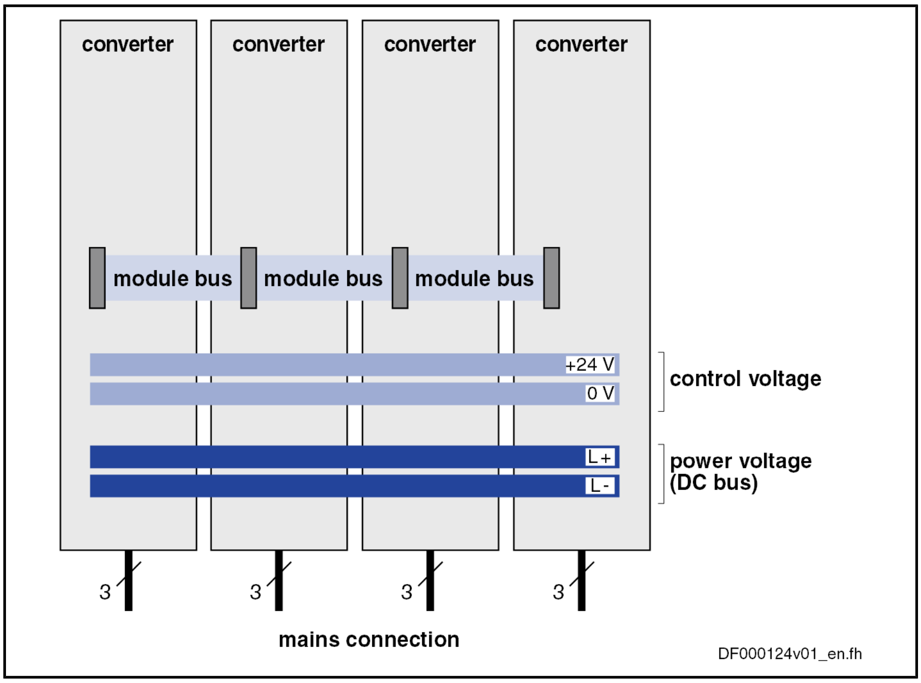


Fig.6-81: Mains supply via all devices

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. For this purpose, IndraDrive devices are interconnected via the module bus.

Note Regarding Converters

A converter combines 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:

- Supplying its integrated inverter and further inverters

- or -

- Operation only as inverter on a DC bus (only for HCS02.1)

Regenerated Energy

In the case of regenerative operation (e.g. deceleration mode) of the motors connected to a drive controller, the regenerated energy is first absorbed by the DC bus. Depending on the supply unit or supply section, the absorbed energy is regenerated to the supply mains or converted to heat via a braking resistor.

Braking Resistor

The braking resistor is connected on the DC bus side. Depending on the device line, an internal braking resistor is available or an external braking resistor can be connected.

Description of Hardware

As regards hardware, connections and signals, the module bus is described in the documentations of the devices (Project Planning Manuals).

☞ Recommendations on mains connection and control of the power supply, including external braking resistor and DC bus short circuit, are contained in the separate documentation "Rexroth IndraDrive – Drive System, Project Planning Manual" (DOK-INDRV*-SYSTEM*****-PR**-EN-P; Part no.: R911309635) .

6.7.2 Functional Description

Information on 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 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)	■	■	--	--	↑
prewarning "supply overload"	■	■	--	■	↑
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 converter
IV inverter
HLB DC bus resistor unit
1) only if F8 errors signaled at supply unit (P-0-0118)
2) only if F2/F4/F6 errors signaled in drive system (P-0-0118)
Fig.6-82: 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.

Resetting Error Messages of the Supply Unit

Error messages of supply unit output via:

- Display of supply unit

- and -

- Inverter or converter connected at module bus (collective error message "F2086 Error supply module")

Error messages of supply unit cleared via:

- "Esc" key at display of supply unit

- or -

- Module bus, triggered by command "S-0-0099, C0500 Reset class 1 diagnostics" for an inverter of the module group

- or -

- "Reset" input at the DC bus resistor unit HLB (if available)

☞ Inverters can reset error messages of the supply unit via the module bus, as supply units do not have any master communication interface. In the case of converters, error messages of the integrated supply unit are reset via their own master communication interface. Resetting error messages at the supply has the highest priority in order that power supply can be immediately reestablished!

Supply Unit Ready for Operation

The supply unit or the supply section of the converter signals "ready for operation" via the module bus, when the required control voltage is provided at the device and there isn't any supply error present.

If the supply unit 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.

Inverters Ready for Operation

The inverter or converter signals "ready for operation" via the module bus, when the required control voltage is provided at the device, communication phase P4 has been reached and there isn't any error present in the inverter or inverter section of the converter.

HLB Ready for Operation

The DC bus resistor unit HLB signals "ready for operation" via the module bus, when the required control voltage is provided at the device and the thermal load of the components is in the allowed range.

Voltage Messages of the Supply

The supply unit or 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 converters connected to the module bus and can be read by the control master via the master communication (warning "E2026 Undervoltage in power section" or error "F2026 Undervoltage in power section", 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 "Basics on Power Supply" section.

Overload Warning of the Supply

The supply unit or 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 "prewarning supply module overload" is output via the inverters or converters connected to the module bus (E2086). 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 supply unit or 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

☞ The message "prewarning supply module overload" can be generated by HLB, too, because HLB contains a braking resistor which can be thermally overloaded.

Diagnosis of Module Bus Status

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 messages currently available on the module bus are displayed in "P-0-0461, Module group, status word".

ℹ See also Parameter Description "P-0-0460, Module group, control word" and "P-0-0461, Module group, status word"

Basics on Power Supply

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

The mains voltage for charging the DC bus can only be switched on when all devices connected via the module bus are signaling the status "error-free". If one of the devices displays an error,

- the activation of the internal mains contactor is prevented for supply units,
- the activation of the external mains contactor is prevented (message "E2810 Drive system not ready for operation") for converters, by the opened "Rel1" contact that has to be available in the switch-off path of the mains contactor.

☞ For this reason, the status information "supply ready for operation" (respective bit in parameter "P-0-0861, Status word of power section") has to be assigned to the "Rel1" contact of the control section for converters; no other signal may be assigned to this contact. **Otherwise it is possible to switch power on, although an error condition is present!**

☞ Recommendations on the hardware-side control of supply units or converters are contained in the separate documentation "Rexroth IndraDrive – Drive System, Project Planning Manual" (DOK-INDRV*-SYSTEM*****-PR**-EN-P; Part no.: R911309635) .

Soft Start

When the mains voltage is switched on, the DC bus is charged via a so-called "soft start device". This limits the charging current for the DC bus first uncharged to the value indicated 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. The soft start fault is signaled to the other devices via the module bus as a supply error with "F2086 Error supply module" (displayed for supply unit and other converters).

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 ("ZK ok" = "DC bus ok").

Minimum Voltage for Power Output

In the case of power output of the DC bus and correct mains voltage, the minimum value of the DC bus voltage for signaling the readiness for power output ...

- in the case of supply units, is 75% of the crest value of the mains voltage detected when switching on (cannot be set),
- in the case of converters, is 75% of the crest value of the mains voltage detected when switching on, unless a higher minimum value has been set via "P-0-0114, Undervoltage threshold".

In case the voltage value has fallen below the minimum voltage, the error message "F2026 Undervoltage in power section" is generated and power is switched off.

☞ In the case of HMV supply units, the readiness for power output is additionally signaled by the relay contact "UD" closed (see documentation "Supply Units and Power Sections, Project Planning Manual").

☞ The crest value of the mains voltage is detected when the mains contactor is activated. It is displayed in parameter "P-0-0815, Nominal mains voltage crest value" (only for converters, not for supply units).

Power Off

In the case of error, power is switched off automatically,

- in the case of supply units, by switching the integrated mains contactor off,
- in the case of converters, by opening the "Rel1" contact that has to be available in the switch-off path of the mains contactor.

☞ For this purpose, the status information "supply ready for operation" (respective bit in parameter "P-0-0861, Status word of power section") has to be assigned to the "Rel1" contact of the control section for converters; no other signal may be assigned to this contact. **Otherwise power is not switched off automatically!**

Depending on the hardware-side design and control of the supply unit or converter, "DC bus short circuit" (for decelerating synchronous motors) can be activated, too.

☞ Recommendations on the hardware-side control of supply units or converters are contained in the documentation of the respective device.

Criteria for power off (for supply units) or opening the "Rel1" contact (for converters):

- Error in supply (see below "Diagnostic and status messages"")
- Fatal error in inverter or converter (F8xxx), is signaled at supply unit by corresponding configuration of the inverter or converter as regards power supply (P-0-0118)
- Charged DC bus has fallen below "minimum voltage for power output" (see above)

> ☞ When an inverter signals missing readiness for operation via the module bus, power is not switched off when DC bus is ready for power output (exception see above "fatal error... (F8xxx), ...")!

Mains Failure Detection

Due to hardware differences, there are different requirements for mains failure detection in supply units and converters:

- The supply unit has an integrated mains contactor, the mains voltage must have been provided at the mains input terminals of the supply unit before power is switched on.
- The converter doesn't have an integrated mains contactor, the mains voltage is only provided at the mains input terminals of the converter by switching power on.

The mains voltage is therefore monitored when

- the mains contactor has been switched on in the case of supply units,
- the mains contactor has been switched on and drive enable has been set in the case of converters.

> ☞ For converters, mains failure monitoring is only convenient when the drive is active ("AF"). The disconnection of power (mains contactor disconnection) would otherwise always cause the error message "F2819 Mains failure", although the mains voltage is available without error at the mains contactor. For this reason, error reset would be required even if the device status is correct!

Immediate Measure at Mains Failure

When the failure of mains voltage is detected, the following immediate measures are taken:

- The warning "E2818 Phase failure" or "E2819 Mains failure" (for supply units), or "E2819 Mains failure" (for converters) is displayed.
- The message "failure DC bus supply" is signaled via the module bus.

Permanent Mains Failure

> ☞ In the case of HMV supply units, the mains failure is additionally signaled by the relay contact "UD" opened (see documentation "Supply Units and Power Sections, Project Planning Manual").

In case the mains voltage fails permanently, the DC bus voltage is continuously decreasing, the voltage value falls below the "minimum voltage for power output" (see above). The following reactions are then triggered:

- In the case of supply units, the integrated mains contactor is switched off. The converter opens the "Rel1" contact via which the external mains contactor has to be switched off.
- The error message "F2819 Mains failure" appears on the display of the supply unit or converter.
- The message "readiness for operation of supply unit missing" is signaled via the module bus.

Temporary Mains Failure

If the voltage value, in the case of temporary mains voltage failure, does **not** fall below the "minimum voltage for power output" (see above), there are the following reactions:

- The warning "E2818 Phase failure" or "E2819 Mains failure" (for supply units), or "E2819 Mains failure" (for converters) automatically disappears from the display.
- The message "DC bus ready for power output" is generated via the module bus again.

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 (configuration of power supply in parameter P-0-0118).

There are the following possibilities:

- Error reaction triggered according to setting in parameter "P-0-0119, Best possible deceleration"
- No error reaction (i.e. the message is handled as "non-fatal warning")

Configuration of Power Supply

For each of the drives connected by the module bus, it is possible to make basic settings for power supply in parameter "P-0-0118, Power supply, configuration":

- Reaction to drive errors signaled via module bus
- Individual drive errors signaled via module bus
- Drive-side handling of undervoltage (voltage value of DC bus falling below a minimum) defined as error or warning
- Fatal drive errors (F8xxx) signaled to supply unit because of power off and possibly DC bus short circuit for shutting down synchronous motors

Information on Inverters

The motors are controlled via inverters. Inverters can be designed as modular devices or together with a supply unit be integrated in converters. For motor control, the inverter converts the DC bus voltage into alternating voltage (AC).

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 with the following procedures:

- Evaluation of the message "failure DC bus supply" signaled by the supply unit via the module bus

- or -

- Monitoring of the internally measured DC bus voltage with regard to an individual minimum threshold value

The desired procedure is determined in parameter "P-0-0114, Undervoltage threshold":

- P-0-0114 = 0 → Drive detects undervoltage, when the supply unit signals "DC bus not ok" via the module bus
- P-0-0114 ≠ 0 → Determination and activation of undervoltage threshold active in the drive greater 75% of nominal mains voltage crest value

Depending on the configuration of the power supply (P-0-0118), undervoltage is handled as an error (error reaction according to setting in P-0-0119) or non-fatal warning (no reaction).

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.

Operating Converters as Inverters

It is possible to operate converters of the HCS02.1 type as inverters only. When doing this, power supply is carried out by a DC bus (power voltage); there is no mains voltage applied to the converter. The inverter operation of a converter is configured via the respective bit in "P-0-0860, Converter configuration".

☞ Converters of the HCS03.1 type cannot be operated as inverters on a DC bus!

Mains Voltage Data

When a converter is directly connected to the supply mains (converter operation), the following mains voltage data are made available:

- P-0-0806, Current mains voltage crest value
- P-0-0810, Minimum mains crest value
- P-0-0815, Nominal mains voltage crest value

In parameter P-0-0810 it is possible to set a threshold value, for triggering the warning "E2814 Undervoltage in mains", higher than the minimum value of the mains connection voltage range; this possibly enables the control master to react to the situation in the mains. The tolerance limit can be influenced via the level of the threshold value.

Identifying the Charging Circuit for DC Bus

The control section of 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.

Status of Power Supply

The converter signals the status of power supply, mains voltage, DC bus charging status and the readiness for operation of the supply unit via parameter "P-0-0861, Status word of power section". This allows diagnosing the converter in the case of error.

Supply Section Ready for Operation

The readiness for operation of the supply section of a converter is displayed via a bit in P-0-0861. This status information has to be assigned to the "Rel1" contact of the control section; the "Rel1" contact has to be integrated in the mains contactor control circuit. There mustn't be any other information assigned to the "Rel1" contact, because otherwise the power of the converter cannot be switched off automatically!

See also "Digital Inputs/Outputs"

☞ Data on the hardware-side control of converters are contained in the documentation of the device.

Data on the Braking Resistor and the DC Bus Resistor Unit HLB01

External/Internal Braking Resistor

Converters of the HSC02.1 type and HMV supply units are equipped with an integrated braking resistor. For the devices with higher maximum current, it is possible to connect an external braking resistor as an alternative to the internal braking resistor (device option). The presetting for whether an internal or external braking resistor becomes active is made in parameter "P-0-0860, Converter configuration".

Converters of the HCS03.1 type do not have an internal braking resistor. Depending on the device option it is possible, however, to connect an external braking resistor.

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 read-only 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 resistor value that can be connected has to be taken into consideration (see documentation of the respective device).

DC Bus Short Circuit

The function "DC bus short circuit" can be triggered at DC bus resistor units HLB01.

Switch-On/Switch-Off Threshold of Braking Resistor

For the switch-on/switch-off threshold of the braking resistor in the case of HCS drive controllers there are

- reference values that can be selected

  \- and -

- dynamic adjustment to the current load of the braking resistor.

The reference values for the switch-on/switch-off threshold can be set to fixed standard values or variable values in parameter "P-0-0860, Converter configuration".

See also Parameter Description "P-0-0860, Converter configuration"

For the switch-on or switch-off threshold of the braking resistor in the case of supply units of the HMV type and the DC bus resistor unit HLB01 there is

- for HMV01.1E-..., a fixed or a mains voltage dependent reference value, depending on the signal level at the HMV terminal X32/3
- for HMV01.1R-... and HLB01, a fixed reference value for the switch-on threshold of DC820V

  \- and -

- dynamic adjustment to the current load of the braking resistor.

> Explanations on the reference values for the switch-on/switch-off thresholds of the braking resistor and on the control of X32 are contained in the documentation of the supply units of type HMV (see documentation "Supply Units and Power Sections, Project Planning Manual").

As parameterization is impossible for HMV supply modules and the DC bus resistor unit HLB, the available options are limited:

- **Regenerative supply units HMV01.1R and DC bus resistor unit HLB01**

  → The basic switch-on threshold of the braking resistor is 820 V. There always is dynamic adjustment to the active load.

- **Infeeding supply units HMV01.1E**

  → Via an interface input, the customer can choose between mains-oriented threshold and fixed threshold. The default setting (open-circuited interface) is mains-oriented. The basic switch-on threshold then is 80 V above the mains voltage crest value measured at the first power on. In the "fixed threshold" mode the basic switch-on threshold is 820 V. In both operating modes there always is dynamic adjustment to the active load.

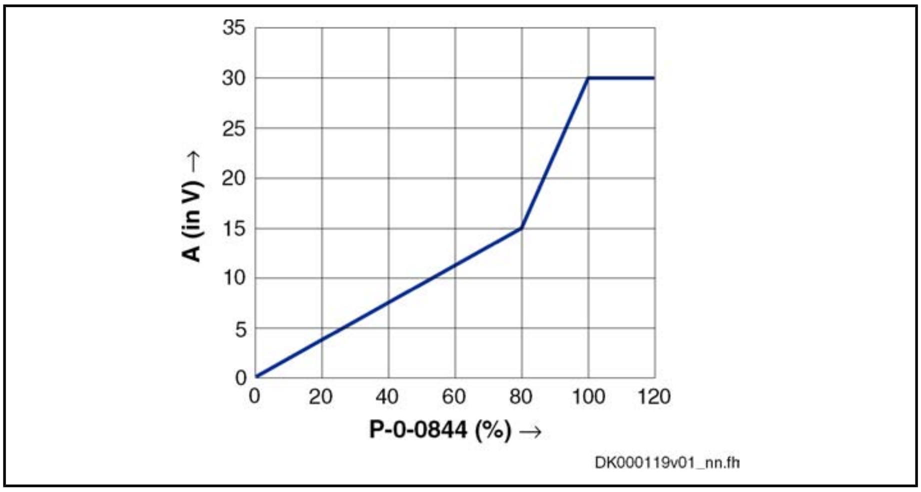
Dynamic Adjustment of the Switch-On Threshold

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, Braking resistor load".

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.6-83: 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 (see P-0-0860, bits 10,11); 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!

☞ In the case of HMV supply units, overload of the braking resistor and overtemperature of supply are additionally signaled by the relay contact "WARN" (see documentation "Supply Units and Power Sections, Project Planning Manual").

6.7.3 Notes on Commissioning

Configuration of Power Supply

The required or desired axis-specific settings of the power supply of the device connected by the module bus have to be made in parameter "P-0-0118, Power supply, configuration".

The following settings or definitions can be made:

- Signaling of drive errors inside the drive system and reaction to signaled errors
- Handling of undervoltage as error or warning
- Signaling of fatal drive errors to the supply for switching power off (if necessary with DC bus short circuit)

Setting the Undervoltage Threshold

If an individual threshold value is to be used for monitoring with regard to undervoltage, enter the desired value in parameter

- P-0-0114, Undervoltage threshold.

Otherwise, the undervoltage threshold is 75% of the mains voltage crest value that was measured when the mains was switched in.

Configuration of Converter Operated as Inverter

If a converter is to be operated as an inverter at a DC bus, the bit for power supply has to be set in parameter

- P-0-0860, Converter configuration.

The "Rel1" contact for the mains contactor control circuit has to be configured. To do this, the status information "supply ready for operation" from

- P-0-0861, Power supply status word

has to be assigned to the "Rel1" contact of the control section.

The wiring of the "Rel1" contact has to correspond to the data contained in the documentation of the converter devices!

Setting Threshold Value for Message "Mains Undervoltage"

In the case of converters, the threshold value for the message "mains undervoltage" can be set in parameter

- P-0-0810, Minimum mains crest value.

If there isn't any value entered, the default setting remains active (see Parameter Description for P-0-0810)!

Selecting the Braking Resistor

For certain converters of the HCS02.1 type, it is possible to determine whether the internal braking resistor is to be switched off and 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 parameter

- P-0-0858, Data of external braking resistor.

Switch-On/Switch-Off Threshold for Braking Resistor

In the case of converters, the reference values for the switch-on/switch-off thresholds of the braking resistor can be selected. This is done in parameter

- P-0-0860, Converter configuration.

In accordance with the setting in parameter P-0-0860, the switch-on threshold can be dynamically increased depending on the load. The switch-on threshold currently effective is displayed in parameter

- P-0-0833, Braking resistor threshold.

The current load of the braking resistor is displayed in parameter

- P-0-0844, Braking resistor load.

CAUTION

Property damage caused by inadmissibly high voltage on the motor terminals!

⇒ For third-party motors, observe the maximum allowed terminal voltage!

6.7.4 Diagnostic and Status Messages

Module Bus

Displaying module bus status:

- 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

Mains voltage diagnoses:

- P-0-0806, Current mains voltage crest value
- P-0-0815, Nominal mains voltage crest value

Mains voltage warnings:

- E2814 Undervoltage in mains
- E2818 Phase failure
- E2819 Mains failure

Mains voltage error messages:

- F2814 Undervoltage in mains
- F2816 Softstart fault power supply unit
- F2818 Phase failure
- F2819 Mains failure
- F2834 Contactor control error
- F2840 Error supply shutdown
- F2860 Overcurrent in mains-side power section

DC Bus

DC bus diagnosis:

- 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
- F2817 Overvoltage in power section
- F2833 Ground fault in motor line
- F2836 DC bus balancing monitor error

Braking Resistor

Braking resistor diagnoses:

- P-0-0844, Braking resistor load
- P-0-0833, Braking resistor threshold

Braking resistor warnings:

- E2820 Braking resistor overload prewarning
- E2802 HW control of braking resistor
- 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
- F8838 Overcurrent external braking resistor

Power Section Supply

Power section warnings:

- E8028 Overcurrent in power section
- 8057 Device overload, current limit active

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

  Supply in this case signals:

  – E2810 Drive system not ready for operation

Error message if supply has switched off in the case of error:

- F2086 Error supply module

7 Operating Modes

7.1 General Information on the Operating Modes

7.1.1 Supported Operating Modes

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

The following overview illustrates by which basic or functional packages the respecitve operating mode is supported (if not stated otherwise, this applies for all 3 firmware versions, MPB, MPD and MPH).

Operating mode	In base package (characteristic)	In functional package ... (on the basis of a base package with the following characteristics)		
		Servo function	Synchronization	Main spindle
standard operating 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	–
- electronic cam shaft	–	–	CL	–
- electronic motion profile	–	–	CL	–

OL open-loop characteristic
CL closed-loop characteristic
Fig.7-1: Supported operating 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"

7.1.2 Operating Mode Handling

Selecting the Operating Mode

It is possible to configure up to 8 different operating modes in the drive (depending on "S-0-0292, List of all operating modes"). Assignment and configuration are made via the following parameters:

- S-0-0032, Primary mode of operation

- 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 operating mode" is generated when this operating mode is activated.

Activating the Operating Mode

The operating mode is activated and controlled via bits 8, 9 and 11 in parameter "P-0-0116, Device control: control word".

The following applies to parameter P-0-0116:

- Bits 8 and 9 → Selecting primary mode of operation and secondary oper. modes 1 to 3
- Bit 11 → Selecting secondary operation modes 4 to 7 (only SERCOS)

☞ 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 operating mode selection.

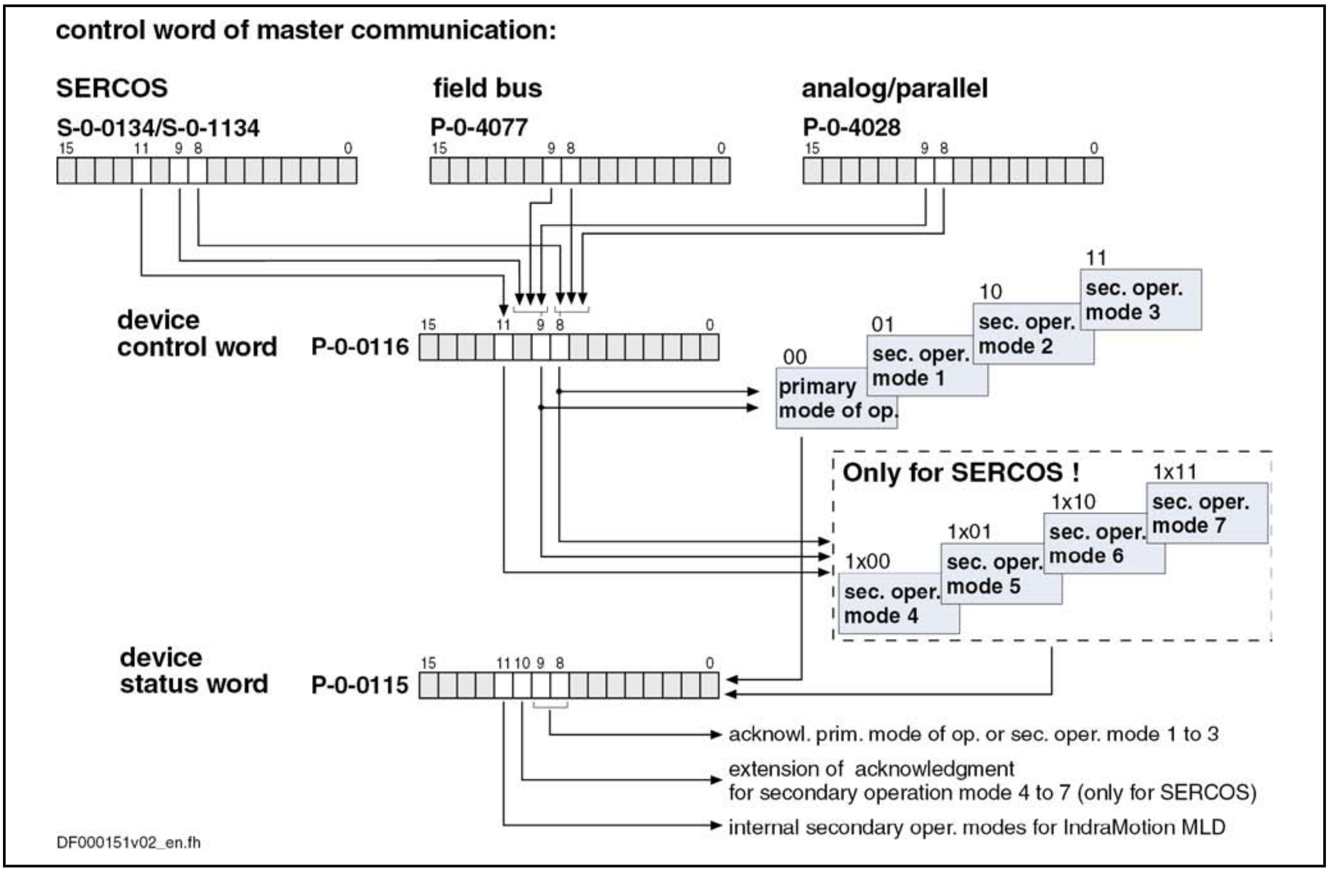


Fig.7-2: Operating mode selection via control word

☞ 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 operating mode defined via the operating 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 Operating Mode

As regards the activation of an operating mode, there are the following kinds of feedback:

- With active operating 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 operating mode is displayed (e.g. "A0101" in "velocity control" mode).
- In parameter "S-0-0095, Diagnostic message", the active operating 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 operating mode or not.
- In parameter "P-0-0115, Device control: status word", bits 8, 9 and 10 ("acknowledgment of operating mode") are used to signal the operating 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 Operating Mode

When drive enable is activated, the drive, after having gone through the initialization routines, changes to the operating 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 4028 or P-0-0116).

☞ The change of operating modes is carried out within one position loop clock (Advanced: 250 µs; Basic: 500 µs). Another position loop clock passes until the command values of the activated operating mode become effective, because the initialization of the operating mode is carried out first.

Special Cases

With the following **exceptional circumstances**, the desired operating mode is not carried out in spite of the operating 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 measuring, ...) 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 Operating Mode

In order to achieve a quick and smooth change of operating mode in running operation, it is possible to make a "drive-controlled change of operating mode". Drive-internally this procedure ensures that, when the operating 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 operating 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 Shaft 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:

- Operating 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**
- Operating mode "positioning block mode"

  Acceptance of the positioning block selected via "P-0-4026, Positioning block selection" by a 0-1 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:

- Operating mode "drive-controlled positioning"

  The drive acknowledges the command value acceptance by toggling bit 0 of parameter "S-0-0419, Positioning command acknowledge".
- Operating 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.

7.2 Torque/Force Control

7.2.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.7-3: Assignment to Functional Firmware Package

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 operating mode has been activated, the diagnostic message is "A0100 Torque control".

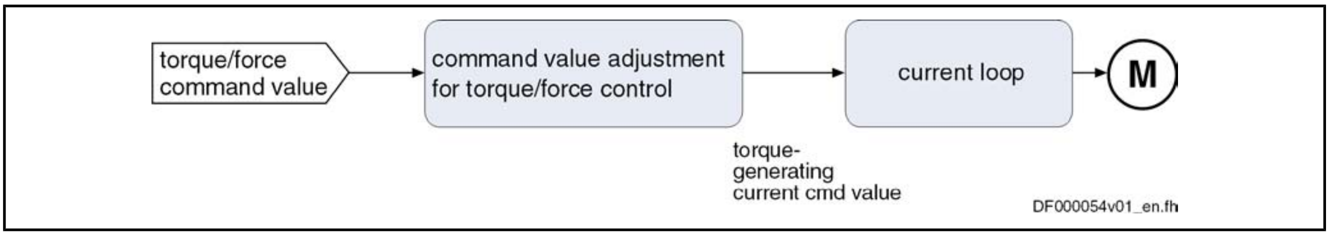


Fig.7-4: "Torque/Force Control" Block Diagram

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 loop; 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 parameters "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, Message torque/force command value reached
- 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

7.2.2 Command Value Adjustment in Torque/Force Control

Principle of Command Value Adjustment

Filtering the Command Value

The command value preset by parameter "S-0-0080, Torque/force command value" is filtered. The filter effect can be modified by the settings in parameters "S-0-0822, Torque/force ramp" and "S-0-0823, Torque/force ramp time".

The message "torque/force command value reached" (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 the parameter "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.

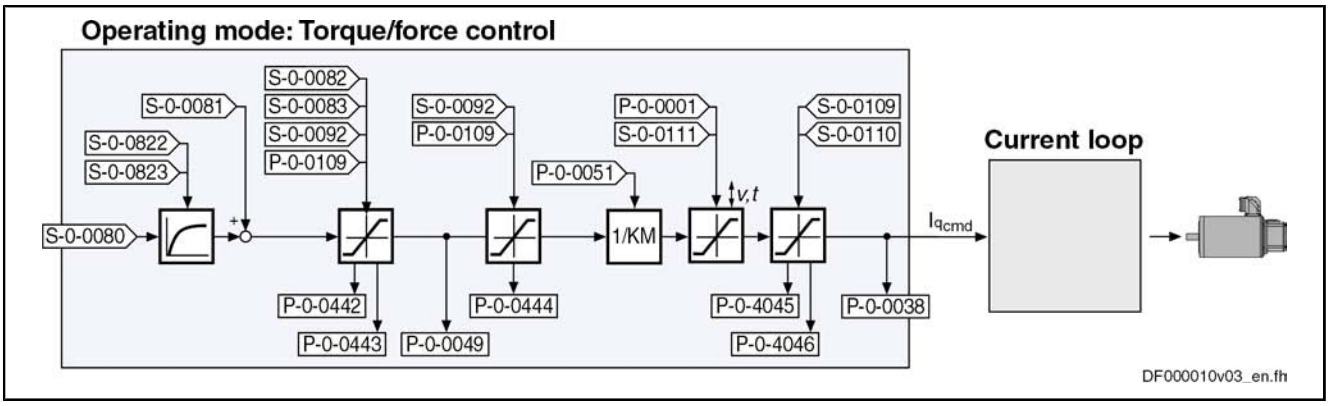


Fig.7-5: Command Value Adjustment in Torque/Force Control

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.

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 "Parameter Description for IndraDrive Controllers"

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-0-4046, Effective peak current" results from the current and torque limits.

See also section below "Current Loop"

7.2.3 Current Loop

Operating Principle of the Current Loop

The current loop is a typical PI loop 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%).

Control Loop 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 Loop

The parameter values for the current loop 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 loop parameters and other motor parameters can be loaded via the "IndraWorks D" commissioning tool.

7.2.4 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 operating 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 Troubleshooting Guide).

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 parameter "S-0-0040, Velocity feedback value" is monitored. 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.

7.3 Velocity Control

7.3.1 Brief Description

Base package of the variants **MPH, MPB and MPD**

Fig.7-6: Assignment to Functional Firmware Package

In the "velocity control" mode, a velocity command value is preset for the drive. The velocity command value is limited by ramps and filters.

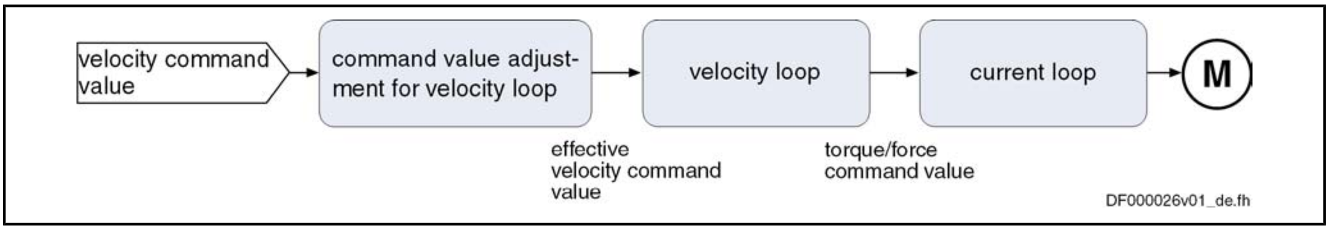


Fig.7-7: "Velocity Control" Block Diagram

Features

- An external velocity command value (sum of "S-0-0036, Velocity command value" and "S-0-0037, Additive velocity command value") is preset 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, ...)
- 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 (cf. 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 is done with selectable velocity and run-up stop that can be parameterized
- Velocity control via a digital PI loop with extensive filter measures
- Monitoring the command velocity and actual velocity for exceeding parameter "S-0-0091, Bipolar velocity limit value"
- 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 loop clock; 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 loop internally generates the torque/force command value to which the value of parameter "S-0-0081, Additive torque/force command value" can be added as an additive component
- Control word and status word especially for "velocity control" mode (cf. P-0-1200 and P-0-1210)

Pertinent Parameters

- S-0-0036, Velocity command value
- S-0-0037, Additive velocity command value
- S-0-0091, Bipolar velocity limit value
- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- P-0-0004, Velocity loop smoothing time constant
- P-0-0048, Effective velocity command value
- 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-0-1125, Velocity control loop: average value filter clock
- 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

Pertinent Diagnostic Messages

- A0101 Velocity control
- E2059 Velocity command value limit active
- E2063 Velocity command value > limit value
- F8078 Speed loop error
- F8079 Velocity limit value exceeded

7.3.2 Command Value Adjustment in Velocity Control

Overview

The figure below illustrates command value processing in the "velocity control" mode as a block diagram.

Operating Modes

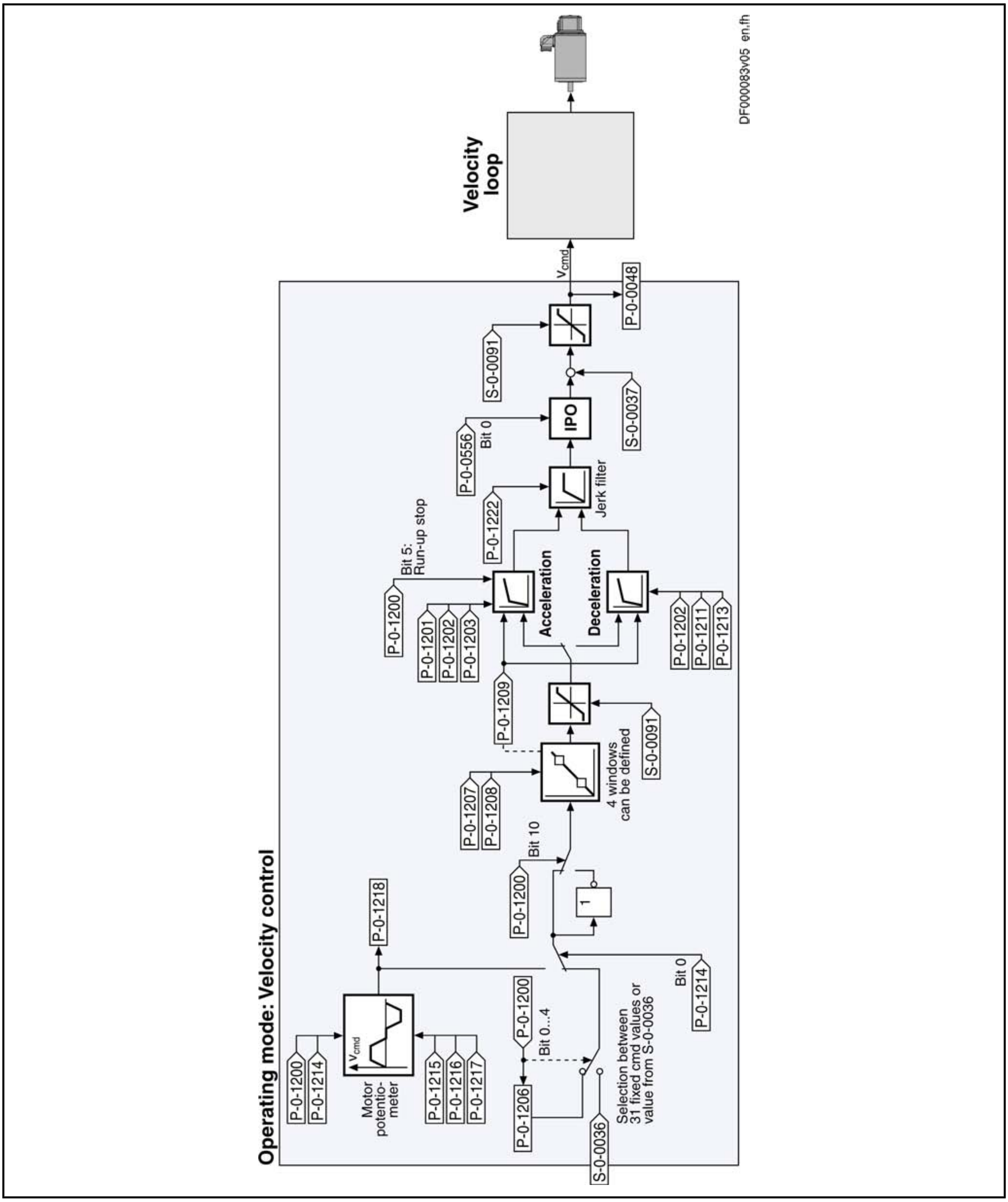


Fig.7-8: Command Value Adjustment in Velocity Control

☞ 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 loop.

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
- Using 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 status of the ramp-function generator is contained in parameter 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 parameter 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 **direct selection** (P-0-1214, bit 8 = 0) via the bits 4…0 of P-0-1200:

- 00000 → Value from S-0-0036 active
- 0000**1** → Fixed value 1 from P-0-1206 selected and active
- 000**1**0 → Fixed value 2 from P-0-1206 selected and active
- 00**1**00 → Fixed value 3 from P-0-1206 selected and active
- 0**1**000 → Fixed value 4 from P-0-1206 selected and active
- **1**0000 → Fixed value 5 from P-0-1206 selected and active

The following assignment applies to **binary selection** (P-0-1214, bit 8 = 1) via the bits 4…0 of P-0-1200:

- 00000 → Value from S-0-0036 active
- 0000**1** → Fixed value 1 from P-0-1206 selected and active
- 000**10** → Fixed value 2 from P-0-1206 selected and active
- 000**11** → Fixed value 3 from P-0-1206 selected and active
- etc.
- **11111** → Fixed value 31 from P-0-1206 selected and active

Command Value Generation via Motor Potentiometer

In the operating mode "velocity control", the command value generator (so-called motor potentiometer) provides the possibility of generating a velocity command value characteristic (parameter "P-0-1218, Motor potentiometer, command value") via digital input signals ("ramp+" and "ramp–").

Activating Motor Potentiometer

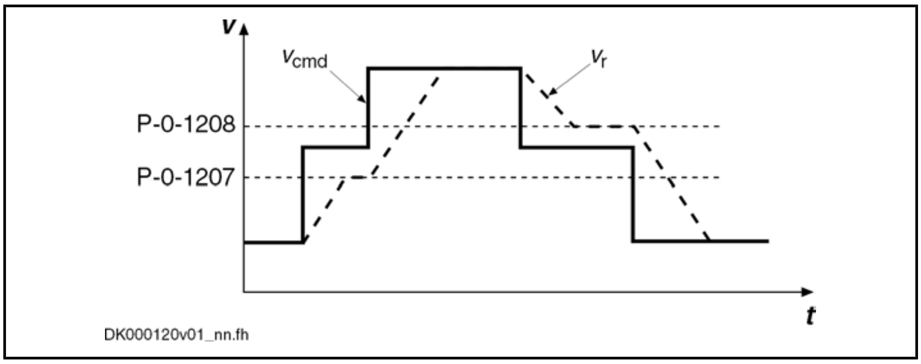
The motor potentiometer is activated by setting bit 0 = 1 in "P-0-1214, Motor potentiometer, control parameter".

Inverting the Velocity Command Value

Before it is processed in the ramp-function generator, the provided velocity command value can be inverted. Inverting takes place by setting bit 10 = 1 in parameter "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).

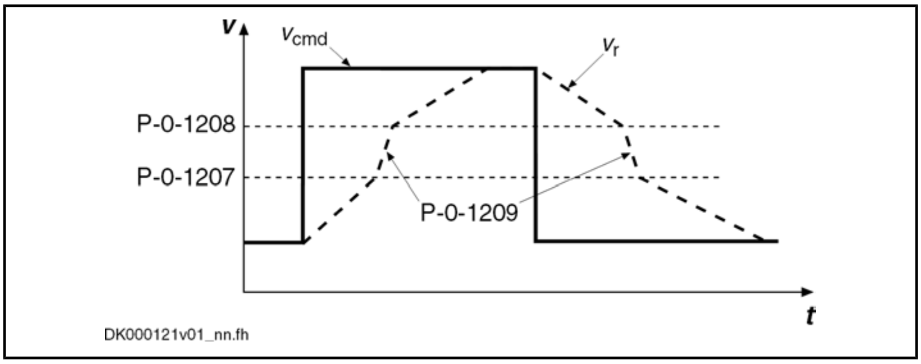


P-0-1207	Lower limit of velocity masking window
P-0-1208	Upper limit of velocity masking window
v_{cmd}	Velocity command value
v_r	Velocity ramp

Fig.7-9: Function "Velocity Masking Window With Hysteresis"

See also Parameter Descriptions "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.7-10:	*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

The increase (acceleration) and deceleration of the velocity command value 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 parameter "P-0-1202, Final speed of ramp 1", the increase of the command value is limited with the value of "P-0-1203, Ramp 2 pitch" (acceleration ramp 2).
- Deceleration or braking process

  → Parameters "P-0-1211, Deceleration ramp 1" or "P-0-1213, Deceleration ramp 2" are used accordingly for deceleration.

This allows parameterizing different ramps for the acceleration and braking process.

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 function "run-up stop" was introduced that is controlled via parameter "P-0-1200, Control word 1 velocity control".

Possible settings for activating the function "run-up stop" via the respective bits of P-0-1200:

- Activation of the function without additional condition
- Triggering of torque limitation (E2060)
- Triggering of command value limitation (cf. S-0-0091)
- Triggering of command value or torque limitation

While a speed masking window is passed, the function "run-up stop" is deactivated.

Jerk Limitation

The velocity command value, the increase and maximum of which are limited, is jerk-limited by means of a moving average filter (parameter "P-0-1222, Velocity command filter").

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 loop. To do this, a command value input in the position loop clock is fine interpolated in the velocity loop clock.

This function has to be activated via bit 0 of parameter "P-0-0556, Config word of axis controller".

7.3.3 Velocity Control Loop

Velocity Loop

The velocity loop is a typical PI loop 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"

Control Loop Performance and Cycle Times

The minimum possible control loop cycle time of the velocity loop depends

- on the available control section (CSH, CSB, CDB),
- on the respective firmware variant (MPH, MPB or MPD)

- and -

- in the case of variant MPH, on the parameterized performance (Basic or Advanced; cf. "P-0-0556, Config word of axis controller", bit 2).

See "Performance Data"

Current Loop 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 Loop"

Possibilities of Filtering

To filter noise components possibly present in the actual velocity value or to attenuate resonance frequencies, the following filter settings can be made:

- Via parameter "P-0-0004, Velocity loop smoothing time constant", the low-pass filter that filters the control difference for the velocity loop can be set.
- With the parameter "P-0-1125, Velocity control loop: average value filter clock" it is possible to filter the velocity control loop deviation by means of moving average filter.
- To filter the control deviation, it is possible to configure four filters connected in series as low-pass filters or band-stop filters with parameter "P-0-1120, Velocity control loop filter: filter type".

The "S-0-0081, Additive torque/force command value" is added to the output signal of the velocity loop and the resulting value is transmitted to the current and torque/force limit (see also "Current and Torque Limitation (Closed-Loop)").

7.3.4 Notes on Commissioning

Memory of Fixed Command Values

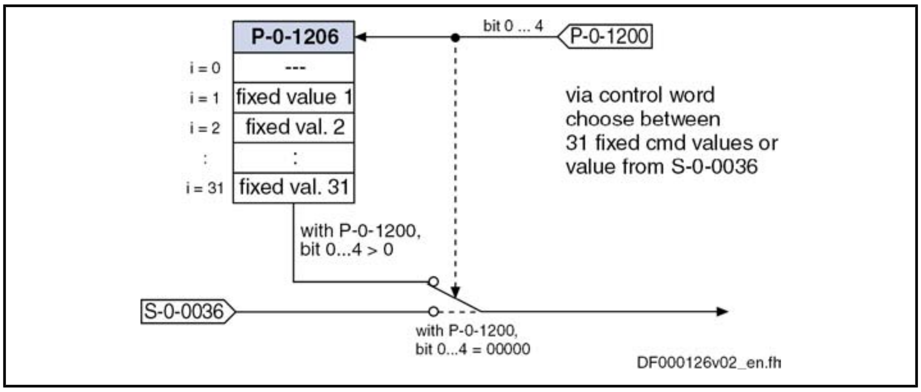
In addition to the cyclic velocity command value (S-0-0036), the drive can be moved with fixed constant velocity command values stored in the drive.

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.7-11: 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, Motor potentiometer, control parameter", the selected fixed command values won't 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.

Motor Potentiometer

Activating the Function

After the motor potentiometer has been activated by setting bit 0 of "P-0-1214, Motor potentiometer, control parameter", 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 serial interface or the interface of the master communication

Start or Initial Value for the Command Value Generator

Bits 1 and 2 of "P-0-1214, Motor potentiometer, control parameter" 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 actual velocity value in parameter S-0-0040
- **11** → Selection not allowed!

Acceleration of the Ramps

Bit 3 of "P-0-1214, Motor potentiometer, control parameter" 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 parameter "P-0-1215, Motor potentiometer, acceleration".

  – With the control bit "ramp-", the velocity command value is reduced up to the negative limit value (= minimum value of S-0-0091 and S-0-0039), with the deceleration entered in parameter "P-0-1216, Motor potentiometer, deceleration".
- **Bit 3 = 1: Linearly variable acceleration**

  → Square adjustment of command velocity

  The acceleration is varied 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 reduced up 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, Motor potentiometer, control parameter" 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, Command value generator, step size"

  – With a 0-1 edge of "ramp+", the command value is increased by the value of parameter P-0-1217.

  – With a 0-1 edge of "ramp-", the command value is reduced 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:

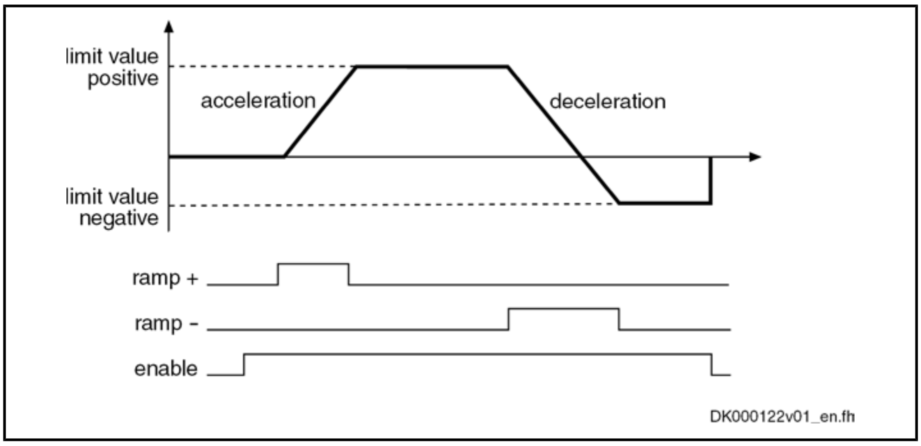


Fig.7-12: Linear Adjustment of Command Velocity With Status-Controlled Evaluation of "Ramp+" and "Ramp-"

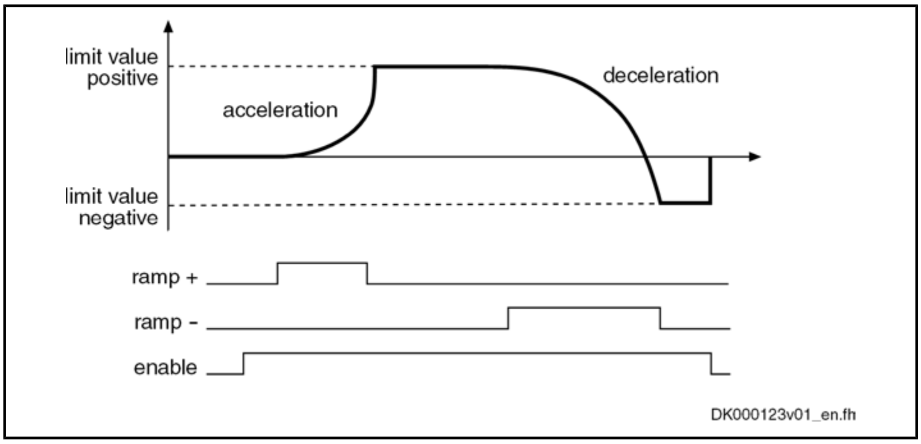


Fig.7-13: Square Adjustment of Command Velocity With Status-Controlled Evaluation of "Ramp+" and "Ramp-"

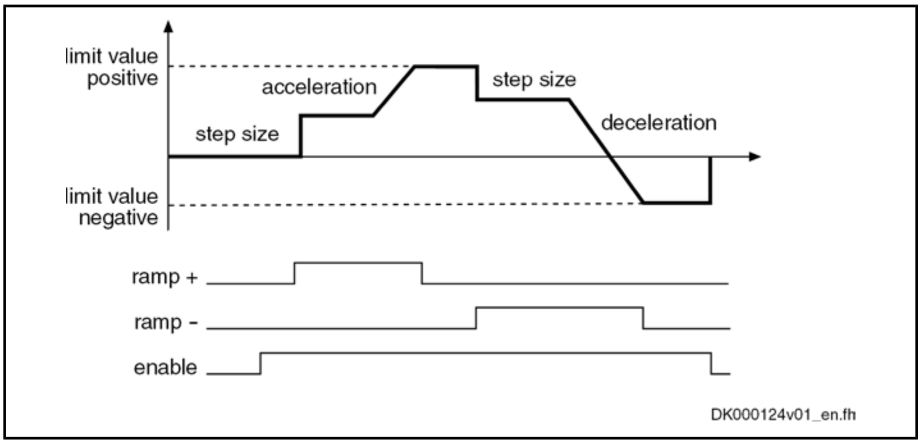


Fig.7-14: Linear Adjustment of Command Velocity With Edge-Controlled Evaluation of "Ramp+" and "Ramp-"

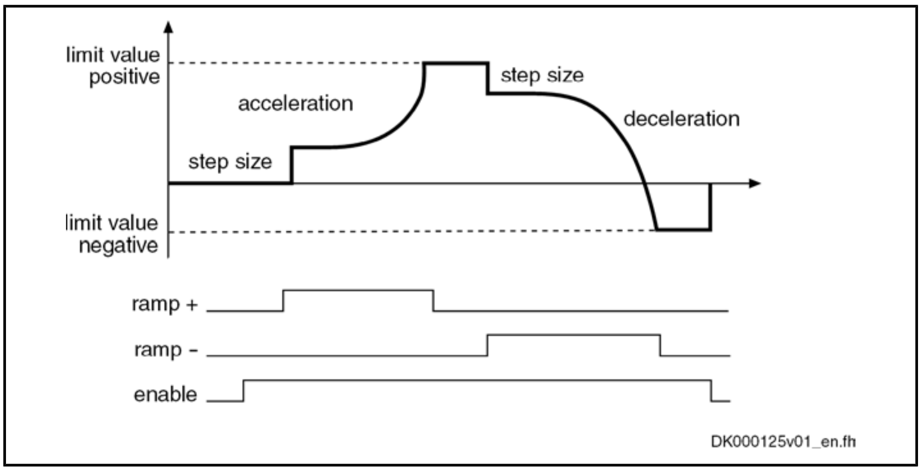


Fig.7-15: Square Adjustment of Command Velocity With Edge-Controlled Evaluation of "Ramp+" and "Ramp-"

Velocity Mixing

Via parameter "P-0-1119, Velocity mix factor feedback 1 & 2", it is possible to mix the different actual encoder values in the case of control-related stability problems.

Acceleration Feedforward

To improve the control performance it is possible to add the speed command value, bypassing the velocity loop, to the velocity loop output in a derivative way and scaled via parameter "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 value of the parameters P-0-1207 and P-0-1208 is zero which means that the speed window hasn't been defined.

7.3.5 Diagnostic Messages and Monitoring Functions

Diagnostic Status Message

Active Operating Mode

The activated "velocity control" mode is displayed by the following diagnostic message:

- A0101 Drive in 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 loop via the fine interpolation, is mapped to parameter "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 parameter "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 command "run-up stop" 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" is set.

Monitoring Functions

Monitoring functions specific to the operating 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 indicated 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 (S-0-0091)

- The value of parameter "S-0-0036, Velocity command value" is limited to "S-0-0091, Bipolar velocity limit value". If 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 loop 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 parameter "S-0-0040, Velocity feedback value" is monitored. 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 Position Control With Cyclic Command Value Input

7.4.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.7-16: Assignment to Functional Firmware Package

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 loop.

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 operating mode was activated (see below "Pertinent Diagnostic Messages").

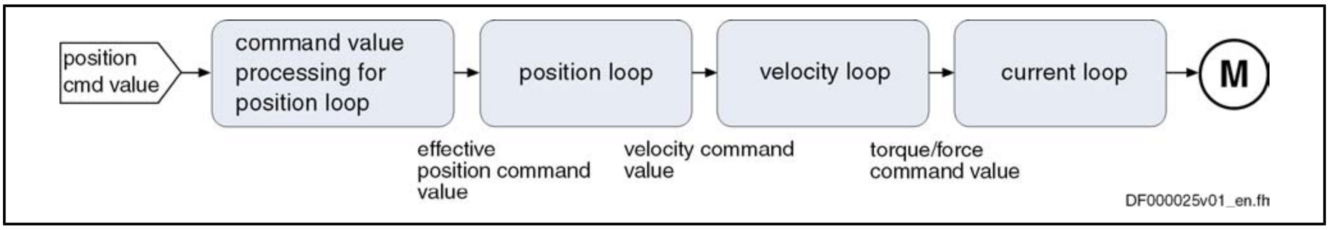


Fig.7-17: "Position Control With Cyclic Command Value Input" Block Diagram

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 operating 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 unit smoothed by means of adjustable average value filter; calculation from acceleration and jerk limit values; display in parameter "P-0-0042, Current position command average value filter order"
- Fine interpolation of position command value of the control unit to position loop clock; can be switched via "P-0-0187, Position command processing mode"
- 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 %)
- Acceleration monitor for position command value can be switched on (P-0-0556, bit 15)

☞ The condition for this operating mode is synchronous communication between the control unit and the drive, as it is the case with SERCOS interface, for example.

Pertinent Parameters

- S-0-0047, Position command value
- S-0-0091, Bipolar velocity limit value
- S-0-0138, Bipolar acceleration limit value
- 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-0-0099, 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 controller

- 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
- F2037 Excessive position command difference
- F2039 Maximum acceleration exceeded

7.4.2 Command Value Adjustment in Position Control

NC- or Drive-Controlled Position Control

We distinguish the following characteristics of the operating 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 operating 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 loop is displayed in parameter "P-0-0434, Position command value 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:

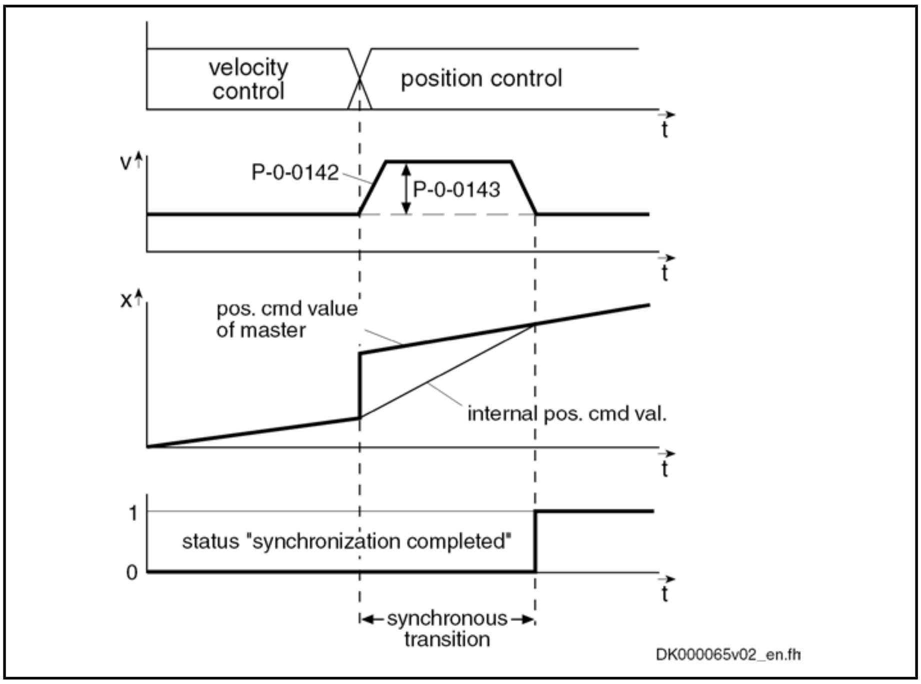
- Cubic fine interpolator (according to contour),
- Linear fine interpolator or
- Cubic approximator.

See also Parameter Description "P-0-0187, Position command processing mode"

☞ It is recommended to use the cubic fine interpolator according to contour (default setting), because it provides clearly higher quality of velocity and acceleration feedforward, particularly with lagless position control.

Drive-Controlled Change of Operating Mode

During drive-controlled change of operating mode, the drive makes sure internally that when the operating 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.7-18: Chronological Diagram "Drive-Controlled Change of Operating Mode"

See also "Changing the Operating Mode"

Block Diagram

The figure below illustrates command value processing in the "position control" mode as a block diagram.

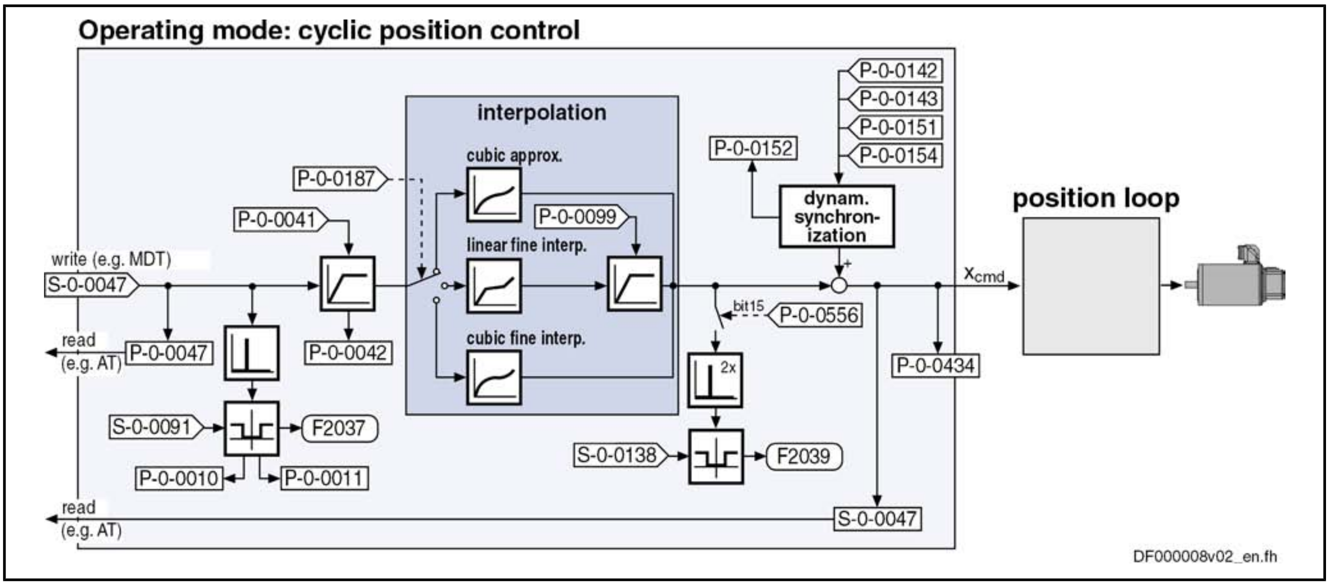


Fig.7-19: Command Value Adjustment in Position Control

See also "Position Loop" in the same section

See also "Velocity Loop" in section "Velocity Control"

See also "Current Loop" in section "Torque/Force Control"

7.4.3 Position Loop

The position loop is a simple P-loop, its proportional gain can be set with the value of "S-0-0104, Position loop Kv-factor".

See also "Control Loop Structure"

Control Loop Performance and Cycle Times

The position control loop is closed according to the available performance design (see "Performance Data").

According to the application, it is possible to set via bit 3 of the operating mode parameters (S-0-0032 to S-0-0035):

- 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 parameter "S-0-0189, Following distance".

☞ If the mechanical system and the application permit it, lagless operation should always be selected.

Possibilities of 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 current command value) is set via parameter "S-0-0348, Acceleration feedforward gain" and the velocity-proportional feedforward component (additive velocity command value) is 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 and with P-0-0040 = 100%, there is a minimum lag error of "0" at constant velocity.

☞ In addition, it is possible to make a feedforward via parameter "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 didn't activate both feedforward values by mistake!

See also "Axis Control: Position Loop (With Respective Feedforward Functions and Actual Value Adjustment)"

7.4.4 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 Operating 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.

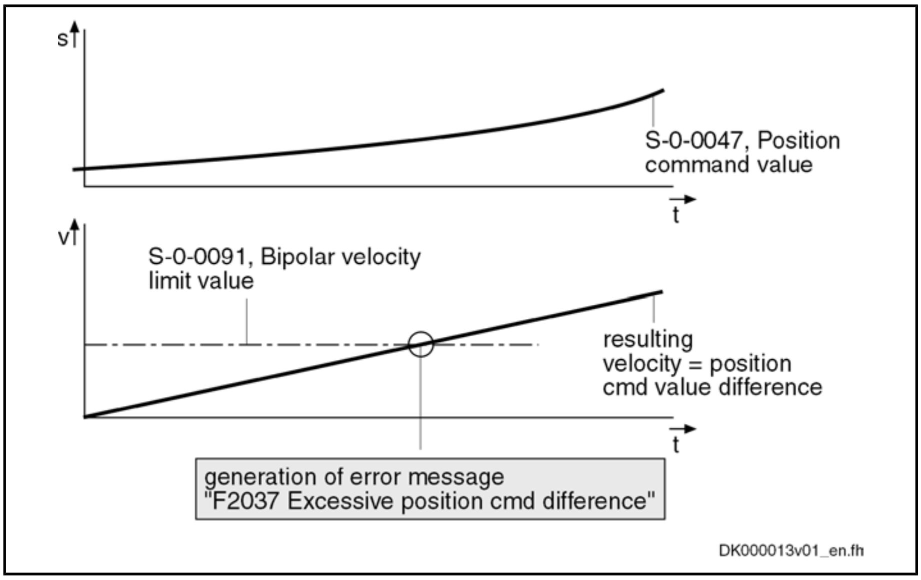


Fig.7-20: Monitoring for Error "F2037 Excessive Position Command Difference"

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.

Maximum Acceleration Exceeded

In parameter "P-0-0556, Config word of axis controller" (bit 15), it is possible to set that the command acceleration is monitored for compliance with "S-0-0138, Bipolar acceleration limit value". When the value of S-0-0138 is exceeded, the error message "F2039 Maximum acceleration exceeded" is generated.

7.5 Drive-Internal Interpolation

7.5.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.7-21: Assignment to Functional Firmware Package

The operating 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 loop.

There are different forms of the "drive-internal interpolation" mode which result in the corresponding diagnostic messages when the operating mode was activated (see below "Pertinent Diagnostic Messages").

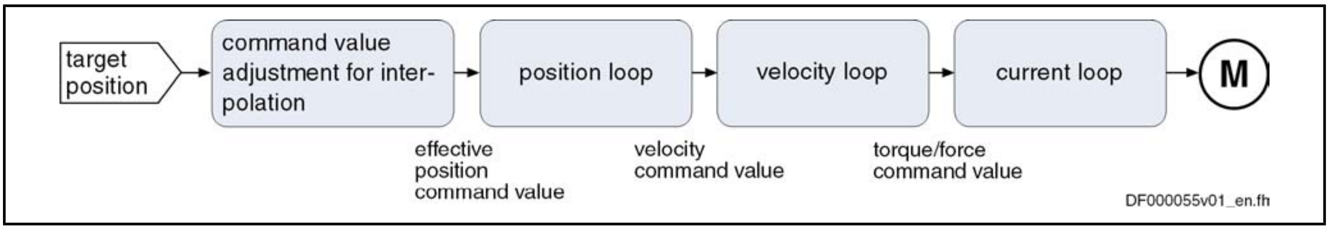


Fig.7-22: "Drive-Internal Interpolation" Block Diagram

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
- Jerk limitation of the generated position command value via "S-0-0193, Positioning Jerk"
- 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"
- 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 1 value" (motor encoder) or "S-0-0053, Position feedback 2 value" [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" equal "shortest distance", if v_{act} > S-0-0417
- "Shortest distance" mode when "command value mode in modulo format" equal "only positive/negative direction of motion" and target position within "S-0-0418, Target position window in modulo format"

☞ In this operating 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-0-0193, 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 word
- P-0-0434, Position command value controller

Pertinent Diagnostic Messages

- A0106 Drive controlled interpolation, encoder 1
- A0107 Drive controlled interpolation, encoder 2
- A0108 Drive controlled interpolation, lagless, encoder 1
- A0109 Drive controlled interpolation, lagless, encoder 2
- E2047 Interpolation velocity = 0
- E2048 Interpolation acceleration = 0
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2055 Feedrate override
  S-0-0108 = 0

7.5.2 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 command value processing in the "drive-internal interpolation" mode as a block diagram.

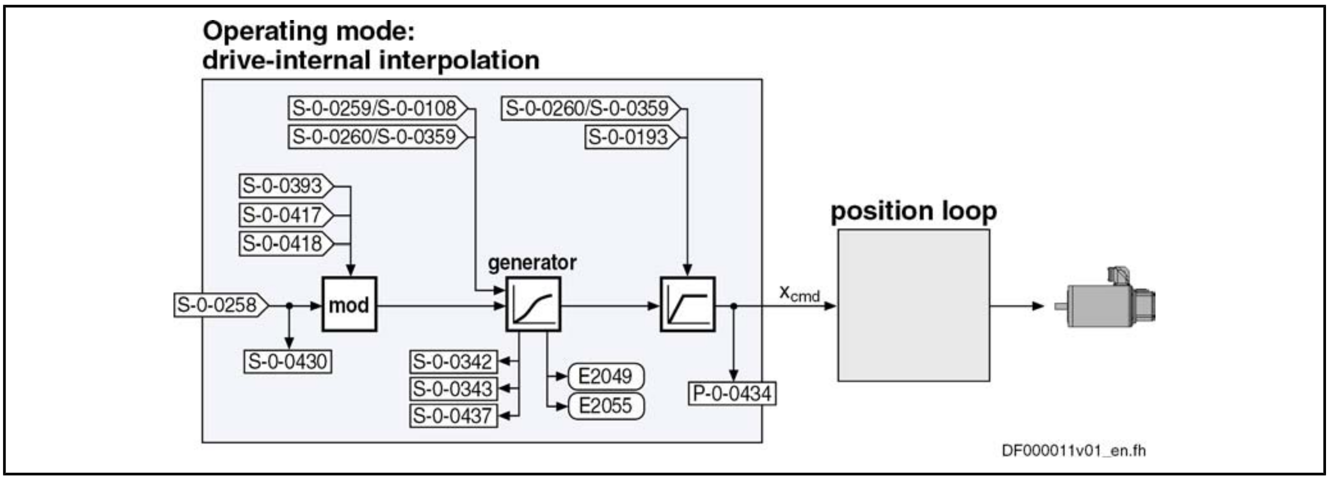


Fig.7-23: Command Value Adjustment With "Drive-Internal Interpolation"

7.5.3 Position Loop 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 controller" and can be output at the analog output.

In this operating 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 Loop" in section "Position Control With Cyclic Command Value Input"

7.5.4 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 procedure 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.7-24: 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.

CAUTION

Property damage caused by incorrect parameterization!

If the values for positioning deceleration and positioning acceleration are zero, the drive cannot brake. The specified target is never reached or overrun.

⇒ Always enter a value > 0 for positioning acceleration!

Smoothing Filter (or Jerk Filter)

In the "drive-internal interpolation" mode, the position command value can be filtered at the output of the positioning generator. The filter order of the (moving) average filter available to do this (cf. P-0-0041 and 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 × $T_{A\_position}$.

In this case, $T_{A\_position}$ is the cycle time of the position loop or the positioning generator. Therefore, the cycle time to be used is different according to the control performance (Advanced: 250 µs, Basic: 500 µs).

$$P\text{-}0\text{-}0042 = \frac{S\text{-}0\text{-}0260}{S\text{-}0\text{-}0193}$$

– or –

$$P\text{-}0\text{-}0042 = \frac{S\text{-}0\text{-}0359}{S\text{-}0\text{-}0193}$$

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.7-25: Internally Determining the Value of P-0-0042 for Operating 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.

The maximum filter order is restricted depending on the control section design; for ADVANCED control sections to 1024 position clocks, for BASIC control sections to 512 position clocks.

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

ℹ 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, Velocity threshold for positioning in modulo format"), 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.

☞ 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.

ℹ 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"

7.5.5 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 controlled interpolation, encoder 1
- A0107 Drive controlled interpolation, encoder 2
- A0108 Drive controlled interpolation, lagless, encoder 1
- A0109 Drive controlled interpolation, lagless, encoder 2

Monitoring Functions

Monitoring functions specific to the operating mode:

Target Position out 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 operating 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 it exceeds the limit values, the warning "E2053 Target position out of travel range" is generated.

  The preset target position will not be accepted.

Interpolation Velocity = 0

- If the positioning velocity preset in "S-0-0259, Positioning Velocity" equals zero, the warning "E2047 Interpolation velocity = 0" is generated.

Interpolation Acceleration = 0

- If the positioning acceleration preset in "S-0-0260, Positioning Acceleration" equals zero, the warning "E2048 Interpolation acceleration = 0" is generated.

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 factor of the positioning velocity "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 word" contains all important status information for the operating mode "drive-internal interpolation".

See Parameter Description "S-0-0437, Positioning status word"

The figures below illustrate the operating principle of the status messages:

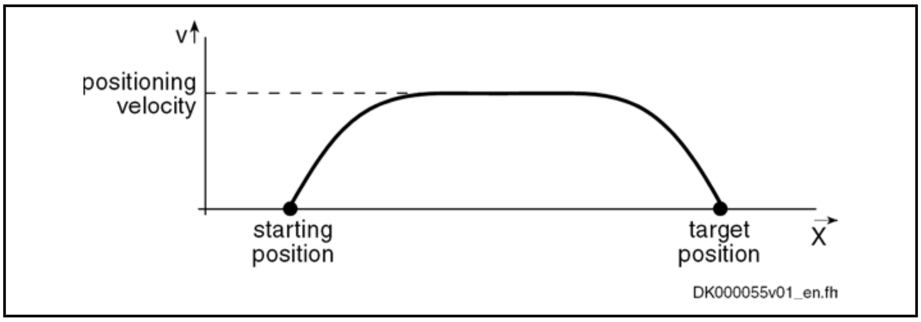


Fig.7-26: Travel Profile to Explain how the Interpolation Status Messages Work

In this example, the drive is at the starting position when the new target position is preset.

The result is the following time diagram:

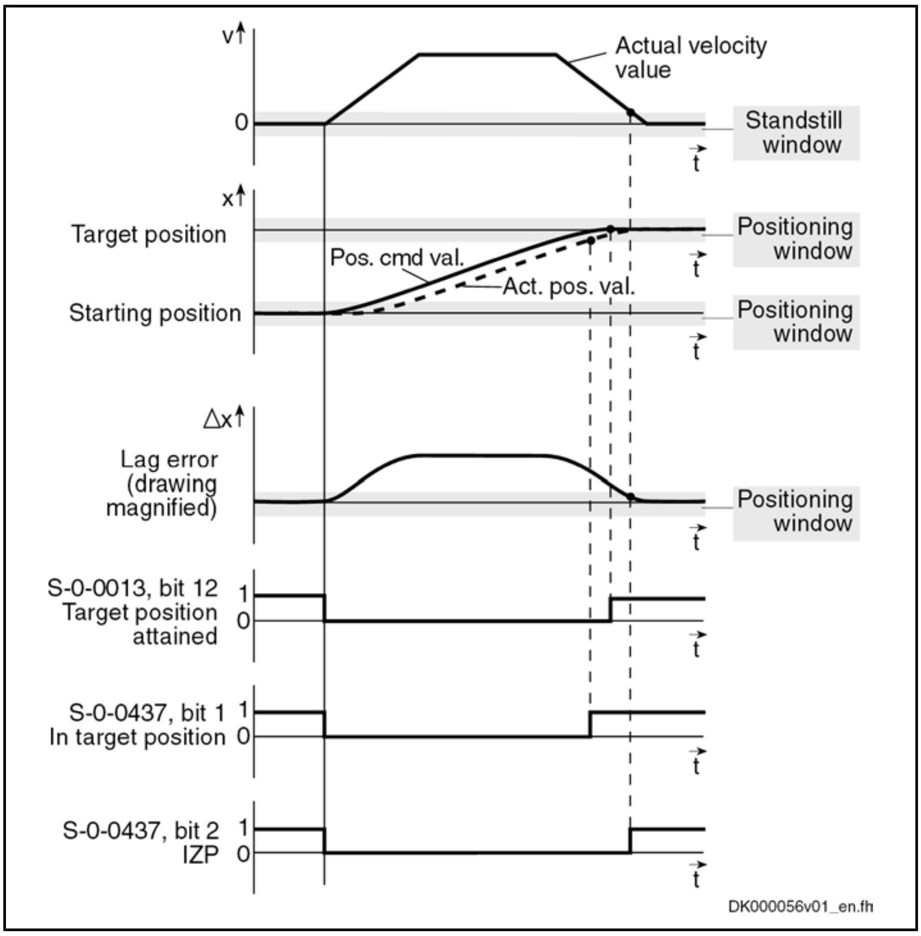


Fig.7-27: Generating the Status Bits of the Operating Modes With Drive-Internal Interpolation

7.6 Drive-Controlled Positioning

7.6.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.7-28: Assignment to Functional Firmware Package

The operating 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 loop from the preset positioning data (effective target position, velocity, acceleration and jerk).

There are different forms of the "drive-controlled positioning" mode which result in the corresponding diagnostic messages when the operating mode was activated (see below "Pertinent Diagnostic Messages").

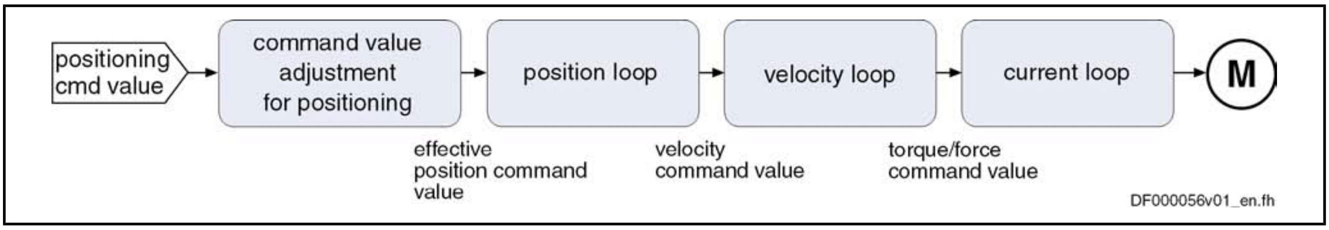


Fig.7-29: "Drive-Controlled Positioning" Block Diagram

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
- 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"
- 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"
- 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 1 value" (motor encoder) or "S-0-0053, Position feedback 2 value" [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 operating 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-0-0108, Feedrate override
- 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 word
- P-0-0434, Position command value controller

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
- E2047 Interpolation velocity = 0
- E2048 Interpolation acceleration = 0
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2055 Feedrate override
  S-0-0108 = 0
- E2064 Target position out of num. range
- F2050 Overflow of target position preset memory

7.6.2 Command Value Adjustment With Drive-Controlled Positioning

Overview

The figure below illustrates command value processing in the "drive-controlled positioning" mode as a block diagram.

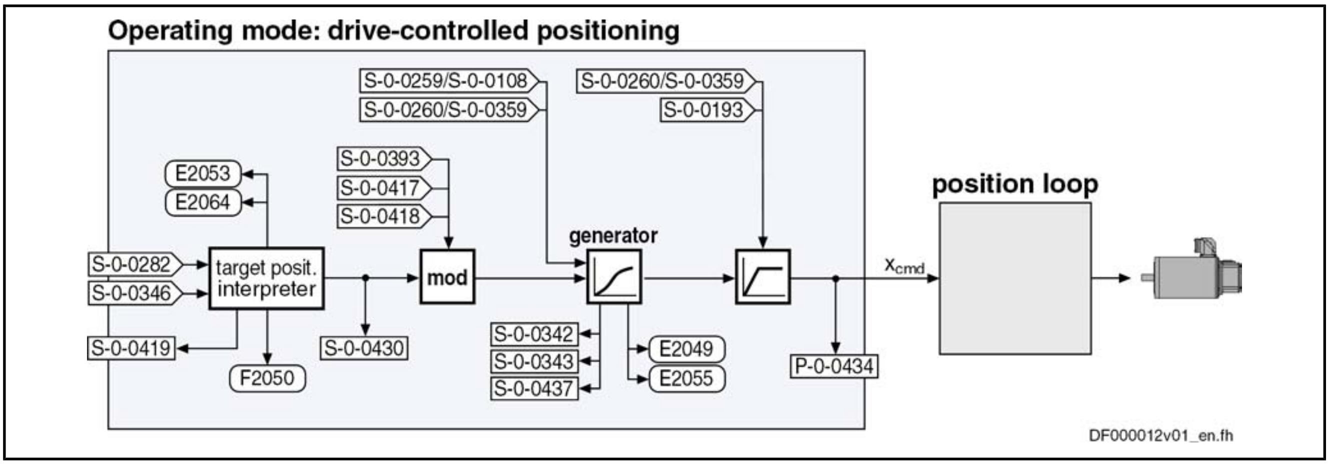


Fig.7-30: Command Value Adjustment With "Drive-Controlled Positioning"

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".

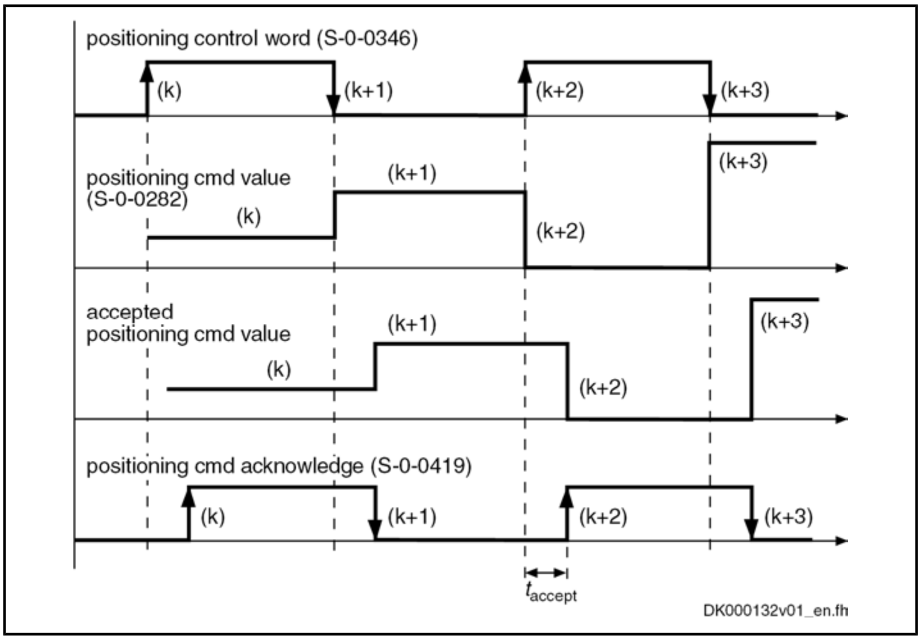


Fig.7-31: Positioning Command Value Acceptance and Acknowledgment

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 operating 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.

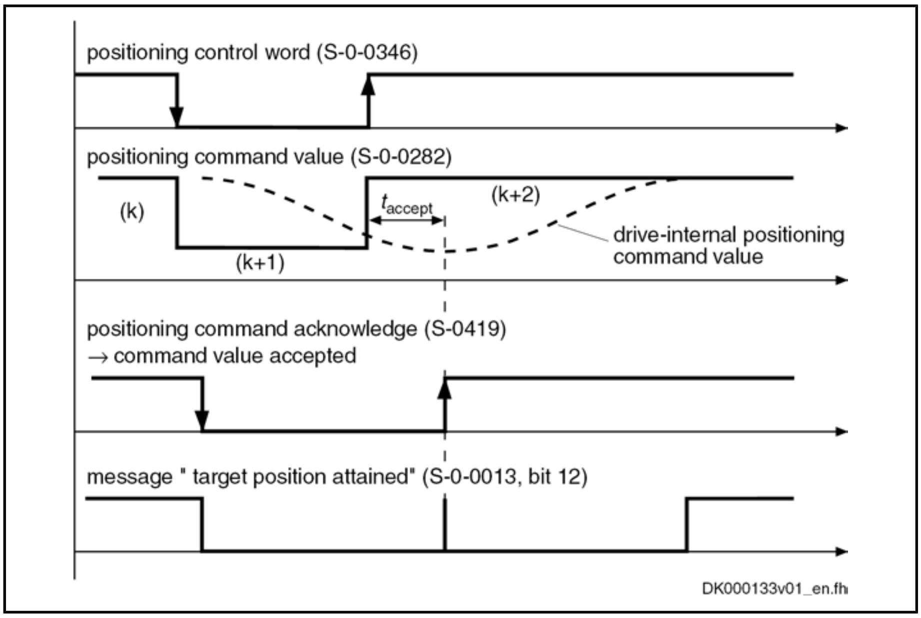


Fig.7-32: Acknowledgment of Positioning Command Value Acceptance in Mode "Complete Move to Positioning Command Value (k+2)"

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.

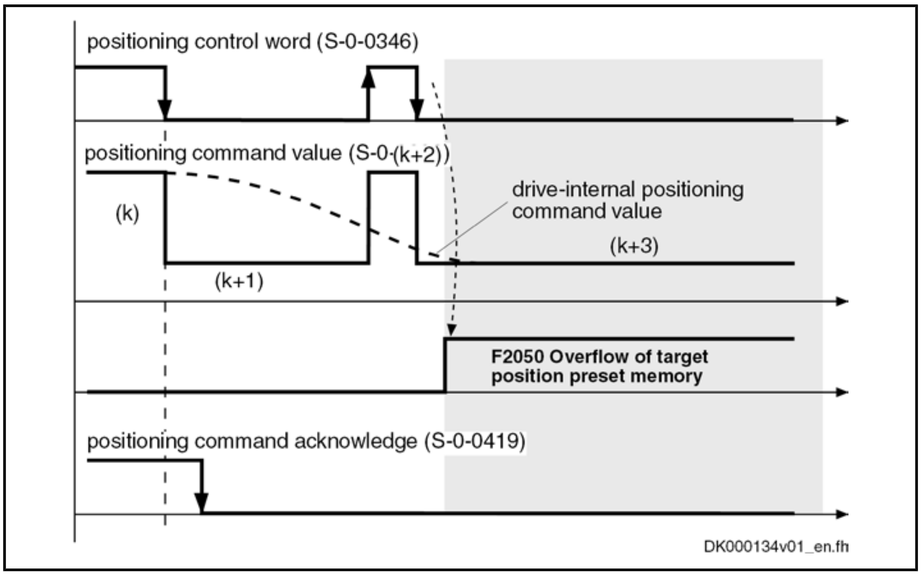


Fig.7-33: Acknowledgment With Error "Overflow of Target Position Preset Memory"

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 hasn't 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 operating 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 operating 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 (parameter "S-0-0417, Velocity threshold for positioning in modulo format"), 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.

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

7.6.3 Position Loop 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 controller" and can be output at the analog output.

In this operating 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 Loop"

7.6.4 Jog Mode With Drive-Controlled Positioning ("Jogging")

☞ The jog mode is part of the positioning mode and not an individual operating mode! This means that there aren't any separate parameters for the jog mode, but you have to use the parameters of the operating mode "drive-controlled positioning".

Activating the Jog Mode

To use the jog mode, make the following settings:

- Activate the operating mode "drive-controlled positioning"

  \- 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
- 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

☞ 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"

7.6.5 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 procedure 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. 7-34: 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.

CAUTION

Property damage caused by incorrect parameterization!

If the values for positioning deceleration and positioning acceleration are zero, the drive cannot brake. The specified target is never reached or overrun.

⇒ Always enter a value > 0 for positioning acceleration!

Smoothing Filter (or Jerk Filter)

In the "drive-controlled positioning" mode, the position command value can be filtered at the output of the positioning generator. The filter order of the (moving) average filter available to do this (cf. P-0-0041 and 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 × $T_{A\_position}$.

In this case, $T_{A\_position}$ is the cycle time of the position loop or the positioning generator. Therefore, the cycle time to be used is different according to the control performance (Advanced: 250 µs, Basic: 500 µs).

$$\text{P-0-0042} = \frac{\text{S-0-0260}}{\text{S-0-0193}}$$

– or –

$$\text{P-0-0042} = \frac{\text{S-0-0359}}{\text{S-0-0193}}$$

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.7-35: Internally Determining the Value of P-0-0042 for Operating 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.

The maximum filter order is restricted depending on the control section design; for ADVANCED control sections to 1024 position clocks, for BASIC control sections to 512 position clocks.

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 format", 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

  → 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 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, Velocity threshold for positioning in modulo format", the drive moves with or without reversal of 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

7.6.6 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 operating mode:

Target Position out 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 operating 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 it exceeds the limit values, the warning "E2053 Target position out of travel range" is generated.

  The preset target position will not be accepted.

Interpolation Velocity = 0

- If the positioning velocity preset in "S-0-0259, Positioning Velocity" equals zero, the warning "E2047 Interpolation velocity = 0" is generated.

Interpolation Acceleration = 0

- If the positioning acceleration preset in "S-0-0260, Positioning Acceleration" equals zero, the warning "E2048 Interpolation acceleration = 0" is generated.

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 factor of the positioning velocity "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 word" contains all important status information for the operating mode "drive-controlled positioning".

See Parameter Description "S-0-0437, Positioning status word"

The figures below illustrate the operating principle of the status messages:

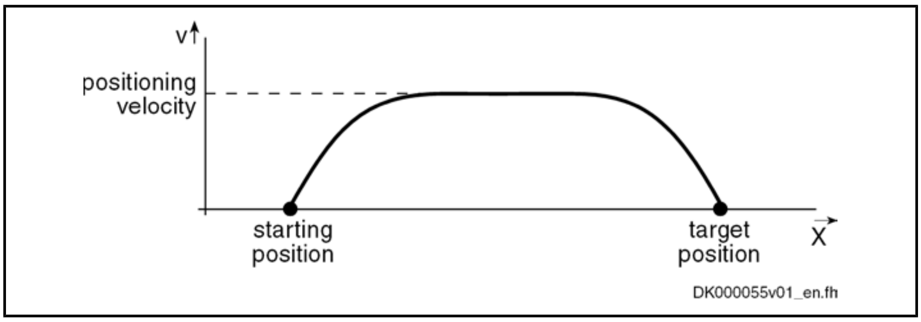


Fig.7-36: Travel Profile to Explain how the Interpolation Status Messages Work

In this example, the drive is at the starting position when the new target position is preset.

The result is the following time diagram:

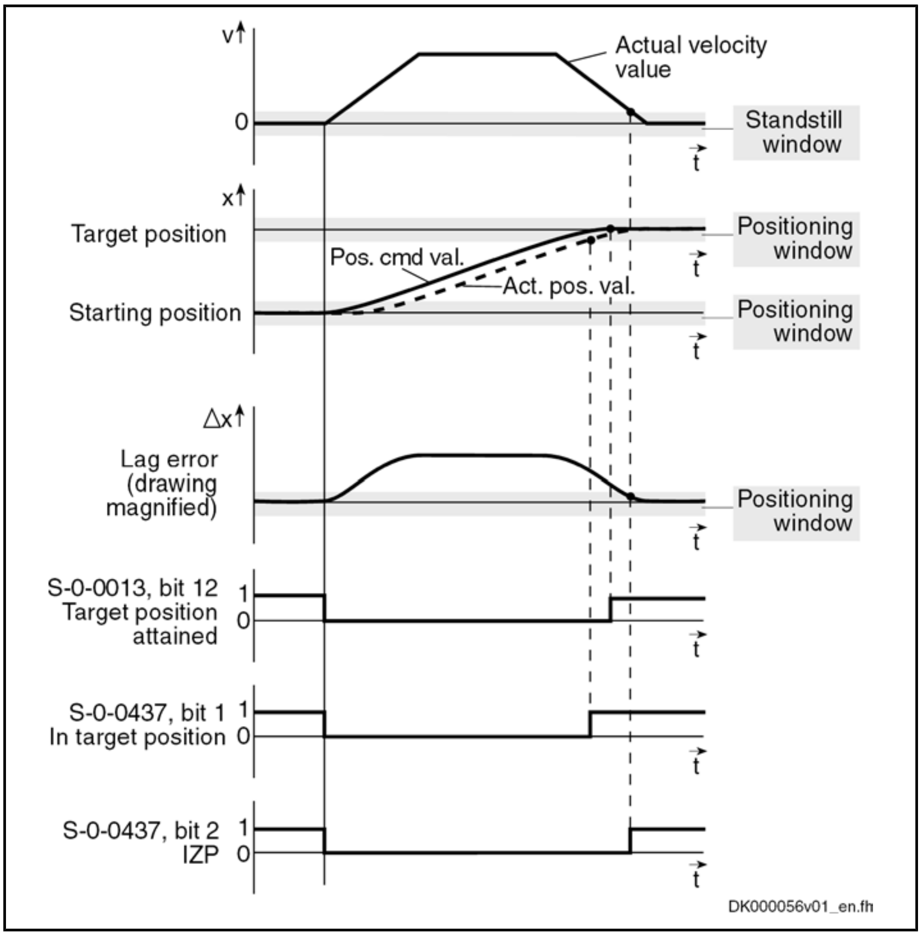


Fig.7-37: Generating the Status Bits of the Operating Modes With Drive-Internal Interpolation

7.7 Positioning Block Mode

7.7.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.7-38: Assignment to Functional Firmware Package

In the "positioning block 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.

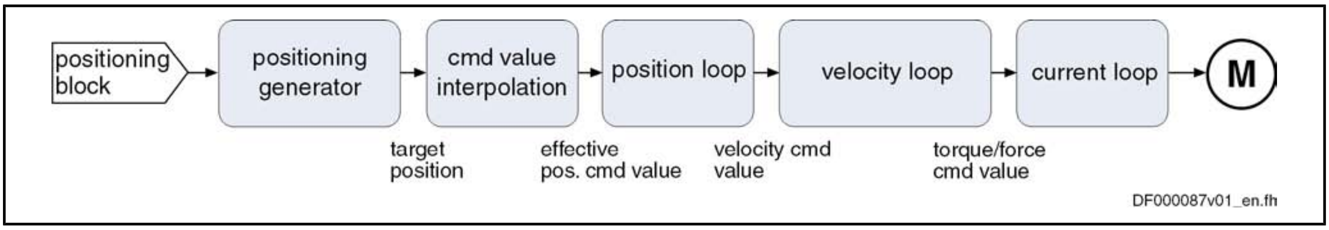


Fig.7-39: "Positioning Block Mode" Block Diagram

Features

- Parameterization of up to 64 positioning blocks; each with target position/travel distance, velocity, acceleration, deceleration and jerk
- 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 and control via the parallel interface are exceptions. In these cases, acceptance takes place by a 0-1 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 advance:
  - 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

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
  - Execution of 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 word
- 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 mode 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
- E2047 Interpolation velocity = 0
- E2048 Interpolation acceleration = 0
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2054 Not homed
- E2055 Feedrate override
  S-0-0108 = 0

- E2058 Selected process block is not programmed.
- E2064 Target position out of num. range
- F2028 Excessive deviation

7.7.2 Command Value Adjustment With Positioning Block Mode

The figure below illustrates command value processing in the "positioning block mode" as a block diagram.

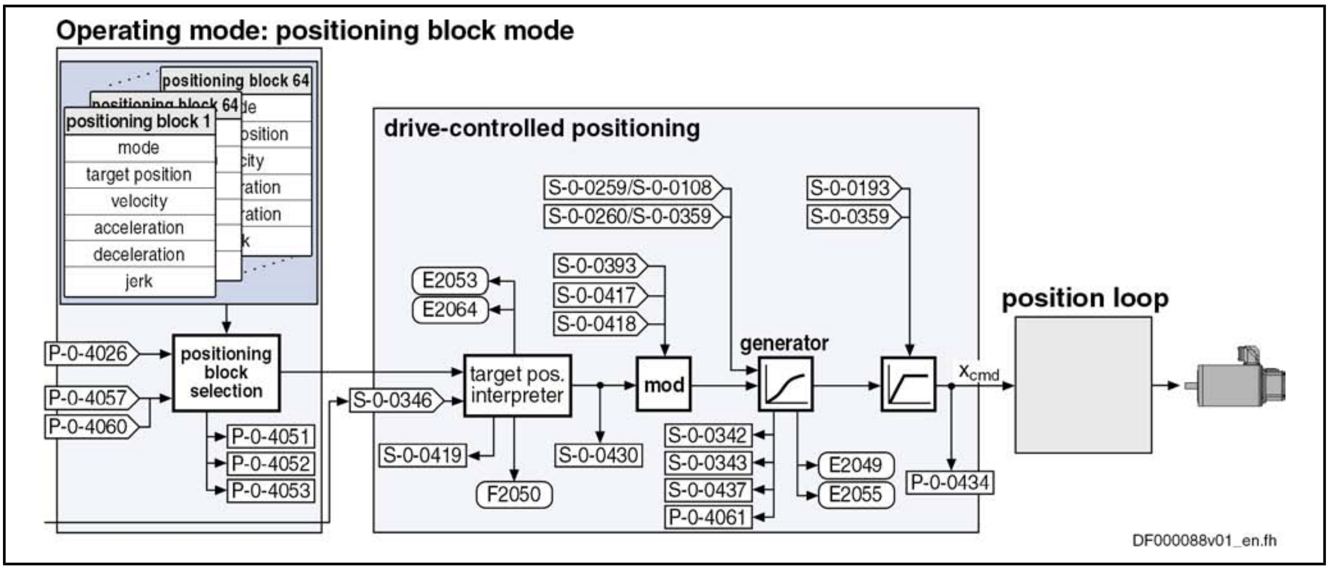


Fig.7-40: Command Value Adjustment With Positioning Block Mode

7.7.3 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 mode delay time
- P-0-4019, Positioning block mode
- P-0-4063, Positioning block deceleration

Each 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.7-41: Effective Velocity During a Positioning Process

Effective Acceleration and Deceleration

The maximum deceleration is specified by parameter "P-0-4063, Positioning block deceleration".

☞ If P-0-4063 is parameterized with the value "0", the warning "E2048 Interpolation acceleration = 0" is generated.

⚠ CAUTION

Property damage!

If the acceleration or deceleration values are equal to zero, the drive can no longer brake. The specified target is never reached or overrun.

⇒ 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 operating 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. The filter order of the (moving) average filter available to do this (cf. P-0-0041 and 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 × $T_{A\_position}$.

☞ In this case, $T_{A\_position}$ is the cycle time of the position loop or the positioning generator. Therefore, the cycle time to be used is different according to the control performance (advanced: 250 µs, Basic: 500 µs).

$$P\text{-}0\text{-}0042 = \frac{P\text{-}0\text{-}4008}{P\text{-}0\text{-}4009}$$

– or –

$$P\text{-}0\text{-}0042 = \frac{P\text{-}0\text{-}4063}{P\text{-}0\text{-}4009}$$

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.7-42: 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.

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 operating 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 mode (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

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 operating 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 -

- 0-1 edge of bit 0 in parameter "P-0-4060, Positioning block control word", with **parallel interface orfield bus interface in I/O mode**

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 0-1 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).
- **Parallel interface**
  – Bit 0 of P-0-4060 has to be configured on a digital input (see also "Digital Inputs/Outputs")

See also "Command Value Acceptance and Acknowledgment" in section "General Information on the Operating Modes"

If bit 0 is different in S-0-0346 and in S-0-0419 when the operating 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	Parallel interface
Via cyclic data channel	■	■	--
Via digital inputs	■	■	■
Via serial interface	■	■	■
Via field bus control word	--	■	--

Fig.7-43: 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)

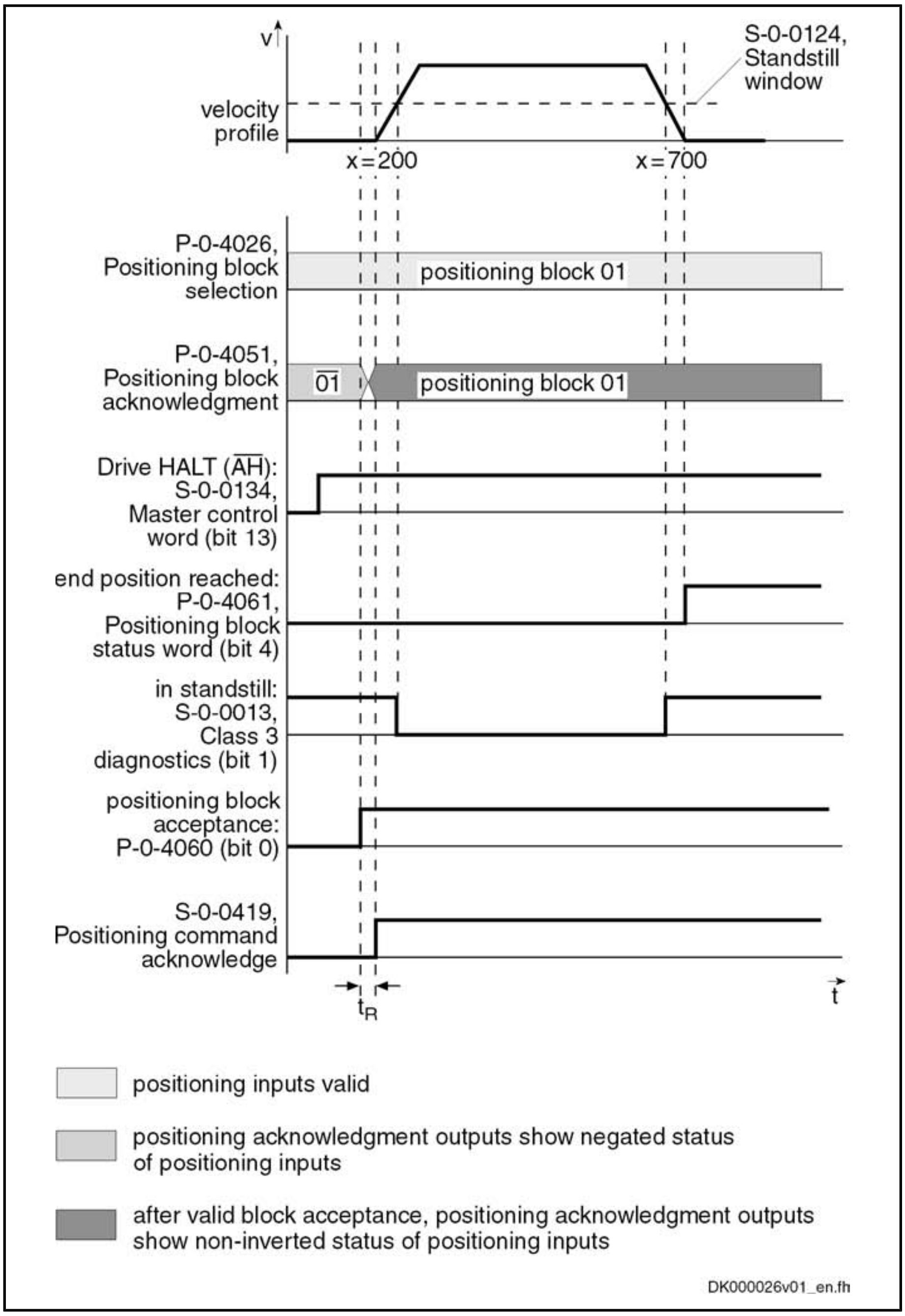


Fig.7-44: Absolute Positioning Block

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 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**

Reference 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)

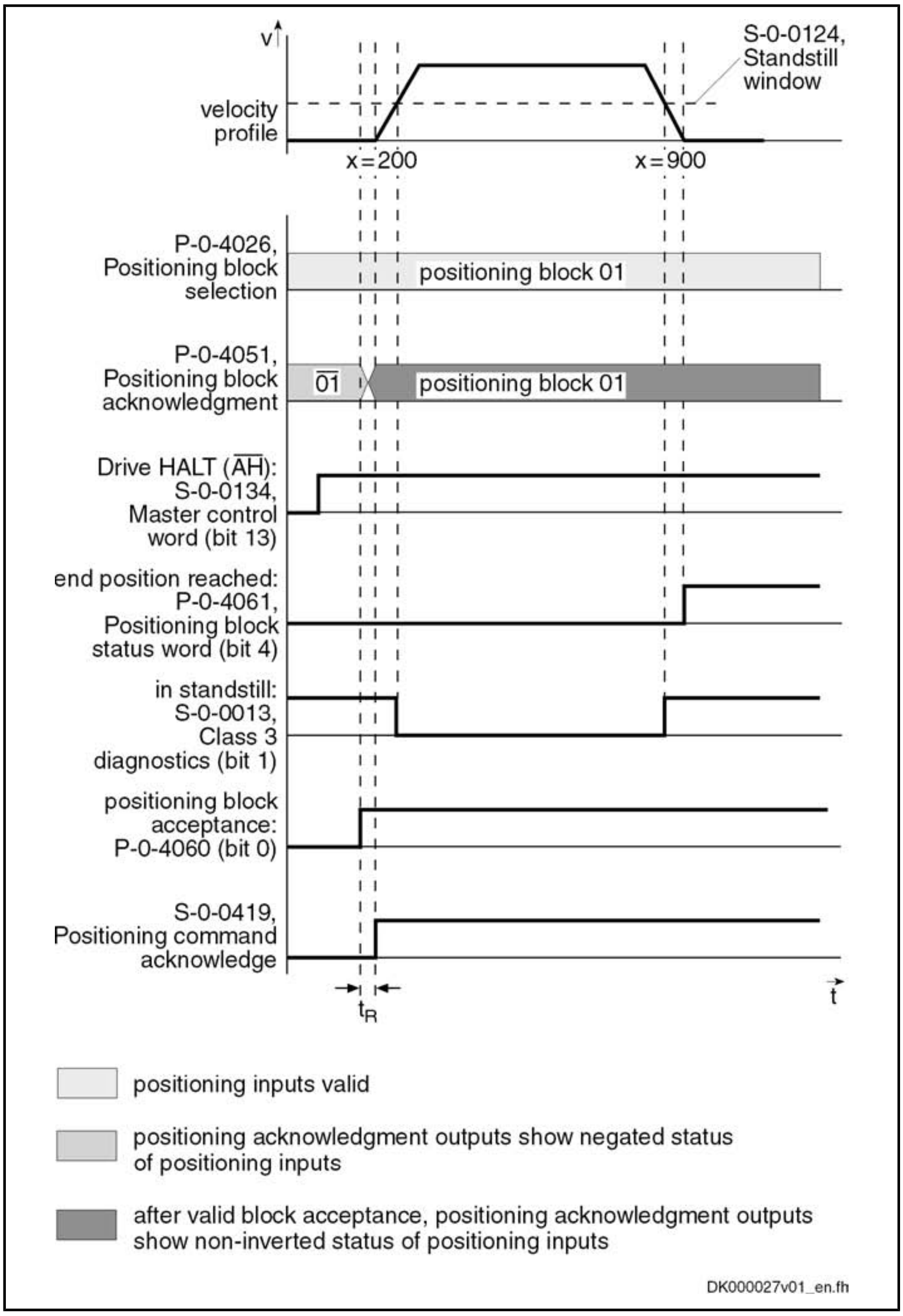


Fig.7-45: Relative Positioning Block Without Residual Path Storage

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☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 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

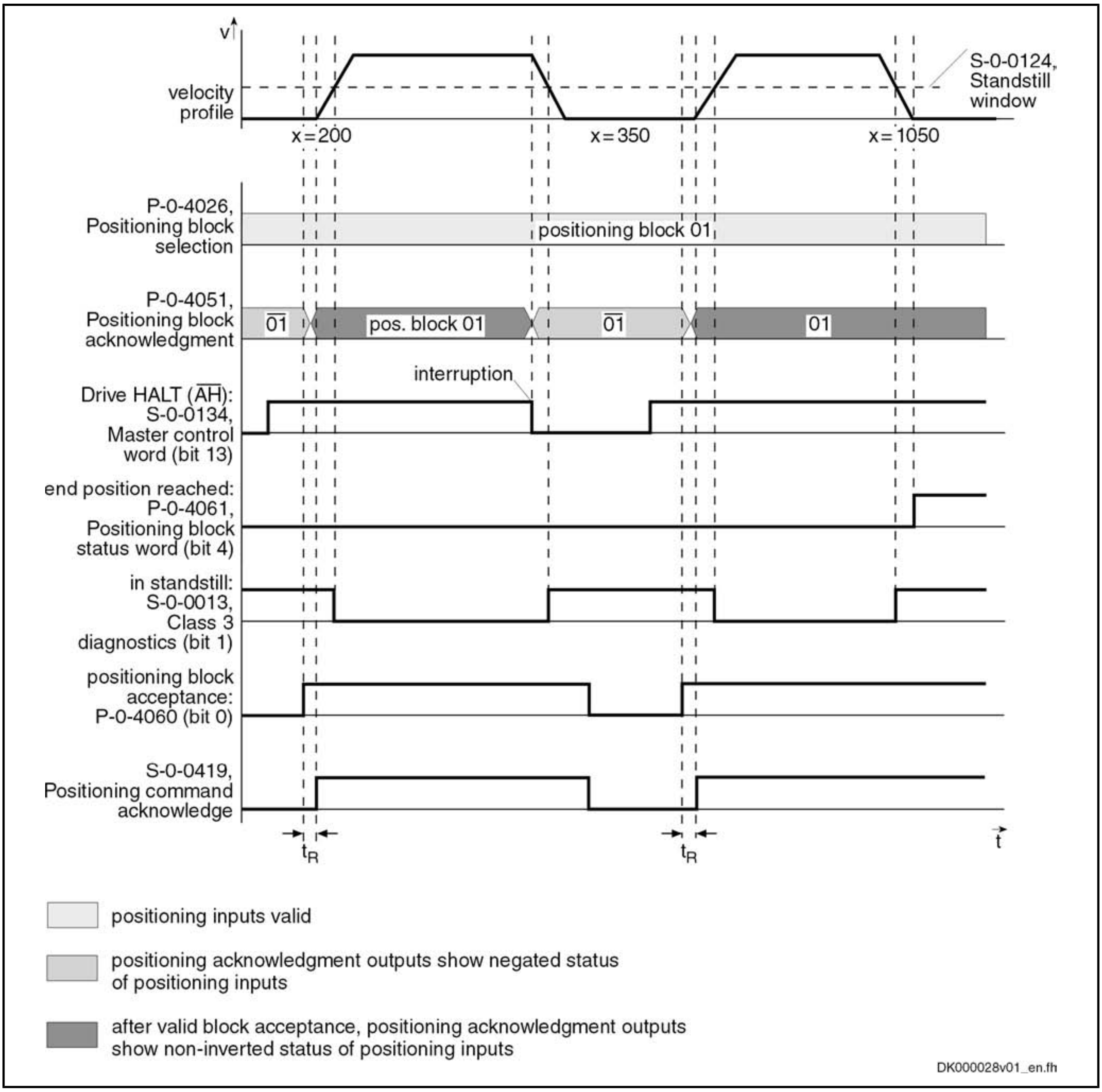


Fig. 7-46: Interrupting a Relative Positioning Bock Without Residual Path Storage

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 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

Reference Position

The last valid target position is used as reference position (in the example, position = 200 of positioning block n-1).

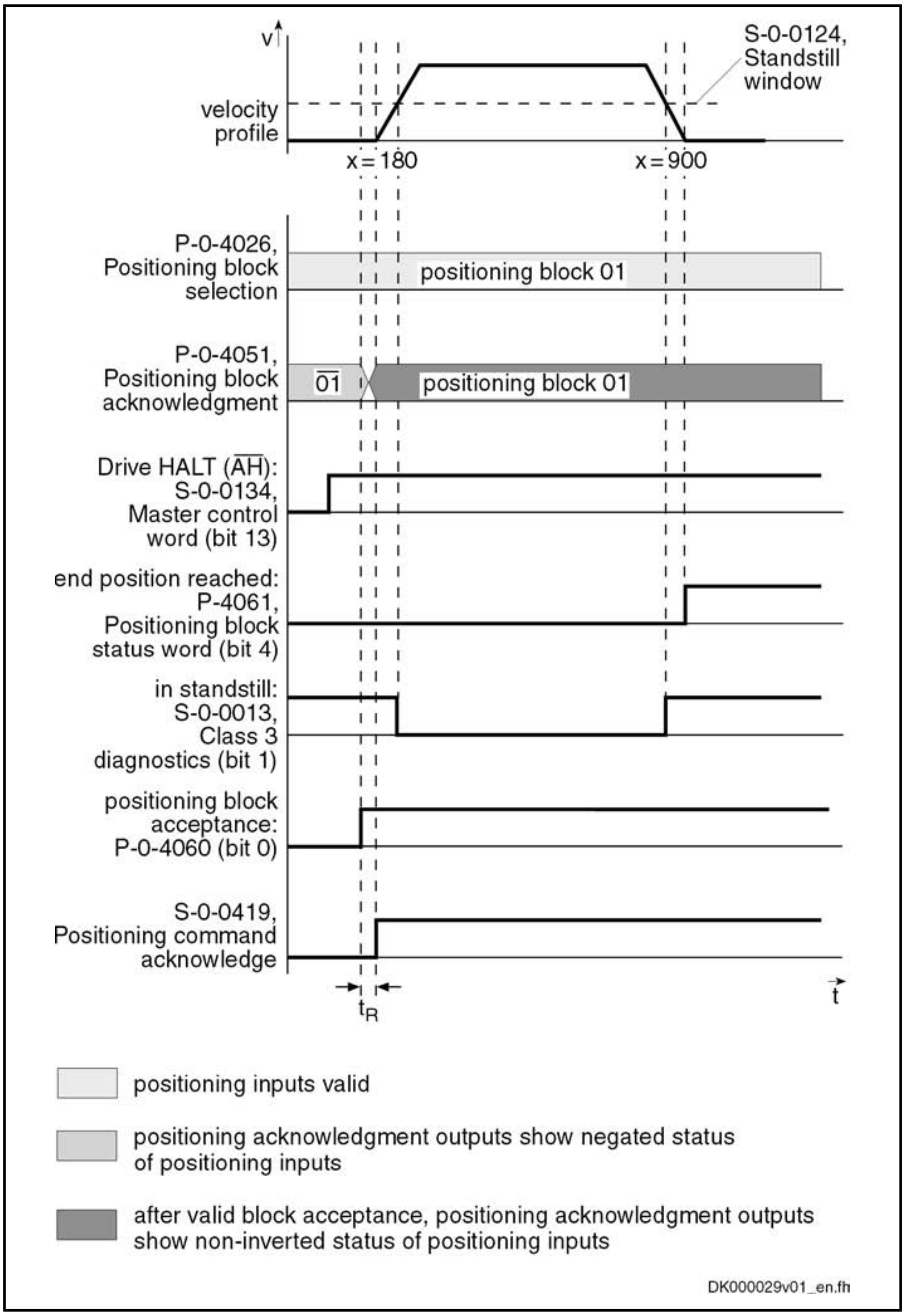


Fig.7-47: Relative Positioning Block With Residual Path Storage

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 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).

Reference Position The position command value at the last "end position reached" (position = 200) message is used as the reference position.

☞ The incremental dimension reference is ensured.

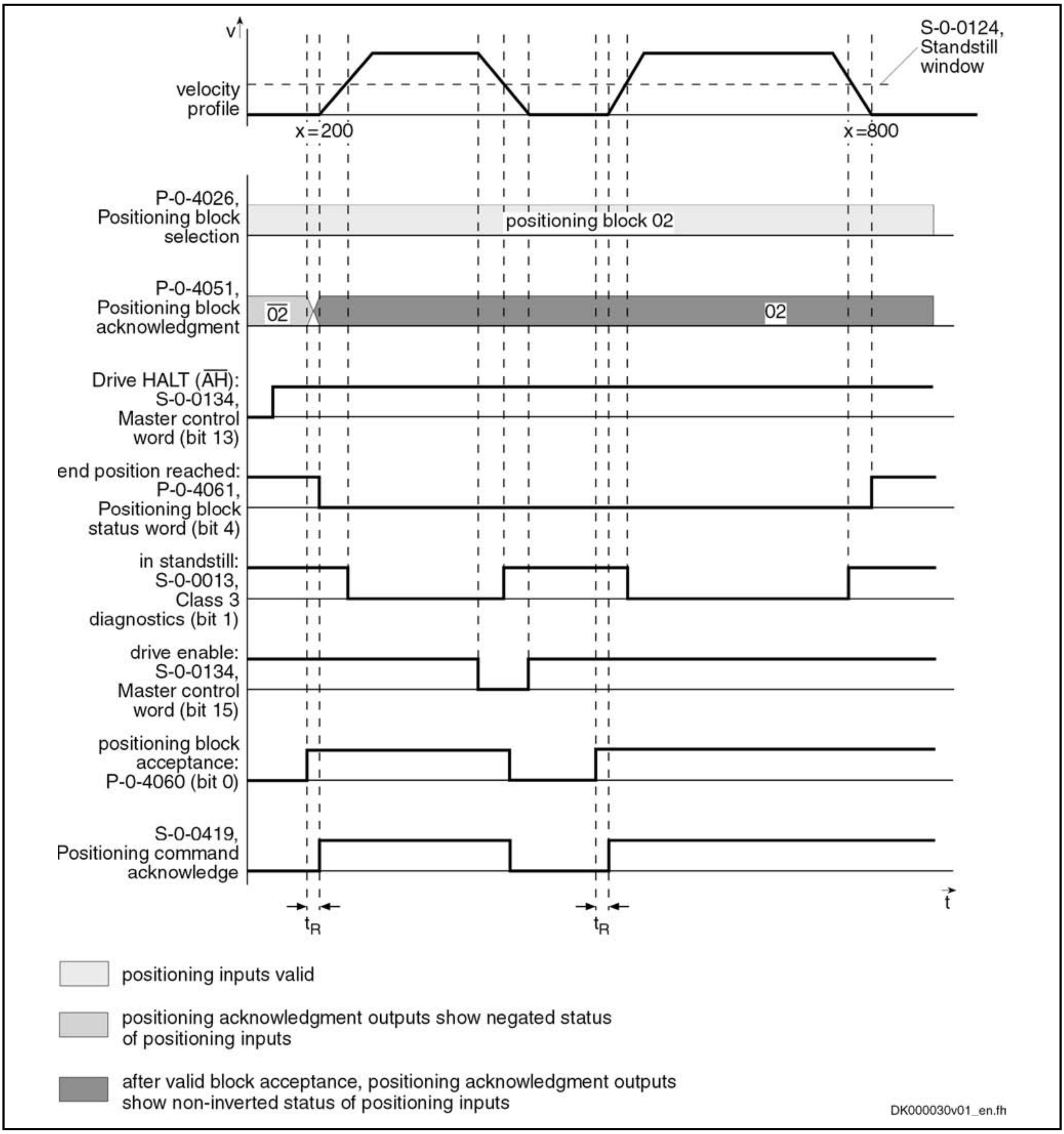


Fig.7-48: Relative Positioning Block With Residual Path Storage After Activating Drive Enable

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Relative Positioning Block With Residual Path Storage After Interrupting 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

Reference Position Positioning is always continued at the current actual position value.

Behavior An interruption by means of jogging or positioning stop clears the residual path memory.

☞ The incremental dimension reference is no longer ensured!

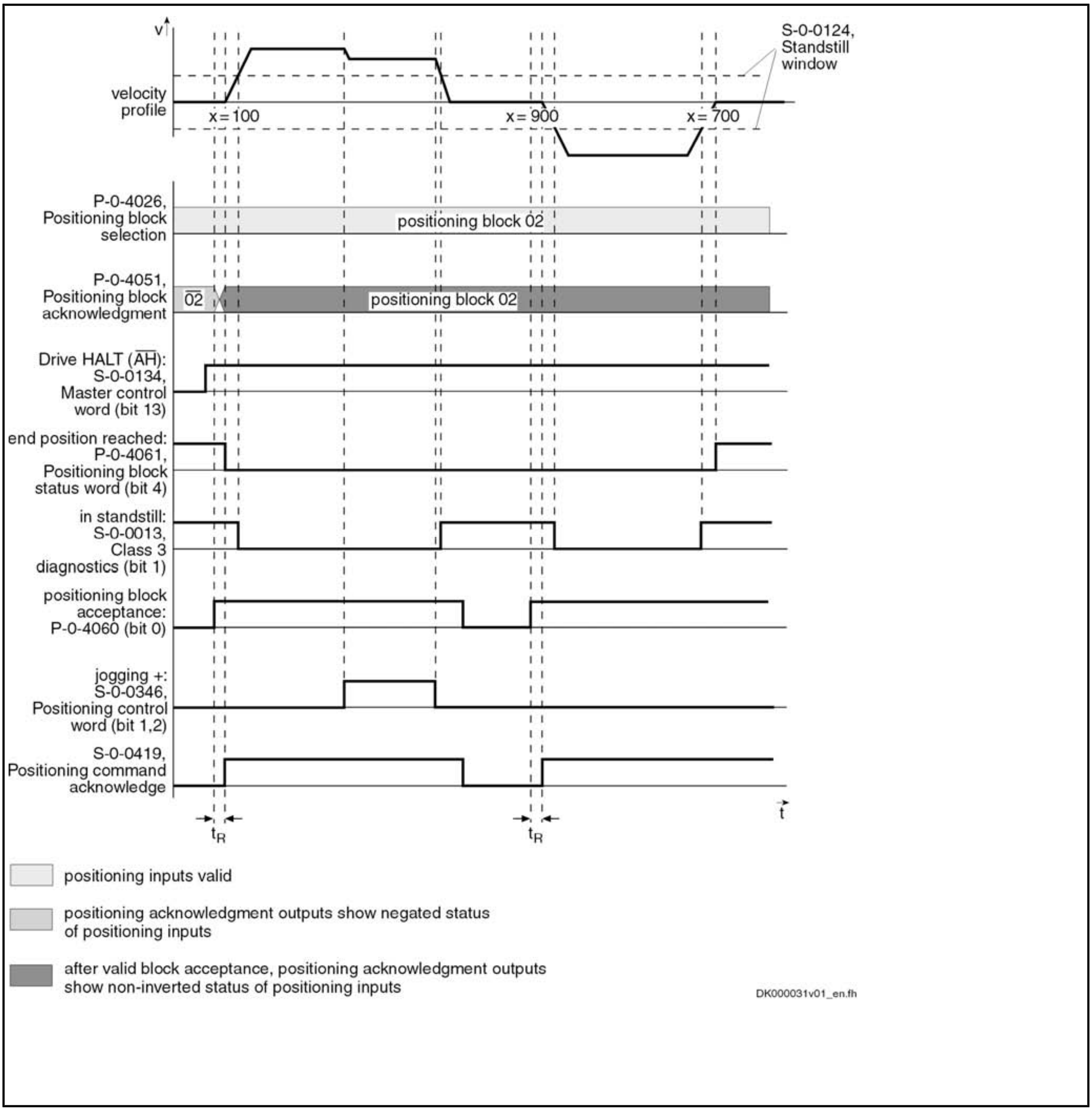


Fig.7-49: Relative Positioning Block With Residual Path Storage After Jog Mode

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 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.

Reference Position The position command value at the last "end position reached" (position = 100) message is used as the reference 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

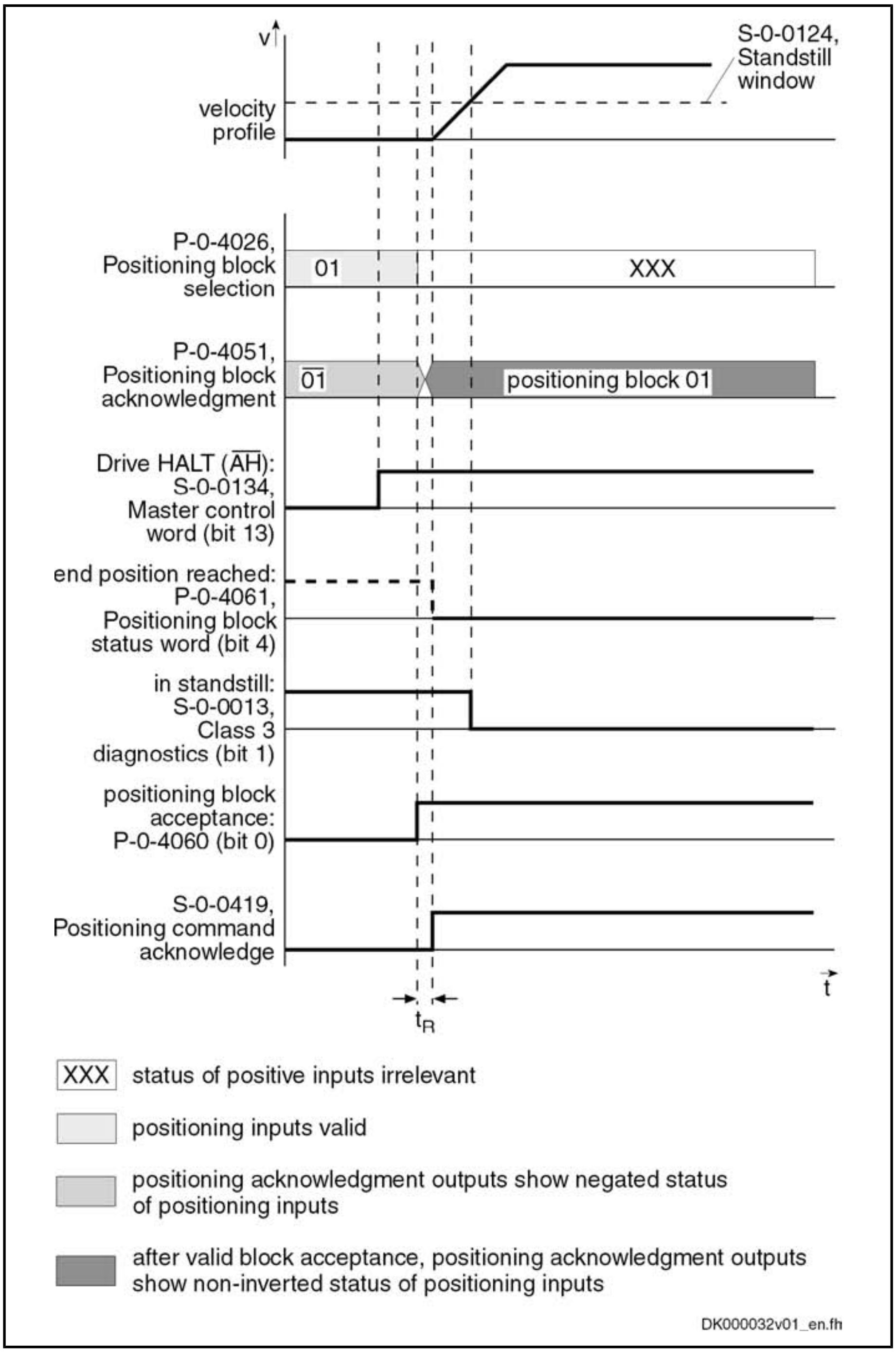


Fig.7-50: Example: Infinite Travel in Positive/Negative Direction

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

7.7.4 Sequential Block Processing

Basic Function

☞ For sequential block processing, it is first of all the same basic rules as for single-block processing which apply (see that section). 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.

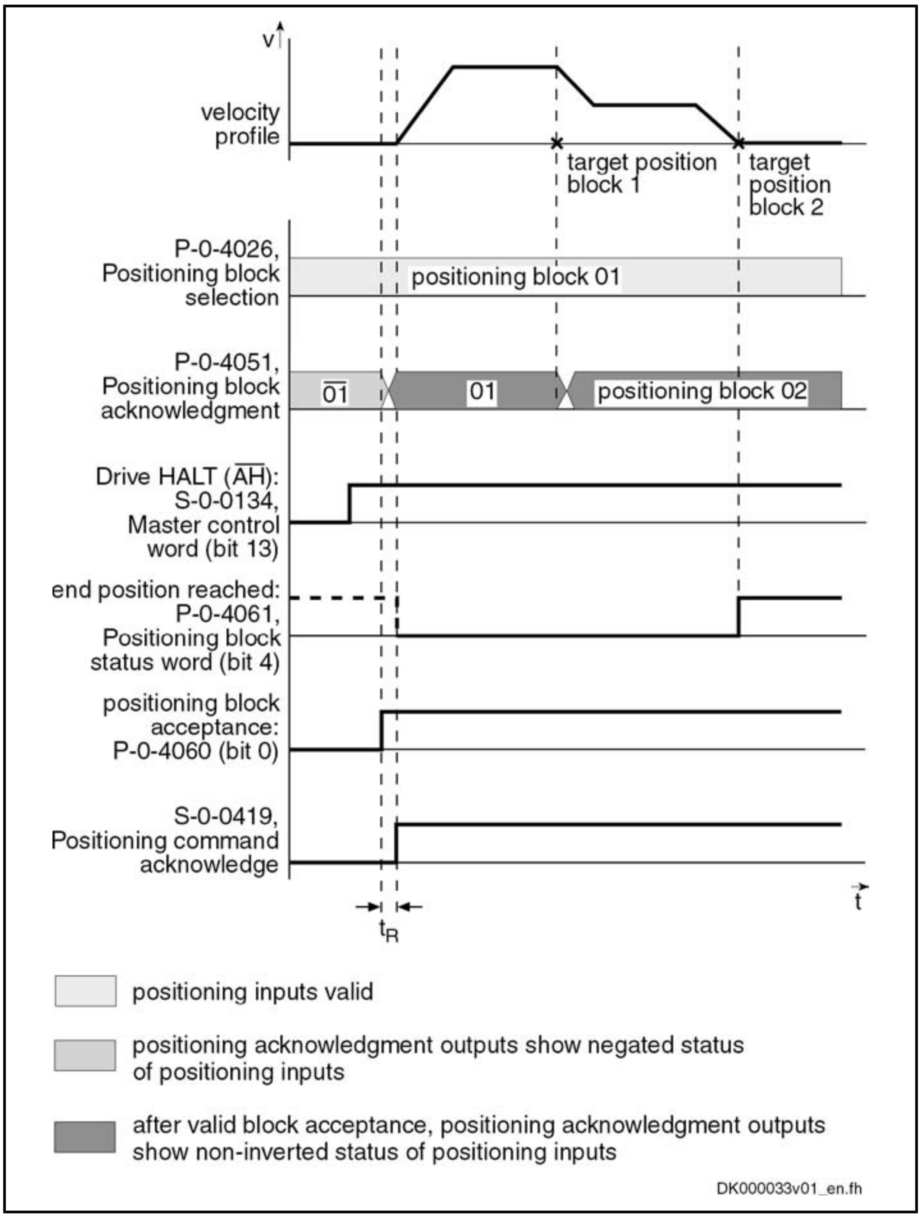


Fig.7-51: Example: Position-Dependent Block Advance (Mode 1)

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 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.

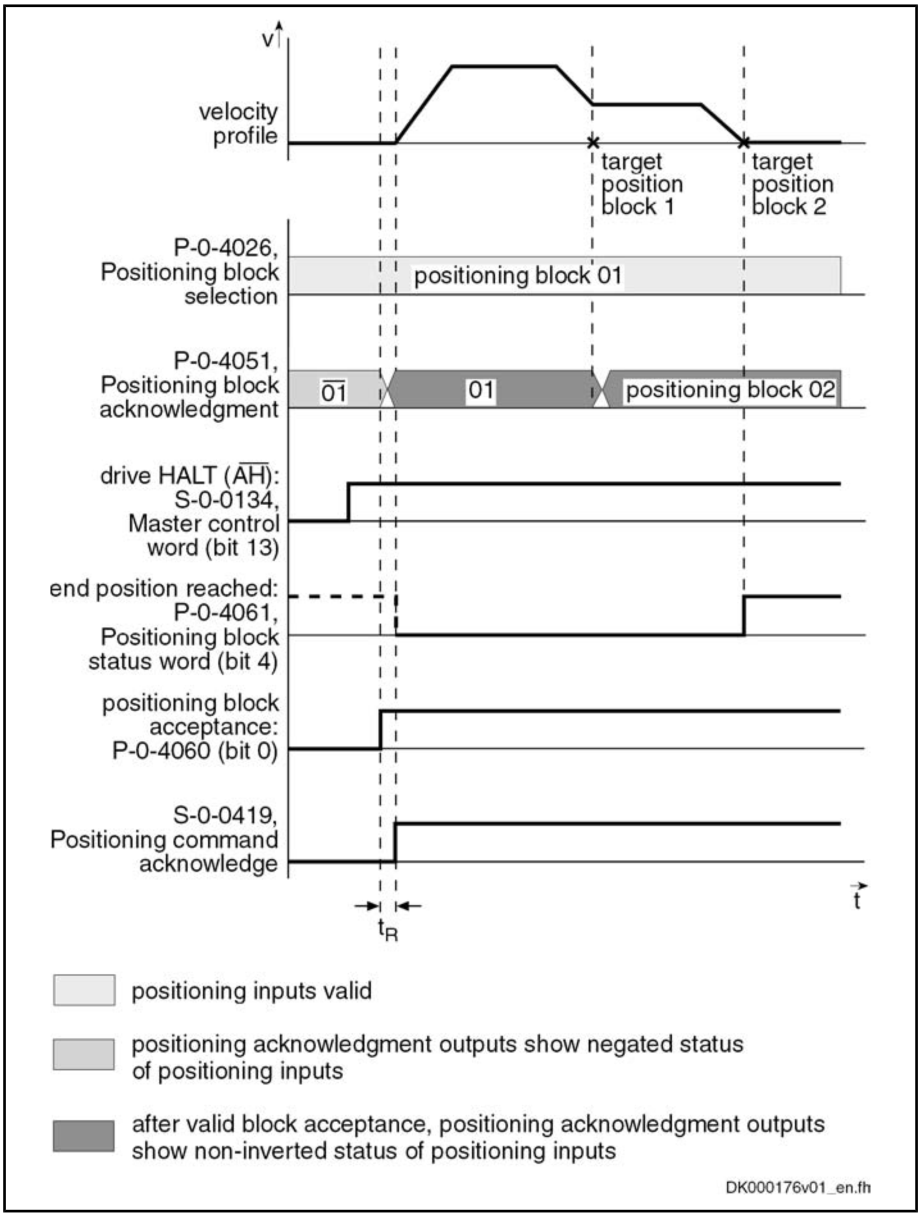


Fig. 7-52: Example: Position-Dependent Block Advance (Mode 2)

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 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 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.

☞ Advance 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.

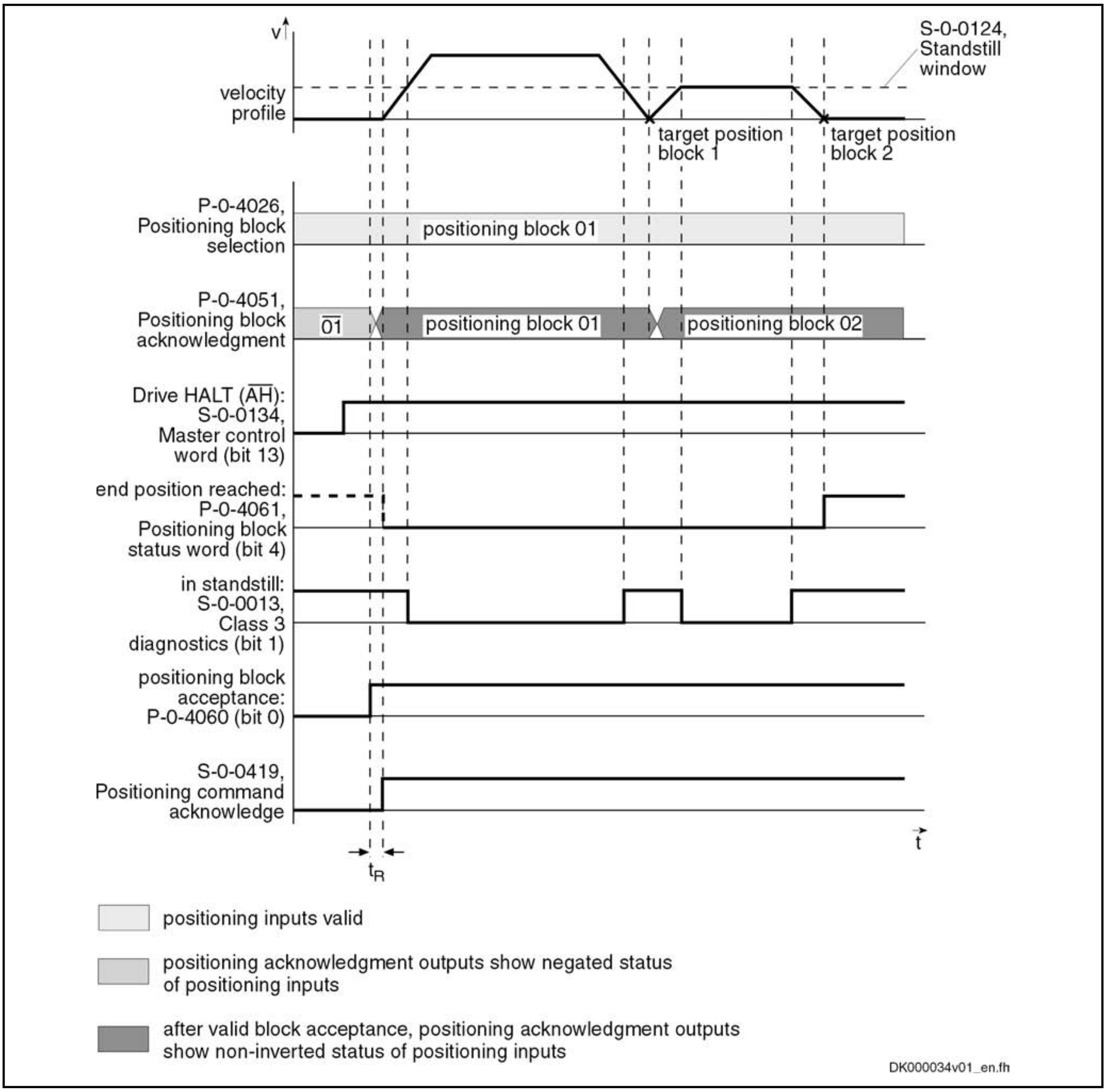


Fig.7-53: Example: Sequential Block Advance for Target Position With Intermediate Stop

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 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 status 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 **travel block after the next n+2**, 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.

Reference 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 loop 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

Fig.7-54: Drive Reaction With Different Switch Signal Sequences

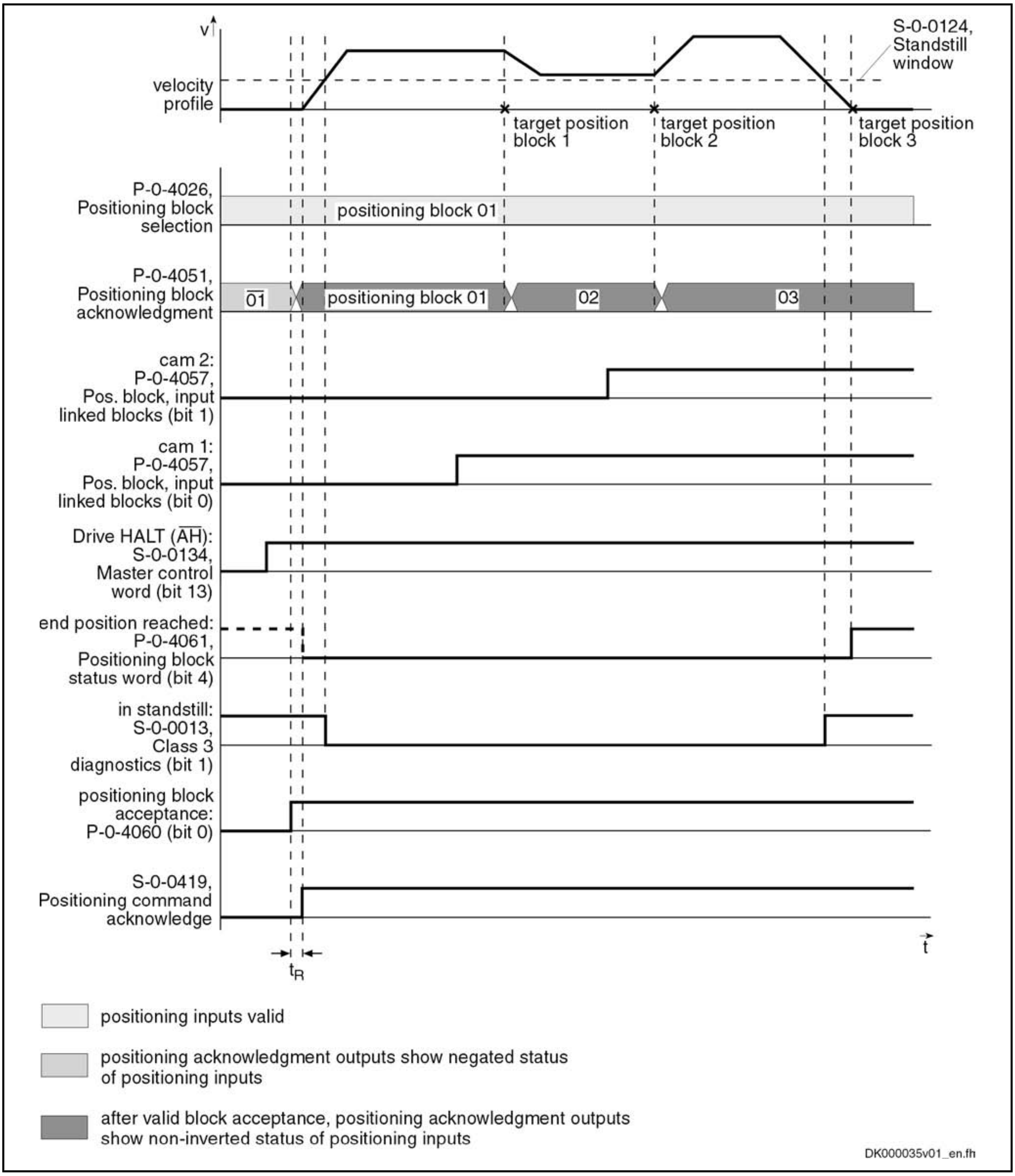


Fig.7-55: Example: Switch-Signal-Dependent Block Advance

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

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.

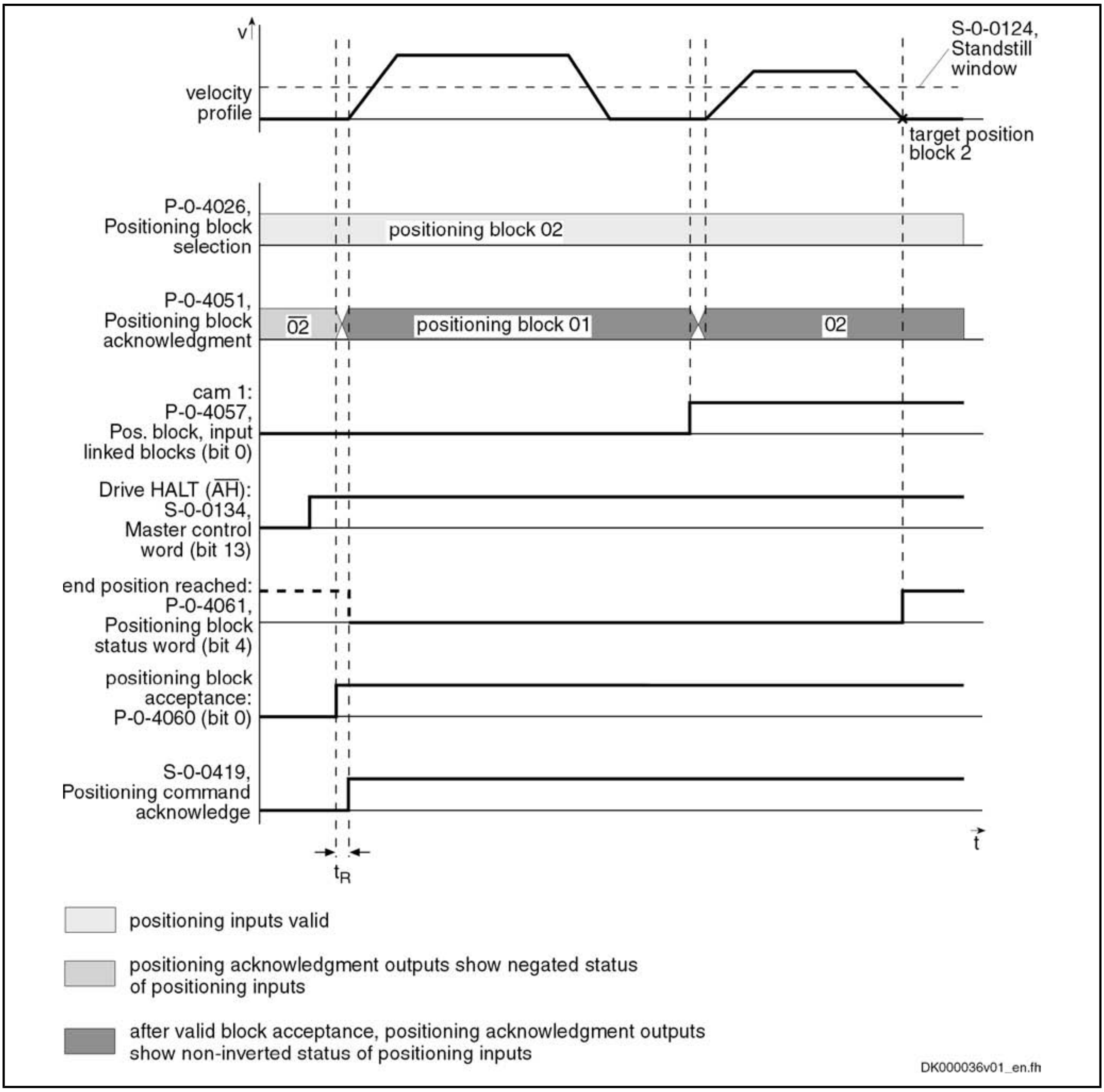


Fig.7-56: Example: Switch-Signal-Dependent Block Advance (Behavior With Failure of Switch Signal)

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

☞ All conditions for advance 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 advance 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 operating 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.

Reference Position

The reference 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!

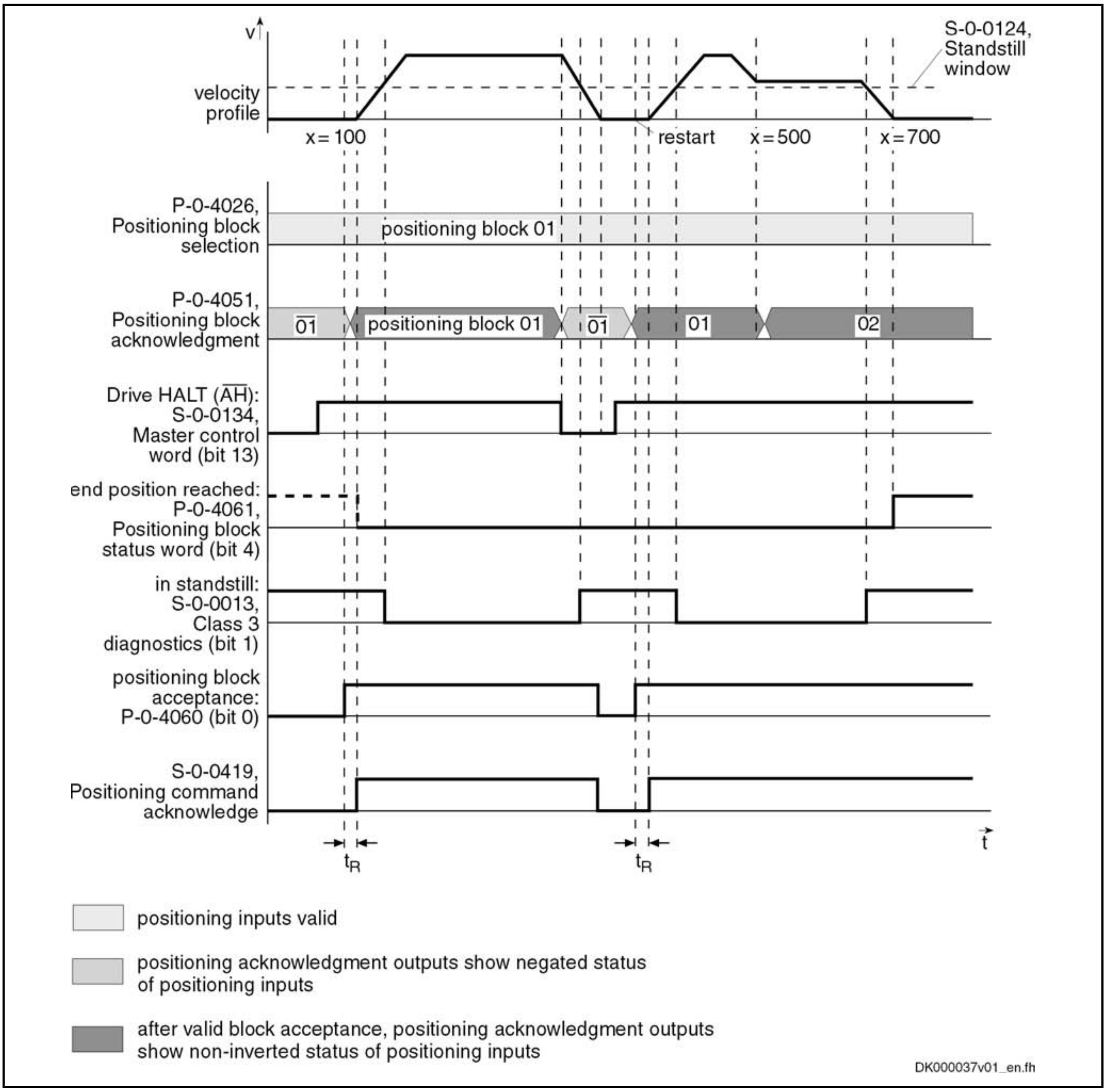


Fig.7-57: Example: Sequential Block Interruption With Same Block Selected

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Changing to Different Operating Mode

When changing the operating 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 advance 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 advance condition 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.

Reference Position

The reference position is the current actual position value.

> The incremental dimension reference gets lost, if the sequential block is interrupted.

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 0-1 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 0-1 edge of bit 0 in "P-0-4060, Positioning block control word".

7.7.5 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 values 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

If the acceleration values are too low, this can cause 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.7-58: 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 mode "switching at target position with halt" 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, sign of the velocity at target position n changes. 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.

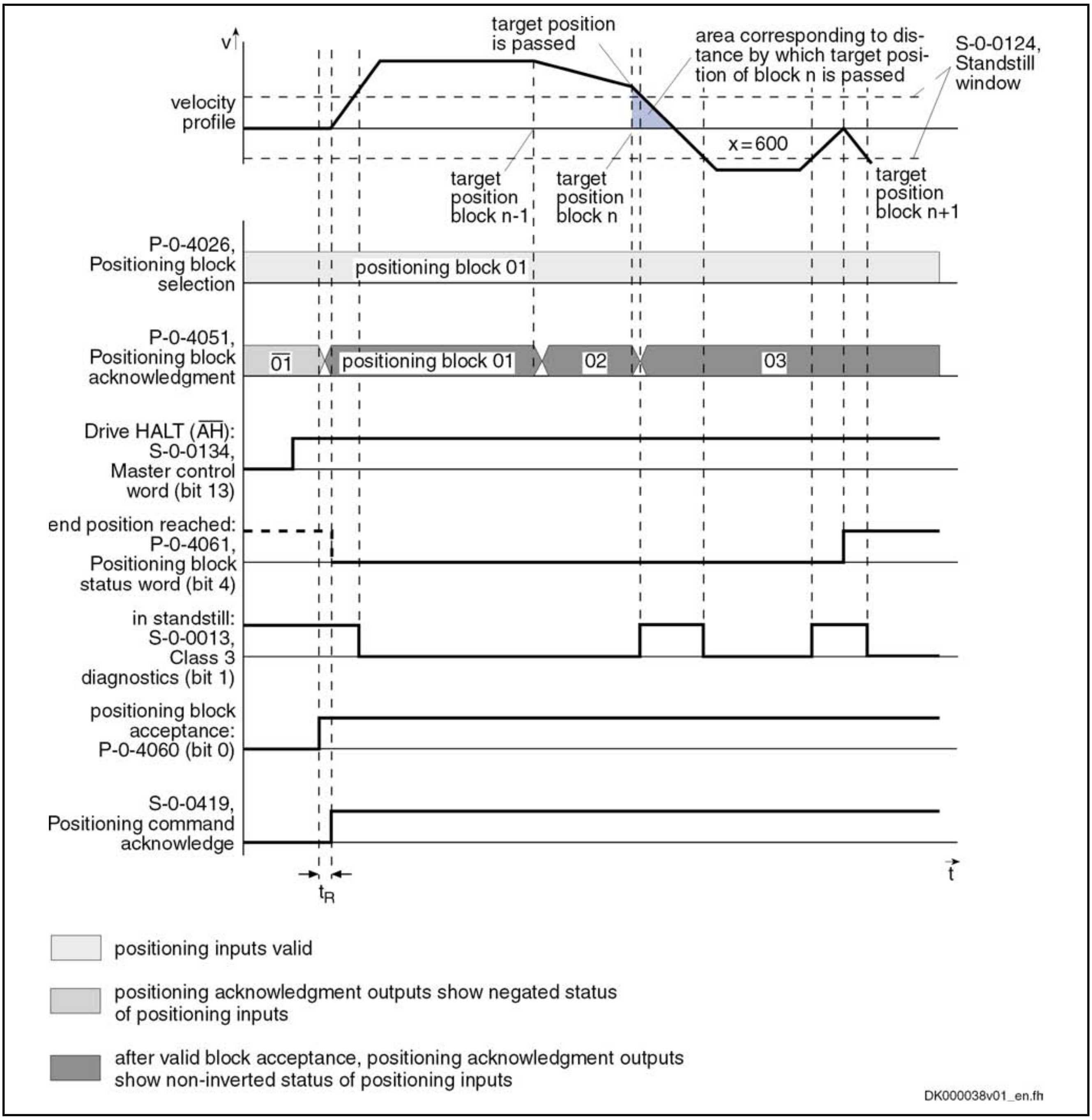


Fig.7-59: Parameterizing a Sequential Block With Directional Change

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 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!

7.7.6 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 Operating 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 0-1 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.

Acknowledgment at "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 Operating Modes

The acknowledgment is not affected by secondary operating 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.

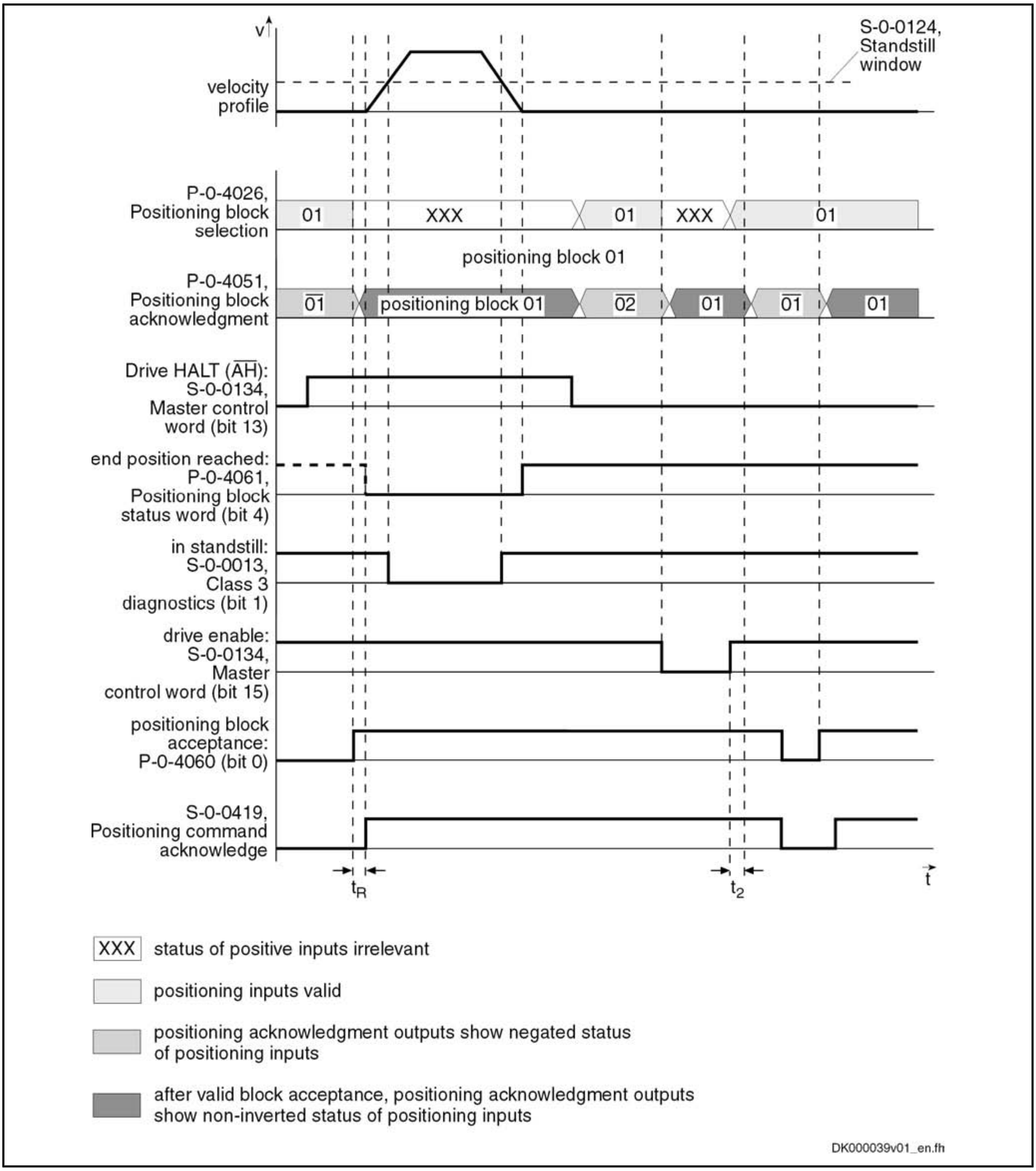


Fig.7-60: Acknowledgment and Message "End Position Reached" After Drive Enable Switched Off

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 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 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" for the operating 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:

- E2047 Interpolation velocity = 0
- E2048 Interpolation acceleration = 0
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2054 Not homed
- E2055 Feedrate override
  S-0-0108 = 0
- E2058 Selected process block is not programmed.
- E2064 Target position out of num. range

Error messages:

- F2028 Excessive deviation

7.8 Synchronization Modes

7.8.1 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** with real/virtual master axis
- **Synchronous position control modes:**
  - Phase synchronization with real/virtual master axis
  - Electronic cam shaft with real/virtual master axis
  - Electronic motion profile with real/virtual master axis

The figure below illustrates how the synchronization modes are integrated in the control loop structure.

Operating Modes

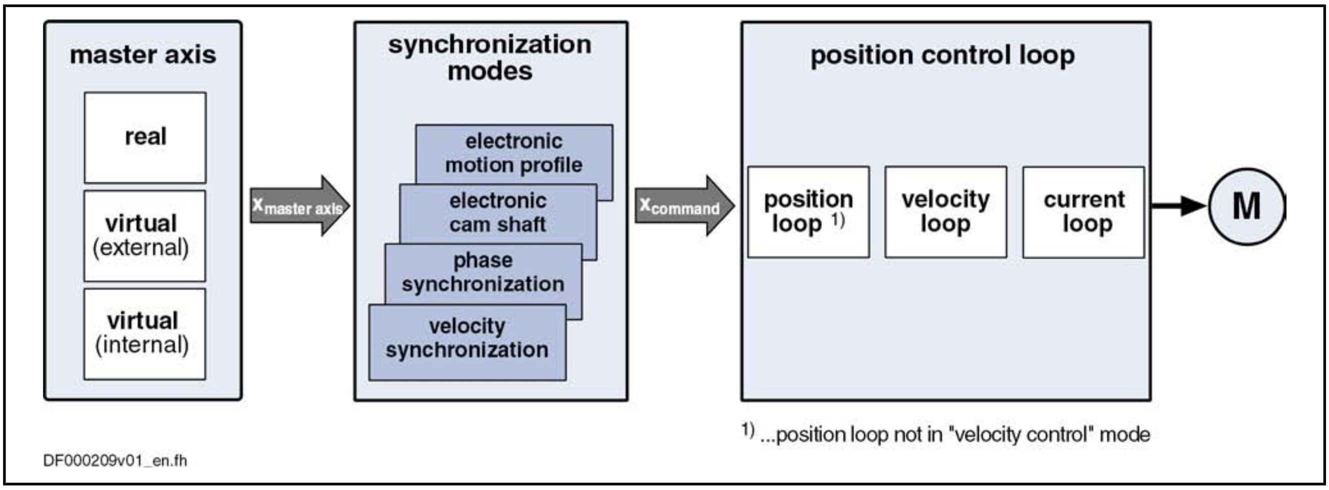


Fig.7-61: General Block Diagram of the Synchronization Modes

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 adjust
- Drive-controlled dynamic synchronization

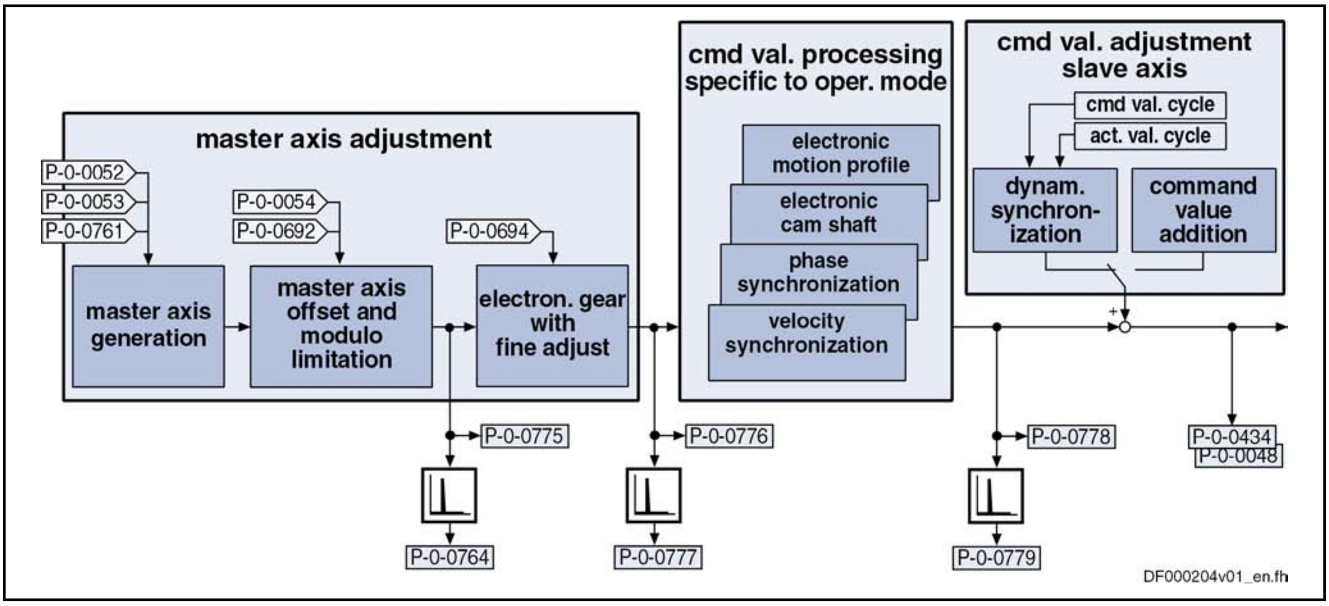
☞ The individual synchronization modes basically differ in the following function blocks:

- Command value processing specific to operating mode

- Command value addition for slave axis

These function blocks are described specific to operating 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-0-0434	Position command value of controller
P-0-0692	Additive position command value, process loop
P-0-0694	Gear ratio fine adjust, process loop
P-0-0761	Master axis position for slave axis
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

Fig.7-62: Function Blocks of the Synchronization Modes

Explanation of Terms

Master axis:

The drive which makes available the master axis position for generating the synchronous position command value for the slave axis is called master axis.

Slave axis:

The drive which in position control follows a synchronous position command value internally derived from the master axis is called slave axis.

Actual value cycle:

The modulo range within which the actual position values of the slave axis are to be found is called actual value cycle. It can also be used to limit the travel range during synchronization.

The modulo range of the actual value cycle corresponds to the integral multiple of the synchronization range.

Command value cycle:

The modulo range within which the synchronous position command values of the slave axis are to be found is called command value cycle. If necessary (depending on P-0-0155), it can be used to limit the actual position value in the actual value cycle (cf. P-0-0753).

Configuring and Controlling the Synchronization Modes

The synchronization modes are configured and controlled by means of the following synchronization parameters:

Pertinent Parameters (Synchronization Parameters)

- S-0-0520, Control word of axis controller
- S-0-0521, Status word of position loop
- P-0-0086, Configuration word synchronous operating modes
- P-0-0088, Control word for synchronous operation modes
- P-0-0089, Status word for synchronous operating modes

After having selected the required synchronization mode, you can make, among other things, the following settings via these parameters:

- Position control with lag error or lagless
- Use of encoder 1 or encoder 2

See also "Operating Mode Handling"

Command Value Addition

This section contains an overview of the basic possibilities of adding command values. The characteristics and details specific to operating 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 additional pos. command
- 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, Additive master axis position, process loop
- 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.

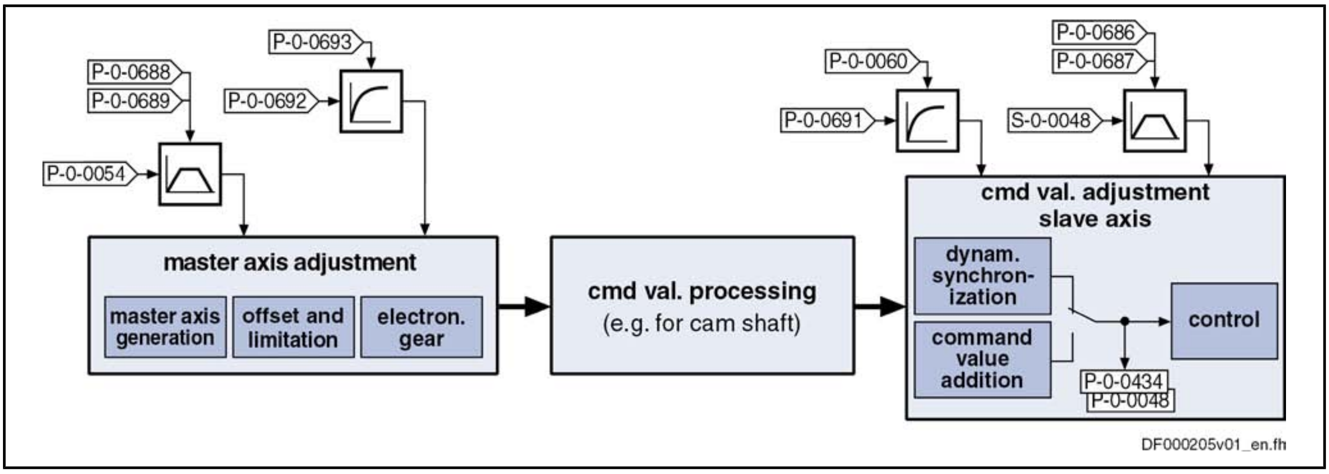


Fig.7-63: Possibilities of Command Value Addition for Master and Slave Axis

Master Axis Adjustment

Brief Description

Master Axis Generation

Possible signal sources for the effective master axis of the synchronization modes:

- **Real master axis**
- **Virtual master axis, external**
- **Virtual master axis, internal**

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, Additive master axis position, process loop"
- Limitation to modulo range of master axis

Electronic Gear Function

By means of factors to be set (e.g. input revolutions, output revolutions, polarity), the electronic gear function can influence the master axis position relevant for the operating 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-0-0688, Additive master axis position, positioning velocity
- P-0-0689, Additive master axis position, positioning acceleration
- P-0-0692, Additive master axis position, process loop
- 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

The following parameters are used in conjunction with the electronic gear with fine adjust:

- P-0-0083, Gear ratio fine adjust
- 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 adjust, 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 kind 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".

  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 parameter "P-0-0761, Master axis position for slave axis".

  See also "Virtual Master Axis Generator"

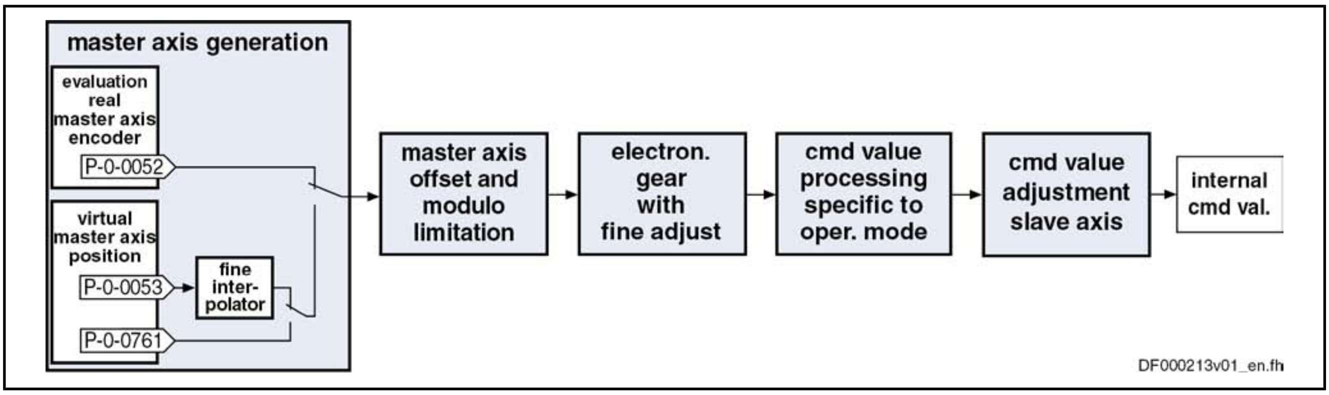


Fig.7-64: Function Block "Master Axis Generation" for Real/Virtual Master Axis

For master axis generation (real or virtual), observe the following conditions:

- The master axis position can only be processed in a binary format (1 master axis revolution = 2^{20} 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^{20}).

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.

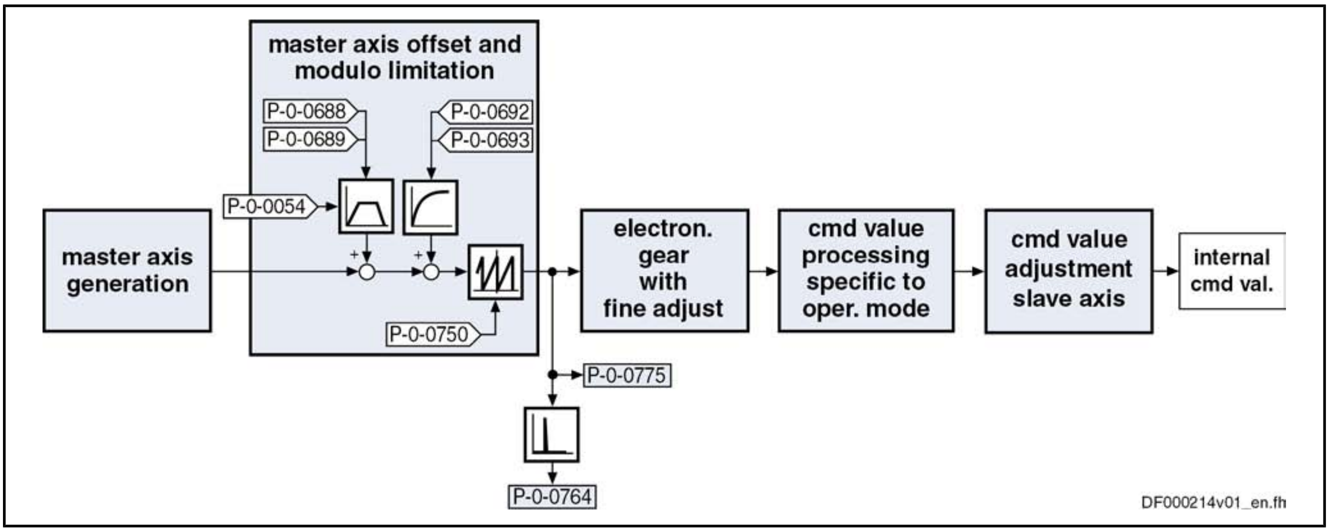


Fig.7-65: Function Block "Master Axis Offset and Modulo Limitation" for Real/Virtual Master Axis

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, Additive master axis position, process loop". 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.

Resulting Master Axis Position

The resulting master axis position (P-0-0775) is generated from the preset master axis (P-0-0052, P-0-0053 or P-0-0761) and the additive components (P-0-0054 and, if required, P-0-0692).

Limiting the Master Axis Position

The resulting master axis position is limited to the modulo range of the master axis with parameter "P-0-0750, Master axis revolutions per master axis cycle".

The following applies: Modulo value master axis = P-0-0750 × 2^{20}

Observe the following aspects:

- The master axis range is set as an integral multiple of a master axis revolution (= 2^{20} increments) with parameter "P-0-0750, Master axis revolutions per master axis cycle".
- The sum from P-0-0052/P-0-0053, P-0-0054 and P-0-0765 mustn't exceed the double master axis range (P-0-0750 × 2^{20})!

Master Axis Speed

The master axis speed is generated by differentiating the master axis position and displayed in parameter "P-0-0764, Master axis speed". The component of an external virtual master axis is generated in the NC clock.

Electronic Gear Function With Fine Adjust

The input value for the electronic gear is the resulting master axis position (P-0-0775).

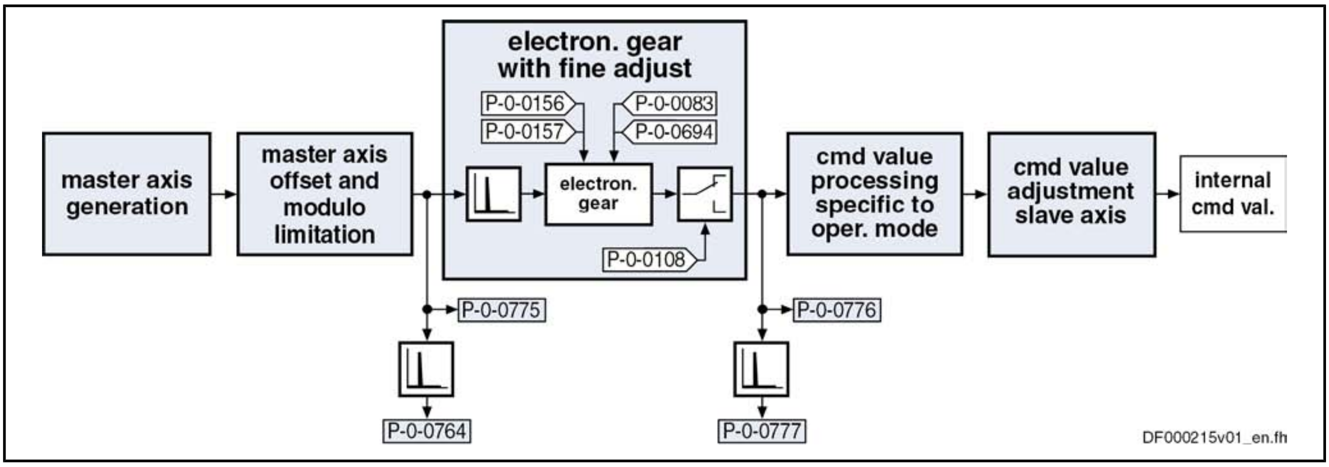


Fig.7-66: Function Block "Electronic Gear With Fine Adjust"

Functional Principle

The function block "electronic gear with fine adjust" is divided into the following subfunctions:

- **Electronic master axis gear with fine adjust**

  The master axis position or master axis velocity is first multiplied with the factor from P-0-0157/P-0-0156 (output revolutions/input revolutions).

  The fine adjust is carried out by multiplication of the resulting master axis position or master axis velocity with the sum of 1 + P-0-0083 (gear ratio fine adjust) and the subsequent multiplication with the sum of 1 + P-0-0694 (gear ratio fine adjust, process loop).

- **Polarity reversal of master axis position**

  Via parameter "P-0-0108, Master drive polarity", it is possible to invert the polarity of the master axis position or master axis velocity.

Input Value of Electronic Gear

The input value for the electronic gear is the resulting master axis position (P-0-0775).

Output Value of Electronic Gear

The currently effective master axis position and master axis velocity after the function block "electronic gear with fine adjust" are generated in the position loop clock (see "Performance Data") and displayed in the following parameters:

- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity

Command Value Processing for Slave Axis Depending on Operating Mode

When the output value of the electronic gear 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 operating mode" is described in the sections on the respective operating mode:

- See "Velocity Synchronization"
- See "Phase Synchronization"
- See "Electronic Cam Shaft"

- See "Electronic Motion Profile"

Dynamic Synchronization of the Slave Axis

Brief Description

Synchronization With Velocity Synchronization

Features of synchronization in the "velocity synchronization" mode:

- Synchronization takes place as velocity adjustment
- 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 in Synchronous Position Control Modes

Features of synchronization for synchronous position control modes:

- Sequence of synchronization is **single-step or double-step**
- 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)
- 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 init window for modulo format"
- Display of the difference between actual position value in the 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)
- **Mode "standard" or "register controller"** for command value addition for the slave axis
- Generation of status message "synchronous mode in synchronization" ("P-0-0089, Status word for synchronous operating modes", bit 8)

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 additional pos. command
- P-0-0071, C3100 Recalculate actual value cycle
- P-0-0142, Synchronization acceleration
- P-0-0143, Synchronization velocity
- P-0-0151, Synchronization init 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

General Information on Synchronization

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 (single-step)
- Synchronization in synchronous position control modes (double-step)

Synchronization Mode

The basic settings for carrying out synchronization are made in parameter "P-0-0155, Synchronization mode"; these settings comprise, for example:

- Mode for command value addition
- Synchronization "absolute" or "relative"
- Range of synchronization
- Reaction to other command value changes after absolute synchronization had been reached for the first time

See Parameter Description "P-0-0155, 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:

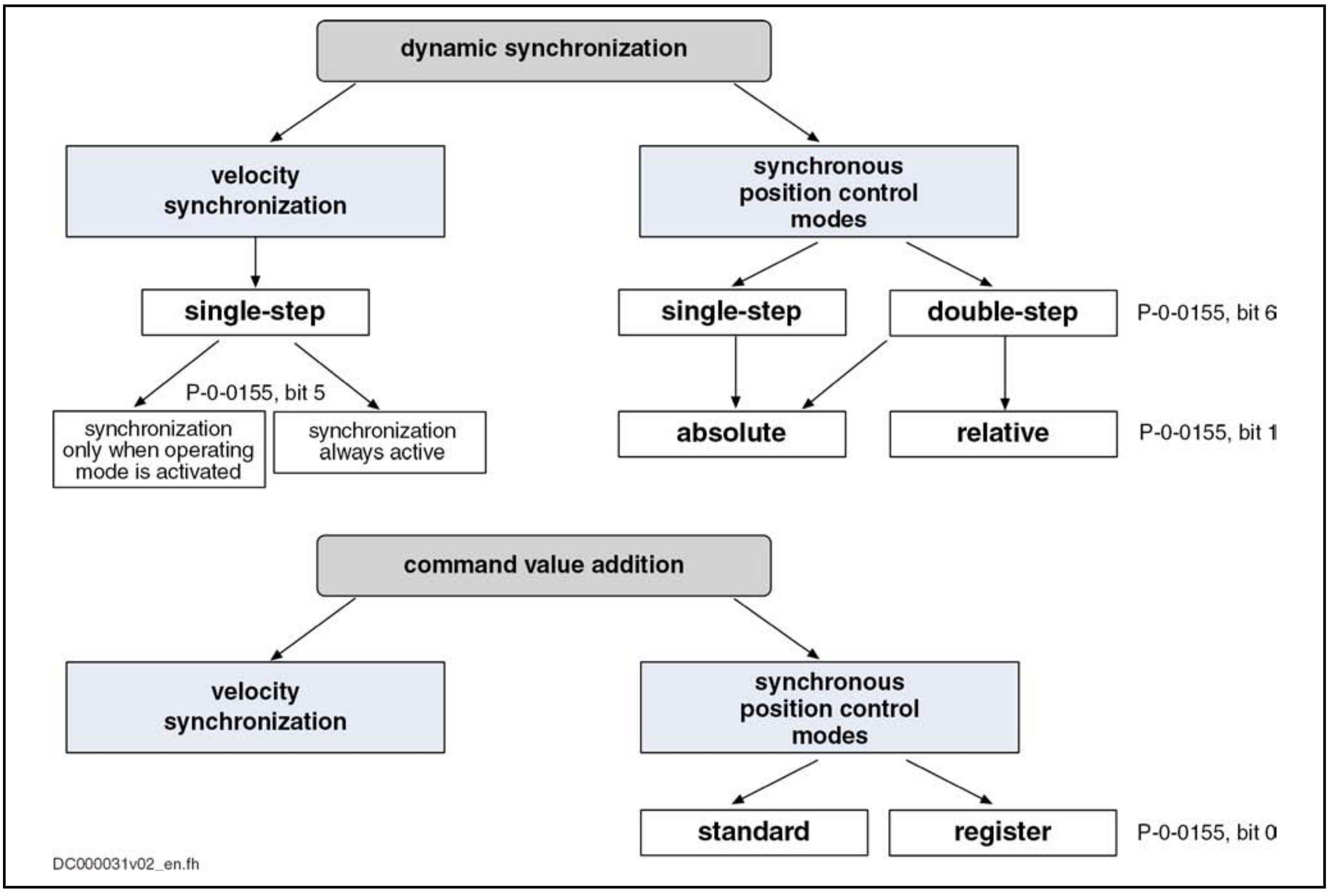


Fig.7-67: Overview of Methods to be Selected for Synchronization and for Command Value Addition

In the default setting of parameter P-0-0155, all bits are at value "0"!

Synchronization With Velocity Synchronization

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 operating mode is activated
- 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.

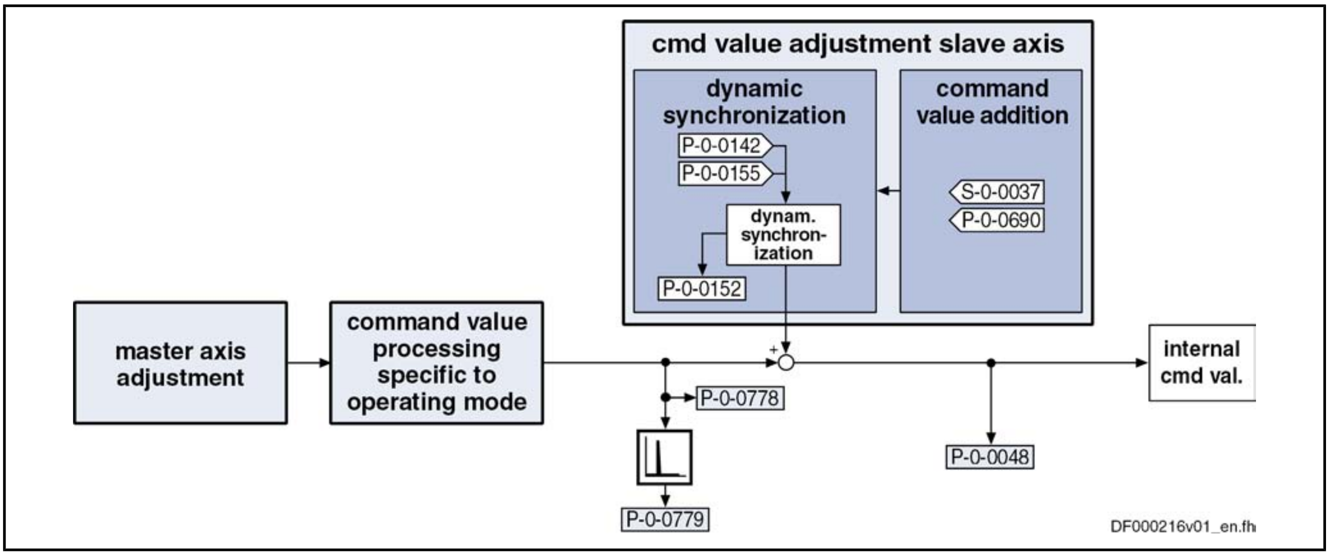


Fig.7-68: Function Block "Dynamic Synchronization" for Velocity Synchronization

Synchronization in Synchronous Position Control Modes

In the synchronous position control modes (phase synchronization, cam shaft and motion profile), drive-controlled dynamic synchronization is carried out when a synchronous position control mode is activated.

In the case of double-step synchronization, the values of the parameters "P-0-0142, Synchronization acceleration" and "P-0-0143, Synchronization velocity" are used for generating an additive command value for compensating the slave axis which is not velocity- and position-synchronous.

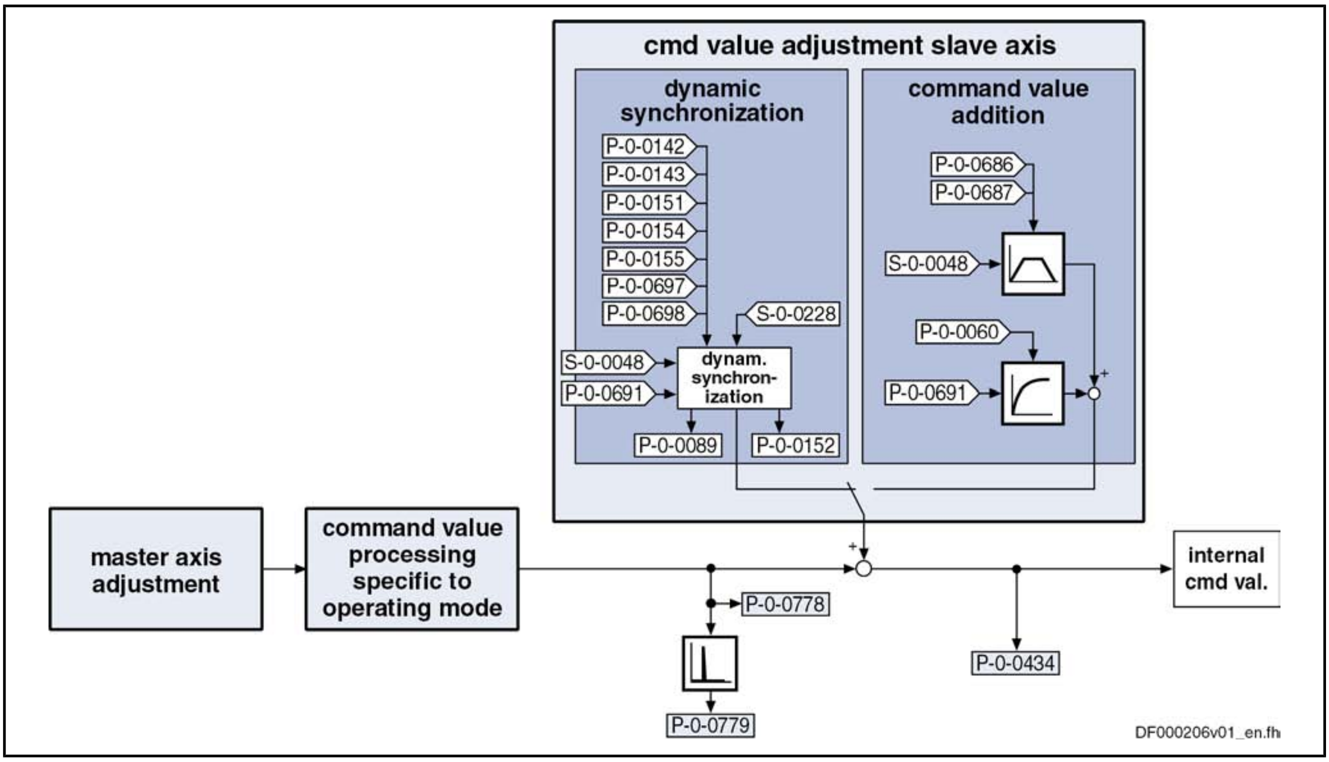


Fig.7-69: Function Block "Dynamic Synchronization" With Synchronous Position Control Modes

☞ All settings relevant for synchronization have to be made in parameter "P-0-0155, Synchronization mode".

The drive is absolutely synchronous when the following condition has been fulfilled:

$$\text{S-0-0228} \geq \left|\%\text{modulo}\left[(\text{P-0-0753}) - \left((\text{S-0-0048}) + (\text{P-0-0691}) + \text{P-0-0778}\right)\right]\right|$$

S-0-0228	Position synchronization window
P-0-0753	Actual position value in actual value cycle
S-0-0048	Additive position command value
P-0-0691	Additive position command value, process loop
P-0-0778	Synchronous position command value

Fig.7-70: 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!

Single-Step/Double-Step Synchronization

Depending on the synchronization mode, there are the following options:

- In the "velocity synchronization" mode, only single-step synchronization is possible.
- In synchronous position control modes, you can select either single-step or double-step synchronization.

Single-Step Synchronization

In the case of absolute synchronization, single-step synchronization can be set in bit 6 of parameter "P-0-0155, Synchronization mode".

In this case, the corresponding parameters take effect:

- P-0-0697, Synchronization, master axis synchronous position
- P-0-0698, Synchronization, master axis synchronization range

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☞ The parameters P-0-0697 and P-0-0698 refer to the output of the electronic gear.

With bit 7 = 1 of parameter P-0-0155, you can set that synchronization starts immediately when the synchronization mode is activated. The parameter for the master axis synchronous position (P-0-0697) in this case does not take effect.

With bit 7 = 0, you can set that the master-axis-synchronous synchronization motion only starts when the master axis start position is passed. 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.

For single-step synchronization, observe the following notes on utilization:

- Single-step synchronization is only active when the operating mode is activated. This means that, after the synchronous operating 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 "P-0-0776, Effective master axis position"

– **In cam shaft mode** by "P-0-0227, Cam shaft profile, 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.
- 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 init 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, "P-0-0155, " then defines how subsequent changes of "S-0-0048, Additive position command value" are processed (see below section "Command Value Addition for Slave Axis").

To be noticed for synchronization in the "electronic motion profile" mode

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. The shortest distance is traveled for the synchronization motion added to the synchronous motion.
- 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 on single-step synchronization are described in the section "Electronic Motion Profile"!

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 operating 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 loop (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 loop
P-0-0434	Position command value of controller

Fig.7-71: 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.

Relative/Absolute Synchronization

In the synchronous position control modes, it is possible to select either relative or absolute synchronization:

- **Relative synchronization** (P-0-0155, bit 1 = 1)

  → There is no fixed position reference between master axis and slave axis.
- **Absolute synchronization** (P-0-0155, bit 1 = 0)

  → There is a fixed position reference between master axis position and position command value that results from the master axis position and the parameterized additive position command value.

Relative Synchronization

The figure below illustrates the relative synchronization to a virtual master axis, the master axis being in standstill when the operating mode is activated.

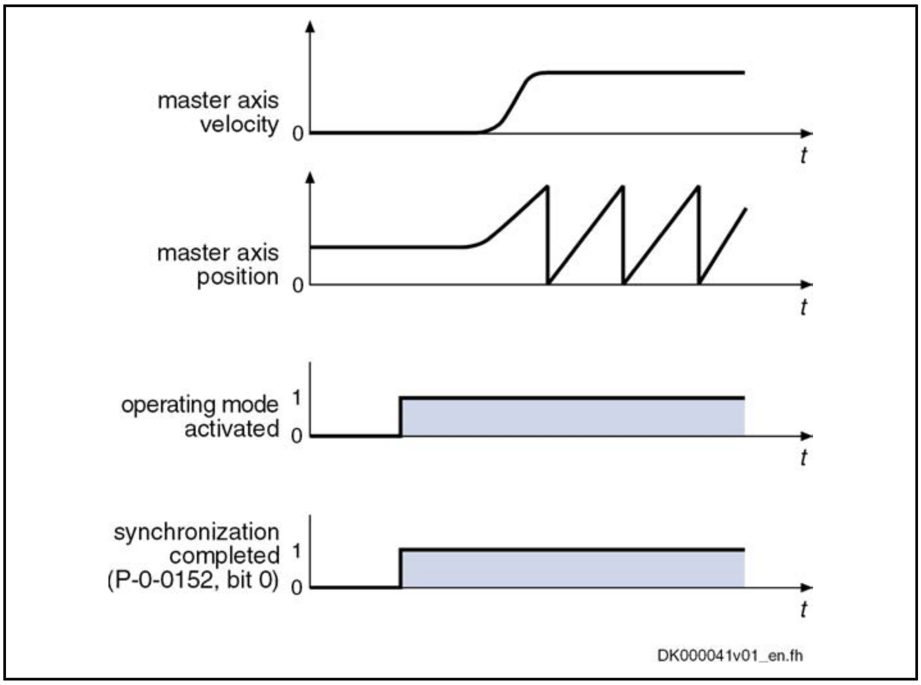


Fig.7-72: Example: Relative Synchronization out of Standstill

- When the operating mode is activated, the synchronous velocity = 0.
- Upon activation of the operating mode, 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 operating mode is activated.

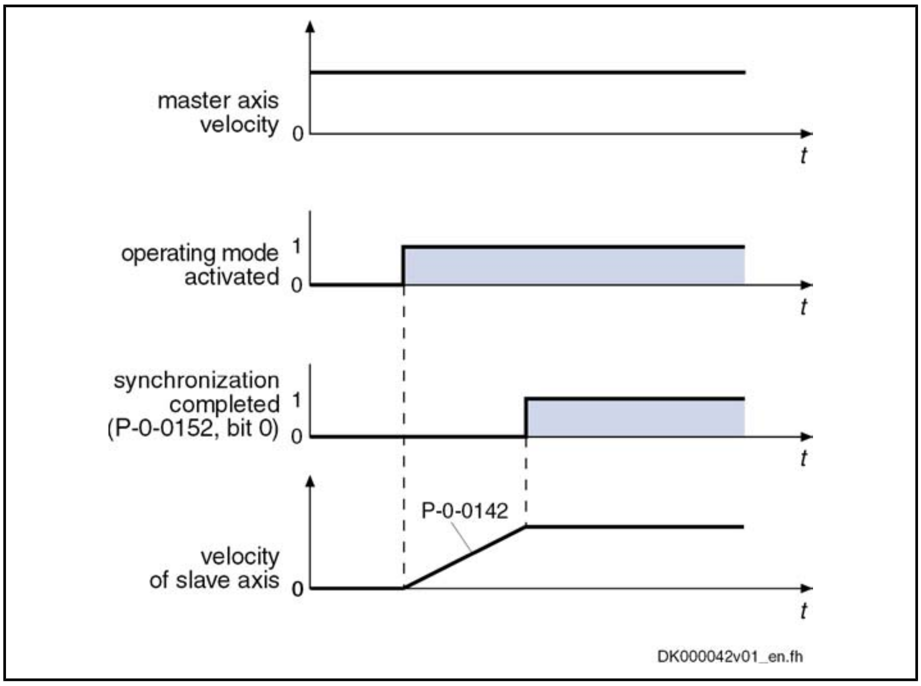


Fig.7-73: Example: Relative Synchronization in Running Operation

- When the operating 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.

Absolute Synchronization

The figure below illustrates the absolute synchronization to a virtual master axis, the master axis being in standstill when the operating mode is activated.

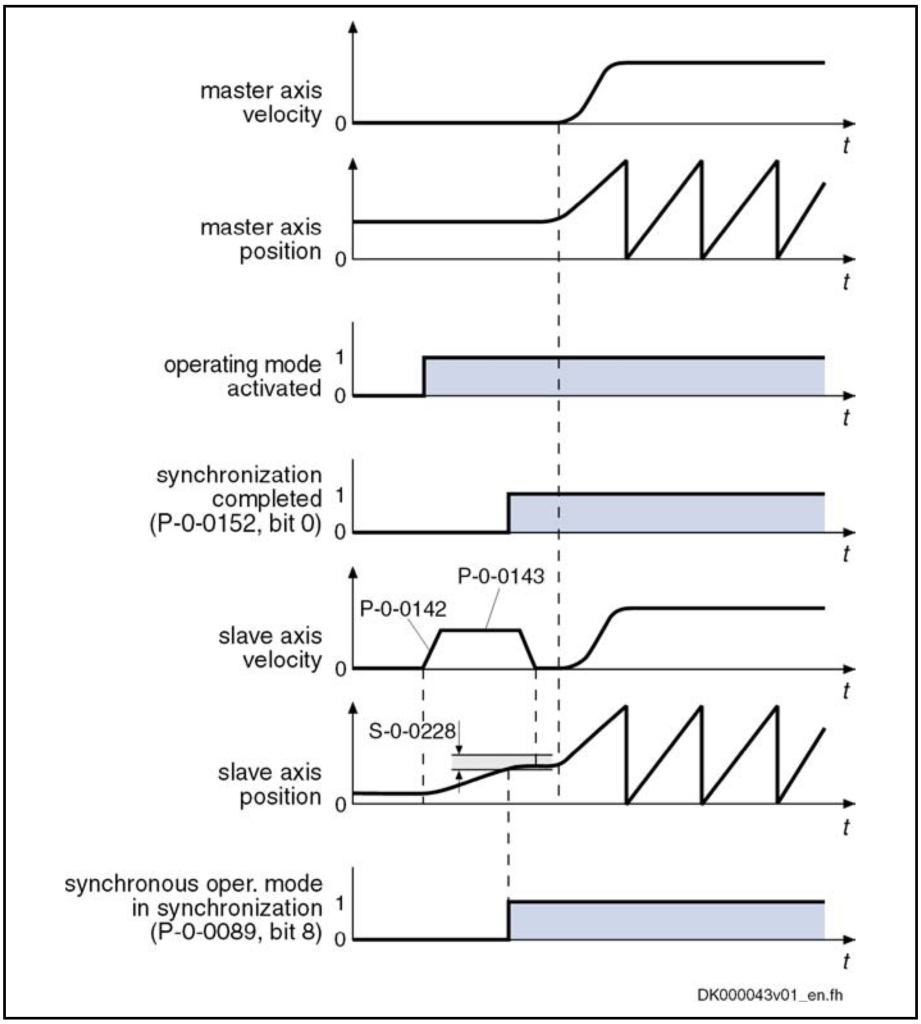


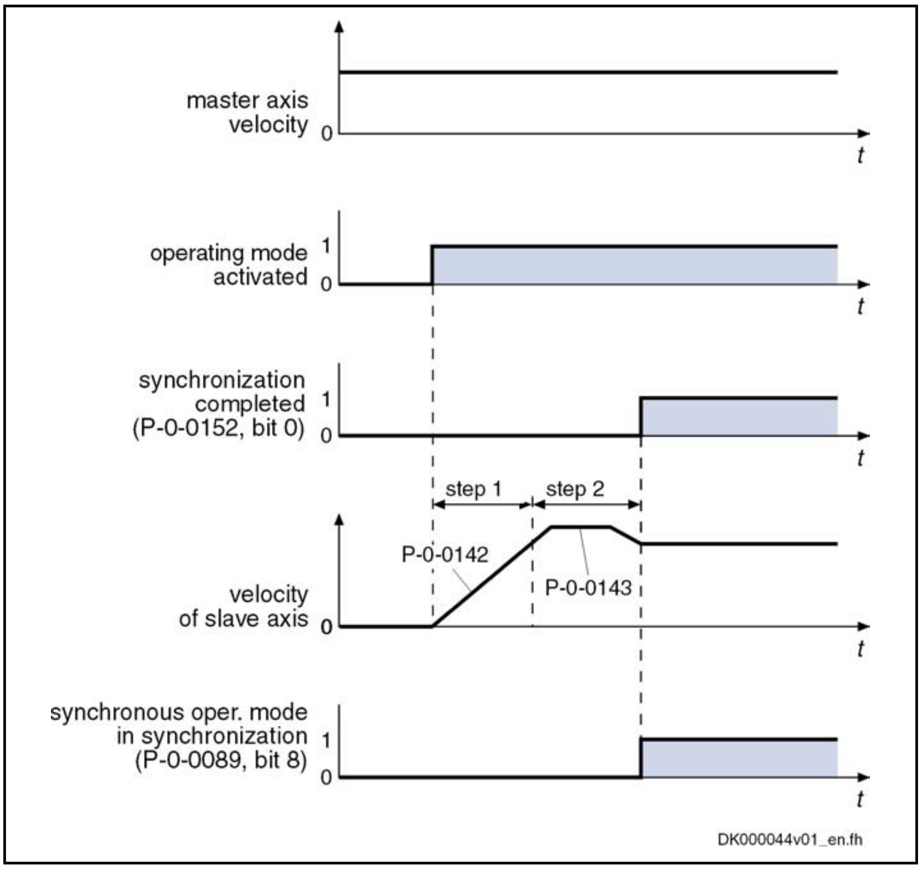
Fig.7-74: Example: Absolute Synchronization out of Standstill

- When the operating 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 master 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 operating mode is activated.



Step 1 Velocity adjustment
Step 2 Position adjustment
Fig.7-75: Example: Absolute Synchronization in Running Operation

- When the operating 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.

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)

"Standard" Mode

In the "standard" mode, all further changes in the value of parameter "S-0-0048, Additive position command value", after double-step synchronization, are 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 init 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 additional pos. command".

☞ The status bit "synchronization completed" is only set when the condition P-0-0434 = S-0-0048 + x_{sync} has been fulfilled.

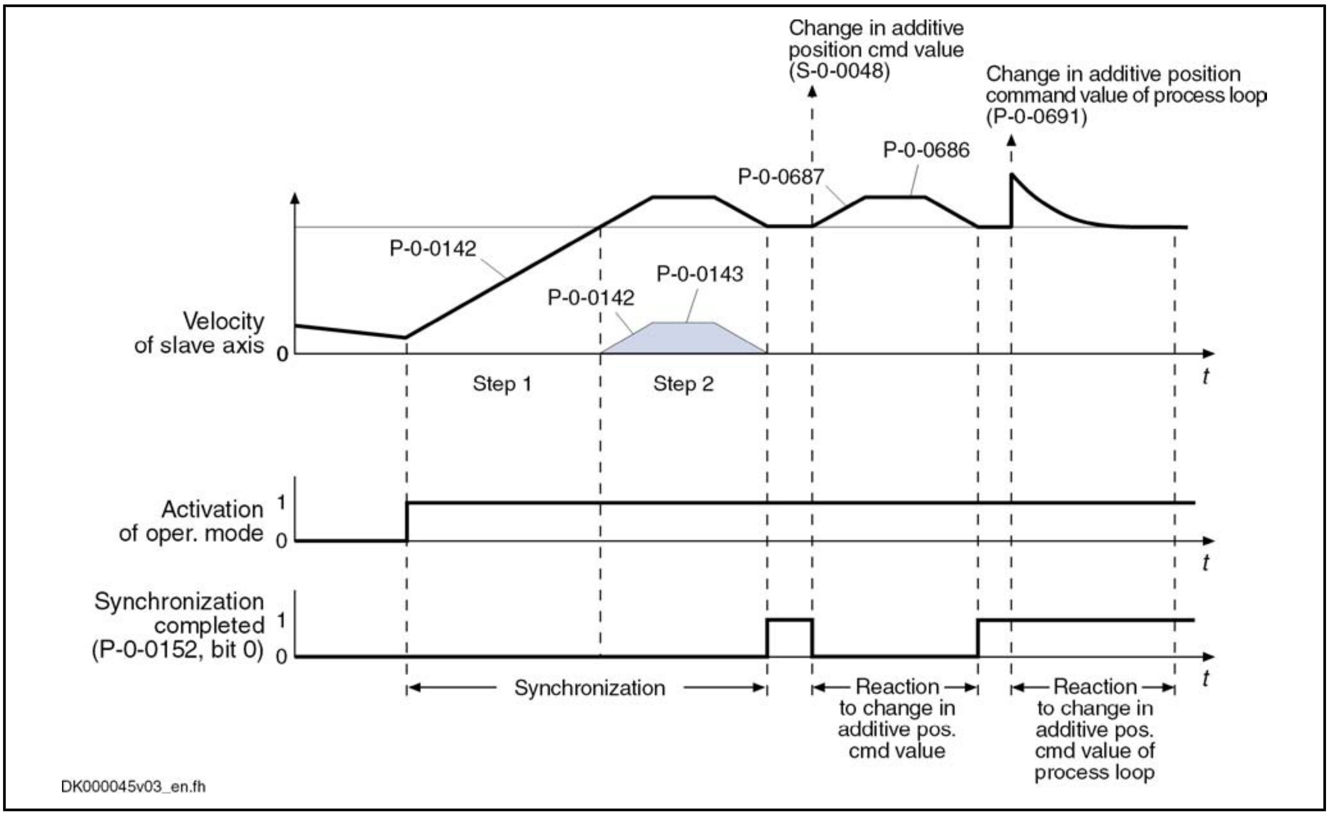


Fig.7-76: "Standard" Mode

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 smoothed by a 1st order filter. The time constant of the filter is set in parameter "P-0-0060, Filter time constant additional pos. command". 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 won't be cleared, even with further changes in "S-0-0048, Additive position command value" and "P-0-0691, Additive position command value, process loop".

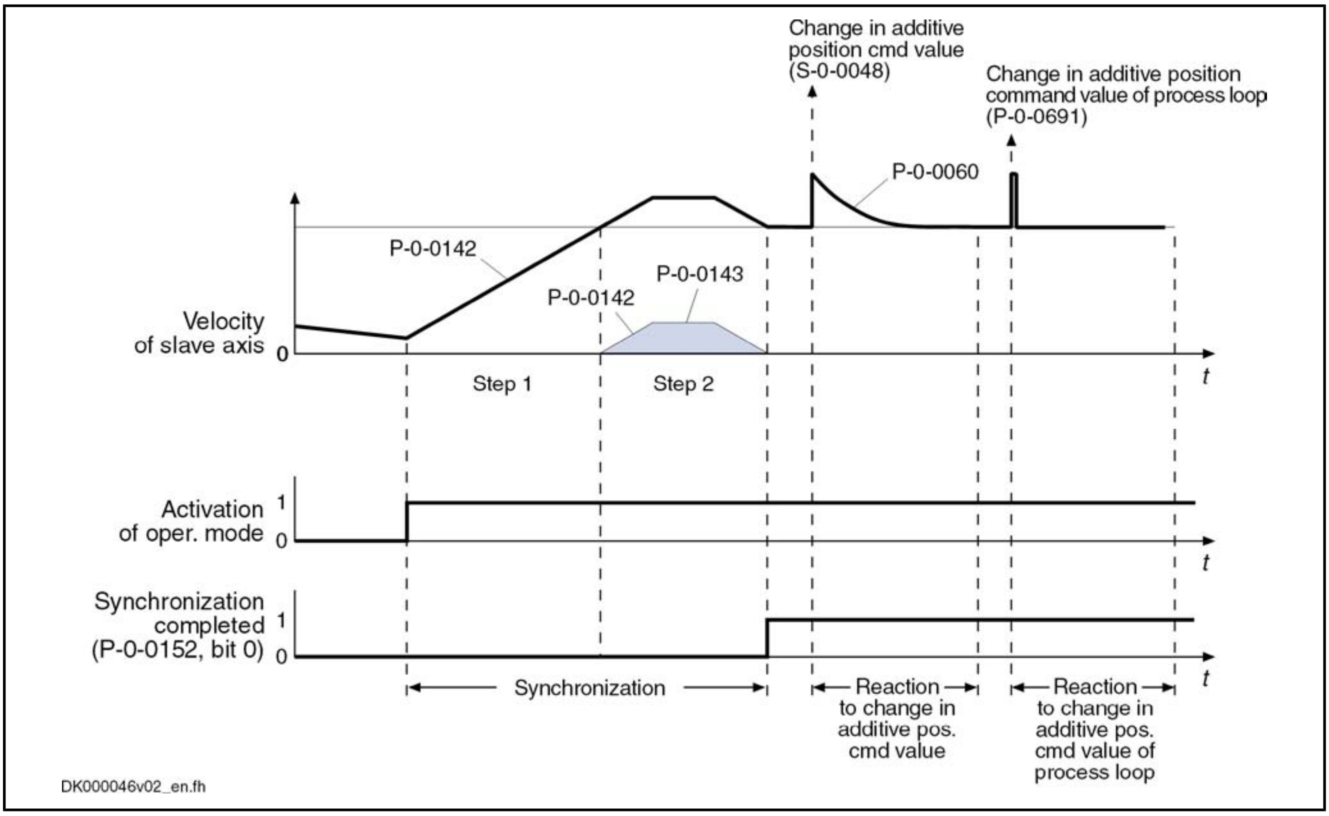


Fig.7-77: "Register Controller" Mode

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 messages "F2037 Excessive position command difference" or "F2039 Maximum acceleration exceeded" are 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

Extended Functions (Command Value Cycle and Actual Value Cycle)

Applications

The extended functions of synchronization (command value cycle and actual value cycle) are required in conjunction with the following applications:

- Change of format, i.e. variable master axis gear settings in operation
- Necessity of mechanical relation of slave axis to master axis

Command value cycle and actual value cycle are only relevant for the synchronization modes "phase synchronization", "cam shaft" and "motion profile".

The figure below illustrates the interaction of the pertinent parameters for the command value cycle and the actual value cycle:

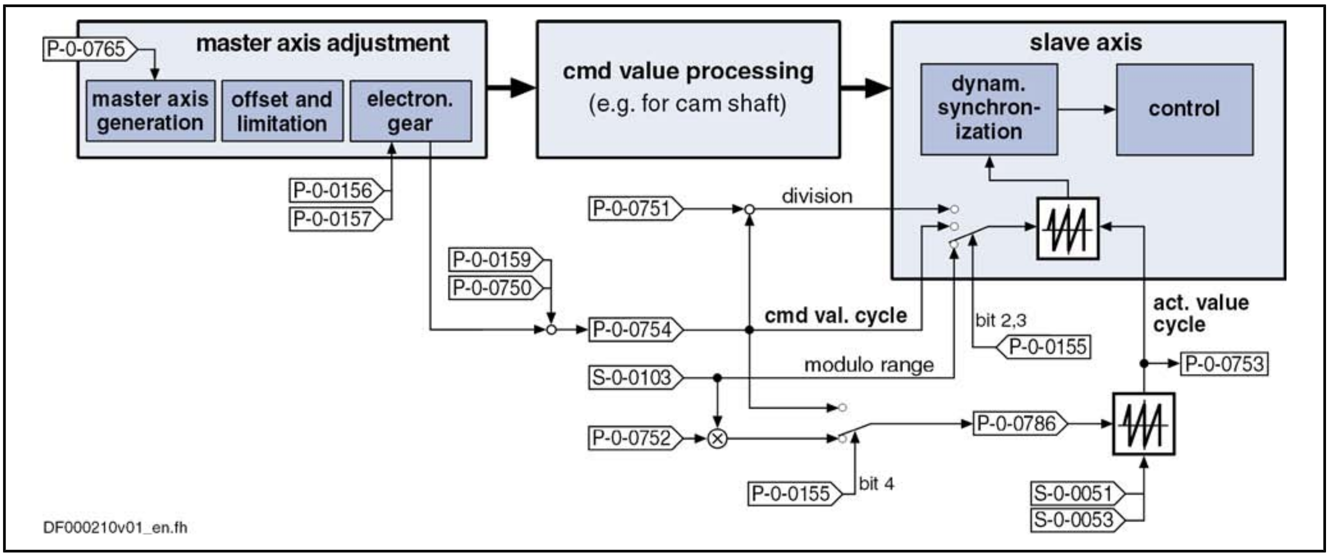


Fig.7-78: Generation and Operating Principle of the Command Value and Actual Value Cycle

Command Value Cycle

The command value cycle defines a modulo limitation of the synchronous position command values, which takes effect in a synchronous position control mode during synchronization, in the slave axis.

☞ The command value cycle is calculated internally by the drive and displayed in parameter "P-0-0754, Command value cycle".

$$\text{P-0-0754} = \frac{\text{P-0-0157}}{\text{P-0-0156}} \times \frac{\text{P-0-0750}}{\text{P-0-0159}}$$

Fig.7-79: Internal Calculation Formula of the Value for P-0-0754

Actual Value Cycle

In the case of modulo position scaling (S-0-0076, bit 7), the actual value cycle determines the modulo range of the actual position values at the slave axis relevant for the synchronization process.

☞ The actual value cycle is calculated internally by the drive and displayed 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 calculated internally by the drive and can be modified by means of the setting in "P-0-0752, Load revolutions per actual value cycle slave axis".

$$\text{P-0-0786} = \text{S-0-0103} \times \text{P-0-0752}$$

Fig.7-80: Internal Calculation Formula of the Value for P-0-0786

☞ The parameterization of the actual value cycle is required if, in the case of phase synchronization, synchronization is to be carried out in a range greater than the modulo value (S-0-0103).

Actual Position Value in Actual Value Cycle

In the case of "phase synchronization" or "cam shaft and modulo position scaling", the parameter "P-0-0753, Position actual value in actual value cycle" displays a current actual position value of the slave axis limited via P-0-0786.

When activating the operating mode for synchronization, the **travel distance for synchronization** is determined with the actual position value in the actual value cycle.

The value of P-0-0753 is again limited to the synchronization range which has been set (P-0-0754 or S-0-0103) and then is used as travel range for synchronization (see figure above).

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 from which the actual position value is derived must therefore be determined in such a way that is a multiple of the synchronization range.

By setting "P-0-0750, Master axis revolutions per master axis cycle" = 0, it is possible to select absolute handling of the master axis within a range of ± 2048 revolutions.

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, Position command value additional" + "P-0-0691 Additive position command value, process loop") and the actual position value. 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.7-81: Synchronization Distance During Synchronization in Command Value Cycle

The range for the command value cycle at the slave axis is defined by the master axis cycle and the electronic gear.

- **Modulo scaling**

For "phase synchronization" and "cam shaft without gear reduction" (P-0-0755 = 0):

$$\text{cmd value cycle} = \text{P-0-0750} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times \text{S-0-0103}$$

For "cam shaft with gear reduction" (P-0-0755 ≠ 0):

$$\text{cmd value cycle} = \text{P-0-0750} \times \frac{\text{P-0-0157} \times \text{S-0-0103}}{\text{P-0-0156} \times \text{P-0-0755}}$$

Fig.7-82: Command Value Cycle With Modulo Scaling

- **Linear modulo scaling**

For "path synchronization" and "cam shaft without gear reduction" (P-0-0755 = 0):

$$\text{cmd value cycle} = \text{P-0-0750} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times \text{P-0-0159}$$

For "cam shaft with gear reduction" (P-0-0755 ≠ 0):

$$\text{cmd value cycle} = \text{P-0-0750} \times \frac{\text{P-0-0157} \times \text{P-0-0159}}{\text{P-0-0156} \times \text{P-0-0755}}$$

Fig.7-83: Command Value Cycle With Linear Modulo Scaling

The active value is displayed in parameter "P-0-0754, Command value cycle". The command value cycle describes the range containing the calculated synchronous position command values.

For modulo division, the number of command value cycles per actual value cycle is used. The number is calculated with the following formula:

$$\text{Number of cmd value cycles} = \frac{\text{actual value cycle}}{\text{command value cycle}}$$

Fig.7-84: Number of Command Value Cycles per Actual Value Cycle

Synchronization in a Division of the Command Value Cycle

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ "S-0-0048, Position command value additional" + "P-0-0691 Additive position command value, process loop") and the actual position value. 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.7-85: Synchronization Distance for Synchronization in a Division of the Command Value Cycle

The actual position value in the division of the command value cycle is derived from "P-0-0753, Position actual value in actual value cycle". For modulo division, the number of divisions per actual value cycle is used. The number is calculated with the following formula:

$$\text{Number of divisions} = \text{P-0-0751} \times \frac{\text{actual value cycle}}{\text{command value cycle}}$$

Fig.7-86: Number of Synchronization Divisions per Actual Value Cycle

Synchronization in the Modulo Range

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ "S-0-0048, Position command value additional" + "P-0-0691 Additive position command value, process loop") and the actual position value. The synchronization distance is limited to the modulo value.

$$\text{Distance} = \text{\% modulo value} \left[x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - \text{actual position value} \right]$$

Fig.7-87: Synchronization Distance for Synchronization in Modulo Range

Notes on Usage and Parameterization

Selecting the Actual Value Cycle and Command Value Cycle

When using the command value cycle or actual value cycle, observe the following aspects:

- For synchronization, the actual position value in the command value cycle or a division of it is deduced from the actual position value in the actual value cycle by means of modulo division. In order to always have unequivocal values, the actual value cycle has to be an integer multiple of the command value cycle. Take this into account for the parameter setting of P-0-0752, P-0-0750, P-0-0751, P-0-0159 and P-0-0155!

- Take the value of parameter "P-0-0156, Master drive gear input revolutions" into account as a factor for determining the master axis cycle (P-0-0750).

  Note: 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 in parameter "P-0-0155, Synchronization mode".
- If several electronic gear ratios are to be set at an axis (e.g. because of different formats), there are several command value cycles resulting at this axis. The actual value cycle then has to be set in such a way that it complies with the least common multiple (LCM) of these command value cycles (P-0-0155; bit 4 = 0).
- If the electronic gear is not to be changed, the actual value cycle is set in such a way that it complies with the command value cycle or a multiple of it.
- If synchronization is to be carried out only within the modulo range, the number of load revolutions per actual value cycle of the slave axis can be set to "1".

Establishing the Position Data Reference

"P-0-0753, Position actual value in actual value cycle" is set by

- the command "set absolute measuring",
- "drive-controlled homing" for the actual position value which was selected in the synchronization mode that has been set.

If, for example, the operating mode "phase synchronization with virtual master axis, encoder 1" has been set, 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 actual position value in actual value cycle is displayed in bit 4 of parameter "P-0-0089, Status word for synchronous operating modes".

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 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 for synchronous operating 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":

$$\text{P-0-0786} = \text{S-0-0103} \times \text{P-0-0752}$$

Fig.7-88: "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:

For "phase synchronization" and "cam shaft without gear reduction" (P-0-0755 = 0):

$$\text{actual value cycle (P-0-0786)} = \text{P-0-0750} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times \text{S-0-0159}$$

For "cam shaft 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.7-89: "Modulo Value Actual Value Cycle" With Modulo Scaling and P-0-0155, Bit 4 = 1

Synchronization Direction

In the case of absolute position scaling, the calculated synchronization distance is always traveled. The setting in parameters "P-0-0154, Synchronization direction" and "P-0-0151, Synchronization window for modulo format" is **not** taken into account.

For modulo axes, the distance is limited to +/-0.5 × synchronization range. In addition, the setting in parameters "P-0-0154, Synchronization direction" and "P-0-0151, Synchronization window for modulo format" is 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.

Absolute synchronization is only possible up to ± 2048 revolutions, because the max. master axis encoder range is only 2^{32} 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 Switch"

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.7-90: Synchronization Distance With Absolute Scaling

☞ The synchronization range corresponds to the maximum travel range.

☞ When the "register controller" mode (P-0-0155, bit 0 = 1) has been activated, it isn't possible any more to switch back to the "standard" mode (P-0-0155, bit 0 = 0).

Diagnostic and Status Messages

Status Messages

In addition to some status and display parameters that are valid for all operating modes, the parameters "P-0-0089, Status word for synchronous operating 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 for synchronous operating 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:

$$\left| dx_{sync} + (\text{S-0-0037}) + (\text{P-0-0690}) - (\text{S-0-0040}) \right| < \text{S-0-0183}$$

Fig.7-91: Condition for "Slave Axis has Been Synchronized" in the Case of Velocity Synchronization

In the case of synchronous position control modes:

$$\left| x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - (\text{P-0-0753}) \right| < \text{S-0-0228}$$

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 shaft":

- 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 operating 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:

- E2047 Interpolation velocity = 0
- E2048 Interpolation acceleration = 0
- E2049 Positioning velocity >= limit value
- E2063 Velocity command value > limit value

Diagnostic messages for errors:

- F2005 Cam shaft invalid
- F2037 Excessive position command difference
- F2039 Maximum acceleration exceeded

7.8.2 Velocity Synchronization With Real/Virtual Master Axis

Brief Description

Expansion package **synchronization** (order code **SNC**) for the variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.7-93: Assignment to Functional Firmware Package

In the operating mode "velocity synchronization with real/virtual master axis"", the drive follows a preset master axis velocity in a velocity-synchronous way.

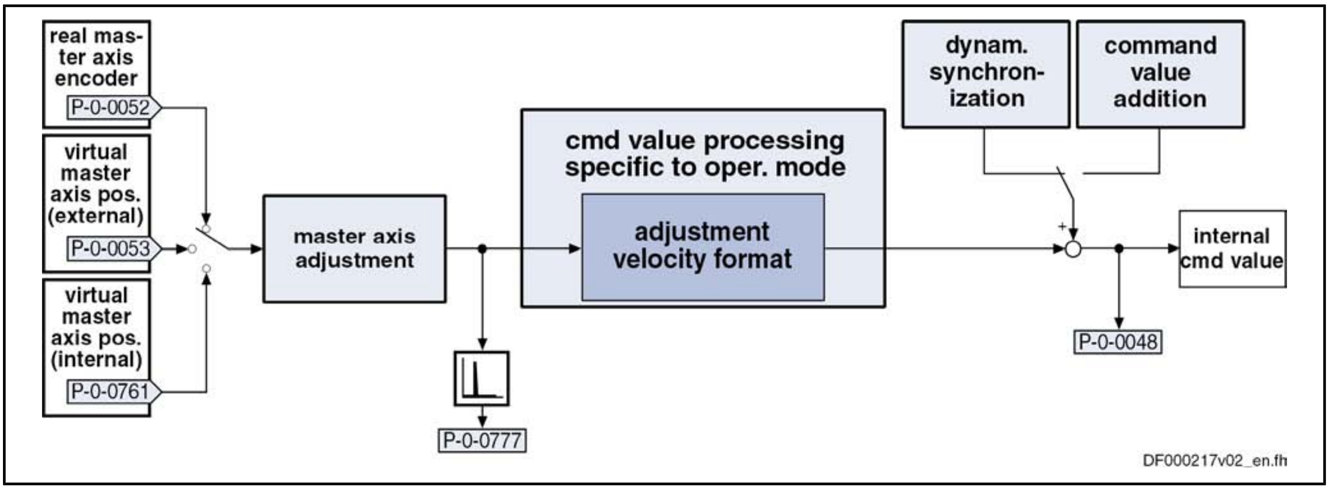
The real master axis velocity is generated by a measuring encoder, the virtual master axis velocity is preset by the master or the integrated master axis generator.

See also "Dynamic Synchronization of the Slave Axis" in 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, Additive master axis position, process loop", multiplied with master axis gear and fine adjustment
- Adjustable master axis polarity
- Synchronization takes place in single-step form
- Activation time for synchronization can be selected

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-0-0761	Master axis position for slave axis
P-0-0777	Effective master axis velocity

Fig.7-94: Function Blocks of the Operating Mode "Velocity Synchronization With Real/Virtual Master Axis"

Variants of the Operating Mode

There are the following variants of the operating mode to be selected:

- Velocity synchronization with real master axis
- Velocity synchronization with virtual master axis

Application of the Operating 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-0-0103, Modulo value
- S-0-0183, Velocity synchronization window
- P-0-0088, Control word for synchronous operation modes
- P-0-0089, Status word for synchronous operating modes
- P-0-0159, Slave drive feed travel
- 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 Operating Mode

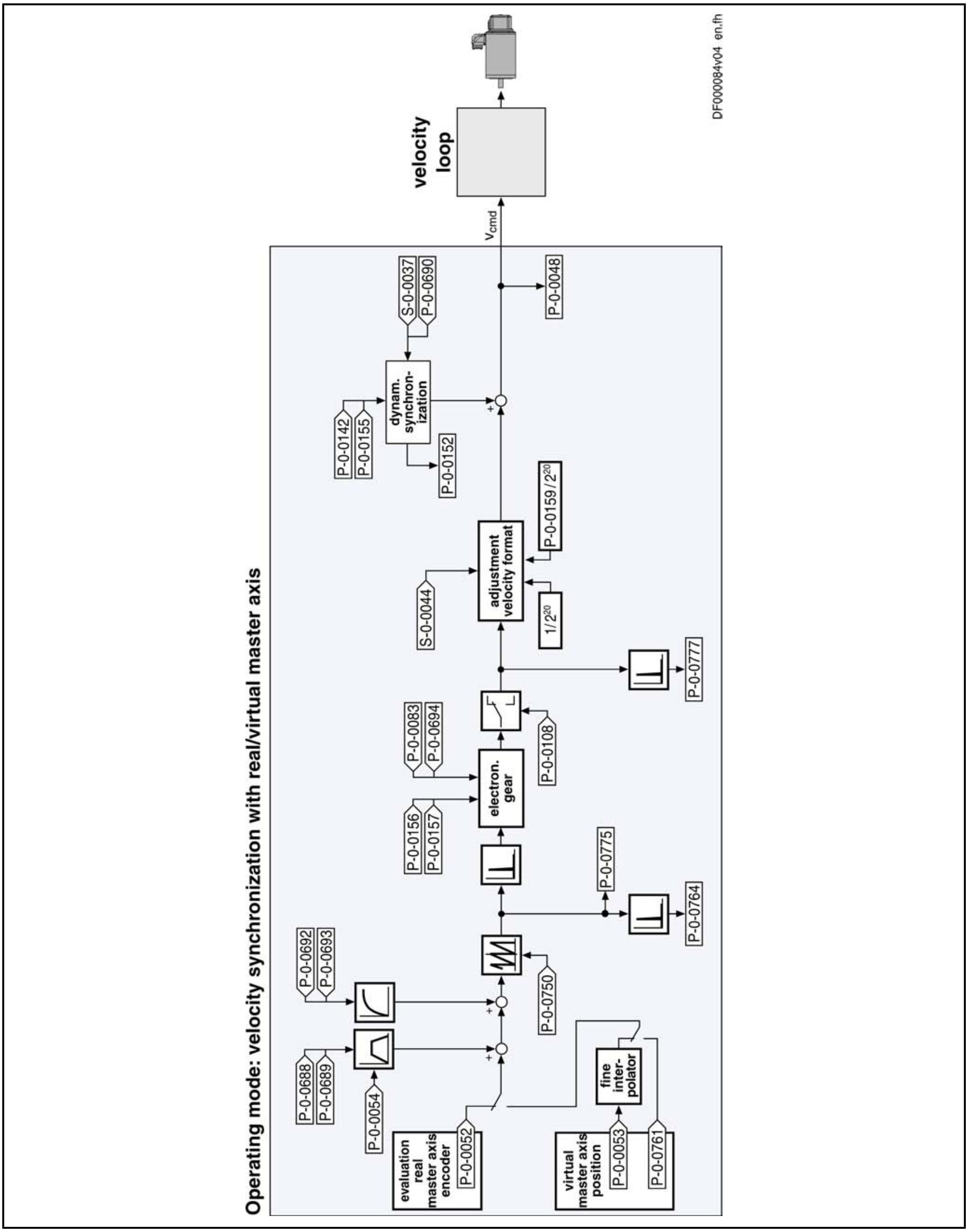


Fig.7-95: Block Diagram: Velocity Synchronization With Real/Virtual Master Axis

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 gear with fine adjust

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 operating 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"

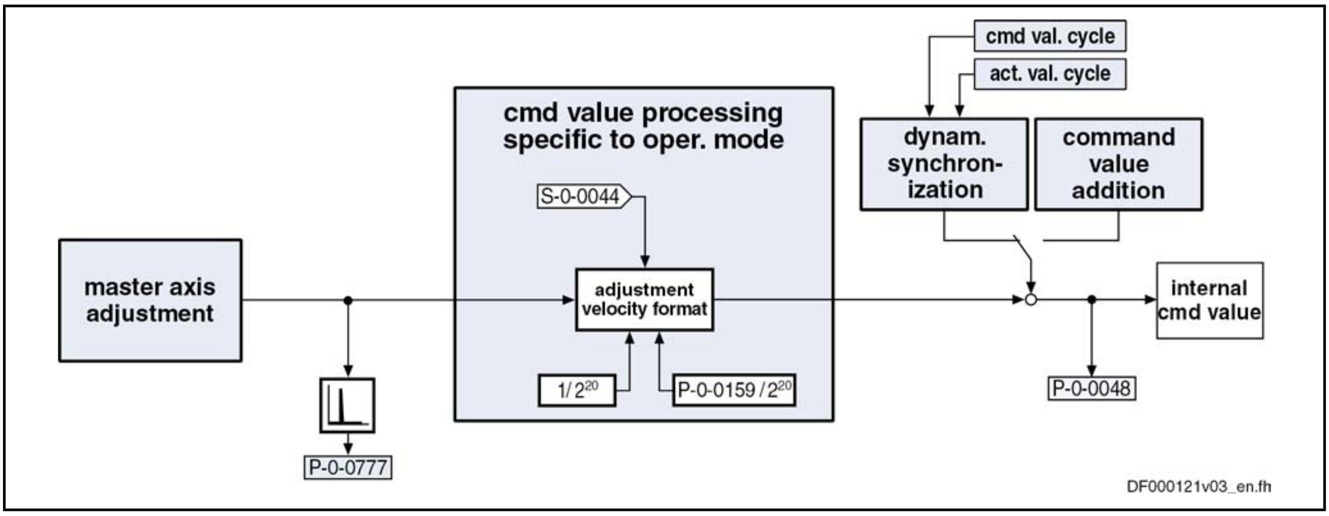


Fig. 7-96: Command Value Processing Specific to Operating Mode for Velocity Synchronization

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:

$$dx_{sync} = \pm\Delta\ [(P\text{-}0\text{-}0053) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)] \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times [1 + (P\text{-}0\text{-}0083)] \times [1 + (P\text{-}0\text{-}0694)] \times \frac{1}{2^{20}}$$

dx_{sync} Synchronous velocity command value

Fig. 7-97: Generating the Synchronous Velocity Command Value With Rotary Scaling

$$dx_{sync} = \pm\Delta\ [(P\text{-}0\text{-}0053) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)] \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times [1 + (P\text{-}0\text{-}0083)] \times [1 + (P\text{-}0\text{-}0694)] \times \frac{P\text{-}0\text{-}0159}{2^{20}}$$

dx_{sync} Synchronous velocity command value

Fig.7-98: Generating the Synchronous Velocity Command Value With Linear Scaling

As a standard, one master axis revolution is fixed at 2^{20} increments. This means that the LSB of the master axis position corresponds to 2^{-20} 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.7-99: Condition for Velocity Synchronism of the Slave Axis

Synchronization Process

Upon activation of the operating mode, a **velocity adjustment** is first executed.

This means that the drive either accelerates or decelerates from the current actual velocity at the time of activation to the synchronous velocity.

The drive generates the synchronous velocity by differentiating the master axis position:

$$\Delta\ [(P\text{-}0\text{-}0053) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)]$$

-or-

$$\Delta\ [(P\text{-}0\text{-}0052) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)]$$

Fig.7-100: Drive-Side Generation of 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"

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 Operating Mode

Sequence of parameterization specific to operating 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 2047 × 2^{20} increments. In the special case P-0-0750 = 0, the master axis range is from –(2^{31}) to (2^{31})-1.
2. The distance that the slave axis covers per master axis revolution is determined in parameter "P-0-0159, Slave drive feed travel".
3. Settings for the electronic gear are made in the following parameters:
   - P-0-0083, Gear ratio fine adjust
   - P-0-0108, Master drive polarity
   - P-0-0156, Master drive gear input revolutions
   - P-0-0157, Master drive gear output revolutions
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 operating 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 operating mode:

- E2063 Velocity command value > limit value

There are also several status messages specific to operating mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word for synchronous operating modes" and "P-0-0152, Synchronization completed").

7.8.3 Phase Synchronization With Real/Virtual Master Axis

Brief Description

Expansion package **synchronization** (order code **SNC**) for the variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.7-101: Assignment to Functional Firmware Package

In the operating mode "phase synchronization with real/virtual master axis", the drive follows a preset master axis position in an absolute or relative phase synchronous way.

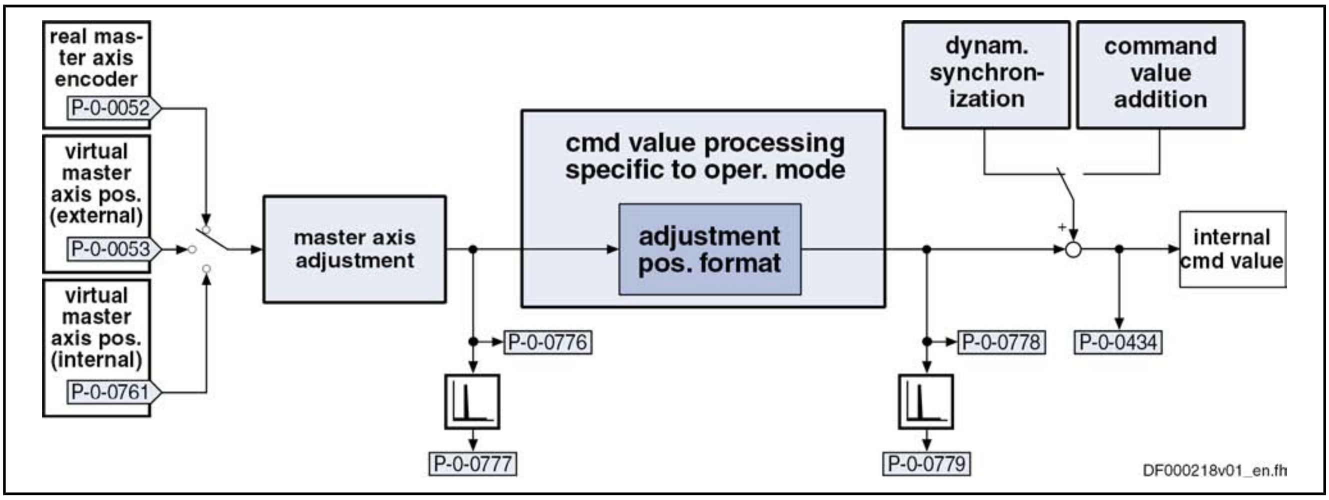
The real master axis velocity is generated by a measuring encoder, the virtual master axis velocity is preset by the master or the integrated master axis generator.

See also "Dynamic Synchronization of the Slave Axis" in 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 adjust, adjustable master axis polarity
- Synchronization mode to be selected
- Single-step or 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-0-0434	Position command value of controller
P-0-0761	Master axis position for slave axis
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.7-102: Function Blocks of the Operating Mode "Phase Synchronization With Real/Virtual Master Axis"

Variants of the Operating Mode

There are the following variants of the operating mode to be selected:

- Position 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

☞ In the operating mode variant "position synchronization", select phase synchronization and the master axis in "P-0-0088, Control word for synchronous operation modes". The encoder selection and lagless position control are set in "S-0-0520, Control word of axis controller".

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 operating mode "phase synchronization". 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, Control word of axis controller
- S-0-0521, Status word of position loop
- P-0-0086, Configuration word synchronous operating modes
- P-0-0088, Control word for synchronous operation modes
- P-0-0089, Status word for synchronous operating 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"

Pertinent Diagnostic Messages

In addition to the general diagnostic messages of all synchronization modes, there are other diagnostic messages involved in phase synchronization:

- 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

See also "Pertinent Diagnostic Messages" in the subsections of "Basic Functions of the Synchronization Modes"

Operating Modes

Overview of the Operating Mode

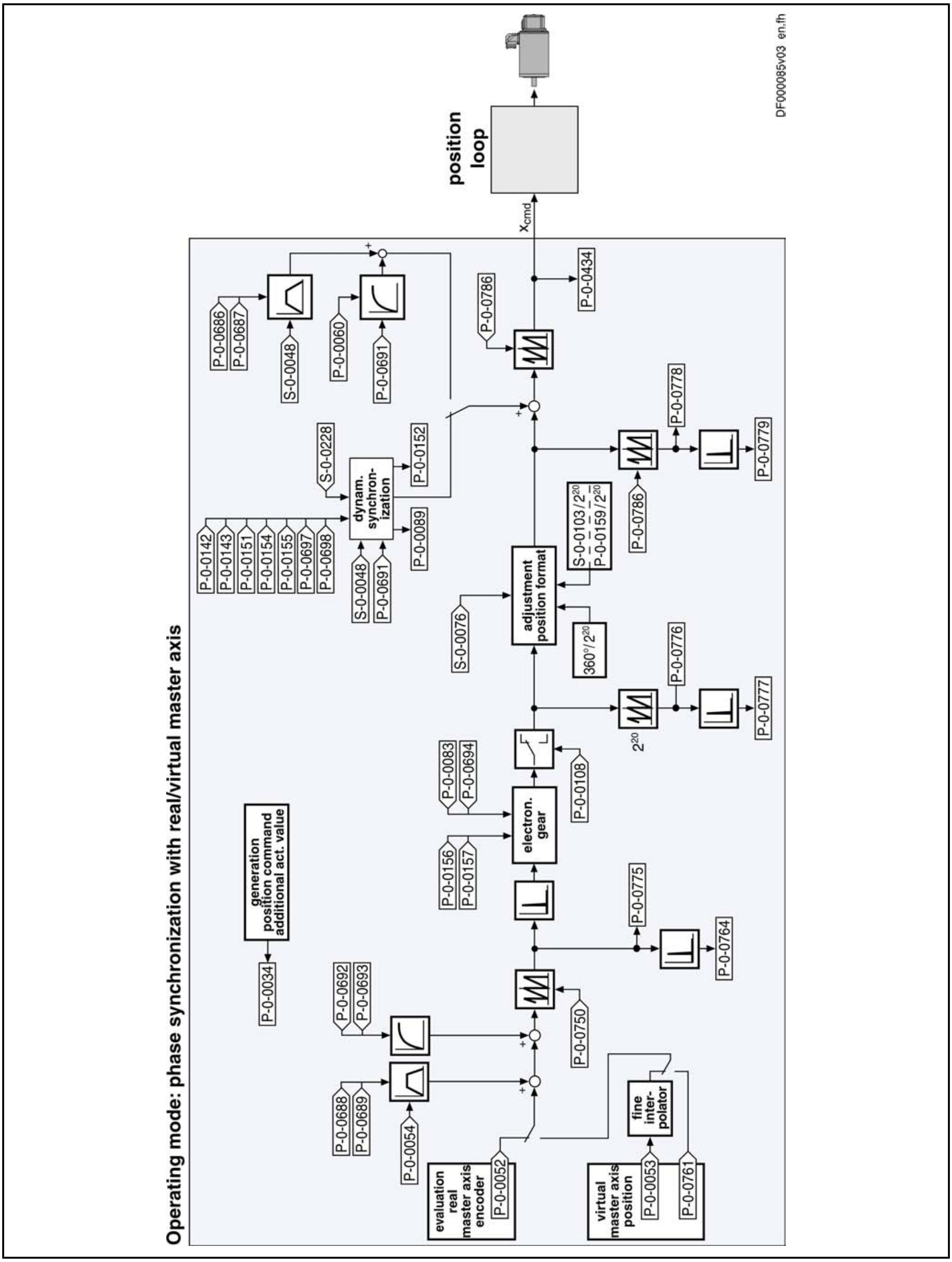


Fig.7-103: Block Diagram: Phase Synchronization With Real/Virtual Master Axis

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 gear with fine adjust

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 operating 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"

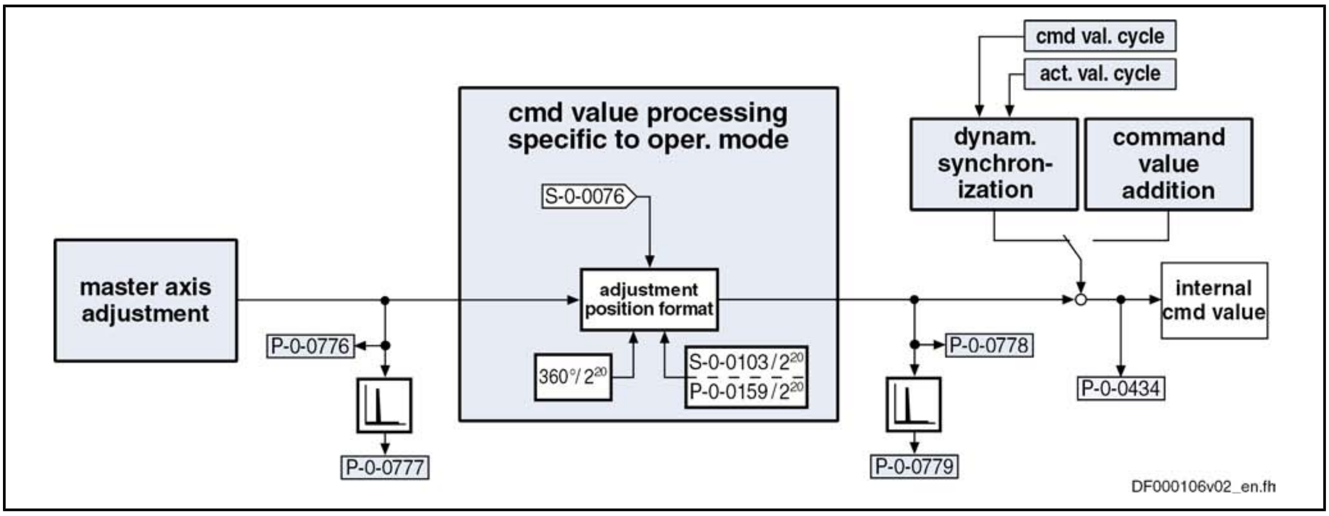


Fig. 7-104: Command Value Processing Specific to Operating Mode for Phase Synchronization

Generating the Internal Position Command Value

In the operating 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 loop (P-0-0691).

$$P\text{-}0\text{-}0434 = x_{sync} + x_{add} + x_{add\_PR}$$

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.7-105: Generating the Internal Position Command Value

Note: In the synchronized status (P-0-0089; bit 8 = 1), the following applies:

$$P\text{-}0\text{-}0434 = x_{sync} + (S\text{-}0\text{-}0048) + (P\text{-}0\text{-}0691)$$

Fig.7-106: Generating the Internal Position Command Value in the Synchronized Status

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:

$$x_{sync} = \left\langle P\text{-}0\text{-}0775 \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times \left[1 + (P\text{-}0\text{-}0083)\right] \times \left[1 + (P\text{-}0\text{-}0694)\right] \times \frac{S\text{-}0\text{-}0103}{2^{20}} \right\rangle \% \, P\text{-}0\text{-}0786$$

Fig.7-107: Generating the Synchronous Position Command Value With Modulo Scaling

$$x_{sync} = \left\langle P\text{-}0\text{-}0775 \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times \left[1 + (P\text{-}0\text{-}0083)\right] \times \left[1 + (P\text{-}0\text{-}0694)\right] \times \frac{360\,^\circ}{2^{20}} \right\rangle \% \, P\text{-}0\text{-}0786$$

Fig.7-108: Generating the Synchronous Position Command Value With Rotary Absolute Scaling

$$x_{sync} = \left\langle P\text{-}0\text{-}0775 \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times \left[1 + (P\text{-}0\text{-}0083)\right] \times \left[1 + (P\text{-}0\text{-}0694)\right] \times \frac{P\text{-}0\text{-}0159}{2^{20}} \right\rangle \% \, P\text{-}0\text{-}0786$$

Fig.7-109: Generating the Synchronous Position Command Value With Linear Absolute Scaling

☞ As a standard, one master axis revolution is fixed at 2^{20} increments. This means that the LSB of the master axis position corresponds to 2^{-20} 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" 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. Set the actual value cycle greater than or equal to the modulo range (S-0-0103).

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 2047 × 2^{20} increments. In the special case P-0-0750 = 0, the master axis range is from –(2^{31}) to (2^{31})-1. This case is used, among other things, for the "flying saw" application. The actual value cycle in which "P-0-0753, Position actual value in actual value cycle" is contained, then has to be selected in such a way that the synchronous position data generated by the determined master axis cycle can be displayed.

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 Gear

   Settings for the electronic gear are made in the following parameters:

   - P-0-0083, Gear ratio fine adjust
   - P-0-0694, Gear ratio fine adjust, 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. "Modulo" 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)
   - 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" 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 2047 × 2^{20} increments. In the special case P-0-0750 = 0, the master axis range is from –(2^{31}) to (2^{31})-1. This case is used, among other things, for the "flying saw" application. The actual value cycle in which "P-0-0753, Position actual value in actual value cycle" is contained, then has to be selected in such a way that the synchronous position data generated by the determined master axis cycle can be displayed.

3. "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.

   Note: 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 Switch")!

4. Slave Drive Feed Travel

   The distance that the slave axis covers per master axis revolution is determined in parameter "P-0-0159, Slave drive feed travel".

5. Electronic Gear

   Settings for the electronic gear are made in the following parameters:

   - P-0-0083, Gear ratio fine adjust
   - P-0-0694, Gear ratio fine adjust, 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. "Absolute" 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)

Commissioning Summary

The figure below illustrates the basic sequence of commissioning.

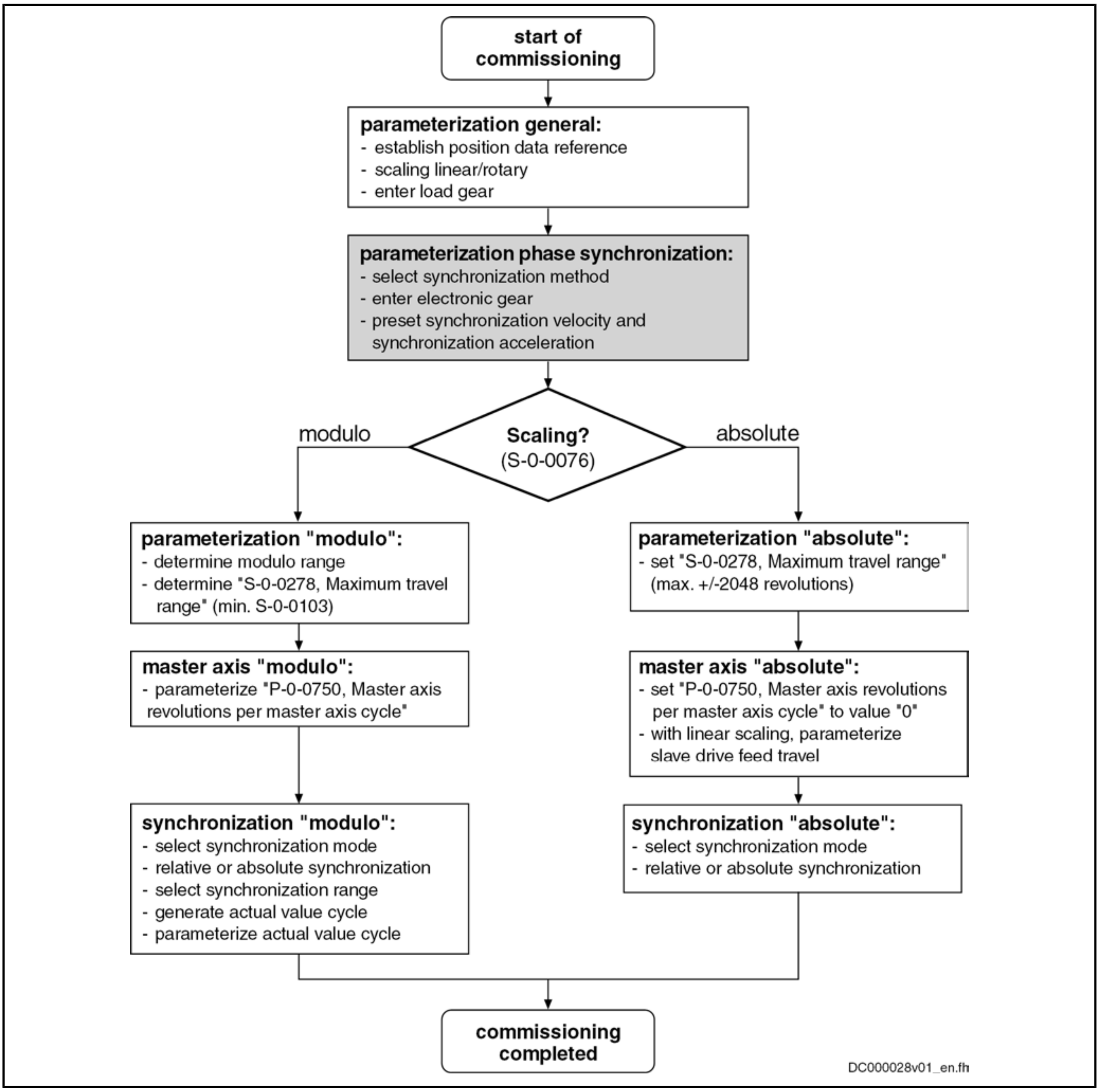


Fig.7-110: Overview of Commissioning Steps for Phase Synchronization

Diagnostic and Status Messages

Diagnostic Status Messages

The following diagnostic status messages are displayed in normal operation of the operating 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 operating mode:

- F2039 Maximum acceleration exceeded

  → The preset acceleration value of two successive command values was greater than the value parameterized in "S-0-0138, Bipolar acceleration limit value".

- F2037 Excessive position command difference

  → The velocity preset for the drive by two successive command values is greater than the value in "S-0-0091, Bipolar velocity limit value".

Status Bits

There are also several status messages specific to operating mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word for synchronous operating modes" and "P-0-0152, Synchronization completed").

Position Loop Status

The status display via the control encoder and for lagless operation or operation with lag error takes place in parameter "S-0-0521, Status word of position loop".

7.8.4 Electronic Cam Shaft With Real/Virtual Master Axis

Brief Description

Expansion package **synchronization** (order code **SNC**) for the variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.7-111: Assignment to Functional Firmware Package

In the operating mode "electronic cam shaft with real/virtual master axis", there is a fixed relationship between the master axis position and the slave axis.

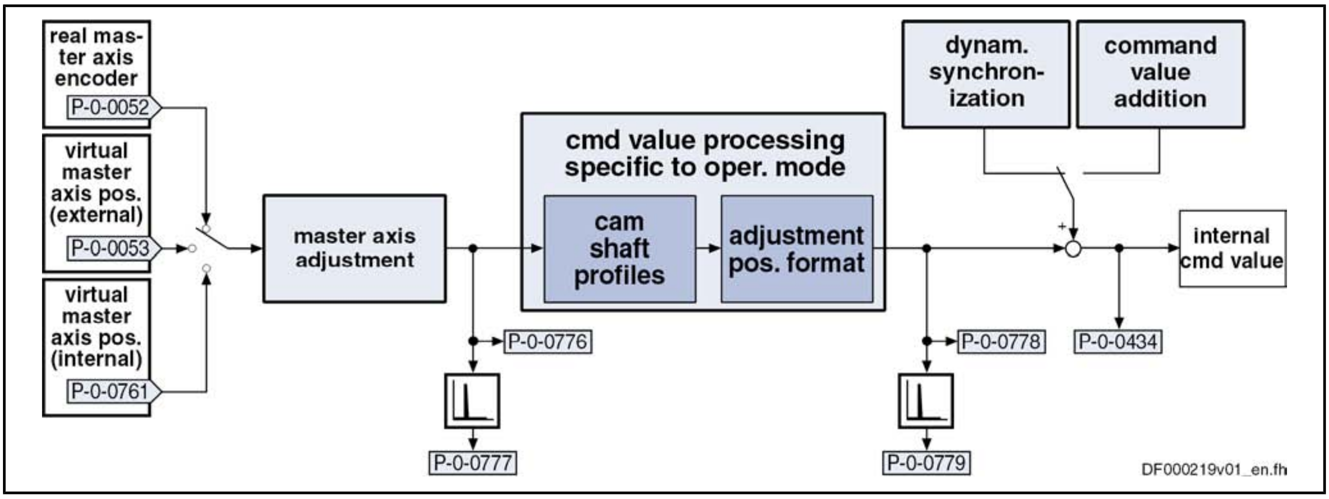
The real master axis velocity is generated by a measuring encoder, the virtual master axis velocity is preset by the master or the integrated master axis generator.

See also "Dynamic Synchronization of the Slave Axis" in section "Basic Functions of the Synchronization Modes"

Features

- 4 cam shaft profiles with a max. of 1024 data points (P-0-0072, P-0-0092, P-0-0780, P-0-0781)
- 4 cam shaft profiles 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 shaft data points
- Dynamic angle offset and angle offset at begin of profile
- Freely definable switch angle for cam shaft and cam shaft distance
- Synchronization mode to be selected
- Single-step or 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 shaft" mode:



P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0434	Position command value of controller
P-0-0761	Master axis position for slave axis
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.7-112: Function Blocks of the Operating Mode "Electronic Cam Shaft"

Variants of the Operating Mode

There are the following variants of the operating mode to be selected:

- Position synchronization
- Cam shaft with real master axis, encoder 1
- Cam shaft with real master axis, encoder 2
- Cam shaft with real master axis, encoder 1, lagless
- Cam shaft with real master axis, encoder 2, lagless
- Cam shaft with virtual master axis, encoder 1
- Cam shaft with virtual master axis, encoder 2
- Cam shaft with virtual master axis, encoder 1, lagless
- Cam shaft with virtual master axis, encoder 2, lagless

☞ In the operating mode variant "position synchronization", select the electronic cam shaft and the master axis in "P-0-0088, Control word for synchronous operation modes". The encoder selection and lag-less position control are set in "S-0-0520, Control word of axis controller".

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in this operating mode:

- S-0-0103, Modulo value
- S-0-0520, Control word of axis controller
- S-0-0521, Status word of position loop
- P-0-0061, Angle offset begin of profile
- P-0-0072, Cam shaft profile 1
- P-0-0073, Cam shaft distance 2
- P-0-0085, Dynamic angle offset

- P-0-0086, Configuration word synchronous operating modes
- P-0-0088, Control word for synchronous operation modes
- P-0-0089, Status word for synchronous operating modes
- P-0-0092, Cam shaft profile 2
- P-0-0093, Cam shaft distance
- P-0-0094, Cam shaft switch angle
- P-0-0144, Cam shaft distance switch angle
- P-0-0158, Angle offset change rate
- P-0-0159, Slave drive feed travel
- P-0-0227, Cam shaft profile, access angle
- P-0-0695, Angle offset begin of profile, 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 shaft profile 3
- P-0-0781, Cam shaft profile 4
- P-0-0782, Cam shaft profile 5
- P-0-0783, Cam shaft profile 6
- P-0-0784, Cam shaft profile 7
- P-0-0785, Cam shaft profile 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 operating mode:

- A0128 Cam shaft, encoder 1, virtual master axis
- A0129 Cam shaft, encoder 2, virtual master axis
- A0130 Cam shaft, encoder 1, real master axis
- A0131 Cam shaft, encoder 2, real master axis
- A0132 Cam shaft, lagless, encoder 1, virt. master axis
- A0132 Cam shaft, lagless, encoder 2, virt. master axis
- A0134 Cam shaft, lagless, encoder 1, real master axis
- A0135 Cam shaft, lagless, encoder 2, real master axis
- A0163 Position synchronization
- F2005 Cam shaft invalid

See also "Pertinent Diagnostic Messages" in the subsections of "Basic Functions of the Synchronization Modes"

Overview of the Operating Mode

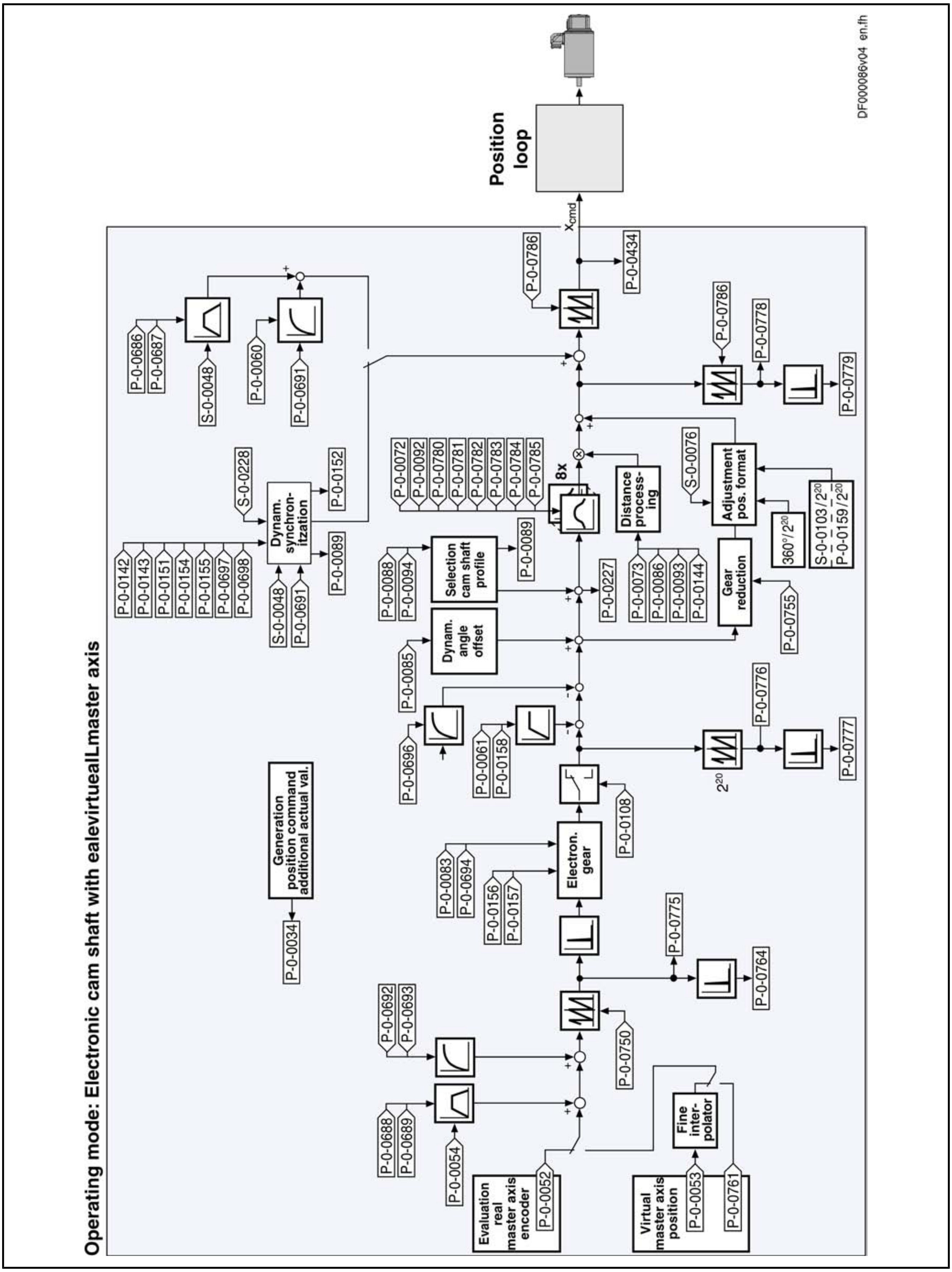


Fig.7-113: Block Diagram: Electronic Cam Shaft With Real/Virtual Master Axis

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 gear with fine adjust

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "electronic cam shaft" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operating mode, consisting of
  - Cam shaft profiles (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 shaft 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"

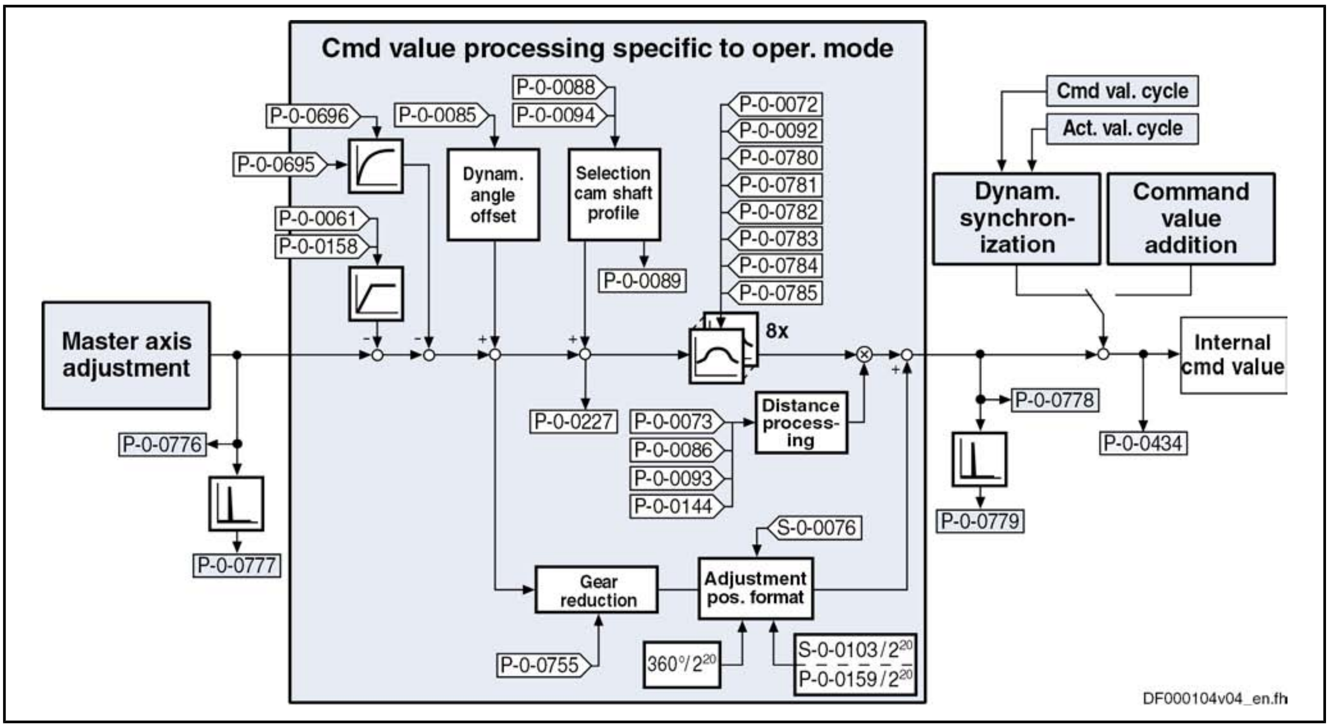


Fig.7-114: Command Value Processing Specific to Operating Mode for Cam Shaft Mode

Generating the Internal Position Command Value

In the operating mode "electronic cam shaft 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.7-115: Generating the Internal Position Command Value

Note: In the synchronized status (P-0-0089; bit 8 = 1), the following applies:

$$\text{P-0-0434} = x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691})$$

Fig.7-116: Generating the Internal Position Command Value in the Synchronized Status

In the function block "command value processing specific to operating mode" the calculations specific to the cam shaft mode are carried out for generating the synchronous position command value.

Depending on "P-0-0061, Angle offset begin of profile" and "P-0-0695, Angle offset begin of profile, process loop", an interpolated profile value is taken from the cam shaft profiles in every control cycle and the difference to the last interpolated profile value is multiplied by the cam shaft distance. The result is added to the position command value.

If the phase-synchronous path has been activated by bit 4 of parameter "P-0-0086, Configuration word synchronous operating modes", the master axis position at the output of the electronic gear 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 profile limit is exceeded in positive direction, the profile 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 operating mode "electronic cam shaft with real/virtual master axis", the position command value of the drive is first initialized in terms of the following relation:

$$x_{F(\varphi L)} = \left[h \times tab(\varphi_{ZGW}) + \frac{\varphi_{ZGW}}{U} + x_V + x_{VPR} \right] \% \, IWZ$$

x_F	Position command value of slave drive (P-0-0434)
ϕL	Resulting master axis position (P-0-0775)
h	Cam shaft distance (P-0-0093 or P-0-0073)
tab(ϕ)	Cam shaft profiles (P-0072, P-0-0092, P-0-0780, P-0-0781)
ϕ_{ZGW}	Profile access angle
U	Gear reduction (P-0-0755)
x_V	Additive position command value (S-0-0048)
x_{VPR}	Additive position command value, process loop (P-0-0691)
IWZ	Modulo actual value cycle (P-0-0786)

Fig.7-117: Initializing the Position Command Value

$$\varphi_{ZGW} = \pm \varphi_L \times \frac{G_a}{G_e} \times (1+F) \times (1+F_{PR}) - \varphi_V - \varphi_{VPR}$$

ϕ_{ZGW}	Profile 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 adjust (P-0-0083)
F_{PR}	Gear ratio fine adjust, process loop (P-0-0694)
ϕ_V	Angle offset begin of profile (P-0-0061)
ϕ_{VPR}	Angle offset begin of profile, process loop (P-0-0695)

Fig.7-118: Determining the Profile Access Angle

☞ With the operating mode activated, differences, that later on will be added again, are processed in the electronic gear and the cam shaft profiles. Therefore, changes in the electronic gear and the cam shaft distance do not cause position command value jumps. Velocity jumps, however, can occur and the absolute position reference, established when activating the operating mode, is lost.

Accessing the Cam Shaft Profile

In every position loop cycle (Advanced: 250 µs, Basic: T = 500 µs), an interpolated profile value is taken from the activated cam shaft profile, the difference to the last interpolated profile value is generated and a multiplication with the cam shaft distance is carried out. The result is added to the position command value.

Cubic spline interpolation takes place between the profile values.

☞ With an infinite cam shaft, the difference between initial value and final value of the cam shaft profile is 100%.

Calculating the Internal Position Command Value (in Cyclic Operation)

The position command value is generated as per the following relation:

$$x_{F(n)(\varphi L)} = \left\langle x_{F(n-1)(\varphi L)} + \left[h \times \Delta tab(\pm \varphi_L) \times \frac{G_a}{G_e} - \varphi_V + \varphi_d \right] \pm \Delta\varphi_L \times \left[\frac{G_a}{G_e} \times (1+F) - \frac{\varphi_V}{U} + x_V \right] \right\rangle \% \, IWZ$$

x_F	Position command value of slave drive (P-0-0434)
ϕ_L	Resulting master axis position (P-0-0775)
h	Cam shaft distance (P-0-0093 or P-0-0073)
tab(ϕ)	Cam shaft profiles (P-0-0072, P-0-0092, P-0-0780, P-0-0781)
+/-	Master drive polarity (P-0-0108)
G_a	Master drive gear output revolutions (P-0-0157)
G_e	Master drive gear input revolutions (P-0-0156)
ϕ_V	Angle offset begin of profile (P-0-0061+ P-0-0695)
ϕ_d	Dynamic angle offset (P-0-0085)
F	Fine adjust (P-0-0083)
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.7-119: 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 Active Cam Shaft

Select and acknowledge the active cam shaft profile:

- The active cam shaft profile (P-0-0072, P-0-0092, P-0-0780 to P-0-0785) is selected with parameters "P-0-0088, Control word for synchronous operating modes" and "P-0-0094, Cam shaft switch angle".
- The active cam shaft is included in parameter "P-0-0089, Status word for synchronous operating modes". Switching of the cam shaft 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 shaft 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 shaft profile can be superimposed. When using an infinite cam shaft profile (difference between first and last profile value > 50%), a small error can occur with each profile sequence. Exception: Cam shaft distance corresponds to modulo value (S-0-0103).

☞ When cam shafts are used with a difference between the profile values of two cam shaft elements > 50%, the "linear cam shaft interpolation" must be activated (P-0-0086, bit 7 = 1). An exception is a difference of > 50% between the first and the last profile value of one cam shaft.

Parameterizing the Cam Shaft Distance

Parameterize the cam shaft distance:

- Parameter "P-0-0144, Cam shaft distance switch angle" defines at which profile access angle and thus profile element a change in value becomes effective for "P-0-0093, Cam shaft distance". If the profile 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 operating modes", select with bits 0 and 1 whether new values for cam shaft distance (P-0-0093) and for the electronic gear (P-0-0156/P-0-0157) take effect

immediately or only when the cam shaft distance switch angle is passed or when the cam shaft profile is switched.

In bit 3 you can determine which reference is to be valid for delayed acceptance of changes (cam shaft distance switch angle or cam shaft profile switching).

See also Parameter Description "P-0-0086, Configuration word synchronous operating modes"

Parameterizing Angle Offset

To avoid great position jumps when changing the profile access angle, a new value for parameter "P-0-0061, Angle offset begin of profile" 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 loops can additionally write data to parameter "P-0-0695 Angle offset begin of profile, process loop". After the electronic gear, 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 profile 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 gear (P-0-0156/P-0-0157) and fine adjust (P-0-0083)

Fig.7-120: 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 operating modes", to change between "P-0-0093, Cam shaft distance" and "P-0-0073, Cam shaft distance 2", depending on the gradient of the cam shaft.

Positive gradient means that "P-0-0093, Cam shaft distance" is active, negative gradient means that "P-0-0073, Cam shaft 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 gear. With an electronic gear 1:1, the format corresponds to the circumference of the cutting cylinder (with number of knives = 1). Smaller formats are realized by an electronic gear [(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 shaft to the constant speed of the axis that is caused by the linear component of the gear reduction. With constant cam shaft profile, it is then possible to define, by means of the cam shaft 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 shaft profile 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 gear and cam shaft distance in the cutting range. This function is switched on by setting bit 1 in "P-0-0086, Configuration word synchronous operating modes". A change in the electronic gear will only take effect, when the new value, after having changed the cam shaft distance, is accepted when passing the angle of "P-0-0144, Cam shaft distance switch angle".

"Modulo" 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. Set the actual value cycle greater than or equal to the modulo range (S-0-0103).

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 2047×2^{20} 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 Gear

   Settings for the electronic gear are made in the following parameters:

   - P-0-0083, Gear ratio fine adjust
   - P-0-0694, Gear ratio fine adjust, 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. "Modulo" 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)
- 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" 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 2047×2^{20} 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 cam shafts (e.g. linear cam shafts) and/or when a gear reduction (P-0-0755) unequal zero is selected.

   Note: 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 shaft (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.

   Note: 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 Switch")!

4. Slave Drive Feed Travel

   The distance that the slave axis covers per master axis revolution is determined in parameter "P-0-0159, Slave drive feed travel".

5. Electronic Gear

   Settings for the electronic gear are made in the following parameters:

   - P-0-0083, Gear ratio fine adjust

- P-0-0694, Gear ratio fine adjust, 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. "Absolute" 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)
   - Relative or absolute synchronization (P-0-0155, bit 1)

Commissioning Summary

The figure below illustrates the basic sequence of commissioning.

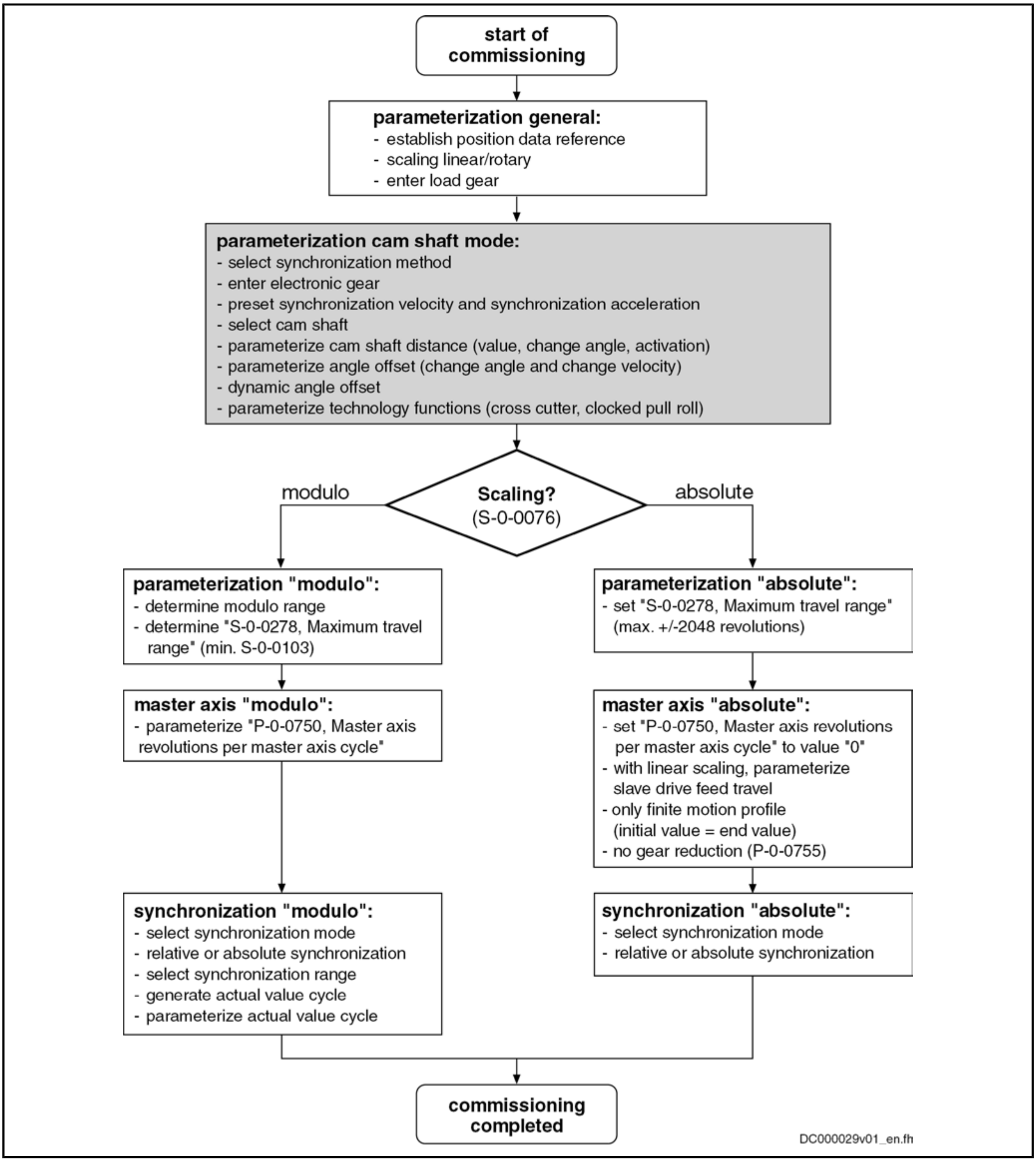


Fig.7-121: Overview of Commissioning Steps for Cam Shaft Mode

Diagnostic and Status Messages

Diagnostic Status Messages

The following diagnostic status messages are displayed in normal operation of the operating mode (drive enabled, "AF"):

- A0128 Cam shaft, encoder 1, virtual master axis
- A0129 Cam shaft, encoder 2, virtual master axis
- A0130 Cam shaft, encoder 1, real master axis

- A0131 Cam shaft, encoder 2, real master axis
- A0132 Cam shaft, lagless, encoder 1, virt. master axis
- A0132 Cam shaft, lagless, encoder 2, virt. master axis
- A0134 Cam shaft, lagless, encoder 1, real master axis
- A0135 Cam shaft, 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 operating mode:

- F2005 Cam shaft invalid

  → This message is generated when there is, with the drive having been enabled, an access to a cam shaft profile (P-0-0072, P-0-0092, P-0-0780, P-0-0781) that hasn't been written with 8, 16, 32, 64, 128, 512 or 1024 valid values.

Status Bits

There are also several status messages specific to operating mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word for synchronous operating modes").

Position Loop Status

The status display via the control encoder and for lagless operation or operation with lag error takes place in parameter "S-0-0521, Status word of position loop".

7.8.5 Electronic Motion Profile With Real/Virtual Master Axis

Brief Description

Expansion package **synchronization** (order code **SNC**) for the variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.7-122: Assignment to Functional Firmware Package

In the operating mode "electronic motion profile 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, the virtual master axis velocity is preset by the master or the integrated master axis generator.

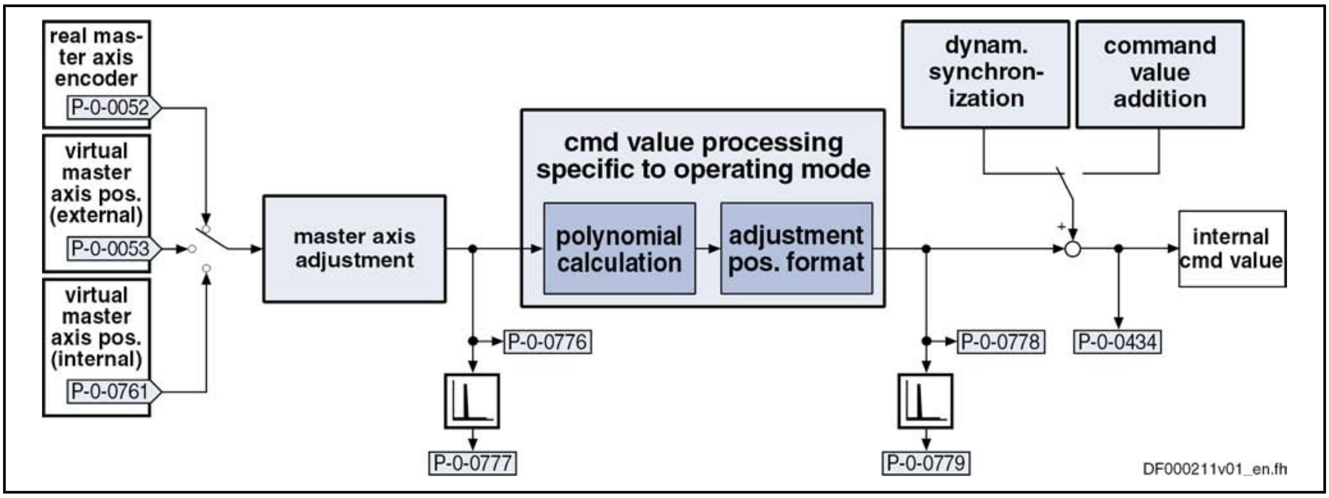
See also "Dynamic Synchronization of the Slave Axis" in section "Basic Functions of the Synchronization Modes"

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 shaft profile
- Standard profiles can be selected (rest in rest, rest in velocity, velocity in rest, velocity in velocity, constant velocity)
- Standard profiles realized by 5th order polynomial or, in the case of rest in rest, alternatively by inclined sine curve
- Individual cam shaft 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 "electronic motion profile" mode:

Operating Modes



P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0434	Position command value of controller
P-0-0761	Master axis position for slave axis
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. 7-123: Function Blocks of the Operating Mode "Motion Profile With Real/Virtual Master Axis"

Variants of the Operating Mode

There are the following variants of the operating mode to be selected:

- Position synchronization
- Motion profile with real master axis, encoder 1
- Motion profile with real master axis, encoder 2
- Motion profile with real master axis, encoder 1, lagless
- Motion profile with real master axis, encoder 2, lagless
- Motion profile with virtual master axis, encoder 1
- Motion profile with virtual master axis, encoder 2
- Motion profile with virtual master axis, encoder 1, lagless
- Motion profile with virtual master axis, encoder 2, lagless

☞ In the operating mode variant "position synchronization", select the electronic motion profile and the master axis in "P-0-0088, Control word for synchronous operation modes". The encoder selection and lagless position control are set in "S-0-0520, Control word of axis controller".

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in this operating mode:

- S-0-0103, Modulo value
- S-0-0520, Control word of axis controller
- S-0-0521, Status word of position loop
- P-0-0061, Angle offset begin of profile
- P-0-0085, Dynamic angle offset
- P-0-0086, Configuration word synchronous operating modes
- P-0-0088, Control word for synchronous operation modes

- P-0-0089, Status word for synchronous operating modes
- P-0-0158, Angle offset change rate
- P-0-0159, Slave drive feed travel
- P-0-0227, Cam shaft profile, access angle
- P-0-0695, Angle offset begin of profile, process loop
- P-0-0696, Filter time constant, angle offset profile, process loop
- P-0-0700, Motion profile, master axis switching position
- P-0-0701, Motion step 1, slave axis initial position
- P-0-0702, Motion profile, diagnosis, set 0
- P-0-0703, Number of motion steps, set 0
- 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 step modes, set 0
- P-0-0707, List of distances, set 0
- P-0-0708, List of slave axis velocities, set 0
- P-0-0709, Motion profile, diagnosis, set 1
- P-0-0710, Number of motion steps, set 1
- 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 step modes, 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 operating mode:

- A0136 Motion profile, encoder 1, virtual master axis
- A0137 Motion profile, encoder 2, virtual master axis
- A0138 Motion profile, encoder 2, real master axis
- A0139 Motion profile, encoder 1, real master axis
- A0140 Motion profile lagless, encoder 1, virtual master axis
- A0141 Motion profile lagless, encoder 2, virtual master axis
- A0142 Motion profile lagless, encoder 1, real master axis
- A0143 Motion profile lagless, encoder 2, real master axis
- A0163 Position synchronization
- F2003 Motion step skipped
- F2004 Error in motion profile

See also "Pertinent Diagnostic Messages" in the subsections of "Basic Functions of the Synchronization Modes"

Overview of the Operating Mode

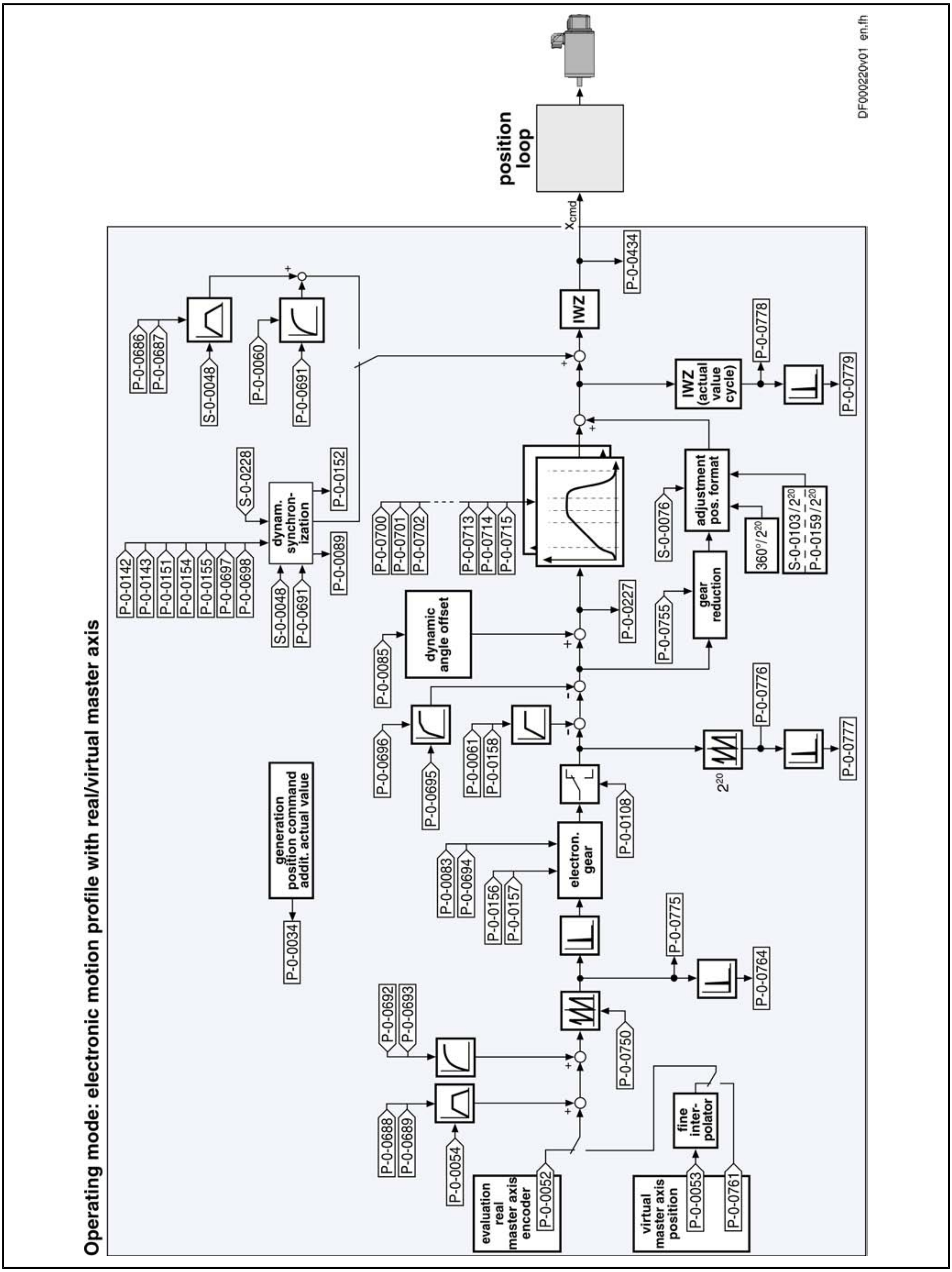


Fig.7-124: Block Diagram: Electronic Motion Profile With Real/Virtual Master Axis

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 gear with fine adjust

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "electronic motion profile" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operating mode, consisting of
  – Cam shaft profiles (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 electronic motion profile 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"

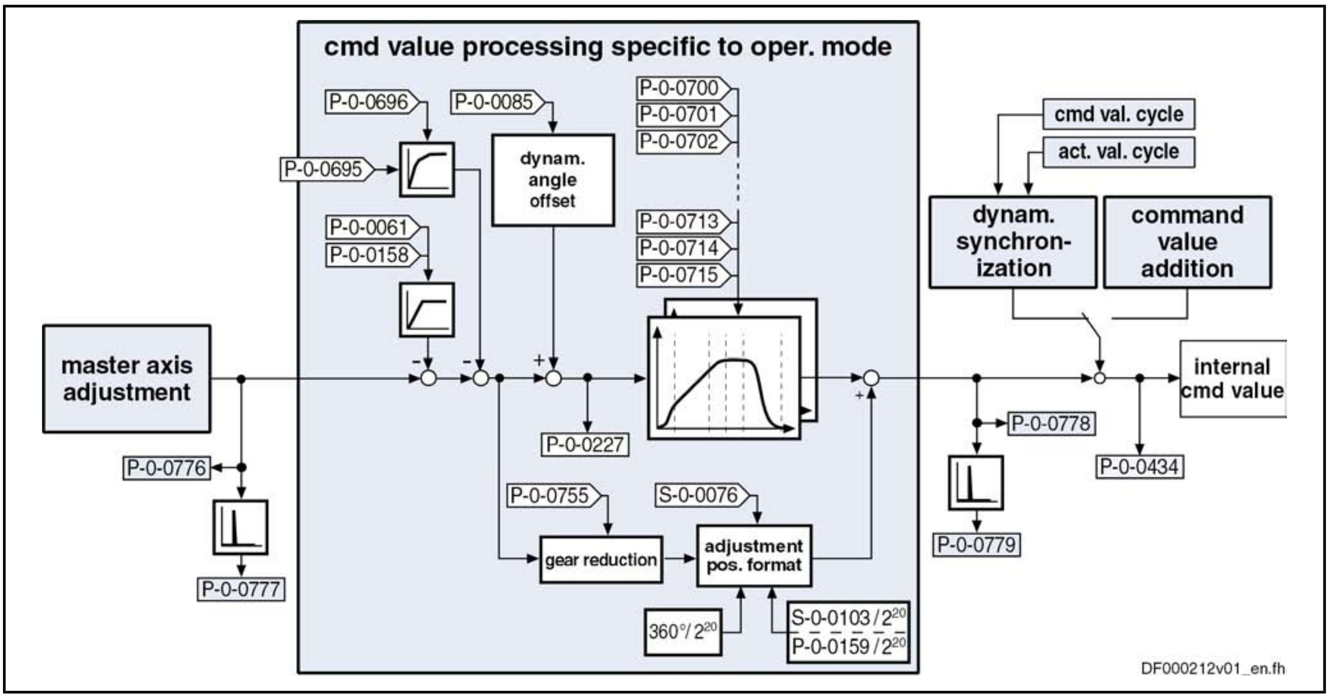


Fig.7-125: Command Value Processing Specific to Operating Mode for Electronic Motion Profile

Generating the Internal Position Command Value

In the operating mode "electronic motion profile 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).

$$\text{P-0-0434} = x_{\text{sync}} + x_{\text{add}} + x_{\text{add\_PR}}$$

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.7-126: Generating the Internal Position Command Value

Note: In the synchronized status (P-0-0089; bit 8 = 1), the following applies:

$$\text{P-0-0434} = x_{\text{sync}} + (\text{S-0-0048}) + (\text{P-0-0691})$$

Fig.7-127: Generating the Internal Position Command Value in the Synchronized Status

In the function block "command value processing specific to operating mode" the calculations specific to the motion profile are carried out for generating the synchronous position command value.

"P-0-0227, Cam shaft profile, 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 mode parameter of this motion step, the decision is taken as to whether the current step is determined by a cam shaft profile or a standard profile. With the profile access angle, profile 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 shaft profile 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 mode parameter 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 operating modes", the master axis position at the output of the electronic gear 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 operating mode "electronic motion profile 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
$f_{n\,(\phi ZGW)}$	Standardized function value of the current motion step from profile access or polynomial calculation
ϕ_{ZGW}	Profile 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 loop (P-0-0691)
IWZ	Modulo actual value cycle

Fig.7-128: Initializing the Position Command Value

$$\varphi_{ZGW} = \pm\varphi_L \times \frac{G_a}{G_e} \times (1 + F) \times (1 + F_{PR}) - \varphi_V - \varphi_{VPR}$$

ϕ_{ZGW}	Profile 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 adjust (P-0-0083)
F_{PR}	Gear ratio fine adjust, process loop (P-0-0694)
ϕ_V	Angle offset begin of profile (P-0-0061)
ϕ_{VPR}	Angle offset begin of profile, process loop (P-0-0695)

Fig.7-129: Determining the Profile 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 synchronous operation 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.

☞ With the operating mode activated, differences, that later on will be added again, are processed in the electronic gear. Therefore, changes in the electronic gear do not cause position command value jumps. Velocity jumps, however, can occur and the absolute position reference, established when activating the operating mode, is lost.

Synchronization

See "Basic Functions of the Synchronization Modes"

Notes on Commissioning and Parameterization

General Parameterization

Parameterizing Angle Offset

The parameter "P-0-0061, Angle offset begin of profile" allows shifting the profile access angle. To avoid great position jumps when changing the profile 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 profile 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 gear (P-0-0156/P-0-0157) and fine adjust (P-0-0083)

Fig.7-130: 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 Gear

When bit 1 (gear switching) has been set in parameter "P-0-0086, Configuration word synchronous operating modes", any change, with active operating mode, in the electronic gear (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 gear 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 Motion Profile

Number of Motion Steps

In the parameters "P-0-0703, Number of motion steps, set 0" and "P-0-0710, Number of motion steps, set 1", 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 synchronous operation 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.

☞ In the case of relative processing, at least 2 motion steps have to be used.

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 gear.

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 step modes, 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 step modes, 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 shaft profile can be defined as the mode of a step.

The following modes are available:

- Rest in rest (R-R)
- Rest in velocity (R-G)
- Velocity in rest (G-R)
- Constant velocity (G)
- Velocity in velocity (G-G)
- Cam shaft profile

Rest in Rest

For the profile "rest in rest", there are two 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 laws of motion "5th order polynomial" and "inclined sine curve".

These profiles are defined by the distance and the master axis range. The final velocity of the step is determined by the following step.

The following relation applies to the profile "5th order polynomial":

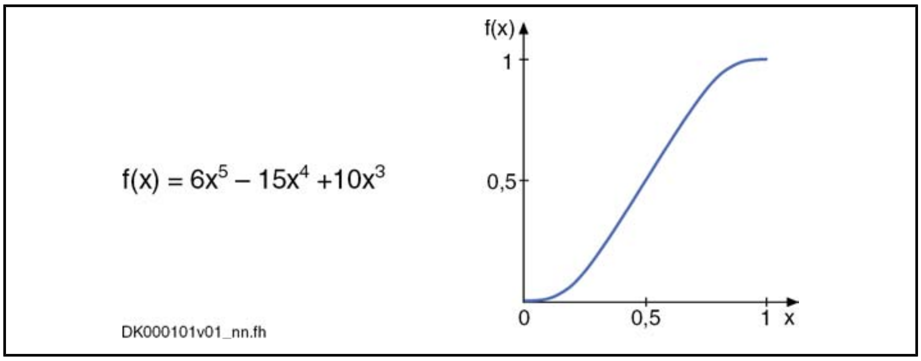


Fig.7-131: Profile "5th Order Polynomial"

The following relation applies to the profile "inclined sine curve":

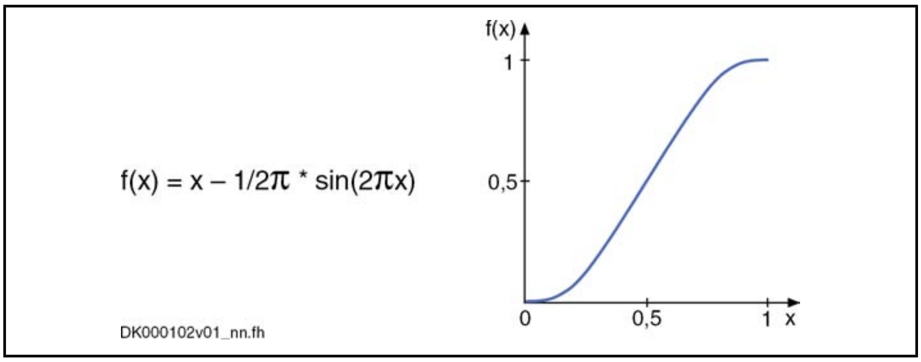


Fig.7-132: Profile "Inclined Sine Curve"

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.

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:

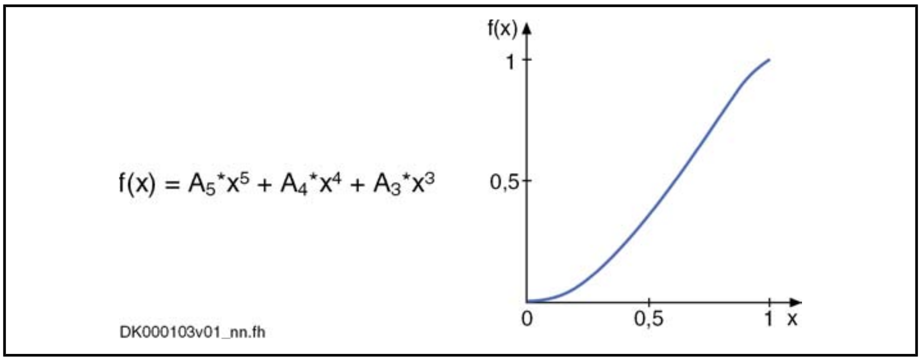


Fig.7-133: Profile "Rest in Velocity"

☞ 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:

$$v_{\text{standard}} = \frac{v_{\text{slave axis}} \times \text{master axis range}}{v_{\text{master axis}} \times \text{distance}}$$

Fig.7-134: 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 indicated 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:

$$f(x) = A_5{*}x^5 + A_4{*}x^4 + A_3{*}x^3 + A_1{*}x$$

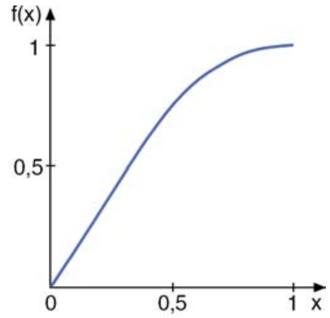


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Fig.7-135: Profile "Velocity in Rest"

☞ 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:

$$v_{\text{standard}} = \frac{v_{\text{slave axis}} \times \text{master axis range}}{v_{\text{master axis}} \times \text{distance}}$$

Fig.7-136: 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):

$$f(x) = x$$

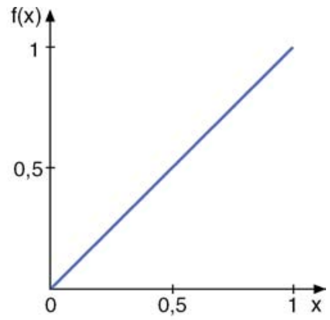

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Fig.7-137: Profile "Constant Velocity"

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.7-138: 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:

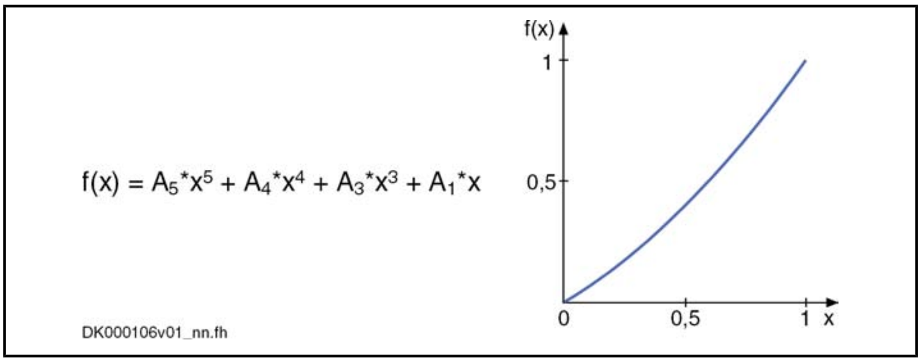


Fig.7-139: Profile "Velocity in Velocity"

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 $v_{\text{standard0}}$ and $v_{\text{standard1}}$ 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.

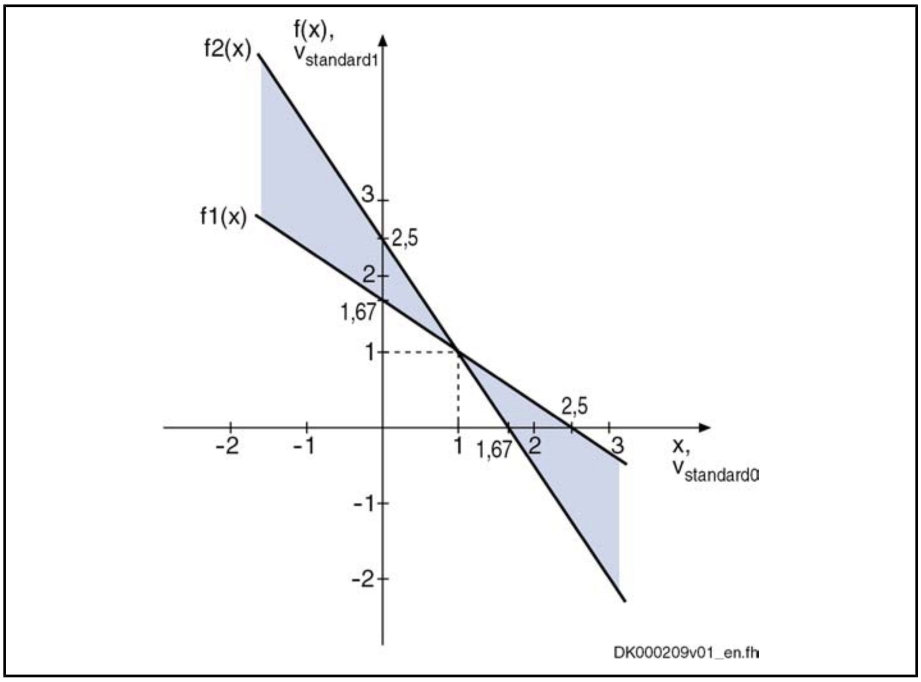


Fig.7-140: Advantageous Range for the Pair of Values v_standard0 and v_standard1

$$v_{standard0} = \frac{v_{BS0} \times \text{master axis range}}{v_{\text{master axis}} \times \text{distance}}$$

$$v_{standard1} = \frac{v_{BS1} \times \text{master axis range}}{v_{\text{master axis}} \times \text{distance}}$$

v_{BS0}	Slave axis velocity i
v_{BS1}	Slave axis velocity i+1
Master axis range	Difference of two master axis initial positions

Fig.7-141: Calculating the Standardized Velocities v_standard0 and v_standard1

☞ The distance belonging to this motion step mustn't be zero!

Cam Shaft Profile

When you select a cam shaft profile via "P-0-0706, List of motion step modes, set 0" or "P-0-0713, List of motion step modes, set 1", the selected cam shaft 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 profile element, the master axis end position determines the position of the last profile 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 profile is variable. The profile length results from the parameterized actual length.

The data point distance is calculated according to the formula below:

$$\text{Data point distance} = (\text{master axis end position} - \text{master axis initial position}) \times 2^{20} / 360 / (n-1)$$

n Number of profile elements

Fig.7-142: Calculating the Data Point Distance (in Increments)

The profile values can be between –799,999999 % and +799,999999 %.

The first profile value has to be zero. The value of the last profile element is arbitrary.

For one profile sequence the traveled path results from the product of the distance and the last profile element.

Cubic spline interpolation is carried out between the data points.

☞ The format of the cam shaft in the motion profile must be the "new" cam shaft format for which the last profile value corresponds to the value at 360 degrees (corresponding bit in parameter P-0-0086, bit 8...15 = 1).

See also operating mode "Electronic Cam Shaft With Real/Virtual Master Axis"

Changing the Motion Profile

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 operating 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 operating 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 for synchronous operation 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, Motion profile, master axis switching position" is passed.

The active set in displayed in bit 3 of "P-0-0089, Status word for synchronous operating 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.

Checking a Motion Profile

To check a motion profile, 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 bit "profile check carried out" 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 operating mode, the message "F2004 Error in motion profile" (class 1 diagnostics error) is generated. This error message is also generated when the active set, with active operating 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.

- Motion profile "constant velocity"

  → 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.
- Motion profile "rest in velocity"

  → 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 mustn't be zero.
- Motion profile "velocity in rest"

  → 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 mustn't be zero.
- Motion profile "velocity in velocity"

  → 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 mustn't be zero.
- The first value of a cam shaft profile must be zero.
- In the case of absolute position scaling and absolute motion profile, 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 profile, from the product of final profile value and distance.
- In the case of modulo position scaling and absolute motion profile, 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 bit "profile check carried out" has been set for a set and the bit "without error" has not been set, an extended diagnosis can be read in the respective diagnosis 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.

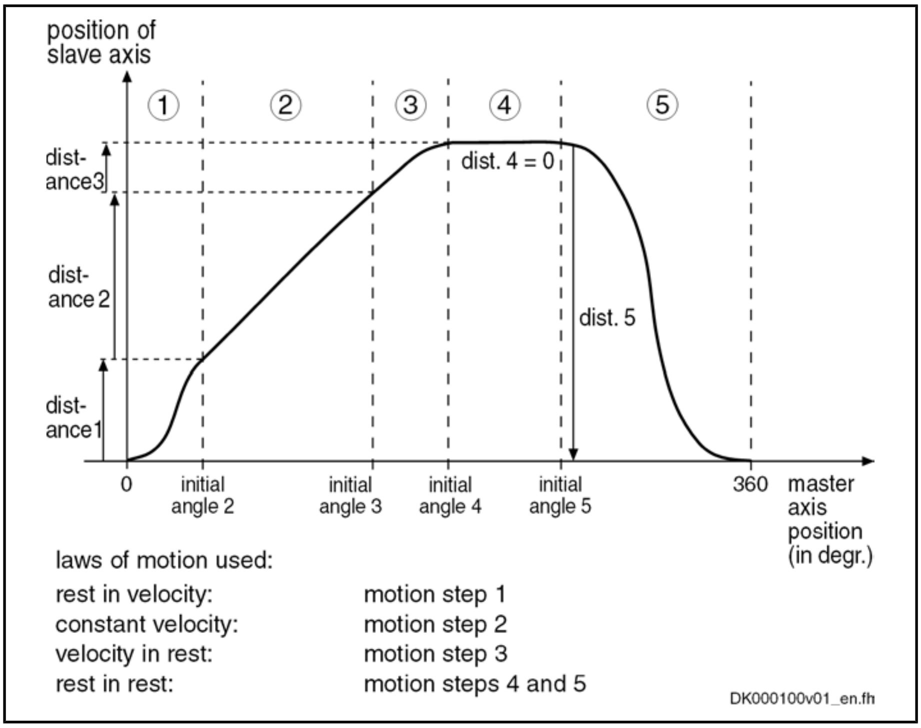


Fig.7-143: Example of a Motion Profile With 5 Motion Steps

Commissioning Summary

The figure below illustrates the basic sequence of commissioning.

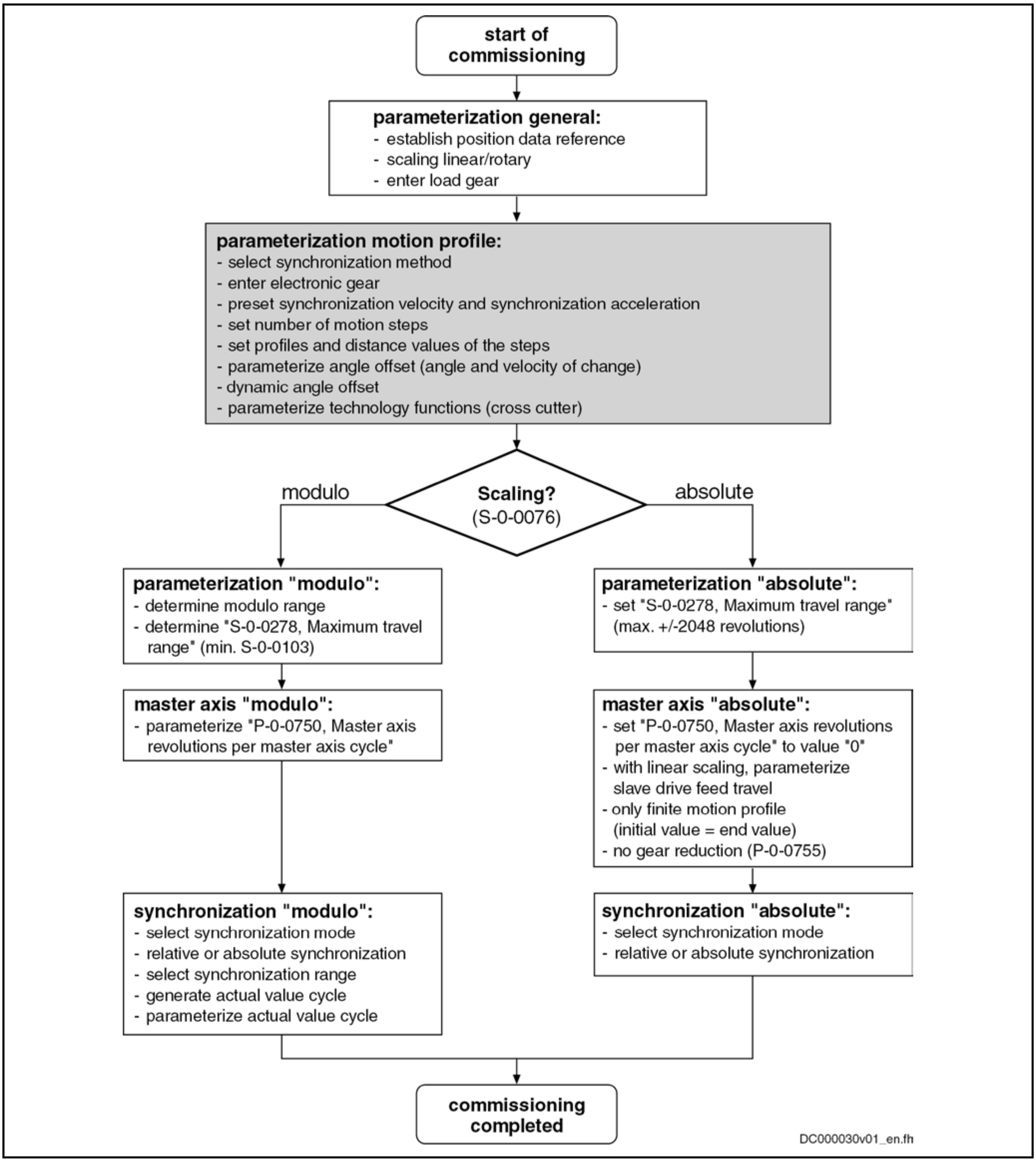


Fig.7-144: Overview of Commissioning Steps for Motion Profile

Diagnostic and Status Messages

Diagnostic Status Messages

The following diagnostic status messages are displayed in normal operation of the operating mode (drive enabled, "AF"):

- A0136 Motion profile, encoder 1, virtual master axis
- A0137 Motion profile, encoder 2, virtual master axis
- A0138 Motion profile, encoder 2, real master axis

- A0139 Motion profile, encoder 1, real master axis
- A0140 Motion profile lagless, encoder 1, virtual master axis
- A0141 Motion profile lagless, encoder 2, virtual master axis
- A0142 Motion profile lagless, encoder 1, real master axis
- A0143 Motion profile 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 operating mode:

- F2004 Error in motion profile

  → 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 can be taken from the diagnosis parameters:

- P-0-0702, Motion profile, diagnosis, set 0
- P-0-0709, Motion profile, diagnosis, set 1

Status Bits

There are also several status messages specific to operating mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word for synchronous operating modes").

Position Loop Status

The status display via the control encoder and for lagless operation or operation with lag error takes place in parameter "S-0-0521, Status word of position loop".

8 Extended Axis Functions

8.1 Availability of the Extended Axis Functions

The following overview illustrates by which basic or functional packages the respective extended axis function is supported (if not stated otherwise, this applies to all 3 firmware versions, MPB, MPD and MPH).

Extended axis function	In base package (characteristic)	In functional package ... (additionally on the basis of a base package with the following characteristics)		
		Servo function	Synchronization	Main spindle
Drive Halt	OL/CL	–	–	–
v_{cmd} reset ("emergency halt")	OL/CL	–	–	–
v_{cmd} reset with ramp ("quick 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	–	–	–
E-Stop function	OL/CL	–	–	–
Friction torque compensation	CL	–	–	–
Encoder error correction	CL	–	–	–
Backlash on reversal correction	CL	–	–	–
Precision axis error correction	–	CL 1)	–	–
Control-side axis error correction	–	CL 1)	–	–
Temperature error correction	–	CL	–	–
Quadrant error correction	–	CL	–	–
Cogging torque compensation	–	CL 1)	CL 1)	–
Measuring wheel mode	–	–	CL	–
Positive stop drive procedure	OL/CL	–	–	–
Redundant motor encoder	CL	–	–	–
Spindle positioning	–	–	–	CL
Parameter set switching	–	–	–	OL/CL 2)
Drive-controlled oscillation	–	–	–	OL/CL 2)
Parking axis	OL/CL	–	–	–
Integrated safety technology	Only available with the corresponding hardware configuration			

OL Open-loop characteristic
CL Closed-loop characteristic
1) Not for the firmware version MPB
2) Not for the firmware version MPD

Fig.8-1: 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"

8.2 Drive Halt

8.2.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.8-2: Assignment to functional firmware package

The "Drive Halt" function is used to shut down an axis with defined acceleration and defined jerk.

The kind of shutdown is determined by the operating mode active before.

☞ In addition to the "Drive Halt" function, there is an operational stop for the operating modes "drive-controlled positioning" and "drive-internal interpolation".

Features

- Activated via "halt bit" of master communication (see "Device Control and State Machines")
- Active operating mode interrupted; drive remains in control (after setting the "halt bit" the interrupted operating mode is continued)
- **Quick stop**

  → Shutdown with acceleration (S-0-0372) and jerk limit values (S-0-0349), when position control mode was active before
- **Shutdown with ramp**

  → Shutdown with ramp (S-0-0372), when velocity or torque control was active before
- Acknowledgment "Drive Halt" in parameter P-0-0115

Pertinent Parameters

- S-0-0124, Standstill window
- S-0-0349, Jerk limit bipolar
- S-0-0372, Drive Halt acceleration bipolar
- P-0-0115, Device control: Status word

8.2.2 Functional Description

When the "Drive Halt" function is activated, the drive no longer follows the command values of the active operating 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 SERCOS, 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")

Going Back to the Operating Mode Active Before

The operating 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.

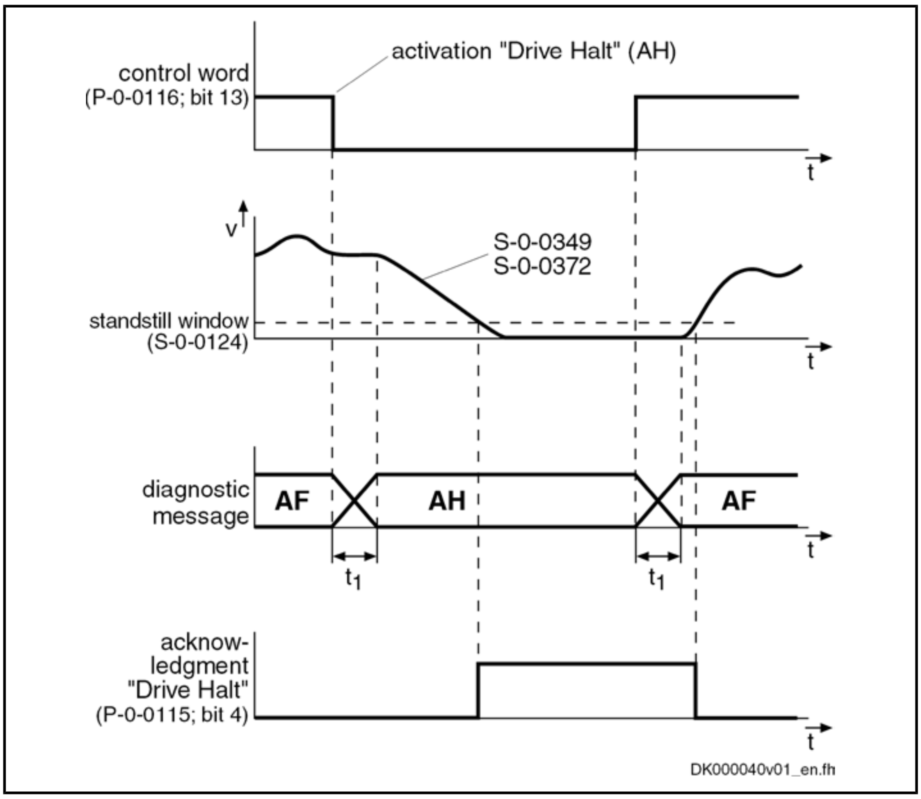
The kind of shutdown, in the case of "Drive Halt", depends on the operating mode active before.

Quick Stop in Position Control

In position control, shutdown is carried out using the deceleration in "S-0-0372, Drive Halt acceleration bipolar" and the jerk in "S-0-0349, Jerk limit bipolar", when a position control mode was active before.

Operating modes with internal position control:

- Position control with cyclic command value input
- Drive-internal interpolation
- Drive-controlled positioning (incl. jog mode)



S-0-0349 Jerk limit bipolar
S-0-0372 Drive Halt acceleration bipolar
Fig.8-3: Principle of "Drive Halt" with position control mode active before

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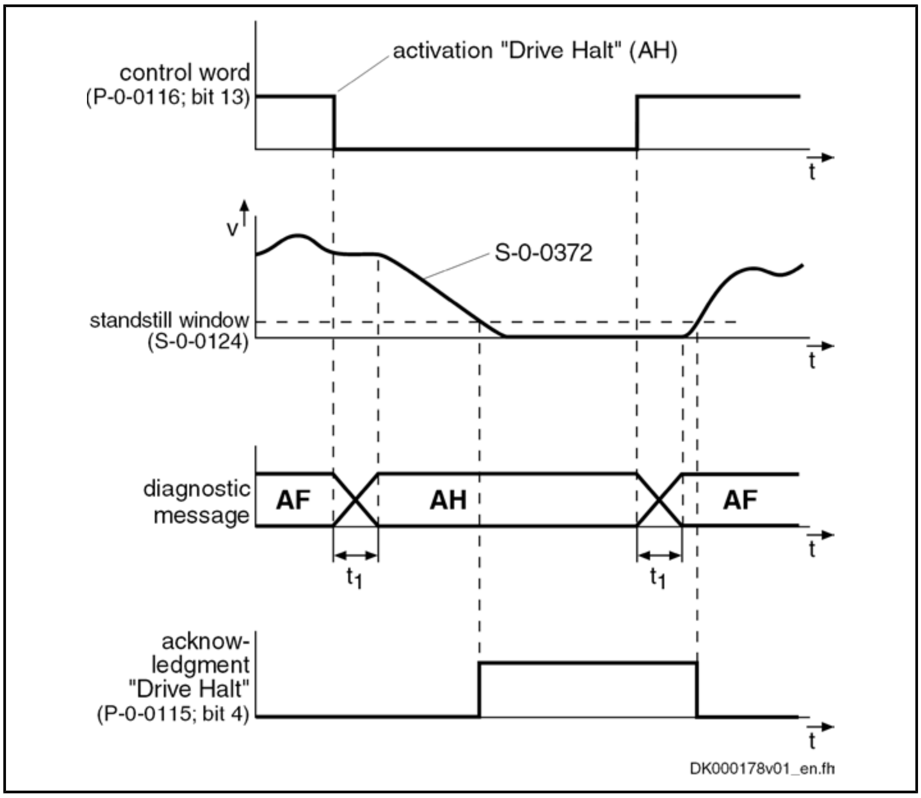
☞ Position-controlled shutdown is carried out with position control with lag error, if an operating mode that also contained position control with lag error was active before. If not, the function is carried out with lagless position control.

If the value in parameter "S-0-0372, Drive Halt acceleration bipolar" equals "0", the axis does not stop.

Shutdown in Velocity Control

When the operating mode "velocity control" or "torque/force control" was active before, shutdown is carried out in velocity control using the value in parameter "S-0-0372, Drive Halt acceleration bipolar".

☞ If the content of "S-0-0372, Drive Halt acceleration bipolar" equals "0", deceleration is carried out at the current limit.



S-0-0372 Drive Halt acceleration bipolar

Fig.8-4: Principle of "Drive Halt" with velocity control active before

8.2.3 Notes on Commissioning

Diagnostic and Status Messages

The activated "Drive Halt" function is displayed as described below:

- "AH" appearing on the control panel display at the front of the device
- "A0010" entered in parameter "S-0-0390, Diagnostic message number"
- "A0010 Drive HALT" 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. for SERCOS: bit 3 = 0 in "S-0-0135, drive status word")

Acknowledgment "Drive Halt"

Acknowledgment takes place when the actual velocity falls below the threshold defined in 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".

8.3 Error Reactions

8.3.1 Overview of Error Reactions

Depending on the operating 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 status 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 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 parameter P-0-0118!

Error Classes

There are 8 error classes with different priority:

Diagnostic message number	Error class	Error reaction
F2xxx	non-fatal error	according to setting in parameters "P-0-0119, Best possible deceleration" and "P-0-0117, Activation of control reaction on error"
F3xxx	non-fatal safety technology error	according to setting in parameters "P-0-0119, Best possible deceleration" and "P-0-0117, Activation of control reaction on error"
F4xxx	interface error	according to setting in parameter "P-0-0119, Best possible deceleration"
F6xxx	travel range error	velocity command value reset ("emergency halt")
F7xxx	safety technology error	according to setting in bit 9 of parameter "P-0-3210, Safety technology configuration"
F8xxx	fatal error	immediate torque disable
F9xxx	fatal system error	immediate torque disable
E-xxxx	fatal system error "processor exception"	immediate torque disable

Fig.8-5: Error classes and drive reaction

☞ The error class can be recognized by the diagnostic message number and defines the drive behavior in the case of error.

8.3.2 Best Possible Deceleration

Brief Description

The drive reaction set in parameter "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)
- Change of drive enable signal from "1" to "0" (drive enable is removed)

- Switching from operating mode to parameter mode under control (communication phase is reset)

At the end of each error reaction, the drive goes torque-free!

The setting in parameter "P-0-0119, Best possible deceleration" is ignored in the case of:

- Travel range errors (F6xxx)
  → Velocity command value reset ("emergency halt")
- Safety technology errors (F7xxx)
  → Depending on bit 9 of parameter "P-0-3210, Safety technology configuration"
- Fatal errors (F8xxx)
  → Immediate torque disable
- Fatal system errors (F9xxx)
  → Immediate torque disable

Possible Drive Reactions

One of the following reactions for "best possible deceleration" can be set in parameter P-0-0119:

Reaction	Value of P-0-0119
Velocity command value reset ("**emergency halt**")	0
Torque disable	1
Velocity command value reset with ramp and filter ("**quick stop**")	2
Return motion [1]	3

[1] Only possible, if expansion package "servo function" has been enabled!

Fig.8-6: Parameterization Options of the Error Reaction "Best Possible Deceleration"

See also Parameter Description "P-0-0119, Best possible deceleration"

Velocity Command Value Reset ("Emergency Halt")

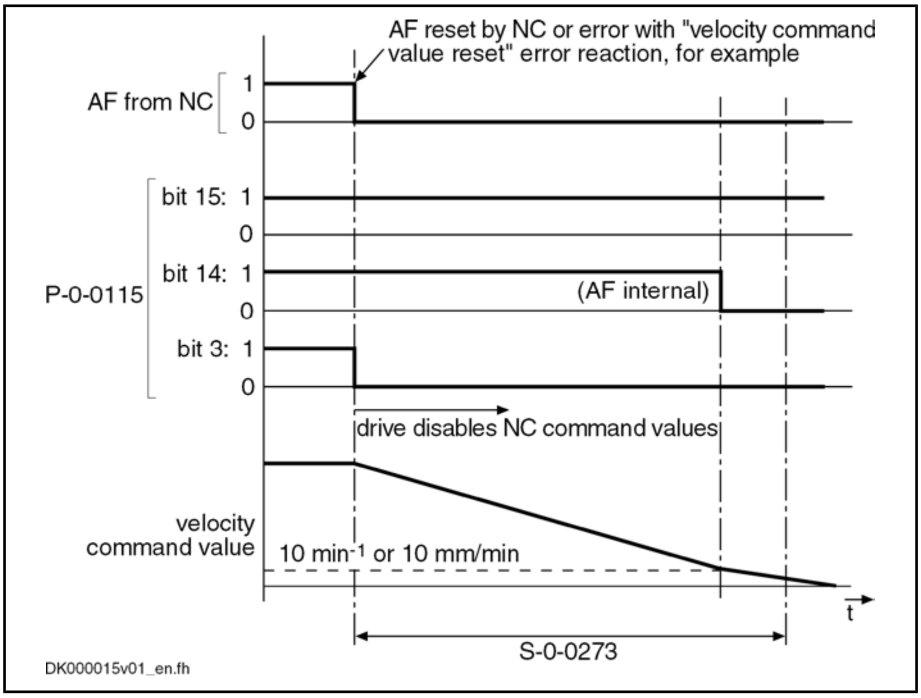
Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.8-7: Assignment to Functional Firmware Package

P-0-0119 = 0

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 (see also "Limitations: Current and Torque Limitation (Closed-Loop)").

In the case of open-loop-controlled U/f operation, deceleration at the torque limit only takes place, when the stall protection loop has been activated (cf. "P-0-0045, Control word of current controller"). The maximum deceleration is set by the value entered in the parameter "P-0-0569, Maximum stator frequency slope".



S-0-0273 Maximum drive off delay time
P-0-0115 Device control: status word
Fig.8-8: Time Flow of Velocity Command Value Reset

If the value entered for S-0-0273 is too small, the error reaction is sometimes aborted without axis standstill!

Time Flow of the Error Reaction With Motor Holding Brake Available

The time flow of the error reaction with motor holding brake available and of the output stage release in the case of velocity command value reset, 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 Parameter Description "P-0-0525, Holding brake control word"

See also "Motor Holding Brake"

Velocity Command Value Reset With Filter and Ramp ("Quick Stop")

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.8-9: Assignment to Functional Firmware Package

P-0-0119 = 2

In the case of error

- the closed-loop-controlled servo drive in velocity control

- or -

- the open-loop-controlled drive in U/f operation

is decelerated to the final value "0" with a command value ramp and a jerk-limiting command value smoothing filter.

In open-loop-controlled U/f operation, deceleration takes place taking the delay entered in parameter "P-0-0569, Maximum stator frequency slope" into account!

Pertinent Parameters

- S-0-0349, Jerk limit bipolar
- S-0-0372, Drive Halt acceleration bipolar

The parameters take effect as described under "Drive Halt".

Time Flow of the Error Reaction With Motor Holding Brake Available

The time flow of the error reaction with 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 Parameter Description "P-0-0525, Holding brake control word"

See also "Motor Holding Brake"

Torque Disable

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.8-10: Assignment to Functional Firmware Package

P-0-0119 = 1 or Fatal Error

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.

The "torque disable" error reaction is inevitable with fatal errors (F8xxx), because braking, e.g. with a defective output stage, is no longer possible!

DANGER

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. using "S-0-0040, Velocity feedback value", if possible) and wait for standstill!

Time Flow of the Error Reaction With Motor Holding Brake Available

The time flow of the error reaction with motor holding brake available is described in the section "Functional Description: Error Situation 2" 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 Parameter Description "P-0-0525, Holding brake control word"

See also "Motor Holding Brake"

Return Motion

Expansion package **servo function** (order code **SRV**) of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.8-11: Assignment to Functional Firmware Package

P-0-0119 = 3

If "return motion" was entered as the best possible deceleration, the drive generates a **position command value profile** in order to travel the desired distance in the case of error. This means that a relative process block is activated in the case of error.

Generating the Position Command Value Profile

With the "drive-internal interpolation" mode, the position command value profile is generated internally by means of predefined travel block data (velocity, acceleration, jerk).

See "Drive-Internal Interpolation"

The value of the parameter "P-0-0055, Return distance" depends on the preceding sign, i.e. positive return distance causes positive motion referring to the coordinate system selected.

> The value of "P-0-0055, Return distance" can be configured and transmitted in the cyclic telegram (MDT).

The velocity profile is generated with the parameters

- P-0-0056, Return velocity and
- P-0-0057, Return acceleration.

In addition, the position command values can be smoothed by the position command value average value filter, the order of the average value filter (P-0-0042) being calculated from "P-0-0057, Return acceleration" and "P-0-0058, Return jerk".

$$P\text{-}0\text{-}0042 = \frac{P\text{-}0\text{-}0057}{P\text{-}0\text{-}0058}$$

P-0-0042 Current position command average value filter order
P-0-0057 Return acceleration
P-0-0058 Return jerk
Fig.8-12: Calculating the Value of P-0-0042

Status Messages for Acknowledgment

After the drive has traveled the process block, i.e. after it moved to the desired target position, the drive is torque-free. The process block is considered to have been traveled when the following applies:

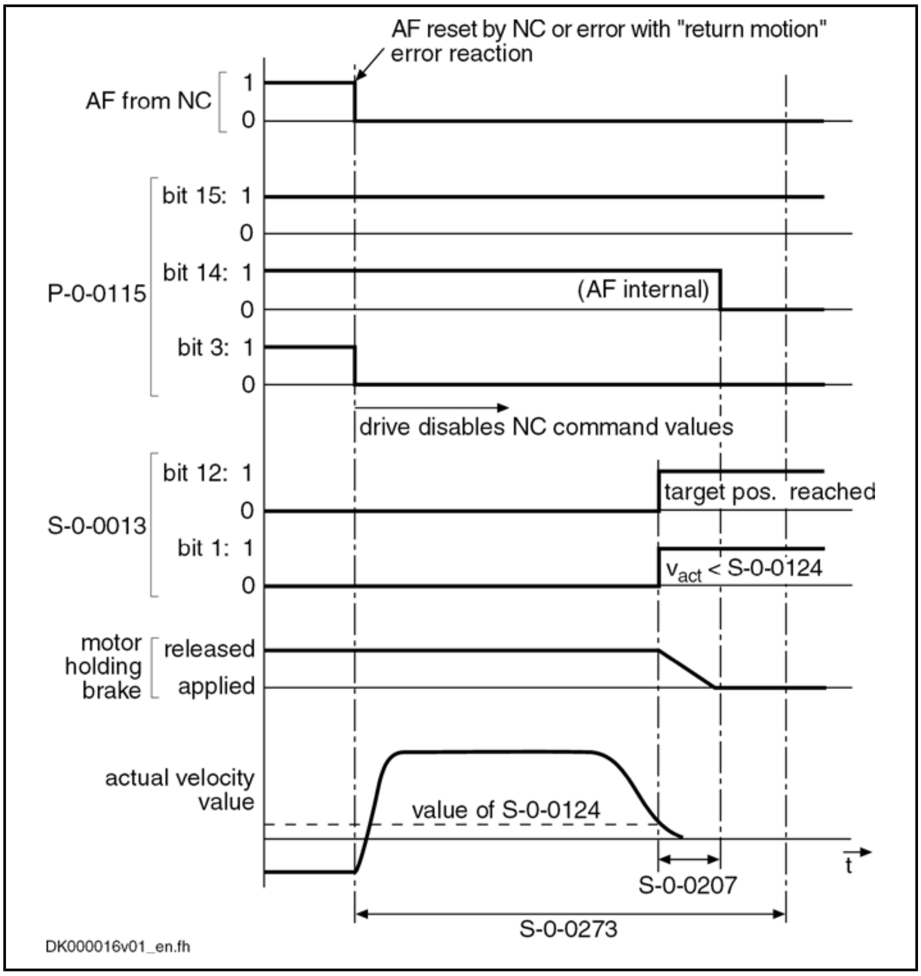
- Target position = active position command value

  → i.e. bit 12 in "S-0-0013, Class 3 diagnostics" = 1

- and -

- $v_{act} = 0$

  → i.e. bit 1 in "S-0-0013, Class 3 diagnostics" = 1 (actual velocity smaller than "S-0-0124, Standstill window")



S-0-0013	Class 3 diagnostics
S-0-0207	Drive off delay time
S-0-0124	Standstill window
S-0-0273	Maximum drive off delay time
P-0-0115	Device control: status word

Fig.8-13: Time Flow of the Error Reaction "Return Motion"

Error Reaction "Return Motion" With Activated Position Limit Values

When the drive-internal position limit values ("S-0-0049, Positive position limit value" and "S-0-0050, Negative position limit value") were activated, i.e. when

- bit 4 for "activating the position limit values" was set to "1" in "S-0-0055, Position polarities"

  - and -

- the encoder selected via "S-0-0147, Homing parameter" (bit 3) is in reference ("S-0-0403, Position feedback value status" = 1),

it is ensured that the drive does not leave the defined allowed travel range by executing the error reaction "return motion".

☞ When the drive is in a position in which the execution of the return motion would exceed a position limit value, the drive in this case only moves up to shortly before the respective position limit value (exactly "S-0-0057, Position window" before the position limit value).

Time Flow of the Error Reaction With Motor Holding Brake Available

The time flow of the error reaction with motor holding brake available is described in the section "Functional Description: Error Situation 2" 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 Parameter Description "P-0-0525, Holding brake control word"

See also "Motor Holding Brake"

8.3.3 Package Reaction on Error

Brief Description

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.8-14: Assignment to functional firmware package

"Package reaction" is the simultaneous error reaction of all axis drives supplied by a common power bus (DC bus). Drive errors of a drive can be signaled 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 individually 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 package"):

- 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

> **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

Fig.8-15: 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 drive enable off
- Signaling of own, fatal drive errors (F8xxx) to the supply via module bus

8.3.4 Control Reaction on Error

NC Reaction on Error

Brief Description

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.8-16: Assignment to functional firmware package

To avoid damages to the machine, some applications require that the master (e.g. NC) retains control of the travel profile of the axes in the case of error, too, 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 reaction on error
- P-0-0119, Best possible deceleration

Functional Description

In the case of NC reaction on error, the axis reporting 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 parameter "P-0-0117, Activation of control reaction on error".

P-0-0117, bit 0:

- Bit 0 = 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 0 = 1 → The drive carries out its error reaction according to the setting in parameter 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: In case that after the recognition of the error, within this waiting period the error message is deleted, **no** drive reaction set in parameter P-0-0119 will be 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

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.8-17: Assignment to functional firmware package

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 inasfar that by means of IndraMotion MLD, even for an interface error (F4xxx) an error reaction to be defined by the operator can be executed for the (local) axis.

☞ Prerequisite for the utilization of the MLD error reaction is an enable 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 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 any control over by an external controller to be interrrupted.

Activating the NC Reaction

The MLD reaction on error is activated in parameter "P-0-0117, Activation of control 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 parameter 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**.

  Note: In case that after the recognition of the error, within this waiting period the error message is deleted, **no** drive reaction set in parameter P-0-0119 will be 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 very fast and - above all - flexible reaction on occurrance of an error.

8.4 E-Stop Function

8.4.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.8-18: Assignment to functional firmware package

The E-Stop function is used to shut down the drive with 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)

  → **Reaction:** Best possible deceleration (as set in P-0-0119)
- E-Stop with reaction to travel range error (F6034 Emergency-Stop)

  → **Reaction:** Velocity command value reset
- E-Stop as fatal warning "E8034 Emergency-Stop"

  → **Reaction:** Best possible deceleration (as set in P-0-0119)

☞ If E-Stop was parameterized as a warning, it isn't necessary to clear the diagnostic message!

Pertinent Parameters

- P-0-0008, Activation E-Stop function
- P-0-0119, Best possible deceleration
- P-0-0223, E-Stop input

Pertinent Diagnostic Messages

- E8034 Emergency-Stop
- F4034 Emergency-Stop
- F6034 Emergency-Stop

8.4.2 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 first of all depends on the setting of bit 2 in parameter 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 parameter "P-0-0119, Best possible deceleration".

- The warning "E8034 Emergency-Stop" appears. Bit 15 is set in parameter "S-0-0012, Class 2 diagnostics" (manufacturer-specific warning).
- Simultaneously, the bit "change bit class 2 diagnostics" is set in the drive status word.

☞ This change bit is cleared by reading the parameter "S-0-0012, Class 2 diagnostics". Using parameter "S-0-0097, Mask class 2 diagnostic", 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 was set in parameter P-0-0008 (bit 2 = 0), the reaction selected in bit 1 is carried out:

- The diagnostic error message "F4034 Emergency-Stop" (or "F6034 Emergency-Stop") appears.
- Bit 15 is set in parameter "S-0-0011, Class 1 diagnostics".
- Bit 13 (drive interlock, 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 panel if the E-Stop input is no longer active.

☞ The error reaction is carried out without delay, independent of parameter "P-0-0117, Activation of control 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".

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 parameter 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".

8.4.3 Notes on Commissioning

Activation and Polarity of the E-Stop Input

Assigning 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.

☞ Without this assignment to the digital input, the E-Stop reaction fails to occur in spite of the input having been activated!

Activating 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 parameter "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 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 determined via "P-0-0119, Best possible deceleration".

Connecting the E-Stop Input

See documentation "Drive Controllers, Control Sections; 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.

8.4.4 Diagnostic and Status Messages

Diagnostic Warning and Error Messages

There are the following diagnostic messages for the E-Stop function:

- Warning "E8034 Emergency-Stop"
  → E-Stop with best possible deceleration
- Error "F4034 Emergency-Stop"
  → E-Stop with best possible deceleration
- Error "F6034 Emergency-Stop"
  → E-Stop with velocity command value reset

Status Messages

The status of the E-Stop input can be read via parameter "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

8.5 Compensation Functions / Corrections

8.5.1 Friction Torque Compensation

Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.8-19: Assignment to Functional Firmware Package

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.

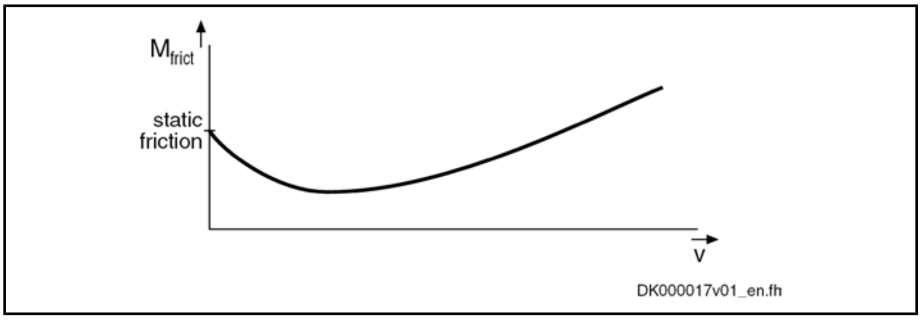


Fig.8-20: Friction Torque Curve With Static Friction

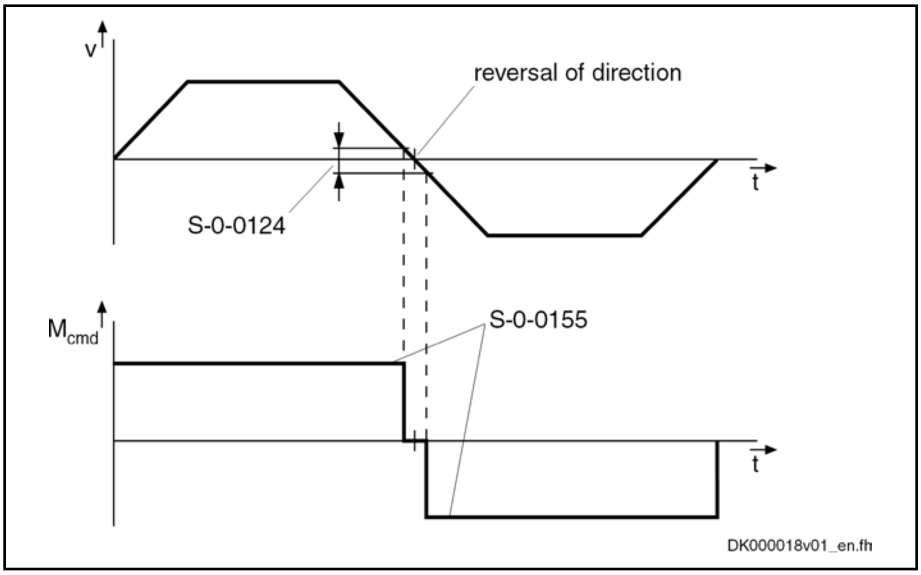
☞ Friction torque compensation is mainly intended to be used in precision machine tools and to reduce the path errors caused by static friction. This applies particularly to circular errors at the quadrant transitions.

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, especially when reversing the direction of movement, improving the control behavior (little lag error). Precision of drive control is thereby increased.



S-0-0124 Standstill window
S-0-0155 Friction compensation
Fig.8-21: 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

The following requirements must have been fulfilled for using this function:

- 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 more approximately constant, independent of the current machining process.

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 operating 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, switch off the lag error monitor, 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 movement 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 parameter "S-0-0155, Friction compensation".

$$\text{S-0-0155} = \frac{|\text{friction value\_positive}| + |\text{friction value\_negative}|}{2}$$

Fig.8-22: Generating the Average Value for the Entry in Parameter S-0-0155

8.5.2 Encoder Error Correction

Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.8-23: Assignment to functional firmware package

The quality of machining or the precision with which an axis can follow a given path is determined by several factors. One of the factors of influence is the precision with which a measuring system can identify the position of an axis or shaft.

IndraDrive controllers provide the possibility of improving inaccuracy inherent in position measuring systems with sinusoidal signals. This improves the ability of a drive or an axis to follow the position and velocity command values. The bandwidth of the control loops can also be improved in many cases by the possibility of setting the control loop gain to a higher value.

Pertinent Parameters

- P-0-0340, C3500 Command Determine encoder correction values
- P-0-0341, Control word for encoder correction
- P-0-0342, Correction value table for encoder correction

Pertinent Diagnostic Messages

- C3500 Command Determine encoder correction values
- C3501 Acquisition velocity not allowed
- C3502 Motor encoder not available
- C3503 Optional encoder not available
- C3504 Measuring encoder not available
- C3505 No encoder selected
- C3506 Correction value table cannot be stored

Functional Description

The precision of the actual position values that the controller determines from the signals of a measuring system depends, in the case of sinusoidal signals, to a high degree on how well the measuring system complies with the sine form.

Inaccuracy of Sinusoidal Encoder Signals

The most important inaccuracies with sinusoidal signals are caused by:

- Signal offset

  → The evaluated sine signal is not symmetrical to the zero line
- Amplitude error

  → The signal amplitude is either too low (bad resolution) or too high (crest range cannot be displayed)
- Signal shape error

  → The curve shape differs from the exact sine shape

Actual position values are calculated from both sinusoidal signals of an encoder that are offset by a quarter of a division period. The mentioned errors cause differing sine signals and therefore differing actual position values compared to ideal actual position values of exactly sinusoidal signal curves.

The controller automatically compensates the signal offset and the amplitude error for all encoders connected to the controller.

Compensating Signal Shape Errors

Due to the high degree of required calculated capacity, the correction of signal shape errors can only be activated for one of the encoders that can be connected. To do this, it is necessary to determine one encoder, for which the correction is to be carried out, in parameter "P-0-0341, Control word for encoder correction". The controller measures signal shape errors by activation of "P-0-0340, C3500 Command Determine encoder correction values".

To record the signal shape errors of the encoder division periods, it is necessary to control the drive in the "velocity control" mode with a constant velocity command value.

The formulas below apply to the maximum velocity for determining the correction values related to the encoder shaft (rotary encoder) or the sensor head (linear encoder):

$$\text{Rotary encoder} \quad S\text{-}0\text{-}0040 \leq \frac{0{,}03125}{T_{Vreg} \times DP/rev.}$$

$$\text{Linear encoder} \quad S\text{-}0\text{-}0040 \leq \frac{0{,}03125 \times DP}{T_{Vreg}}$$

S-0-0040	Velocity feedback value
T_{Vreg}	sampling time of the velocity loop
DP/rev.	division periods per encoder revolution (number of lines of the rotary encoder)
DP	length of the division period (linear encoder)

Fig.8-24: Maximum velocity for determining the correction values

When all required measured values have been recorded, the correction values calculated and stored in "P-0-0342, Correction value table for encoder correction", the controller completes the command execution. If with the command C3500 being active the actual velocity value should be lower than 50% or higher than 100% of the maximum value calculated above, the recording of the signal shape errors is aborted (error message "C3501 Acquisition velocity not allowed"). For trouble-free recording of the correction values, a command value of approx. 75% of the maximum velocity is recommended.

☞ The values in the correction table P-0-0342 are only suitable for the encoder for which they were determined! In case an encoder is replaced, the correction values have to be determined again (command C3500)!

Activation/Deactivation

The correction values are determined once during initial commissioning. If encoder error correction has been activated with the drive in operation (respective bits of P-0-0341), the signal shape errors of the encoder tracks are compensated by adding a correction value. The correction values are generated from the table values of parameter P-0-0342. If there hasn't been any encoder selected, the encoder error correction is deactivated!

Notes on Application

According to experience, the encoder error correction can be effectively used for encoders with the following characteristics:

- Rotary encoders → Up to approx. 1000 cycles/revolution
- Linear encoders → Division periods up to approx. 0.1 mm

Observe the following basic principles for application:

- If the encoder error correction shouldn't cause any improvement, this function has to be deactivated (relieving the processor!).
- If the constant speed of a drive is to be improved, the encoder error correction has to be applied to the motor encoder.
- If the positioning precision is to be improved, the encoder error correction has to be applied to the position control encoder.

Notes on Commissioning

Preparations

Before starting the command C3500, make the following preparations for the respective drive:

- Determine the encoder to be corrected in "P-0-0341, Control word for encoder correction".
- Determine the velocity that mustn't be exceeded for recording the signal shape errors.

- Estimate the travel range of the axis for a motion time of at least 4 s with the maximum recording velocity and make sure that the travel range is sufficient (start position, direction of motion).
- Activate the "velocity control" mode.

Carrying Out Encoder Error Correction

During initial commissioning, the encoder error correction has to be carried out once:

- Activate drive ("AF") and start "P-0-0340, C3500 Command Determine encoder correction values"
- Input velocity command value of approx. 75% of calculated maximum value
- Observe the status of command execution and with the end of the command execution set the velocity command value to zero.
- Check the effectiveness of the encoder error correction, e.g. by checking the amplitude of the speed jitter, if, as in the case of the recording of the signal shape errors with activated and deactivated encoder error correction, the same distance is traveled in the same way. With active encoder error correction, the amplitude has to be distinctly smaller!

  If necessary, repeat the command C3500 with modified recording velocity!

CAUTION

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

⇒ Make sure that the travel range of the axis is sufficient! Activate axis end position switches and set them to collision-safe positions!

Activating Encoder Error Correction

When the drive is switched on again (after initial commissioning), the correction values stored in parameter "P-0-0342, Correction value table for encoder correction" are automatically activated when the respective bit has been set in parameter "P-0-0341, Control word for encoder correction".

8.5.3 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

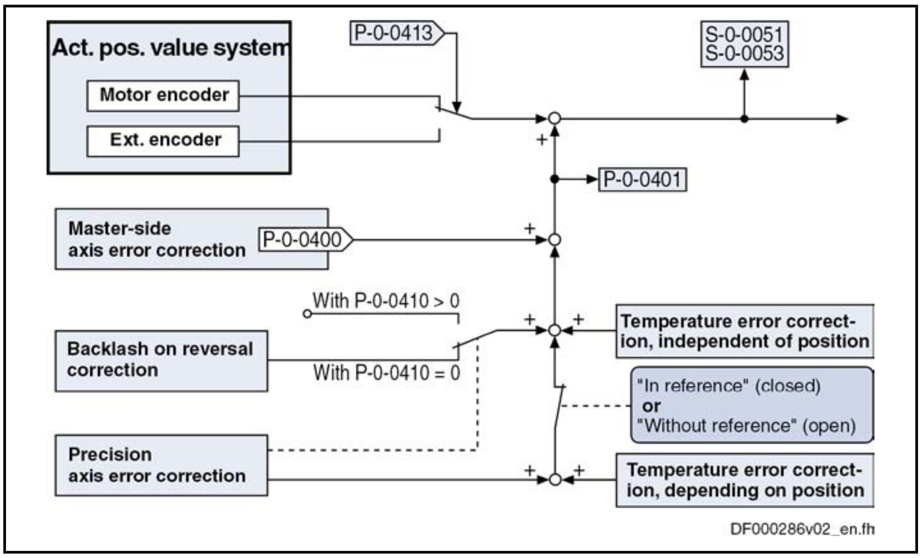
The sum of active correction values is displayed in parameter "P-0-0401, Axis correction active correction value". The value refers to the encoder selected in parameter P-0-0413.

How to Use 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.

Extended Axis Functions



S-0-0051	Position feedback 1 value
S-0-0053	Position feedback 2 value
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.8-25: Overview of How to Use the Functions of Axis Error Correction

Backlash on Reversal Correction

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.8-26: Assignment to Functional Firmware Package

By means of the backlash on reversal correction, it is easily possible to correct backlash in the mechanical axis system.

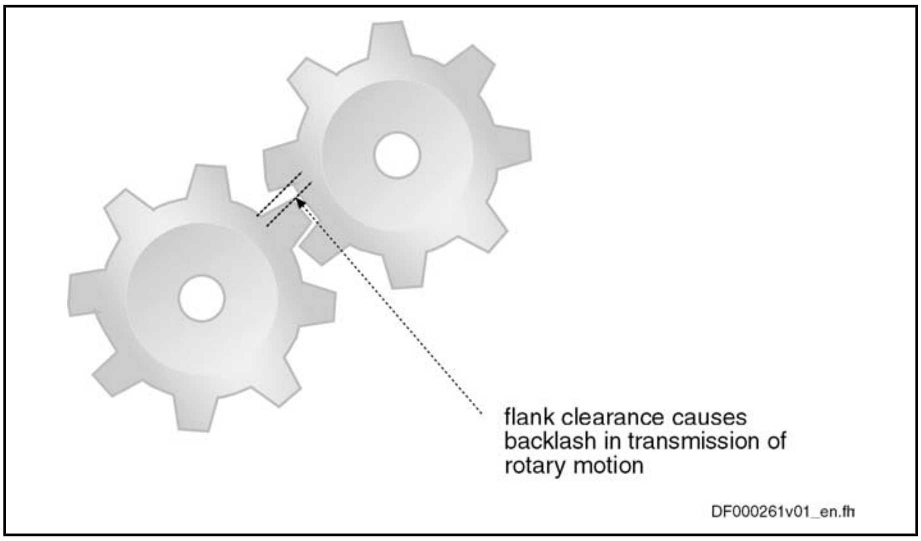


Fig.8-27: Illustration of Backlash With Toothed Wheels

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).

In 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.

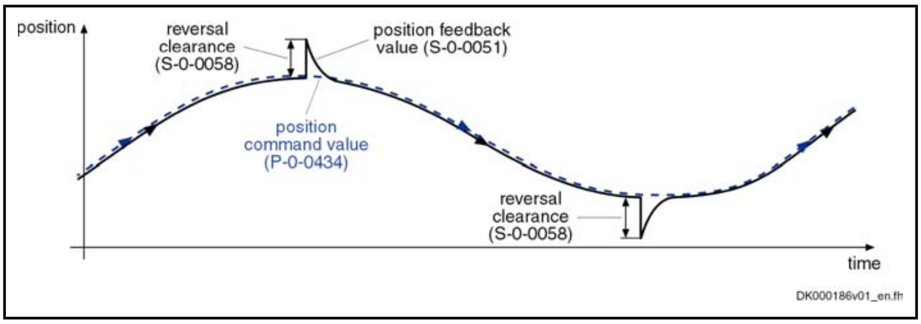


Fig.8-28: Operating Principle of Backlash on Reversal Correction in Position Control (Reversal Clearance Added in the Case of Negative Sign of the Value of P-0-0434)

In 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 hysteresis!

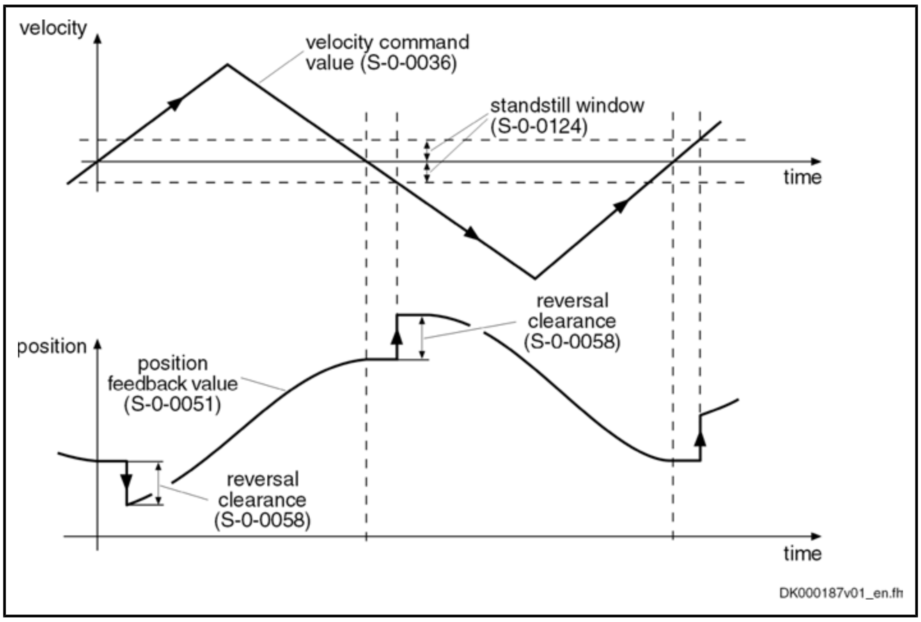


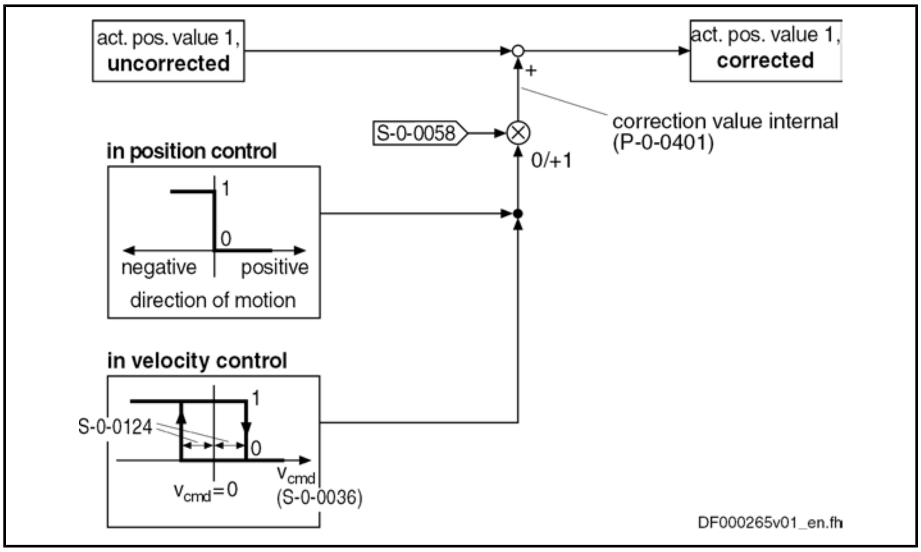
Fig.8-29: Operating Principle of Backlash on Reversal Correction in Velocity Control (Reversal Clearance Added When Velocity Command Value Leaves Standstill Window With Negative Velocity)

$$x_{act\_corr} = x_{act}$$

x_{act_corr} Corrected actual position value 1
x_{act} Uncorrected actual position value 1
Fig.8-30: 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.8-31: 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.8-32: Block Diagram of Backlash on Reversal Correction

Determining the Reversal Clearance

The following procedure is recommended for determining the value for parameter "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:

$$\text{Reversal clearance} = \Delta x_{\text{control}} - \Delta x_{\text{dial gauge}}$$

$\Delta x_{control}$	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.8-33: Determining the Input Value for S-0-0058

Precision Axis Error Correction

Expansion package **servo function** (order code **SRV**) of variants **MPH and MPD** in **closed-loop** characteristic

Fig.8-34: Assignment to Functional Firmware Package

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-0-0408, 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", position-dependent and direction-dependent correction values, so-called correction support points, can be entered 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 starting 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 operating 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 hysteresis!

Activating the Precision Axis Error Correction

The precision axis error correction is active when the parameter "P-0-0410, Axis correction support point distance" has a value greater than zero and position data reference has been established for the encoder the actual position value of which is to be corrected.

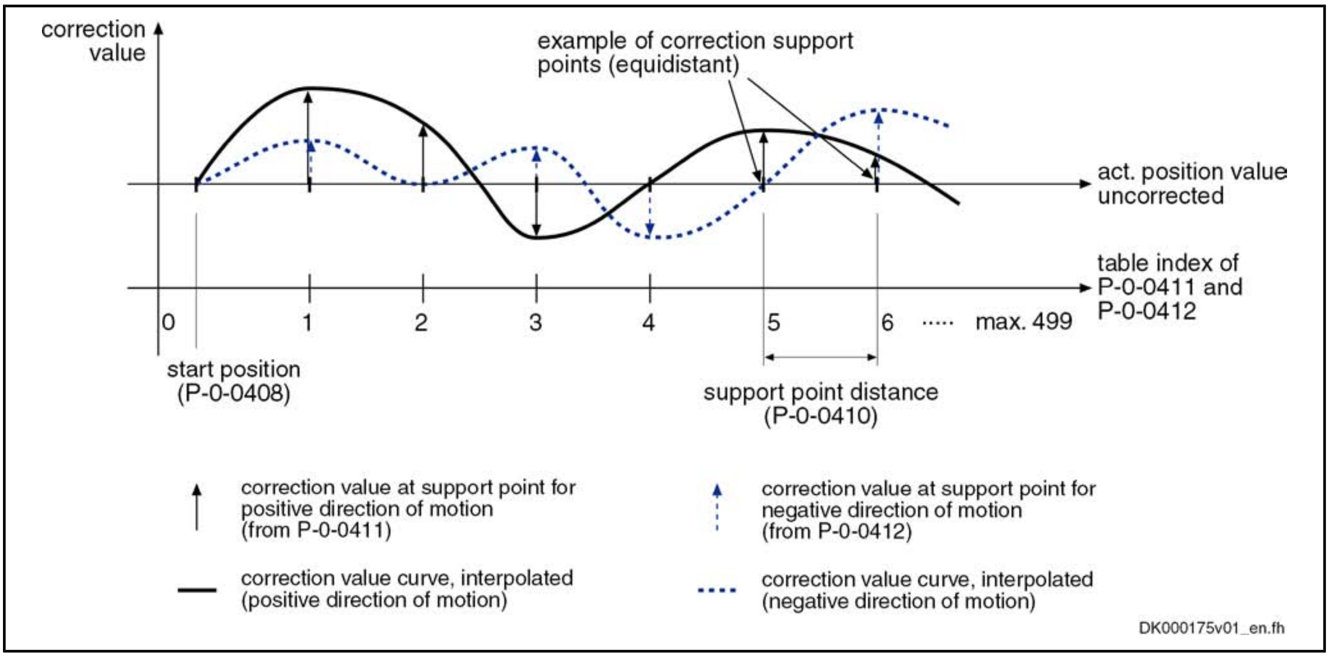


Fig.8-35: Illustration of Correction Value Generation From the Entered Correction Support Points

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

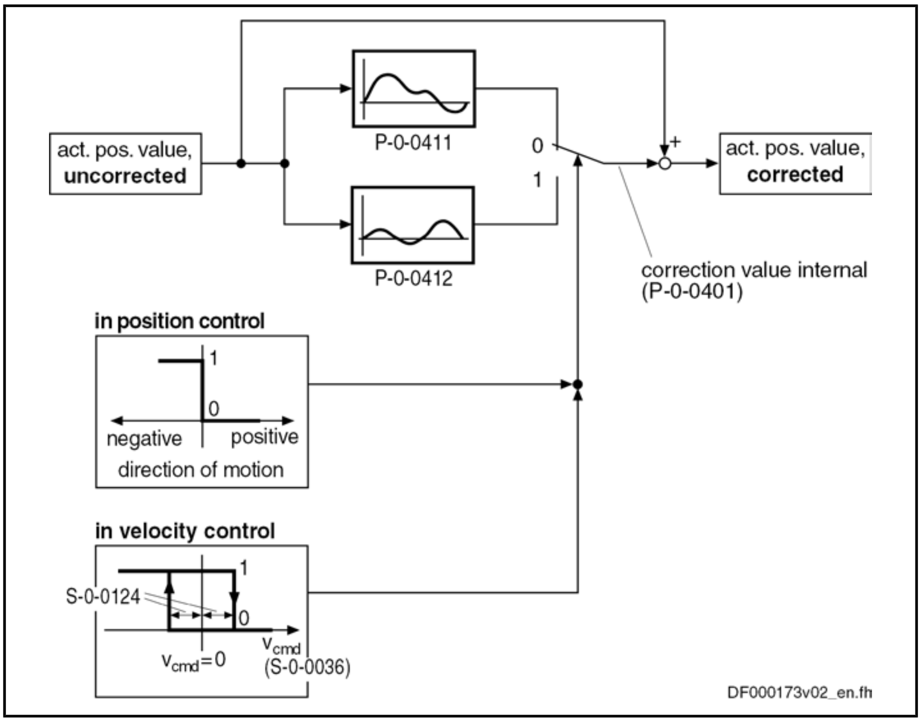
Fig.8-36: Assignment of Support Point Correction Values to Table Index of Correction Tables P-0-0411 and P-0-0412

☞ 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.8-37: 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.8-38: Determining Correction Value 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 value 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.8-39: Determining the Support Point Distance

When the value in parameter P-0-0410 equals zero, the precision axis error correction is deactivated!

Determining 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

Expansion package **servo function** (order code **SRV**) of variants **MPH and MPD** in **closed-loop** characteristic

Fig.8-40: Assignment to Functional Firmware Package

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 the parameter "P-0-0400, Axis correction external correction value" is available in the master data telegram. The correction values act on the encoder selected in parameter "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!

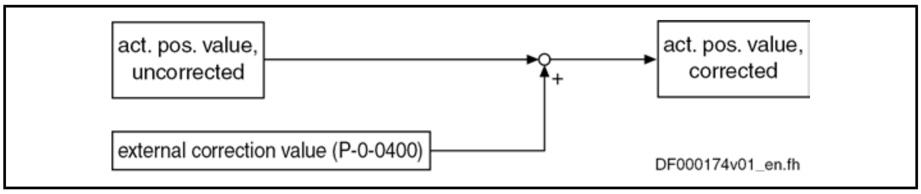


Fig.8-41: Control-Side Axis Error Correction

Temperature Error Correction

General Information

Expansion package **servo function** (order code **SRV**) of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.8-42: Assignment to Functional Firmware Package

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 temperature and on 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 parameter "P-0-0402, Axis correction reference temperature".

☞ When actual position reference values are measured, all machine parts have to 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).

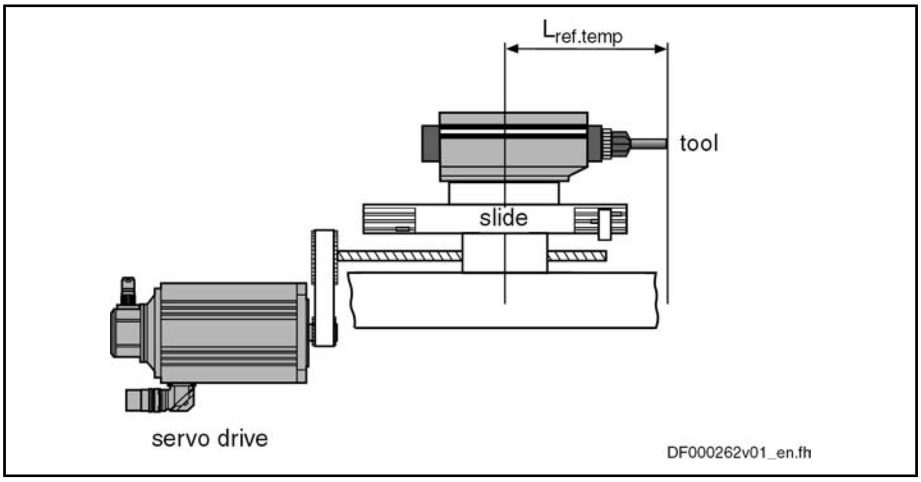
Position-Independent Temperature Error Correction

Usage

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.8-43: 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:

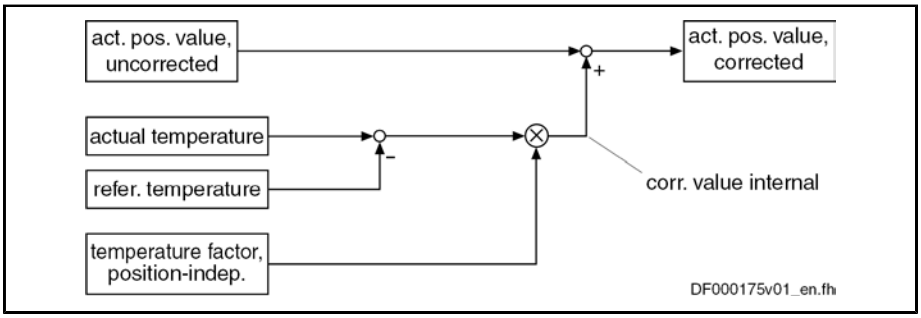


Fig.8-44: Position-Independent Temperature Error Correction

Drive-internal determination of the correction value:

$$x_{korr} = \text{P-0-0407} \times [(\text{P-0-0405}) - (\text{P-0-0402})]$$

x_{korr}	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.8-45: Determining the Correction Value

Position-Independent Temperature Factor

Determining the value for "P-0-0407, Axis correction temperature factor pos.-independent" can be carried out by calculation or by 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.

$$\text{P-0-0407} = \alpha \times L_{ref.\ temp.}$$

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.8-46: Calculating the Value for P-0-0407

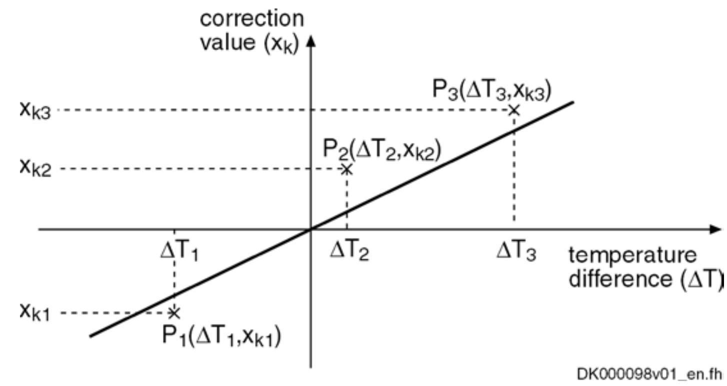
$$\begin{aligned}\text{P-0-0407} &= \alpha \times L_{ref.\ temp.}\\ &= 0{,}000018\ 1/K \times 100\ mm\\ &= 0{,}00018 mm/0{,}1K\end{aligned}$$

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, 100mm (preferred scaling)

Fig.8-47: Example of How to Calculate 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 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.8-48:	*Approximated Straight Correction Line on the Basis of Measured Correction Values at Different ΔT*

Calculation by Means of 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:

$$P\text{-}0\text{-}0407 = \frac{n \times \sum(\Delta T_n \times x_{kn}) - \sum \Delta T_n \times \sum x_{kn}}{n \times \sum \Delta T_n^2 - \left(\sum \Delta T_n\right)^2}$$

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.8-49:	*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

Usage

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 reference position for the position-dependent temperature error correction.

Pertinent Parameters

- P-0-0402, Axis correction reference temperature

Extended Axis Functions

- 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

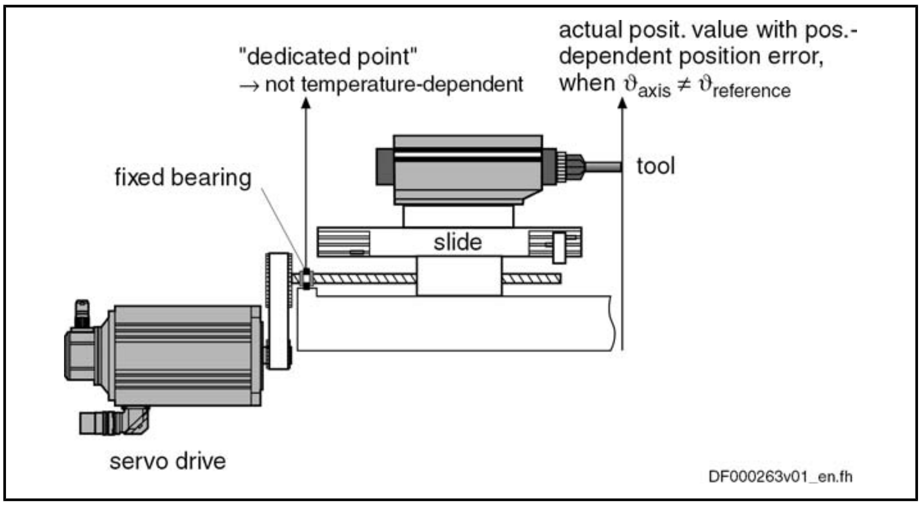


Fig.8-50: Example of Application for Position-Dependent Temperature Error Correction

☞ 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:

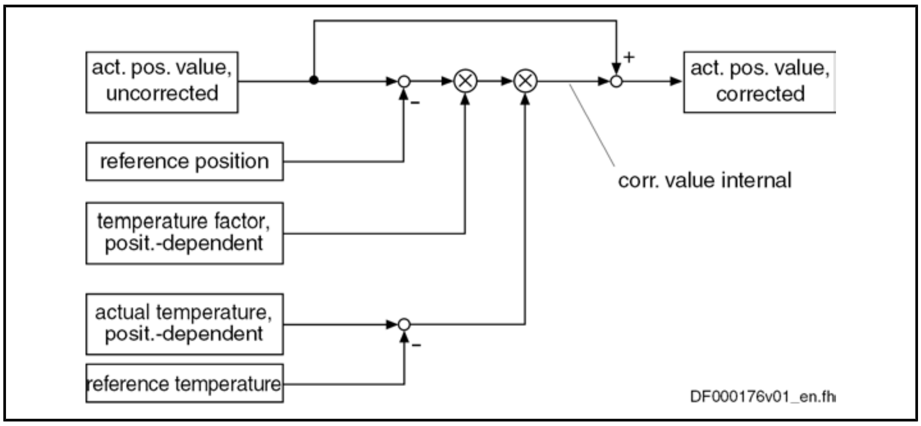


Fig.8-51: Position-Dependent Temperature Error Correction

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:

$$x_{korr} = \left[(S\text{-}0\text{-}0051) - (P\text{-}0\text{-}0403)\right] \times \left[(S\text{-}0\text{-}0404) - (P\text{-}0\text{-}0402)\right] \times P\text{-}0\text{-}0406$$

X_{korr}	Correction value, temperature- and position-dependent
S-0-0051	Position feedback 1 value (or S-0-0053 for position feedback 2)
P-0-0403	Axis correction reference 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.8-52: Determining the Correction Value, Temperature- and Position-Dependent

Determining the Reference Position

For position-dependent temperature error correction, there is an axis position that is not invalidated by variations of temperature. It is the reference position for position-dependent temperature error correction and is entered in parameter "P-0-0403, Axis correction reference position for temp. corr.".

Determine the reference position by:

- Direct measurement, if the arrangement of the mechanical transmission elements allows unequivocally recognizing the reference position

- or -

- A series of measurements with which the actual position value error is measured at axis positions clearly different from the reference position (at constant temperature that is clearly different from the reference temperature (P-0-0402))

Reference 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.

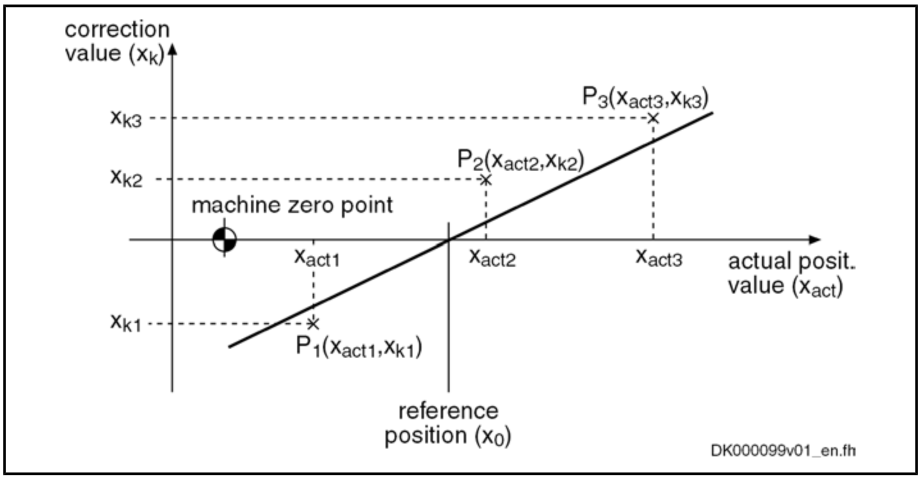


Fig.8-53: Illustration of the Reference Position

By means of the measuring points (P_1, P_2, P_3), it is possible to determine the reference position by the equation of an approximated straight line:

$$x_0 = \frac{-b}{a}$$

x_0	Reference position
b	Intersection point of straight line and correction value axis (x_k)
a	Gradient of the straight line

Fig.8-54: Determining the Reference Position

Gradient of the straight line:

$$a = \frac{n \times \sum\left(x_{act\_n} \times x_{kn}\right) - \sum x_{act\_n} \times \sum x_{kn}}{n \times \sum\left(x_{act\_n}\right)^2 - \left(\sum x_{act\_n}\right)^2}$$

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.8-55: Auxiliary Equation 1 for Determining Dedicated Point

Intersection point of straight line and correction value axis (x_k):

$$b = \frac{\sum x_{kn} \times \sum\left(x_{act\_n}\right)^2 - \sum x_{act\_n} \times \sum\left(x_{act\_n} \times x_{kn}\right)}{n \times \sum\left(x_{act\_n}\right)^2 - \left(\sum x_{act\_n}\right)^2}$$

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.8-56: Auxiliary Equation 2 for Determining 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

Fig.8-57: 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:

$$\begin{aligned}
\sum x_{kn} &= (-0{,}03 + 0{,}01 + 0{,}025)\ \text{mm} &&= +\ 0{,}005\ \text{mm} \\
\sum x_{act_n} &= (10{,}0 + 70{,}0 + 105)\ \text{mm} &&= 185{,}0\ \text{mm} \\
\sum\left(x_{act_n}\right)^2 &= (10^2 + 70^2 + 105^2)\ \text{mm}^2 &&= 16025\ \text{mm}^2 \\
\sum x_{act_n} \times x_{kn} &= (-0{,}3 + 0{,}7 + 2{,}625)\ \text{mm}^2 &&= +\ 3{,}025\ \text{mm}^2
\end{aligned}$$

Fig.8-58: Example: Partial Sums for Auxiliary Equations

$$a = \frac{3 \times 3{,}025\text{mm}^2 - 185{,}0\text{mm} \times 0{,}005\text{mm}}{3 \times 16025\text{mm}^2 - (185{,}0\text{mm})^2} = \frac{8{,}15\text{mm}^2}{13850\text{mm}^2} = 0{,}00058845$$

Fig.8-59: Example: Auxiliary Equation 1

$$b = \frac{0{,}005 \times 16025\text{mm}^2 - 185{,}0\text{mm} \times 3{,}025\text{mm}}{3 \times 16025\text{mm}^2 - (185{,}0\text{mm})^2} = \frac{-479{,}5\text{mm}^2}{13850\text{mm}^2} = -0{,}034621$$

Fig.8-60: Example: Auxiliary Equation 2

$$x_0 = \frac{-(-0{,}034621)}{0{,}00058845} = 58{,}83\ \text{mm}$$

x_0 Reference position

Fig.8-61: Example: Determining the Reference Position

In order to be able to determine the reference position as exactly as possible, several series of measurements should 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

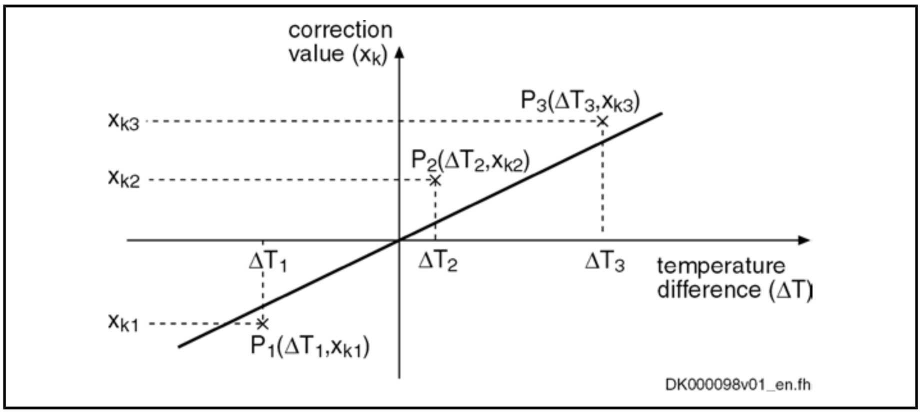
- or -

- 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 reference 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.8-62: 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:

$$\text{P-0-0406} = \frac{n \times \sum (\Delta T_n \times x_{kn}) - \sum \Delta T_n \times \sum x_{kn}}{n \times \sum \Delta T_n^2 - \left(\sum \Delta T_n\right)^2}$$

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.8-63:	*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 parameter "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!

8.5.4 Quadrant Error Correction

Brief Description

Expansion package **servo function** (order code **SRV**) of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.8-64: *Assignment to functional firmware package*

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

For 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 loop. 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.

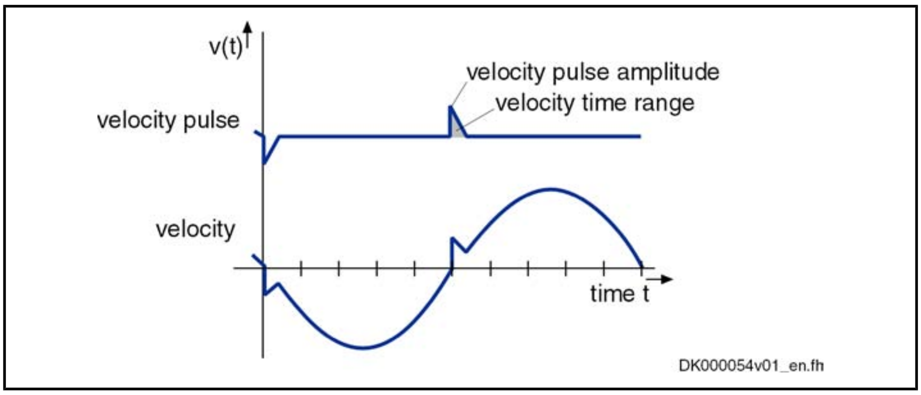


Fig.8-65: Schematic curves of velocity pulse and velocity command value with quadrant error correction

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 parameter "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 input in parameter "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 should be done with regard to the path velocity and the duration for processing the reference circle (P-0-0436):

$$P\text{-}0\text{-}0437 = \frac{1}{2} \times \frac{a}{100\%} \times v_{\text{path}} \times \frac{b}{100\%} \times T_{\text{circle}}$$

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.8-66: 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 parameter "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 should 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 should be deactivated. To do this, the respective bit of P-0-0435 should 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 parameter "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 should 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 parameter "P-0-0435, Control word of position controller"
   - Set "P-0-0437, Velocity time range for quadrant error correction" to "0"
   - Write 50% and 70% (list lines 1 and 2), for example, of maximum circular velocity to "P-0-0438, Table of path velocities for quadrant error correction"
   - In parameter "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 parameter "P-0-0435, Control word of position controller".
4. Write approx. 1% of current path velocity to list line 2 of parameter "P-0-0439, Table of velocity pulse for quadrant error correction".
5. Increase value in parameter "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)!

8.5.5 Cogging Torque Compensation

Brief Description

Expansion packages **servo function** (order code **SRV**) and **synchronization** (order code **SNC**) of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.8-67: Assignment to Functional Firmware Package

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, additive torque command values take effect in drive control in a position-dependent way.

Hardware Requirements

The compensation of cogging torque/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:

- The position measuring range may have only **one** reference mark or it is equipped with distance-coded reference marks!

Pertinent Parameters

- 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, Status word of cogging torque compensation
- 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, Cogging torque compensation adaption factor

Pertinent Diagnostic Messages

- 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

☞ To get a more detailed description of the cogging torque compensation and information on its possibilities of use with MPx04 firmware, please contact your Bosch Rexroth sales representative!

8.6 Measuring Wheel Mode

8.6.1 Brief Description

Expansion package **synchronization** (order code **SNC**) of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.8-68: Assignment to functional firmware package

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.

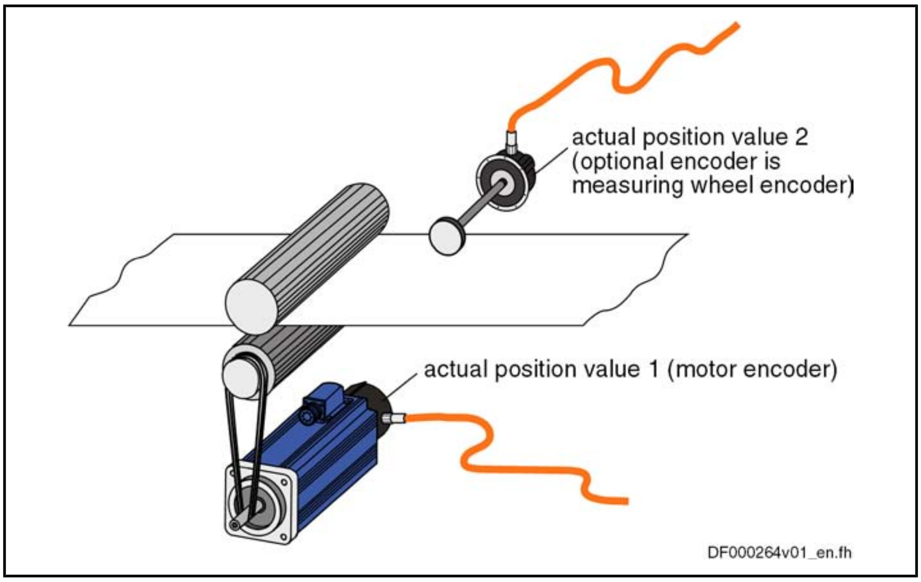


Fig.8-69: Typical arrangement of drive for material infeed with measuring wheel encoder

Hardware Requirements

The measuring wheel encoder is an optional (external) encoder that is connected according to the connection diagram contained in the "Drive Controllers, Control Sections; Project Planning Manual" documentation.

See also "Measuring Systems"

Pertinent Parameters

The following parameters are used to parameterize this function:

- S-0-0520, Control word of axis controller
- S-0-0521, Status word of position loop
- P-0-0241, Actual pos. smoothing time constant for hybrid pos. control
- P-0-0242, Current actual slip value in %
- P-0-0243, Maximum occurred actual slip value in %
- P-0-0244, Monitoring window of slip in %

The following parameters are used to parameterize the measuring wheel encoder:

- S-0-0115, Position feedback 2 type
- S-0-0117, Feedback 2 resolution
- 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)

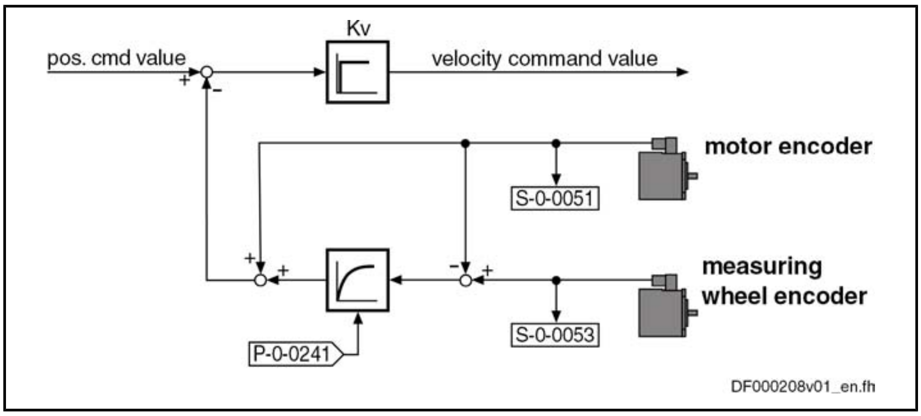
- P-0-0185, Control word of encoder 2 (optional encoder)

Pertinent Diagnostic Messages

- F2036 Excessive position feedback difference

8.6.2 Functional Description

The measuring wheel mode can only be used in operating 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.

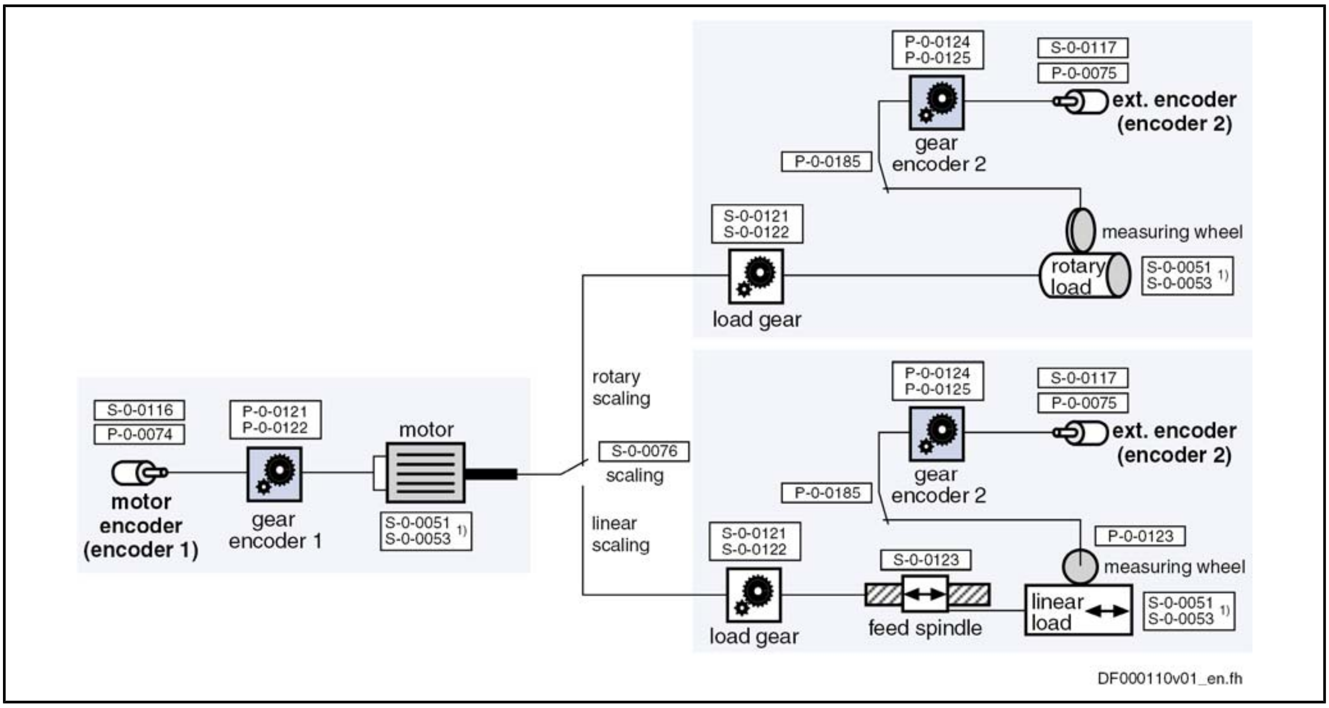


S-0-0051 Position feedback 1 value
S-0-0053 Position feedback 2 value
P-0-0241 Actual pos. smoothing time constant for hybrid pos. control
Fig.8-70: Generating the "hybrid actual position value" in measuring wheel mode

For measuring wheel mode you have to activate the optional encoder in parameter "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 parameter "S-0-0520, Control word of axis controller".

☞ By the value "0" in parameter "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 encoder 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 1 value
S-0-0053	Position feedback 2 value
S-0-0076	Position data scaling type
S-0-0116	Feedback 1 Resolution
S-0-0117	Feedback 2 Resolution
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.8-71: Arrangement of the measuring wheel encoder in the mechanical drive system

Operating Modes and Measuring Wheel Mode

The measuring wheel mode can only be used in position-controlled operating modes.

Position Data Reference

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.

Position-Controlled Operating Modes

When activating the measuring wheel mode in position-controlled operating modes, the actual position value of the motor encoder is applied to the actual position value of the measuring wheel encoder ("S-0-0051, Position feedback 1 value" → "S-0-0053, Position feedback 2 value").

When switching to a non-position-controlled operating mode while the measuring wheel mode has been activated, the actual position value of the measuring wheel encoder is applied to the actual position value of the motor encoder ("S-0-0053, Position feedback 2 value" → "S-0-0051, Position feedback 1 value").

Non-Position-Controlled Operating Modes

In non-position-controlled operating modes control, as a basic principle, takes place with regard to the motor encoder. If first the measuring wheel mode is activated and only then the drive is switched to a position-controlled operating mode, the actual position value of the motor encoder is applied to the actual position value of the measuring wheel encoder ("S-0-0051, Position feedback 1 value" → "S-0-0053, Position feedback 2 value"), **when the drive is switched to the position-controlled operating mode**.

In non-position-controlled operating modes, it is possible, with active measuring wheel mode, to lift the feed rolls off the material (discharge the feed rolls), for example.

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 parameter "P-0-0242, Current actual slip value in %". It refers to

- one measuring wheel revolution, if "feed constant 2" is active in parameter 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 parameter P-0-0185 (encoder is measuring rotary infeed).

If the calculated slip exceeds the value in parameter "P-0-0244, Monitoring window of slip in %" (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 parameter "P-0-0243, Maximum occurred actual slip value in %".

☞ The slip monitor is deactivated with the value "0" in parameter P-0-0244!

8.6.3 Notes on Commissioning

Presettings

First set the parameter values relevant to the mechanical arrangement of motor, motor encoder, axis and measuring wheel (see fig. "Arrangement of the measuring wheel encoder in the mechanical drive system"). In addition, configure parameter "P-0-0185, Control word of encoder 2 (optional encoder)" in such a way that the external (optional) encoder is used as "measuring wheel encoder".

Activating the Measuring Wheel Mode

CAUTION

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 parameter "S-0-0520, Control word of axis controller". As a prerequisite, the drive has to be in a position-controlled operating 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 parameter "S-0-0520, Control word of axis controller",
- 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 parameter "P-0-0241, Actual pos. smoothing time constant for hybrid pos. control".

☞ The value "0" in parameter P-0-0241 switches off the attenuation and causes only the actual position value of the measuring wheel encoder to be effective!

Procedure:

1. Enter value "0" in parameter 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 parameter "P-0-0244, Monitoring window of slip in %".

☞ The value "0" in parameter P-0-0244 causes the slip monitor to be switched off! The value in parameter "P-0-0242, Current actual slip value in %" thereby 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 parameter "P-0-0244, Monitoring window of slip in %" so that slip monitor cannot be triggered.
2. Enter value "0" in parameter "P-0-0243, Maximum occurred actual slip value in %" 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 parameter "P-0-0244, Monitoring window of slip in %".

If the value in parameter "P-0-0242, Current actual slip value in %" 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.

8.7 Positive Stop Drive Procedure

8.7.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.8-72: Assignment to functional firmware package

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

Pertinent Diagnostic Messages

- C1300 Positive stop drive procedure command
- C1301 Class 1 diagnostics error at command start

8.7.2 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 diagnostic errors:

- Monitor "drive does not follow command value"

  → "F2028 Excessive deviation"
- Velocity command value monitor

  → "F2037 Excessive position command difference"
- Acceleration command value monitor

  → "F2039 Maximum acceleration exceeded"
- Velocity control loop monitor

  → "F8078 Speed loop error"

The command is acknowledged on the following conditions:

- The axis has stopped, i.e. the actual velocity 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 actual torque/force 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!

CAUTION

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 command "positive stop drive procedure" cannot be started!

8.7.3 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 function "positive stop drive procedure" 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!

Diagnosis

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

8.8 Redundant Motor Encoder

8.8.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.8-73: Assignment to functional firmware package

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 failure: signal amplitude wrong
- F2042 Encoder 2: incorrect encoder signals.
- F8022 Encoder 1: incorrect encoder signals (can be deleted in phase2)
- F8042 Encoder 2 failure: signal amplitude wrong

8.8.2 Functional Description

Relevance of the Function

By means of the function "redundant motor encoder", 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 function "redundant motor encoder", 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)".

☞ The function "redundant motor encoder" can be used for axes with linear motor, too, if an external measuring system is available.

Operating Principle

With activated redundant motor encoder, in case of a motor encoder failure, the error message "F2031 Encoder 1 failure: signal amplitude wrong" is triggered and a possibly existing position data reference is cleared. The controller switches the internal signal paths of the encoder evaluation so that both parameter "S-0-0051, Position feedback 1 value" and parameter "S-0-0053, Position feedback 2 value" receive the signals of the external encoder (activated as redundant motor encoder). The signal path for the commutation of the motor is switched, too.

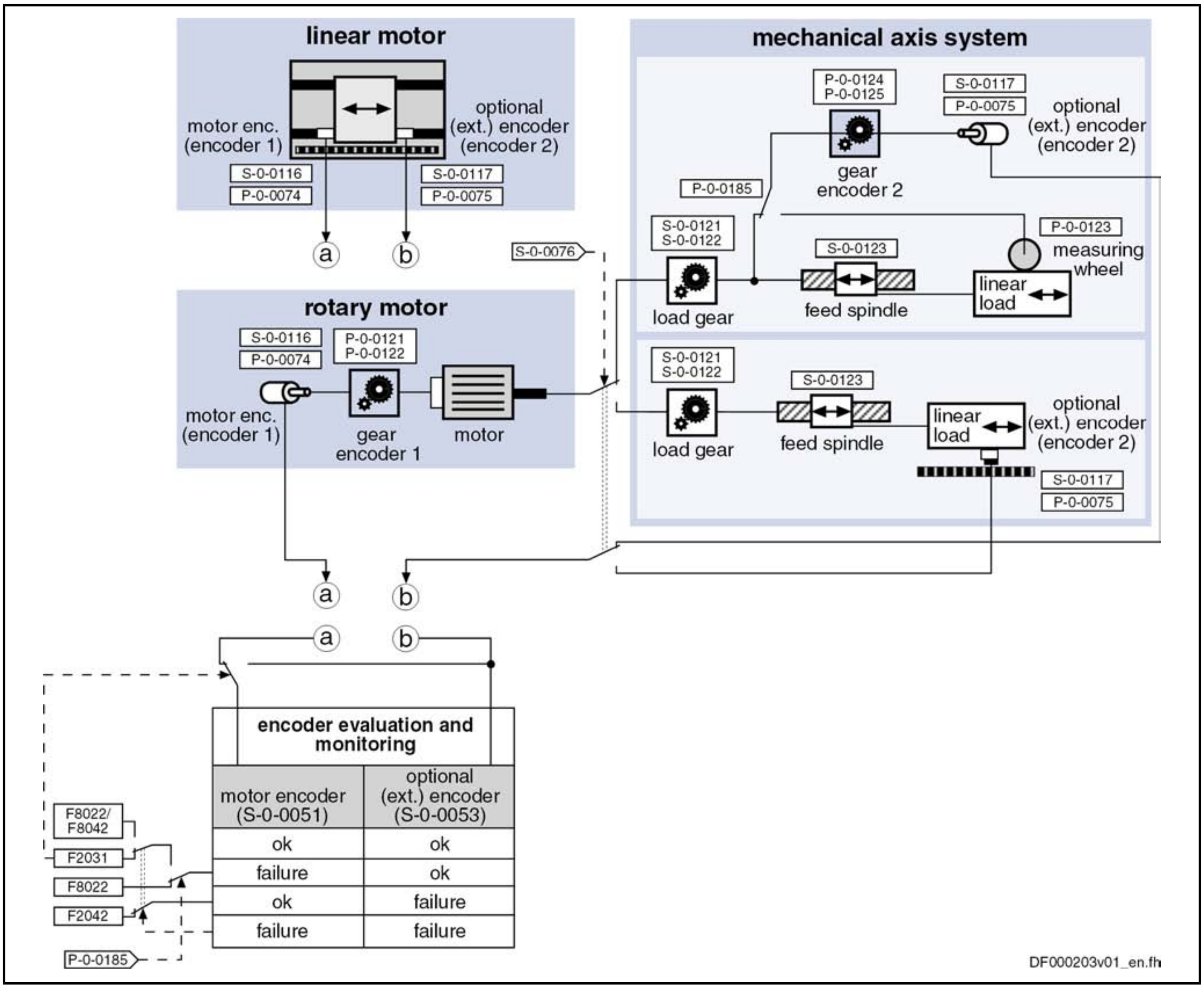


Fig.8-74: Redundant encoder evaluation for axes with rotary motors and linear motors

Reactions if Motor Encoder Defective

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 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 (external 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.

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 failure: Signal amplitude incorrect" if motor encoder was defective first,
- "F8022 Encoder 1: Encoder signals incorrect (can be cleared in ph. 2)", if redundant motor encoder was defective first.

The drive torque is disabled and the drive coasts to stop.

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.

8.8.3 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 "Measuring Systems")
- Determine behavior of drive in the case of error (see Error Reactions")

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 loop 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 loop is 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.

8.9 Spindle Positioning

8.9.1 Brief Description

Expansion package **main spindle** (order code **MSP**) of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.8-75: Assignment to functional firmware package

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 operating 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 command
- S-0-0153, Spindle angle position
- S-0-0154, Spindle position 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-0-0430, Effective target position
- 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

8.9.2 Functional Description

Basic Sequence of the Function

The positioning of the spindle is started via "S-0-0152, C0900 Position spindle command". During the execution of the command, the controller ignores the current command value of the active operating mode.

The presetting for the kind of positioning and motion of the spindle towards the target position in made in "S-0-0154, Spindle position parameter".

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.

Kind 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".

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 doesn't 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".

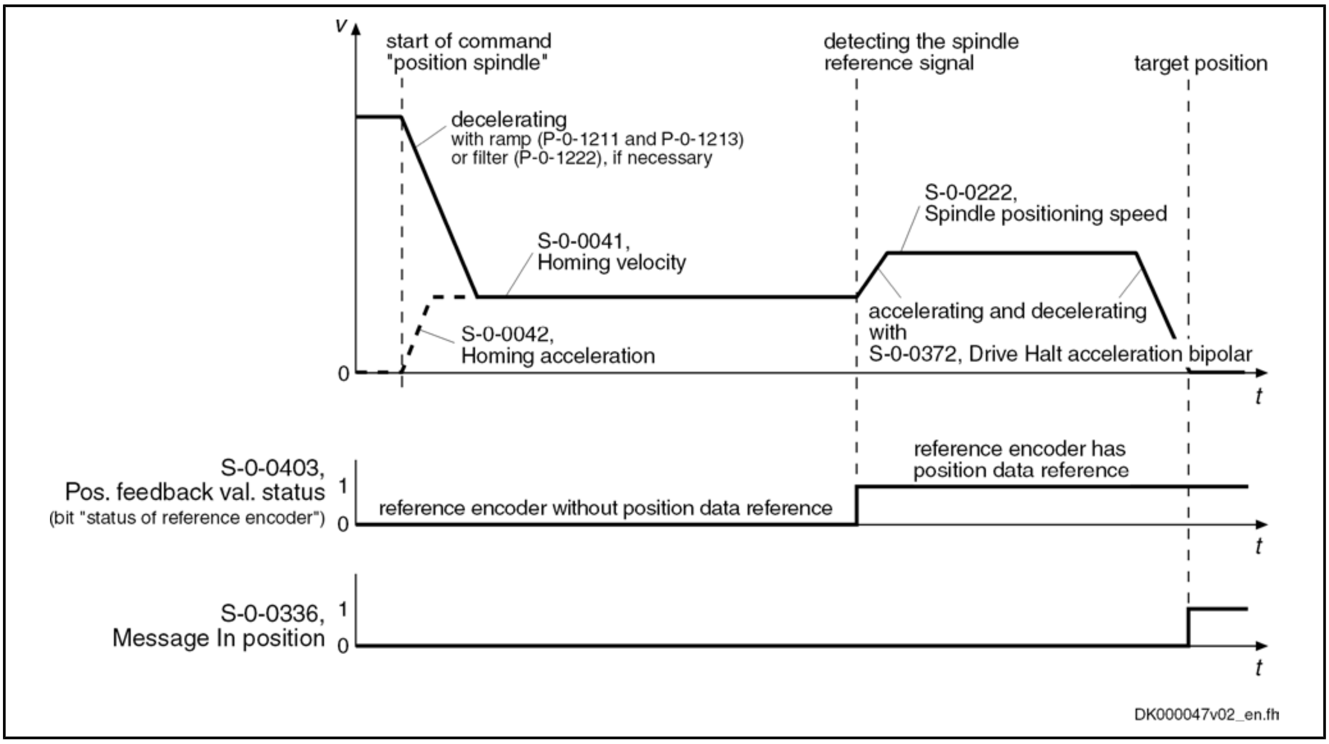


Fig.8-76: Basic sequence of spindle positioning (including establishing the position data reference)

Message "Target Position Reached"

The following parameters signal that the target position for spindle positioning has been reached:

- S-0-0336, Message 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 for machine tools or rotary axes mostly are 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 position 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 reversion 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.

Fig.8-77: Dependence of the positioning process on the start position with determined direction of positioning movement "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 reversion of velocity direction, at next target position to be reached.

Fig.8-78: Dependence of the positioning process on the velocity at the start of spindle positioning with determined direction of positioning motion "shortest distance"

8.9.3 Notes on Commissioning

Presettings

Determining kind of positioning and direction of positioning motion:

- S-0-0154, Spindle position 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 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, Message 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".

8.9.4 Diagnostic Messages

The execution of spindle positioning required 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

8.10 Parameter Set Switching

8.10.1 Brief Description

Expansion package **main spindle** (order code **MSP**) of variants **MPH and MPB** in **closed-loop and open-loop** characteristic

Fig.8-79: Assignment to Functional Firmware Package

IndraDrive devices have been equipped with up to eight parameter sets; it is possible to switch between these sets in operation. One of the switchable parameter sets is always active. Switching takes place upon command of the control master.

Notes on Applications

With the possibility of adjusting the values of different parameters to different operating phases or machining processes by switching parameter sets, if necessary during operation, the IndraDrive firmware 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
- Winding parameters

- Encoder parameters

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

  Note: 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

- 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)

8.10.2 Functional Description

General Information

Parameter set switching is activated

- by triggering command "C4100 Switch parameter set" (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".

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.)
- **Winding** (current loop parameters, temperature sensor code, warning and shutdown temperature, etc.)
- **Encoder** (motor encoder parameters)

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 seen in 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 are addressed via their IDNs. In the case of the switchable parameters, it is necessary to observe the number for the respective parameter set.

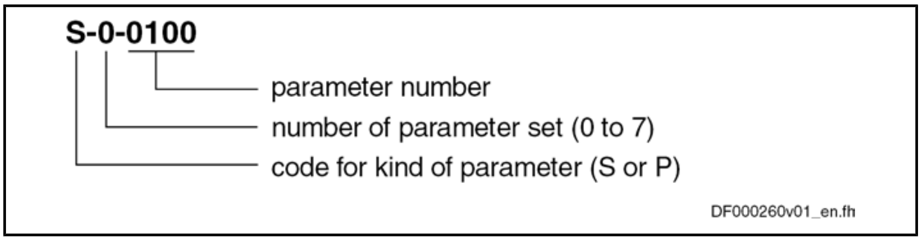


Fig.8-80: Structure of the IDN of a Switchable Parameter (Example)

Defining the Parameter Groups

Application Parameters

The following switchable parameters are permanently assigned to the "application" group:

- 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-0-0261, Coarse position window
- S-0-0349, Jerk limit bipolar
- S-0-0372, Drive Halt acceleration bipolar
- S-0-0822, Torque/force ramp
- S-0-0823, Torque/force ramp time
- P-0-0041, Position command average value filter time constant
- P-0-0214, Analog input, assignment A, scaling per 10V full scale
- P-0-0215, Analog input, assignment A, signal value at 0V
- P-0-0216, Analog input, assignment A, dead zone
- 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, Analog input 4, time constant input filter
- P-0-0237, Analog input, assignment B, scaling per 10V full scale
- P-0-0238, Analog input, assignment B, signal value at 0V
- P-0-0239, Analog input, assignment B, dead zone
- 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

Control Loop Parameters

The following switchable parameters are permanently assigned to the "control loop" group:

- 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
- P-0-0004, Velocity loop smoothing time constant
- P-0-0040, Velocity feedforward evaluation
- P-0-0180, Acceleration feedforward smoothing time constant
- 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, Velocity control loop filter: center frequency of band-stop filter
- P-0-1125, Velocity control loop: average value filter clock
- P-0-1126, Velocity control loop: acceleration feedforward

Load Gear Parameters

The following switchable parameters are permanently assigned to the "load gear" group:

- 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-0-0150, Reference offset 1
- S-0-0222, Spindle positioning speed
- S-0-0299, Home switch offset
- P-0-0109, Torque/force peak limit

☞ Switching the parameters of the "load gear" group is impossible with active safety technology!

Winding Parameters

The following switchable parameters are permanently assigned to the "winding" group:

- 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-0-0446, Ramp reference velocity for acceleration data
- P-0-0018, Number of pole pairs/pole pair distance
- P-0-0045, Control word of current controller
- P-0-0051, Torque/force constant
- P-0-0506, Amplitude for angle acquisition
- P-0-0507, Test frequency for angle acquisition
- P-0-0508, Commutation offset
- P-0-0510, Rotor inertia
- P-0-0512, Temperature sensor
- P-0-0513, Temperature sensor characteristic
- P-0-0517, Commutation: required harmonics component
- P-0-0522, Control word for commutation setting
- 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, Voltage loop proportional gain
- P-0-0534, Voltage loop integral action time
- P-0-0535, Motor voltage at no load
- P-0-0536, Maximum motor voltage
- P-0-0540, Torque of motor holding brake
- 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-0-0590, Frequency loop proportional gain
- P-0-0591, Frequency loop integral action time
- P-0-0592, Motor model adjust factor
- P-0-0640, Cooling type
- 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-0-4014, Type of construction of motor
- P-0-4016, Direct-axis inductance of motor

- P-0-4017 Quadrature-axis inductance of motor
- P-0-4032, Motor type plate data
- P-0-4034, Thermal time constant of winding
- P-0-4035, Thermal time constant of motor
- P-0-4036, Rated motor speed
- P-0-4037, Thermal short-time overload of winding
- 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

Encoder Parameters

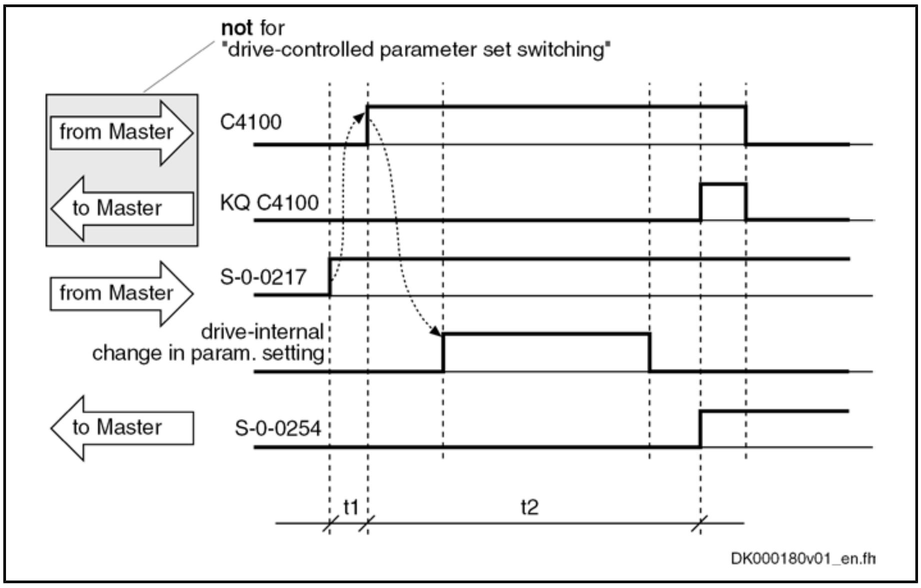
The following switchable parameters are permanently assigned to the "encoder" group:

- S-0-0116, Feedback 1 resolution
- S-0-0206, Drive on delay time
- S-0-0207, Drive off delay time
- S-0-0277, Position feedback 1 type
- 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-0-0540, Torque of motor holding brake

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.8-81: Sequence Diagram for Switching Application, Control Loop and Load Gear Parameters

Parameter Group "Load Gear" and Safety Technology

If the drive function "safety technology" is used and the parameter group "load gear" is to be included in the switching process, the option "data reference with respect to motor" must be selected (see "scaling" in parameter "P-0-3210, Safety technology configuration").

☞ If the gear ratio changes by parameter set switching, the reference of the encoders gets lost. The content of parameter "S-0-0403, Position feedback value status" is cleared. In order to get defined position reference again, carry out homing procedure again!

CAUTION

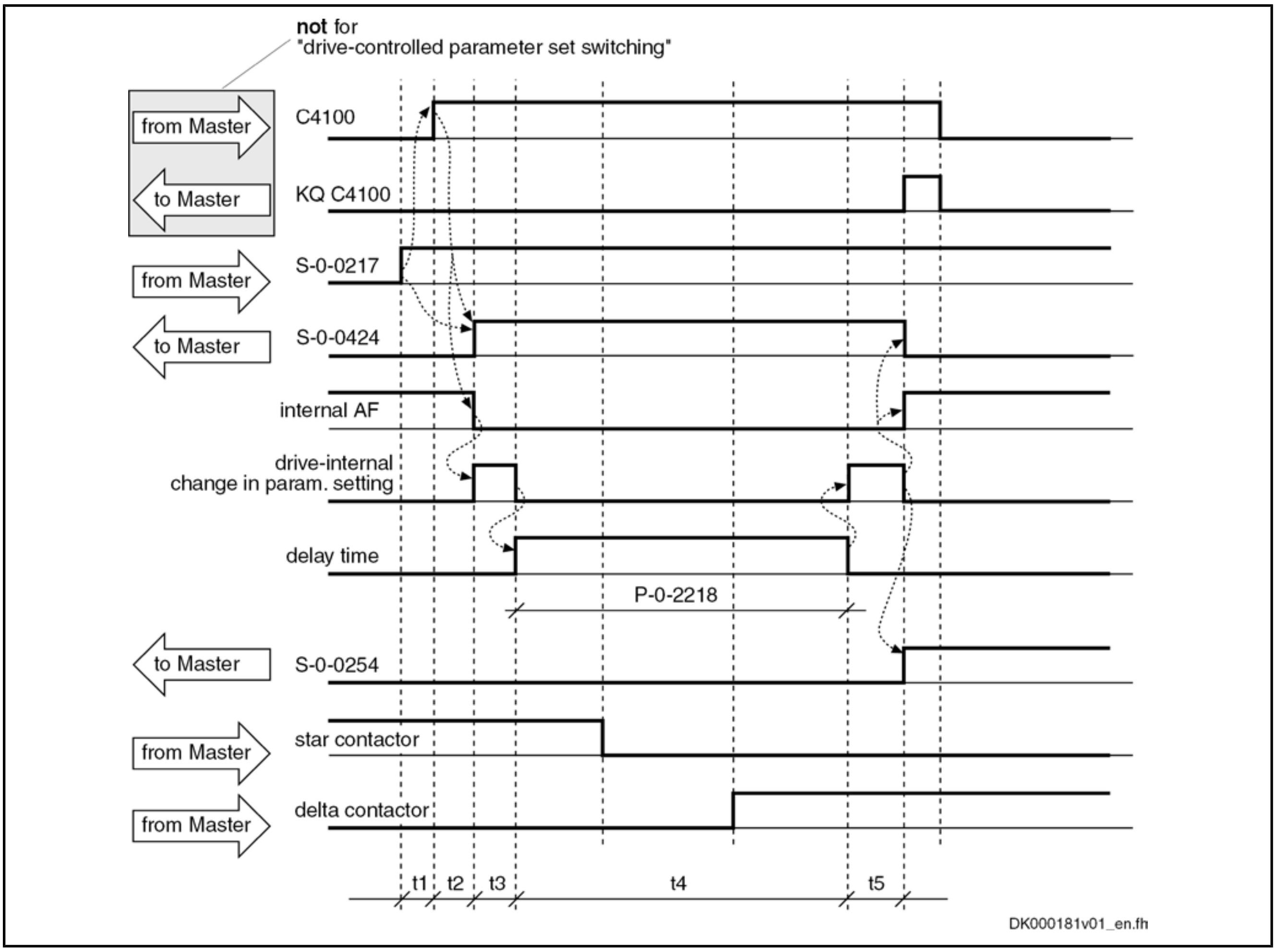
By parameter set switching with "AF", the command values can change internally. This can cause accidental axis motion!

⇒ 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 activated again in the controller after the delay time which can be set (see P-0-2218) is over (see sequence diagram below).

Winding switching thereby takes place in the shortest possible time. By the appropriate setting in parameter P-0-2218, you nevertheless have sufficient delay until switching times of contactors, relays etc. are over.



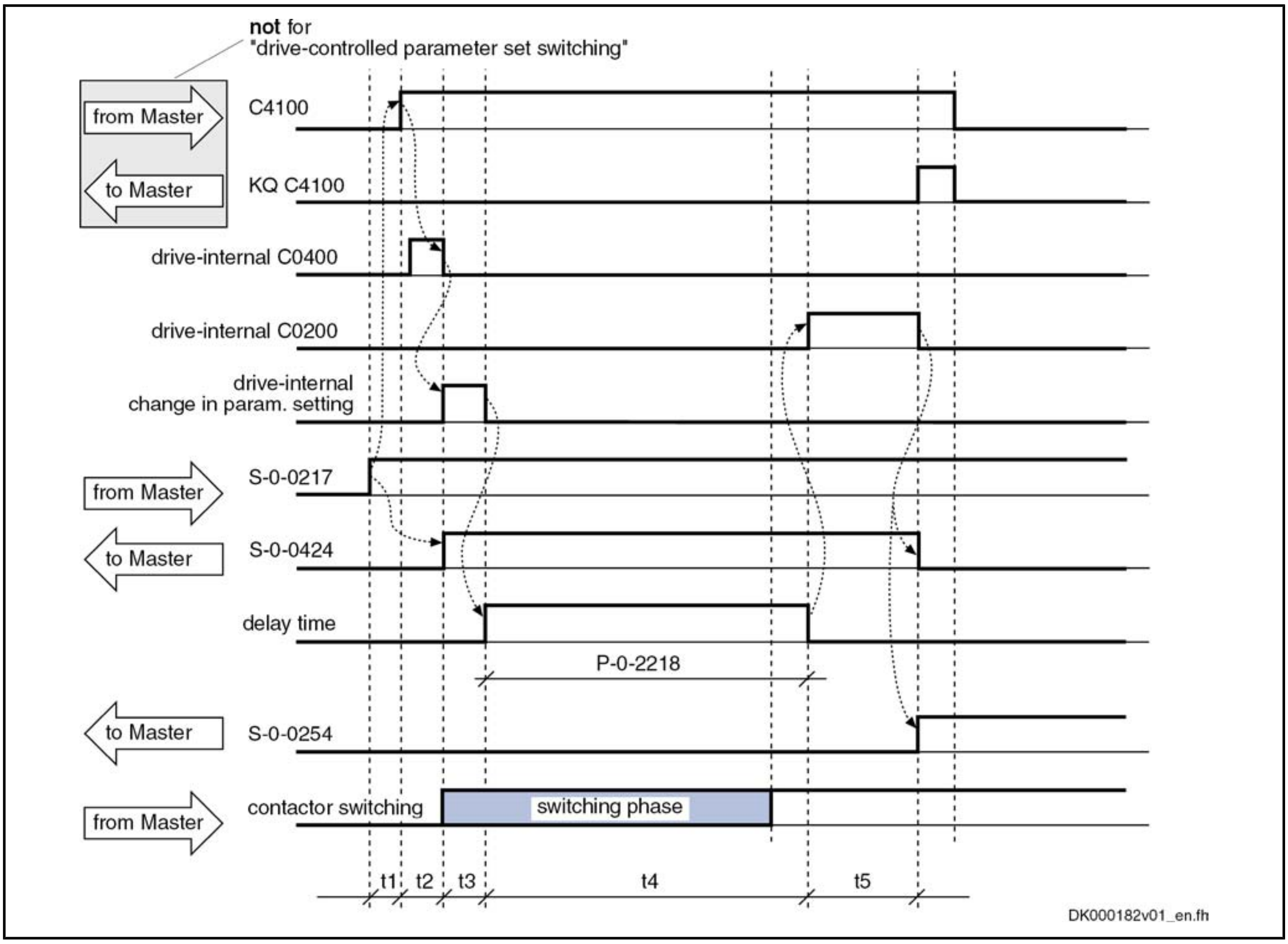
C4100	Switch parameter set command
KQ C4100	Switch parameter set command acknowledgment
S-0-0217	Preselect parameter set command
S-0-0254	Current parameter set
S-0-0424	Status parameterization level
P-0-2218	Parameter set switching, delay time
t1	Approx. 6 ms (drive-controlled parameter set switching)
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.8-82: Sequence Diagram for Switching the Winding Parameters

Parameter Group "Encoder"

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. 7…15 s (for MPB) or approx. 1…15 s (for MPH)

Fig.8-83: Sequence Diagram for Switching the 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!

8.10.3 Notes on Commissioning

Presettings

Preselect parameter groups to be switched in:

- P-0-2216, Parameter set switching, configuration

Determine number of switchable parameter sets in:

- P-0-2217, Parameter set switching, preselection range

If desired, activate "drive-controlled parameter set switching" in parameter P-0-2216, too.

Writing 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-1-xxxx to P-7-xxxx) but are not listed, cannot be written in communication phase 4!

Initial State

After switching on, it is always "parameter set 0" that is active first. Parameter "S-0-0254, Current parameter set" displays "0".

Carry 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" (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 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)

8.11 Drive-Controlled Oscillation

8.11.1 Brief Description

Expansion package **main spindle** (order code **MSP**) of variants **MPH and MPB** in **closed-loop and open-loop** characteristic

Fig.8-84: Assignment to functional firmware package

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 Applications

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 i.c. engine equipment under test to test stands)

Pertinent Parameters

- 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

8.11.2 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.

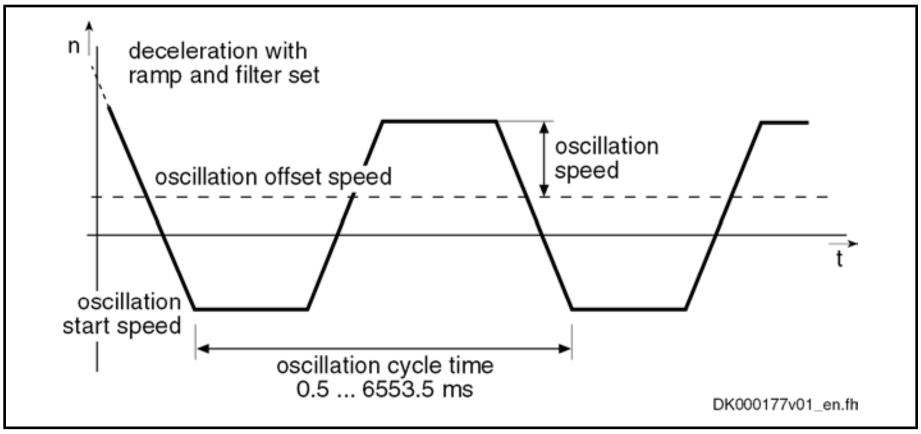


Fig.8-85: Speed characteristic with drive-controlled oscillation

Start "Drive-Controlled Oscillation"

Triggering the command "C4200 Drive-controlled oscillation" 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.

8.11.3 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-0-0157, Velocity window" 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" have to be

checked and values allowed for the spindle mechanics entered, if necessary.

Value in parameter "S-0-0215, Oscillation cycle time" has to be between 0.5 ms and 6553.5 ms (steps of 0.5 ms)!

Activate Oscillation The function is activated by starting command "C4200 Drive-controlled oscillation" (S-0-0190) via the control master.

Complete Oscillation The function is completed by clearing command C4200 by the control master, when the master has detected the meshing of the gear shaft to have been carried out.

Diagnostic Messages During execution of the command, the message "C42" appears on the display of the controller.

Possible failures are displayed by the following diagnostic messages:

- C4201 Oscillation requires drive enable
- C4202 Oscillation command speed cannot be reached

8.12 Parking Axis

8.12.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.8-86: Assignment to functional firmware package

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 function "parking axis" can be activated via command.

When a drive has been put into the status "parking axis", 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 status "parking axis" 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 command

Pertinent Diagnostic Messages

- C1600 Parking axis command

8.12.2 Functional Description

The parameter "S-0-0139, C1600 Parking axis command" can only be activated in the 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
- Drive initializations are not carried out when "S-0-0128, C0200 Communication phase 4 transition check" is executed
- "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 1 procedure command". By activating "S-0-0422, C0200 Exit parameterization level procedure command", the drive returns to the operating mode.

8.13 Integrated Safety Technology

8.13.1 General Information

☞ The section below contains an overview of the integrated safety functions of the IndraDrive hardware and the IndraDrive firmware. Details concerning function, notes on commissioning and examples of application are described in the separate documentation "Rexroth IndraDrive: Integrated Safety Technology" (DOK-INDRV*-SI*-**VRS**-FK**-EN-P; part no. R911297838).

8.13.2 Brief Description

What is "Integrated Safety Technology"?

The control sections of the IndraDrive range can be equipped with

- an optional module "starting lockout" ("L1") or
- an optional module "safety technology I/O" ("S1")

IndraDrive is thereby equipped with integrated safety technology which provides the user with an electronic starting lockout, as well as with universally programmable safety related motion and standstill monitoring.

Definition

"Integrated safety technology" refers to application-related safety functions that are applicable for personal protection at machines in accordance with EN 954-1 (category 3).

Selecting the Function

The safety functions can be alternatively selected via

- 24 V inputs at the drive controller or

- 24 V inputs at the drive controller and master communication (one channel each) or
- the safety related channel in PROFIBUS (PROFIsafe).

Certification The safety technology was tested and certified by an EU type examination of "Certification Authority SIBE Schweiz" (http://www.sibe.ch). (On demand, you can get copies of the declarations of conformity and mark certificates from our Bosch Rexroth sales representative.)

Requirements That Can Be Realized The integrated safety technology is independent of the type of master communication, the higher-level control units and the supply modules. It is available as optional module for the standard drive system. The requirements below can be realized in the machine or in the installation:

- Measures according to EN 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 in accordance with EN 954-1 category 3, as stipulated in EN 1010-1 (printing and paper converting machines), EN 12415 (turning machines) and EN 12417 (machining centers).
- Control functions in the case of error according to EN 60204-1 (see "Using diversity" in EN 60204-1).

Integrated Safety Technology as IndraDrive Platform Solution

The different characteristics of the integrated safety technology (e.g. PROFIsafe, I/O, ...) require different hardware conditions:

Control section type	Designation	Characteristics of integrated safety technology		
			Safety On Board	
		Starting lockout (optional module "L1")	Safety technology I/O (optional module "S1")	PROFIsafe
CSH01.1C	ADVANCED	X	X	X
CSH01.2C	ADVANCED	X	X	X
CSB01.1C	BASIC UNIVERSAL (single-axis)	X		
CDB01.1C	BASIC UNIVERSAL (double-axis)	X	X	X
CSB01.1N-FC	BASIC OPENLOOP	X		
CSB01.1N-AN	BASIC ANALOG	X		
CSB01.1N-SE	BASIC SERCOS	X		
CSB01.1N-PB	BASIC PROFIBUS	X		

Fig.8-87: Overview of the Hardware Conditions for the Integrated Safety Technology

☞ In addition to the optional module "S1", using PROFIsafe requires the master communication module "PROFIBUS" (PB) together with the respective firmware version (as of MP*03VRS)!

Safety Related Starting Lockout ("AS")

☞ Using the function "safety related starting lockout" requires the optional safety technology module "starting lockout" ("L1").

The energy supply to the drive is safely interrupted with the safety function "safety related starting lockout". The drive cannot generate any torque/force and, as a consequence, it cannot generate any dangerous motions, either.

☞ Before activating starting lockout, the drive system must be decelerated via the command value input; there is no drive-controlled deceleration!

DANGER

Lethal injury and/or property damage caused by unintended axis motion!

⇒ If external force influences are to be expected with the safety function "safety related starting lockout", e.g. in the case of a vertical axis, this motion has to be safely prevented by additional measures, e.g. a mechanical brake or weight compensation.

Features

The safety function "safety related starting lockout" has the following features:

- It corresponds to the stop category 0 according to EN 60204-1.
- It has been realized for **personal protection in accordance with EN 954-1 category 3**.
- The energy supply to the motor is safely interrupted via two channels.
- The **selection** is made via two channels using either a N/C-N/O or a N/C-N/C combination.
- The safe status is **acknowledged** by an N/C-N/O contact.
- For **dynamization of the selection**, the function must be activated at least every 168 hours. For this reason, the operating hours of the power section, at which the safety function "safety related starting lockout" was selected the last time, are stored in parameter "P-0-0102, Oper. hours power section at last activat. of start. lockout".
- Monitoring the validity of the selection: 100 ms after selection change
- The time intervals for activating the starting lockout have to be set via "P-0-0103, Time interval of forced dynamization".
- The history of the time intervals that were set is displayed in parameter "P-0-0104, Change history time interval of forced dynamization".
- The status of starting lockout is displayed via parameter "P-0-0106, Operating status of starting lockout".

Pertinent Parameters

The parameters below are used in connection with the safety function "safety related starting lockout":

- P-0-0101, Configuration for starting lockout selector
- P-0-0102, Oper. hours power section at last activat. of start. lockout
- P-0-0103, Time interval of forced dynamization
- P-0-0104, Change history time interval of forced dynamization
- P-0-0106, Operating status of starting lockout

Pertinent Diagnostic Messages

The diagnostic messages below are generated in connection with the safety function "safety related starting lockout":

- F8027 Safety related standstill while drive enabled
- F7043 Error of output stage interlock
- F3130 Error when checking input signals
- F3131 Error when checking acknowledgement signal
- E3110 Time interval of forced dynamization exceeded

- E8027 Safety related standstill while drive enabled

With active starting lockout, the control panel of the IndraDrive controller displays "AS".

Integrated Safety Technology (Safety on Board)

Features

- Dual-channel selection on safety functions via digital inputs/outputs (24V) or digital inputs/outputs (24V) and master communication or a safety related process data channel for PROFIBUS-DP (PROFIsafe)
- **Integrated functionality for detecting "sleeping" errors:**
  - Dual-channel data processing with structure by diversity
  - Cross comparison of the safety-relevant data
  - Dynamization of static states
- Password protection for all safety technology parameters
- Safety functions in normal operation

  → Safety related maximum speed, safety related limited absolute end position
- Safety functions in status "safety related halt"

  → **Safety related standstill, safety related operational stop,** safety related drive interlock
- Safety functions in status "safety related motion"

  → **Safety related reduced speed,** safety related direction of motion, safety related limited increment, safety related limited absolute position
- Other auxiliary functions

  → Safety related monitored stopping process, safety related homing procedure, safety related parking axis
- Safety functions for "safety related feedback"

  → Safety related diagnostic outputs, safety related control of a door locking device, safety related inputs/outputs for PROFIsafe

Pertinent Parameters

The parameters for safety technology are assigned to the IDN range from P-0-3200 to P-0-3399. For information on the pertinent parameters, see the separate documentations "Integrated Safety Technology; Functional and Application Description" and "Parameter Description".

Pertinent Diagnostic Messages

The pertinent diagnostic messages in connection with the integrated safety technology are contained in the separate documentation "Integrated Safety Technology; Functional and Application Description" in the sections for the respective safety functions.

8.13.3 Functions of the Integrated Safety Technology

Overview

For integrated safety technology ("Safety on Board"), we distinguish the following operating states:

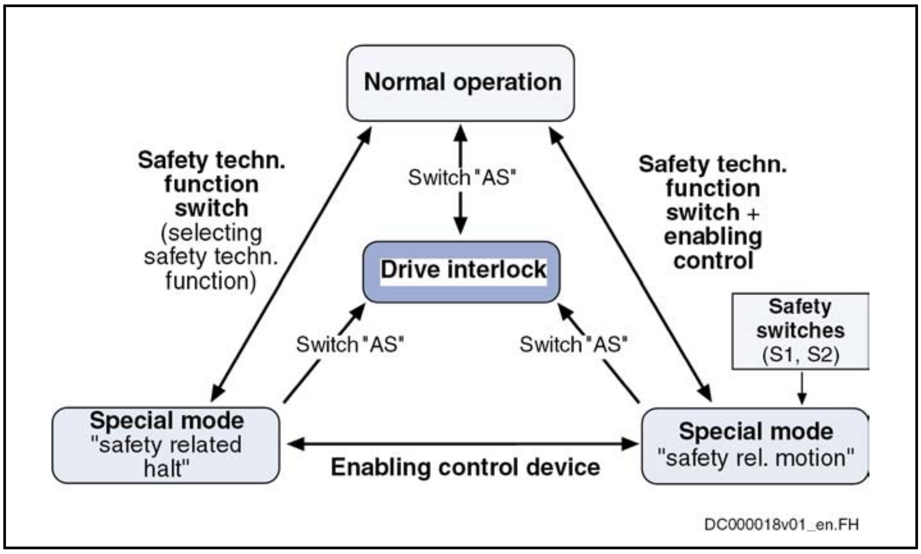


Fig.8-88: Operating States of the Integrated Safety Technology

Principles for Error Detection

In order to prevent danger for persons in the danger zone of a machine motion in the case of temporary errors, precautions for minimizing motion errors due to errors have to be taken.

During operation, the safety functions are monitored by the drive system. For this purpose, three principles for discovering so-called sleeping errors were realized in the system:

- **Dual-channel data processing** with structure by diversity
- **Cross comparison** of the safety-relevant data
- **Dynamization** of static states

Drive-internal realization of these principles guarantees that a single error cannot cause the safety functions to get lost.

☞ To find out whether the safety functions realized by the drive are sufficient for an existing installation or machine, the installation or machine manufacturer has to carry out a hazard analysis according to annex I of Directive 98/37/EG.

States of Integrated Safety Technology

Normal Operation

In the status "normal operation", the following safety function is supported by "Safety on Board":

- **Safety related limited maximum speed**

  → Defines a safety-related maximum velocity in normal operation
- **Safety related limited absolute end position**

  → Defines a positive and a negative safety related end position in normal operation

  Note: Safety related reference must be established for the safety related absolute position!

Safety Related Halt

In the status "safety related halt", the following safety functions are supported by "Safety on Board":

- **Safety related standstill**

  → Corresponds to stop category 1 according to EN 60204-1; with drive-controlled best possible deceleration and time monitoring

- As an alternative -

- **Safety related operational stop**

  → Corresponds to stop category 2 according to EN 60204-1; i.e. the drive control remains active, transition to standstill is carried out by the NC; drive monitors reaching of standstill within preset tolerance time via two channels

- Additionally -

- **Safety related drive interlock**

  → Like "safety related standstill", but switching to "safety related motion" by actuating the enabling control device is not possible; safety related standstill/operational stop selected by safety switches S1/S2; starting lockout selected via specific switches ASP1/ASP2

Safety Related Motion

In the status "safety related motion", the following safety functions are supported by "Safety on Board":

- **Safety related reduced speed**

  → 2-channel monitoring for exceeding a velocity threshold

- **Safety related direction of motion**

  → 2-channel monitoring for allowed direction of motion

- **Safety related limited increment**

  → 2-channel monitoring for allowed travel distance

- **Safety related limited absolute position**

  → 2-channel monitoring for allowed absolute position

  Note: Safety related reference must be established for the safety related absolute position!

Auxiliary Functions

The following auxiliary functions are provided:

- **Safety related monitored stopping process**

  → 2-channel monitoring of transition to safety related halt or safety related motion

- **Safety related homing procedure**

  → To establish the reference for channel 1 and channel 2

  Note: The safety related reference is a requirement for safety related end position and safety related limited absolute position!

- **Safety related parking axis**

  → Safety related parking of the axis by safety related locking of the output stage and acknowledgment of safety, although no encoder is available

Safety Functions for "Safety Related Feedback"

The following safety functions are provided for "safety related feedback":

- **Safety related diagnostic outputs**

  → To transmit the "safety related status" to additional system components

- **Safety related control of a door locking device** (not with PROFIsafe)

  → A drive that acts as the diagnostic master can summarize the safety related status of several axes within a protective zone and control a safety door.

- **Safety related inputs/outputs for PROFIsafe**

  → Safety related inputs/outputs of the drive are used for connecting sensors and actuators which the higher-level master controls via PROFIsafe.

8.13.4 Notes on Commissioning

Starting Lockout

Using the starting lockout does not require any special kind of commissioning; the corresponding wiring is sufficient.

For detailed descriptions and information, see separate documentation "Rexroth IndraDrive: Integrated Safety Technology"

Integrated Safety Technology (Safety on Board)

Commissioning takes place with menu prompts via the commissioning tool "IndraWorks D".

For detailed descriptions and information, see separate documentation "Rexroth IndraDrive: Integrated Safety Technology"

9 Optional Device Functions

9.1 Availability of the Optional Device Functions

The following overview illustrates by which basic or functional packages the respective optional device function is supported (if not stated otherwise, this applies to all 3 firmware versions, MPB, MPD and MPH).

Optional device function	In base package (characteristic)	In functional package ... (additionally on the basis of a base package with the following characteristics)		
		Servo function	Synchronization	Main spindle
Cross communication (CCD)	Only available with the corresponding hardware configuration			
IndraMotion MLD	Independent extension packages (ML, MA or TF)			
Digital inputs/outputs 1)	OL/CL	–	–	–
Analog inputs 1)	OL/CL	–	–	–
Analog outputs 1)	OL/CL	–	–	–
Virtual master axis generator	–	–	OL/CL	–
Command value generator	OL/CL	–	–	–
Encoder emulation	CL	–	–	–
Programmable position switch	–	CL	CL	–
Probe function	–	CL	OL/CL	–
Measuring encoder	–	–	OL/CL	–

OL Open-loop characteristic
CL Closed-loop characteristic
1) Depending on hardware configuration
Fig.9-1: 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"

9.2 Cross Communication (CCD)

9.2.1 Brief Description

Overview The device function "cross communication" (**C**ross **C**ommunication **D**rives → CCD) of IndraDrive allows electronic (digital) coupling of axes.

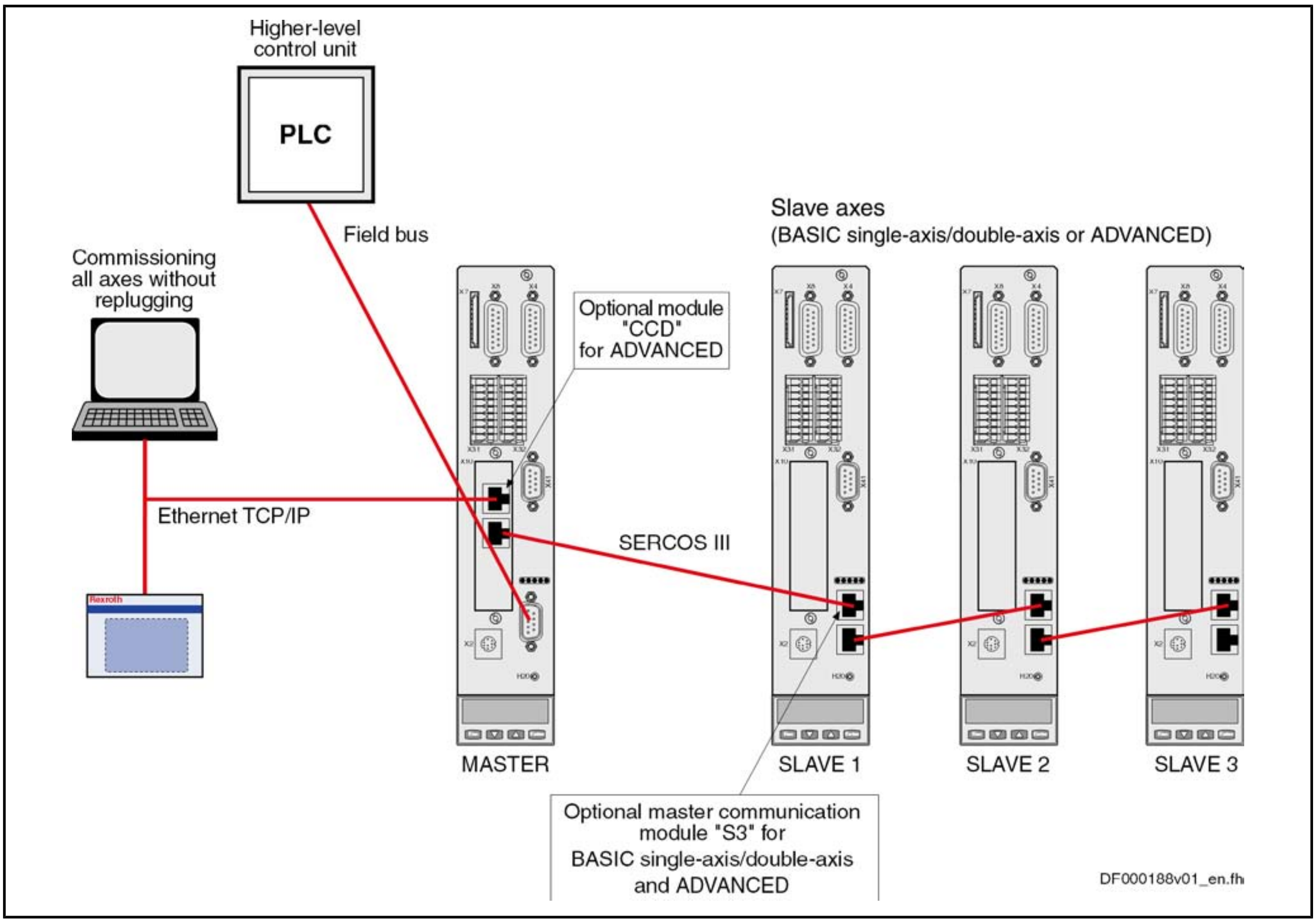


Fig.9-2: Hardware Topology of Drive Cross Communication (CCD)

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 III interface. Therefore, external access always takes place via the CCD master which, apart from the optional module for CCD ("SERCOS III master connection"), has a master communication interface (e.g. PROFIBUS).

CCD Modes (Kinds of Coupling)

When cross communication (CCD) is used between the drives, we distinguish the following variants (CCD modes):

- **CCD system mode**

  The CCD slaves have a direct logic connection to the field bus CCD 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 the 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 linkage by transmission of freely configurable process data of the CCD axes (e.g. master/slave, Gantry axis)
- CCD (SERCOS III) cycle time can be parameterized (0.5 ms to 4 ms; depends on controller performance and number of axes)
- Max. baud rate: 100 MBaud
- CCD communication protocol: SERCOS III (see "SERCOS III")
- Data channels:
  – Cyclic data channel (MDT, AT): Max. 48 bytes and 16 IDN
  – Parameter or service channel: 4 bytes
- Parameterization of all axes of the CCD group via interfaces of the CCD master (RS232, Engineering Port, field bus, …)
- Command triggering of the CCD slaves depending on selected CCD mode via external control unit or internally via MLD-M in CCD master
- Max. number of CCD slaves: 5 to 7 (depends on CCD mode; see below "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 linkage
  – Position command value linkage (Gantry axes)
  – Torque/force linkage
- Simple motion controls with decentralized command value adjustment for single-axis positioning and master axis linkage

Restrictions

When using cross communication, observe the following restrictions:

- With the cross communication function, "Coordinated Motion" is not possible!
- The higher-level master mostly is a PLC with a field bus which does **not** have real-time and synchronization ability (PROFIBUS, DeviceNet).

Hardware Requirements

Using the drive function "cross communication" requires the following control section design:

- **CCD master**

  Control section in ADVANCED design with optional module CCD at optional slot 3

  → CSH-01.2C-xx-xxx-xxx-CCD-xx-x-..
- **CCD slaves**

  Control section with master communication interface "SERCOS III" (S3); possible with the following designs:
  – BASIC UNIVERSAL single-axis → CSB-01.xC-S3-xxx-xx-x
  – BASIC UNIVERSAL double-axis → CDB-01.xC-S3-xxx-xx-x
  – ADVANCED single-axis → CSH-01.xC-S3-xxx-xx-x

See documentation "Drive Controllers, Control Sections; Project Planning Manual"

Firmware Requirements

For using the drive function "cross communication", observe the following aspects regarding the firmware:

- This drive function is supported as of the firmware version MPx04.
- All drives of a CCD group (CCD master and CCD slaves) have to be operated with the same firmware version.
- 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-0-1600, CCD: configuration
- P-0-1601, CCD: addresses of projected drives
- P-0-1602, CCD: timing settings
- P-0-1603, CCD: actual topology
- P-0-1605, CCD: command communication phase
- P-0-1606, CCD: actual communication phase
- P-0-1607, CCD: axis error
- P-0-1609, CCD: status word
- P-0-1611, CCD: configuration list signal status word
- P-0-1612, CCD: configuration list signal control word
- P-0-1613, CCD: assignment list signal status word
- P-0-1614, CCD: assignment list signal control word
- P-0-1615, CCD: extrapolated command value IDN list signal selection
- P-0-1616, CCD: extrapolated cmd value signal selection
- P-0-1617, CCD: number of extrapolation steps
- P-0-1618, CCD: extrapolated command value
- P-0-1621, CCD: configuration list master communication cmd values
- P-0-1622, CCD: configuration list master communication actual values
- P-0-1623, CCD: configuration list master cmd values
- P-0-1624, CCD: configuration list actual master values
- P-0-1625, CCD: configuration list slave cmd values
- P-0-1626, CCD: configuration list actual slave values
- P-0-1630, CCD: diagnosis
- P-0-1632, CCD: system data 2 bytes
- P-0-1633, CCD: system data 4 bytes
- 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-0-1651, CCD: master control word, slave 1 (to P-0-1657)
- P-0-1661, CCD: drive status word, slave 1 (to P-0-1667)

- P-0-1670, CCD: active actual position value, master
- P-0-1671, CCD: active actual position value, slave 1 (to P-0-1677)
- P-0-1680, CCD: actual velocity value, master
- P-0-1681, CCD: actual velocity value, slave 1 (to P-0-1687)
- P-0-1690, CCD: actual torque/force value, master
- P-0-1691, CCD: actual torque/force value, slave 1 (to P-0-1697)
- P-0-1701, CCD: diagnostic message number, slave 1 (to P-0-1707)
- P-0-1710, CCD: signal status word, master
- P-0-1711, CCD: signal status word, slave 1 (to P-0-1717)
- P-0-1720, CCD: signal control word, master
- P-0-1721, CCD: signal control word, slave 1 (to P-0-1727)
- P-0-1730, CCD: MDT real-time container 1, master
- P-0-1731, CCD: MDT real-time container 1, slave 1 (to P-0-1737)
- P-0-1740, CCD: MDT real-time container 2, master
- P-0-1741, CCD: MDT real-time container 2, slave 1 (to P-0-1747)
- P-0-1750, CCD: MDT real-time container 3, master
- P-0-1751, CCD: MDT real-time container 3, slave 1 (to P-0-1757)
- P-0-1760, CCD: MDT real-time container 4, master
- P-0-1761, CCD: MDT real-time container 4, slave 1 (to P-0-1767)
- P-0-1770, CCD: AT real-time container 1, master
- P-0-1771, CCD: AT real-time container 1, slave 1 (to P-0-1777)
- P-0-1780, CCD: AT real-time container 2, master
- P-0-1781, CCD: AT real-time container 2, slave 1 (to P-0-1787)
- P-0-1790, CCD: AT real-time container 3, master
- P-0-1791, CCD: AT real-time container 3, slave 1 (to P-0-1797)
- P-0-1800, CCD: AT real-time container 4, master
- P-0-1801, CCD: AT real-time container 4, slave 1 (to P-0-1807)
- P-0-1810, CCD: status word synchronous operating modes, master
- P-0-1811, CCD: status word synchronous operating modes, slave 1 (to P-0-1817)

☞ For configuring the SERCOS III communication in the slaves, we use the standard SERCOS III parameters (see S-0-1001 et seq.).

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
- E4012 Maximum number of CCD slaves exceeded
- E4013 Incorrect CCD addressing
- E4014 Incorrect phase switch of CCD slaves
- F2140 CCD slave error
- F4140 CCD communication error
- F6140 CCD slave error (emergency halt)
- F8140 Fatal CCD error

9.2.2 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
Parameter gateway of CCD-master-side field bus interface to CCD slaves 1)	Yes	Yes	Yes
Process data gateway and profile interpreter from external master (e.g. field bus PLC) to CCD slaves	Yes	No	No
Synchronization of CCD slaves to CCD master	Yes	Yes	Yes
Cross communication to command value linkage in CCD group	Yes	Yes	Yes
Command triggering via external control unit, i.e. slaves get elementary information on device control (e.g. drive enable, operating mode input) for slaves from external master (e.g. field bus PLC)	Yes	Restricted 2)	Restricted 3)
Command triggering by MLD-M in CCD master, i.e. slaves get elementary information on device control (e.g. drive enable, operating mode input) from MLD in CCD master	No	Restricted 2)	Yes

1) Parameter gateway does not exist with SERCOS interface, SERCOS III, CANopen interface and parallel interface

2) Command triggering is possible, if control words are configured and operated accordingly (e.g. P-0-1651)

3) Command triggering is possible, if MLD registers (e.g. P-0-1370 et seq.) are configured and operated accordingly and accordingly interpreted in MLD-M of CCD master

Fig.9-3: Comparison of the CCD Modes

Performance Features

The table below contains the main features and important data of the CCD modes:

	Command triggering (Motion Control)		Possible master communication					Max. number of slaves
	CCD master	CCD slave	PROFIBUS	DeviceNet	CANopen	SERCOS	Parallel/ analog	
CCD system mode	Remote	Remote	Profiles 0xFFFE, 0xFFFD for all CCD nodes		--	--	--	5
CCD basic mode	Local (remote)	Local (remote)	All profiles (only for CCD master)			Yes	Yes	7
MLD-M system mode	Local	Remote MLD-M	All profiles (only for CCD master)			Yes	Yes	7

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

Fig.9-4: Performance Features of the CCD Modes

Maximum Number of Axes and CCD Cycle Time

The maximum number of possible axes in the group (CCD slaves) depends on:

- Selected CCD mode
- CCD cycle time which was set
- Number of cyclic data (MDT, AT) per CCD slave

CCD cycle time	CCD system mode	MLD-M system mode[1)]	CCD basic mode
500 µs	1 slave + 1 master	--	1 slave + 1 master
1000 µs	3 slaves + 1 master	3 slaves + 1 master	3 slaves + 1 master
2000 µs / 4000 µs	5 slaves + 1 master	7 slaves + 1 master	7 slaves + 1 master

1) MLD-M system mode can only be selected in basic performance.

Fig.9-5: Maximum Number of Axes Depending on CCD Cycle Time

Cyclic Data

Per slave it is possible to transmit a maximum of 48 bytes (for command values and actual values each) at a maximum of 16 IDNs (for command values and actual values each).

In the **CCD system mode** only the freely configurable profile (0xFFFE and 0xFFFD) is supported in the CCD master!

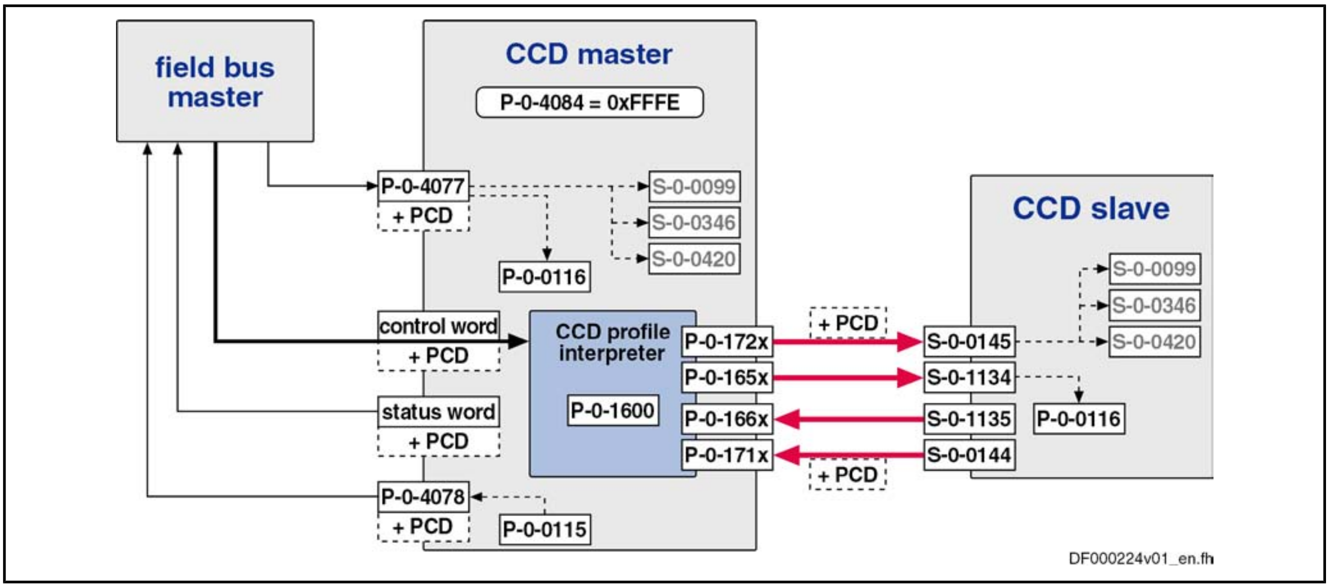
CCD System Mode

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 PLC).

System Structure

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.

Optional Device Functions



PCD	Process data (cyclic command values and actual values)
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 1 procedure command
S-0-1134	SERCOS-III: Master control word
S-0-1135	SERCOS-III: Drive status word
P-0-0115	Device control: status word
P-0-0116	Device control: control word
P-0-1600	CCD: configuration
P-0-165x	CCD: master control word, slave x
P-0-166x	CCD: drive status word, slave x
P-0-171x	CCD: signal status word, slave x
P-0-172x	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

Fig.9-6: *Overview CCD System Mode With Field Bus Interface*

☞ The CCD system mode presently is only available in conjunction with field bus master communication at the CCD master!

Features

The following aspects apply to the CCD system mode:

- For each logic field bus slave (CCD slave), the field bus control word is segmented and converted by the CCD master to a master control word (S-0-1134) for the corresponding CCD slave, and a signal control word (S-0-0145) is segmented and converted for the CCD slave. The higher-level master thereby has full control over the slaves (e.g. enable, operating mode selection).
- For each logic field bus slave (CCD slave), the field bus status word is generated by means of the drive status word (S-0-1135) 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. For this purpose, the parameters P-0-1623 to P-0-1626 have to be configured accordingly.

- 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-0-1621 and P-0-1622 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.
- The cyclic process data (command values and actual values) of master communication (P-0-1621 and P-0-1622 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.

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-0-1623 to P-0-1626 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 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-0-1621 and P-0-1622).
  – 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.
  – The bits 0 to 11 in the signal status word of the CCD slave are always zero for the control.
  – Parameter setting of the signal control word of the slaves is made by the master via the parameters P-0-1612 and P-0-1614.
  – Parameter setting of the signal status word of the slaves is made by the master via the parameters P-0-1611 and P-0-1613.

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.

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: Bit 0	S-0-0145: Bit 0
1	Operating mode setting	S-0-0420: C0400 parameterization level 1 S-0-0422: C0200 exit parameterization level	S-0-0145: Bit 8 S-0-0145: Bit 9
2	Going to zero	S-0-0148: C0600 drive-controlled homing	S-0-0145: Bit 2
3	Absolute / relative	S-0-0346: Bit 3	S-0-0145: Bit 3
4	Immediate block change	S-0-0346: Bit 5	S-0-0145: Bit 4
5	Clear error	S-0-0099: Command clear error	S-0-0145: Bit°5

Bit in P-0-4077	Significance in field bus profile	Target parameter in slave	Access to slave via ...
6,7	Positioning / jogging	S-0-0346: Bit 1,2	S-0-0145: Bit°6,7
8,9	Command operating mode	S-0-1134: Master control word bit 8,9	Direct access to S-0-1134
10,11	--	--	--
12	IPOSYNC	S-0-1134: Master control word bit 10	Direct access to S-0-1134
13	Drive Halt	S-0-1134: Master control word bit 13	Direct access to S-0-1134
14	Drive enable	S-0-1134: Master control word bit 14	Direct access to S-0-1134
15	Drive ON	S-0-1134: Master control word bit 15	Direct access to S-0-1134

Fig.9-7: Conversion of Field Bus Control Word (P-0-4077) to CCD Slave Parameters With Field Bus Profile Type 0xFFFE

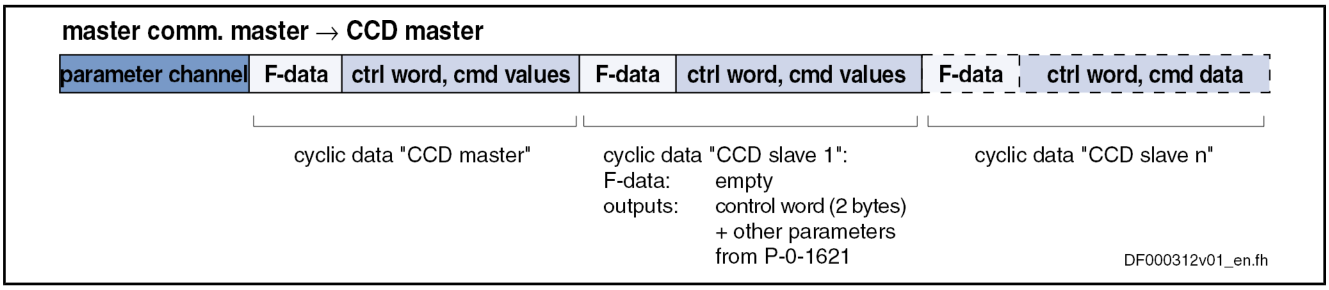
☞ As parameter "S-0-0145, Signal control word" is used to map the control bits which are not contained in parameter "S-0-1134, SERCOS III: Master control word", it has already been configured by default in the cyclic master data telegram (MDT → S-0-0024) of the respective CCD slaves in the CCD system mode! 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-0-1621).

Cyclic Command Values of 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-0-1621, CCD: configuration list master communication cmd values". The control word is always transmitted at the beginning of the cyclic data for a slave (is not contained in parameter P-0-1621, but has to be taken into account accordingly in the cyclic output data of the control unit!), followed by the data from parameter P-0-1621.

☞ 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!



P-0-1621 Configuration list of master communication command values for CCD

Fig.9-8: Command Value Channel From Master Communication Master to CCD Group

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.

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 1
2	In_Reference	S-0-0403: Position status in signal status word	S-0-0144: Bit 2
3	In_Standstill	S-0-0331: N_{act} = 0	S-0-0144: Bit 3
4	Command value reached	P-0-0115: Bit 12	S-0-0144: Bit 4
5	Command change bit	S-0-1135: Drive status bit 5	Direct access to S-0-1135
6	--	--	--
7	Status of command value processing	S-0-1135: Drive status bit 3	Direct access to S-0-1135
8,9	Actual operating mode	S-0-1135: Drive status bit 8,9	Direct access to S-0-1135
10	Command value acknowledgment	S-0-0419: Bit 0	S-0-0144: Bit 10
11	Class 3 diagnostics message	S-0-1135: Drive status bit 11	Direct access to S-0-1135
12	Class 2 diagnostics warning	S-0-1135: Drive status bit 12	Direct access to S-0-1135
13	Class 1 diagnostics drive error	S-0-1135: Drive status bit 13	Direct access to S-0-1135
14/15	Readiness for operation	S-0-1135: Drive status bit 14,15	Direct access to S-0-1135

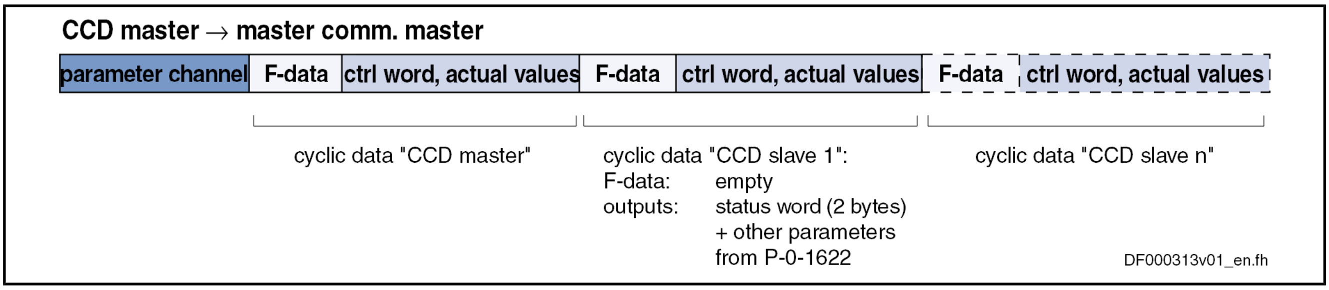
Fig.9-9: Conversion of Field Bus Status Word (P-0-4078) to CCD Slave Parameters With Profile 0xFFFE

☞ As parameter "S-0-0144, Signal status word" is used to map the control bits which are not contained in parameter "S-0-1135, SERCOS III: drive status", this parameter has already been configured by default in the cyclic drive telegram (AT → S-0-0016) in the CCD system mode! 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-0-1622).

Cyclic Actual Values of Master Communication

The cyclic actual values of a CCD slave consist of at least 2 bytes status word (same structure as field bus status word; see P-0-4078) and the data from parameter "P-0-1622, 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-0-1622, but has to be taken into account accordingly in the cyclic input data of the control unit!), followed by the data from parameter P-0-1622.

☞ The 2-byte status word P-0-4078 is composed of 4 bytes drive status word + 2 bytes signal status word!



P-0-1622 Configuration list of master communication actual values for CCD

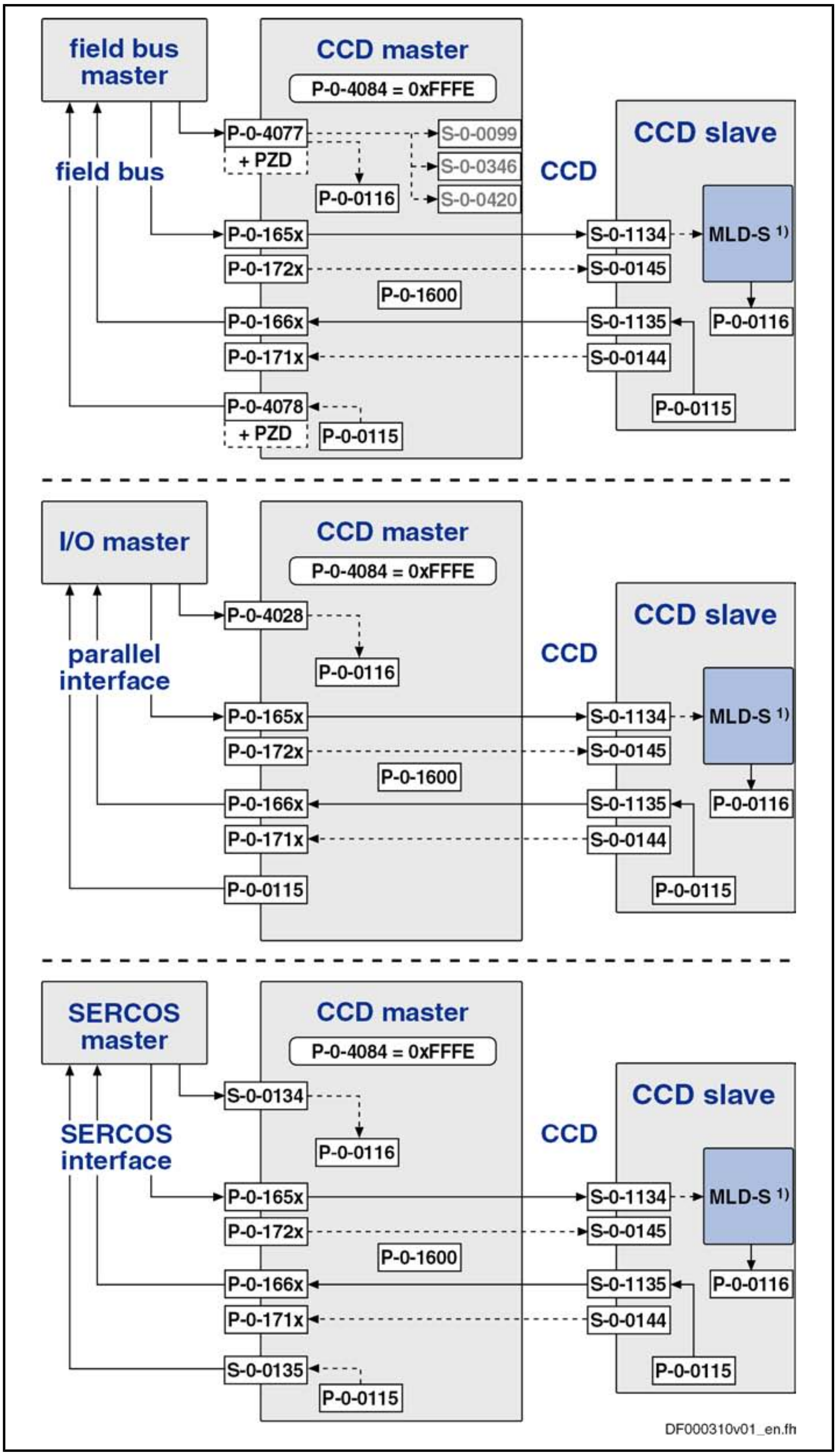
Fig.9-10: Command Value Channel From CCD Group to Master Communication Master

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 parallel/analog interface:



PCD	Process data (cyclic command values and actual values)
1)	With permanent control

Fig.9-11: Overview CCD Basic Mode for Different Master Communication Interfaces

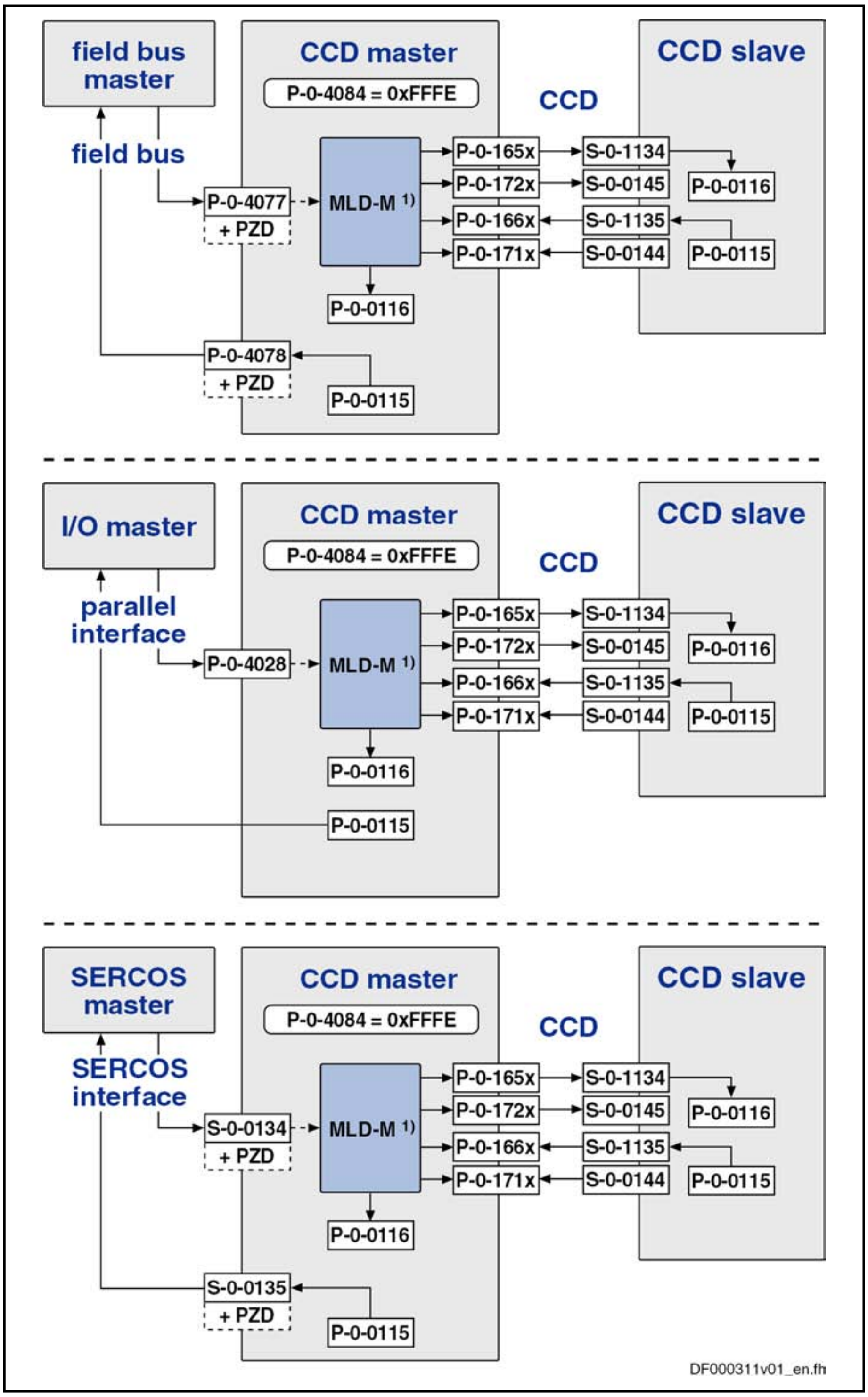
Features In the CCD basic mode, the external master (field bus, SERCOS interface, analog/parallel interface) has **restricted access** to the CCD slaves. The following applies:

- 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-0-1623 to P-0-1626 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-0-1611 to P-0-1614 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-0-1623 to P-0-1626) must be used for this purpose. In the CCD master, the parameters P-0-172x and P-0-171x have to be written or read therefore.
- 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-0-1661 to P-0-1667 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-0-1651 to P-0-1657 (e.g. by MLD-S or via parallel interface). In the CCD basic mode, this allows controlling basic input, such as enable, operating mode selection etc., for the slaves via the CCD master.

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 parallel/analog interface:



PCD Process data (cyclic command values and actual values)

1) With permanent control

Fig.9-12: Overview 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 parameters P-0-1651 to P-0-1657.

- 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 parameters P-0-1661 to P-0-1667.
- 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 loop, 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.

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-0-1611 to P-0-1614.

See also separate documentation "Rexroth IndraMotion MLD".

State Machine and Phase Input

Multi-Axis Field Bus Connection

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.

- The input value of the state machine is the value of parameter "P-0-1605, CCD: command communication phase".
- The present communication phase of the CCD bus is displayed in parameter "P-0-1606, CCD: actual communication phase".
- In the parameter "P-0-1609, CCD: status word", you can find information on the phase state machine, such as "target phase", "actual phase", "phase switch active", "phase switch aborted with error" etc.

Data are primarily provided to the phase state machine of the CCD bus from the device state machine of the CCD master.

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-0-1605 = 4).
- S-0-0420, C0400 Activate parameterization level 1 procedure command

  → By activating the command C0400, all functions are switched to the status "inactive" again (parameter mode → P-0-1605 = 2).

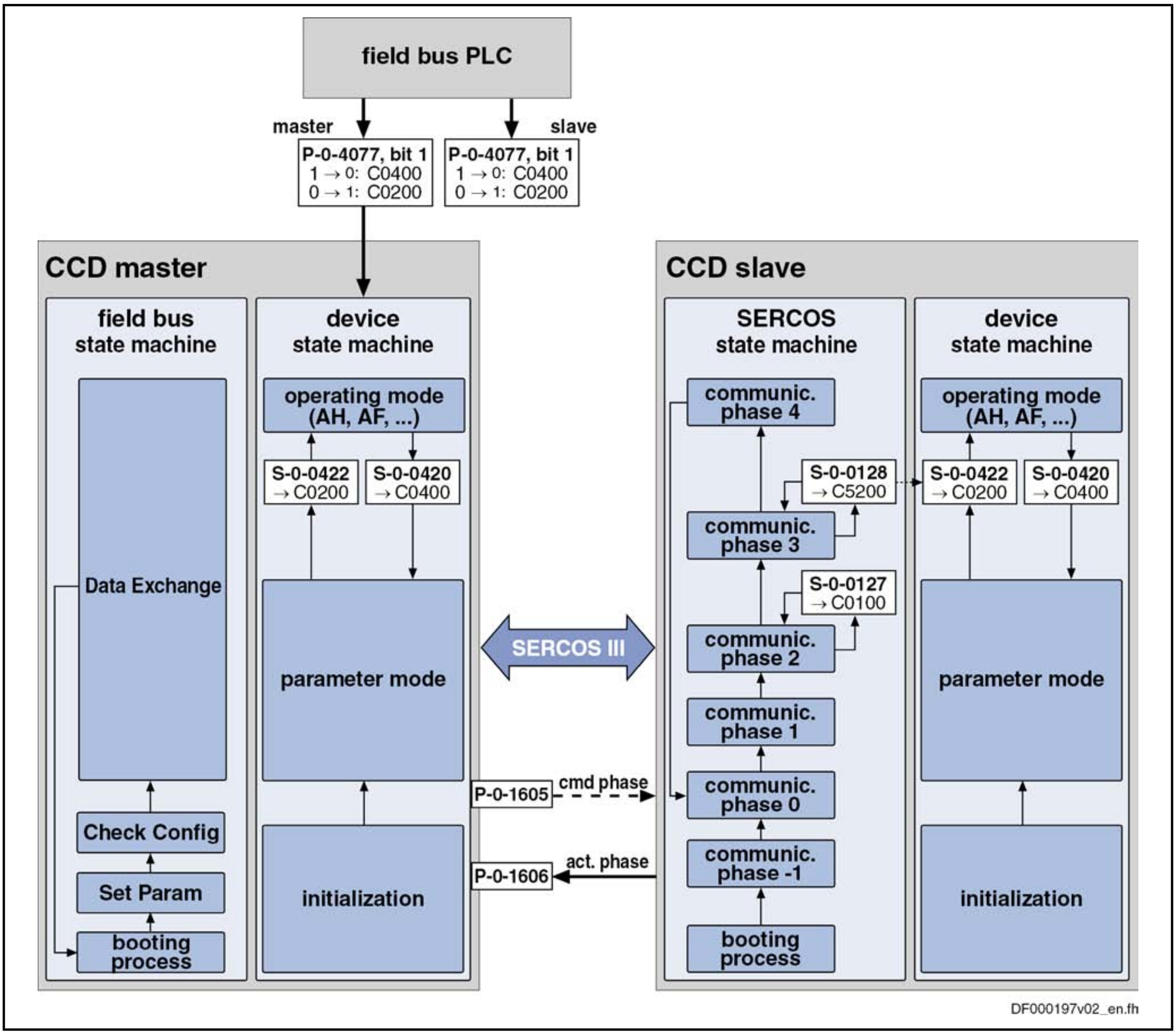


Fig.9-13: State Machine of Cross Communication

CCD - Diagnostic System

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-0-1630, CCD: diagnosis"

  This parameter displays the status of the CCD group in the CCD master in plain text.

  Note: 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-0-1701, CCD: diagnostic message number slave 1" to "P-0-1707, CCD: diagnostic message number slave 7"

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-0-170x in parameter "P-0-1624, CCD: configuration list actual master values" and S-0-0390 in parameter "P-0-1626, CCD: configuration list actual slave values", the diagnostic message number of the CCD slave is transmitted to the master.

Error Reaction of the CCD Group

The CCD error reaction is selected and activated via the bits 7 and 8 of the parameter "P-0-1600, CCD: configuration".

Basic setting:

- In the parameter "P-0-1600, 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-0-1701 (slave 1), to P-0-1702 (slave 2), to P-0-1703 (slave 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-0-1600. 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 (P-0-1624[i] = P-0-170x and P-0-1626[i] = S-0-0390).

☞ The **CCD error reaction is switched off by default**, i.e. the bits 7, 8 and 10 in parameter P-0-1600 have not been set!

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 process data channel of the CCD group is exclusively parameterized at the CCD master via the parameters P-0-1621 to P-0-1626. During phase progression, the master then automatically takes over the parameterization of the slaves via S-0-0016, S-0-0024, ...

The figure below illustrates the parameterization of the process data channel and the effect of the parameters P-0-1621 to P-0-1626 for the following cases:

1. Configuration of the MDT data (cyclic command values)
2. Configuration of the AT data (cyclic actual values)

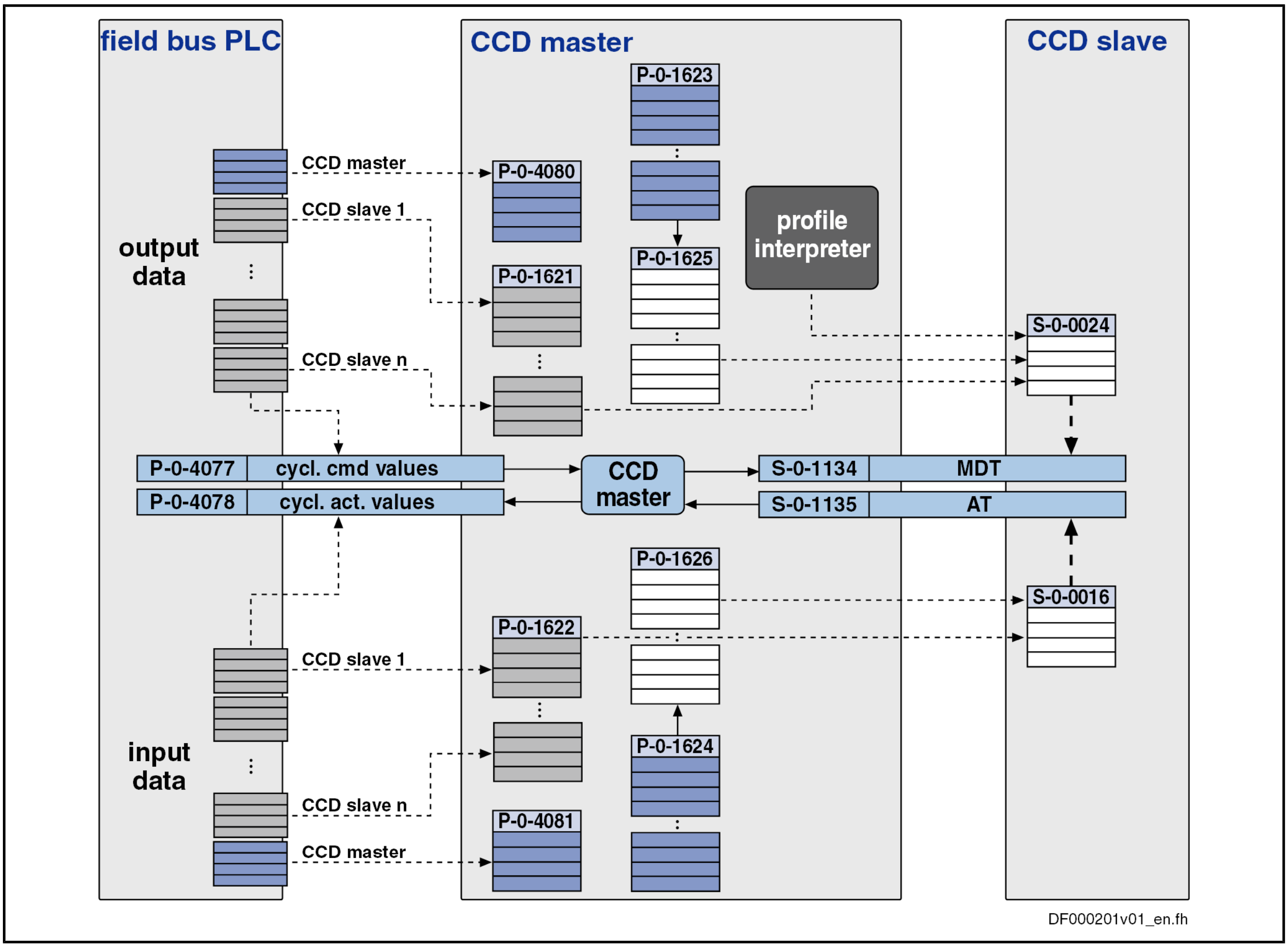


Fig.9-14: Configuring the Cyclic Process Data

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-0-1621 (MDT) or P-0-1622 (AT).
- The command values (MDT) to be transmitted from the CCD master to the CCD slave are configured in the relationship P-0-1623 ↔ P-0-1625. The list parameter P-0-1623 contains the parameters which the master puts into the MDT for the slave. The list parameter P-0-1625 contains the information for which parameters in the slave the data from the master are intended (S-0-0024).
- The actual values (AT) to be transmitted from the CCD slave to the CCD master are configured in the relationship P-0-1624 ↔ P-0-1626. The list parameter P-0-1624 contains the information for which parameters in the master the data from the slave are intended. The list parameter P-0-1626 contains the information which parameters the slave puts into the AT for the master (S-0-0016).

Addressing

We distinguish the following schemes of addressing:

- Logic individual axis addressing → for CCD communication setting of 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

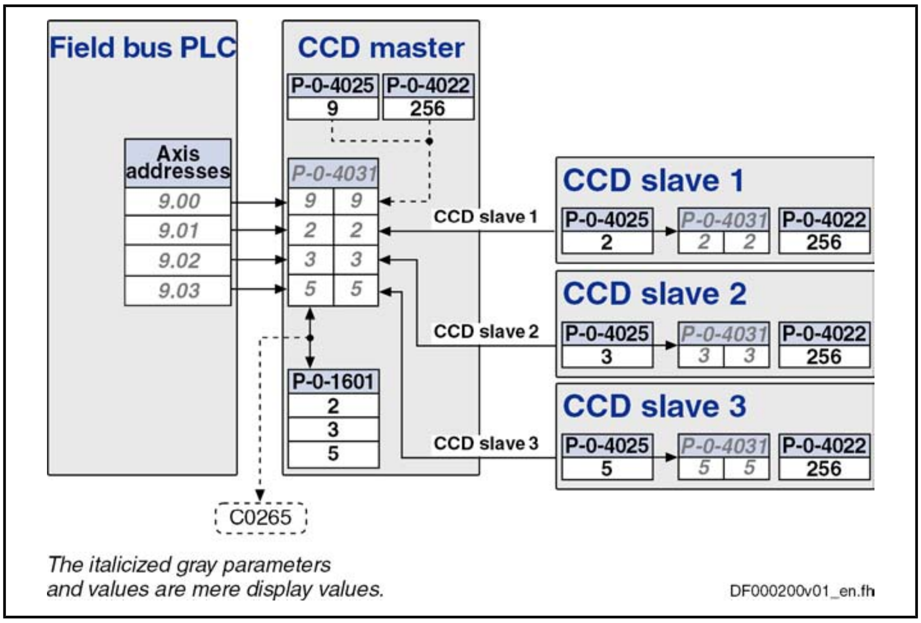
☞ Any individual setting of the serial addressing via the parameter "P-0-4022, Drive address of serial interface" does not take effect via the CCD group! Via CCD, the remote axes can only be addressed via their master communication address.

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 must be entered in parameter "P-0-1601, CCD: addresses of projected drives".
- The slaves found by the CCD master in phase 0 of the CCD axis group are entered in the list parameter "P-0-4031, Overview of device addresses":
  – List element 0: Address of CCD master
  – List element 1: CCD slave with lowest address
  – .....
  – List element n: CCD slave with highest address

☞ The list in parameter P-0-4031 must contain at least the slave addresses from the parameter "P-0-1601, CCD: addresses of projected drives", otherwise the error message "C0265 Incorrect CCD address configuration" will be generated during the phase progression of the master.

By means of an example, the figure below shows how the individual parameters interact:



P-0-1601	CCD: addresses of projected drives
P-0-4022	Drive address of serial interface
P-0-4025	Drive address of master communication
P-0-4031	Overview of device addresses
C0265	Incorrect CCD address configuration

Fig.9-15: Example of How to Address the CCD Group

Acyclic Communication (Parameterization Gateway)

To allow accessing 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, RS-232, Ethernet, …) regarding parameters of the slaves.

Acyclic parameter services, requested via RS-232, master communication or drive PLC in the CCD master, must be transmitted to the slaves by the cross communication.

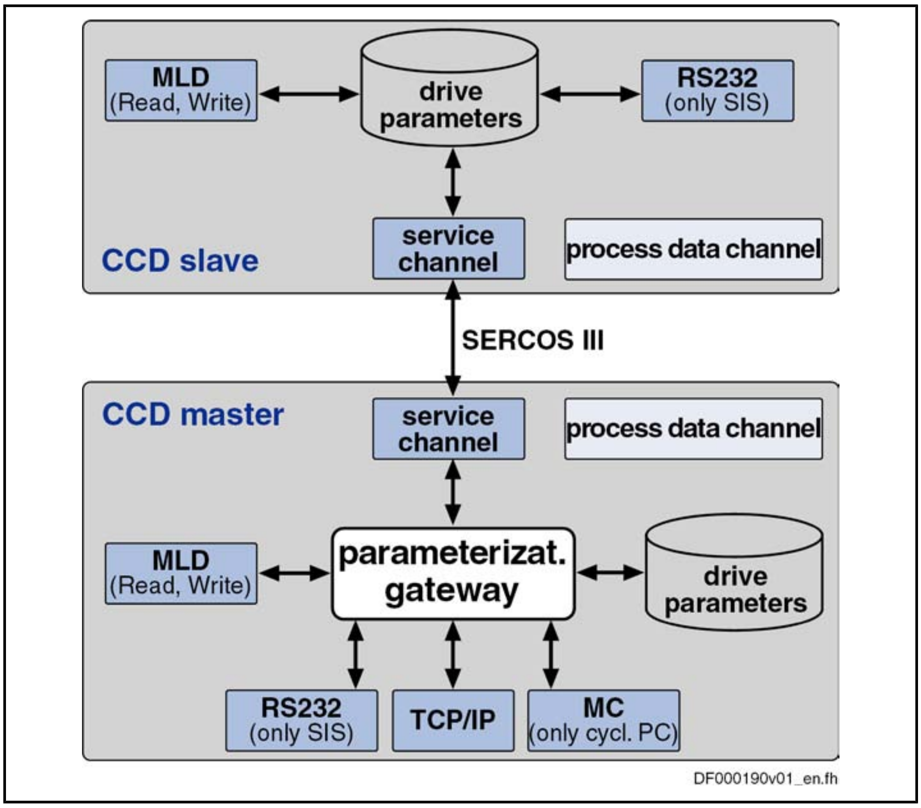
For this purpose, the following interfaces with the following possibilities are supported:

- Serial interface with binary SIS protocol (see also "Serial Communication"

  Note: The parameterization gateway does **not** support the DKC-ASCII format (RSKO)! That is why acyclic access to parameters of the slave drives is only possible via SIS protocol!

- Field bus interface with the available parameterization options (DPV1, …)
- Ethernet interface with TCP/IP

  Note: For this application, the unassigned Ethernet connection (so-called "Engineering Port") at the CCD master can be used for parameterization.



MC Master communication

Fig.9-16: Functional Scheme of the Parameterization Gateway

Cycle Time

Configuration of CCD Cycle Time

The CCD cycle time is set in the master via the parameter "S-0-0001, NC cycle time (TNcyc)" (parameter S-0-1001 for SERCOS III). The CCD master then presets this time for the slaves in parameter "S-0-1001, SERCOS III: NC cycle time (TNcyc)".

The SERCOS cycle time of the CCD slaves in parameter "S-0-1002, SERCOS III: SERCOS cycle time (TScyc)" is automatically set to the value of the NC cycle time (S-0-1001) by the master.

The timing settings made by the master can be seen in the parameter "P-0-1602, CCD: timing settings".

The number of CCD slaves limits the possible CCD cycle time (see "Performance Features").

Dead Time Compensation

For command value linkage (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.

☞ 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").

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-0-1618, 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-0-1617, 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.

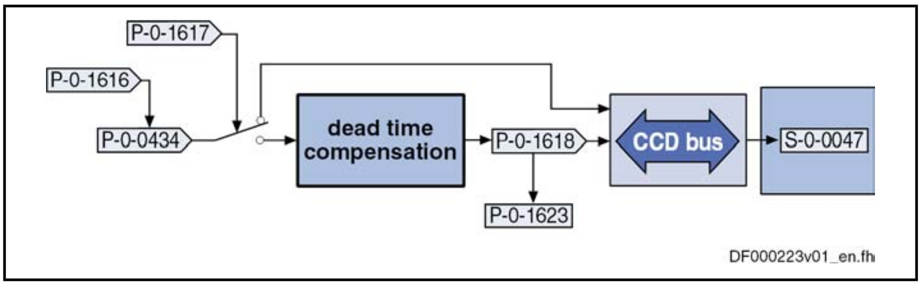


Fig.9-17: Command Value Extrapolation for Dead Time Compensation of the Command Values for the CCD Slaves

Example of Application With Configuration

The operating principle of the function is described for a Gantry axis (position command value linkage).

The CCD master is to preset the position loop command value (P-0-0434) for the slaves as the value for parameter S-0-0047. The position loop command value is active in the master the next time the position loop 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 loop.

To avoid this, activate the dead time compensation by the following setting:

- Dead time compensation is activated, if in parameter "P-0-1617, CCD: number of extrapolation steps", a value unequal "0" has been entered (default setting).
- Enter the desired command value (with position command value linkage → P-0-0434) in the parameter "P-0-1616, CCD: extrapolated cmd value signal selection".
- In parameter "P-0-1623, CCD: configuration list master cmd values", the value of parameter "P-0-1618, CCD: extrapolated command value" is 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-0-1617) increases.

9.2.3 Notes on Commissioning and Utilization

Navigation in IndraWorks

The dialogs for parameterizing the CCD communication can be found in IndraWorks under the SERCOS III junction (→ right mouse key):

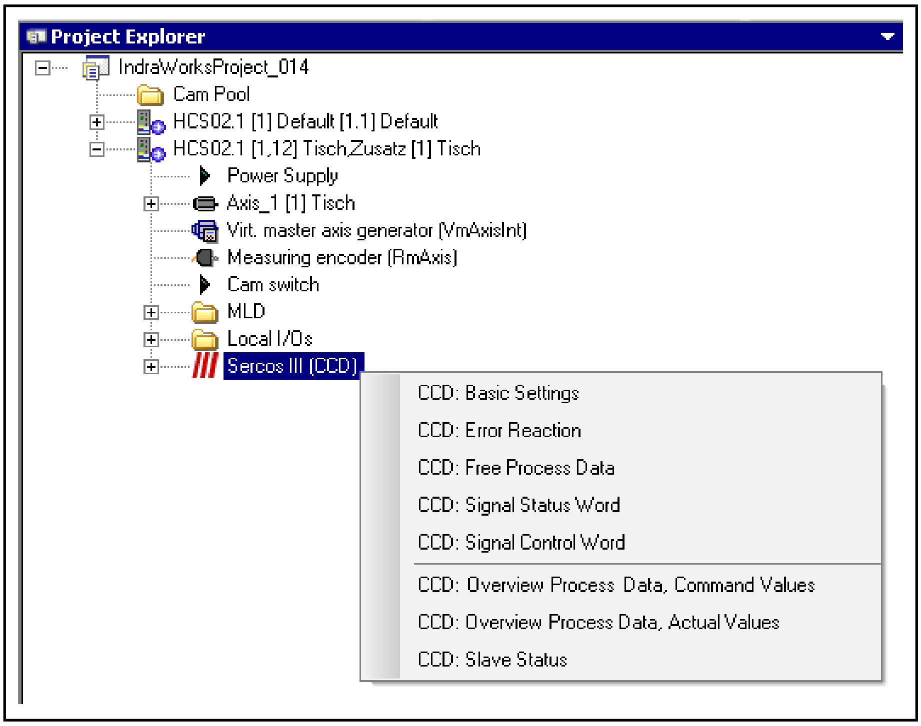


Fig.9-18: Overview of IndraWorks Dialog Windows for CCD Communication

By analogy to drives under a control unit, the slaves of the CCD group are displayed below a SERCOS III junction in the project tree.

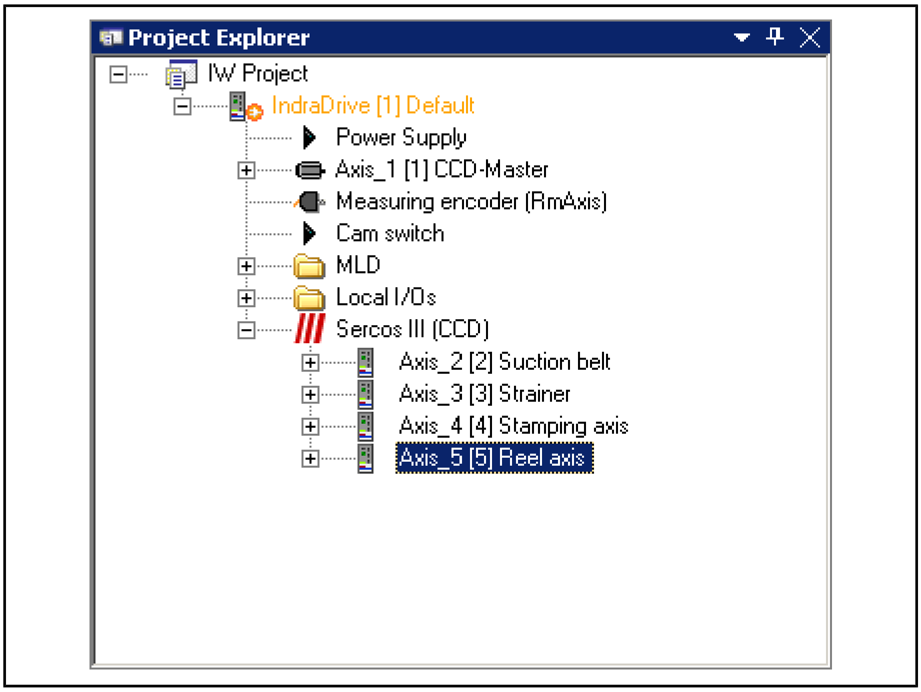


Fig.9-19: CCD Display in the Project Explorer

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 III junction. The configuration found is used in the online mode.

Basic Settings

The figure below shows the basic settings for parameterizing the CCD communication.

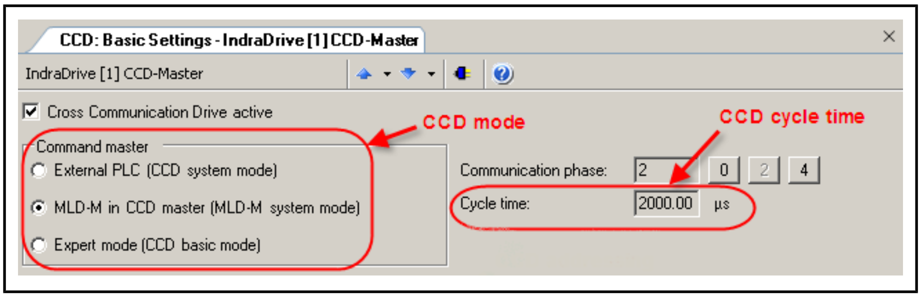


Fig.9-20: IndraWorks Dialog for Basic Settings of CCD Communication

Selection of 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 linkage 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 (command triggering master: MLD-M in the CCD master)**, when an MLD with permanent control is used in at least one CCD slave,

  - or -

  mere command value linkage is to be realized with master communication "SERCOS", "parallel" or "analog" 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-0-165x 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 (expert mode)**, 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).

  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:

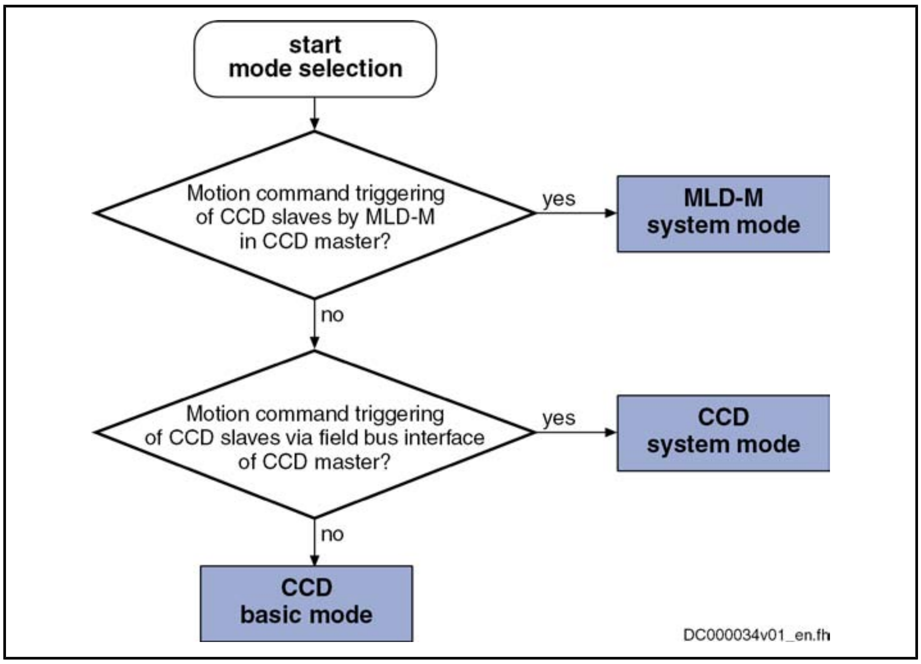


Fig.9-21: Selection Criteria for CCD Mode (See P-0-1600)

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 PLC) and the CCD slaves,
- other process data apart from the external process data are input by the CCD master to the CCD slaves (e.g. command value linkage).

Using the **CCD basic mode** makes sense when:

- The external master is to have control over the CCD slaves,
- only process data are preset to the CCD slaves by the CCD master (e.g. command value linkage),
- 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 loop clock), the minimum CCD cycle time to be set can be selected in the CCD group. The CCD cycle time mustn't be smaller than the slowest position loop clock in the CCD group:

- Advanced performance: 0.5 ms, 1 ms, 2 ms, 4 ms
- Basic performance: 0.5 ms, 1 ms, 2 ms, 4 ms
- Economy performance: 1 ms, 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 loop 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 loop 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.

Error Reaction

CCD Error Reaction

As regards 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
Autarkical 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!

Fig.9-22: 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:

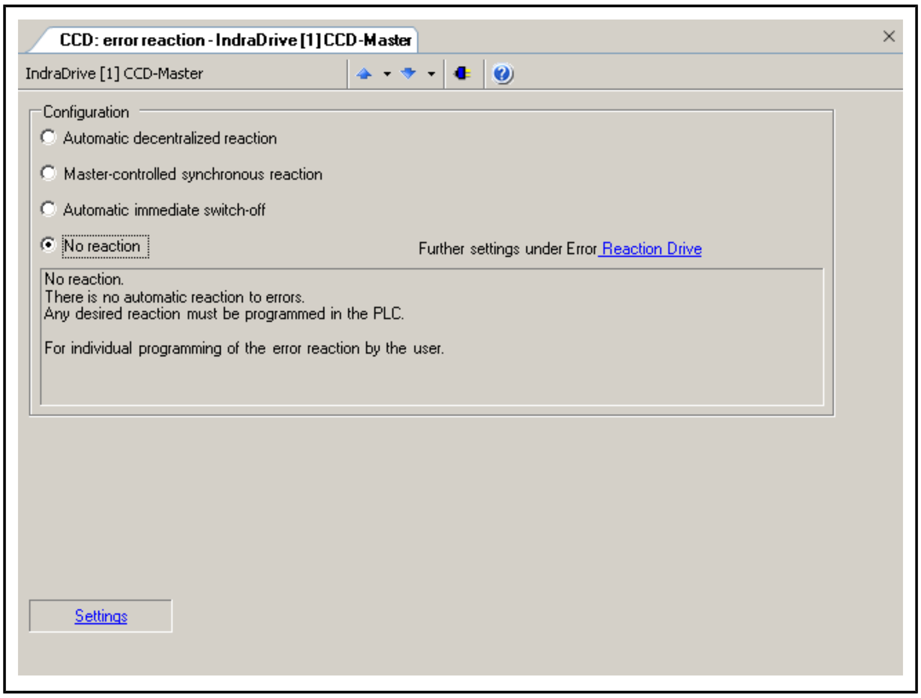


Fig.9-23: IndraWorks Dialog for Configuring the CCD Error Reaction

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).

Note: In the MLD-M mode, motion function blocks of the 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" is displayed in the master (example of application: master-axis-synchronous deceleration).

  Note: 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 parameter "P-0-1367, PLC configuration".

- **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-0-1600, CCD: configuration"; see fig. below (example of application: mechanically coupled axes).

  Note: In the MLD-M mode, the error "F2140" 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, PLC configuration". 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" 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-0-170x ("x" is the 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-0-1600 (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.

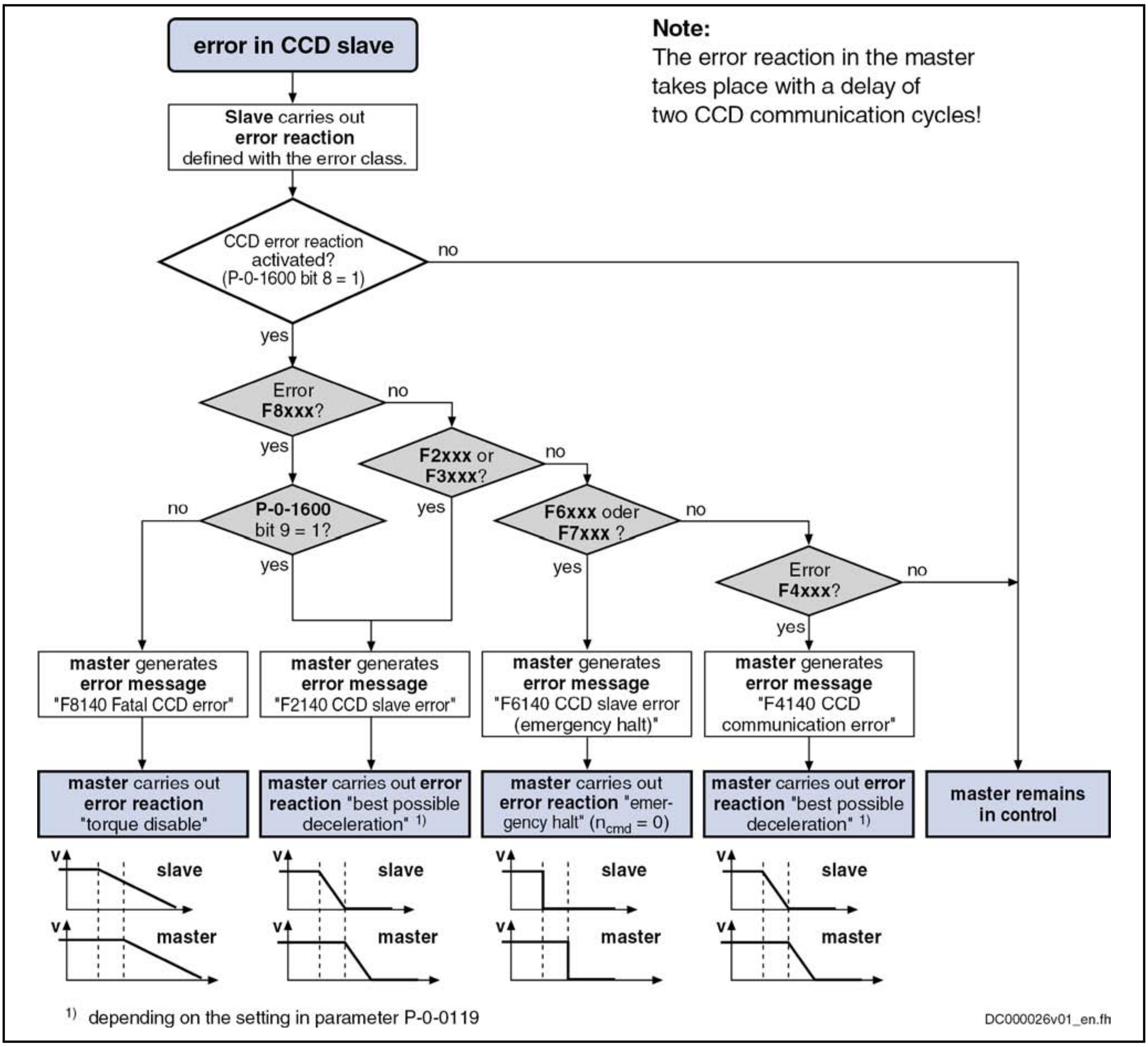


Fig.9-24: CCD Error Reaction for Master-Controlled Synchronous Error Reaction With Errors in the Slave

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

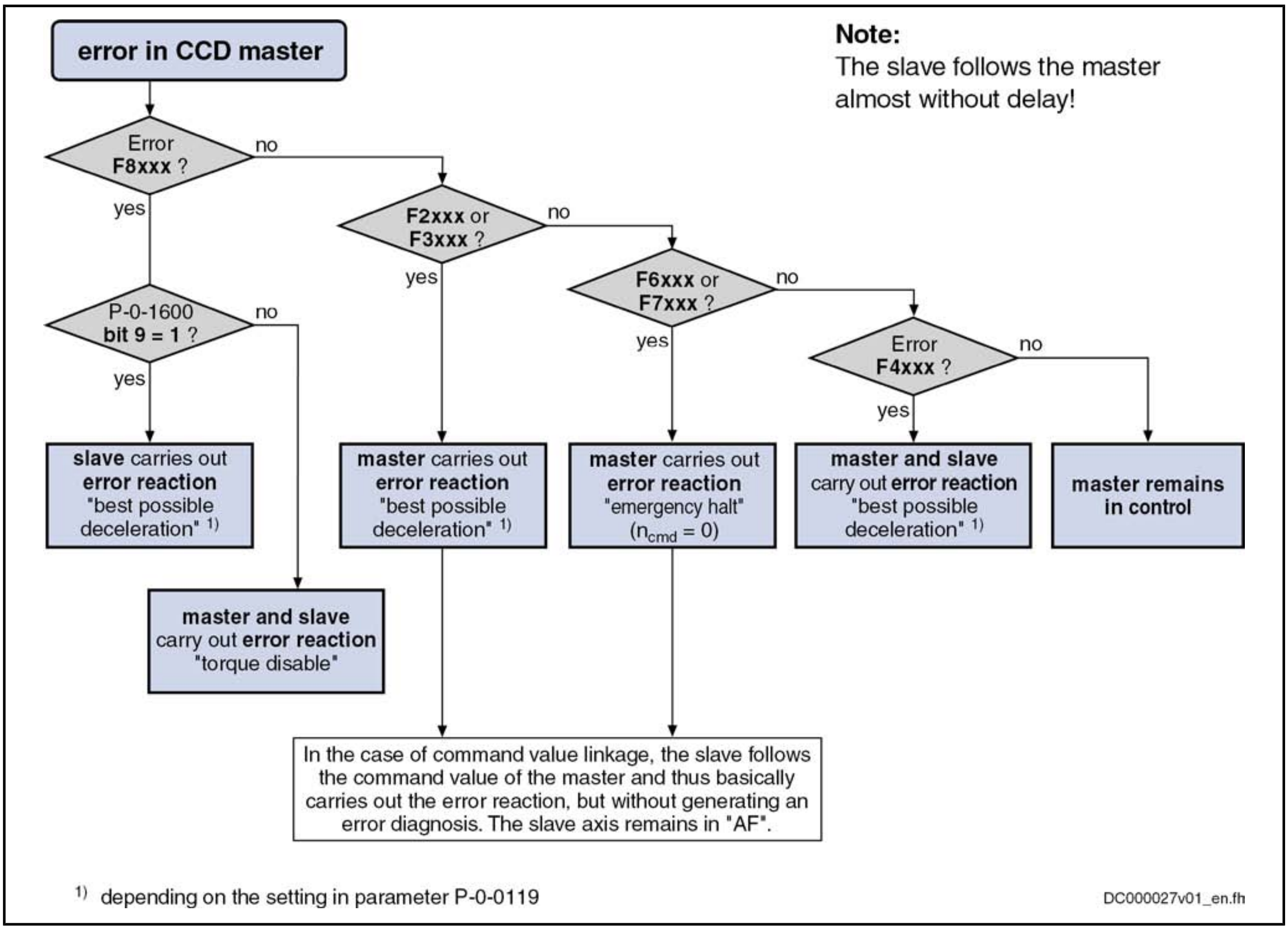


Fig.9-25: CCD Error Reaction for Master-Controlled Synchronous Error Reaction With Errors in the Master

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 it is additionally possible to exchange data between higher-level control unit and the CCD slaves.

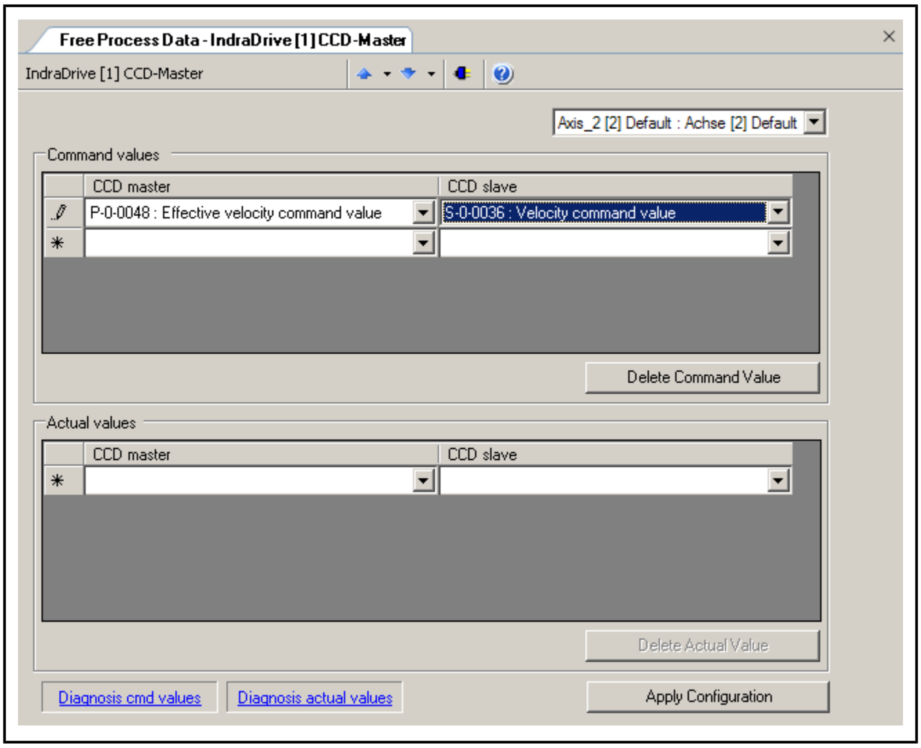


Fig.9-26: IndraWorks Dialog for Configuring the Process Data Between CCD Master and CCD Slave

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 line, 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 line, 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.

Optional Device Functions

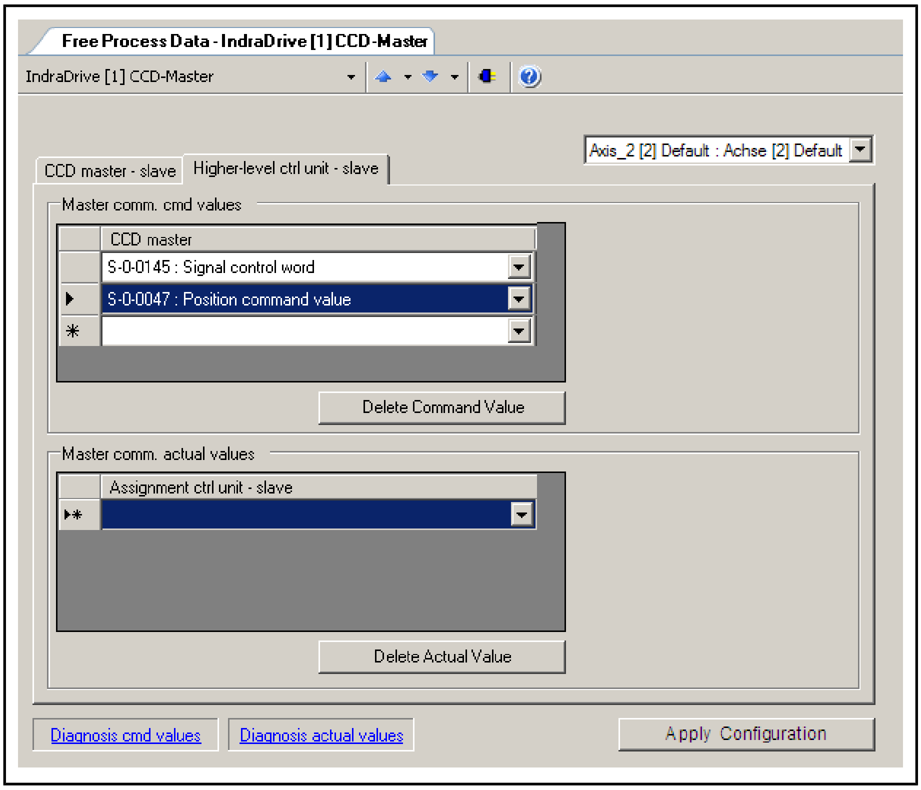


Fig.9-27: IndraWorks Dialog for Configuring the Process Data Between Higher-Level Control Unit and CCD Slave (Only With CCD System Mode)

Under the command values of master communication, enter the parameters of the CCD slave which are directly 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.
- What is always contained in the master communication command values, is a control word for the CCD slave, with a structure identical to the parameter "P-0-4077, Field bus: control word". 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 Values"). Via these bytes, the control unit can command each CCD slave individually like a normal field bus drive.
- What is always contained in the actual master communication values, is a status word of the CCD slave, with a structure identical to the parameter "P-0-4078, Field bus: status word". 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

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 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 9 to 11 are always zero in the control unit)!

Use 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.

Use 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-0-1624 and P-0-1626) have to be used for this purpose. The parameter S-0-0144 of the CCD slave has to be copied to parameter P-0-171x of the CCD master. The parameter P-0-171x 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**.

Optional Device Functions

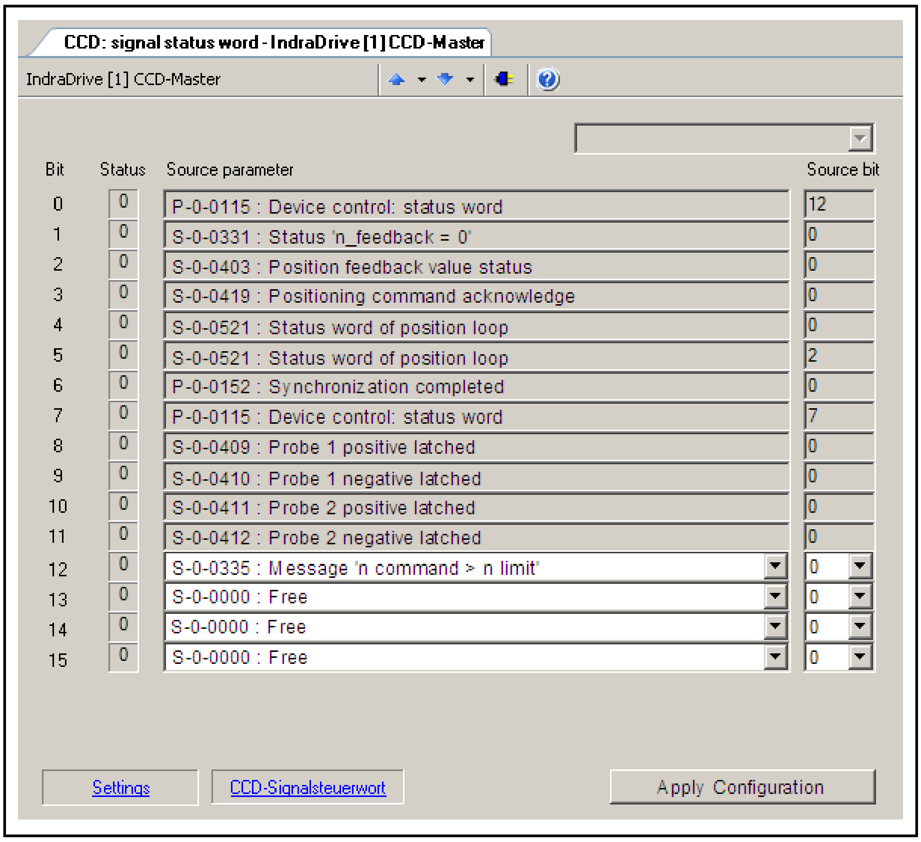


Fig.9-28: IndraWorks Dialog for Configuring the Signal Status Word

Signal Control Word

Use in the CCD System Mode

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 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.

Use 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.

Use 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-0-1623 and P-0-1625) have to be used for this purpose. The parameter P-0-172x of the CCD master has to be copied to parameter S-0-0145 of the CCD slave. The parameter P-0-172x 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**.

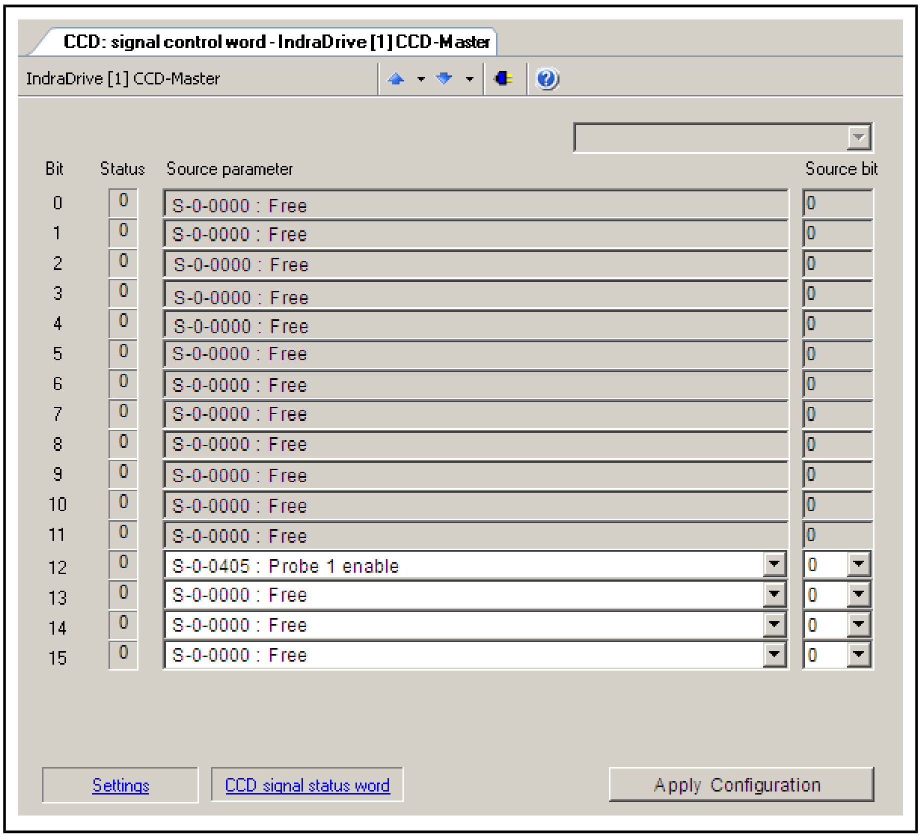


Fig.9-29: IndraWorks Dialog for Configuring the Signal Control Word

9.2.4 Diagnostic and Status Information

Overview Process Data, Command Values

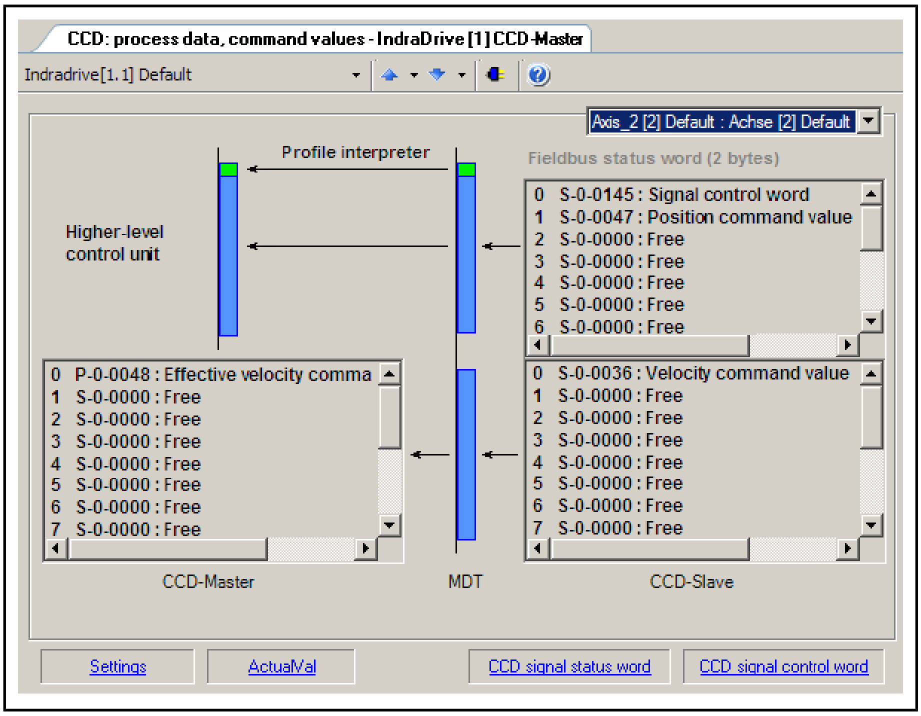


Fig.9-30: IndraWorks Overview Window of Process Data Command Values

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

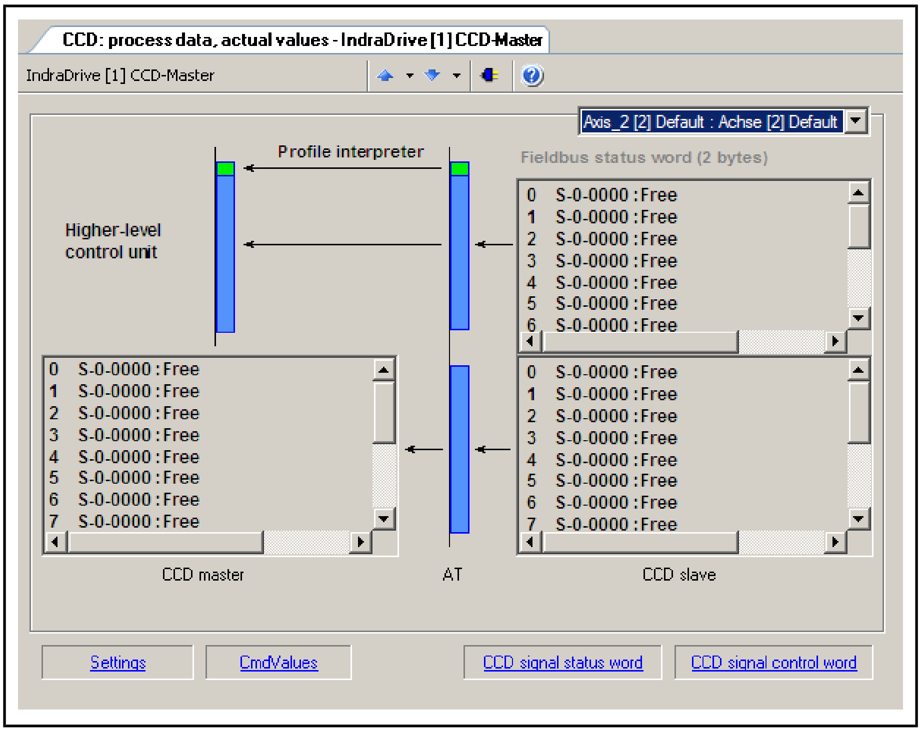


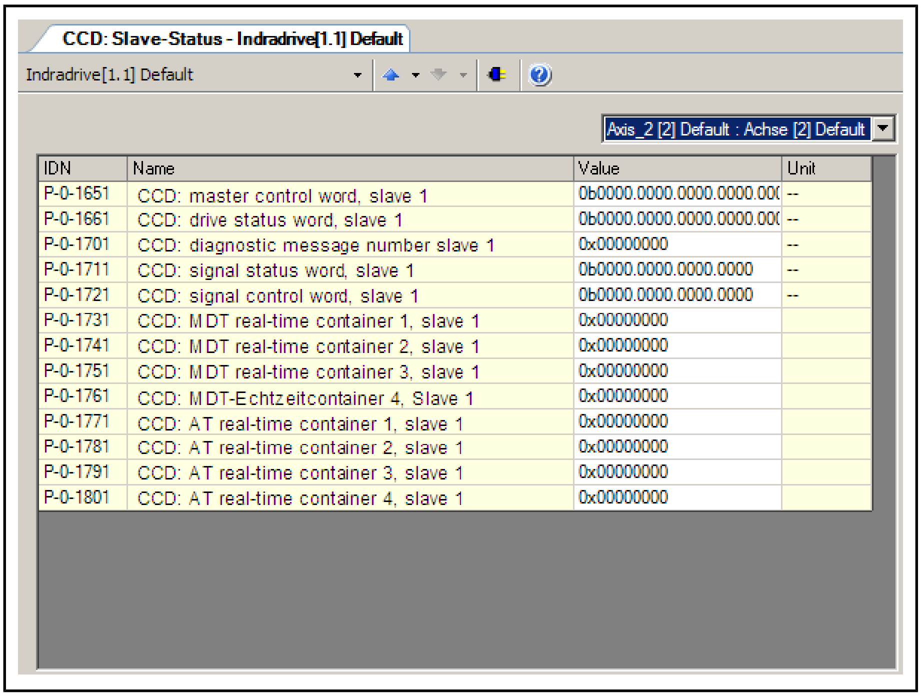
Fig.9-31: IndraWorks Overview Window of Actual Process Data Values

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.

Optional Device Functions

Slave Status



IDN	Name	Value	Unit
P-0-1651	CCD: master control word, slave 1	0b0000.0000.0000.0000.00	--
P-0-1661	CCD: drive status word, slave 1	0b0000.0000.0000.0000.00	--
P-0-1701	CCD: diagnostic message number slave 1	0x00000000	--
P-0-1711	CCD: signal status word, slave 1	0b0000.0000.0000.0000	--
P-0-1721	CCD: signal control word, slave 1	0b0000.0000.0000.0000	--
P-0-1731	CCD: MDT real-time container 1, slave 1	0x00000000	
P-0-1741	CCD: MDT real-time container 2, slave 1	0x00000000	
P-0-1751	CCD: MDT real-time container 3, slave 1	0x00000000	
P-0-1761	CCD: MDT-Echtzeitcontainer 4, Slave 1	0x00000000	
P-0-1771	CCD: AT real-time container 1, slave 1	0x00000000	
P-0-1781	CCD: AT real-time container 2, slave 1	0x00000000	
P-0-1791	CCD: AT real-time container 3, slave 1	0x00000000	
P-0-1801	CCD: AT real-time container 4, slave 1	0x00000000	

Fig.9-32: 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).

9.3 Rexroth IndraMotion MLD (Drive-Integrated PLC)

9.3.1 Brief Description

Extension package **IndraMotion MLD** (order code **ML**)

Fig.9-33: Assignment to Functional Firmware Package

The optional expansion package "IndraMotion MLD" provides the function of a PLC integrated in the drive according to IEC61131-3 with the following scope of functions:

- **Integrated logic control** (standard PLC tasks)
  - Completely in conformity with IEC 61131-3
  - Online Change
  - Debugging
  - Offline simulation
- **Integrated multi-axis/single-axis motion control**

  Motion function block according to PLCopen for single-axis positioning on local and remote axes and synchronization mode (synchronous running, cam shaft, ...) → "low-level motion functions"
  - Programming predominantly via SFC combined with ST
  - Single-Action-Steps (non-IEC steps) for "single" steps
  - Motion function blocks per libraries
  - Cyclic parameters available as direct variables (system-wide variables)
  - Library management

- **Basis for technology functions**

  Examples: Following-on cutting devices, pick&place, process controller (register controller, winding computation, etc.), preventive maintenance, free function block combination

  – Synchronous, consistent data exchange with drive control, configurable cyclic data channel
  – Periodic, high-priority user task
  – Runtime monitor

☞ This optional extension of the drive functionality is described in detail in the separate documentation "Rexroth IndraMotion MLD" (DOK-INDRV*-MLD-S*VRS**-AW**-EN-P; part no. R911306084).

Hardware Requirements

The expansion package "IndraMotion MLD" requires one of the following control section designs:

- Single-axis ADVANCED (CSH01.1C)
- Single-axis BASIC (CSB01.1)

☞ The expansion package "IndraMotion MLD" is **not** available for double-axis control sections (CDB01.1C)!

Firmware Requirements

In the firmware **MPx-04VRS**, the function "IndraMotion MLD" is available in the following variants:

- Advanced design (**MPH**)
- Basic single-axis design (**MPB**)

☞ Using the function "IndraMotion MLD" generally requires the enabling of the additive expansion package "**ML**".

See also sections:

- "Overview of Functions/Functional Packages"

- "Enabling of Functional Packages"

Features/Characteristic Values

- **Up to 4 preemptive user tasks are possible**
- **Task types:**
  – Periodic (min. cycle time: 1 ms for Advanced; 2 ms for Basic)
  – Free-running (permanently cyclic)
  – Event-controlled (min. reaction time: 1 ms for Advanced; 2 ms for Basic)
- **Memory resources:**
  – 192 kbytes program memory
  – 512 kbytes data memory
  – 250 bytes retain or 32 kbytes on MD1/2
- **Digital I/Os:**
  – 7...11 digital inputs, 0...4 digital outputs on X3 (with Advanced control section CSH01.1)

    → PLC and drive are sharing the inputs!
  – 12 digital inputs, 8 digital outputs on MD1 (optional)

   - 16 digital inputs, 16 digital outputs on PL (parallel master communication)
   - 1 relay output on X3 (control section CSH01.1)

     → PLC and drive are sharing the inputs!

     Note: For BASIC control sections there are restrictions regarding the available inputs/outputs (see documentation "Drive Controllers, Control Sections; Project Planning Manual").

- **Analog I/Os:**
   - 1 analog input (+/-10 V) on X3 (control section CSH01.1)
   - 2 analog outputs (0...5 V) on X3 (control section CSH01.1)
   - Analog inputs/outputs (+/-10 V) on MA1 (optional)

     Note: For BASIC control sections there are restrictions regarding the available inputs/outputs (see documentation "Drive Controllers, Control Sections; Project Planning Manual").

- **PLC registers**
   - 16 global PLC registers G0...G15 with 16 bits each and definable format (P-0-1386)
   - 2 global text registers with 255 characters each
   - 2 global list registers with 1024 or 8192 elements with 4 bytes each and definable format (P-0-1386)

- **Other data:**
   - Extensive debug possibilities (Single-Step, Watch, Force/Write, Breakpoints, Powerflow)
   - MMC data handling:

     - Save source code on MMC

     - Store symbol file on MMC for access to PLC variables
   - Performance of the programming system:

     - IEC-61131 programming in IL, ST, SFC, CFC, LAD, FUP

     - Source Download, Online Change, Debugging, Offline Simulation

     - Libraries

     - Debug Monitor for drive (PLC browser)

     - 2 parameters (P-0-1362, P-0-1363) with information on PLC project currently loaded in the memory or on boot project

Pertinent Parameters

General:

- P-0-1350, PLC control word
- P-0-1351, PLC status word
- P-0-1352, PLC user program administration data
- P-0-1362, PLC boot project info
- P-0-1363, PLC project info
- P-0-1367, PLC configuration
- P-0-1369, PLC internally reserved

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

Global PLC registers:

- P-0-1370, PLC Global Register G0
- P-0-1371, PLC Global Register G1
- P-0-1372, PLC Global Register G2
- P-0-1373, PLC Global Register G3
- P-0-1374, PLC Global Register G4
- P-0-1375, PLC Global Register G5
- P-0-1376, PLC Global Register G6
- P-0-1377, PLC Global Register G7
- P-0-1378, PLC Global Register G8
- P-0-1379, PLC Global Register G9
- P-0-1380, PLC Global Register G10
- P-0-1381, PLC Global Register G11
- P-0-1382, PLC Global Register G12
- P-0-1383, PLC Global Register G13
- P-0-1384, PLC Global Register G14
- P-0-1385, PLC Global Register G15
- P-0-1386, PLC display format Global Register

Global text registers:

- P-0-1387, PLC Global text register GT0
- P-0-1388, PLC Global text register GT1

Global list registers:

- P-0-1368, PLC Global Register AL0
- P-0-1389, PLC Global Register GL0

There are further parameters available for configuring the inputs/outputs (see separate documentation "Rexroth IndraMotion MLD").

9.3.2 Notes on Installation/System Configuration

Installation

For installing "IndraMotion MLD" on the PC, it is necessary to install the current version of the **"IndraWorks D" commissioning tool** on the PC. By doing this, the **"SCP" communication platform** that is contained on the installation CD is installed on the PC, too.

After successful installation the **"IndraLogic" PLC programming system** and **"IndraWorks D"** can simultaneously communicate with the drive via SCP.

System Configuration

The system configuration of "IndraMotion MLD" is carried out via a PC with the "IndraLogic" program installed that communicates with the SCP communication platform via the serial interface with the drive.

The projects are filed on the PC. The generated binary code is loaded to the drive and stored in parameters. As of firmware version **MPx-03VR** and with the MMC plugged, the source code and the symbols can be stored there, too.

9.3.3 Overview of the Available Libraries

☞ This chapter only gives a short explanation of the basic functions or libraries. The functional details are described in the separate documentation "Rexroth IndraMotion MLD".

The following data channels to the drive are available:

- **Parameter functions**, **function blocks** and **cycl. parameters**

  → Library **MX_Base.lib**
- **Real-time channel** for consistent data exchange (a max. of 4 parameters per direction)

  → Library **MX_DSP.lib**
- **Drive-specific motion function blocks** according to PLCopen

  → Library **MX_PLCopen.lib**
- **Diagnosis**, **error handling** and **axis addressing** (for multi-axis operation possible in the future)

  → Library **RIL_CommonTypes.lib**
- **Global registers** for data exchange of variables via master communication

Additionally for drive-internal functions (not user-relevant):

- Library **MX_Internal.lib**

MX_Base.lib

The library **MX_Base.lib** contains important data types, basic firmware function blocks and cyclic parameters as direct variables (system-wide variables).

General functions:

- ATAN2
- MX_fGetFreeTicks
- MX_fGetHighResTime
- MX_fHighResTimerTicks_to_us

Blocks/functions for drive control:

- MX_Command
- MX_Power
- MX_Reset
- MX_SetControl
- MX_SetDeviceMode
- MX_SetOpMode
- Functions for diagnosis:
  - MX_fGetDriveWarning
  - MX_fSetDriveWarning
  - MX_fSetDriveError
- Blocks/functions for parameters:
  - MX_fReadParamDINT
  - MX_fReadStringParam
  - MX_fWriteParamDINT
  - MX_fWriteStringParam
  - MX_ReadParamDINT
  - MX_WriteParamDINT

- MB_ReadMaxRealValue
- MB_ReadMaxValue
- MB_ReadMinRealValue
- MB_ReadMinValue
- MB_ReadName
- MB_ReadParameter
- MB_ReadRealParameter
- MB_ReadSercosAttribute
- MB_ReadUnit
- MB_WriteParameter
- MB_WriteRealParameter

- Functions for scaling:
  - MX_fDINT_AccTo_REAL
  - MX_fDINT_DistTo_REAL
  - MX_fDINT_VelTo_REAL
  - MX_fREAL_AccTo_DINT
  - MX_fREAL_DistTo_DINT
  - MX_fREAL_VelTo_DINT

List of global variables "DirektvariablenIdents":

- Direct variables (e.g.):
  - DV_P_0_0009 (*Error_number*)
  - DV_P_0_0038 (*Torquegenerating_current_command_value*)
  - DV_P_0_0039 (*Fluxgenerating_current_command_value*)
- IDN addressing (e.g.):
  - FP_P_0_0008 (*Activation_Estop_function*)
  - FP_P_0_0009 (*Error_number*)
  - FP_P_0_0019 (*Initial_position_value*)
- Axis addressing (e.g.):
  - Axis1: AXIS_REF

MX_DSP.lib

The library **MX_DSP.lib** contains globally defined real-time variables and a control block:

- List "RTCR_VariablenIdents"
- List "RTCW_VariablenIdents"
- MX_SynchronControl

MX_PLCopen.lib

The library **MX_PLCopen.lib** contains IEC function blocks according to PLCopen:

- MB_GearInPos
- MC_CamIn
- MC_CamOut
- MC_GearIn
- MC_GearOut
- MC_MoveAbsolute
- MC_MoveAdditive
- MC_MoveRelative

- MC_MoveVelocity
- MX_MoveAbsolute
- MX_MoveAdditive
- MX_MoveRelative
- MX_Stop

9.4 Digital Inputs/Outputs

9.4.1 Brief Description

General Information

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.9-34: Assignment to Functional Firmware Package

In their basic configuration (without optional modules), all IndraDrive controllers already have configurable digital inputs/outputs.

Hardware Requirements

The number, assignment and function of the digital inputs/outputs depend on the type and configuration of the respective control section and are contained in the respective hardware description (Project Planning Manual).

See separate documentation "Drive Controllers, Control Sections; Project Planning Manual"

Digital Inputs/Outputs on Control Section

Features

- Sampling of digital inputs and outputs or transmitting data to them in the position loop clock $T_{A\_position}$ (see "Performance Data")
- Configurable digital inputs/outputs with effective direction that can partly be freely set (input or output):
  - **ADVANCED** control sections with firmware **MPH**:
    - 4 digital inputs/outputs
    - 3 digital inputs
    - 2 inputs can alternatively be used as analog input (differential input)
    - 2 rapid inputs as probe inputs (in steps of µs)
    - 1 isolated relay switch contact (can be configured)
  - **BASIC single-axis** control sections with firmware **MPB**:
    - 3 digital inputs/outputs
    - 4 digital inputs
    - No analog input
    - 1 rapid input as probe input (in steps of µs)
    - 1 isolated relay switch contact (can be configured)
  - **BASIC double-axis** control sections with firmware **MPD**:
    - 4 digital inputs/outputs
    - 6 digital inputs
    - 2 inputs can alternatively be used as analog input (differential input)
    - 2 rapid inputs as probe inputs (in steps of µs)
    - 2 isolated relay switch contacts (can be configured)

- All inputs/outputs (except for the relay contact) designed for level of 0 V (LOW) or 24 V (HIGH)
- Assignment of inputs/outputs to internal parameters or bits
- Signal states of digital inputs and digital outputs mapped to individual parameter
- Signal states of digital inputs can be directly read by the control master
- Digital outputs can be directly controlled by the control master, if not used on drive-side
- External 24 V supply of the digital outputs required
- Inputs/outputs galvanically isolated from control section

☞ Each individual input/output can be assigned to parameters of the drive; IDN of the permitted parameters from IDN lists in S-0-0398 and S-0-0399.

Pertinent Parameters

- S-0-0398, IDN list of configurable data in signal status word
- S-0-0399, IDN list of configurable data in the signal control word
- P-0-0300, Digital I/Os, assignment list
- P-0-0301, Digital I/Os, bit numbers
- P-0-0302, Digital I/Os, direction
- P-0-0303, Digital I/Os, inputs
- P-0-0304, Digital I/Os, outputs

Pertinent Diagnostic Messages

- C0246 Trav. range lim. switch not ass. to dig. input
- C0247 Dig. output already assigned to another axis
- C0248 Dig. input assigned differently to axes
- C0249 Dig. I/Os: bit number too large
- F2010 Error when initializing digital inputs/outputs
- F2033 External power supply X10 error

Digital Inputs/Outputs on Optional Module MD1

For the configurable ADVANCED control sections, it is possible to individually configure, apart from the standard digital inputs/outputs, an extension of these inputs/outputs.

This requires the optional module MD1 which can be used for the following purposes:

- Making available digital inputs/outputs to external control unit
- Enabling input/output of drive parameters
- Making available digital inputs/outputs to drive-integrated PLC (IndraMotion MLD-S)
- Extension of memory (32 kB non-volatile memory) for drive-integrated PLC (IndraMotion MLD)

☞ Utilization of digital I/O extension by using the optional module MD1 is **only possible for ADVANCED** control sections!

Features

- Connection via 25-pin D-Sub connector
- All inputs/outputs designed for level of 0 V (LOW) or 24 V (HIGH)
- External 24 V supply of the digital outputs required
- Inputs/outputs galvanically isolated from control section

- Assignment of inputs/outputs to internal parameters or bits
  – Parameters P-0-0081 and P-0-0082 can be completely assigned to parameters of the drive or of the integrated PLC
  – Free configuration of the digital inputs/outputs via "S-0-0144, Signal status word" and "S-0-0145, Signal control word"
- 12 digital inputs (freely configurable and protected from reverse polarity)
- 8 digital outputs (max. output current 0.5 A and sustained short-circuit-proof)

Pertinent Parameters

- S-0-0144, Signal status word
- S-0-0145, Signal control word
- S-0-0398, IDN list of configurable data in signal status word
- S-0-0399, IDN list of configurable data in the signal control word
- P-0-0081, Parallel output 1
- P-0-0082, Parallel input 1
- P-0-0681, Assignment IDN -> parallel output 1
- P-0-0682, Assignment parallel input 1 -> IDN

9.4.2 Function and Commissioning of the Digital Inputs/Outputs of the Control Section

Overview

Configuring the Inputs/Outputs

The IDNs of the target or source parameters for digital inputs/outputs are contained in parameter "P-0-0300, Digital I/Os, assignment list". Further definitions for the indicated IDN are made via parameters P-0-0301 and P-0-0302, the assignment being carried out via the list line number (index).

Direct Bit Transfer

As a standard, the parameter of an IDN entered in P-0-0300 is considered to be the direct data source (when configured as output) or the target (when configured as input).

Cases to Distinguish for Determining Source or Target

The IDNs entered in the list parameter P-0-0300 can have two different functions:

- **1. Input**

  In the case of an input, the bit, configured in "P-0-0301, Digital I/Os, bit numbers", of a parameter defined via P-0-0300 is written with the logic value (0 or 1) provided at the input.
- **2. Output**

  In the case of an output, the content of the bit configured in P-0-0301 is taken from the IDN determined in P-0-0300 and transmitted to the hardware output.

The following table shows some exemplary standard configurations frequently used:

Function	P-0-0300[i]	P-0-0301[i]	P-0-0302[i]	Notes
Relay contact "ready for operation"	P-0-0115	0	1	Only makes sense for HCS!
Positive limit switch	P-0-0222	0	0	

Function	P-0-0300[i]	P-0-0301[i]	P-0-0302[i]	Notes
Negative limit switch	P-0-0222	1	0	
E-Stop	P-0-0223	0	0	

i = index No. of list line/terminal slot

Fig.9-35: Standard Configurations for Digital Inputs/Outputs (Examples)

Source or Target Parameter

The respective bit in the source or target parameter is selected via "P-0-0301, Digital I/Os, bit numbers".

☞ When P-0-0300[i] = "S-0-0000", the respective entry in P-0-0301 is ignored!

Operating Principle

A number of digital inputs/outputs can be used both as an input and as an output. The operating principle (direction) of these combined inputs/outputs is determined via the list parameter "P-0-0302, Digital I/Os, direction". The following applies:

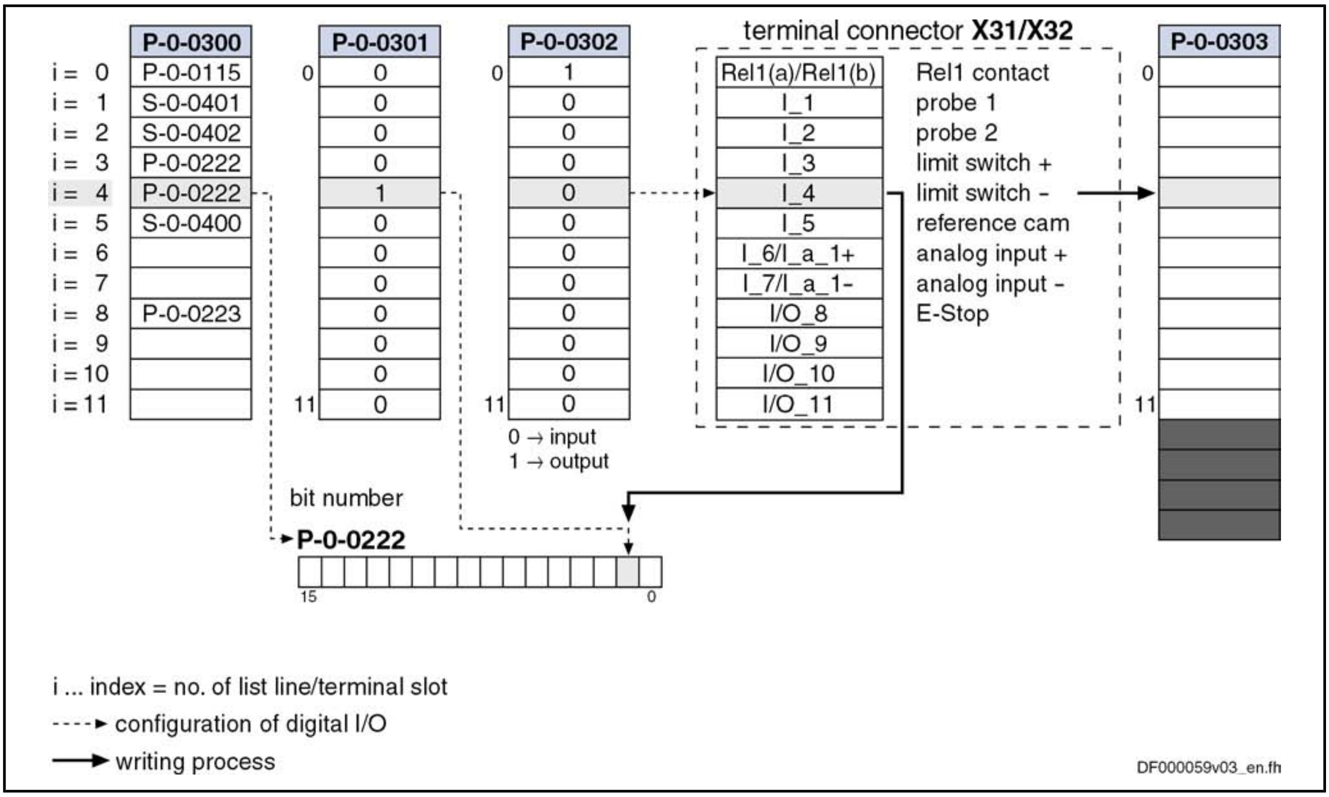
- Entry "0" → digital input (default setting)
- Entry "1" → digital output

☞ When determining the operating principle (direction) of the inputs/outputs, the hardware requirements have to be taken into consideration. The relay contacts, for example, can only be operated as outputs.

See also section "X31/X32, Digital and Analog Inputs/Outputs" in the documentation "Drive Controllers, Control Sections; Project Planning Manual"

As an example, the following figure illustrates the configuration of pin I_4 (terminal connector X31/X32) as an input signal for bit 1 of parameter S-0-0222 (negative travel range limit switch); the configuration assignment takes place via i = 4.

☞ This example applies to control sections of ADVANCED design; for BASIC and BASIC double-axis design, the distribution of the digital inputs/outputs is different.



P-0-0300	Digital I/Os, assignment list
P-0-0301	Digital I/Os, bit numbers
P-0-0302	Digital I/Os, direction
P-0-0303	Digital I/Os, inputs

Fig.9-36: Configuring the Digital Inputs/Outputs (Configuration for ADVANCED Control Section With Default Settings)

☞ The signal status of the digital inputs/outputs is displayed in the following parameters:

- P-0-0303, Digital I/Os, inputs
- P-0-0304, Digital I/Os, outputs

Deactivation

To deactivate an input/output, the IDN "S-0-0000" has to be input in the respective list element of parameter "P-0-0300, Digital I/Os, assignment list".

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 (Rel1 contact → output; all other pins → inputs).

Specific Features of Double-Axis Devices (Firmware MPD)

Basically, the existing inputs and outputs can be freely assigned to all axes. To do this, the parameters P-0-0300, P-0-0301, P-0-0302 are available for both axes.

There are the following restrictions:

- A digital output can only be used by one axis. All other axes have to deactivate this output by the entry "S-0-0000" in parameter P-0-0300.

- The output contact of the relay "Rel1" is an exception. It can be used by both axes. The default assignment is the "ready for operation" message (see Parameter Description P-0-0300). For controlling the relay the information of both axes is ANDed.
- An input can only be used simultaneously by both axes, if it is used by both axes with the same IDN, bit number and directional assignment (for inputs/outputs).
- A digital input **cannot be used simultaneously** by both axes, if the assignment parameters of both axes differ in the respective line with regard to the IDN (P-0-0300), bit number (P-0-0301) or directional assignment (P-0-0302). The respective line of P-0-0300 of one of the two axes has to contain "S-0-0000" (→ no assignment)!

☞ The above-mentioned restrictions are checked in the transition command from phase 3 to phase 4 (cf. C2000). In the case of conflict, the corresponding diagnostic message is generated.

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. An example is the probe function. In this case, the entry in P-0-0301 is irrelevant, it is only a valid value that has to be contained (e.g. "0").

All special functions are listed in the following table:

Function	P-0-0300[i]	P-0-0301[i]	P-0-0302[i]	Notes
Probe 1	S-0-0401	Not relevant	Not relevant	Only possible when "i = 1"!
Probe 2	S-0-0402	Not relevant	Not relevant	Only possible when "i = 2"!
Reference cam	S-0-0400	Not relevant	Not relevant	

i = index No. of list line/terminal slot

Fig.9-37: 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 status after "basic parameter load"), the inputs/outputs are appropriately predefined (see below).

☞ All changes in the parameters P-0-0300, P-0-0301 and P-0-0302 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

Access to Digital Outputs

In order to directly control ("set") the digital outputs of the control section via the master communication or directly poll ("read") the digital inputs, the parameters "P-0-0303, Digital I/Os, inputs" and "P-0-0304, Digital I/Os, outputs" can be included in the cyclic data of the master communication.

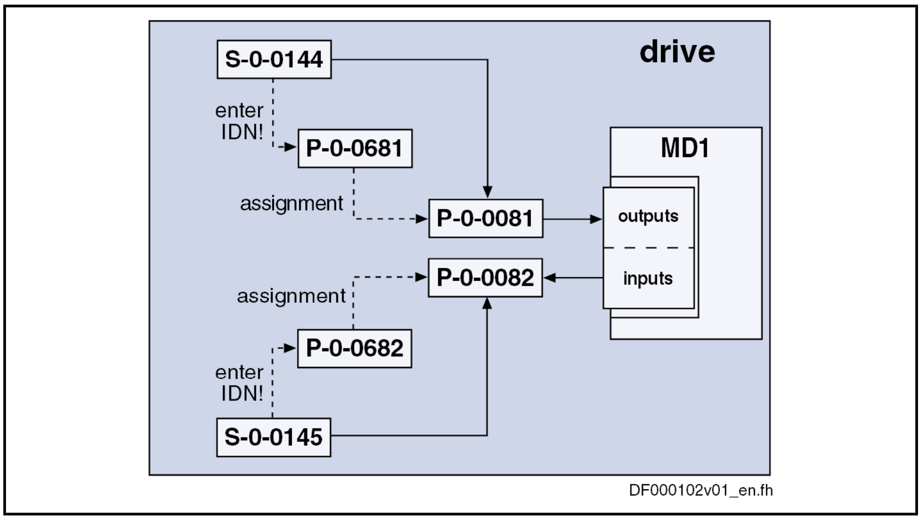
Requirements:

- Including parameter P-0-0303 in the group of cyclic actual values (SERCOS: S-0-0016, field bus: P-0-4080)

- Including parameter P-0-0304 in the group of cyclic command values (SERCOS: S-0-0024, field bus: P-0-4081)

☞ The digital outputs can only be directly controlled by the master communication, if they are not used on the drive side (enter "S-0-0000" in the respective list line of parameter P-0-0300; setting as output in parameter P-0-0302)!

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 I/Os, inputs
P-0-0304 Digital I/Os, outputs
Fig.9-38: Access to Digital Inputs/Outputs of the Control Section via SERCOS Master Communication

Default Configurations of Digital Inputs/Outputs of Control Section

Depending on the design of the control section, there are the following factory-provided default settings for the digital inputs/outputs:

Signal name	ADVANCED	BASIC UNIVERSAL single-axis	BASIC UNIVERSAL double-axis	BASIC-OPEN-LOOP	BASIC-SERCOS	BASIC-PROFIBUS	BASIC-ANALOG
I_1	Probe 1	Probe 1	Axis 1: Probe 1	Clear error	Probe 1	Probe 1	Clear error
I_2	Probe 2	X	Axis 2: Probe 1	Drive ON	X	X	Drive ON
I_3	Travel range limit switches	Travel range limit switches	Axis 1: Travel range limit switches	Vel. cmd value from memory of fixed values	Travel range limit switches	Travel range limit switches	Travel range limit switches
I_4	Travel range limit switches	Travel range limit switches	Axis 1: Travel range limit switches	Vel. cmd value from memory of fixed values	Travel range limit switches	Travel range limit switches	Travel range limit switches

Signal name	ADVANCED	BASIC UNI-VERSAL single-axis	BASIC UNIVER-SAL double-axis	BASIC-OPEN-LOOP	BASIC-SER-COS	BASIC-PRO-FIBUS	BASIC-ANA-LOG
I_5	Home switch	Home switch	Axis 1: Home switch	Vel. cmd value from memory of fixed values	Home switch	Home switch	Home switch
I_6	Analog input (I_a_1+)	--	X	--	--	--	--
I_7	Analog input (I_a_1-)	--	X	--	--	--	--
I/O_8	As input: E-Stop	As input: E-Stop	As input for axis 1: E-Stop	As input: E-Stop	As input: E-Stop	As input: E-Stop	As input: E-Stop
I/O_9	X	X	As input for axis 2: Travel range limit switches	As input: Vel. cmd value from memory of fixed values	X	X	As input: Drive Halt
I/O_10	X	X	As input for axis 2: Travel range limit switches	As input: Vel. cmd value from memory of fixed values	X	X	As output: Ready signal
I/O_11	X	--	As input for axis 2: Home switch	--	--	--	As output: Warning
I_12 to I_22	--	--	X	--	--	--	--

x Signal name available, but no default setting
-- Signal name not assigned in this control section type
I/O Can be used as input or output (not for BASIC OPENLOOP)
Fig.9-39: Default Setting of Digital Inputs/Outputs of Different Control Section Designs

See documentation "Drive Controllers, Control Sections; Project Planning Manual"

9.4.3 Function and Commissioning of the Digital Inputs/Outputs of the Optional Module MD1

Overview

Mapping the Inputs/Outputs

To map the digital inputs and outputs of the optional module MD1, the following parameters are available:

- P-0-0081, Parallel output 1

  → Contains the bits that are output via the digital outputs of the MD1 module
- P-0-0082, Parallel input 1

  → Contains the bits that are read in via the digital inputs of the MD1 module

---

The parameters P-0-0081 and P-0-0082 are only available when the optional module MD1 has been plugged.

Configuration

The two above parameters can be cyclically configured (MDT or AT data). This allows assigning the complete digital inputs or outputs to existing, cyclically configurable drive parameters (see S-0-0398, S-0-0399). The following parameters are used for assignment:

- P-0-0681, Assignment IDN -> parallel output 1
- P-0-0682, Assignment parallel input 1 -> IDN

Possibilities of Access

There are the following possibilities for using the digital inputs/outputs on the optional module MD1:

- Direct access via master communication by the master (e.g. PLC)
- Configuration of inputs/outputs to any drive parameter and bit (see S-0-0398 and S-0-0399)
- Direct access to inputs/outputs via drive-integrated PLC
- Configuration of digital inputs for safety technology on MD1

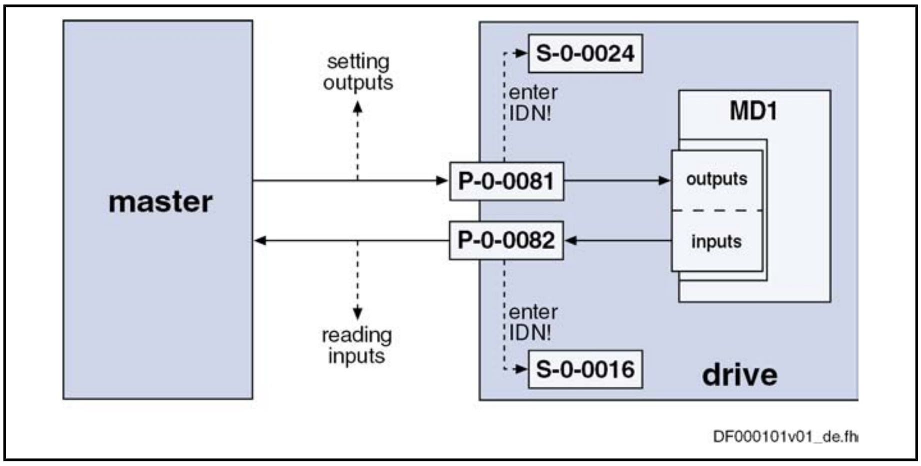
Direct Access to Digital Inputs/Outputs of the Module MD1 via Master Communication

In order to transmit data to the digital inputs/outputs directly via the master communication, the following steps are required:

- Configuration of:
  - [P-0-0681] = "S-0-0000"
  - [P-0-0682] = "S-0-0000"

  The parameters P-0-0081 and P-0-0082 can then be used as mere "data containers" for exchanging data between drive and master.
- Configuration of P-0-0081 and P-0-0082 in the cyclic data
- Including parameter P-0-0081 in the group of cyclic command values (SERCOS: S-0-0024, field bus: P-0-4081)
- Including parameter P-0-0082 in the group of cyclic actual values (SERCOS: S-0-0016, field bus: P-0-4080)

The figure below illustrates the access to the digital inputs/outputs of the optional module MD1 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-0-0081 Parallel output 1
P-0-0082 Parallel input 1

Fig.9-40: Access to Digital Inputs/Outputs of the Optional Module MD1 via SERCOS Master Communication

Configuring the Digital Inputs/Outputs of Module MD1 to any Parameter and Bit

It is possible to assign the digital inputs/outputs of the optional module MD1 to any drive parameter.

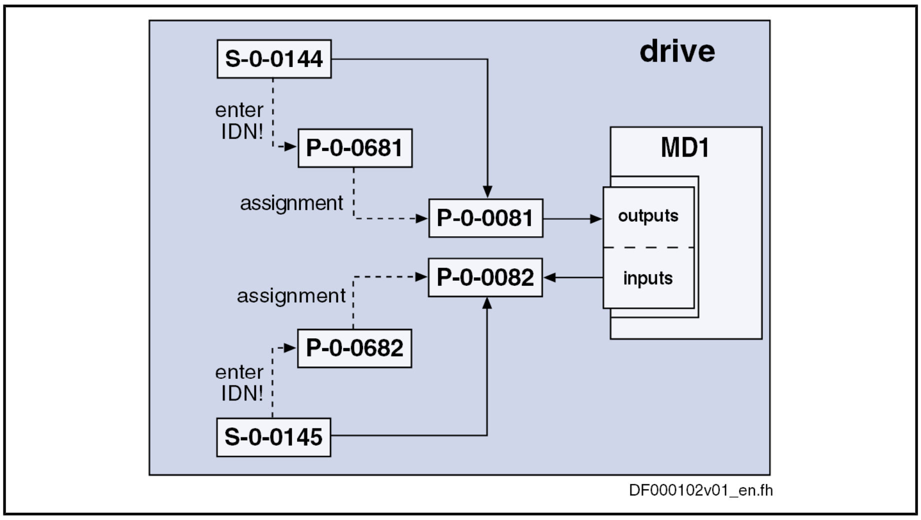
To do this, the following steps are required:

- Configuration of
  - P-0-0681 = [S-0-0144] → [S-0-0144] → P-0-0081
  - P-0-0682 = [S-0-0145] → [P-0-0082] → S-0-0145

  The contents of the parameters P-0-0081 and P-0-0082 are thereby mapped to the parameters S-0-0144 and S-0-0145.
- Configuration of the desired parameters and bits for the digital inputs/outputs by means of the mechanism of the freely configurable signal control word and signal status word (see also Parameter Description for "S-0-0145, Signal control word" and "S-0-0144, Signal status word")
- Configuration of parameter S-0-0144 via S-0-0026 and S-0-0328 (see also "S-0-0398, IDN list of configurable data in signal status word")
- Configuration of parameter S-0-0145 via S-0-0027 and S-0-0329 (see also "S-0-0399, IDN list of configurable data in signal control word")

☞ If the parameters "S-0-0144, Signal status word" or "S-0-0145, Signal control word" are used for configuring the digital inputs/outputs of the optional module MD1, they can no longer be used for master communication (as cyclic data).

The figure below illustrates the access to any drive parameter via the digital inputs/outputs of the optional module MD1:



S-0-0144	Signal status word
S-0-0145	Signal control word
P-0-0081	Parallel output 1
P-0-0082	Parallel input 1
P-0-0681	Assignment IDN -> parallel output 1
P-0-0682	Assignment parallel input 1 -> IDN

Fig.9-41: Access to Any Drive Parameter via Digital Inputs/Outputs of the Optional Module MD1

☞ For the digital inputs/outputs of the optional module MD1 there is no default configuration.

See documentation "Drive Controllers, Control Sections; Project Planning Manual"

Direct Access to Inputs/Outputs of Module MD1 via Drive-Integrated PLC

In order to transmit data directly from the drive-integrated PLC (IndraMotion MLD) to the digital inputs/outputs, the respective assignments to the drive-integrated PLC have to be made via "P-0-0681, Assignment IDN -> parallel output 1" and "P-0-0682, Assignment parallel input 1 -> IDN":

- **Inputs** (cf. P-0-1390 to P-0-1397)
- **Outputs** (cf. P-0-1410 to P-0-1417)
- **Registers** (cf. P-0-1370 to P-0-1385)

☞ P-0-0081 and P-0-0082 are used as mere display parameters that are mapping the status of the digital inputs/outputs on the optional module MD1.

Example of Application (PLC Uses Inputs of MD1)

The digital inputs of the optional module MD1 are to be used as PLC inputs. This requires the following configuration:

- Assign "P-0-0082, Parallel input 1" to parameter "P-0-1390, PLC input WORD0 AT %IB0" by making the following entry in parameter P-0-0682

  → [P-0-0682] = "P-0-1390"

☞ An internal parameter may only be assigned via "P-0-0681, Assignment IDN -> parallel output 1", if "P-0-0081, Parallel output 1" is not written via a 1st class master communication (e.g. SERCOS).

Configuration of Digital Inputs/Outputs for Integrated Safety Technology

In order to use the digital inputs/outputs for the safety technology integrated in the drive, the corresponding assignments have to be made via the parameters P-0-0681 and P-0-0682:

- **Inputs** (e.g. "P-0-3212, Safety technology signal control word, channel 1")
- **Outputs** (e.g. "P-0-3214, Safety technology signal status word, channel 1")

9.4.4 Diagnostic and Status Messages

Digital Inputs/Outputs on Control Section

Status of Digital Inputs/Outputs

The status (= signal status) of the digital inputs/outputs is displayed in the parameters "P-0-0303, Digital I/Os, inputs" and "P-0-0304, Digital I/Os, outputs":

- Bit set ("1")

  → At the assigned input/output, a HIGH level (+24 V) is provided or the Rel1 contact is closed.

- Bit not set ("0")

  → At the assigned input/output, a LOW level (0 V) is provided or the Rel1 contact is opened.

Check for Invalid Bit Numbers

When entering data in parameter "P-0-0301, Digital I/Os, bit numbers", 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.

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 haven't been configured yet, "-1" is displayed as bit number.

Checks in Transition Command

The following monitoring functions are used for guaranteeing an efficient configuration of the digital inputs/outputs and preventing invalid configurations:

- If the limit switch function (Limit+/-) was activated in P-0-0090 (bit 1) but not assigned to any digital input via P-0-0300, the error message "C0246 Trav. range lim. switch not ass. to dig. input" will appear when progressing to the operating mode. This message is output to avoid moving the drive without configured limit switch function.
- For double axis devices the digital inputs/outputs basically can be assigned to both axes. This is the reason why an input or output is sometimes configured for both axes. In this case, the error message "C0247 Dig. output already assigned to another axis" will be displayed.
- Monitoring and possibly error message "C0248 Dig. input assigned differently to axes"
- If the bit number entered in P-0-0301 is too large, the error message "C0249 Dig. I/Os: bit number too large" will be generated.

Digital Inputs/Outputs on Optional Module MD1

Status of Digital Inputs/Outputs

The status of the digital inputs/outputs on the optional module MD1 is displayed in the following parameters:

- P-0-0081, Parallel output 1

  → Contains the information regarding the digital output bits
- P-0-0082, Parallel input 1

  → Contains the information regarding the digital input bits

The following applies to these parameters:

- Bit set ("1")

  → At the assigned input/output, a HIGH level (+24 V) is provided.
- Bit not set ("0")

  → At the assigned input/output, a LOW level (0 V) is provided.

> ☞ There is no additional configuration check, as the restriction of the IDN selection lists already prevents invalid configurations.

9.5 Analog Inputs

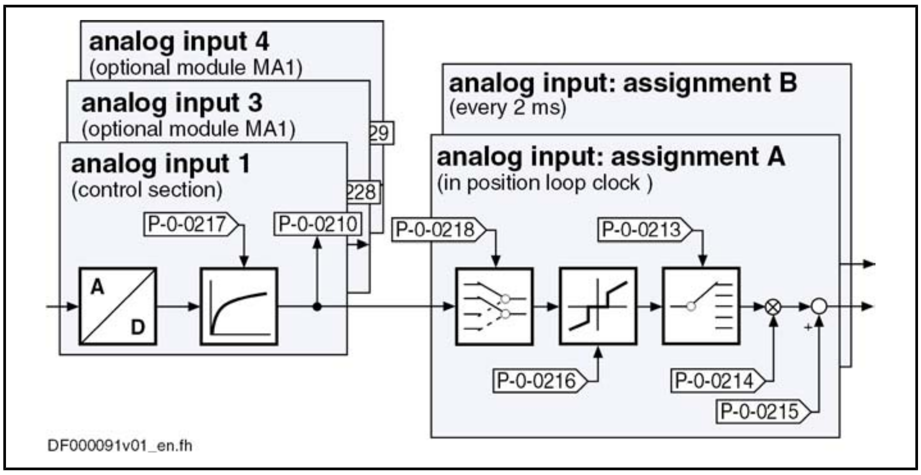
9.5.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.9-42: Assignment to Functional Firmware Package

Overview

According to the control section type, IndraDrive controllers already have analog inputs in their basic configuration (without optional modules). Configurable control sections can be upgraded with this function by using the optional module MA1. The number and function of the analog inputs differ according to the type and configuration of control section (see "Hardware Requirements" below).



P-0-0210	Analog input 1
P-0-0213	Analog input, assignment A, target parameter
P-0-0214	Analog input, assignment A, scaling per 10V full scale
P-0-0215	Analog input, assignment A, signal value at 0V
P-0-0216	Analog input, assignment A, dead zone
P-0-0217	Analog input, time constant input filter
P-0-0218	Analog input, control parameter

Fig.9-43: Overview: Analog Inputs and Their Assignments (Example of Control Section CSH01.1C)

Features

General features:

- 2 assignment mechanisms for analog inputs (assignment A or B)
- Different sampling rates of assignments A and B
  - Assignment channel A works in position loop clock (see "Performance Data")
  - Assignment channel B works in 2-ms clock
- Assignment to command value/limit value/control parameters of the drive by means of adjustable scaling
- Possible assignment of only max. 2 analog inputs to internal drive parameters
- Variable scaling for 2 analog channels
- Dead zone to be entered for suppressing the zero drift for both analog channels
- Offset and amplification adjust for both analog channels via command

Features of analog inputs at control section:

- Number and resolution of analog inputs depend on control section design:
  - ADVANCED → 1 analog input with resolution of 14 bits (by means of 8-fold oversampling for both analog channels)
  - BASIC OPENLOOP and BASIC ANALOG → each have 2 analog inputs with 12 bits (other Basic variants do not have any analog inputs)
  - BASIC UNIVERSAL double-axis → 1 analog input with resolution of 14 bits (by means of 8-fold oversampling for both analog channels) for both axes in common. The input can, however, be used by both axes at the same time!
- Low-pass filtering to be activated for both analog channels
- Analog inputs designed as differential input
- Input voltage range of ± 10 V

Features of analog inputs on optional module MA1:

The optional module MA1 was developed according to VDE 0411-part 500 (programmable logic controllers) and should be used according to the specifications contained in this standard.

Properties of the analog inputs on the optional module MA1:

- Connection via 15-pin D-Sub connector
- 2 analog inputs with resolution of 14 bits (by means of 8-fold oversampling for both analog channels)
- Low-pass filtering to be activated for both analog channels
- Analog inputs designed as differential input
- Input voltage range of ± 10 V

Hardware Requirements

The table below shows the hardware requirements of the analog inputs and their assignment to the connection points (terminal connectors) of the control section (on basic circuit board or at optional module MA1).

Control section type	Analog input no.					
	1	2	3	4	5	6
	... to be found …					
	on basic circuit board		at optional module MA1			
CSH01.1C,	X32 (4/5)	--	Optional slot **2** X8 (2/9)	Optional slot **2** X8 (4/11)	--	--
	X32 (4/5)	--	Optional slot **3** X10 (2/9)	Optional slot **3** X10 (4/11)	--	--
CSB01.1C	--	--	Optional slot **2** X8 (2/9)	Optional slot **2** X8 (4/11)	--	--
CDB01.1C	X32 (4/5)	--	Optional slot **3** X8.1 (2/9)	Optional slot **3** X8.1 (4/11)	--	--
	X32 (4/5)	--	Optional slot **4** X8.2 (2/9)	Optional slot **4** X8.2 (4/11)	--	--
	X32 (4/5)	--	Optional slot **3** X8.1 (2/9)	Optional slot **3** X8.1 (4/11)	Optional slot **4** X8.2 (2/9)	Optional slot **4** X8.2 (4/11)
CSB01.1N-AN	X32 (4/5)	X32 (1/2)	Control section type cannot be configured			
CSB01.1N-SE	--	--				
CSB01.1N-PB	--	--				
CSB01.1N-FC	X32 (4/5)[1)]	X32 (1/2)[1)]				
	X36 (1/2) [2)]	X36 (2/3) [2)]				

1) For voltage signals (selected via bit 12 in P-0-0218)
2) For current signals (selected via bit 12 in P-0-0218)

Fig.9-44: Overview of Hardware Requirements of Analog Inputs (Incl. Assignment of Connection Points)

See also section "Optional Module MA1" in the documentation "Control Sections for Drive Controllers; Project Planning Manual"

Pertinent Parameters

Configuring the analog inputs:

- P-0-0212, Analog input, list of assignable parameters
- P-0-0218, Analog input, control parameter
- P-0-0219, Analog input, maximum value for adjust
- P-0-0220, C2800 Analog input adjust command
- P-0-3901, Adjust values of control section
- P-0-3904, Adjust values analog I/O interface 3-4
- P-0-3905, Adjust values analog I/O interface 5-6

Analog input values:

- P-0-0210, Analog input 1
- P-0-0211, Analog input 2
- P-0-0228, Analog input 3
- P-0-0229, Analog input 4
- P-0-0208, Analog input 5
- P-0-0209, Analog input 6
- 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, Analog input 4, time constant input filter
- P-0-0234, Analog input 5, time constant input filter
- P-0-0235, Analog input 6, time constant input filter

Assignment A:

- P-0-0213, Analog input, assignment A, target parameter
- P-0-0214, Analog input, assignment A, scaling per 10V full scale
- P-0-0215, Analog input, assignment A, signal value at 0V
- P-0-0216, Analog input, assignment A, dead zone

Assignment B:

- P-0-0236, Analog input, assignment B, target parameter
- P-0-0237, Analog input, assignment B, scaling per 10V full scale
- P-0-0238, Analog input, assignment B, signal value at 0V
- P-0-0239, Analog input, assignment B, dead zone

Pertinent Diagnostic Messages

- C2800 Analog input adjust 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 adjust failed

9.5.2 Functional Description

Reading and Assigning an Analog Input

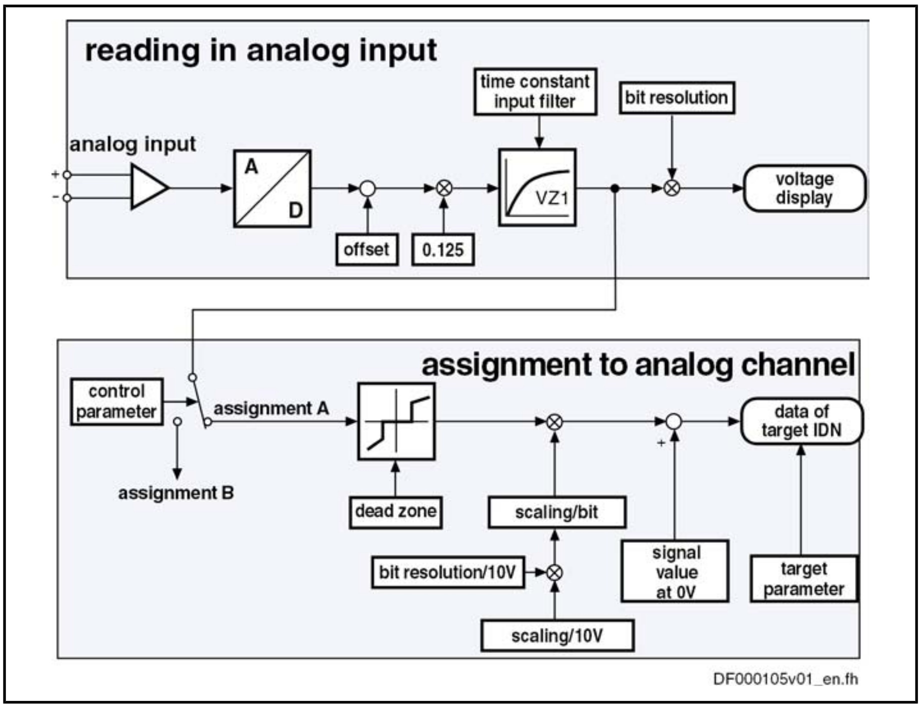


Fig.9-45: Overview of Functions: Reading and Assigning an Analog Input

Sampling and Signal Adjustment of Analog Inputs

Sampling The analog input signals (a maximum of 5 analog inputs can be used) are sampled with 8-fold oversampling in the position loop clock (see "Performance Data").

Filtering All sampled analog input signals can be smoothed by a PT1 filter. The following parameters are available to set the respective filter:

- 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, Analog input 4, time constant input filter
- P-0-0234, Analog input 5, time constant input filter
- P-0-0235, Analog input 6, time constant input filter

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 (in ms)

Fig.9-46: Limit Frequency of the Activated Filter

Voltage Display of Analog Inputs The sampled and possibly smoothed voltage (14-bit resolution) of the analog inputs channels is displayed 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, Analog input 4
- P-0-0208, Analog input 5
- P-0-0209, Analog input 6

☞ These parameters can be, for example, transmitted to the higher-level master or directly processed in the drive-integrated PLC (IndraMotion MLD).

Factory-Provided Adjust

During the adjust of the control module or the optional module MA1 at the factory, the adjust values, among other things for offset and amplification of the analog inputs, are stored in the following parameters:

- P-0-3901, Adjust values of control section
- P-0-3904, Adjust values analog I/O interface 3-4
- P-0-3905, Adjust values analog I/O interface 5-6

Internal Processing of Analog Input Values

Via two assignment mechanisms, the analog input values can be assigned to internal drive parameters.

Assignment of Analog Inputs

The assignment of an analog input to an internal channel (assignment A or B) takes place via parameter "P-0-0218, Analog input, control parameter".

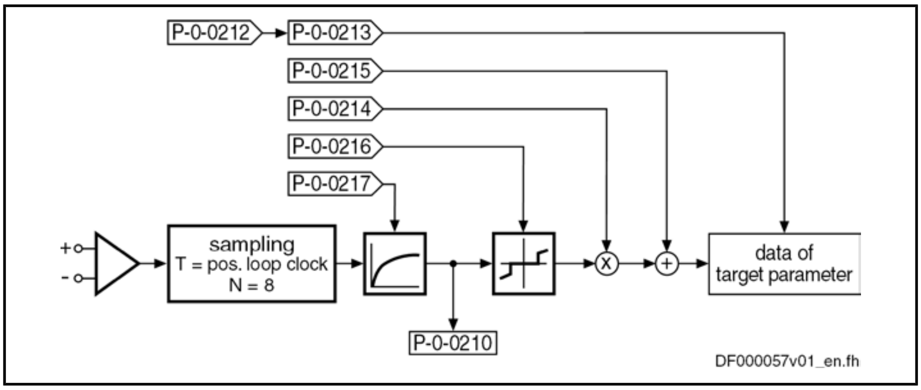
- Bits 4 to 7 → assignment of an analog input for assignment A
- Bits 8 to 11 → assignment of an analog input for assignment B

See also "Notes on Commissioning" in the same section

See also Parameter Description "P-0-0218, Analog input, control parameter"

☞ It is therefore only possible to assign a maximum of 2 analog inputs to internal drive parameters (assignment A or B). All other analog inputs can then only be used for direct access via the master communication or the drive-integrated PLC (IndraMotion MLD) (e.g. reading the voltage levels).

The assignment channels to internal parameters available in the drive basically have the same functionality. That is why we will only describe assignment channel A. The description of assignment channel B corresponds to that of assignment channel A.



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, scaling per 10V full scale
P-0-0215	Analog input, assignment A, signal value at 0V
P-0-0216	Analog input, assignment A, dead zone
P-0-0217	Analog input, time constant input filter

Fig.9-47: Functional Principle of Analog Input (Example for Assignment A)

Processing Clock for Analog Input Values

The processing of the analog input values in the two channels (assignment A or B) only differs in the cycle time:

- **Assignment A**

  → The **position loop clock** is used (see "Performance Data")
- **Assignment B**

  → A clock of **T = 2 ms** is used

Controlling the Internal Processing

Settings in parameter "P-0-0218, Analog input, control parameter" control the internal processing functions (adjust and assignment):

- Bit 0 → determining the adjust mode (for command "C2800 Analog input adjust command")
- Bit 1 → determining assignment channel for adjust (for command "C2800 Analog input adjust command")
- Bits 4...7 → assignment of the analog inputs for assignment channel A
- Bits 8...11 → assignment of the analog inputs for assignment channel B

Automatic Scaling (or Zero Point Shifting)

Apart from manual adjust or scaling of the analog inputs (assignment A or B), it is also possible to adjust them automatically by activating the command "C2800 Analog input adjust command".

In the case of automatic scaling, the parameters P-0-0214 and P-0-0215 or P-0-0237 and P-0-0238 are written by the drive.

☞ The analog channels are already adjusted at the factory and the correction values are stored in the parameters P-0-3901, P-0-3904 and P-0-3905.

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 adjust ("0" → zero point shifting)

- Bit 1 → defines the assignment channel for the adjust (A or B)

The result of automatic zero point shifting is directly entered in

- P-0-0215, Analog input, assignment A, signal value at 0V

- or -

- P-0-0238, Analog input, assignment B, signal value at 0V.

In addition, it is possible to define the reference point manually. To do this, enter the value, that is to be contained in the target parameter with an analog input voltage of 0 V, in P-0-0215 or P-0-0238.

☞ Unit, decimal places and data type of the value in P-0-0215 or P-0-0238 depend on the target parameter selected in "P-0-0213, Analog input, assignment A, target parameter".

Scaling

For scaling the analog input value to the desired range of values it is possible to use the automatic amplification adjust. 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 (bit 0 = 1 → amplification adjust)
  - Bit 1 → defines the assignment channel for the adjust (A or B)
- P-0-0219, Analog input, maximum value for adjust

  This parameter indicates the value to which the analog input is set when the amplification adjust (P-0-0218, bit 0 = 1) is carried out.

The result of automatic amplification adjust is directly entered in parameter

- P-0-0214, Analog input, assignment A, scaling per 10V full scale

- or -

- P-0-0237, Analog input, assignment B, scaling per 10V full scale.

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 in the target parameter (→ pitch), in P-0-0214 or P-0-0237.

☞ Unit, decimal places and data type of the value in P-0-0215 or P-0-0238 depend on the target parameter selected in "P-0-0213, Analog input, assignment A, target parameter".

"Dead Zone" to be Parameterized

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

☞ Parameterizing a "dead zone" is useful mainly for noisy analog values!

Assignment to Internal Drive Parameters

Assigning Analog Inputs to Parameters

The analog input values are stored in the following parameters for display and further internal processing:

- P-0-0210, Analog input 1
- P-0-0211, Analog input 2 (only for CSB01.1N-FC and CSB01.1N-AN)
- P-0-0228, Analog input 3
- P-0-0229, Analog input 4

- P-0-0208, Analog input 5 (only for CDB01.1C)
- P-0-0209, Analog input 6 (only for CDB01.1C)

By the assignment mechanisms via the parameters P-0-0213 (assignment A) and P-0-0236 (assignment B), it is possible to assign two analog input values (cf. P-0-0210, P-0-0228 or P-0-0229) to other drive parameters and thereby process them cyclically (cf. "P-0-0212, Analog input, list of assignable parameters").

Parameters to be Assigned

Only such parameters can be assigned that are contained in the list parameter "P-0-0212, Analog inputs, IDN list of assignable parameters".

Configuring the Analog Input

The assignment of an analog input to a parameter is activated when a value unequal "S-0-0000" (S-0-0000 corresponding to "Off") was parameterized in parameter P-0-0213 or P-0-0236.

9.5.3 Notes on Commissioning

Carrying Out the Automatic Scaling (or Adjust)

Automatic adjust takes place in 2 steps that have to be carried out one after the other in order to achieve reliable execution of the function.

1. **Zero point shifting**
   (or reference point shifting, because reference is not obligatorily established to U_e = 0 V)
2. **Amplification or amplitude scaling**

There is only one command for both assignment channels. In "P-0-0218, Analog input, control parameter" (bit 1), you have to define which channel is adjusted:

- Bit 1 = 0 → scaling of assignment channel A
- Bit 1 = 1 → scaling of assignment channel B

Configuration and Assignment to Drive Parameters

Assignment to Internal Channel (Assignment A or B)

The assignment of an analog input to an internal analog channel (assignment A or B) takes place via "P-0-0218, Analog input, control parameter":

- Bits 4 to 7 → selection of an analog input for assignment A
- Bits 8 to 11 → selection of an analog input for assignment B

See also Parameter Description "P-0-0218, Analog input, control parameter"

Assignment to Drive Parameters

By means of the assignment mechanism (assignment A or B), it is possible to assign the analog input values to drive parameters. Assignment takes place in the following parameters:

- P-0-0213, Analog input, assignment A, target parameter
- P-0-0236, Analog input, assignment B, target parameter

Possibilities of Access via Master Communication and IndraMotion MLD

The analog input values of the analog inputs are stored in the following parameters for display and further internal processing:

- P-0-0210, Analog input 1
- P-0-0211, Analog input 2 (only for CSB01.1N-FC and CSB01.1N-AN)
- P-0-0228, Analog input 3
- P-0-0229, Analog input 4
- P-0-0208, Analog input 5 (only for CDB01.1C)
- P-0-0209, Analog input 6 (only for CDB01.1C)

It is therefore possible to configure these digitized analog values into the cyclic telegram of the master communication (cf. S-0-0016 or P-0-4081) or to access one of the above parameters directly from a PLC program.

Specific Features of Double-Axis Design (MPD)

Each analog input (1 and, if required, 3 to 5) can be parameterized without restrictions for both axes of a double axis.

Only the provided input voltage is used in common.

The respective evaluation and interpretation depends on how the individual axes have been parameterized (cf. assignment A and B).

☞ The parameters P-0-0210 to P-0-0239 are available separately for each axis. The parameters P-0-3901, P-0-3904 and P-0-3905 are only available once per device!

9.5.4 Diagnostic and Status Messages

As regards the "analog inputs" function, the following diagnostic command messages can occur:

- C2800 Analog input adjust 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 adjust failed

ⓘ See descriptions of these diagnostic messages in the separate documentation "Notes on Troubleshooting" (description of diagnostic messages)

9.6 Analog Outputs

9.6.1 Brief Description

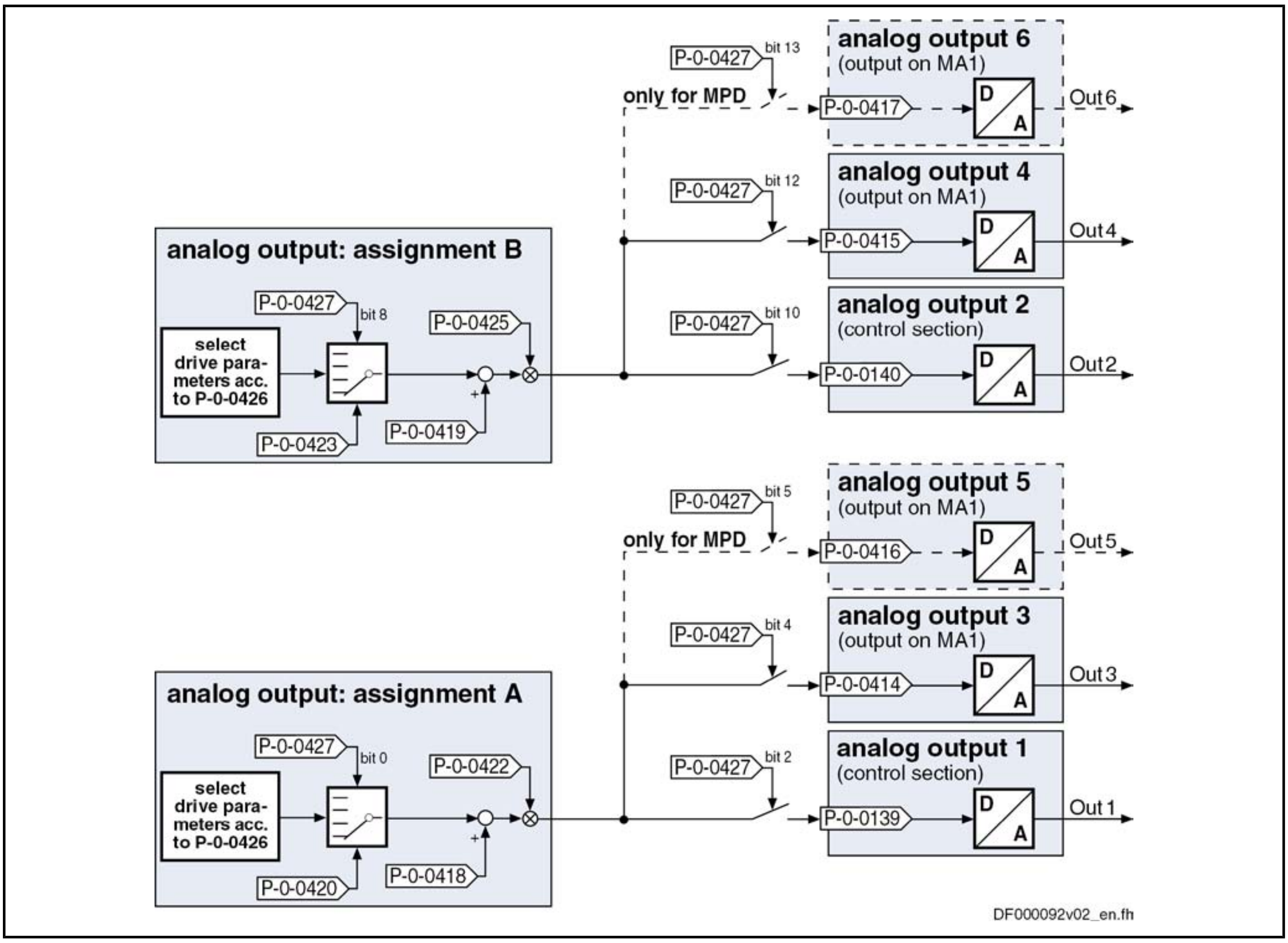
Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.9-48: Assignment to Functional Firmware Package

Overview

According to the control section type, IndraDrive controllers already have analog outputs in their basic configuration (without optional modules). Configurable control sections can be upgraded with this function by using the optional module MA1. The number and function of the analog outputs differ according to the type and configuration of control section (see "Hardware Requirements" below).

The figure below illustrates the interaction of the two analog output channels with the analog outputs.



MA1 Optional module MA1 (analog I/O extension)

Fig.9-49: Assignment Mechanism for the Analog Outputs

The drive function "analog outputs" allows using 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.

Features

General features:

- Number and characteristics of analog outputs depending on type and configuration (with/without optional module MA1) of the control section
- Up to 6 analog outputs available according to control section design
- Update of analog outputs in velocity loop 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 "Drive Controllers, Control Sections; 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

Features of analog outputs at control section:

- Number and resolution of analog outputs depend on control section design:
  - ADVANCED → 2 analog outputs with 8 bits
  - BASIC UNIVERSAL double-axis → 2 analog outputs with 8 bits
  - BASIC OPENLOOP → 2 analog outputs with 10 bits
- Output voltage range: 0 to 5 V
  (for BASIC OPENLOOP → 0 to 10 V)
- Available quantization: 19.5 mV (= $5V/2^8$)

Features of analog outputs at optional module MA1:

The optional module MA1 was developed according to VDE 0411-part 500 (programmable logic controllers) and should be used according to the specifications contained in this standard.

Properties of analog outputs at optional module MA1:

- Connection via 15-pin D-Sub connector
- 2 analog outputs with 12 bits each
- Output voltage range: ±10 V with reference to 0 VA
- Available quantization: 5 mV (= $10V/2^{11}$)

Hardware Requirements

The table below shows the hardware requirements of the analog outputs and their assignment to the connection points (terminal connectors) of the control section (on basic circuit board or at optional module MA1).

Control section type	Analog output no.					
	1	2	3	4	5	6
	... to be found …					
	on basic circuit board		at optional module MA1			
CSH01.1C, CSH01.2C	X32 (1)	X32 (2)	Optional slot **2** X8 (5)	Optional slot **2** X8 (14)	--	--
	X32 (1)	X32 (2)	Optional slot **3** X10 (5)	Optional slot **3** X10 (14)	--	--
CSB01.1C	--	--	Optional slot **2** X8 (2/9)	Optional slot **2** X8 (4/11)	--	--
CDB01.1C	X32 (1)	X32 (2)	Optional slot **3** X8.1 (5)	Optional slot **3** X8.1 (14)	--	--
	X32 (1)	X32 (2)	Optional slot **4** X8.2 (5)	Optional slot **4** X8.2 (14)	--	--
	X32 (1)	X32 (2)	Optional slot **3** X8.1 (5)	Optional slot **3** X8.1 (14)	Optional slot **4** X8.2 (5)	Optional slot **4** X8.2 (14)

<table>
<tr><th rowspan="4">Control section type</th><th colspan="6">Analog output no.</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
<tr><th colspan="6">... to be found ...</th></tr>
<tr><th colspan="2">on basic circuit board</th><th colspan="4">at optional module MA1</th></tr>
<tr><td>CSB01.1N-AN</td><td>X32 (4/5)</td><td>X32 (1/2)</td><td colspan="4" rowspan="4">Control section type cannot be configured</td></tr>
<tr><td>CSB01.1N-SE</td><td>--</td><td>--</td></tr>
<tr><td>CSB01.1N-PB</td><td>--</td><td>--</td></tr>
<tr><td>CSB01.1N-FC</td><td>X32 (9)</td><td>X35 (3)</td></tr>
</table>

MA1 Optional module MA1 (analog I/O extension)

Fig.9-50: Overview of Hardware Requirements of Analog Inputs (Incl. Assignment of Connection Points)

See also section "Optional Module MA1" in the documentation "Drive Controllers, Control Sections; Project Planning Manual"

In the case of double-axis devices (control section CDB01.1-...), the analog outputs are used by both axes, simultaneous use of an analog output by both axes is impossible.

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 - assignment A:

- P-0-0418, Analog output, assignment A, signal value at 0V
- P-0-0420, Analog output, assignment A, signal selection
- P-0-0422, Analog output, assignment A, scaling [1/V]

Analog output - assignment B:

- P-0-0419, Analog output, assignment B, signal value at 0V
- P-0-0423, Analog output, assignment B, signal selection
- P-0-0425, Analog output, assignment B, scaling [1/V]

Analog output values:

- P-0-0139, Analog output 1
- P-0-0140, Analog output 2
- P-0-0414, Analog output 3
- P-0-0415, Analog output 4
- P-0-0416, Analog output 5
- P-0-0417, Analog output 6

9.6.2 Functional Description

General Information

For assigning the signal sources for the analog outputs of the drive controller, it is basically 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 both analog channels A and B

  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, Analog output 3
- P-0-0415, Analog output 4
- P-0-0416, Analog output 5
- P-0-0417, Analog output 6

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.

Output of Predefined Drive Parameters

List of Assignable Parameters

Values of drive parameters are output on the basis of a predefined selection list. Parameter "P-0-0426, Analog output IDN list of assignable parameters" contains all parameter IDNs of status variables and signals of the drive that 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, assignment A, signal selection
- P-0-0423, Analog output, assignment B, signal selection

☞ The parameters for "...assignment A..." act on the analog outputs 1, 3 and 5.

The parameters for "...assignment B..." act on the analog outputs 2, 4 and 6.

Via the parameters it is possible to determine, separately for each output channel, the reference definition (P-0-0418, P-0-0419) and the scaling (P-0-0422, P-0-0425) 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, assignment A, scaling [1/V]
- P-0-0425, Analog output, assignment B, scaling [1/V]

☞ The output voltage is 1 V 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, assignment A, signal value at 0V
- P-0-0419, Analog output, assignment B, 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

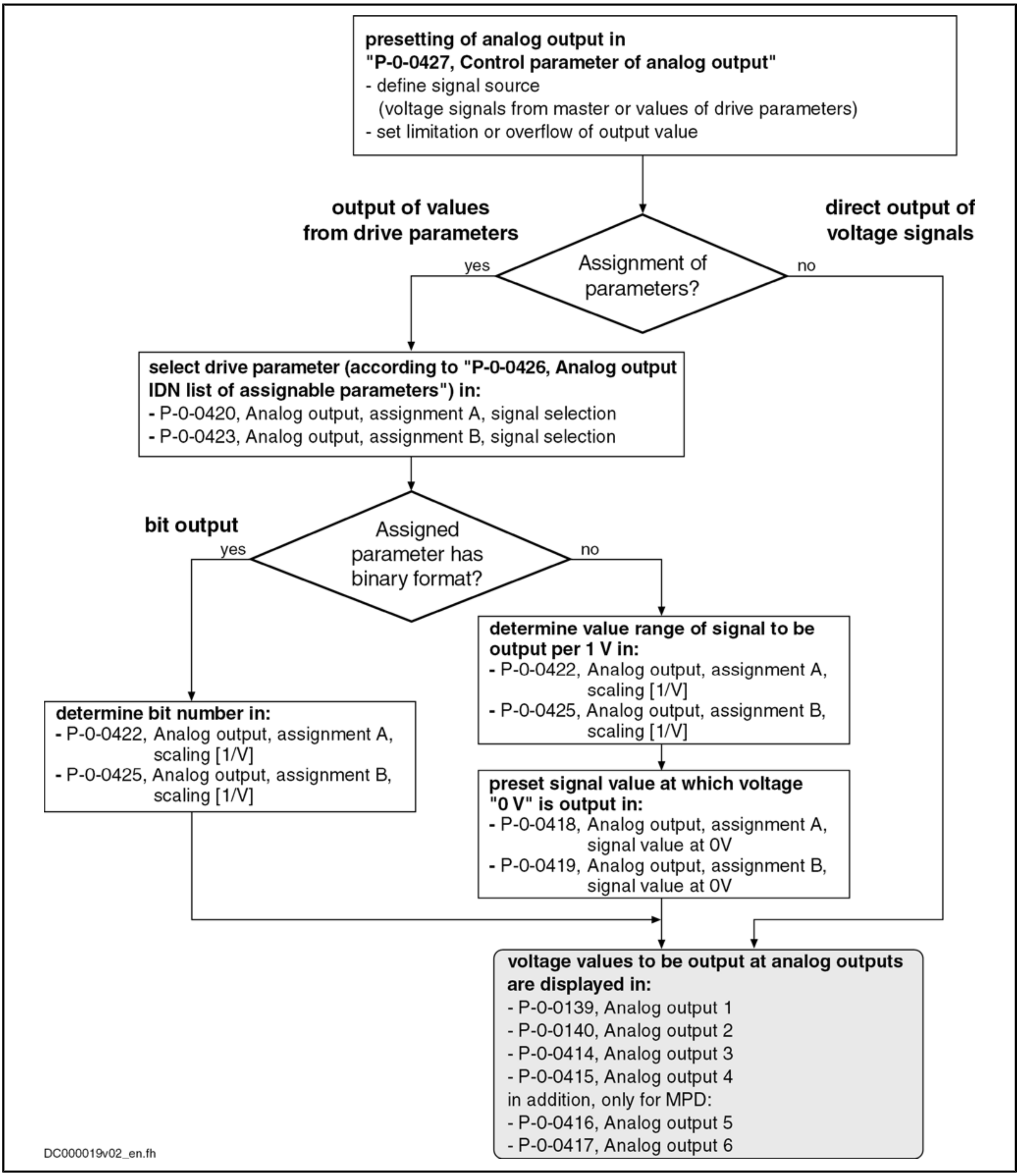


Fig.9-51: Commissioning the Analog Outputs

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, assignment A, scaling [1/V]
- P-0-0425, Analog output, assignment B, scaling [1/V]

Example of "Scaleable" Output

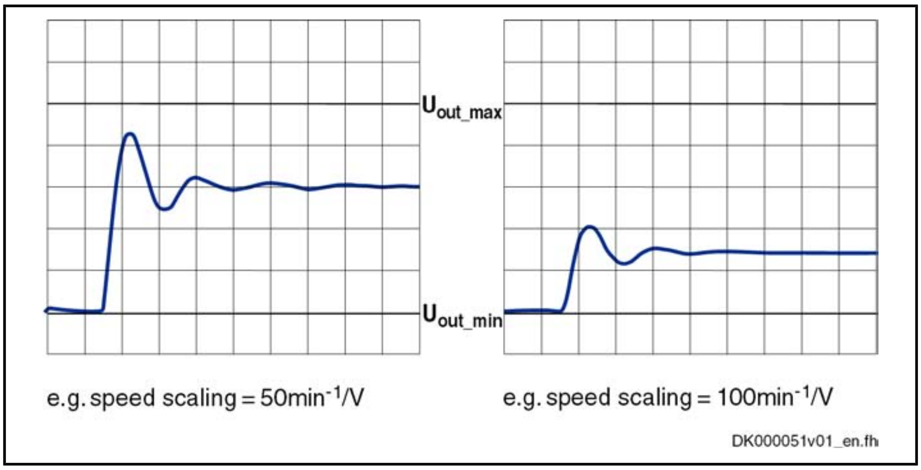


Fig.9-52: Example of Scaleable Analog Output

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, assignment A, signal value at 0V
- P-0-0419, Analog output, assignment B, signal value at 0V

☞ The parameters for "...assignment A..." act on the analog outputs 1, 3 and 5.

The parameters for "...assignment B..." act on the analog outputs 2, 4 and 6.

Example of "Reference-Defined" Output for Analog Output 1 and 2

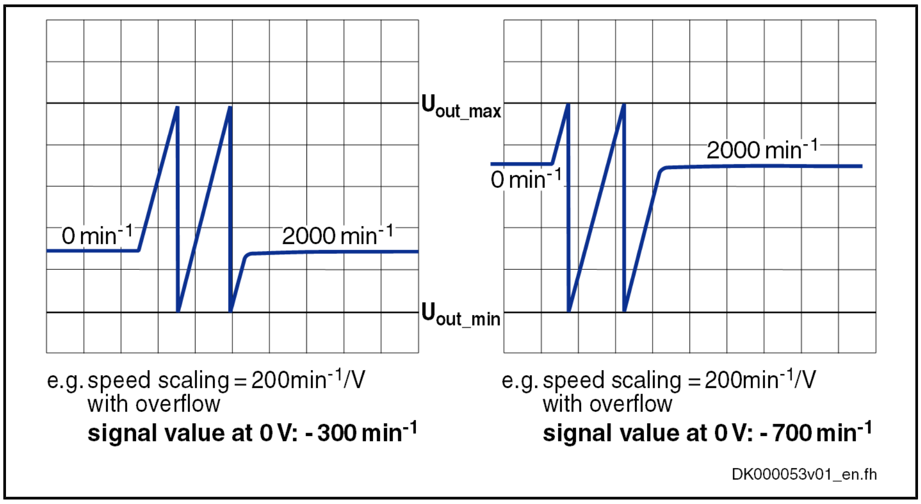


Fig.9-53: Example of Reference-Defined Analog Output

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

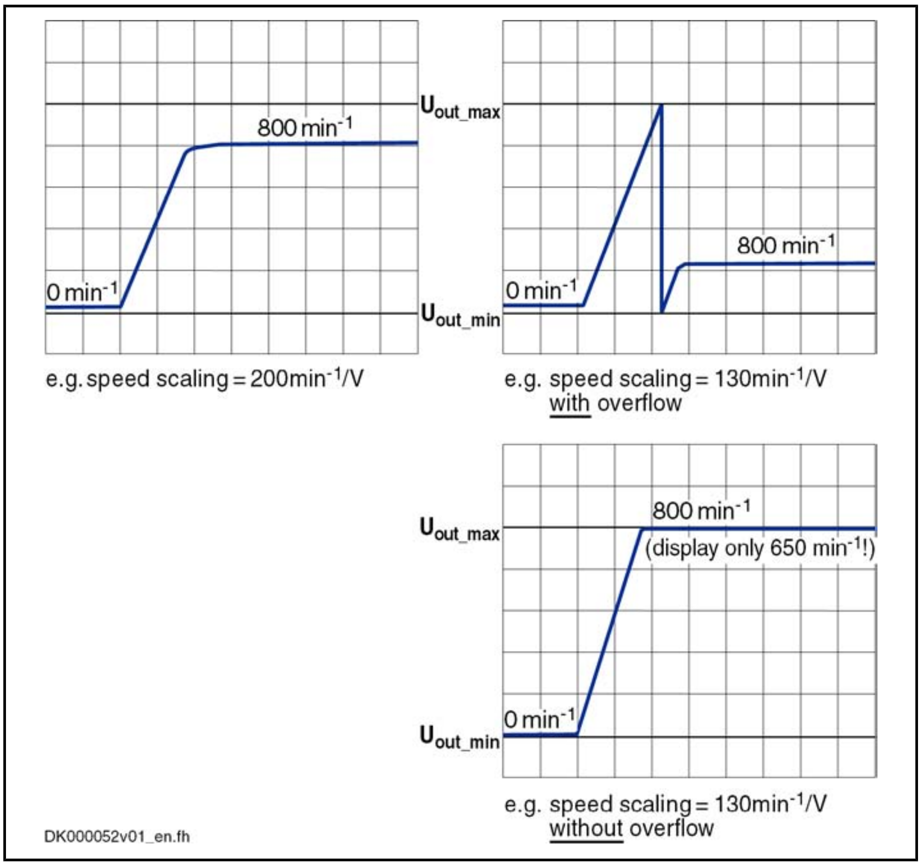


Fig.9-54: Example of Limited or "Overflowing" Analog Output

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 Virtual Master Axis Generator

9.7.1 Brief Description

Expansion package **synchronization** (order code **SNC**) of variants **MPH, MPB and MPD** in **closed-loop and open-loop** characteristic

Fig.9-55: Assignment to Functional Firmware Package

The master axis generator serves for generating a master axis position, which is used as input variable for the position synchronization operation modes and the operation mode "velocity synchronization".

There are two 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]**
- Generating a virtual actual position value via a positioning motion and subsequent format conversion **[2]**

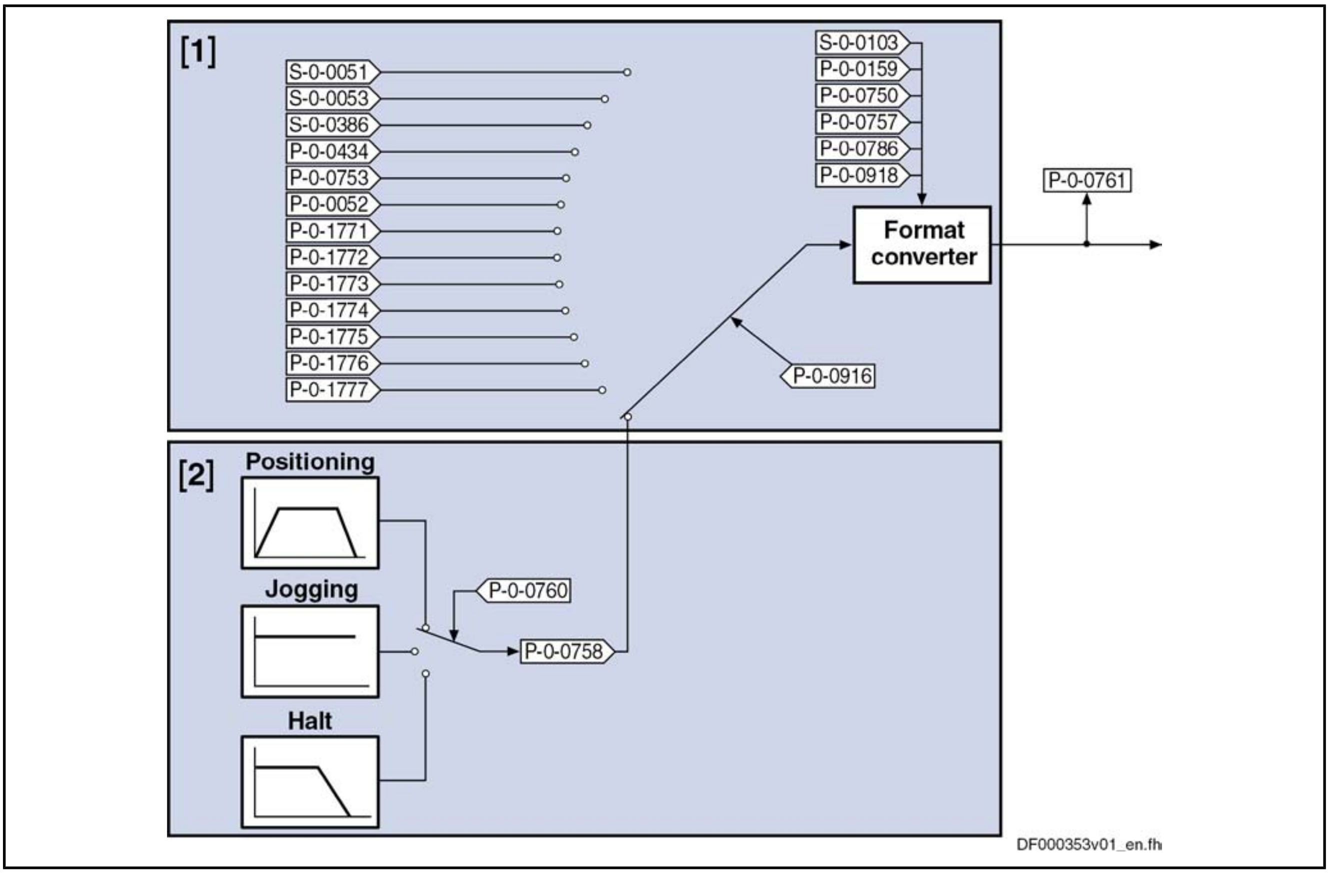


Fig.9-56: Possibilities of Generating the Master Axis Position for the Slave Axis

Features Features of generating the virtual actual position value with the master axis generator:

- 2nd order command value interpolator with subsequent jerk limitation
- 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^{20} × P-0-0750)
- 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 must behave exactly like those for a real axis. The diagnostic and error messages, however, are different.

Pertinent Parameters

- 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-0-0766, 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-0-0774, 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-0-0917, Control word of master axis generator

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

9.7.2 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 generating the virtual actual position value with the virtual master axis generator and the effect of the individual parameters.

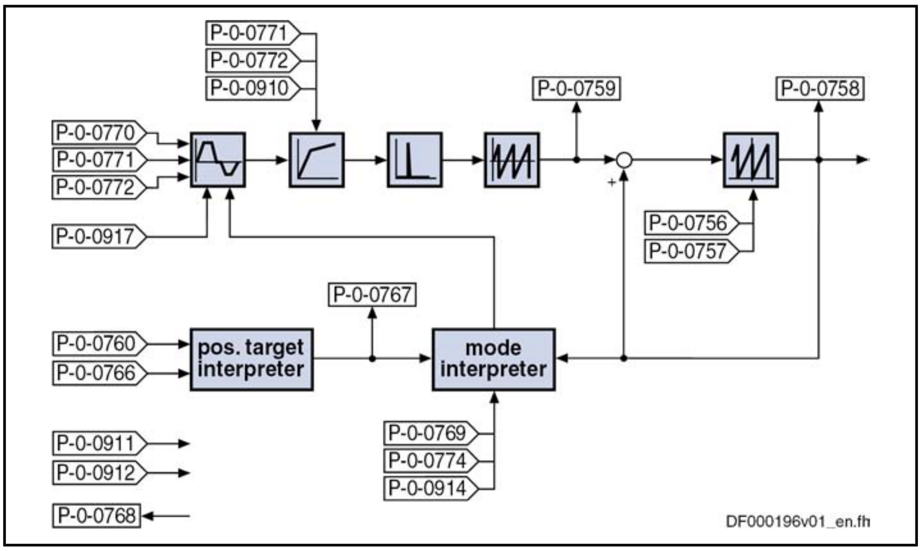


Fig.9-57: Overview of Function "Virtual Master Axis Generator"

Positioning by means of the virtual master axis generator basically functions in the same way as for the positioning generator of the "drive-controlled positioning" mode (see description of the operating 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	P-0-0774
Effective target position	S-0-0430	P-0-0767
Velocity threshold	S-0-0417	P-0-0914

Fig.9-58: Parameter Comparison

Differences to operating mode "drive-controlled positioning"

"Jog" Mode When the "jog" mode is activated, the following values are applied:

- Positioning command value
- Positioning velocity
- Positioning acceleration
- Positioning deceleration
- Positioning jerk

Afterwards, a new positioning velocity is immediately applied with active "jog" mode.

Via the toggle bit (P-0-0760, bit 0), new values for positioning acceleration, positioning deceleration and positioning jerk can be accepted. Acknowledgment of command value acceptance, if accepted via toggle bit, can be taken from parameter "P-0-0768, Virtual master axis, positioning status" (bit 1).

"Halt" Mode When the "halt" mode is activated, the positioning deceleration and positioning jerk are accepted.

Via the toggle bit (P-0-0760, bit 0), new values for positioning deceleration and positioning jerk can be accepted. Acknowledgment of command value acceptance, if accepted via toggle bit, can be taken from parameter "P-0-0768, Virtual master axis, positioning status" (bit 1).

Processing Clock The generator function of the master axis generator runs in a clock of 2 ms. The calculated values are fine interpolated in linear form with regard to the position loop 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 (2^{20} 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: 0.0001 mm / 0.0001 inch
  - 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 to 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 have to be converted to the master axis format (2^{20} increments per master axis revolution).

☞ 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 are relevant in conjunction with the format converter function:

- S-0-0103, Modulo value
- 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-0-0786, 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-0-0918, Feed travel internal virtual master axis

Pertinent Diagnostic Messages

The following diagnostic message is relevant in conjunction with the format converter function:

- C0218 Double signal selection master axis format converter

Signal Sources

The format converter can process the values of the following signal sources:

- S-0-0051, Position feedback 1 value
- S-0-0053, Position feedback 2 value
- S-0-0386, Active position feedback value
- P-0-0052, Actual position value of measuring encoder
- P-0-0434, Position command value of controller
- P-0-0753, Position actual value in actual value cycle
- P-0-0758, Virtual master axis, actual position value
- P-0-1771, CCD: AT real-time container 1, slave 1

  - to -

  P-0-1777, CCD: AT real-time container 1, slave 7

Conversion

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:

- **Signal source S-0-0051, S-0-0053 or S-0-0386**

$$\text{P-0-0761} = \frac{\text{S-0-0051}}{\text{S-0-0103}} \times \text{P-0-0750} \times 2^{20}$$

$$\text{P-0-0761} = \frac{\text{S-0-0053}}{\text{S-0-0103}} \times \text{P-0-0750} \times 2^{20}$$

$$\text{P-0-0761} = \frac{\text{S-0-0386}}{\text{S-0-0103}} \times \text{P-0-0750} \times 2^{20}$$

Fig.9-59: Rotary/Linear Modulo Scaling of the Signal Source

$$\text{P-0-0761} = \frac{\text{S-0-0051}}{360°} \times 2^{20}$$

$$\text{P-0-0761} = \frac{\text{S-0-0053}}{360°} \times 2^{20}$$

$$\text{P-0-0761} = \frac{\text{S-0-0386}}{360°} \times 2^{20}$$

Fig.9-60: Rotary Absolute Scaling of the Signal Source

$$\text{P-0-0761} = \frac{\text{S-0-0051}}{\text{S-0-0159}} \times 2^{20}$$

$$\text{P-0-0761} = \frac{\text{S-0-0053}}{\text{S-0-0159}} \times 2^{20}$$

$$\text{P-0-0761} = \frac{\text{S-0-0386}}{\text{S-0-0159}} \times 2^{20}$$

Fig.9-61: Linear Absolute Scaling of the Signal Source

- **Signal source P-0-0052**

$$\text{P-0-0761} = \text{P-0-0052}$$

Fig.9-62: For all Scalings of the Signal Source

- **Signal source P-0-0434 (special case)**

$$\text{P-0-0761} = \frac{\text{P-0-0434}}{360°} \times 2^{20}$$

Fig.9-63: Rotary Absolute Scaling

$$\text{P-0-0761} = \frac{\text{P-0-0434}}{\text{P-0-0159}} \times 2^{20}$$

Fig.9-64: Linear Absolute Scaling

$$\text{P-0-0761} = \frac{\text{P-0-0434}}{\text{S-0-0103}} \times \text{P-0-0750} \times 2^{20}$$

Fig.9-65: Rotary/Linear Modulo Scaling and no Synchronous Position Control Mode Active

$$\text{P-0-0761} = \frac{\text{P-0-0434}}{\text{P-0-0786}} \times \text{P-0-0750} \times 2^{20}$$

Fig.9-66: Rotary/Linear Modulo Scaling and a Synchronous Position Control Mode Active

- **Signal source P-0-0753**

$$\text{P-0-0761} = \frac{\text{P-0-0753}}{\text{P-0-0786}} \times \text{P-0-0750} \times 2^{20}$$

Fig.9-67: Rotary/Linear Modulo Scaling of the Signal Source

$$\text{P-0-0761} = \frac{\text{P-0-0753}}{360°} \times 2^{20}$$

Fig.9-68: Rotary Absolute Scaling of the Signal Source

$$\text{P-0-0761} = \frac{\text{P-0-0753}}{\text{P-0-0159}} \times 2^{20}$$

Fig.9-69: Linear Absolute Scaling of the Signal Source

- **Signal source P-0-0758**

$$\text{P-0-0761} = \frac{\text{P-0-0758}}{\text{P-0-0757}} \times \text{P-0-0750} \times 2^{20}$$

Fig.9-70: 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.9-71: 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.

$$\text{P-0-0761} = \frac{\text{P-0-0758}}{\text{P-0-0918}} \times 2^{20}$$

Fig.9-72: Absolute Scaling of the Position Data Master Axis Generator

- **Signal sources P-0-1771 to P-0-1777**

$$\text{P-0-0761} = \text{P-0-177x}$$

x Selected parameter from range P-0-1771 to P-0-1777

Fig.9-73: For all Scalings of the Signal Source

9.8 Drive-Integrated Command Value Generator

9.8.1 Brief Description

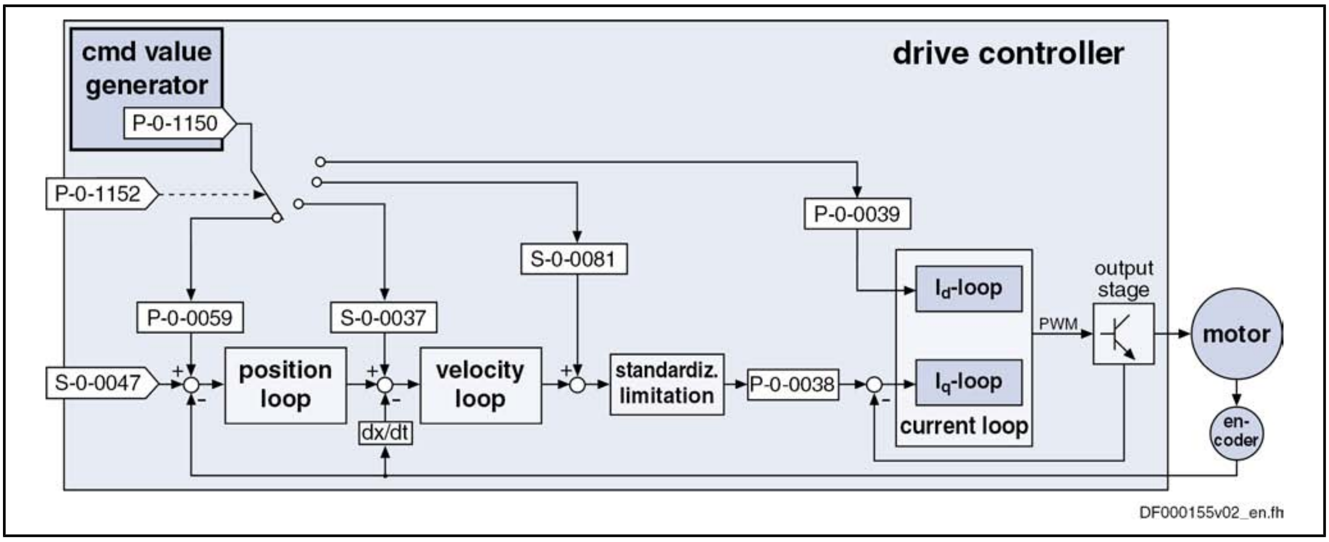
Base package of variants **MPH, MPB and MPD** in **open-loop and closed-loop** characteristic

Fig.9-74: Assignment to functional firmware package

The drive-integrated command value generator can be used for commissioning and controller optimization of drives. The command value generator generates the command values required for the active operating mode in different shapes (square-wave, sine, noise); these command values are added to the main command value in the closed control loop.

☞ In conjunction with the integrated oscilloscope function and an additional FFT calculation, 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.9-75: Points at which function "command value generator" can take effect

Features

- Possibility of generating different signal shapes that are added 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**
- Generating **velocity and position command values** in the position loop clock; **current command values** in the velocity loop clock
- With regard to **amplitude and frequency**, generated command values can be freely defined

☞ The drive-integrated PLC (IndraMotion MLD) provides further possibilities of generating command values, but it can generate command values with a clock rate of 1 ms.

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-0-0028, Oscilloscope: Control word

- P-0-0031, Oscilloscope: Time resolution
- P-0-0032, Oscilloscope: Size of memory

9.8.2 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 loop 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 command values take effect, the operating mode has to be selected and drive enable (bit "drive on" = 1) has to be set.

This can be done in the following ways:

- Via a digital input
- Via the serial interface in "easy startup" mode
- Via the master communication
- Via the drive-integrated PLC (IndraMotion MLD)

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-0-0036, Velocity command value
- S-0-0037, Additive velocity command value
- S-0-0080, Torque/force 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.

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 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

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**

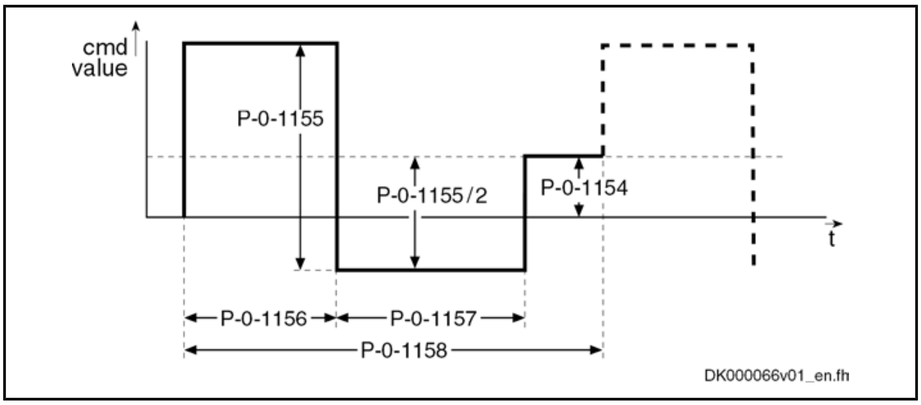
  → Drive enable can be set with a delay, i.e. adjusted to the signal period

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
- Direct component (DC offset; positive/negative)
- Pulse/pause relationship

The exemplary figure below illustrates the output signal of the pulse generator with the possibilities of influencing:



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.9-76: 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.

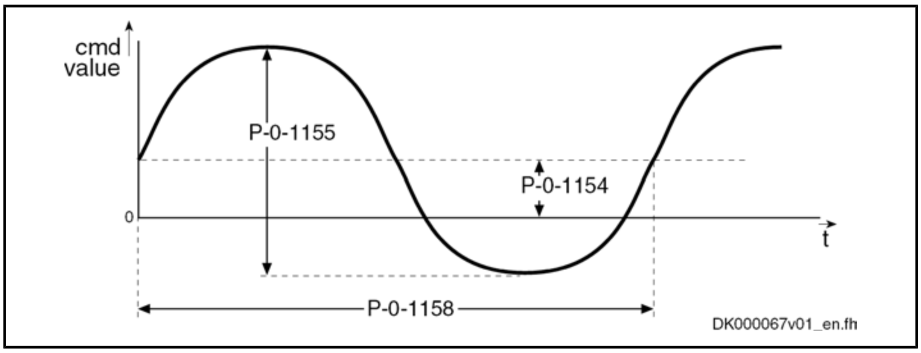
In the case of P-0-1158 = (P-0-1156) + (P-0-1157), there is a periodic square-wave signal resulting, if the periodic output has additionally been activated in the control word.

Sine Generator

A sine generator is available for checking the bandwidth; its output signal can be varied in the following properties:

- Frequency or periodic time of the signal
- Amplitude
- Direct component (DC offset; positive/negative)

The exemplary figure below illustrates the output signal of the sine generator with the possibilities of influencing:



P-0-1154 Command value generator, offset
P-0-1155 Command value generator, amplitude
P-0-1158 Command value generator, periodic time
Fig.9-77: 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

In many cases it is important that the sine signal contains no direct component. In parameter "P-0-1153, Command value generator, control word", it is possible to set that switching off the command value generator is delayed until the period is complete.

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 pulsed quantities there are the following possibilities:

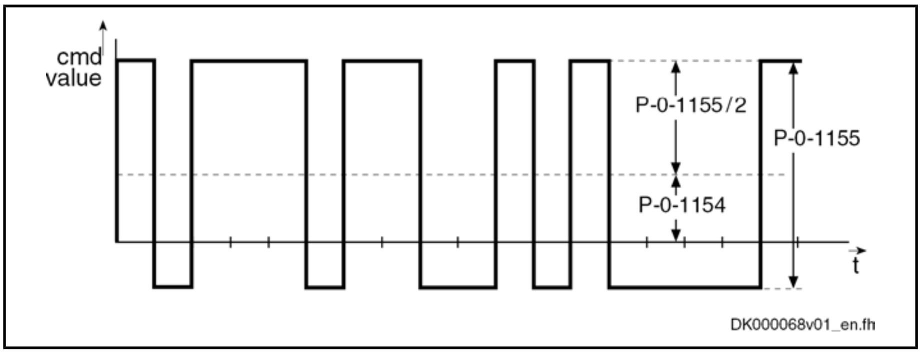
- Noise signal as square-wave signal with parameterizable amplitude and, if necessary, offset component

→ Amplitude is set positive or negative 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 possibilities of influencing:



P-0-1154 Command value generator, offset
P-0-1155 Command value generator, amplitude
Fig.9-78: Output signal of noise generator

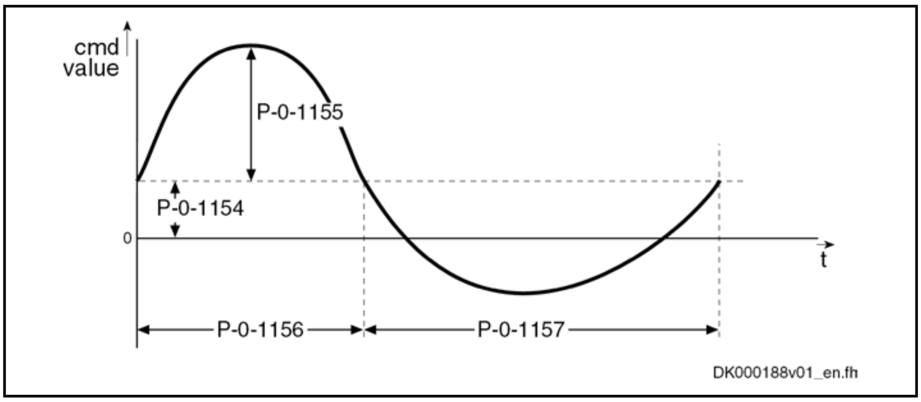
☞ For an FFT calculation, P-0-1154 = 0 has to be set!

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
- Direct component (DC offset; positive/negative)

The exemplary figure below illustrates the modifiable output signal of the sine generator with the possibilities of influencing:



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.9-79: Output signal of noise generator

9.8.3 Notes on Commissioning

Bandwidth and Frequency Response Measurement

Frequency response measurement always requires accordingly wide-band excitation that is made available by the noise generator. In addition to the generation of the noise 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 periodic time of the noise signal to the recording duration of the oscilloscope function.

The periodic time of the noise signal results from the following relationship:

$$T_R = \text{P-0-0031} \times \text{P-0-0032}$$

T_R periodic time of noise signal
P-0-0031 Oscilloscope: Time resolution
P-0-0032 Oscilloscope: Size of memory
Fig.9-80: Calculating the periodic time of the noise signal

☞ The actual calculation or determination of the frequency response is carried out by means of a technology function for IndraMotion MLD or with the service tool "IndraWorks D".

The overview below illustrates the possible excitation signals and measuring signals for the recording:

Control loop	Command value generator excitation signal	Generator clock frequency		Measuring signals of oscilloscope function
		Basic	Adv.	
torque	additive torque/force cmd value (S-0-0081)	4 kHz	8 kHz	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)	4 kHz	8 kHz	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)	4 kHz	8 kHz	flux-generating current, cmd value (P-0-0039) flux-generating current, actual value (P-0-0044)
velocity	additive velocity command value (S-0-0037)	2 kHz	4 kHz	effective velocity command value (P-0-0048) velocity feedback value (S-0-0040)
position	additive position cmd val., controller (P-0-0059)	2 kHz	4 kHz	position command value controller (P-0-0434) position feedback 1 value (S-0-0051) or position feedback 2 value (S-0-0053)

Fig.9-81: Signals for excitation and recording

The following has to be observed for parameterization:

- The bandwidth of the excitation signal depends on the clock frequency that differs according to the kind of signal and the available control performance (clock frequency).

Note: The bandwidth of the "white noise" is limited to a maximum of half the clock frequency!

- The size of memory for the oscilloscope function has to be 4095 values (P-0-0032 = 4095) so that the necessary condition

  "periodic time of noise signal = recording time of oscilloscope"

  is fulfilled and 4095 values can be recorded.

  Note: The periodic time and clock frequency depend on the kind of signal (current, position, velocity) and performance.

- The periodic time depends on the excitation signal:
  - **Position and velocity excitation**

    → With excitation via the parameters S-0-0036, S-0-0037 or P-0-0059, the resulting periodic time is T = 2.0475s (Basic) or T = 1.02375s (Advanced).
  - **Current excitation**

    → With excitation via the parameters S-0-0081 or P-0-0039, the resulting periodic time is T = 1.02375s (Basic) or T = 0.511875s (Advanced).

Control Loop 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 Loop

The field-oriented current controller that takes effect in closed-loop operation, 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 loop for the torque-generating current control loop, the excitation has to be carried out 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 loop for the flux-generating current, the excitation has to be carried out 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.

☞ If current command values are generated, it is necessary to activate the so-called expert mode (P-0-0028, bit 4 = 1) for the recording with the oscilloscope function, in order to adjust the sampling frequency to the excitation frequency.

Velocity Loop

To evaluate the velocity loop, the excitation has to be carried out 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.

☞ For the output of velocity command values the command value generator takes effect in every position loop cycle (0.250 or 0.500 ms).

Position Loop

To examine the position loop the drive has to be in one of the operating modes "position control with cyclic command value input", "drive-internal interpolation", "drive-controlled positioning" or in the status "Drive Halt".

Under this condition, the excitation via parameter "P-0-0059, Additive position command value, controller" can take place directly for the position loop and the parameters "P-0-0434, Position command value of controller" and "S-0-0051, Position feedback 1 value" or "S-0-0053, Position feedback 2 value" have to be recorded with the oscilloscope function.

9.9 Encoder Emulation

9.9.1 Brief Description

Base package of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.9-82: Assignment to Functional Firmware Package

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:

- **5V-TTL signal of an incremental encoder** with incremental encoder emulation (track A, track B and zero pulse)
- **Serial 24-bit position of an absolute encoder** (SSI format) with absolute encoder emulation

This allows, for example, evaluating the signals in a higher-level master in order to close the position 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, Bosch Rexroth recommends to use digital interfaces, such as SERCOS interface.

See "Restrictions" in section "Notes on Commissioning"

Incremental Encoder Emulation

Incremental encoder emulation is the simulation of a real incremental encoder by the drive controller.

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 (cf. S-0-0076) or encoder-related form; the resolution is input in lines (1 line corresponding to 4 increments) or in mm/inch.

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 (cf. S-0-0076) and the resolution is input is bits.

Features

- Cyclic calculation of the position or increments output by the emulator in the position loop clock (see "Performance Data")
- Freely selectable position signals for emulation (P-0-0900, P-0-0901)
- Resolution that can be parameterized (incremental encoder emulation in lines/revolution; absolute encoder emulation in bits/revolution)
- Scaling-related emulation (SSI and incremental) → S-0-0076
- Encoder-related emulation (incremental)
- Synchronization of SSI emulation to SSI clock can be activated
- Dead-time compensation that can be activated for incremental encoder emulation (P-0-0902, bit 3)
- Zero pulse that can be shifted for incremental encoder emulation (P-0-0904)
- Parameterizable cyclic zero pulse output for incremental encoder emulation referring to zero pulse distance (P-0-0904) and position data reference (P-0-0902)
- Incremental encoder emulation can be switched off in operation (→ pause)
- Internal clock increase of incremental encoder emulation to reduce zero pulse jitter and frequency jitter (not for BASIC ANALOG control sections)
- Signal-related or motor-encoder-related emulation to be freely selected (→ influence on position of zero pulse!)

Hardware Requirements

The firmware encoder emulation function requires the following control section design:

- Single-axis BASIC ANALOG (not configurable) (CSB01.1N-AN)

In addition, it is possible to use the following **configurable control sections**, if they have been designed with the optional module for encoder emulation (MEM):

- Single-axis ADVANCED (CSH01.1C)
- Single-axis BASIC UNIVERSAL (CSB01.1C)
- Double-axis BASIC UNIVERSAL (CDB01.1C)

☞ Encoder emulation is always related to the device, i.e. with a double-axis device (CDB01.1C) emulation can only be used for one of the two axes at a time.

Pertinent Parameters

- P-0-0900, Encoder emulation signal selection list
- P-0-0901, Encoder emulation signal selection
- P-0-0902, Encoder emulation control parameter
- P-0-0903, Encoder emulation resolution
- P-0-0904, Encoder emulation zero pulse offset
- P-0-0905, Encoder emulation zero pulse distance

Pertinent Diagnostic Messages

- C0242 Multiple configuration of a parameter (->S-0-0022)
- C0260 Incremental enc. emulator resol. cannot be displayed
- F2053 Incr. encoder emulator: pulse frequency too high
- F2054 Incr. encoder emulator: hardware fault

9.9.2 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-0-0902, Encoder emulation control parameter".

The following settings can be selected via parameter P-0-0902:

- No encoder emulation activated
- Incremental encoder emulation (IGS) activated
- Absolute encoder emulation (SSI) activated

☞ The settings in parameter P-0-0902 only take effect after progression to the operating mode!

ℹ See also Parameter Description "P-0-0902, Encoder emulation control parameter"

Selecting the Signal to be Emulated

Supported Emulation Signals

The input of the signals that the drive supports for emulation is depending on the following factors:

- Firmware version and enabled functional packages
- Hardware of the control section and its configuration

☞ The emulation signals currently supported by the drive are contained in the list parameter "P-0-0900, Encoder emulation signal selection list".

Determining the Kind of Emulation

In bit 12 of "P-0-0902, 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 (see below).

Selecting the Emulation Signal

If bit 12 = 0 in parameter P-0-0902, the emulation signal is determined by inputting the desired IDN from the list parameter P-0-0900 in parameter "P-0-0901, Encoder emulation signal selection".

☞ The resolution of the emulated signal is determined for both kinds of emulation (SSI and IGS) in parameter "P-0-0903, Encoder emulation resolution".

9.9.3 Incremental Encoder Emulation

General Information

The incremental encoder emulation provides a square-wave signal in TTL level with variable frequency. The position difference of the selected signal in the last position loop clock (see "Performance Data") is calculated. The number of lines to be output and therefore the periodic time of the square-wave signal for the next output interval is calculated depending on the input in parameter "P-0-0903, Encoder emulation resolution".

Incremental Encoder Signals in TTL Format

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), also 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-0-0905 and P-0-0904)!

The figure below illustrates the format and time flow of the incremental encoder signals:

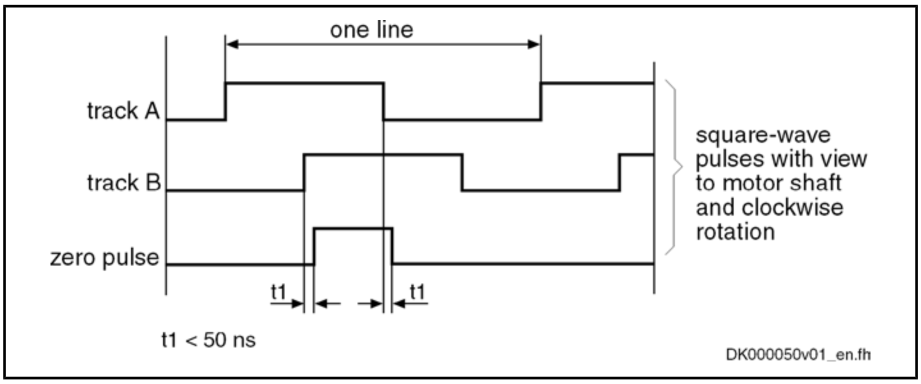


Fig.9-83: Time Flow of the Incremental Encoder Signals

Resolution and Unit of the Emulated Signal

Resolution

The number of increments of the emulated incremental encoder can be determined in parameter "P-0-0903, Encoder emulation resolution" in lines/revolution (or mm or inch for linear motors).

Unit of the Emulated Position

The input range and the unit of the value in parameter P-0-0903 depend on the following settings:

- Type of construction of motor
  - Rotary motors → lines/revolution
  - Linear motors → mm or inch
- Parameterized scaling (cf. "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-0-0905, Encoder emulation zero pulse distance".

Zero Pulse Offset

With the parameter "P-0-0904, 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-0-0904 is determined by the setting in parameter "P-0-0903, 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-0-0905, Encoder emulation zero pulse distance".

The following applies to the zero pulse output:

- Parameter setting **P-0-0905 = P-0-0903** (standard case!)

  → **One zero pulse per revolution** (or per mm) is generated.
- Parameter setting **1 < P-0-0905 < P-0-0903** (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-0-0905 = ½ × P-0-0903).

☞ 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 loop clock)!

- Parameter setting **P-0-0905 = n × P-0-0903**

  → **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-0-0905 is not allowed!

Kind of Emulation

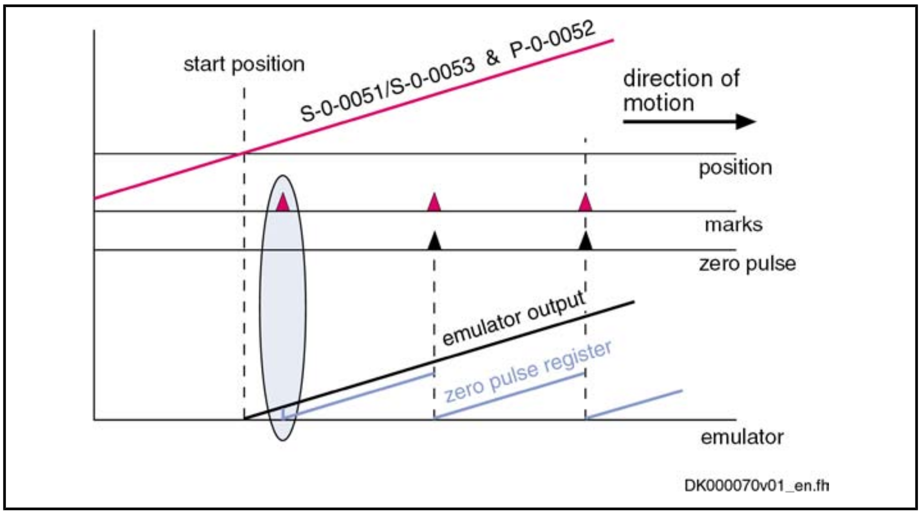
According to the kind of emulation, the zero pulse is emulated with relation to encoder mark or with relation to signal. The kind of emulation is selected in bit 12 of "P-0-0902, Encoder emulation control parameter".

Emulation With Relation to Motor Encoder (P-0-0902, 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 (cf. S-0-0403), zero pulses are generated without reference to the machine zero point existing!



S-0-0051 Position feedback 1 value
S-0-0053 Position feedback 2 value
P-0-0052 Actual position value of measuring encoder
Fig.9-84: Zero Pulse Generation for Incremental Measuring System and Motor Encoder Relation (P-0-0902, Bit 12 = 1)

Emulation With Relation to Signal (P-0-0902, Bit 12 = 0)

In the case of emulation with relation to the signal, 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-0-0905, Encoder emulation zero pulse distance".
- Via parameter "P-0-0904, Encoder emulation zero pulse offset", the emulated coordinate system can be shifted.

☞ The zero pulse is only output when the drive has been homed (cf. 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, Encoder emulation signal selection" are divided into two groups:

- **Emulation of actual values**

  → For the output of zero pulses, "reference" (cf. 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:

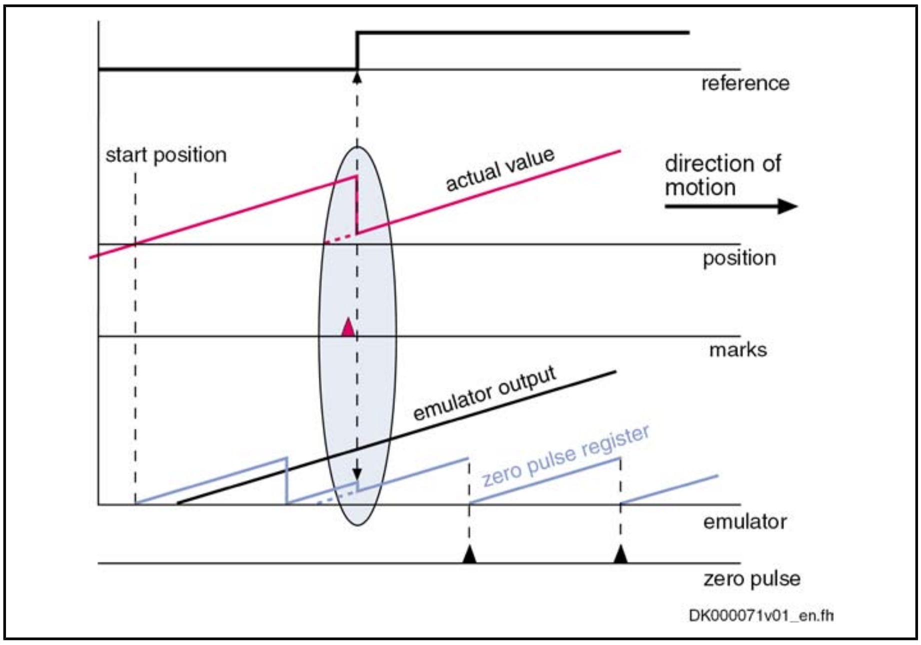
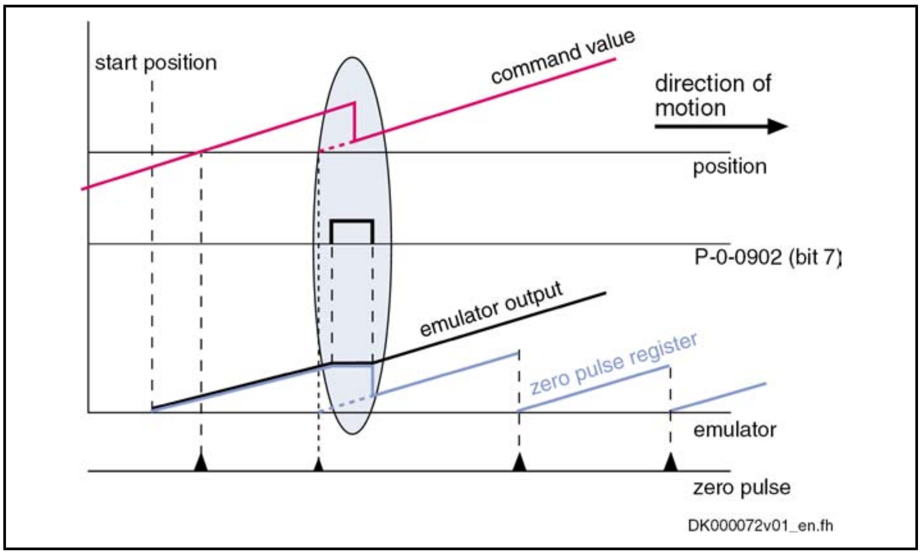


Fig.9-85: Zero Pulse Generation for Incremental Measuring System and Signal Relation (P-0-0902, Bit 12 = 0) With Actual Value Signals

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 (cf. P-0-0902, 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-0-0902 Encoder emulation control parameter

Fig.9-86: Zero Pulse Generation for Incremental Measuring System and Signal Relation (P-0-0902, Bit 12 = 0) With a Command Value Jump

Establishing the Position Data Reference (Drive-Controlled Homing)

For emulating actual values with relation to signal (P-0-0902, bit 12 = 0) and using incremental measuring systems, the drive must have been homed in order 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. **The error message "F2053" in this case is suppressed on purpose.**

See also "Establishing Position Data Reference for Relative Measuring Systems"

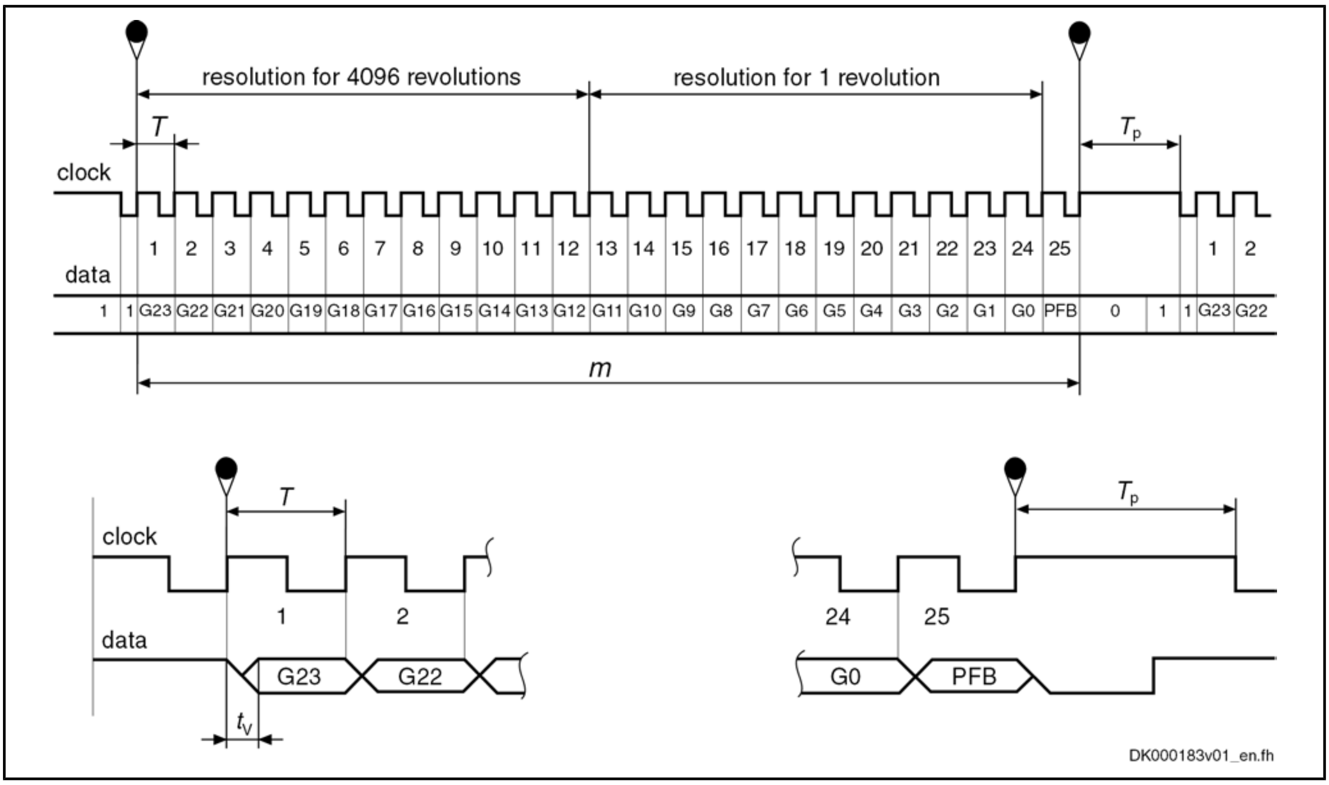
9.9.4 Absolute Encoder Emulation

General Information

The absolute encoder emulation provides a digital, coded, absolute position signal which in the position loop clock (see "Performance Data") can be serially read. 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-0-0903, 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.9-87: 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-0-0903, Encoder emulation resolution".

Unit of the Emulated Position The input range and the unit of the value in parameter P-0-0903 depend on:

- Type of construction of motor:
  - Rotary motors → bits/revolution
  - Linear motors → bits/mm or bits/inch
- Parameterized scaling (cf. "S-0-0076, Position data scaling type")

> ☞ The emulated digital position value is always displayed with 24 bits, the setting in P-0-0903 defining the resolution of one revolution (= decimal place). With P-0-0903 = 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 1 value", "position feedback 2 value" and "position command value" depends on the scaling determined in parameter "S-0-0076, Position data scaling type".

The values of the emulator and the parameters "S-0-0051, Position feedback 1 value", "S-0-0053, Position feedback 2 value" or "S-0-0047, Position command value" are synchronous. This simplifies, among other things, emulation control, e.g. with the commissioning tool "IndraWorks D".

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 Measuring)

Using parameter "P-0-0012, C0300 Command Set absolute measuring", it is possible to home the absolute position that is output by the absolute encoder emulator. When setting absolute measuring, the value of parameter "S-0-0052, Reference distance 1" is processed.

See also "Establishing Position Data Reference for Absolute Measuring Systems"

9.9.5 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 drops, 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.

Restrictions 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 Incremental encoder emulator: 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} depends on the hardware design and is reduced as the clock increase is increased (cf. P-0-0902):

- Clock increase of 8 → f_{max} = 1 MHz
- Clock increase of 16 → f_{max} = 500 KHz
- Clock increase of 32 → f_{max} = 250 KHz

The maximum possible resolution of encoder emulation is scaling-dependent and calculated according to the following formulas:

$$\text{Linear scaling} \quad (\text{P-0-0903})_{max} = \frac{v_{max}}{f_{max}}$$

$$\text{Rotary scaling} \quad (\text{P-0-0903})_{max} = \frac{f_{max}}{v_{max}}$$

P-0-0903 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.9-88: 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 (cf. P-0-0902, bits 0 and 1), it is possible to activate dead time compensation in "P-0-0902, Encoder emulation control parameter" with bit 3 = 1. The 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 so that as many lines as possible can be 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 (cf. P-0-0902, bits 8 and 9). By default, the clock increase has been set to factor 8. If required, it can be increased up to factor 32 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 varying. 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**.

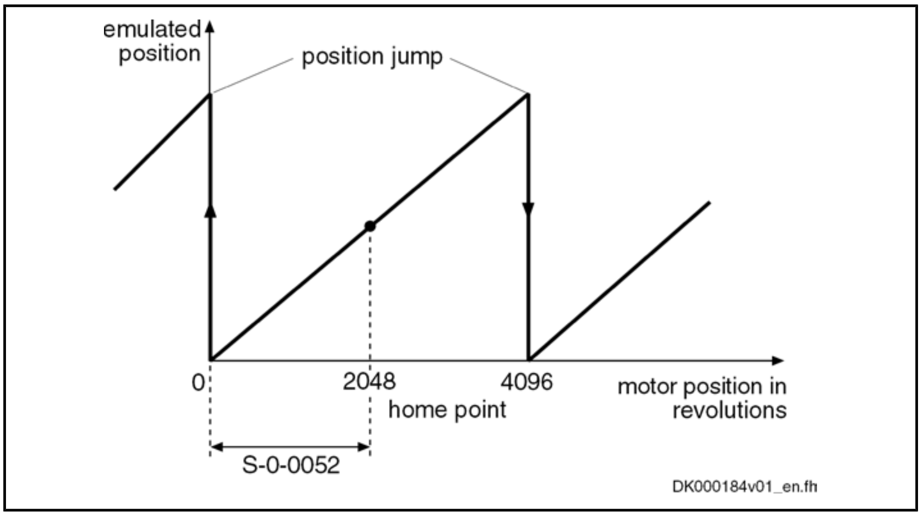
Restrictions of Absolute Encoder Emulation

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.9-89: Display Limits With Absolute Encoder Emulation

This effect can be avoided by shifting the home point by executing "P-0-0012, C0300 Command Set absolute measuring".

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.9-90: Determining the Periodic Time

This beat effect can be avoided by synchronizing the adjustment of the SSI emulation data in the drive to the SSI clock of the external control unit. The mechanism required for this purpose has to be activated via bit 10 of "P-0-0902, Encoder emulation control parameter".

☞ Synchronization only works correctly, when the "sampling rate" of the external control unit is lower than the internal position loop clock which depends on the performance of the firmware variant used!

See "Performance Data"

☞ You have to observe that the probe function (MT1) is occupied for this synchronization process and therefore no longer available for other purposes!

9.9.6 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-0-0903) and the travel velocity exceeds the value of the maximum pulse frequency of 1024 kHz.
- **F2054 Incr. encoder emulator: hardware fault**

  → At the end of each output interval (= position loop 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 run time 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-0-0903 has to be parameterized accordingly.
- **C0242 Multiple configuration of a parameter (->S-0-0022)**

  → For incremental encoder emulation in a double-axis device, it is not allowed to activate the emulator in both axes.

9.10 Programmable Position Switch

9.10.1 Brief Description

Expansion package **servo function** (order code **SRV**) of variants **MPH, MPB and MPD** in **closed-loop** characteristic

Fig.9-91: Assignment to functional firmware package

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 loop 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

☞ "Programmable position switch" is a device function and therefore only available once for double-axis devices!

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-0-0022)

9.10.2 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.

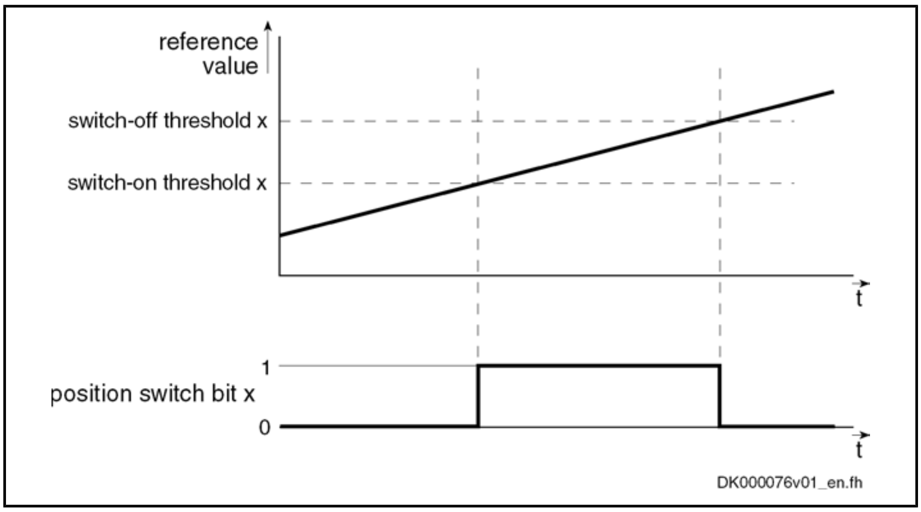


Fig.9-92: General functional principle of the programmable position switch

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

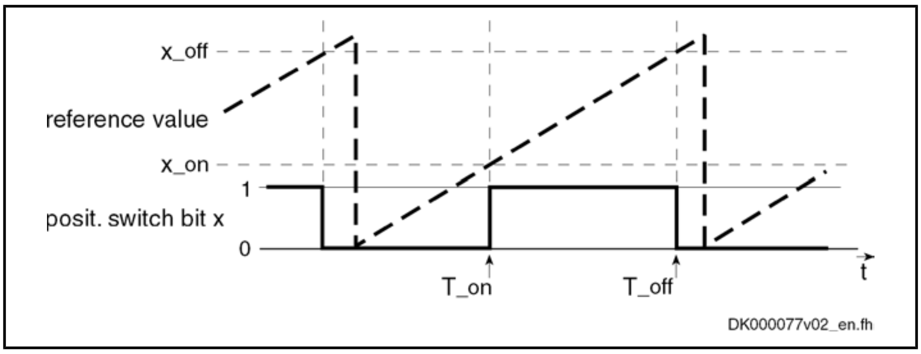
Switch-On Threshold Smaller than Switch-Off Threshold

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.9-93: Position switch bit with "switch-on threshold < switch-off threshold" (P-0-0132 [i] < P-0-0133 [i])

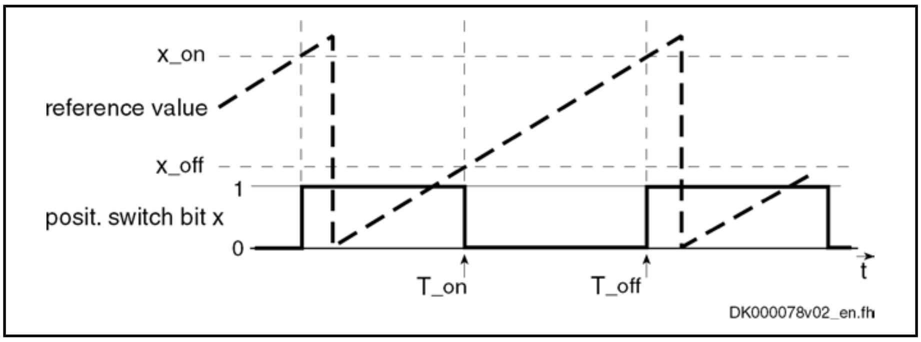
Switch-On Threshold Greater than Switch-Off Threshold

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.9-94: 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.

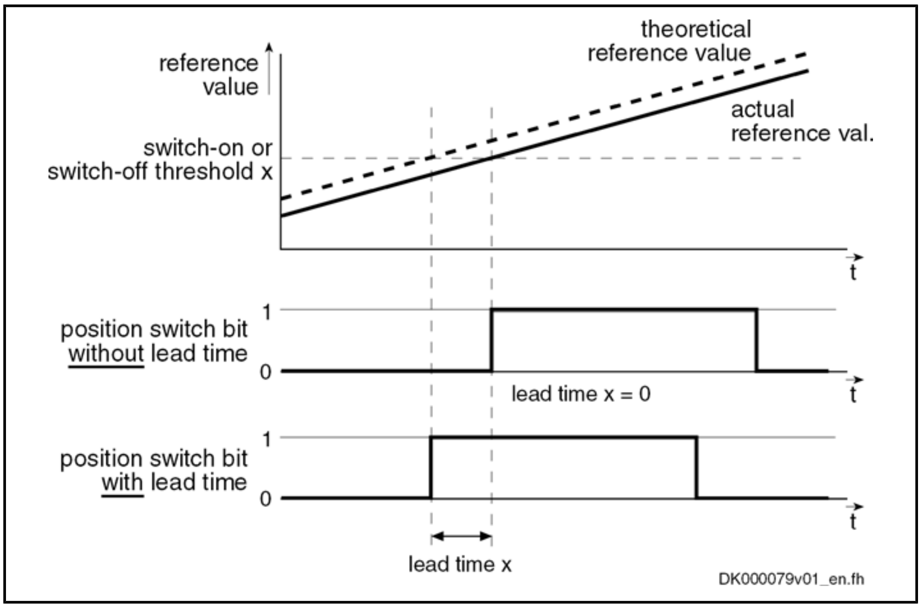


Fig.9-95: Functional principle "lead time" for programmable limit switch

9.10.3 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!

Activation for Double-Axis Devices

For double-axis devices, the content of parameter P-0-0131 is available for both axes, but the configuration for P-0-0131 may only be made in one axis at a time.

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. For an MKD025 motor with 3-pin resolver this distance, for example, is at least 0.4°.

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!

9.10.4 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).

Error Message

In order to avoid multiple activation for double-axis devices, a check is run in the transition command P3 → P 4 to find out whether P-0-0131 ≠ S-0-0000 only has been configured once for each axis. Otherwise, the error message "C0242 Multiple configuration of a parameter (->S-0-0022)" is generated!

9.11 Probe Function

9.11.1 Brief Description

Expansion package **servo function** (order code **SRV**) in **closed-loop** characteristic and expansion package **synchronization** (order code **SNC**) in all designs

Fig.9-96: Assignment to Functional Firmware Package

Features

- Up to 2 probe inputs per axis, depending on hardware design of control section (CSH…, CSB…, CDB…)
- Measuring signals can be actual position values of motor encoder, external encoder or measuring encoder, in addition master axis position values or cam shaft profile values
- Simultaneous storage of two measuring signals when probe signal only via one probe input
- For control sections with only one probe input (rapid digital input), another digital input can be used as probe input
- Measurement of absolute actual position values, of actual position 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
- Sampling time for probe signals depends on performance which has been set or is available:
  - Approx. 0.0416 µs for Advanced performance
  - Approx. 0.0833 µs for standard performance
  - Approx. 0.1666 µs for Economy performance

  Note: For sufficient noise immunity, signal edge reversal must last for at least 4.0 µs in order to be safely detected!
- Accuracy of measurement depends on hardware design (see section "Probe" in the documentation "Control Sections for Drive Controllers; Project Planning Manual")

Hardware Requirements

The probe function is only possible in conjunction with control sections which have **at least one** "rapid" digital input. The rapid digital inputs are obligatory for connecting probes.

By way of an exception, a second, slower digital input (standard digital input) can be configured as probe input for BASIC control sections which have a "rapid" digital input. Realize the assignment of this input for evaluation of probe 2 by means of corresponding parameter setting (see below).

The following control section designs are available:

- **No** rapid digital input (→ probe function **not** possible):
  - CSB01.1N-FC-… → BASIC OPENLOOP
  - CSB01.1N-AN-… → BASIC ANALOG
- **One** rapid digital input and **one** slow digital input:
  - CSB01.1N-SE-… → BASIC SERCOS
  - CSB01.1N-PB-… → BASIC PROFIBUS
  - CSB01.1C… → BASIC UNIVERSAL (single-axis)
- **One** rapid digital input **per axis**:
  - CDB01.1C-… → BASIC UNIVERSAL (double-axis)
- **Two** rapid digital inputs:
  - CSH01.1C-... → ADVANCED
  - IndraDrive Mi

The terminal designations of the "rapid" digital inputs are contained in section "I/O Extensions" in the documentation "Control Sections for Drive Controllers; Project Planning Manual".

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 select probe 1
- S-0-0427, Signal select probe 2
- S-0-0428, Probe, IDN list signal selection
- 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 I/Os, assignment list
- P-0-0301, Digital I/Os, bit numbers
- P-0-0302, Digital I/Os, direction

Pertinent Diagnostic Messages

- C0250 Probe inputs incorrectly configured
- E8035 Quick stop with probe detection is active

9.11.2 Functional Description

General Probe Function

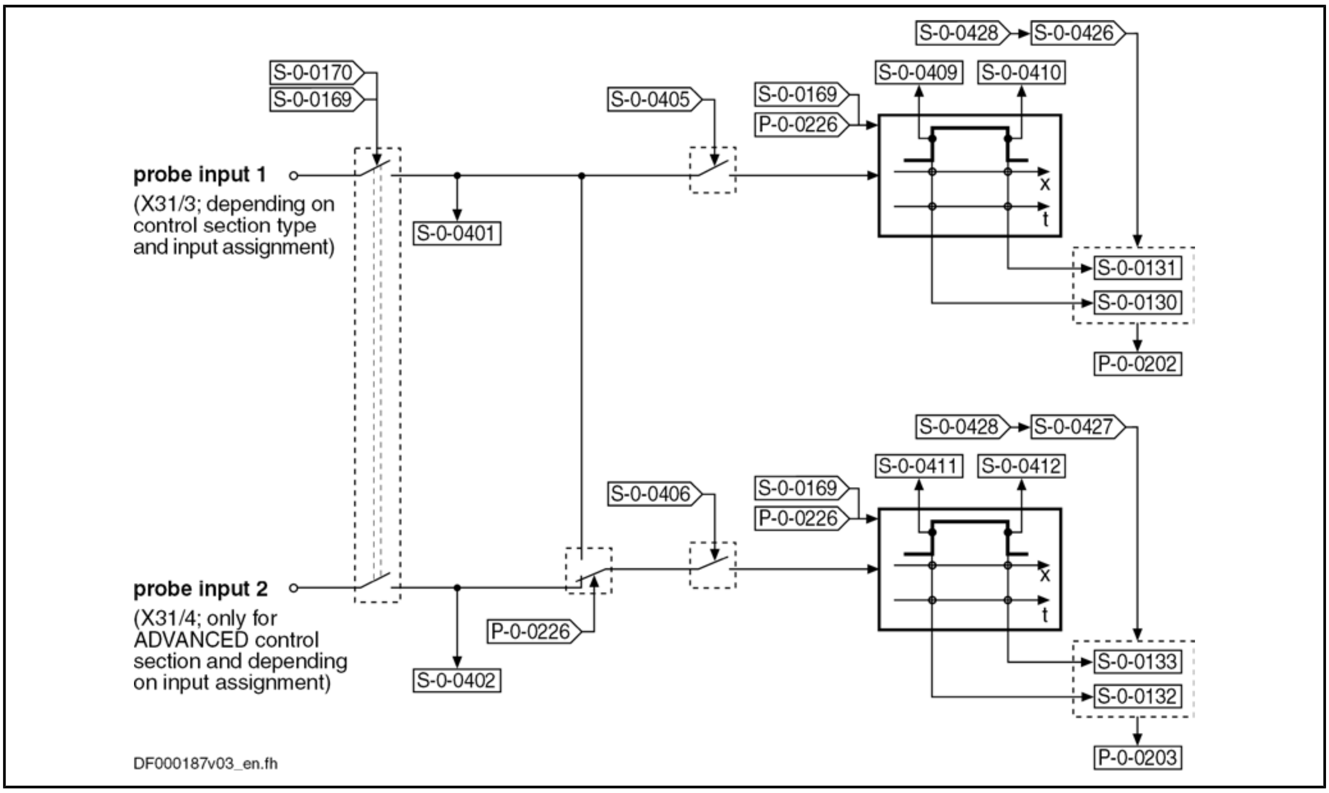
The probe input evaluates the voltage level of the probe signal in digital form, i.e. only the signal states "high" (1) or "low" (0) are recognized. When the probe is activated, the signal status changes; the probe input signals a rising (positive) or falling (negative) switching edge.

The ranges of the signal levels for "high" (1) and "low" (0) of the "rapid" digital inputs are described in the documentation "Project Planning Manual for Control Sections".

Operating Principle of Probe-Related Parameters

The figure below illustrates the operating principle of the probe-related parameters.

Optional Device Functions



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 select probe 1
S-0-0427	Signal select 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.9-97: 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

If both probe evaluations are triggered via probe input 1 (to be configured in parameter "P-0-0226, Probe, extended control word"), S-0-0402 is not written!

> The rapid digital inputs have to be assigned to the parameters S-0-0401 and S-0-0402 (default setting of parameter "P-0-0300, Digital I/Os, assignment list" etc.)!
>
> If only one rapid digital input is available and another digital standard input is to be used as probe input 2, this input has to be assigned to bit 0 of parameter S-0-0402.
>
> For 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 input for measured value detection was enabled (parameter "S-0-0405, Probe 1 enable" or "S-0-0406, Probe 2 enable").

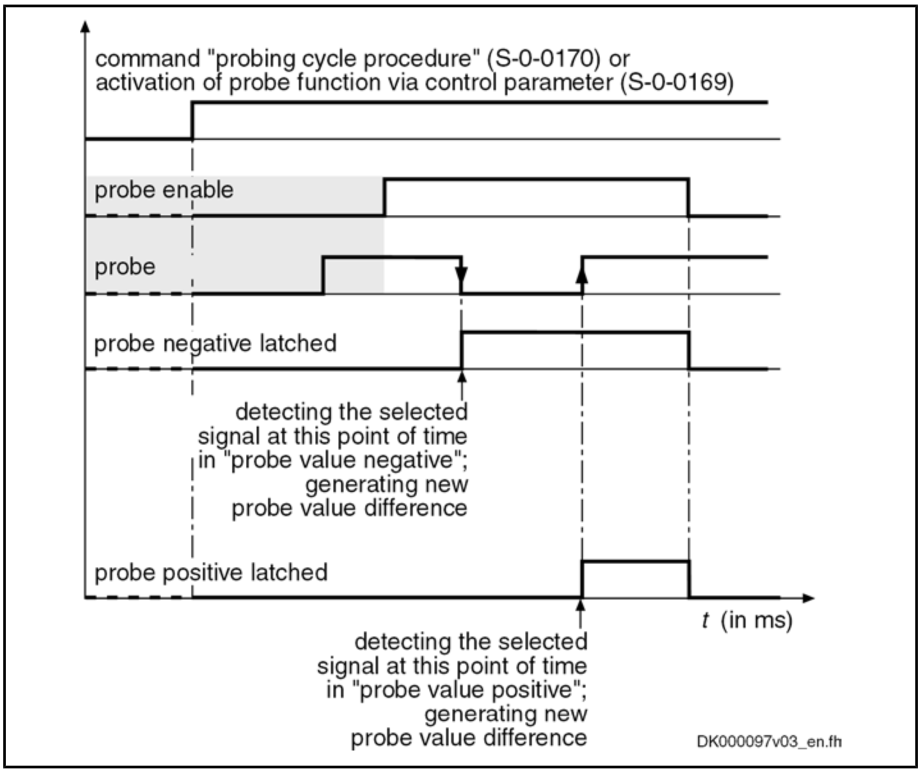


Fig.9-98: Evaluating the Probe Signal Edges (Evaluation of Positive and Negative Edges Activated in Parameter S-0-0169)

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 select probe 1,
- S-0-0427, Signal select 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 1 value
- S-0-0053, Position feedback 2 value
- P-0-0052, Actual position value of measuring encoder
- P-0-0227, Cam shaft profile, 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

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. Depending on the available hardware and firmware, as well as the performance setting in parameter "P-0-0556, Config word of axis controller", the following time differences can be measured (time in µs):

- Time differences up to 1000 s for Economy performance

- Time differences up to 1000 s for Basic performance

- Time differences up to 500 s for Advanced performance

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 controller generates the actual position values, depending on the available hardware and firmware as well as the performance setting in "P-0-0556, Config word of axis controller", on a fixed time base:

- 1000 µs for Economy performance
- 500 µs for Basic performance
- 250 µs for Advanced performance

The actual position value or relative time value corresponding to the time of the signal edge is determined by linear interpolation between the last and the next actual position value or relative time value generated by the controller.

Depending on the hardware, a certain dead time is added to signal edge detection. This dead time is partly compensated by the firmware. The accuracy of measurement depends on hardware design; this is described in section "Probe" in the documentation "Control Sections for Drive Controllers; Project Planning Manual".

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"

- 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 there hasn't any "marker" causing a measured value trigger been detected after completely passing through the "expectation window" (both position limits exceeded), this status 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".
- By registering a measured value trigger 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, aren't 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

The "expectation window" has to cover a minimum range so that at least one actual position value generation can take place within the window after the probe signal edge has been detected:

$$\text{Probe 1} \quad \boldsymbol{s}_{\mathrm{min}} = (\text{P-0-0205}) - (\text{P-0-0204}) \geq \boldsymbol{v}_{\mathrm{max}} \times \Delta \boldsymbol{t}$$
$$\text{Probe 2} \quad \boldsymbol{s}_{\mathrm{min}} = (\text{P-0-0201}) - (\text{P-0-0200}) \geq \boldsymbol{v}_{\mathrm{max}} \times \Delta \boldsymbol{t}$$

s_{min}	Minimum value for "expectation window"
P-0-0205	End position probe function 1 active
P-0-0204	Start position probe function 1 active
P-0-0201	End position probe function 2 active
P-0-0200	Start position probe function 2 active
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)

Fig.9-99: Determining the Minimum Value for the "Expectation Window"

In the case of modulo scaling of the position data, a maximum value for the "expectation window" mustn't be exceeded, as otherwise it exceeds the modulo value range and therefore is without effect:

$$\boldsymbol{s}_{\mathrm{max}} = (\text{S-0-0103}) - \boldsymbol{s}_{\mathrm{min}}$$

s_{max}	Maximum value for "expectation window"
s_{min}	Minimum value for "expectation window"
S-0-0103	Modulo value

Fig.9-100: 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 U/f operation or in sensorless, flux-controlled motor operation

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 operating 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.

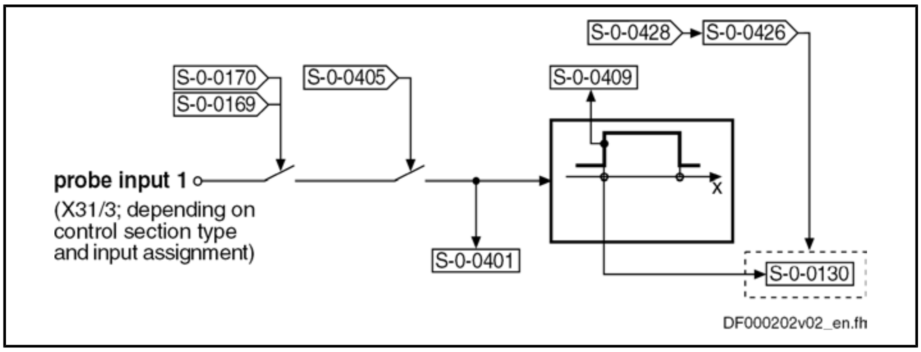
The rapid digital input (probe input 1) evaluates the voltage level of the stop signal in digital form, i.e. only the signal states "high" (1) or "low" (0) are recognized.

Quick stop is triggered at a rising (positive) switching edge.

The ranges of the signal levels for "high" (1) and "low" (0) of the "rapid" digital inputs are described in the section "I/O Extensions" in the 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 select probe 1
S-0-0428	Probe, IDN list signal selection

Fig.9-101: Overview and Operating Principle of Parameters Relevant for Quick Stop via Probe

The currently detected signal status 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 I/Os, 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 select 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 positive switching edge ($0 \rightarrow 1$) at the rapid digital input (probe input 1) triggers 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 bit "activation of probe function" in "S-0-0169, Probe control parameter"
- Enabling of rapid digital input (probe 1) for signal evaluation in parameter "S-0-0405, Probe 1 enable"

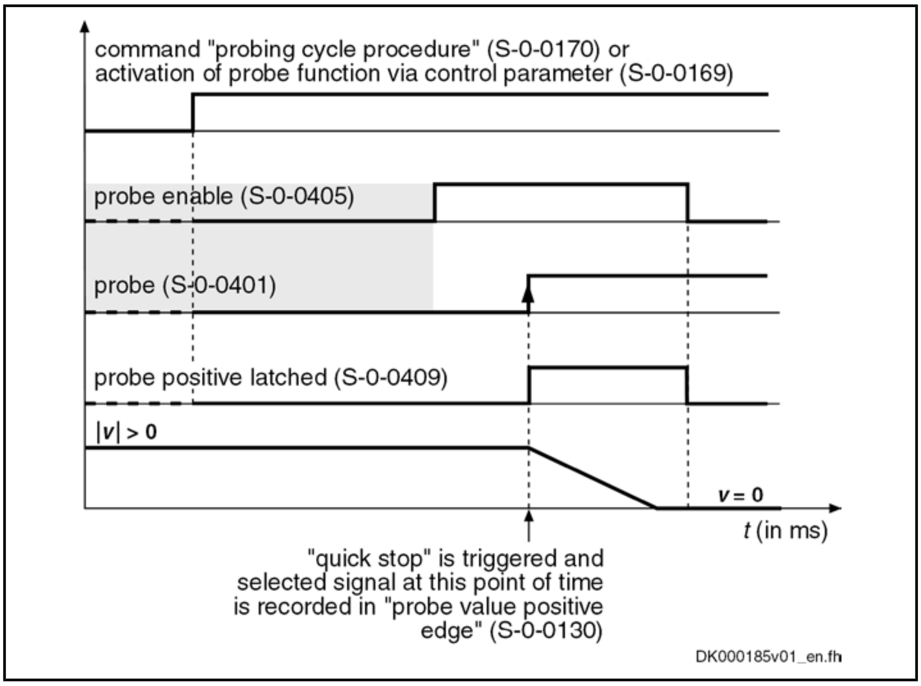


Fig.9-102: Evaluating the Signal for the Quick Stop Function

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 operating mode until the readiness for quick stop is reset. The drive signals quick stop by the message "E8035 Quick stop with probe detection is active".

Behavior After Deactivation of Quick Stop Function

At deactivation of the readiness for quick stop, the drive leaves the quick stop status and again follows the command value of the control master.

9.11.3 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
- Simultaneous triggering of both probe evaluations by probe 1

How to assign a digital standard input to parameter "S-0-0402, Probe 2", if the rapid digital input (maybe the only one available) is not sufficient:

- In parameter "P-0-0300, Digital I/Os, assignment list", assign the respective digital input to parameter S-0-0402

- In parameter "P-0-0301, Digital I/Os, bit numbers", enter the bit number (bit 0) to be written in parameter S-0-0402
- Configure connection of the digital input/output as input via parameter "P-0-0302, Digital I/Os, direction", if it is bidirectional

Select measuring signals from "S-0-0428, Probe, IDN list signal selection"; enter the selected parameters in:

- S-0-0426, Signal select probe 1
- S-0-0427, Signal select 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"

☞ As an alternative to the activation via bit 8 of parameter S-0-0169, you can set, via bit 9 of parameter "P-0-0226, Probe, extended control word", the automatic activation of the command "probing cycle procedure" (S-0-0170) during the transition PM → OM.

As of firmware version MPx05, this functionality of bit 9 of the parameter P-0-0226 is not available anymore!

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:

$$P\text{-}0\text{-}0202 = |(S\text{-}0\text{-}0130) - (S\text{-}0\text{-}0131)|$$

$$P\text{-}0\text{-}0203 = |(S\text{-}0\text{-}0132) - (S\text{-}0\text{-}0133)|$$

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.9-103: 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! The differences are then generated compared to the value "0".

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 select 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!

9.12 Measuring Encoder

9.12.1 Brief Description

Expansion package **synchronization** (order code **SNC**) of variants **MPH, MPB and MPD** in **closed-loop and open-loop** characteristic

Fig.9-104: Assignment to Functional Firmware Package

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 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 measuring").

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 controllers with a double-axis control section (CDB01.1-...), 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 both axes, an error message will be displayed!

See also separate documentation "Drive Controllers, Control Sections; Project Planning Manual"

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-0-0087, 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

- C0161 Incorr. parameterization of measuring enc. (hardware)
- C0162 Measuring encoder unknown
- C0163 Modulo value for measuring encoder cannot be displayed
- 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
- F2076 Actual pos. value 3 outside absolute encoder window
- F2176 Loss of measuring encoder reference
- F2179 Modulo limitation error of measuring encoder

9.12.2 Functional Description

Basics on Measuring Encoder, Resolution

The measuring encoder is mechanically connected to an axis or shaft and detects its position data. These position data can be used as measured values or command variable, but not as control variable.

Encoders to be Used

Only rotary encoders can be used as measuring encoders. The possible encoders are listed in parameter "P-0-0076, Encoder 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.

See also "Scaling of Physical Data"

The modulo range can only be selected as an integral multiple of an axis- or shaft-side revolution and has an upper limit:

$$\text{Modulo range} = \boldsymbol{n} \times (\text{axis or shaft revolutions})$$
$$\boldsymbol{n} = (\text{P-0-0765}) \leq 2^{31-(\text{P-0-0084})} - 1; \quad \boldsymbol{n} \in \boldsymbol{N}$$
$$\text{If } (\text{P-0-0765}) = 0 \rightarrow \boldsymbol{n} = 2^{32-(\text{P-0-0084})}$$

n	Number of revolutions at axis or shaft
P-0-0765	Modulo factor measuring encoder

Fig.9-105: Modulo Range at Axis or Shaft

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.9-106: Maximum Possible Encoder Resolution of Measuring Encoder per Encoder Revolution

Value Range of Position Data

The value range of the position data of the measuring encoder depends on the modulo factor of the measuring encoder (P-0-0765):

$$\text{Modulo range} = \boldsymbol{n} \times 2^{(\text{P-0-0084})} (\text{increments})$$
$$\boldsymbol{n} = (\text{P-0-0765}) \leq 2^{31-(\text{P-0-0084})} - 1; \quad \boldsymbol{n} \in \boldsymbol{N}$$
$$\text{If}\,(\text{P-0-0765}) = 0 \rightarrow \boldsymbol{n} = 2^{32-(\text{P-0-0084})}$$

n	Number of revolutions at axis or shaft
P-0-0765	Modulo factor measuring encoder

Fig.9-107: Modulo Value Range at Axis or Shaft

Depending on "P-0-0327, Encoder resolution of measuring encoder" and the gear ratio of the measuring encoder (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.

Drive-Internal Resolution of Measuring Encoder Position Data

The resulting drive-internal encoder resolution is as follows:

$$\text{Measuring encoder resolution} = (\text{P-0-0326}) \times (\text{P-0-0327})$$
$$\text{internal limitation:}$$
$$\text{P-0-0326} = 2^{30} \times \frac{(\text{P-0-0128})}{(\text{P-0-0127}) \times (\text{P-0-0327}) \times (\text{P-0-0765})} \leq 2^{n}$$
$$\boldsymbol{n} \leq 15\,(\text{in round numbers})$$

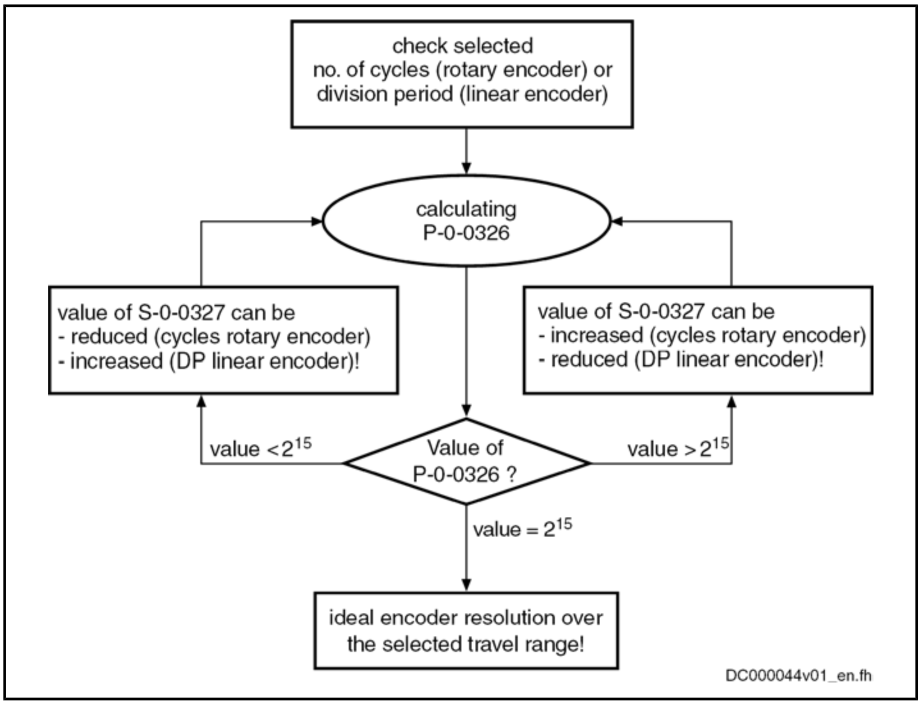
P-0-0326	Multiplication of measuring encoder
P-0-0327	Encoder resolution of measuring encoder
P-0-0128	Output revolutions of measuring gear
P-0-0127	Input revolutions of measuring gear
P-0-0327	Encoder resolution of measuring encoder
P-0-0765	Modulo factor measuring encoder
n	Number of revolutions at axis or shaft

Fig.9-108: 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 formulas "drive-internal measuring encoder resolution" characterizes the encoder dimensioning.



P-0-0326 Multiplication of measuring encoder
P-0-0327 Encoder resolution of measuring encoder
Fig.9-109: Checking the Selected Resolution and Determining the Ideal Resolution for the Measuring Encoder

☞ The value of P-0-0326 calculated according to the formulas "drive-internal measuring encoder resolution" 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.

Smoothing the Actual Measuring Encoder Position Value

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 for Measuring Encoder

For the measuring encoder there are signal monitoring functions that are corresponding to the monitoring functions for motor encoder and optional encoder. The drive, however, outputs warnings or error messages specific to the measuring encoder.

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 current encoder data of an absolute measuring encoder are stored in parameter

- P-0-0179, Absolute encoder buffer 3 (measuring encoder).

When switching on a drive with an absolute measuring encoder, 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 "P4" (bb), 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 determined by the modulo factor is smaller, absolute evaluation is possible!

Depending on relative or absolute evaluation of the measuring encoder, the controller makes available different procedures for establishing the position data reference. Depending on the kind of evaluation there are the following possibilities:

- "Set absolute measuring" 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".

CAUTION

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 Measuring"

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 "P-0-0012, C0300 Command Set absolute measuring".

As it is possible to connect several encoders to be evaluated in absolute form to the controller, the absolute encoder to be homed is selected by a bit in parameter "P-0-0612, Control word for setting absolute measuring". The command "set absolute measuring" only takes effect for the selected encoder.

Dedicated Position

By starting the "set absolute measuring" 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 measuring" is the value of parameter "P-0-0087, Actual position value offset of measuring encoder".

$$[\text{P-0-0052}]_{\text{NEW}} = \text{P-0-0087}$$

P-0-0052 Actual position value of measuring encoder
P-0-0087 Actual position value offset of measuring encoder

Fig.9-110: Actual Position Value of the Measuring Encoder After "Set Absolute Measuring"

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 measuring", 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 command "set absolute measuring" is cyclically used in the operational sequence, it makes sense to store the absolute encoder offset temporarily only. This kind 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 parameter 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 controller is switched off or when the parameter mode ("P2") is activated.

Sequence of "Set Absolute Measuring"

For the measuring encoder, the command "set absolute measuring" can only be activated when the drive is ready for operation but inactive ("bb", "AB").

When the "set absolute measuring" 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. To do this, 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 the homing procedure is the value of parameter "P-0-0087, Actual position value offset of measuring encoder".

$$[\text{P-0-0052}]_{\text{NEW}} = \text{P-0-0087}$$

P-0-0052 Actual position value of measuring encoder
P-0-0087 Actual position value offset of measuring encoder
Fig.9-111: 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 isn't 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 status 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.

9.12.3 Notes on Commissioning

Configuration and Setting

Configuring the Controller 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

Setting the Modulo Value Range Entering modulo range of the axis or shaft to be measured:

- P-0-0765, Modulo factor measuring encoder

Message if the entered value is too high:

- C0163 Modulo value for measuring encoder cannot be displayed

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 Monitor (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 parameter P-0-0334 is incremental!

When the value range (modulo) is smaller than the absolute encoder range of the measuring encoder, it can be evaluated as absolute encoder. This is displayed in the respective 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 "P2"!

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.

☞ Incremental scaling! 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

Make the presetting for "set absolute measuring" by determining the measuring encoder for "set absolute measuring" in parameter "P-0-0612, Control word for setting absolute measuring".

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 Measuring"

Start "P-0-0012, C0300 Command Set absolute measuring"; 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 has to 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.

Shifting the position data reference already takes effect as of communication phase "P2".

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

- C0161 Incorr. parameterization of measuring enc. (hardware)
- C0162 Measuring encoder unknown
- 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 Parameters, Basics

10.1.1 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 serial interface

- 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.	Designation	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
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

Fig. 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 serial interface. Only the operating data can be written, too.

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)
- Status 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 operating data for communication phase 2
- S-0-0019, IDN list of operating data for communication phase 3

The control master can query the IDNs of the parameters with invalid operating data (parameter values) via:

- S-0-0021, IDN list of invalid operating data for communication phase 2
- S-0-0022, IDN list of invalid operating data for communication phase 3
- S-0-0423, IDN-list of invalid op. data for parameterization level

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 status 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:

- C0101 Invalid parameters (->S-0-0021)
- C0102 Limit error in parameter (-> S-0-0021)

- or -

- C0201 Invalid parameters (->S-0-0423)
- C0202 Parameter limit error (->S-0-0423)
- C0203 Parameter calculation 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 operating data for communication phase 2
- S-0-0022, IDN list of invalid operating data for communication phase 3
- S-0-0423, IDN-list of invalid op. data for parameterization level

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 D" commissioning tool.

Setting the Language 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.

10.1.2 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)
- As a MultiMediaCard (MMC), optional

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.
- The MMC contains the drive firmware.

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:

- MMC → copying the parameter values by command
- "IndraWorks D" commissioning tool → saving the 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 basic parameter 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 status (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

- MMC → loading the parameter values by command
- "IndraWorks D" commissioning tool → loading the parameter values from 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 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, Selected IDN list of operation data to backup
- S-0-0293, C2400 Selectively backup working memory procedure command
- S-0-0326, Parameter checksum
- S-0-0327, IDN list of checksum parameter
- P-0-0013, IDN list of modified parameters
- P-0-4023, C0400 Communication phase 2 transition
- P-0-4065, Non-volatile memory active
- P-0-4090, Configuration for loading default values
- P-0-4091, C2500 Copy IDN from optional memory to internal memory
- P-0-4092, C2600 Copy IDN from internal memory to optional memory

Pertinent Diagnostic Messages

Load defaults procedure (loading controller parameters):

- C07_0 Load defaults procedure com. (load controller param.)
- C0702 Default parameters not available
- C0703 Default parameters invalid
- C0704 Parameters not copyable
- C0706 Error when reading the controller parameters

Load defaults procedure (loading basic parameters):

- C07_1 Load defaults procedure com. (load basic parameters)
- C0751 Parameter default value incorrect (-> S-0-0423)
- C0752 Locked with password

Backup working memory procedure:

- C2202 Error when writing data to non-volatile memory
- C2200 Backup working memory procedure command

Loading 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

Copy parameters from MMC to flash:

- C2500 Copy IDN from optional memory to internal memory
- C2502 Error when accessing the MMC
- C2504 Error when writing data to internal memory

Copy parameters from flash to MMC:

- C2600 Copy IDN from internal memory to optional memory
- C2602 Error when accessing the MMC
- C2604 Error when reading the internal memory

Other diagnostic messages:

- F2100 Incorrect access to command value memory
- F2101 It was impossible to address MMC
- F2102 It was impossible to address I2C memory
- F2103 It was impossible to address EnDat memory

Functional Description

Storage Media in the Drive Controller

All operating data referring to hardware are stored in the drive 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. The values of the application-specific parameters can be stored either in the flash memory or in the working memory.

Storage Medium in the Motor Encoder

In the case of the MHD, MKD, MKE, MAD and MAF motor lines, the data memory of the motor encoder contains all motor- and motor-encoder-specific parameter values. In addition, motor-specific control loop parameter values are stored in this data memory; the controller can easily be adjusted to the motor by means of these parameter values.

In the case of the 2AD and ADF motors, the data memory of the motor encoder only contains the encoder-specific parameter values. The motor-specific control loop parameter values for adjusting the controller to the motor are loaded to the controller from a database of the "IndraWorks D" commissioning tool.

Storage Medium MultiMediaCard (MMC)

The MultiMediaCard (MMC) is a non-volatile storage medium that can be permanently or temporarily plugged in the slot provided for this purpose at the front of the drive controller. The MMC is not obligatory!

The MMC can be used as

- permanently plugged medium for saving the firmware and the application-specific parameter values

- or -

- temporarily plugged medium for updating the firmware

- or -

- temporarily plugged medium for transmitting application-specific parameter values.

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 (Loading Basic Parameters)

Via the command "S-0-0262, C07_x Load defaults procedure", it is possible to set a defined initial status of the parameter values.

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"

    → Loads the motor-specific default parameter values for the control loop available in the motor encoder data memory (if available) (see "Axis Control: Default Settings in the Motor Encoder Data Memory ("Load Defaults Procedure")")
  - "Load basic parameters"
  - "Load MLD parameters"

    → Resets/clears the parameters of the drive-integrated PLC (program and register)
  - "Load profile parameters"

    → See "Profile Types (With Field Bus Interfaces)"
  - "Load defaults procedure for safety technology"

    → See separate documentation "Integrated Safety Technology"
- **Scaling of command execution** (bits 4...7):

  With the command "load basic parameters", you have the option to load default values for all parameters or to selectively exclude the following groups, for example:
  - Default values for all parameters except for the communication parameters
  - Default values for all parameters except for the PLC parameters

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.

CAUTION

Damage to the internal memory (flash) caused by cyclic command execution (write access 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 access. For this reason, you should make sure that such write access is not carried out too often.

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 backup operation data
- S-0-0270, Selected IDN list of operation data to backup

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.

To identify the parameters the value of which has changed compared to their default value, the drive makes available the parameter

- P-0-0013, IDN list of modified parameters.

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.

Command "Load Working Memory Procedure"

By means of "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:

- **Start command "P-0-4092, C2600 Copy IDN from internal memory to optional memory"**

  → The parameter values of the list of S-0-0192 are copied to an MMC card plugged in the controller (in the case of volatile storage mode, command C2200 must have been executed!).

- **Commissioning tool "IndraWorks D"**

  → The parameter values of the list of S-0-0192 are stored on an external data carrier (hard disk, floppy disk or the like); target assignment is carried out via the menu of the tool (serial communication with the controller or via SYSDA SERCOS interface).

- **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:

- **Start command "C2500 Copy IDN from optional memory to internal memory" (P-0-4091)**

→ The parameter values (according to list of S-0-0192) stored on a plugged MMC are loaded to the device-internal, non-volatile flash memory.

- **Commissioning tool "IndraWorks D"**

  → The parameter values (according to list of S-0-0192) stored on an external data carrier (hard disk, floppy disk or the like) are loaded to the controller; source assignment is carried out via the menu of the tool (serial communication with the controller or via SERCANS-Box/SERCOS interface).

- **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

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!

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 Basic Parameters

If the desired firmware is available in the controller, load basic parameter values of the firmware by carrying out the following steps:

1. Set parameter "P-0-4090, Configuration for loading default values"
2. Start "S-0-0262, C07_x Load defaults procedure command"

Respective diagnostic command message:

- C07_1 Load defaults procedure com. (load basic parameters)

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"

Load Motor-Specific Control Loop Parameter Values

After loading the basic parameters, the controller signals "RL", if a Rexroth motor with motor encoder data memory was 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 -

- Start of command "S-0-0099, C0500 Reset class 1 diagnostics"

If the initial status 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.

CAUTION

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!

In the case of motors without encoder data memory, loading the motor-specific control loop parameter values by means of the "load defaults procedure" command is impossible! The values can be loaded from a database of the "IndraWorks D" commissioning tool.

Respective diagnostic command message:

- C07_0 Load defaults procedure com. (load controller param.)

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 option "volatile storage" was 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

- starting "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

- starting "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, Selected IDN list of operation data to backup.

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 basic parameter 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

Saving and Loading Parameter Values With MMC

For saving and loading parameter values with MMC, see "MultiMediaCard (MMC)"!

Loading and Saving Parameter Values via Control Master or IndraWorks D

An appropriate master communication interface or the serial interface can be used for loading and saving parameter values via the control master or IndraWorks D.

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).

☞ 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! **The actual position value after the loading process would be incorrect, but this cannot be detected on the controller side!**

For how to reestablish the initial status of parameters for drives with absolute value encoder and modulo scaling, see "Initial Commissioning/Serial Commissioning"!

If other interfaces than SERCOS interface are used for loading and storing, communication phase "P2" has to be activated for loading parameter sets:

- 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 successive start of the commands "S-0-0127, C0100 Communication phase 3 transition check" and "S-0-0128, C0200 Communication phase 4 transition check"!

When reading and writing individual parameters via the control master or IndraWorks D (without command), the following error messages can possibly occur:

- F2100 Incorrect access to command value memory
- F2101 It was impossible to address MMC
- F2102 It was impossible to address I2C memory
- F2103 It was impossible to address EnDat memory

10.1.3 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 backup operation data" contains the IDNs of all parameters that are stored in the non-volatile memory [MultiMediaCard (MMC) or 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 Operating Data for Communication Phase 2 (S-0-0021)

In parameter "S-0-0021, IDN list of invalid operating data for communication phase 2", 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 (MultiMediaCard/MMC, 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 operating data for communication phase 2" upon negative acknowledgment of the command "S-0-0127, C0100 Communication phase 3 transition check" must be corrected.

IDN List of Invalid Operating Data for Communication Phase 3 (S-0-0022)

In parameter "S-0-0022, IDN list of invalid operating data for communication phase 3", 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, C0200 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 (MultiMediaCard/MMC, 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 operating data for communication phase 3" upon negative acknowledgment of the command "S-0-0128, C0200 Communication phase 4 transition check" must be corrected.

IDN-List of Invalid Op. Data for Parameterization Level (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 op. data for parameterization level".

IDN List of Operating Data for 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 operating data for communication phase 2".

IDN List of Operating Data for Communication Phase 3 (S-0-0019)

The IDNs that are checked for validity when the command "S-0-0128, C0200 Communication phase 4 transition check" is executed are stored in the operating data of parameter "S-0-0019, IDN list of operating data for communication phase 3".

IDN-List of all Procedure Commands (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".

Selected IDN List of Operation Data to Backup (S-0-0270)

The IDNs of those parameters are stored in parameter "S-0-0270, Selected IDN list of operation data to backup" that are to be saved when the command "S-0-0293, C2400 Selectively backup working memory procedure" is executed.

IDN-List of Password-Protected Operation 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 Checksum Parameter (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 not Corresponding to Default Value (P-0-0013)

All parameters the operating data of which was changed with regard to the default value are stored in parameter "P-0-0013, List of all IDNs not corresponding to default value".

10.1.4 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 parameters that can be written:

- Parameters that are write-protected as a standard, such as motor parameters, hardware code parameters, encoder parameters, error memory etc. ("administration parameters"). The values of these parameters guarantee 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 parameters that can be written 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 can be written; "administration parameters" remain write-protected.
- **Master password**

  → All parameters that can be written, 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 backup operation data
- S-0-0267, Password
- S-0-0279, IDN-list of password-protected operation data
- P-0-4064, Safety technology 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 include 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 parameter "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.

Handling, Diagnostic and Service Functions

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 Bosch Rexroth development and service staff.

The master password is secret! It mustn't 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 the "S-0-0267, Password" parameter contains the value "007". The write protection is activated and deactivated by means of the customer password according to the following procedure:

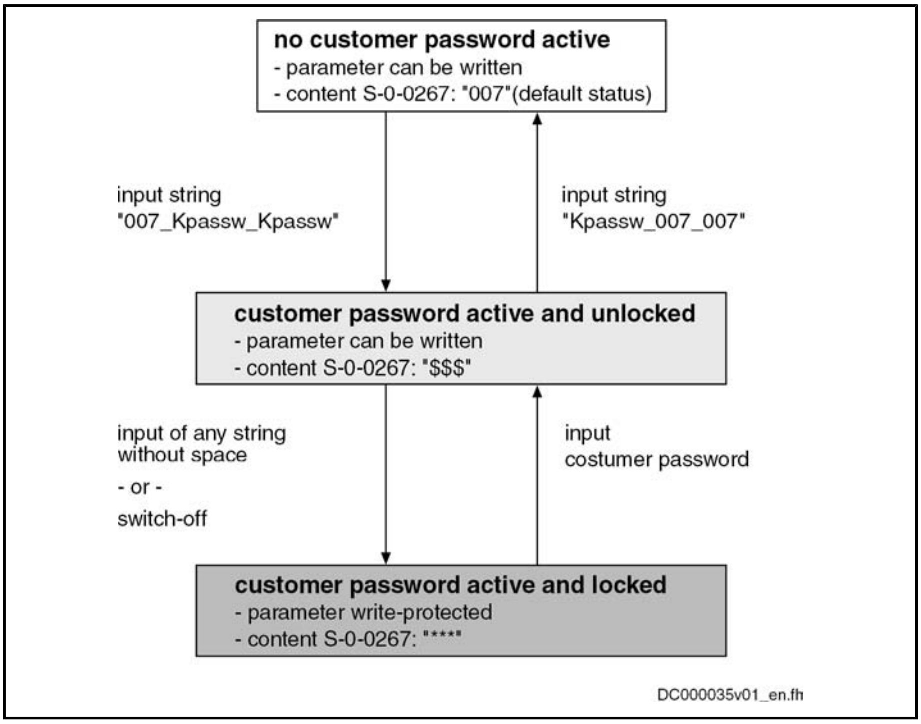


Fig. 10-2: Activating and deactivating the write protection by means of the customer password

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 Bosch Rexroth development and service staff!

WARNING

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 deactivated 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, Safety technology password level.

Diagnosis

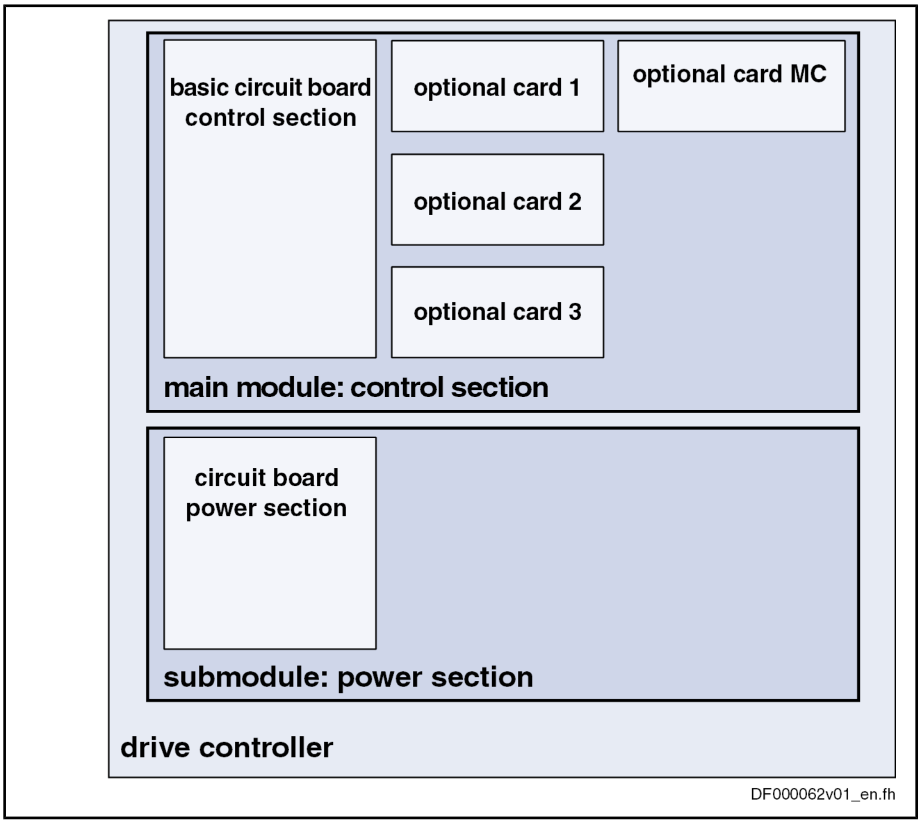
When trying to write data to a write-protected parameter, an error code is sent to the SERCOS master via the non-cyclic data channel, according to the SERCOS specification. The master then recognizes that the respective parameter is write-protected and that it is impossible to write data to it.

10.2 Device Configuration

10.2.1 Controller Design

The drive controllers of the IndraDrive range consist of several modules. We basically distinguish between:

- **Main module**
  → Module directly communicates with the master
- **Submodule**
  → Module only communicates with the master via main module



MC master communication

Fig.10-3: Example of design including device, modules and circuit boards for IndraDrive controllers

The following control and power sections are supported by the firmware:

- **Control sections:**
  - CSH01.xC-…
  - CSB01.xC-...
  - CSB01.xN-...
  - CDB01.xC-...
- **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-W0150-A-07-NNNN
  - HMS01.1N-W0210-A-07-NNNN
  - HMD01.1N-W0012-A-07-NNNN
  - HMD01.1N-W0020-A-07-NNNN
  - HMD01.1N-W0036-A-07-NNNN
  - HCS02.1E-W0012-A-07-NNNN
  - HCS02.1E-W0028-A-07-NNNN
  - HCS02.1E-W0054-A-07-NNNN
  - HCS02.1E-W0070-A-07-NNNN

- HCS03.1E-W0070-A-05-NNNN
- HCS03.1E-W0100-A-05-NNNN
- HCS03.1E-W0150-A-05-NNNN
- HCS03.1E-W0210-A-05-NNNN

☞ The devices are configured at the factory and can be read via parameters, if required.

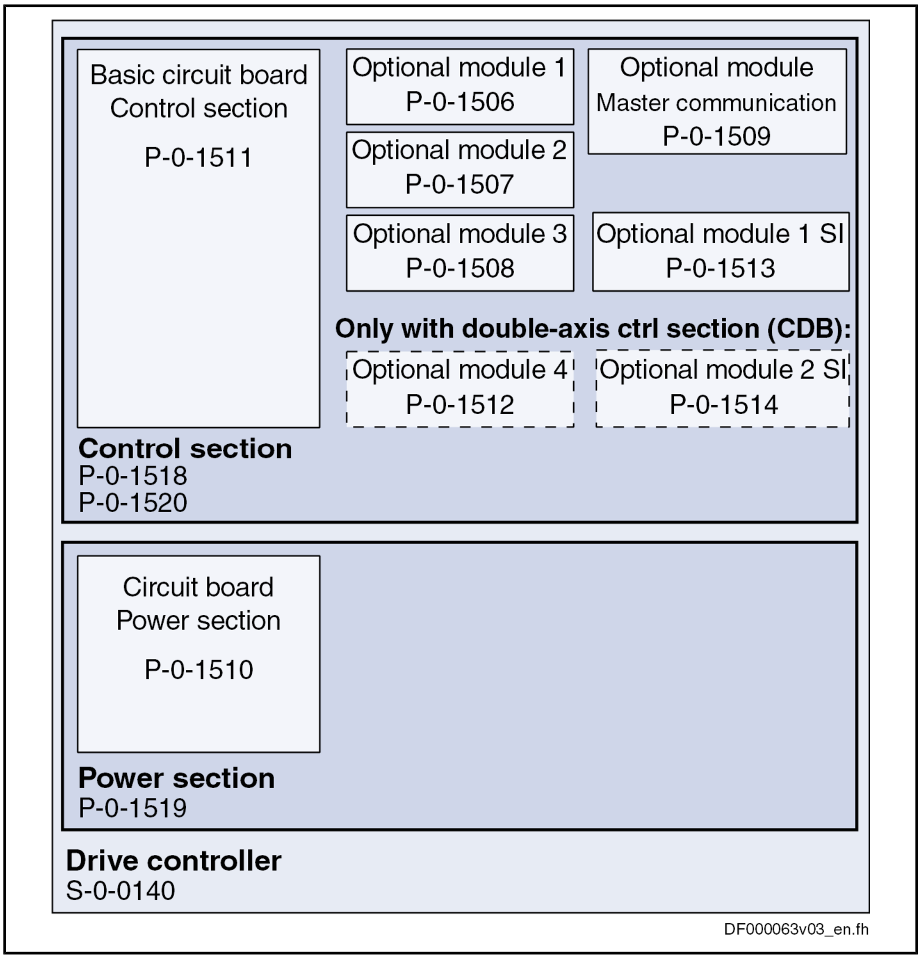
10.2.2 Circuit Board Code

Brief Description

The configurable control section of a drive controller consists of the basic control section circuit board and one or several optional modules (see type code in the documentation "Drive Controllers, Control Sections; Project Planning Manual").

An individual parameter is assigned to each slot for circuit board or optional module (cf. P-0-1506 to P-0-1514). The specific data (circuit board code) of the circuit board that has been plugged are stored in these parameters.

☞ The circuit board codes are stored directly on the circuit board or the respective optional module.



S-0-0140	Controller type
P-0-1506	Circuit board code optional module 1
P-0-1507	Circuit board code optional module 2
P-0-1508	Circuit board code optional module 3
P-0-1509	Circuit board code master communication
P-0-1510	Circuit board code power section
P-0-1511	Circuit board code control section
P-0-1512	Circuit board code optional module 4
P-0-1513	Circuit board code optional module 1 for safety technology
P-0-1514	Circuit board code optional module 2 for safety technology
P-0-1518	Module code of control section
P-0-1519	Module code of power section
P-0-1520	Control section type

Fig. 10-4: Device Configuration and Circuit Board Code for IndraDrive

In the initialization phase (when booting), the drive firmware automatically checks the arrangement (configuration) of the control section by means of the individual circuit board codes, and on this basis generates the content of parameter "P-0-1520, Control section type". The configuration of the control section used can be read via this parameter.

☞ The control section is configured at the factory and the configuration is displayed in parameter P-0-1520 for diagnostic purposes (type designation in plain text)!

Pertinent Parameters

- S-0-0140, Controller type
- P-0-1506, Circuit board code optional module 1

- P-0-1507, Circuit board code optional module 2
- P-0-1508, Circuit board code optional module 3
- P-0-1509, Circuit board code master communication
- P-0-1510, Circuit board code power section
- P-0-1511, Circuit board code control section
- P-0-1512, Circuit board code optional module 4
- P-0-1513, Circuit board code optional module 1 for safety technology
- P-0-1514, Circuit board code optional module 2 for safety technology
- P-0-1518, Module code of control section
- P-0-1519, Module code of power section
- P-0-1520, Control section type

Pertinent Diagnostic Messages

During the initialization phase the drive, apart from checking the existing configuration, carries out some additional checks. Errors detected during the checks are classified according to their cause.

General malfunction of a circuit board with specific error messages:

- F8091 Power section defective
- F8122 Control section defective

Configuration of control section not allowed, i.e. an optional card was plugged into a slot that does not support this card (observe allowed combinations of the individual optional modules; see documentation "Drive Controllers, Control Sections; Project Planning Manual"):

- F8118 Invalid power section/firmware combination
- F8120 Invalid control section/firmware combination

10.2.3 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.

10.2.4 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

☞ 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 of 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.

10.3 Diagnostic System

10.3.1 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 status by means of drive-internal, priority-dependent generation of diagnostic messages
- Collective messages for diverse 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-0-0142, Application type
- S-0-0375, List of diagnostic numbers
- S-0-0390, Diagnostic message number
- P-0-0007, Display text of diagnostic message
- P-0-0009, Error number
- P-0-0478, Logbook event
- P-0-0479, Logbook time stamp
- P-0-3219, Diagnostic safety technology message

☞ For integrated safety technology, an extended diagnosis option is provided in the form of a safety technology error code. When certain safety technology errors occur, this error code can be read in parameter "P-0-3219, Diagnostic safety technology message" which allows quick error diagnosis.

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 transmitted to the master (control unit or commissioning software, e.g. IndraWorks D).

We distinguish the following categories of diagnostic messages (kinds of diagnostic messages):

- Errors
- Warnings
- Commands/command errors
- Status displays/operating states

Generally, the current diagnostic message with the highest priority is displayed or stored at the following locations in the drive:

- **Display of the control panel and parameter "P-0-0007, Display text of diagnostic message"**

  → The diagnostic message number or, if applicable, text appears on the 8-digit display of the standard control panel. The current display is stored in parameter P-0-0007.

- **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.

- **Parameter "S-0-0390, Diagnostic message number"**

  → The diagnostic message number shown on the display is stored in this parameter.

When a diagnostic message of the "error" category occurs, the corresponding diagnostic message number is stored in parameter "P-0-0009, Error number". When there isn't any error present, the value of parameter P-0-0009 equals zero.

In parameter "S-0-0375, List of diagnostic numbers", 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 for displaying the current diagnostic message:

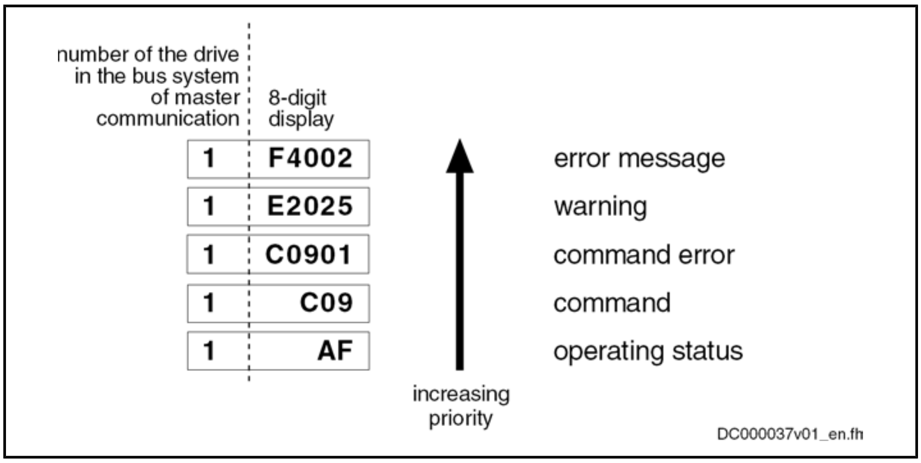


Fig. 10-5: Priorities of displays (with example displays)

An overview of all diagnostic messages and their meanings is included in the documentation "Troubleshooting Guide (description of diagnostic messages)".

Structure of a Diagnostic Message

General Information

Every diagnostic message consists of

- diagnostic message number

  - and -

- diagnostic text.

The diagnostic message for the non-fatal error "Excessive deviation", for example, has the following structure:

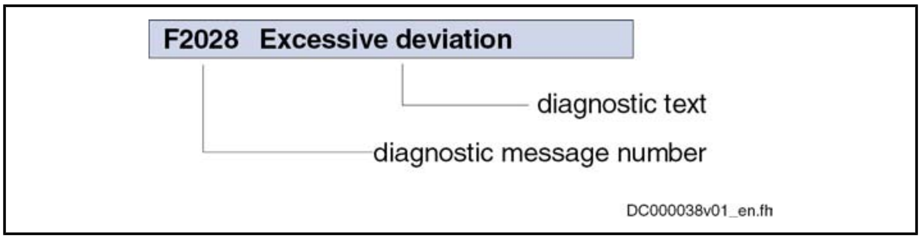


Fig. 10-6: Structure of a diagnostic message

"F2028" flashes on the display of the control panel. The display "F2028" is output via parameter "P-0-0007, Display text of diagnostic message", too. The diagnostic message number is contained in parameter "S-0-0390, Diagnostic message number" in hexadecimal form (for this example: 0x00F2028). The diagnostic message number and the diagnostic text are contained as string "F2028 Excessive deviation" in parameter "S-0-0095, Diagnostic message". "2028" (dec) is written to parameter "P-0-0009, Error number", because it is an error diagnosis.

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

Kind of diagnostic message	Diagnostic message number	Display
error	F2xxx	F2xxx
command	C0200	C02
command error	C02xx	C02xx
warning	E2xxx	E2xxx
communication phase e.g. communication phase 1	A0001	P1
drive ready for operation	A0012	Ab
operating mode e.g. velocity control	A0101	AF

Fig. 10-7: Overview of diagnostic messages displayed

The current operating mode is not shown on the display. When the drive follows the preset operating 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 status 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 can be read via parameter "P-0-0007, Display text of diagnostic message" which allows an operator interface to determine the drive status and display it in a language-independent way.

Error Number

The error number contains only the error number without the diagnostic message text. It can be read via parameter "P-0-0009, Error number" and is a language-independent possibility of determining and displaying an error condition on an operator interface. This parameter only contains a value unequal zero when an error is present in the drive.

The error number is generated from the lowest 4 digits of the diagnostic message number. For example, the error "F2028 Excessive deviation" with the diagnostic message number "(0x)F2028" would produce the error number "2028."

List of Diagnostic Numbers

The last 50 diagnostic message numbers displayed are stored in chronological order in parameter "S-0-0375, List of diagnostic numbers". Every change in the content of "S-0-0390, Diagnostic message number" means that the old content is applied to S-0-0375. When reading the parameter S-0-0375 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"

10.3.2 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"

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 the case of SERCOS)
- Change bits of class 2 and 3 diagnostics (S-0-0097 and S-0-0098) **can be masked** in status word of master communication (e.g. S-0-0135 in the 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 interlock; 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 also 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 the 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 the case of SERCOS) remains set, however, until parameter S-0-0012 has been read once.

☞ Via 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").
  - In the case of a drive message, bit 11 (change bit class 3 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in the 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 the case of SERCOS) remains set, however, until parameter S-0-0013 has at least 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 Bit

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:

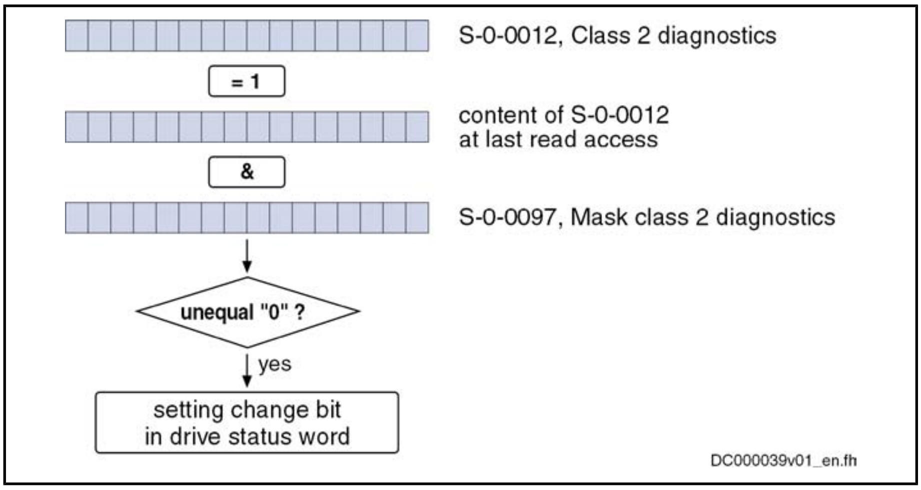


Fig. 10-8: Generating the change bit of class 2 diagnostics

Notes on Commissioning

The figure below illustrates the handling of the change bits in the status word and of the status class parameters:

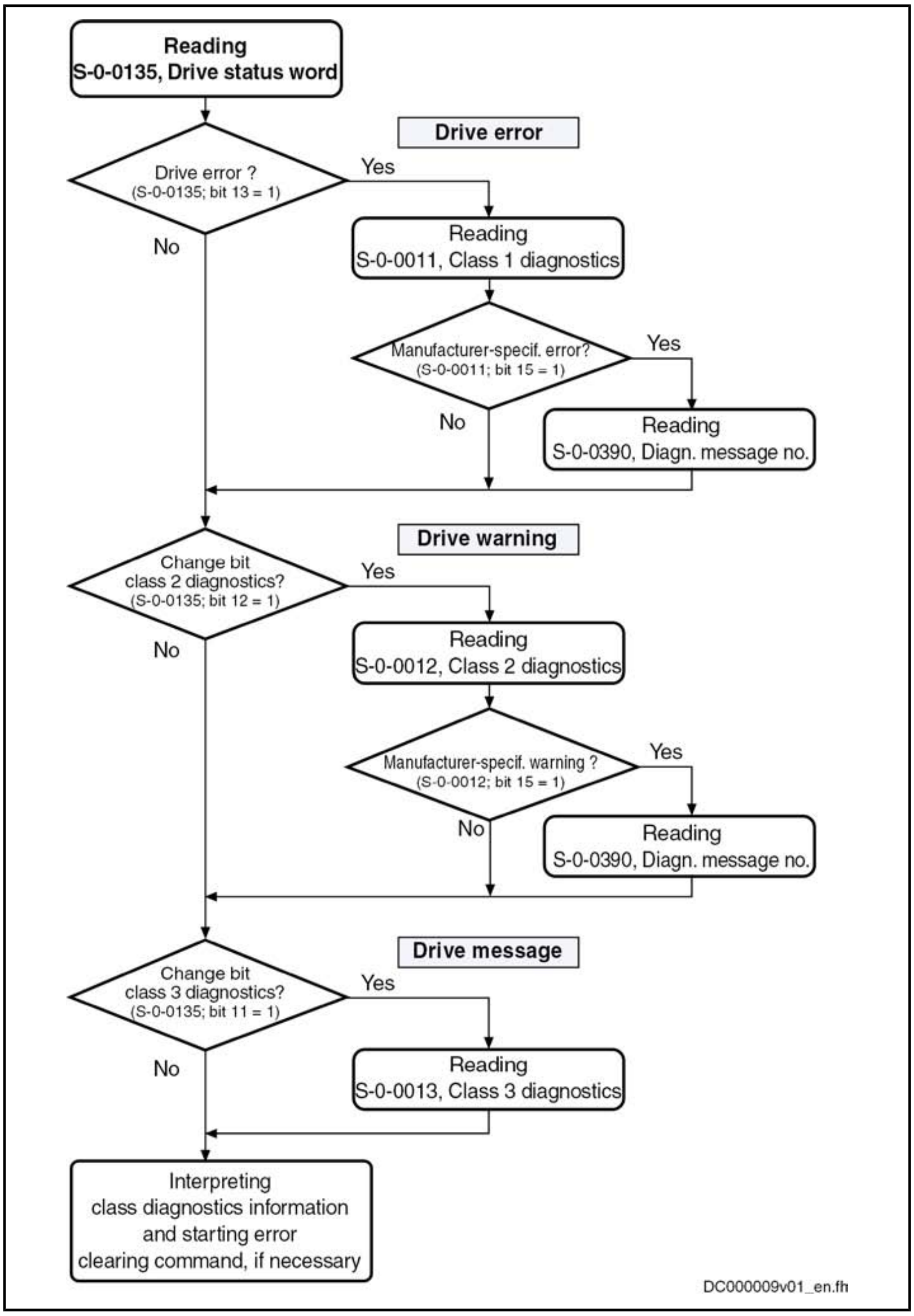


Fig. 10-9: Handling the change bits and status class parameters

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 the "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 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, Status word of axis controller**

  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 interface).
- **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 interface")

- S-0-0330, Message 'n_actual = n_command'
- S-0-0331, Status 'n_feedback = 0'
- S-0-0332, Message 'nactual < nx'
- S-0-0333, Message 'T >= Tx'
- S-0-0334, Message 'T >= Tlimit'
- S-0-0335, Message 'n command > n limit'

- S-0-0336, Message In position
- S-0-0337, Message 'P >= Px'
- S-0-0341, In-Position coarse message
- 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-0-0427, Control parameter of analog output
- P-0-0522, Control word for commutation setting
- P-0-0556, Config word of axis controller
- P-0-0612, Control word for setting absolute measuring
- P-0-4028, Device control word

10.4 Control Panels of the IndraDrive Controllers

10.4.1 General Information on the Operation Options

Variants of the Control Panels

IndraDrive controllers are equipped with a control panel which consists of a display and keys located underneath it. The display shows operating states, command and error diagnoses, as well as present warnings. By means of the keys you can make settings, call information and trigger some commands.

The extent of possible displays and settings depends on the available control panel of the IndraDrive controller. It can be supplied in two variants which differ as regards their performance:

- **Standard control panel**
- **Comfort control panel**

Via the serial interface of the controller, it is additionally possible to connect an independent **VCP operator terminal** that can, for example, be integrated in the front of the control cabinet.

Standard Control Panel

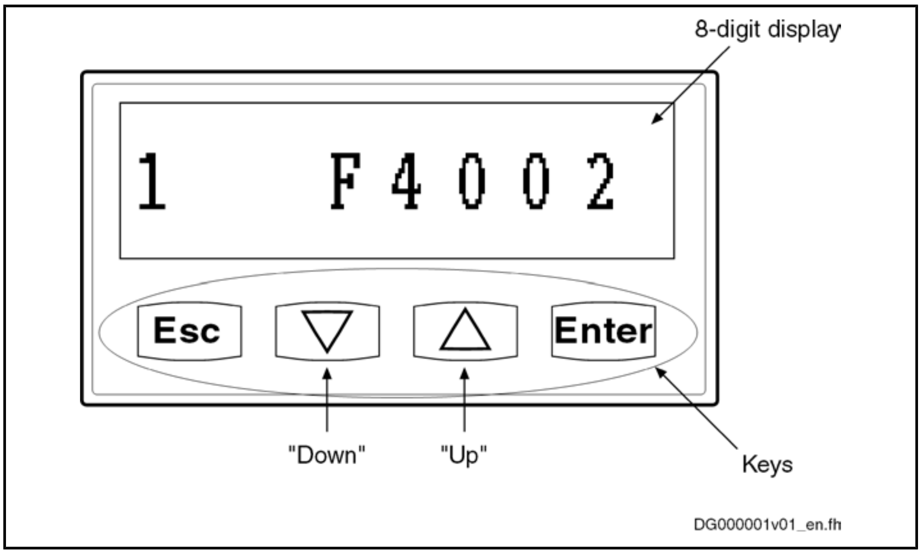


Fig.10-10: Standard control panel with display and control elements (example of display)

Possibilities of Display of Standard Control Panel

The standard control panel allows the following displays:

- Status of the master communication
- Operating status
- Activated commands and command diagnoses
- Warnings and diagnostic error messages
- Extended displays such as contents of error memories, diagnostic message memory, operating hours counter of control section, operating hours counter of power section, type designation of firmware active in the device, safety technology code (if safety technology option available)

Possible Settings with Standard Control Panel

The following settings can be made with the standard control panel:

- Set the drive address (drive number in the bus system of the master communication)
- Set the length of the fiber optic cable
- Activate the master communication mode "Easy Startup"

Command Activation with Standard Control Panel

The following commands can be activated with the standard control panel:

- Activate "S-0-0262, C07_x Load defaults procedure command" (load controller parameters or basic parameters)
- Activate other commands, such as:
  - C2200 Backup working memory procedure command
  - C2300 Load working memory procedure command
  - C2500 Copy IDN from optional memory to internal memory
  - C2600 Copy IDN from internal memory to optional memory
  - C2900 Firmware update from MMC

Comfort Control Panel

Compared to the standard control panel, the comfort control panel, due to the fact that it can be programmed, provides additional settings, as well as additional display and command functions.

Possibilities of Display of Comfort Control Panel

Additional possibilities of display of the comfort control panel (in addition to the possibilities of display of the standard control panel), for example:

- Cyclic parameter display
- Measured value of motor temperature sensor
- Message threshold or shutdown threshold for motor temperature
- Active switching frequency (PWM)

Possible Settings with Comfort Control Panel

Additional possibilities of setting of the comfort control panel (in addition to the possible settings of the standard control panel), for example:

- Language selection
- Set/change single parameters
- Input of motor data acc. to type plate data for asynchronous third-party motors

Command Activation with Comfort Control Panel

Activation of further commands with the comfort control panel (in addition to the command activation with the standard control panel), for example:

- C3200 Command Calculate motor data
- C3600 Command Motor data identification

The comfort control panel particularly supports the commissioning of asynchronous third-party motors; another commissioning tool is not required for this purpose. The required steps are given by the display, the corresponding input is made by means of the keys of the control panel.

Independent VCP Operator Terminals

VCP operator terminals are separate components (terminals) that can be used in addition to the standard or comfort control panel. They are connected to the serial interface of the controller via a separate line. This allows integrating a VCP operator terminal in the front of the control cabinet, for example.

By means of a configuration tool it is additionally possible to configure other application-dependent settings, displays and command functions.

10.4.2 Standard Control Panel

Brief Description

The standard control panel of an IndraDrive controller has an 8-digit display and four keys located underneath it.

The display shows operating states, command and error diagnoses, as well as present warnings.

Using the four keys, the commissioning engineer or service technician can opt to display extended diagnostic messages at the drive controller and to activate simple commands (in addition to master communication using the commissioning tool or NC control unit).

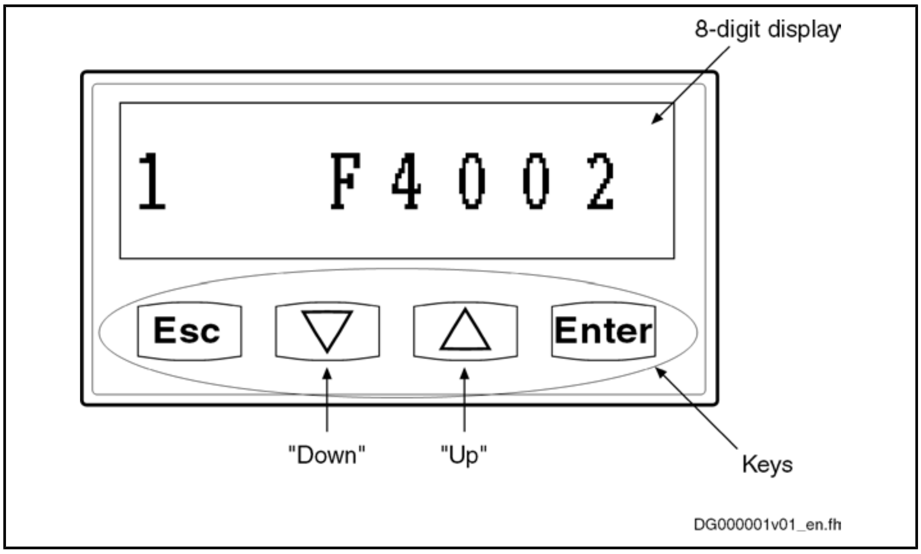


Fig. 10-11: Standard Control Panel With Display and Control Elements (Example of Display)

Functional Description

Standard Displays

The display of the IndraDrive controller automatically shows:

- Status of the master communication
- Operating status
- Activated commands and command diagnoses
- Warnings and diagnostic error messages

The displays have priorities, because it is impossible to have various displays at the same time!

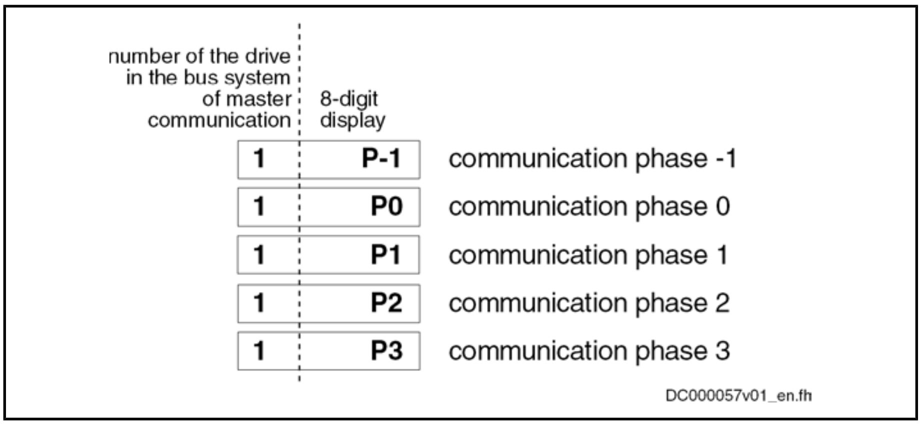


Fig. 10-12: Displays During Phase Progression of the Master Communication

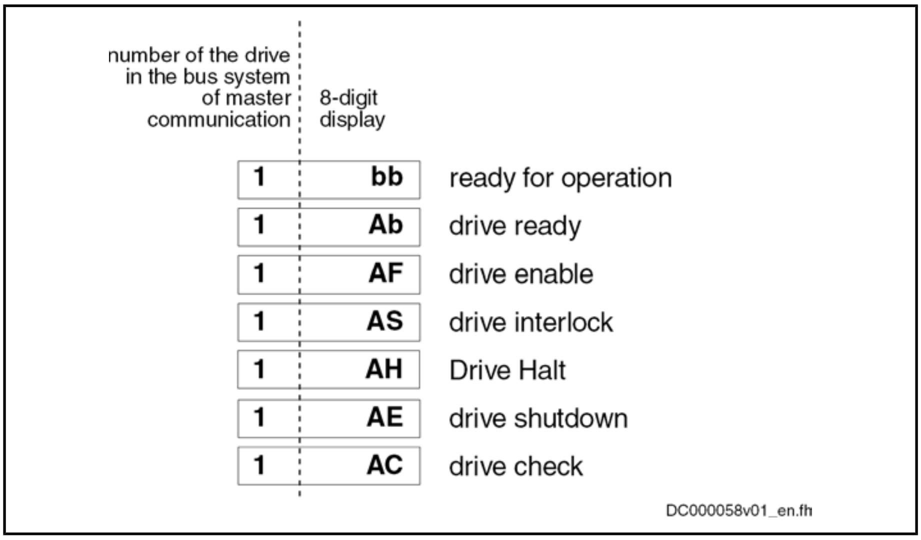


Fig. 10-13: Operating Status Displays

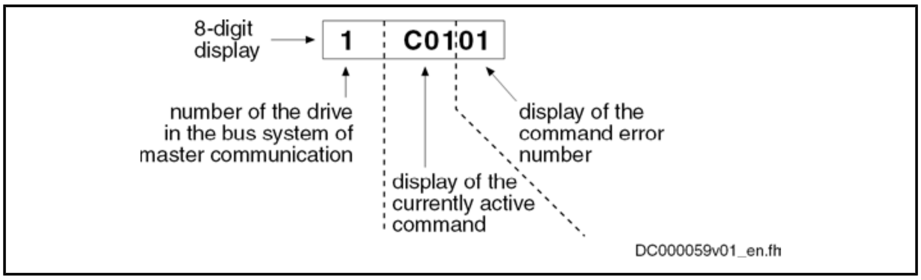


Fig. 10-14: Explanation of Command Error Displays

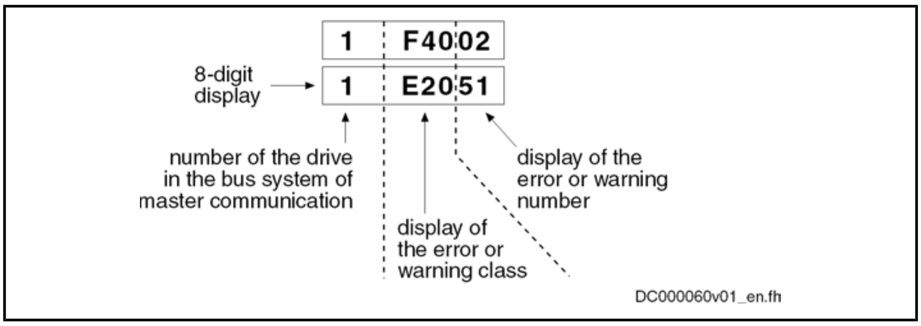


Fig. 10-15: Explanation of Error and Warning Displays

Priorities of Display

The current drive status is displayed with highest priority.

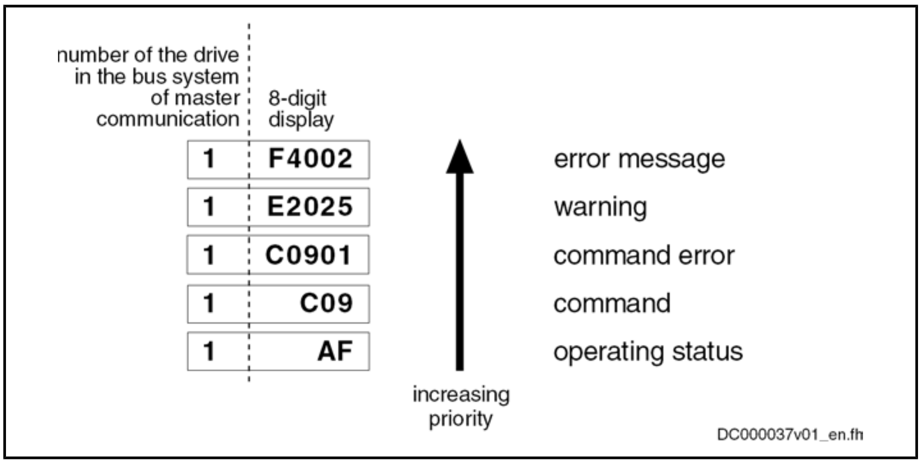


Fig. 10-16: Priorities of Displays (With Example Displays)

Activating Extended Display, Command Menu and Service Menu

By simultaneously pressing the "Enter" and "Esc" keys (for 8 s) in the standard display, you can call up extended displays; subsequently pressing the Up key first activates the command menu and pressing it again activates the service menu.

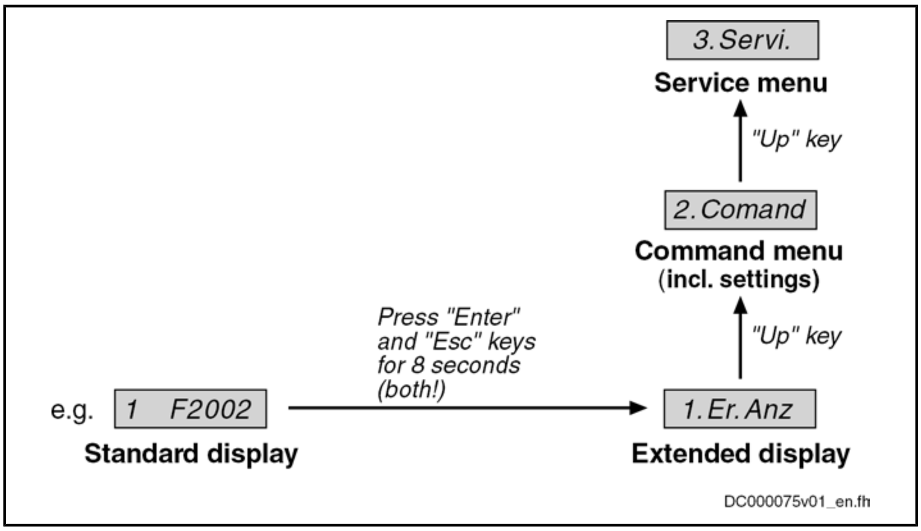


Fig. 10-17: Activating the Extended Display, the Command Menu and the Service Menu

Extended Displays

By means of the extended displays, it is possible to additionally call up the contents of certain parameters:

- Error memory
- Diagnostic message memory
- Operating hours counter control section
- Operating hours counter power section
- Type designation of the firmware active in the device
- Safety technology code, change counter of safety technology and operating hours counter since last change (if safety technology option available)
- MAC address (when using CCD option, SERCOS III master communication or control section CSH01.2)

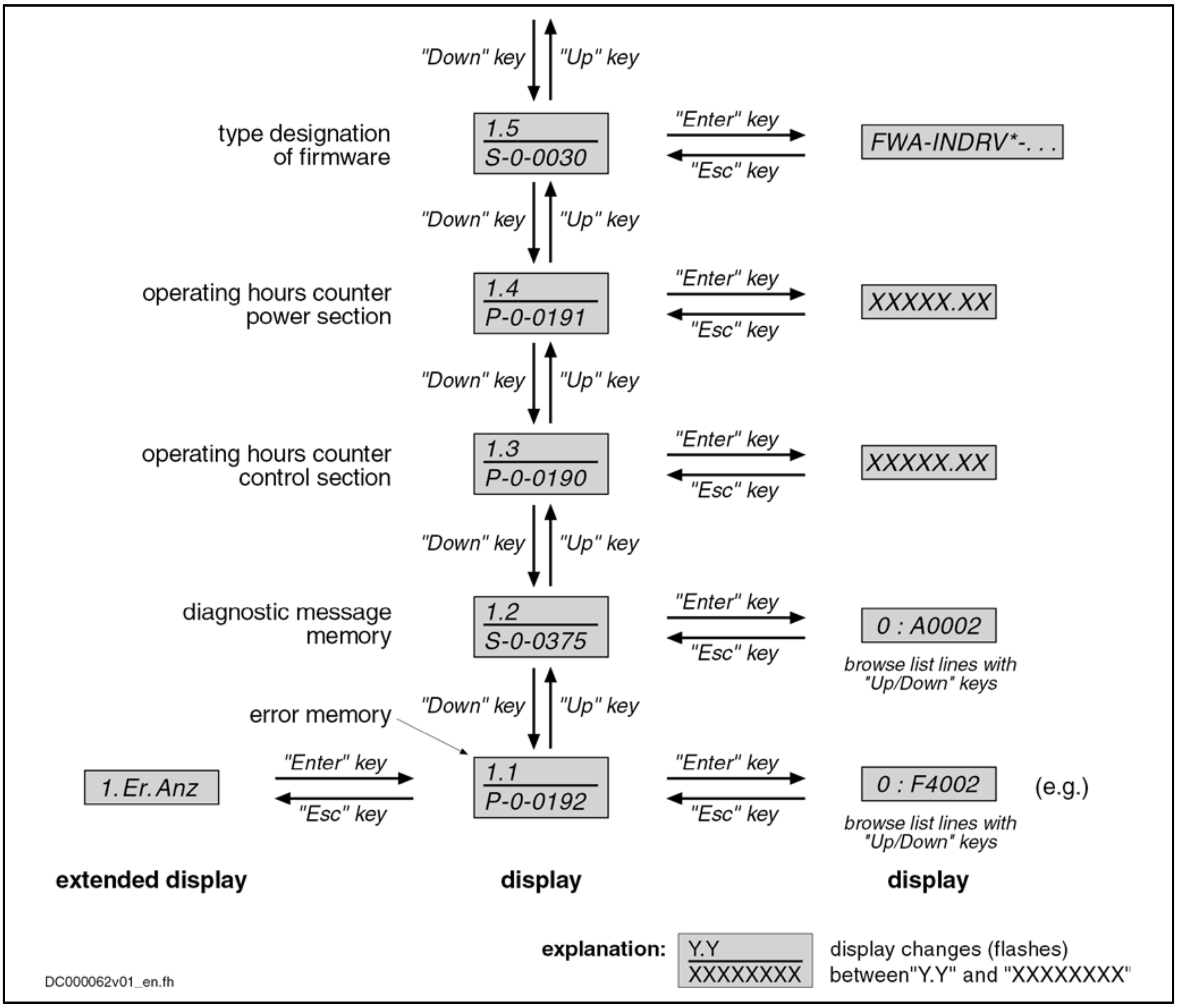


Fig. 10-18: Activating the Extended Displays

For more details on diagnostic messages, error messages and operating hours counters, see the respective sections of the present documentation.

Command Menu

Starting from the extended display, you can activate the command menu by pressing the "Up" key. In this menu, you can make several settings:

- Set the drive address (drive number in the bus system of the master communication)
- Set the length of the fiber optic cable
- Other communication settings (IP address, gateway address and subnet mask) for CCD option, SERCOS III master communication or control section CSH01.2
- Activate the easy master communication mode "Easy Startup"
- Activate "S-0-0262, C07_x Load defaults procedure command" (load controller parameters or basic parameters)
- Activate other commands, such as:
  - C2200 Backup working memory procedure command
  - C2300 Load working memory procedure command
  - C2800 Analog input adjust command

  - C2000 Command Release motor holding brake

    (must be enabled by means of configuration)
- Switch the communication phases between operating mode (OM) and parameter mode (PM)

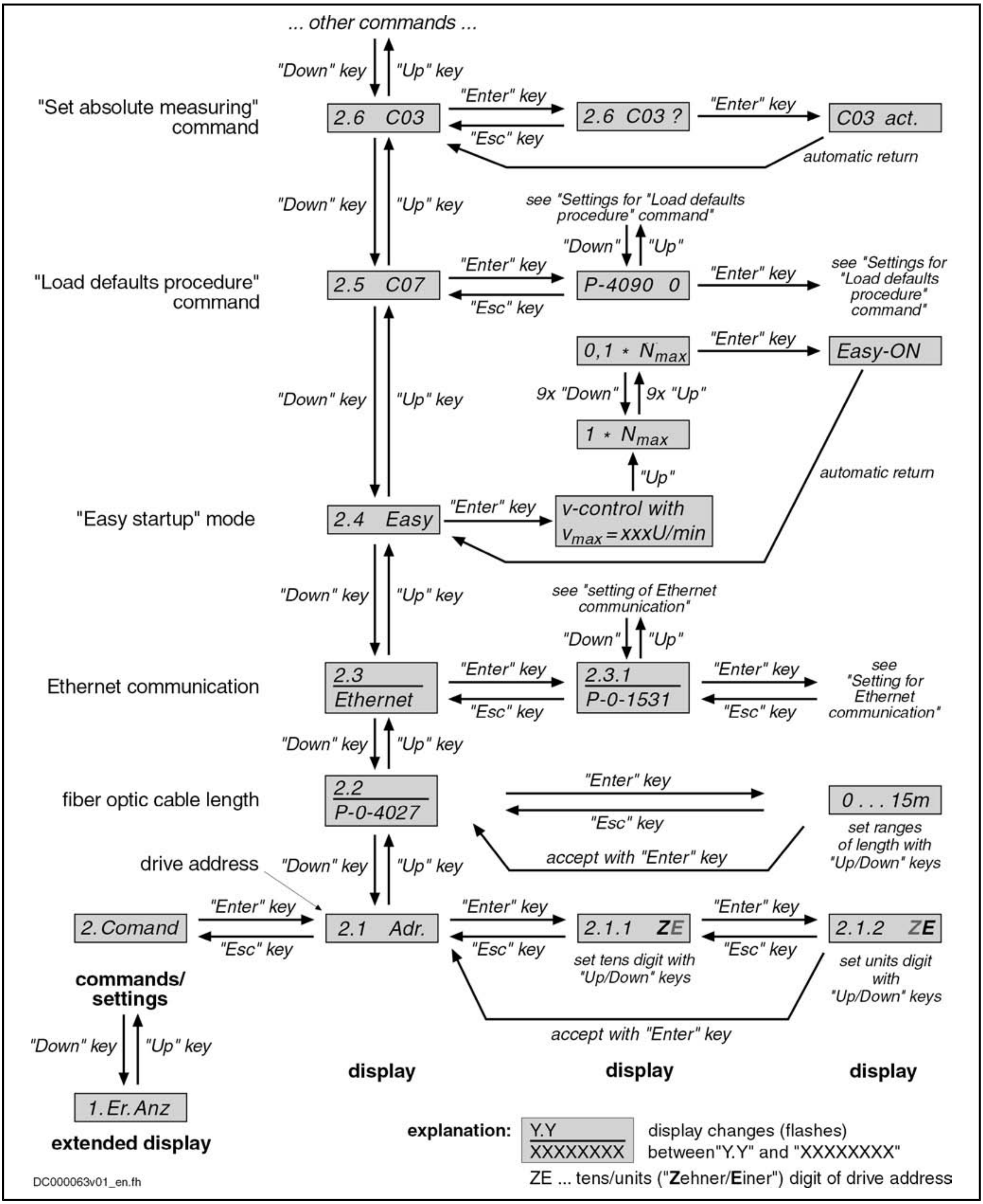


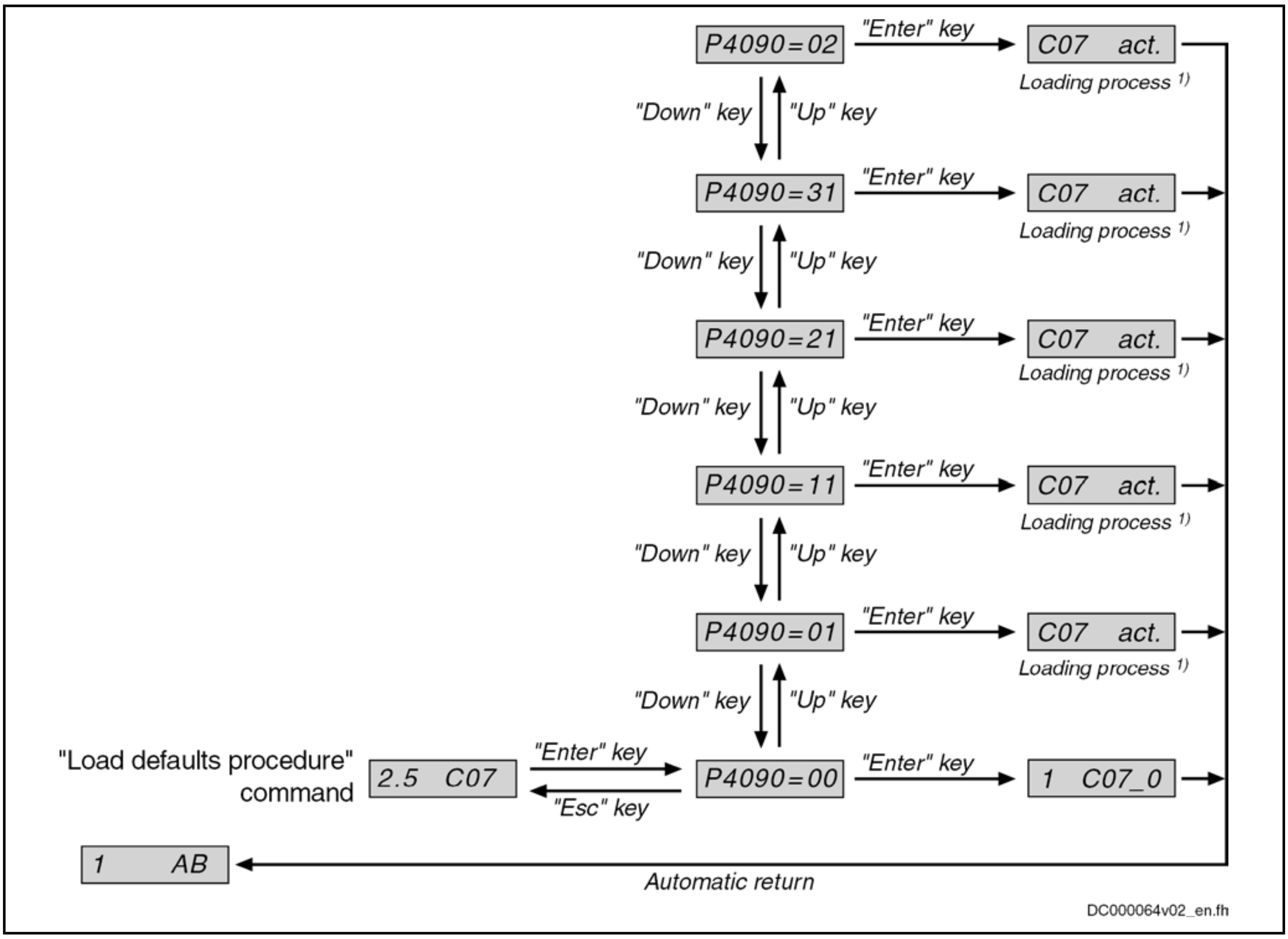
Fig. 10-19: Activating Commands/Settings That Can be Accessed Via the Control Panel

Settings for the "Load Defaults Procedure" Command

The parameter "S-0-0262, C07_x Load defaults procedure command" can be activated via the standard control panel, too. Depending on the configuration in parameter "P-0-4090, Configuration for loading default values", different basic parameter sets are loaded internally. The following configurations in parameter P-0-4090 are possible via the standard control panel, the last two digits of the hexadecimal parameter value being displayed on the standard display:

- Loading motor-specific control loop parameter values → 0x00**00**
- Loading basic parameter values, without exception → 0x00**01**
- Loading basic parameter values, except for master communication parameters → 0x00**11**
- Loading basic parameter values, except for parameters of the drive-internal PLC (MLD) → 0x00**21**
- Loading basic parameter values, except for master communication and MLD parameters → 0x00**31**
- Loading default values to the MLD parameters → 0x00**02**

☞ After the command C07_x has been executed, the parameter P-0-4090 is automatically reset to its default value (0x00**00**)!



1) According to the value in P-0-4090 (see Parameter Description)

Fig. 10-20: Setting the Parameter P-0-4090 for "Load Defaults Procedure" Via the Standard Control Panel

Settings for Ethernet Communication

For communication in Ethernet networks, make the following settings for the relevant interfaces:

- IP address
- Subnet mask
- Default gateway

The following interface is Ethernet-based, can be set via the control panel and is supported by the MPx04 firmware:

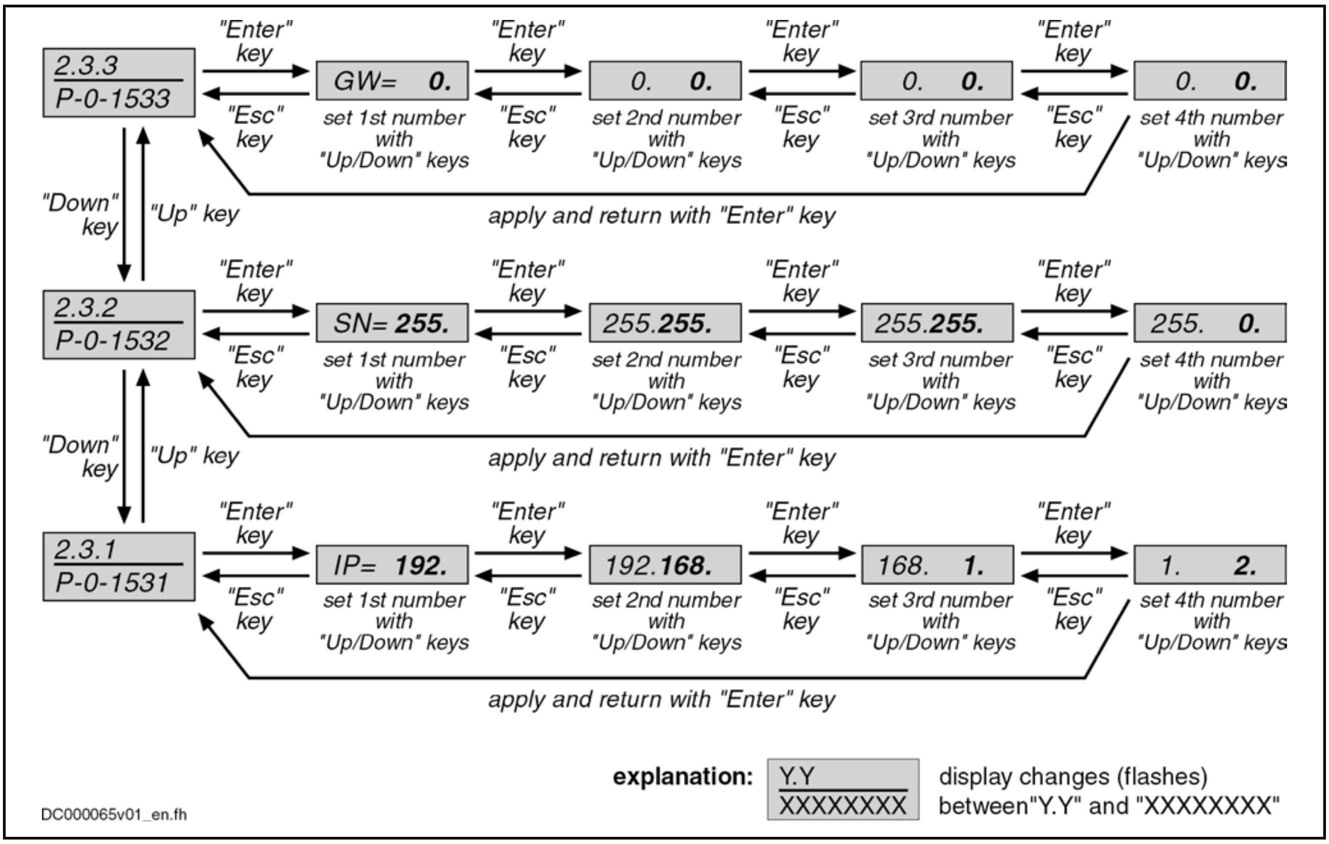
- Engineering Port of control section (P-0-1531, P-0-1532, P-0-1533)

☞ To get a more detailed description of the Ethernet communication and information on its possibilities of use with MPx04 firmware, please contact your Bosch Rexroth sales representative!

Other interfaces are Ethernet-based, can be set via the control panel, but are **not supported** by the MPx04 firmware:

- Master communication SERCOS III (S-0-1020, S-0-1021, S-0-1022)
- CCD interface (P-0-1641, P-0-1642, P-0-1643)

The settings for Ethernet communication can be made via the standard control panel and are basically the same for all Ethernet-based interfaces.



GW	Gateway address, e.g. 0. 0. 0. 0
SN	Subnet mask, e.g. 255.255.255. 0
IP	IP address, e.g. 192.168. 1. 2

Fig. 10-21: Setting the Ethernet Communication, as an Example of the Control Section Engineering Port

Switching the Communication Phases

Switching the communication phases between operating mode (OM) and parameter mode (PM) via the control panel is possible with all master communications, except for SERCOS interface. With SERCOS interface, phase switch controlled via the control panel can only be carried out with active easy startup mode!

☞ In order to execute "C07_1 Load defaults procedure com. (load basic parameters)", the parameter mode (PM) has to be activated.

Handling, Diagnostic and Service Functions

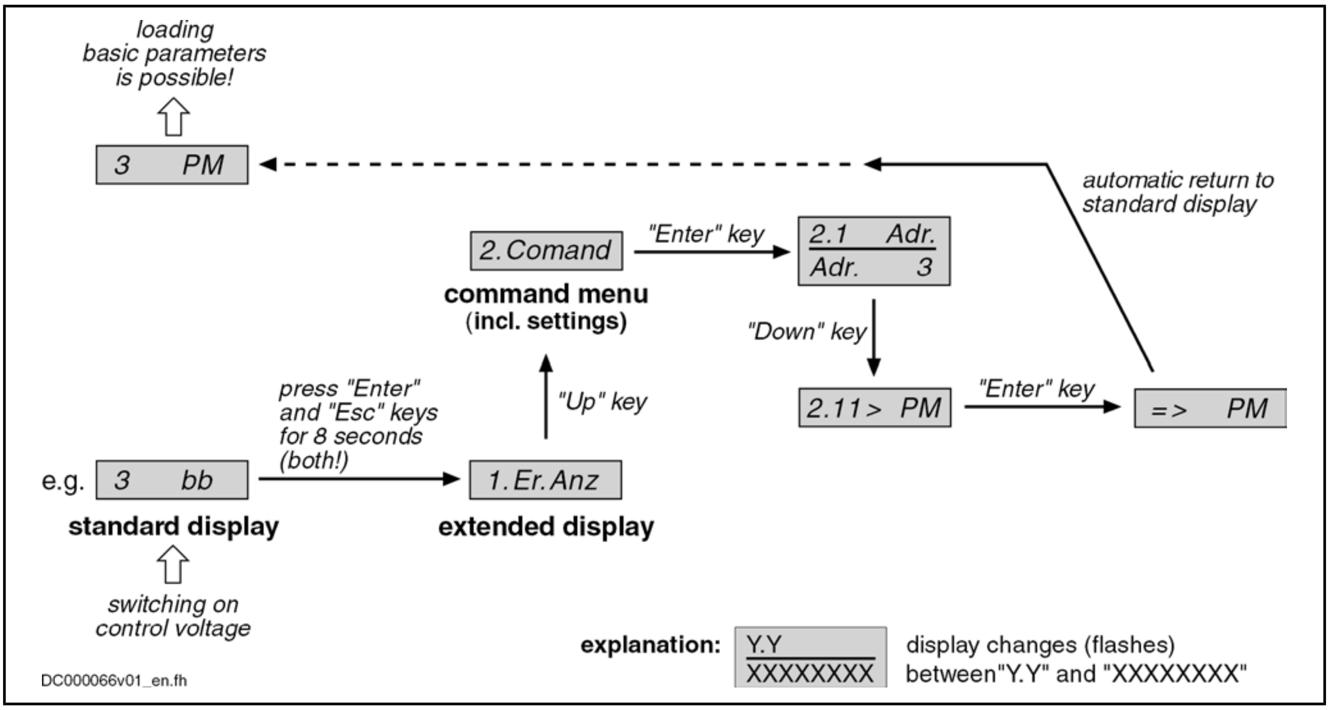


Fig. 10-22: Activating the Parameter Mode Via the Control Panel

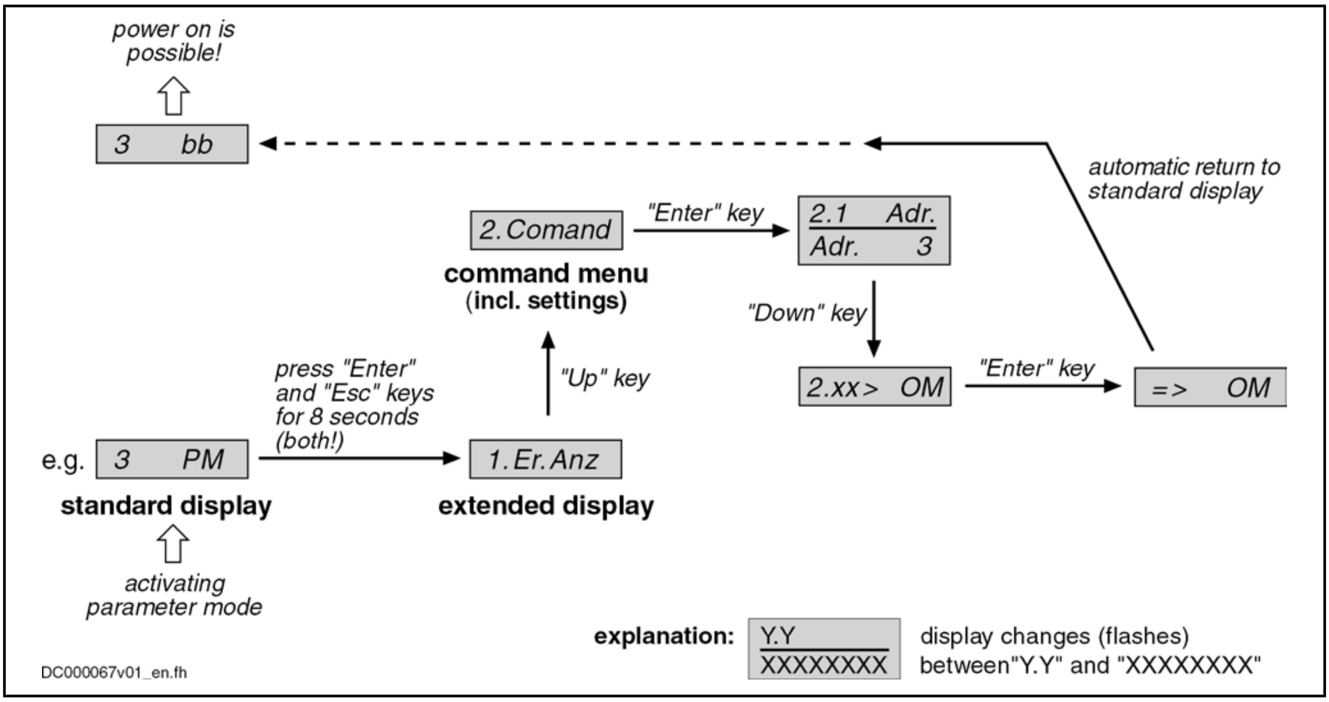


Fig. 10-23: Switching Back From Parameter Mode to Operating Mode Via the Control Panel

Service Menu

Starting from the command menu, you can activate the service menu by pressing the "Up" key. It supports the following actions:

- Firmware update with previous saving of the parameter values on the internal memory (flash), if the optional memory (MMC) is the active memory (MMC as "programming module"). After the update, the parameter values can be loaded to the MMC again from the internal memory (flash).

  Note: If the internal memory (flash) is the active storage medium ("hot plug" of the MMC), the parameter values are already available in the device and do not need to be saved before the MMC-based firmware update.

In this case, pressing the "Enter" key with the display "Save data" is without effect!

- Replacement of device with saving of parameter values on MMC, if the internal memory (flash) is the active memory. After the device has been replaced, firmware and values of the drive parameters, as well as PLC retain data, can be loaded from this MMC to the replacement controller.

  Note: If the control section has been equipped with the optional module "MDx", the retain data of the PLC are saved on the MMC in addition to the values of the drive parameters, when "Save data" is executed! When the MMC is the active memory, the drive parameters are not saved, because they have already been stored on the MMC, but the PLC data are stored on the MMC.

- Copy parameters:
  - Storing the parameter values and, if necessary, the PLC retain data from the device-internal, non-volatile memories (onboard flash and, if available, memory of optional module "MDx") on the MMC
  - Loading the parameter values stored on the MMC to the non-volatile memories of the controller

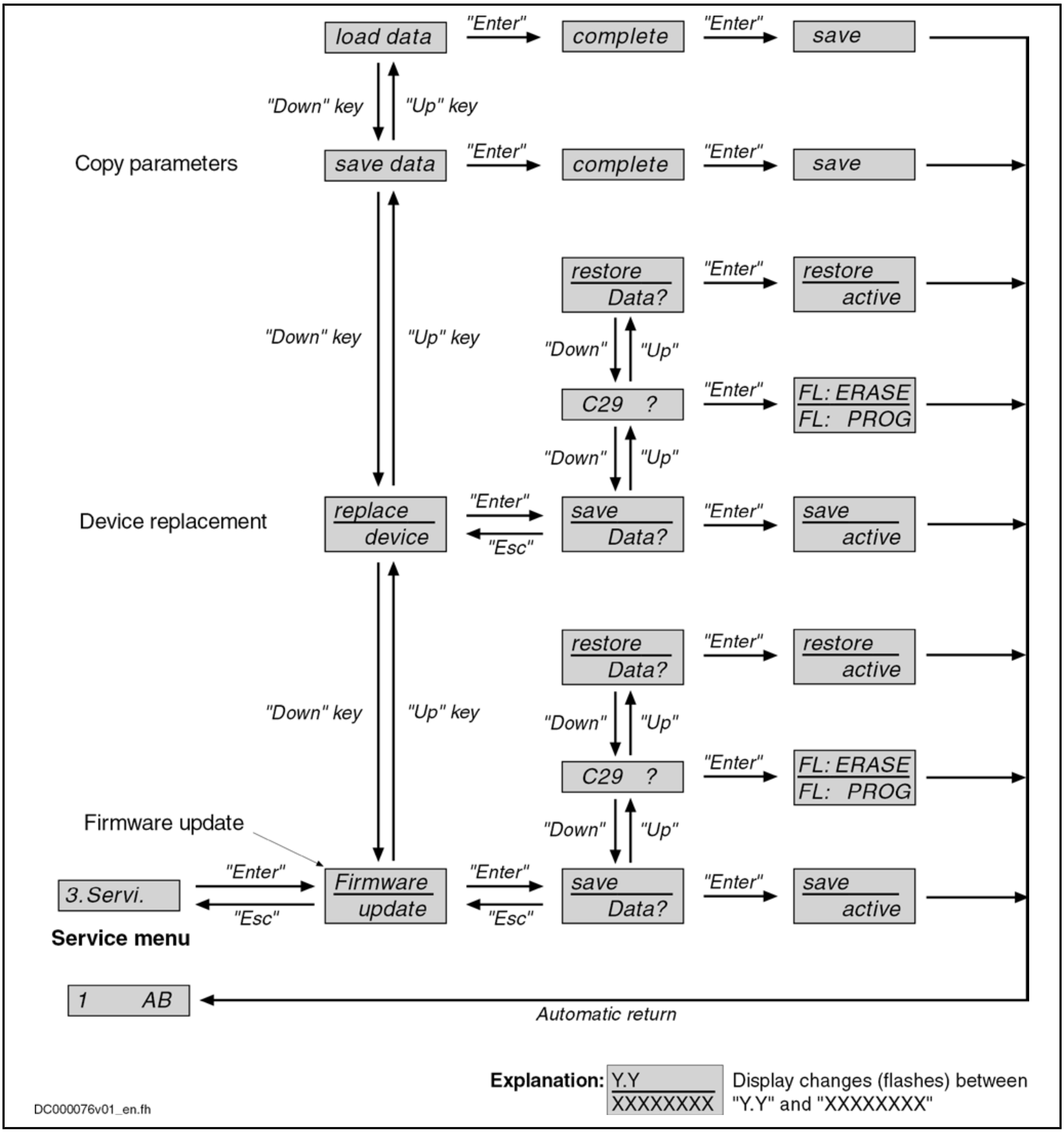


Fig. 10-24: Activating the Functions of the Service Menu

Notes on Commissioning

CAUTION

Property damage caused by command-dependent activation of motors and moving elements!

⇒ Bring axis resp. moving parts in safe initial position; limit travel range and drive power!

By pressing the "Esc" key again, the standard display will reappear.

☞ The input via the keys is polled in an 8ms-cycle, the display is updated in an 8ms-cycle, too!

10.5 MultiMediaCard (MMC)

10.5.1 Brief Description

The MultiMediaCard (MMC) is a storage medium that can be inserted in the slot provided for this purpose at the front of the controller. The MMC can store drive firmware, drive parameters and other files (such as PLC programs or user-side files, e.g. with document properties). The MMC can be used optionally.

As **stationarily** (permanently) plugged storage medium, the MMC can be used as:

- "Programming module", as active, non-volatile memory containing the current axis-specific parameter values and the firmware active in the drive.

As a **temporarily** plugged storage medium, the MMC can be used for:

- Replacing firmware via command
- Transmitting drive parameter sets and firmware to other drives for serial commissioning via command
- Saving the parameter values after initial commissioning
- Reestablishing the initial parameter status of the drive (loading the saved parameter values)

  Attention: Not for drives with absolute value encoder and modulo format!

  See "Initial Commissioning/Serial Commissioning"

Without firmware or parameter loss, the controller can be changed from MMC device status "device without MMC" to the status "device with stationarily plugged MMC" and vice versa.

☞ The MMC commands can be started via the control panel. This is especially advantageous when replacing devices!

☞ It is only allowed to use MMCs by Bosch Rexroth (type designation PFM02.1-****-FW)!

Pertinent Parameters

- P-0-4065, Non-volatile memory active
- P-0-4072, C2900 Command Firmware update from MMC
- P-0-4091, C2500 Copy IDN from optional memory to internal memory
- P-0-4092, C2600 Copy IDN from internal memory to optional memory

Pertinent Diagnostic Messages

Copying parameters from MMC to flash:

- C2500 Copy IDN from optional memory to internal memory
- C2502 Error when accessing the MMC
- C2504 Error when writing data to internal memory

Copying Parameters from flash to MMC:

- C2600 Copy IDN from internal memory to optional memory
- C2602 Error when accessing the MMC
- C2604 Error when reading the internal memory

Replacing firmware via MMC:

- C2900 Command Firmware update from MMC

- C2903 Error when accessing the MMC
- C2904 Error when accessing the flash
- C2905 Programmed firmware defective

Storage medium missing:

- F2006 MMC was removed

10.5.2 MMC Folder Structure

The MMC is a non-volatile storage medium that can be read and written both by the controller and via a PC with the appropriate adapter.

☞ Should it be necessary to reformat an MMC of type PFM02.1-****-FW, make sure that FAT, FAT12 or FAT16 formatting is used! FAT32 formatting is not supported and therefore cannot be used!

When being used in IndraDrive devices, the MMC has to have the following folder structure:

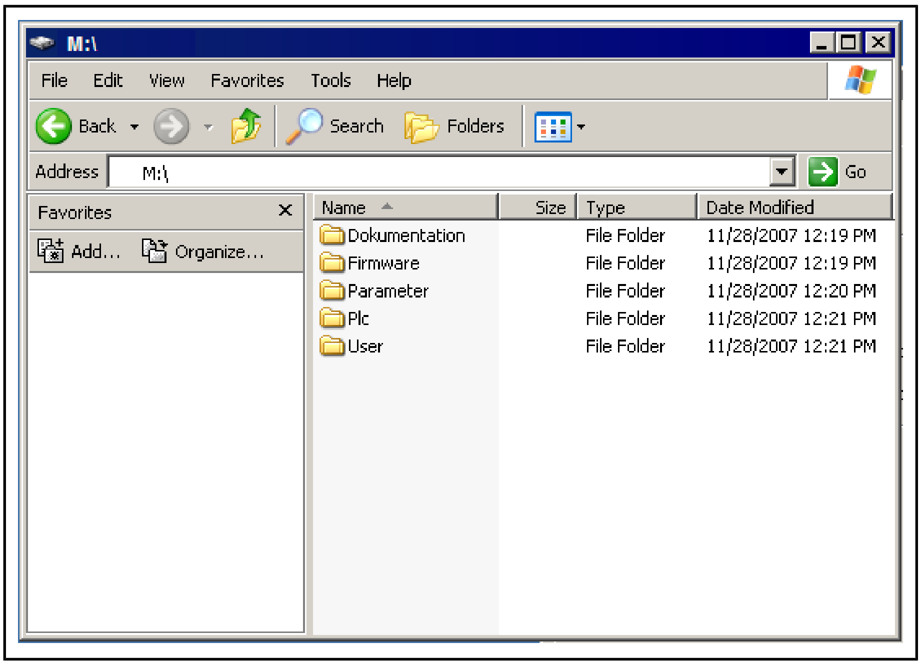


Fig. 10-25: Required Folder Structure of the MMC

The folders on the MMC are provided for the following contents:

Folder "Firmware"

The file with the drive firmware has to be filed in this folder. The file extension has to be **".ibf"**.

The following firmware variants are possible:

- FWA-INDRV*-MPH-… (Advanced single-axis)
- FWA-INDRV*-MPB-… (Basic single-axis)
- FWA-INDRV*-MPD-… (Basic double-axis)

At delivery the MMC has the required folder structure, the "Firmware" folder contains the latest release of the drive firmware.

☞ When replacing the firmware via MMC, make sure that the "Firmware" folder **only contains one file with the extension ".ibf"**. This folder may contain other files, but not with the extension ".ibf"!

Folder "Parameters"

In this folder contains the files with the axis-specific parameter values and the parameter values relevant for replacing the devices:

- A file with the extension "....#1.pbf" (size 320kB)

  → Parameter values to be saved acc. to "S-0-0192 IDN-list of backup operation data"
- A file with the extension "....#1.rbf" (size 16kB)

  → "Retain" data for replacing devices acc. to "P-0-0195, IDN list of retain data (replacement of devices)"

Storage takes place automatically when the MMC is used as "programming module" (stationarily plugged). Storage takes place by a command, if the MMC has only been plugged temporarily.

☞ In the case of the firmware variant "Basic double axis" (FWA-INDRV*-MPD-...), the mentioned files are stored for each of the two axes. The extensions for the files of the second axis are "....#2.pbf" and "....#2.rbf"

If the files are transmitted to the MMC from PC storage media, make sure that the file sizes correspond to the mentioned requirements!

At delivery of the MMC, the basic parameters for the firmware contained on the MMC are included in the folder "parameters".

Folder "Documentation"

At delivery of the MMC, this folder does not contain any files. The customer can store any data in this folder that are useful for handling the firmware or the axis.

Folder "Plc"

The source code and symbol files of the drive PLC ("IndraMotion MLD") are stored in this folder. Storage is triggered via the programming system. At delivery of the MMC, the folder "Plc" is empty.

Folder "User"

At delivery of the MMC, this folder does not contain any files. The customer can store files in this folder. In the future, the folder will be used for extensions of the file handling in the drive PLC ("IndraMotion MLD").

10.5.3 Controller With or Without MMC

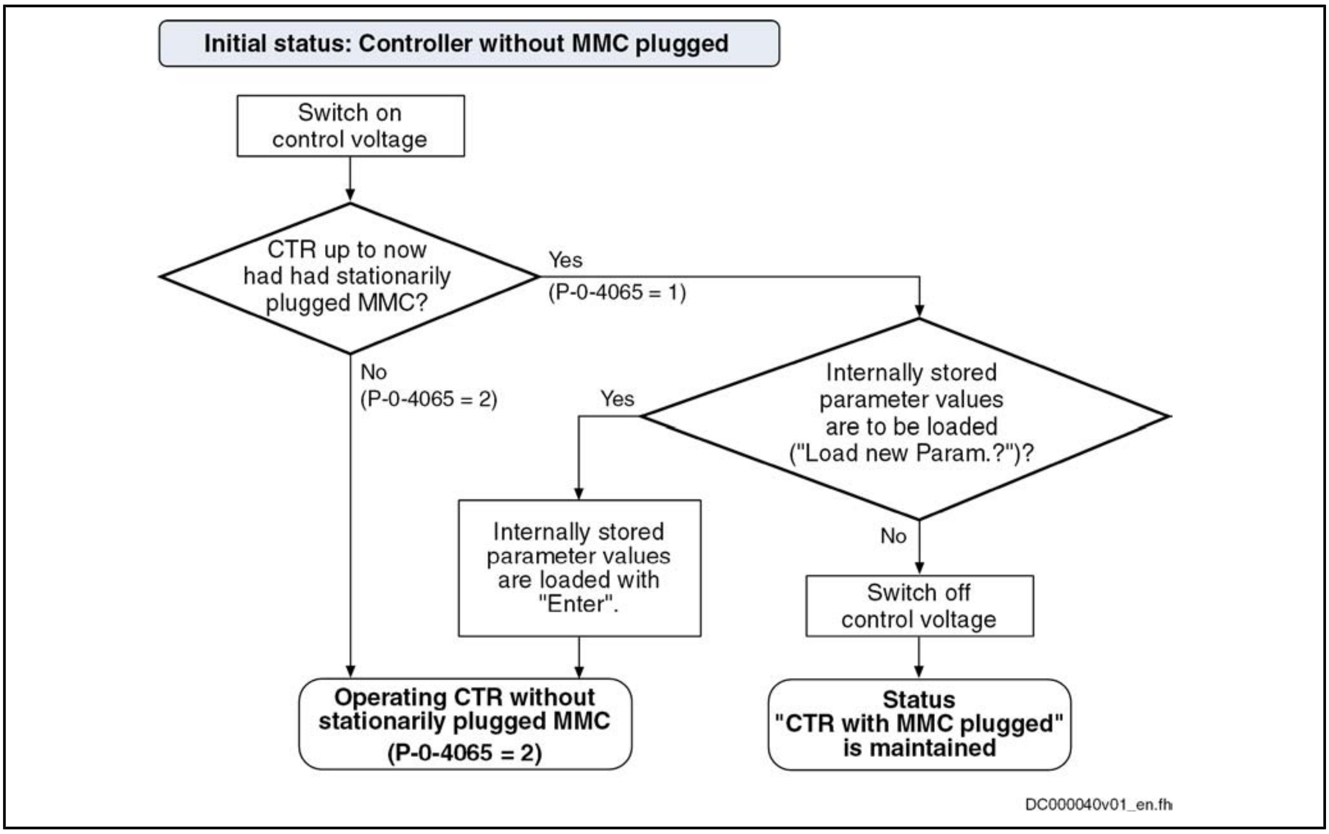
General Information

Depending on the situation of the controller before switching off (device with or without stationarily plugged MMC), it might possibly be necessary to make decisions with regard to parameter update and firmware replacement when switching on.

The device status as regards the MMC is displayed in parameter "P-0-4065, Non-volatile memory active".

Handling, Diagnostic and Service Functions

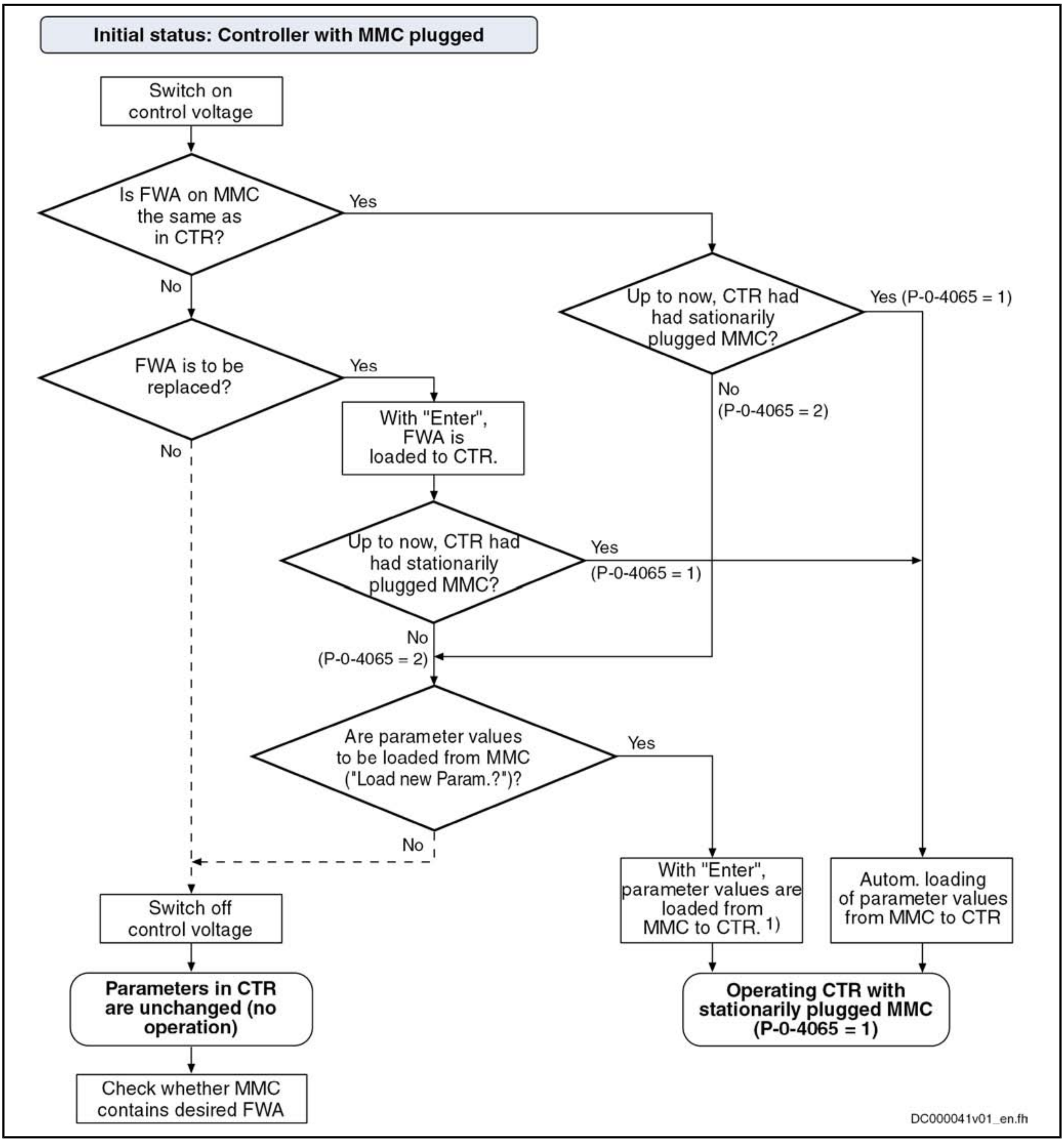
Switching on Controller Without MMC Plugged



MMC	MultiMediaCard (type PFM02.1-…)
CTR	Controller
P-0-4065	Non-volatile memory active

Fig. 10-26: Switching on Controller Without MMC Plugged

Switching on Controller With MMC Plugged



MMC	MultiMediaCard (type PFM02.1-…)
FWA	Drive firmware
CTR	Controller
P-0-4065	Non-volatile memory active
1)	With safety technology option available, further messages will appear (see documentation "Integrated Safety Technology").

Fig. 10-27: *Switching on Controller With MMC Plugged*

If the stationarily plugged MMC is removed from a device during operation, the error message "F2006 MMC was removed" is displayed and the drive reacts with the error reaction that was set. This error message can be deleted, if the same (identical!) MMC has been plugged again. When a different MMC is used, the error message F2006 will appear again!

10.5.4 Using the MMC in the Drive Controller

Replacing Firmware With MMC

The MMC allows transmitting drive firmware to the drive controller in a quick and uncomplicated way. We basically distinguish stationarily and temporarily plugged MMCs.

☞ It is impossible to transmit, the other way round, firmware from the controller to the MMC!

The MMC with the latest release of the drive firmware can be ordered with the type designation

- **PFM02.1-****-FW** with one of the firmware-dependent sub-items:
  - FWA-INDRV*-MPH-**VRS-D5 (Advanced single-axis)
  - FWA-INDRV*-MPD-**VRS-D5 (Basic double-axis)
  - FWA-INDRV*-MPB-**VRS-D5 (Basic single-axis)

☞ An MMC with current release of the required firmware can be ordered from our sales and service facilities.

Carrying out a firmware replacement with MMC depends on different factors. The variants of firmware replacement with MMC, the conditions and the sequence of firmware replacement are described in the section below.

See section "Firmware Replacement"

MMC When Replacing Devices

See "Notes on How to Replace the Devices"

Saving Parameter Values on MMC

Put MMC into controller after boot phase ("hot plug"). In communication phase 2, via control panel or appropriate master communication, activate the command parameter

- P-0-4092, C2600 Copy IDN from internal memory to optional memory.

By starting this command, the application-specific parameter values (according to list parameters S-0-0192 and P-0-0195) are stored on the MMC.

Diagnostic Messages

Respective diagnostic command message:

- C2600 Copy IDN from internal memory to optional memory

The following diagnostic error messages can be signaled:

- C2602 Error when accessing the MMC
- C2604 Error when reading the internal memory

☞ As a matter of principle, it is recommended to additionally save the application-specific parameter values via the "IndraWorks D" commissioning tool or the control master on an external storage medium!

Loading Parameter Values From MMC

Put MMC containing the axis-specific parameter values into controller after boot phase ("hot plug"). In communication phase P2, via control panel or appropriate master communication, activate the command parameter

- P-0-4091, C2500 Copy IDN from optional memory to internal memory.

By starting this command, the application-specific parameter values (according to list parameter S-0-0192) can be

- transmitted to other axes of the same type during serial commissioning

- or -

- loaded to the same controller again to reestablish the initial status.

☞ In the case of drives with absolute value encoder and modulo format, the position data reference has to 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 parameter "S-0-0403, Position feedback value status"!

Diagnostic Messages

Respective diagnostic command message:

- C2500 Copy IDN from optional memory to internal memory

The following diagnostic error messages can be signaled:

- C2502 Error when accessing the MMC
- C2504 Error when writing data to internal memory

If the stationary MMC is removed from a controller in operation or a different MMC is plugged in again, the following message appears:

- F2006 MMC was removed.

Change in Device Status Regarding MMC (Stationary/Temporary)

Device With Stationarily Plugged MMC → Device Without MMC

Sequence for status change "device with stationarily plugged MMC" to "device without MMC":

1. Store axis-specific parameter values stored on previously active MMC via command "C2500 Copy IDN from optional memory to internal memory" in non-volatile memory of controller.
2. Switch control voltage of drive off and remove previously active MMC from controller.
3. Switch drive on again without MMC plugged. During boot phase, display shows message "Load new Param.?". Acknowledge this message by pressing "Enter" key (control panel).

Boot process is completed and drive then waits for other commands or is put into readiness for operation via the control master.

Device Without MMC → Device With Stationarily Plugged MMC

Sequence for status change "device without MMC" to "device with stationarily plugged MMC":

1. Make sure correct firmware has been stored on MMC that in the future is to remain stationarily in device.

   Note: With PC, check whether the folder "Firmware" on the MMC contains the file with the desired firmware!
2. After end of boot phase, plug MMC, in the future remaining in device, in controller, then via command "C2600 Copy IDN from internal memory to optional memory" transmit axis-specific parameter values stored in controller to MMC.

3. After transmission is over, switch control voltage of drive off, leave new MMC in controller and switch drive on again.
4. When controller is booted, message "Firmware update?" appears on display, if firmware stored on MMC differs from firmware stored in device. Acknowledge this message by pressing "Enter" key (control panel)!
5. New firmware now is possibly loaded to controller (firmware update); display shows corresponding download messages.
6. In the course of the boot process, display shows message "Load new Param.?". Acknowledge this message by pressing "Enter" key (control panel). With safety technology option available, further messages will appear (see documentation "Integrated Safety Technology").Acknowledge these messages by pressing "Enter" key (control panel). New MMC now is active MMC of this drive. This means that with each repeated switch-on procedure the parameters are automatically loaded from the MMC and retained on the MMC during operation.

☞ If the parameters stored on the MMC are to be stored in the device-internal non-volatile memory, too, carry out the command "C2500 Copy IDN from optional memory to internal memory"!

Boot process is completed and drive then waits for other commands or is put into readiness for operation via the control master.

10.6 Firmware Replacement

10.6.1 General Notes on How to Replace the Firmware

Basic Principles

Explanation of Terms

For firmware replacement, we distinguish the following cases:

- **Release update**

  An old firmware release (e.g. MPH04**V06**) contained in the device is replaced by a new firmware release (e.g. MPH04**V08**).

- **Version upgrade**

  The old firmware version (e.g. MPH**03**V20) contained in the device is replaced by a new firmware version (e.g. MPH**04**V08).

☞ The paragraphs below describe the recommended options of firmware replacement by higher releases ("update") or versions ("upgrade"). The same conditions and sequences of actions apply to firmware replacement by older releases or older firmware versions.

Firmware for IndraDrive is replaced using the following hardware and software:

- **MultiMediaCard (MMC)**
- **PC with software "IndraWorks D"**

☞ The commissioning software "IndraWorks D" can be ordered from one of our sales and service facilities under the designation SWA-IWORKS-D**-04VRS-D0-CD650-COPY (part no. R911319744). The scope of supply of "IndraWorks D" contains a documentation which describes the operation of the program.

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. Be absolutely sure to save parameter values before any firmware version upgrade (for release update this is recommended), as otherwise complete (re-)commissioning is required.

   See section "Loading, Storing and Saving Parameters"
3. Drive controller **mustn't** be in operating mode (communication phase 4) (cf. P-0-0115).

General Notes on How to Carry Out Firmware Replacement

You have to observe the following points when carrying out the firmware replacement:

- Do not switch off the 24 V control voltage while replacing the firmware.
- Firmware replacement always must be carried out completely, i.e. firmware on optional safety technology module must be replaced, too.
- For firmware replacement, we distinguish between **release update** and **version upgrade**.

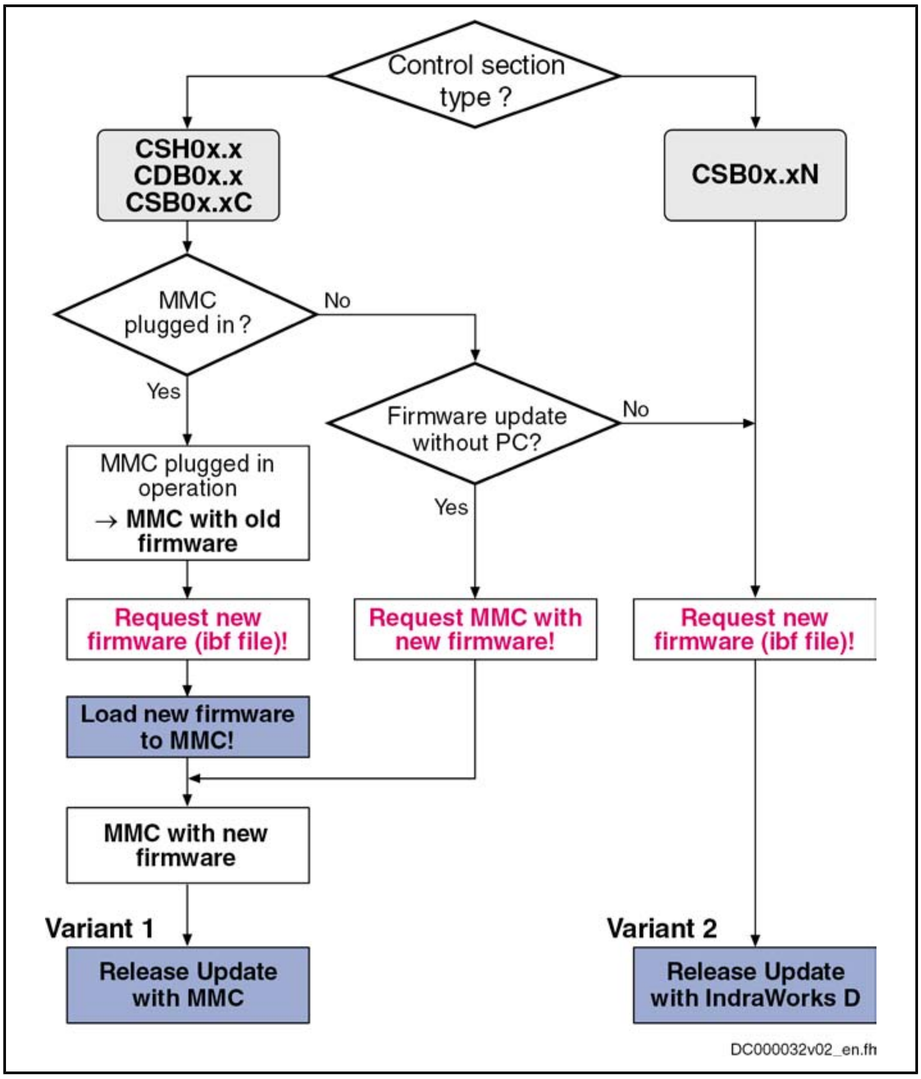
☞ When firmware is replaced in conjunction with the option "starting lockout" (L1), this does not require any specific measure, i.e. the additional measures described below only apply to the use of option "S1"!

10.6.2 Firmware Release Update

General Information

When firmware in a drive controller is replaced by firmware of a **new release**, this is called firmware release update (e.g. FWA-INDRV*-MPH-04**V06**-D5 replaced by FWA-INDRV*-MPH-04**V08**-D5).

The described sequences of the firmware release update depend on the configuration of the control section and the hardware (MMC or PC) used for update. The basically recommended sequence of the firmware release update is illustrated in the scheme below:



CSH0x.x	ADVANCED single-axis control section
CDB0x.x	BASIC double-axis control section
CSB0x.xC	BASIC single-axis control section (configurable)
CSB0x.xN	BASIC single-axis control section (not configurable)

Fig. 10-28: Schematic Sequence of Firmware Release Update

☞ The actions to be taken which are marked with dark background in this figure are described in the paragraphs below.

Loading New Firmware to MMC

Requirements

The following requirements must have been fulfilled for loading firmware to the MMC of the drive:

- New firmware available (ibf file)
- PC with MMC reader
- MMC with old firmware in drive

Loading Firmware to MMC

The following steps are required for loading the firmware to the MMC:

1. Switch drive off and remove MMC.
2. Plug MMC into MMC reader and open folder "Firmware" on MMC.
3. Delete old firmware (e.g. FWA-INDRV*-MPH-04**V06**-D5.ibf).

4. Copy new firmware (e.g. FWA-INDRV*-MPH-04**V08**-D5.ibf) to folder "Firmware".

   Note: Only one firmware file may be stored in the folder "Firmware" on the MMC. With several firmware files, the message "MMC not correct" appears on the display of the drive after booting.

5. Remove MMC from MMC reader after writing process has been completed.

Variant 1: Release Update With MMC

Selection Criterion

Carrying out the firmware release update with MMC makes sense when the controller has **not** been equipped with a BASIC single-axis control section of the CSB0x.xN type.

Firmware Update With MMC

The optional MultiMediaCard (MMC) allows transmitting drive firmware to the drive controller in a quick and uncomplicated way.

☞ As the MMC is a storage medium that can be written in a simple way (e.g. via PC), it is recommended that you check the MMC content before downloading the firmware. You have to make sure that the MMC really contains the appropriate firmware type.

An MMC with the current release of the required firmware can be ordered from one of our sales and service facilities.

Carrying out the firmware release update with MMC requires the following steps:

1. **Load firmware**

   ⇒ Switch drive off!

   ⇒ Plug MMC with new firmware into corresponding slot at controller.

   ⇒ Restart drive with MMC plugged.

   After drive has been booted, the following message appears:

   - "Firmware update ?"

   ⇒ Acknowledge this message by pressing "Enter" key of control panel. By doing this, firmware is loaded from plugged MMC to controller.

   The messages below will be displayed, depending on the operating status of the drive:

   - "Load Param from MMC" or "Load new param?"
   - "Activate new MMC?"
   - "F2120 MMC: defective or missing, replace"

   ⇒ Switch off drive, remove MMC (if drive was operated without MMC plugged) and restart drive!

2. **Put machine into ready-for-operation status**

   ⇒ Put machine into ready-for-operation status again according to machine manufacturer's instructions.

   ⇒ Check functions of drive.

3. **Check safety technology parameters** (only when safety technology has been activated in the drive)

   In the case of a release update, safety technology parameters are retained. With safety technology activated, the following steps are additionally required:

   ⇒ Check whether correct safety technology parameter settings for drive are still available.

To do this, check the following points:

- Data in parameter "P-0-3205, Safety technology device identifier"
- Status of safety technology via parameter "P-0-3207, Safety technology password level" (in the case of active and locked safety technology, level is 2)
- Change counter of safety technology memory (parameter "P-0-3201, Change counter of safety technology memory")
- Operating hours at last change of memory (parameter "P-0-3202, Operating hours at last change of memory")

CAUTION

If the integrated safety technology is used and a firmware release update is carried out for firmware versions older than MPx02V20, it is necessary to repeat the safety technology acceptance test

After firmware release update, the safety technology acceptance test must be carried out again!

Variant 2: Release Update With IndraWorks D

Selection Criterion

The following requirements should have been fulfilled in order that carrying out the firmware release update with IndraWorks D makes sense:

- Controller is operated without MMC.

- or -

- Controller has been equipped with BASIC single-axis control section of type CSB0x.xN.

Firmware Update With IndraWorks D

Carrying out the firmware release update with IndraWorks D requires the following steps:

1. **Load firmware**

   ⇒ Call IndraWorks D.

   ⇒ Load project for corresponding axis or create new project; to do this, address axis via a serial connection.

   ⇒ Switch project "online".

   ⇒ Select/highlight controller and call "Firmware Management" in context menu.

   A new window opens and firmware currently available in drive is displayed on its right side. On left side of window, firmware available in current firmware directory is displayed.

   ⇒ Highlight new firmware (*.ibf file) on left side and start firmware download via "Download" button.

   Firmware download runs automatically and all required firmware components are loaded to drive.

   ⇒ After firmware download has been completed, close "Firmware Management" window.

2. **Put machine into ready-for-operation status**

   ⇒ Put machine into ready-for-operation status again according to machine manufacturer's instructions.

   ⇒ Check functions of drive.

3. **Check safety technology parameters** (only when safety technology has been activated in the drive)

In the case of a firmware release update, safety technology parameters are retained. With safety technology activated, the following steps are additionally required:

⇒ Check whether correct safety technology parameter settings for drive are still available.

To do this, check the following points:

- Data in parameter "P-0-3205, Safety technology device identifier"
- Status of safety technology via parameter "P-0-3207, Safety technology password level" (in the case of active and locked safety technology, level is 2)
- Change counter of safety technology memory (parameter "P-0-3201, Change counter of safety technology memory")
- Operating hours at last change of memory (parameter "P-0-3202, Operating hours at last change of memory")

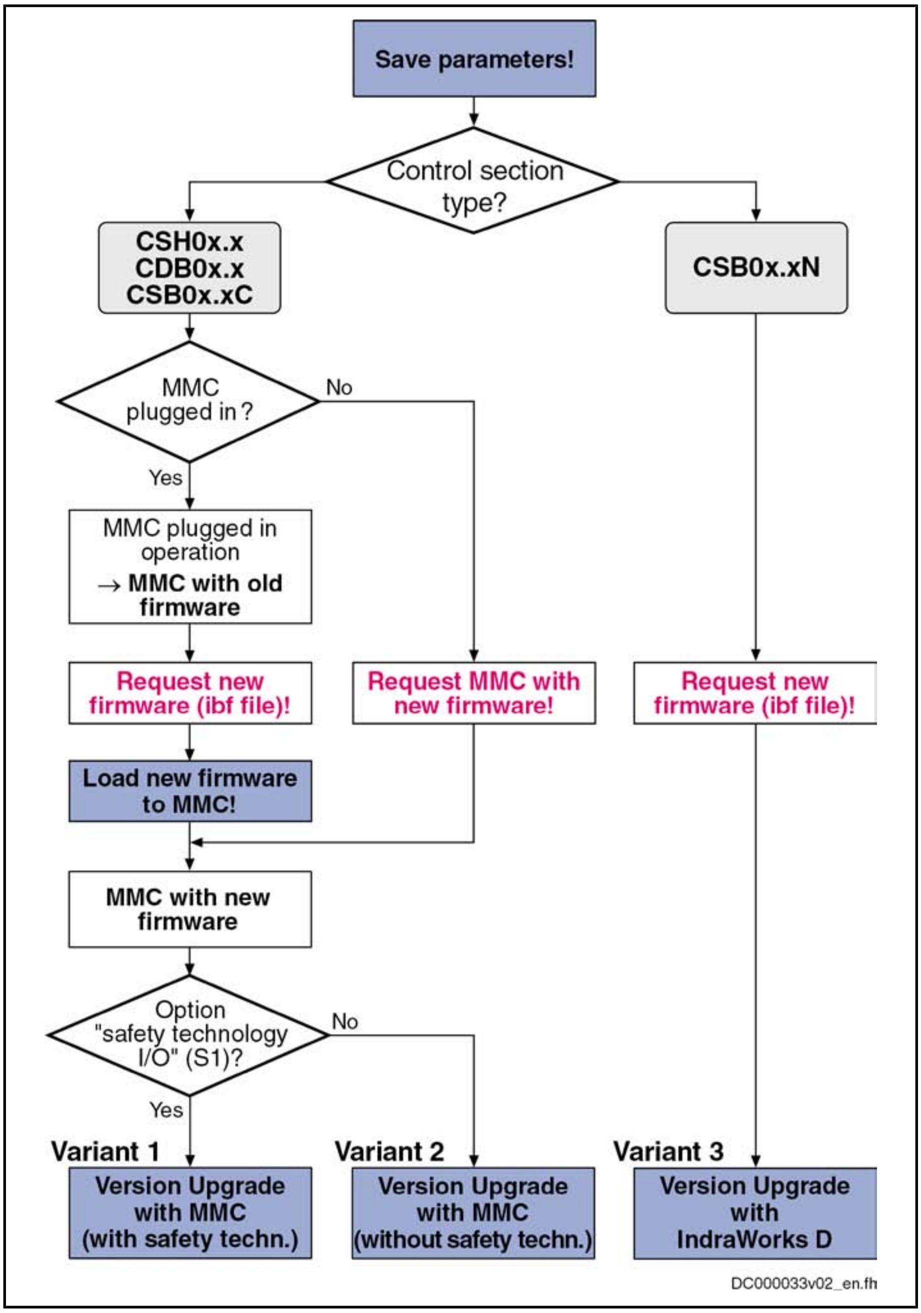
10.6.3 Firmware Version Upgrade

General Information

When firmware in a drive controller is replaced by firmware of a **new version**, this is called firmware version upgrade (e.g. FWA-INDRV*-MPH-**03**V20-D5 replaced by FWA-INDRV*-MPH-**04**V08-D5).

☞ **Before** carrying out the firmware version upgrade, you must save all parameters (e.g. with IndraWorks D). **After** firmware replacement, the parameters must be restored, because the command "C07_1 Load defaults procedure command" is carried out automatically. After the desired parameter file was loaded, the drive controller is ready for operation again.

The described sequences of the firmware version upgrade depend on the configuration of the control section and the firmware used. The basically recommended sequence of the firmware version upgrade is illustrated in the scheme below:



CSH0x.x	ADVANCED single-axis control section
CDB0x.x	BASIC double-axis control section
CSB0x.xC	BASIC single-axis control section (configurable)
CSB0x.xN	BASIC single-axis control section (not configurable)
Fig. 10-29:	*Schematic Sequence of Firmware Version Upgrade*

☞ The actions to be taken which are marked with dark background in this figure are described in the paragraphs below.

Saving Parameter Values

Before firmware upgrade, all application-specific parameter values must be saved on a data carrier. Parameter backup can be carried out by means of:

- **Commissioning software "IndraWorks D"**

  → Saving parameter values on external data carrier

- or -

- **Control master**

  → Saving parameter values on master-side data carrier

☞ Saving the parameters on the MMC available in the drive is without effect, as this backup will be deleted during the firmware upgrade.

Loading New Firmware to MMC

Requirements

The following requirements must have been fulfilled for loading firmware to the MMC of the drive:

- New firmware available (ibf file)
- PC with MMC reader
- MMC with old firmware in drive

Loading Firmware to MMC

The following steps are required for loading the firmware to the MMC:

1. Switch drive off and remove MMC.
2. Plug MMC into MMC reader and open folder "Firmware" on MMC.
3. Delete old firmware (e.g. FWA-INDRV*-MPH-03V20-D5.ibf).
4. Copy new firmware (e.g. FWA-INDRV*-MPH-04V08-D5.ibf) to folder "Firmware".

   Note: Only one firmware file may be stored in the folder "Firmware" on the MMC. With several firmware files, the message "MMC not correct" appears on the display of the drive after booting.
5. Remove MMC from MMC reader after writing process has been completed.

Variant 1: Version Upgrade With MMC (With Safety Technology)

Selection Criterion

The following requirements should have been fulfilled in order that carrying out the firmware version upgrade with MMC makes sense (with safety technology):

- Controller has **not** been equipped with BASIC single-axis control section.
- Optional slot for safety technology has been equipped with the optional module "safety technology I/O" (S1).
- Current parameter setting of axis was saved.

Firmware Upgrade With MMC (With Safety Technology)

Carrying out the firmware version upgrade with MMC requires the following steps (with safety technology):

1. **Load firmware**

   ⇒ Switch drive off!

   ⇒ Plug MMC with new firmware into corresponding slot at controller.

   ⇒ Restart drive with MMC plugged.

   After drive has been booted, the following message appears:

   - "Firmware update ?"

   ⇒ Acknowledge this message by pressing "Enter" key of control panel. By doing this, firmware is loaded from plugged MMC to controller.

   One of the following messages will be displayed, depending on the operating status of the drive:

   - "Load Param from MMC" or "Load new param?"
   - "Activate new MMC?"
   - "F2120 MMC: defective or missing, replace"

⇒ Switch off drive, remove MMC (if drive was operated without MMC plugged) and restart drive!

2. **Put drive into ready-for-operation status**

   ⇒ After restarting the drive, the error message "F8201" is generated.

   ⇒ Clear all present error messages and start execution of "C07_2 Load defaults procedure command (load defaults procedure for safety technology)"!

   ⇒ As the number of parameters to be buffered has changed, "C07_1 Load defaults parameter command (loading basic parameters)" must be activated subsequently. 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 again so that the parameterization becomes active.

4. **Complete commissioning of integrated safety technology**

   ⇒ Switch drive to operating mode (communication phase 4).

   Error message "F3152 Incorrect backup of safety technology data" appears, as safety technology parameter set between firmware versions 02, 03 and 04 has changed.

   ⇒ Clear error message.

   ⇒ Activate command "synchronize and store safety technology IDN" (C3000).

   ⇒ Activate safety technology by inputting safety technology password (P-0-3206).

   ⇒ Carry out new acceptance test.

   See sections "Activating the Safety Technology" and "Acceptance Test" in the separate documentation "Rexroth IndraDrive: Integrated Safety Technology" (DOK-INDRV*-SI*-**VRS**-FK**-EN-P; part no. R911297838)

DANGER

Dangerous movements possible! Danger to life, risk of injury, severe bodily harm or material damage!

In order to ensure correct functioning and to prevent personal damage, a complete acceptance test must be carried out after a firmware version upgrade for drive controllers with the optional module for safety technology (S1).

   ⇒ Make safety technology parameter backup, compile acceptance test protocol and add it to safety-relevant documentation of machine.

5. **Put machine into ready-for-operation status**

   ⇒ Put machine into ready-for-operation status again according to machine manufacturer's instructions.

   ⇒ Check functions of drive.

Variant 2: Version Upgrade With MMC (Without Safety Technology)

Selection Criterion

The following requirements should have been fulfilled in order that carrying out the firmware version upgrade with MMC makes sense (without safety technology):

- Controller has **not** been equipped with BASIC single-axis control section of type CSB0x.xN.
- Optional slot for safety technology has **not** been equipped with the optional module "safety technology I/O" (S1).
- Current parameter setting of axis was saved.

Firmware Upgrade With MMC (Without Safety Technology)

Carrying out the firmware version upgrade with MMC requires the following steps (without safety technology):

1. **Load firmware**

   ⇒ Switch drive off!

   ⇒ Plug MMC with new firmware into corresponding slot at controller.

   ⇒ Restart drive with MMC plugged.

   After drive has been booted, the following message appears:

   - "Firmware update ?"

   ⇒ Acknowledge this message by pressing "Enter" key of control panel. By doing this, firmware is loaded from plugged MMC to controller.

   One of the following messages will be displayed, depending on the operating status of the drive:

   - "Load Param from MMC" or "Load new param?"
   - "Activate new MMC?"
   - "F2120 MMC: defective or missing, replace"

   ⇒ Switch off drive, remove MMC (if drive was operated without MMC plugged) and restart drive!

2. **Put drive into ready-for-operation status**

   ⇒ As number of parameters to be buffered has changed, "PL" appears on display (in case errors are present, remove them first). If you now press "Esc" key, all buffered parameters are set to their default values. During this time, message "C07 Load default parameters" appears on display. If errors are present, they first have to be removed and the command C07_1 must then be manually activated!

3. **Load parameter values**

   ⇒ Load parameter file which was saved.

   ⇒ Switch off drive and start again so that the parameterization becomes active.

4. **Put machine into ready-for-operation status**

   ⇒ Put machine into ready-for-operation status again according to machine manufacturer's instructions.

   ⇒ Check functions of drive.

Variant 3: Version Upgrade With IndraWorks D

Selection Criterion

The following requirements should have been fulfilled in order that carrying out the firmware version upgrade with IndraWorks D makes sense:

- Controller has been equipped with BASIC single-axis control section.
- Current parameter setting of axis was saved.

Firmware Upgrade With IndraWorks D

Carrying out the firmware version upgrade with IndraWorks D requires the following steps:

1. **Load firmware**

   ⇒ Call IndraWorks D.

⇒ Load project for corresponding axis or create new project. To do this, address axis via a serial connection.

⇒ Switch project "online".

⇒ Select/highlight controller and call "Firmware Management" in context menu.

A new window opens and firmware currently available in drive is displayed on its right side. On left side of window, firmware available in current firmware directory is displayed.

⇒ Highlight new firmware (*.ibf file) on left side and start firmware download via "Download" button.

Firmware download runs automatically and all required firmware components are loaded to drive.

⇒ After firmware download has been completed, close "Firmware Management" window.

2. **Put drive into ready-for-operation status**

   ⇒ Switch project "offline" and then "online" again.

   After project has been switched online, a message signals that IndraWorks D could not establish communication to drive via serial interface, as drive-internal settings for serial communication were reset.

   ⇒ Reconfigure communication via button "Search for devices".

   ⇒ As firmware in drive no longer complies with version stored in project, a corresponding message is displayed. To adjust firmware version in project, first select option "Repair" and then options "Delete existing drive from project" and "Add new drive to project".

   ⇒ As number of parameters to be buffered has changed, "PL" appears on display (in case errors are present, remove them first). If you now press "Esc" key, all buffered parameters are set to their default values. During this time, message "C07 Load default parameters" appears on display.

   If errors are present, they first have to be removed and the command C07_1 must then be manually started!

3. **Load parameter values**

   ⇒ Load parameter file which was saved.

4. **Put machine into ready-for-operation status**

   ⇒ Put machine into ready-for-operation status again according to machine manufacturer's instructions.

   ⇒ Check functions of drive.

10.6.4 Possible Problems During Firmware Replacement

Problematic Situations

Firmware replacement is carried out incompletely, if one of the following situations occurs during the sequence of firmware replacement:

- 24V supply of control section is switched off
- Connection to drive is interrupted (e.g. defective interface cable)
- Software crashes

The drive controller then possibly is no longer operable, because the firmware contained in the components is no longer compatible.

If there isn't any valid firmware available in the control section in this case, the loader is started. The drive display signals "LOADER". The loader only allows updating the firmware of the control section. Optional cards, such as "safety technology I/O" (S1) or "cross communication" (CCD) cannot be programmed in this status. This must be done, after successful firmware replacement in the control section, in a second run according to the descriptions of the firmware replacement variants.

In this situation, replacement of the control section firmware is only supported by IndraWorks D.

☞ Upon successful firmware replacement in the control section, a restart has to be carried out. Then all available components have to be updated, too.

Requirements for Loading the Firmware

The following requirements must have been fulfilled for loading firmware to the drive:

- Serial connection to drive available
- Drive display signals "LOADER"

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 D.
2. In menu, call firmware management under "Tools→ Drive → Firmware Management".
3. Select device and COM interface.

   A new window opens and firmware available in current firmware directory is displayed on its left side.
4. Highlight new firmware (*.ibf file) on left side and start firmware download via "Download" button.

   Firmware download runs automatically and all required firmware components are loaded to drive.
5. After firmware download has been completed, close "Firmware Management" window.
6. Restart drive.

If drive has not been equipped with optional modules, such as "safety technology I/O" (S1) or "cross communication" (CCD), continue following instructions for release update or version upgrade! Otherwise, carry out release update or version upgrade again to program optional modules.

10.7 Notes on How to Replace the Devices

10.7.1 Supply Units

General Information

The concept of Rexroth supply units includes safe, quick and uncomplicated replacement of devices. This allows reducing production downtimes, caused by failures of these devices, to a minimum.

Failures in the supply unit are displayed by means of diagnostic messages. According to the diagnostic error message, the measure "replacing the supply unit" can be indicated.

ℹ See documentation "Troubleshooting Guide" (description of diagnostic messages)

Immediately after having replaced the device, the drive is operational again, because it is not required to repeat the adjustment of the drive to the machine.

How to Replace Supply Units

Procure Replacement Device

Identify device to be replaced by means of type plate; procure supply unit of same type from Bosch Rexroth!

See also documentation of the respective supply unit

Fill Out Fault Report

In the documentation of the respective supply unit, you can find a fault report form to be copied. Please copy this fault report, fill it out carefully and completely and enclose it with the defective device! The fault report filled out completely supports quick handling of repair and helps recognizing application-related failure causes.

Replace Supply Unit

De-energize drive system; wait for DC bus to discharge; then replace defective supply unit!

DANGER

Live conductor bars (higher than 50 V), even if mains voltage switched off!

Electric shock when touching!

⇒ Wait for the DC bus (L+/L-) to discharge; before touching the conductor bar, check whether below 50 V!

For notes on how to dismount and mount the supply unit, see documentation of the respective supply unit

Put Drive System Into Operation Again

Put machine into operation again according to machine manufacturer's instructions!

10.7.2 Drive Controllers

General Information

The concept of Rexroth controllers includes safe, quick and uncomplicated replacement of devices. This allows reducing production downtimes, caused by failures of these devices, to a minimum.

Failures in the drive controller are displayed by means of diagnostic messages. According to the diagnostic error message, the measure "replacing the controller" can be indicated.

See documentation "Troubleshooting Guide" (description of diagnostic messages)

IndraDrive controllers are delivered completely with the control section and should be replaced completely, too. Only Bosch Rexroth service engineers or especially trained users are allowed to replace the control section separately. Only service engineers are allowed to replace optional modules of the control section.

Immediately after the device has been replaced and

- the operating data, which were saved before, have been loaded

- or -

- the MultiMediaCard (MMC) possibly plugged in the defective device has been plugged in the replacement device

the drive is operational again, because it is not required to repeat the adjustment of the drive to the machine.

When using the drive-internal safety technology, particular instructions have to be observed for replacing a device!

See separate documentation "Integrated Safety Technology"

How to Replace Drive Controllers

General Information

Procure Replacement Device

Identify defective controller by means of type plates; procure controller of same type from Bosch Rexroth!

The following type designations have to match:

- Type designation of power section
- Type designation of control section

Ideally, the firmware type designation of the replacement device should also comply with that of the defective device.

If the available replacement device has a different firmware type designation (differences in version and release), the same firmware as the one active in the defective device has to be loaded to the replacement controller!

The type designations can be seen on the adhesive labels at the power section and control section (see also documentation for the respective device component).

The firmware type active in the device can be shown on the display of the control panel.

See "Control Panels of the IndraDrive Controllers"

Fill Out Fault Report

In the documentation "Project Planning Manual for Supply Units/Power Sections or Control Sections", you can find a fault report form to be copied. Please copy this fault report, fill it out carefully and completely and enclose it with the defective device! The fault report filled out completely supports quick handling of repair and helps recognizing application-related failure causes.

Replacing a Device With Stationarily Plugged MMC

Save Parameter Values

When the device having a stationarily plugged MMC is switched off (MMC used as "programming module"), the current parameter values are automatically saved on the MMC.

Replace Controller

Replace the controller in the following steps:

1. De-energize drive; wait for DC bus to discharge!
2. Take MMC out of device to be replaced and plug it in new device!
3. Replace defective controller!

DANGER

Live conductor bars (higher than 50 V), even if mains voltage switched off!

Electric shock when touching!

⇒ Wait for the DC bus (L+/L-) to discharge; before touching the conductor bar, check whether below 50 V!

For notes on how to dismount and mount the controller, see documentation "Supply Units and Power Sections; Project Planning Manual"!

Put Controller Into Ready-For-Operation Status Again

Put machine into ready-for-operation status again according to machine manufacturer's instructions; then switch on control voltage!

Depending on the previous configuration of the replacement device, the following messages can appear during the booting phase:

- "Firmware update ?"

Firmware Download

Acknowledge this message by pressing "Enter" key of control panel. The firmware download is then running, the respective messages are appearing.

Load Parameter Values

The drive then is in the booting phase again and the following message can appear:

- "Load new Param.?"

Acknowledge this message by pressing "Enter" key of control panel. With safety technology option available, further messages will appear (see documentation "Integrated Safety Technology").Acknowledge these messages by pressing "Enter" key (control panel). The drive then completes the booting phase and waits for further actions of the control master.

☞ The drive is now running again with the same firmware and the same parameter values as before the device was replaced. The absolute position data reference of measuring systems is maintained!

When the MMC was not plugged in the controller before the control voltage is switched on, the following message is displayed:

- "Load new Param.?".

In this case, switch the control voltage off, plug the MMC of the defective device in the replacement device and then switch the control voltage on again.

☞ The message "Load new Param.?" does not always appear when the MMC hasn't been plugged (depends on the previous configuration of the replacement device)!

Replacing a Device Without Stationarily Plugged MMC

An MMC temporarily plugged in the controller can be used as update medium for firmware and as update and backup medium for parameter values.

Save Parameter Values

Before dismounting the defective device, save the drive parameter values, if possible. To do this, switch drive off and on again, then save parameter values in communication phase "P2".

Parameter values of defective device can be saved via:

- **Control panel of the controller with temporarily plugged MMC ("hot plug")**

  By pressing the buttons on the control panel in a certain order, the command "C2600 Copy IDN from internal memory to optional memory" (P-0-4092) can be activated. By doing this, the active parameter values [according to parameter "S-0-0192, IDN-list of backup operation data" and "P-0-0195, IDN list of retain data (replacement of devices)"] are copied from the controller-internal memory to an MMC temporarily plugged in the controller.

  Note: If the MMC does not remain stationarily (permanently) plugged in the device, it may be temporarily plugged **in the switched-on device after the booting phase** and removed again ("hot plug" or "hot unplug").

  See also "Control Panels of the IndraDrive Controllers"

- **Commissioning tool "IndraWorks D"**

By selecting the respective menu item, the parameter values according to the list parameters S-0-0192 and P-0-0195 are stored on an external data carrier (hard disk, floppy disk or the like) [serial communication with the controller or via SYSDA/SERCOS interface].

- **Control master**

  The parameter values according to the list parameters S-0-0192 and P-0-0195 are stored on a master-side data carrier by the control master.

If saving the parameter values before replacing the device should be impossible due to a total breakdown of the device, only the parameter values backed up after initial commissioning can be loaded when the parameter values are loaded later on (see below "Load Parameter Values in Case of Total Breakdown of Device")!

Replace Controller

De-energize drive; wait for DC bus to discharge; then replace defective supply unit!

DANGER

Live conductor bars (higher than 50 V), even if mains voltage switched off!

Electric shock when touching!

⇒ Wait for the DC bus (L+/L-) to discharge; before touching the conductor bar, check whether below 50 V!

For notes on how to dismount and mount the controller, see documentation "Supply Units and Power Sections; Project Planning Manual"!

Put Controller Into Ready-For-Operation Status Again

Put machine into ready-for-operation status again according to machine manufacturer's instructions!

Load Firmware and Parameters via IndraWorks D

Supply replacement controller without plugged MMC (as for defective device) with control voltage!

Depending on the previous configuration of the replacement device, the following message can appear during the booting phase:

- "Load new Param.?"

Acknowledge this message by pressing "Enter" key of control panel. The drive then completes the booting phase and is ready for other actions via IndraWorks D:

- **Load firmware**

  By selecting the respective menu item, the firmware stored on an external data carrier (hard disk, floppy disk or the like) is loaded to the controller (serial communication with the controller).

- **Load parameters**

  By selecting the respective menu item, the parameter values stored on an external data carrier (hard disk, floppy disk or the like), immediately before the device was replaced, according to list parameters S-0-0192 and P-0-0195 are loaded to the controller (serial communication with the controller or via SYSDA/SERCOS interface).

Load Firmware and Parameters via MMC

When firmware and drive parameters are to be transmitted via MMC to the replacement controller, you have to make sure that the MMC folder "Firmware" contains the firmware required for the drive and the MMC folder "Parameters" contains the parameters saved before having replaced the device.

→ Plug MMC into replacement controller, supply device with control voltage!

Depending on the previous configuration of the replacement device, the following message can appear during the booting phase:

- "Firmware-Update?"

Acknowledge this message by pressing "Enter" key of control panel. By doing this, firmware is loaded from plugged MMC to controller.

☞ If the message "Firmware-Update?" does not appear, the controller already contains the same firmware as the MMC. Loading the firmware in this case is not required!

The following message is then displayed:

- "Load new param.?".

Acknowledge this message by pressing "Enter" key of control panel. Drive parameters are now loaded from MMC to volatile memory of device; the following message then possibly appears:

- "Load new safety?".

Acknowledge this message by pressing "Enter" key of control panel, too. The safety parameters now are loaded from the MMC to the memory of the optional safety technology card (see documentation "Integrated Safety Technology").

☞ If safety technology is to be activated in the replacement device (in accordance with replaced device), the drive after loading the safety parameters has to be run up to operating mode (communication phase 4) before it is switched off!

Now store the parameters from the MMC in the internal, non-volatile memory of the controller by activating the command "C2500 Copy IDN from optional memory to internal memory" (P-0-4091) (storing according to parameters "S-0-0192, IDN-list of backup operation data" and "P-0-0195, IDN list of retain data (replacement of devices)").

After parameter loading processes have been completed, drive waits for further actions of control master.

Now switch controller off and remove MMC from device. The switch on controller again. The following message is then displayed:

- "Load new param.?".

Acknowledge this message by pressing "Enter" key of control panel. Drive parameters are now loaded from the non-volatile memory ("flash") to volatile memory ("RAM") of device. From now on, device behaves like device without MMC plugged (see also chapter "MultiMediaCard (MMC)").

Load Parameters Via Control Master (Saved Before Having Replaced Device)

The axis-specific parameter values saved before having replaced the device can also be loaded via the control master.

The parameter values saved immediately before the replacement of the device on a master-side data carrier (according to list parameters S-0-0192 and P-0-0195) are loaded to the controller by the control master.

Load Parameter Values in Case of Total Breakdown of Device

If it should have been impossible to save the parameter values according to the list parameters S-0-0192 and P-0-0195 immediately before replacing the device (total breakdown of device), the parameter values saved after initial commissioning have to be loaded.

In the case of drives with absolute value encoder and modulo format, the position data reference has to 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 parameter "S-0-0403, Position feedback value status"!

WARNING

The parameter values saved after initial commissioning are not generally suited for reestablishing the operatability of the drive after replacement of devices!

⇒ Check actual position values and active target position before drive enable!

Put Machine Into Ready-For-Operation Status

Reestablish ready-for-operation status of the machine:

- Put machine into ready-for-operation status again according to machine manufacturer's instructions.
- Check functions of drive.

10.8 Enabling of Functional Packages

10.8.1 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.

In the case of drives of double-axis design (firmware variant MPD), it is only possible to enable the same functional packages for both axes. In case the enabling for drive 1 is changed, the enabling for drive 2 is automatically changed, too.

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
- 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 Functional package selection changed. Restart

10.8.2 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 mustn't be used. Enabling functional packages which aren't 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 Bosch 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 Bosch 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 is selected)	Rules for selection via P-0-2003
0	Base package "open-loop"	- As an alternative to bit 1 - Not with safety technology
1	Base package "closed-loop"	- As an alternative to bit 0 - Not with CSB-01.1N-FC
2	Unassigned	--
3	Unassigned	--
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 - Not with CSB-01.1N-FC
6	Expansion package "main spindle" (MSP)	- As an alternative to bit 4 or 5 - Not with "open-loop" for CDB01.1C
7	Unassigned	--
8	Unassigned	--
9	Additional package "IndraMotion MLD" (ML)	- Not with CDB01.1C
10 to 31	Unassigned	--

Fig. 10-30: Selection of Functional Packages

☞ 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

Enabling the base package "closed-loop" and the expansion package "servo function", for example, requires the following setting in P-0-2003:

- 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.

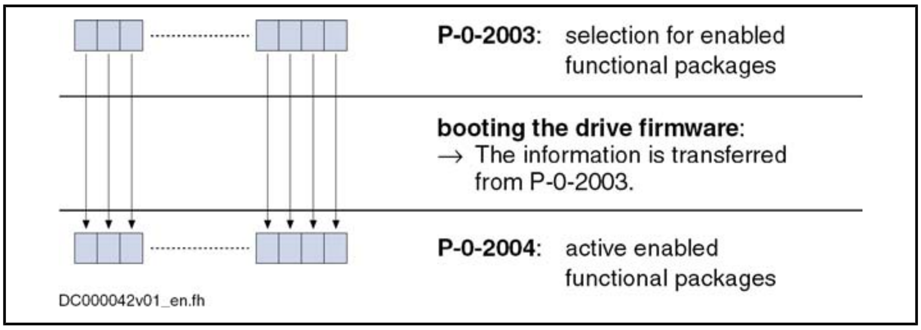


Fig. 10-31: Interaction of Parameters for Functional Package Selection

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".

☞ Bosch Rexroth can at any time provide evidence of non-licensed functional packages that have been enabled subsequently.

For input in "P-0-2003, Selection of functional packages", there presently are the following possible combinations:

Open-Loop Packages

- **Open-loop** without expansion packages

  → P-0-2003 = 0x0000 000**1**
- Open-loop with **synchronization (SNC)**

  → P-0-2003 = 0x0000 00**2**1
- Open-loop with **IndraMotion MLD (ML)**

  → P-0-2003 = 0x0000 0**2**01
- Open-loop with **synchronization (SNC) + IndraMotion MLD (ML)**

  → P-0-2003 = 0x0000 0**22**1

Closed-Loop Packages

- **Closed-loop** without expansion packages

  → P-0-2003 = 0x0000 000**2**
- Closed-loop with **servo function (SRV)**

  → P-0-2003 = 0x0000 00**1**2
- Closed-loop with **synchronization (SNC)**

  → P-0-2003 = 0x0000 00**2**2

- Closed-loop with **main spindle (MSP)**
  → P-0-2003 = 0x0000 00**4**2
- Closed-loop with **IndraMotion MLD (ML)**
  → P-0-2003 = 0x0000 0**2**02
- Closed-loop with **servo function (SRV) + IndraMotion MLD (ML)**
  → P-0-2003 = 0x0000 0**21**2
- Closed-loop with **synchronization (SNC) + IndraMotion MLD (ML)**
  → P-0-2003 = 0x0000 0**22**2
- Closed-loop with **main spindle (MSP) + IndraMotion MLD (ML)**
  → P-0-2003 = 0x0000 0**24**2

☞ 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.

☞ Bosch 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 Bosch Rexroth will expire!

In individual cases, it is possible 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".

10.8.3 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 shows the connection for firmware MPH04V06 and functional package "closed-loop, synchronization and IndraMotion":

Example

- Content of S-0-0030 → FWA-INDRV*-MPH04V06-MS-1-SNC-ML
- Imprint on type plate → FWA-INDRV*-MPH04V06-MS-1-SNC-ML
  - or (with complete licensing) -

→ FWA-INDRV*-MPH04V06-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 Bosch 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 Bosch Rexroth indicating serial number (from P-0-1511) and desired firmware configuration (from S-0-0030)
6. Receive adjusted firmware type plate from Bosch 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 Bosch Rexroth sales representative!

Scope of Supply

The scope of supply consists of

- ordered new firmware type as FWA file incl. parameter file (as files or on MMC)

  \- and -
- adjusted firmware type plate (to stick on).

10.8.4 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" is entered in the list parameter "S-0-0423, IDN-list of invalid op. data for parameterization level".

See also Troubleshooting Guide for "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 Functional package selection changed. Restart" is output.

See also Troubleshooting Guide for "C0299 Functional package selection changed. Restart"

10.9 Extended Diagnostic Possibilities

10.9.1 Monitoring Function

Brief Description

The so-called "monitor function" implemented in the drive is **for internal use** only, or can be used as an extended possibility of diagnosis in the case of error.

The monitoring function provides the following options:

- Displaying memory ranges
- Changing storage locations
- Writing/reading EEPROM memory cells (controller and encoder)
- Adjusting analog measured values
- Displaying internal system states
- Executing several test routines for software and hardware

Using the monitor function requires a VT100 terminal, an ANSI terminal or a corresponding emulation. It is recommended to have a 132-column display.

Notes on Commissioning/Operation

Serial Interface

Connection to the drive is realized via the serial interface. The setting has to be made in accordance with the parameterization of the serial interface in the drive (parameters P-0-4021, P-0-4025, P-0-4095).

Default settings of the serial interface:

- 9600 baud
- 8 data bits
- No parity

- 1 stop bit
- Hardware protocol

Opening the Communication Channel

After starting the terminal (Windows hyper terminal) and the drive, there isn't any output appearing on the terminal.

In order to establish connection to the drive, the following input is required:

→**"BCD:<**drive address**>"**

The drive address corresponds to the number set in parameter P-0-4025 (or can be read on the display, default address in "99"). The drive now responds with

"E<drive address**>:>"**.

☞ After the input there isn't any "echo" appearing on the terminal (i.e. the input is invisible when the local echo of the terminal was disabled).

To get to the monitoring mode, make the following input:

→ **"mon"**

If successful, the drive responds with

"INDRAMAT _ IMON166 _ V1.3 _ May 27 2002 [? = Help]"

as a header with dark background and the prompt "HPC> ".

☞ The monitoring function was started!

Handling

The monitor structure is organized in menus. The content of the individual menus can be displayed by inputting

→ **"?"**.

As a matter of principle, the input is made according to the pattern

"command option1 option2 ... option N".

Submenus are called like normal commands. The submenu is exited by entering

→ **"exit"**.

☞ With the "exit" command the monitoring mode is exited, too, and the drive switches to normal RS232 communication again.

The content of the screen can be cleared with the command "cls".

10.9.2 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.

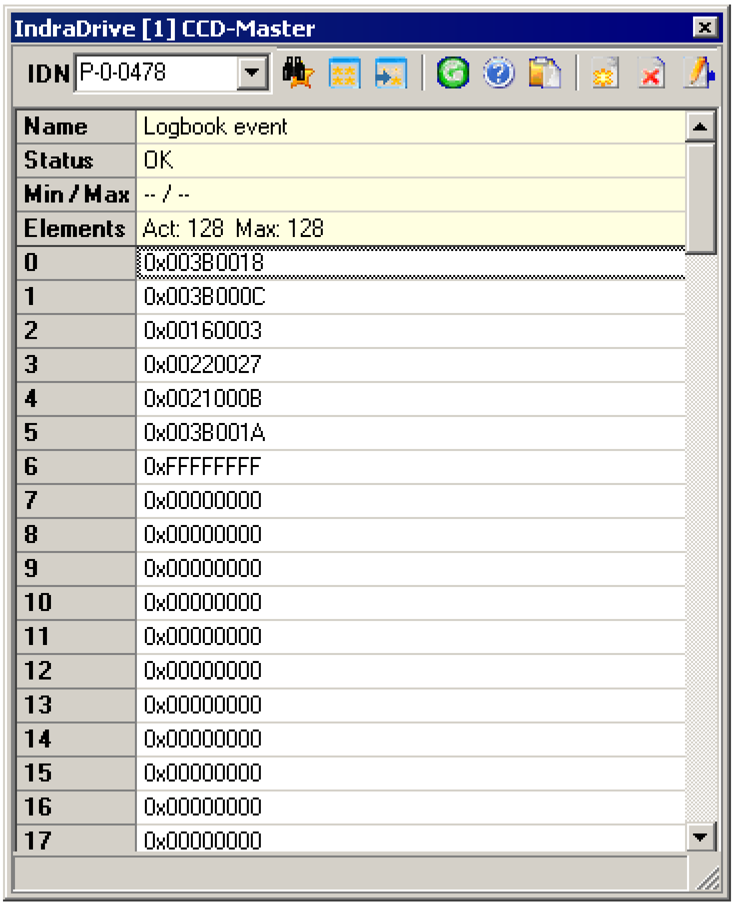


Fig. 10-32: Logbook entries (example)

☞ 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.

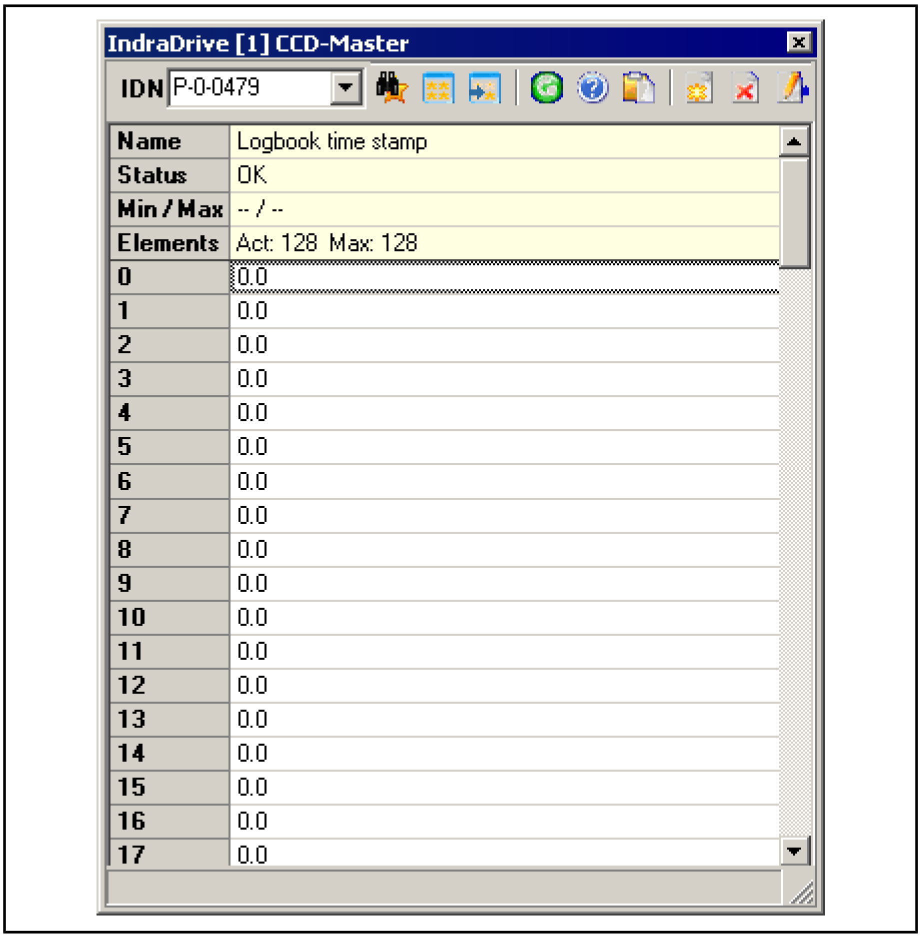


Fig. 10-33: Content of parameter P-0-0479 (example)

10.9.3 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.

☞ 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

- 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

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. To do this, a storage location is preset via the 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 bits 0 to 2 of the 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 memory accesses.

☞ 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).

Access as...	Possible access to source addresses that ...		
	...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

Fig. 10-34: 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 the 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".

☞ 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.

Examples of Application

Patch Function in Conjunction With "Analog Output"

In conjunction with the "analog output" function, it is possible to transmit the content of a storage location to an analog output. To do this, the IDN of the desired patch display (P-0-0485/P-0-0491) has to be entered in one of the parameters "P-0-0420, Analog output 1 signal selection" or "P-0-0423, Analog output 2 signal selection".

☞ Please observe that changes in the patch attributes (P-0-0481/P-0-0487) are not automatically transmitted to the parameters P-0-0418/P-0-0419 and P-0-0422/P-0-0425. After a change in the patch attribute, you should therefore write the parameters P-0-0420/P-0-0423, P-0-0418/P-0-0419 and P-0-0422/P-0-0425 again.

See also "Analog Outputs"

10.10 Oscilloscope Function

10.10.1 Brief Description

The oscilloscope function can be used to record drive-internal and external signals and 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
- **Configuration (basic settings)**
  - 4-channel display in "IndraWorks D"
  - 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

Pertinent Parameters

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, Oscilloscope: signal selection 3
- P-0-0148, Oscilloscope: signal selection 4

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: control offset

- P-0-0036, Oscilloscope: external trigger signal
- P-0-0037, Oscilloscope: internal trigger signal

Handling, Diagnostic and Service Functions

10.10.2 General Information on the Oscilloscope Function

Sequence of a Measurement (Status Diagram)

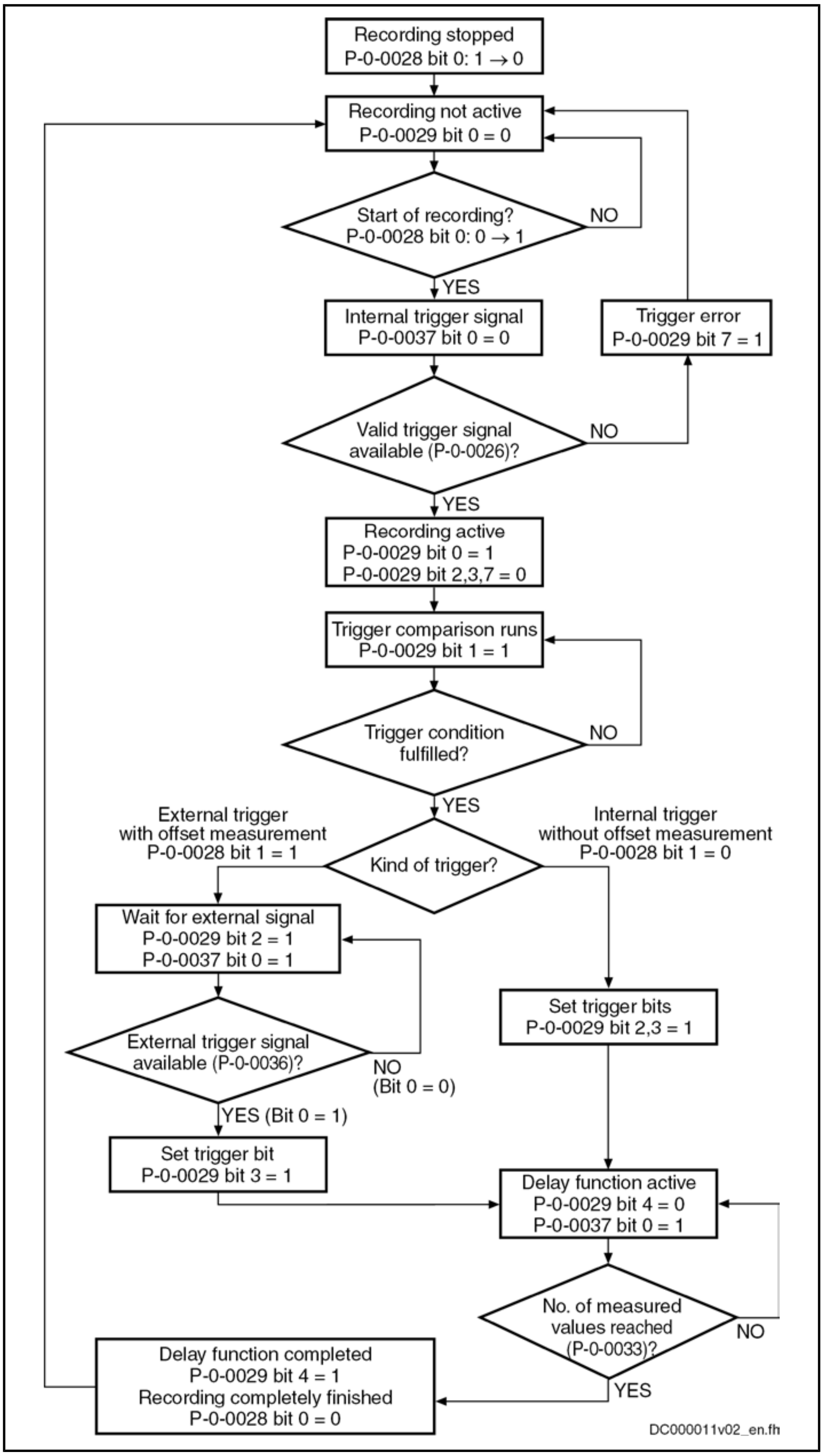


Fig. 10-35: Status Diagram of Oscilloscope Function

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, Oscilloscope: signal selection 3
- P-0-0148, Oscilloscope: signal selection 4

Signal Selection List (P-0-0149)

All IDNs contained in parameter "P-0-0149, Oscilloscope: signal selection list" can be entered.

The parameter 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 1 value" 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, actual position value of axis 1 is recorded in the oscilloscope and transmitted to the master.

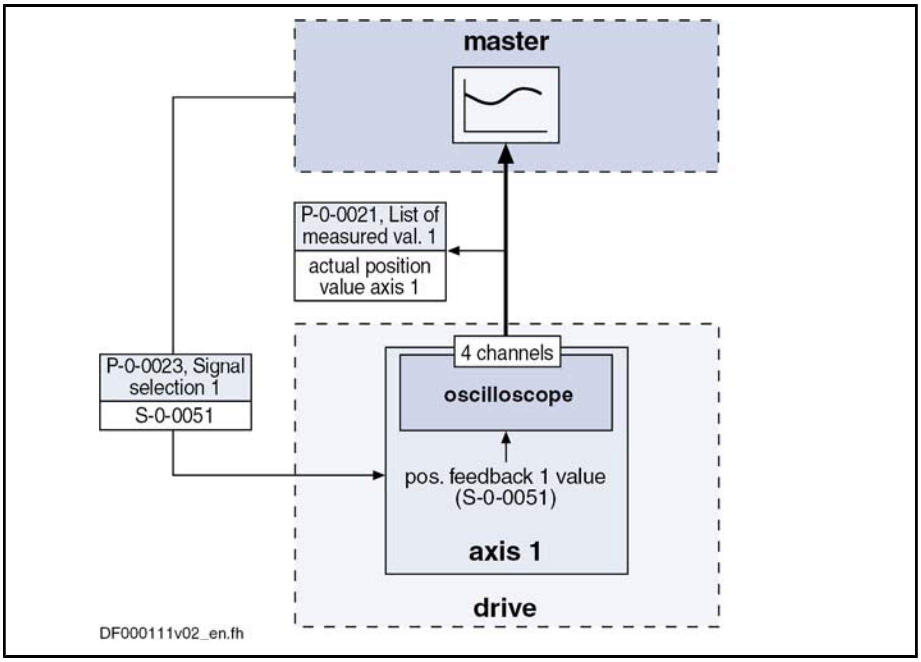


Fig. 10-36: Example of Signal Selection

Expanded 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.

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 parameter "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!

10.10.3 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 means of direct input of parameter IDNs. Only such IDNs are allowed that are contained in the list "P-0-0149, Oscilloscope: signal selection list".

☞ If there isn't any 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".

The parameter "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

In parameter "P-0-0028, Oscilloscope: control word", the kind of trigger can be selected.

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 has been 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 status diagram).

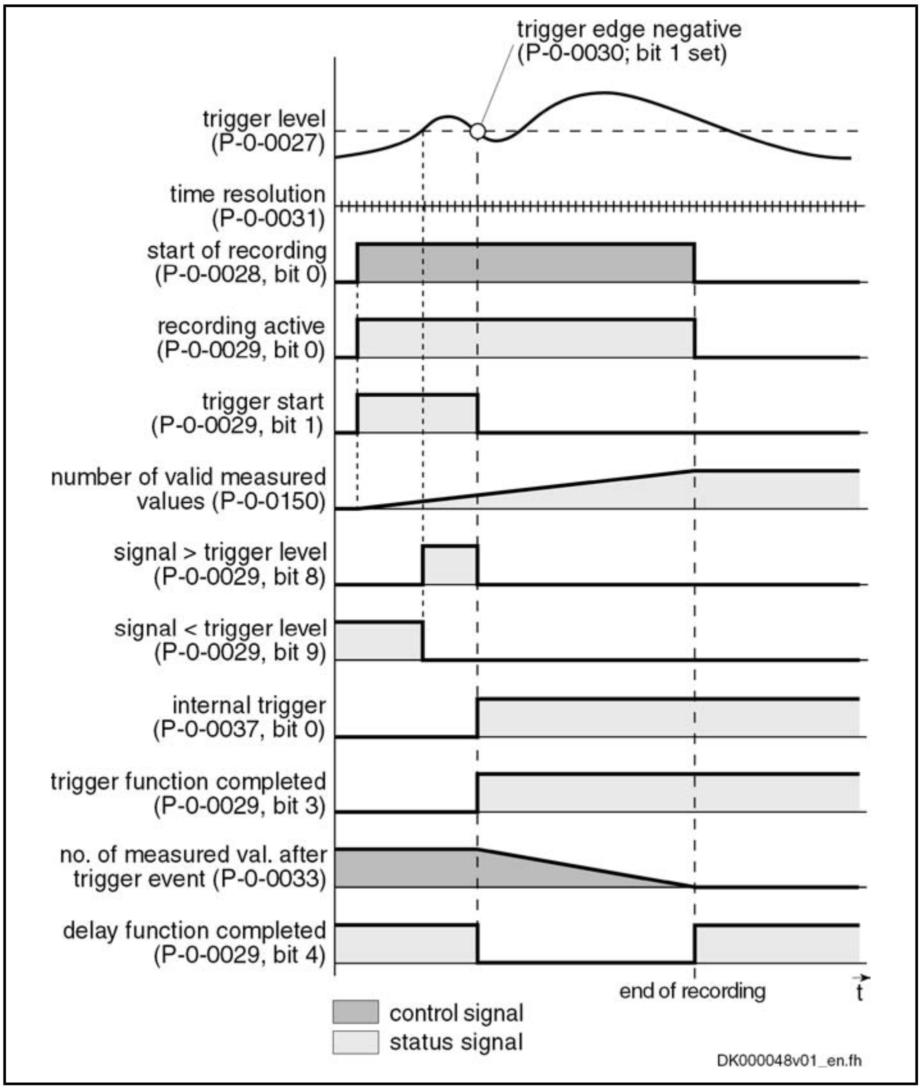


Fig.10-37: Internal Trigger Without Offset Measurement (P-0-0028; Bit 1 = 0)

☞ By parameterizing P-0-0036 (external trigger signal) in "P-0-0026, Oscilloscope: trigger signal selection", it is possible to release the internal trigger function by the external trigger input.

External Trigger With Offset Measurement

When the kind of trigger "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 parameter 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.

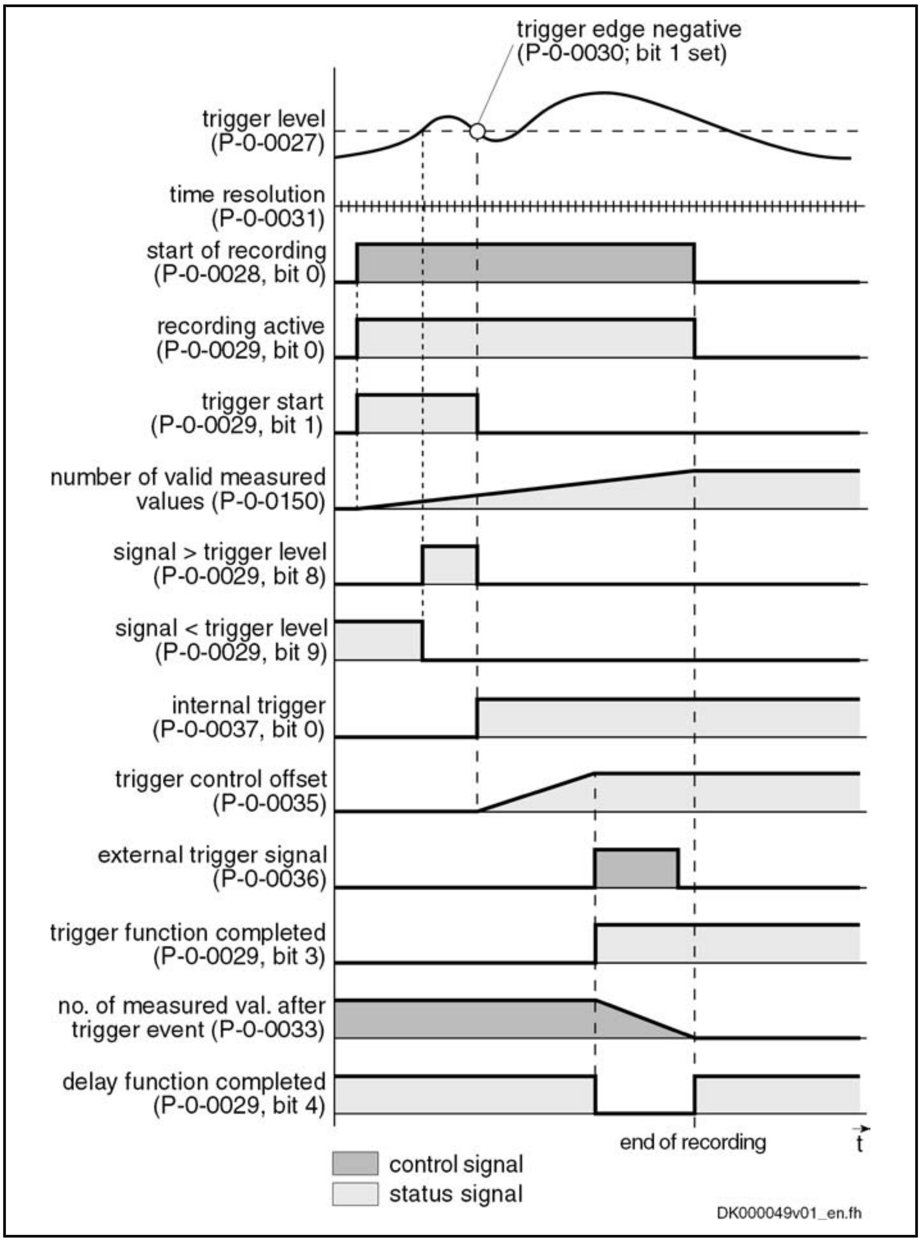


Fig. 10-38: External Trigger With Offset Measurement (P-0-0028; Bit 1 = 1)

☞ The use of the external trigger source with trigger offset determination is described in section "Synchronizing the Measuring Signals of Several Axes" (see below).

Selecting the Trigger Edges

Trigger Edge (P-0-0030)

In parameter "P-0-0030, Oscilloscope: trigger edge", you can 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

See Parameter Description "P-0-0030, Oscilloscope: trigger edge"

Setting the Trigger Delay

Trigger Delay Function

Via parameter "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).

By entering "0" in P-0-0033, only data available before the trigger event will be recorded.

If the value of parameter P-0-0032 is entered, only the measured values that occurred after the trigger event will be recorded.

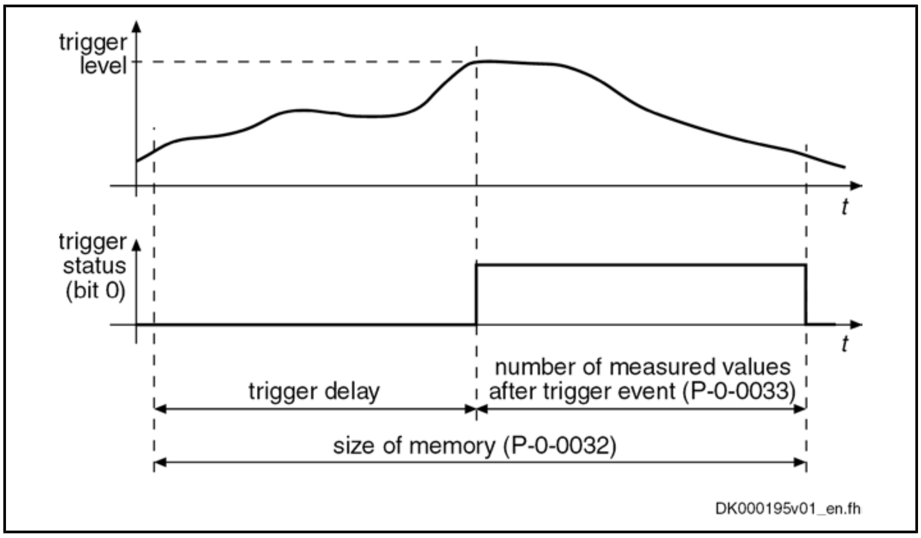


Fig.10-39: Trigger Delay: Number of Measured Values After Trigger Event

Expanded 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 respective selected trigger signal.

See Parameter Description "P-0-0027, Oscilloscope: trigger level"

10.10.4 Synchronizing the Measuring Signals of Several Axes

The parameter "P-0-0035 Oscilloscope: 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: 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.

See also above "Internal or External Trigger"

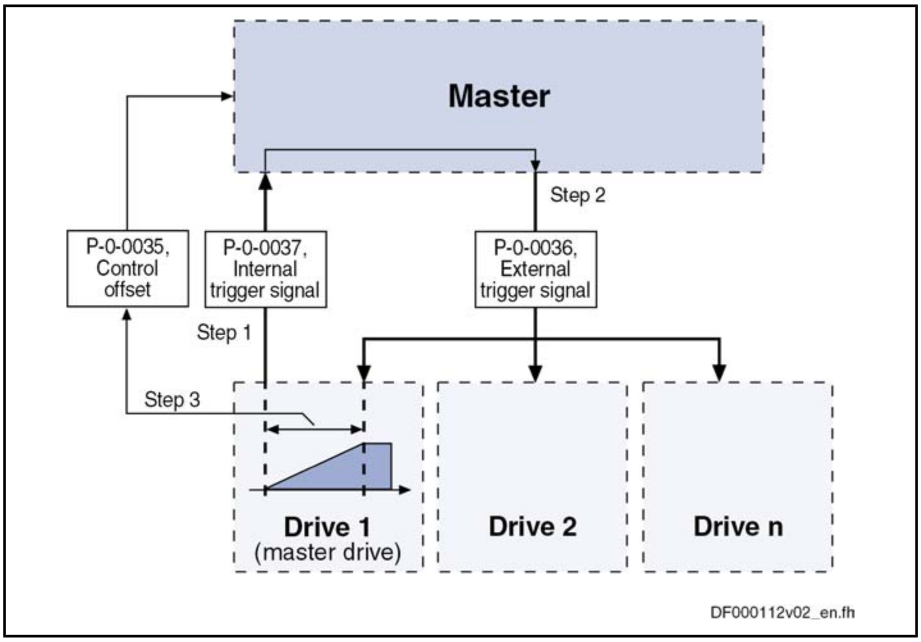


Fig. 10-40: Application for Trigger Source "External" With Determination of Trigger Offset

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☞ 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.

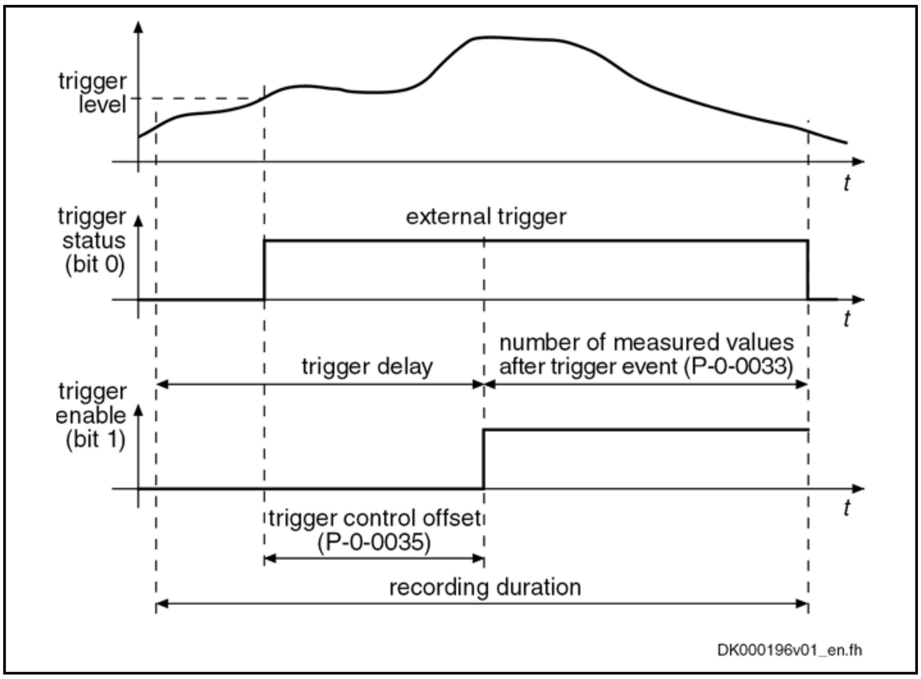

Fig. 10-41: Trigger Control Offset

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)

The parameter "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.

10.10.5 Parameterizing the Oscilloscope Function

Recording Duration

The recording duration is determined according to the following relationship:

$$t_A = (\text{P-0-0031}) \times (\text{P-0-0032})$$

t_A	Recording duration (in µs)
P-0-0031	Oscilloscope: time resolution
P-0-0032	Oscilloscope: size of memory

Fig. 10-42: 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, Oscilloscope: signal selection 3
- P-0-0148, Oscilloscope: signal selection 4

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 above "Trigger Function"

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

By means of "P-0-0032, Oscilloscope: size of memory", the number of measured values is determined. A maximum of 8192 measured values per channel can be recorded.

Time Resolution of Oscilloscope Function

By means of "P-0-0031, Oscilloscope: time resolution", the time intervals, in which the measured values are recorded, are determined (sampling rate). It is possible to select the time resolution on the time base of the position loop clock (T_{osci} = N x $T_{A\_position}$; N = 1, 2, 3, 4, …).

The position loop 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.

See "Performance Data"

10.10.6 Diagnostic and Status Messages

Status of the Oscilloscope Function

The parameter "P-0-0029, Oscilloscope: status word" displays the current status of the oscilloscope function.

Parameter P-0-0029 contains, for example, status information on:

- Start/end of recording
- Trigger function
- Status of trigger signal
- Delay function

See also Parameter Description "P-0-0029, 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

The parameter "P-0-0150, Oscilloscope: number of valid measured values" displays the number of measured values detected in the ring buffer after a measurement. If the ring buffer has been completely filled with the length determined in parameter "P-0-0032, Oscilloscope: size of memory", this parameter displays the size of memory.

See also Parameter Description "P-0-0150, Oscilloscope: number of valid measured values"

10.11 Serial Communication

10.11.1 Overview of Serial Communication

General Information

The serial interface of the drive controller is used as a universal medium of communication for different services. It can be used for master communication (in addition to SERCOS), for reading and writing parameters, for replacing the firmware, for locating errors and for other services. The physical standard used is RS232 (with accessory HAS05.1-005 "RS232/RS485 converter", RS485 is possible, too).

Two protocols are supported for serial communication:

- ASCII-based protocol
- SIS protocol (Rexroth-standard serial binary protocol)

The protocol is automatically recognized by the drive!

The following functions are made possible via the serial interface:

- Reading and writing parameters via terminal or commissioning tool in parallel with the existing master communication
- Connecting a control terminal (BTV04)
- Downloading firmware via the "IndraWorks D" program

The maximum baud rate is 115 kB.

Pertinent Parameters

- P-0-4021, Baud rate RS-232/485
- P-0-4022, Drive address of serial interface
- P-0-4050, Answer delay RS-232/485
- P-0-4095, RS-232/485 Parity

Parameter Structure

All parameters of the drive controller are stored in a uniform parameter structure. Each parameter consists of 7 elements. The table below describes the individual elements and the possibilities of access. The following sections will also refer to the parameter structure below.

Element no.	Data block element	Possibility of access
1	IDN	read
2	name	read
3	attribute	read
4	unit	read
5	min. input value	read
6	max. input value	read
7	operating data	read / write

Fig.10-43: Parameter structure

Interface Mode

The serial interface can optionally be operated in one of the following modes:

- RS232 mode
- RS485 mode

☞ Communication via RS485 is only possible in conjunction with an external RS232/RS485 converter (e.g. with accessory module HAS05.1-005 by Bosch Rexroth).

Depending on the mode, it is necessary to use different cables (see corresponding Project Planning Manual).

Transmission Protocols

Two different protocols are supported on the drive side:

- ASCII protocol
- SIS protocol

When switching on the 24 V supply voltage, automatic protocol detection is activated when receiving signals via the serial interface.

A soon as either

- a valid ASCII start sequence

- or -

- a valid SIS telegram

was received, the drive internally switches to the respective kind of protocol.

Properties of ASCII Protocol

- Transmission rates 9600 and 19200 baud
- 8-bit ASCII protocol
- No parity bit
- One stop bit

> ☞ There isn't any telegram frame used, but the transmitted ASCII signs are converted and interpreted. It is only necessary to comply with a certain order.

Properties of SIS Protocol

- Binary protocol
- Checksum test (higher Hamming distance D)
- All telegrams are identified by an unequivocal start character ("0x02")
- Defined structure of the telegram frame
- It is possible to activate motions (e.g. jogging)

10.11.2 Functional Principle Independent of Protocol

Basic State After Applying the Control Voltage

After the control voltage has been switched on, the serial communication in the drive is in the "passive mode". Communication is impossible in the passive mode.

Determining the Protocol

In order to establish the serial communication with the drive, it is necessary to determine the kind of communication (protocol) by

- a CHANGE DRIVE command (in the case of ASCII protocol)

- or -

- a valid SIS telegram (in the case of SIS protocol).

Setting the Drive Address

The drive address of the serial interface is set by writing data to parameter "P-0-4022, Drive address of serial interface".

This can be done, for example, by means of the standard control panel or the "IndraWorks D" commissioning tool.

Exception: If the value "256" (default value) was entered in parameter P-0-4022, the device address set in parameter "P-0-4025, Drive address of master communication" is used for serial communication.

RS232 Mode

In this mode, it is **not obligatory** to set the drive address, because only one node is connected (peer-to-peer connection).

> ☞ When communicating via the SIS protocol, the address "128" is provided for peer-to-peer communication. Independent of the setting in parameter P-0-4022, the address "128" is always valid.

RS485 Mode

In the case of communication via RS485 bus, it is obligatory to set the drive address, because each bus node is addressed via a specific bus address.

> ☞ In order to avoid access conflicts, each drive address may be assigned only once.

Communication Via RS232 Interface

The RS232 interface is particularly intended to be used for connecting a PC with installed "IndraWorks D" commissioning tool.

Features

- Transmission rates from 9600 to 115,200 baud
- Max. transmission distance 15 m
- ASCII protocol or SIS protocol (8-bit each)
- Parity bit according to parameter "P-0-4095, RS-232/485 Parity"
- One stop bit

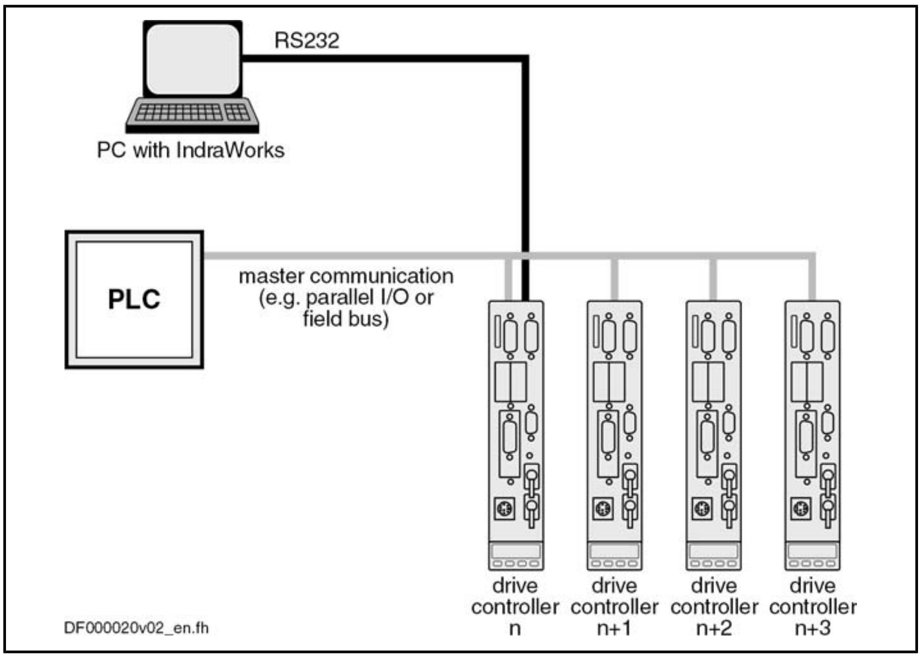

Fig. 10-44: Communication Via RS232 Interface (Example: IndraWorks D)

Communication Via RS485 Interface

General Information

The communication via the RS485 interface allows realizing a serial bus with the following data:

Features

- It is possible to connect up to 31 drives with one bus master
- Transmission rates from 9600 to 115,200 baud
- Max. transmission distance 500 m
- Semi-duplex operation via 2-wire line
- ASCII protocol or SIS protocol (8-bit each)
- Parity bit according to parameter "P-0-4095, RS-232/485 Parity"
- One stop bit

☞ Communication via RS485 is only possible in conjunction with an external RS232/485 converter.

Operating Several Drives With IndraWorks D

Advantages for Application

- Commissioning several drive controllers without plugging the interface cable into a different connection (central parameterization and diagnosis connection)

- Realizing a central PC-based visualization unit

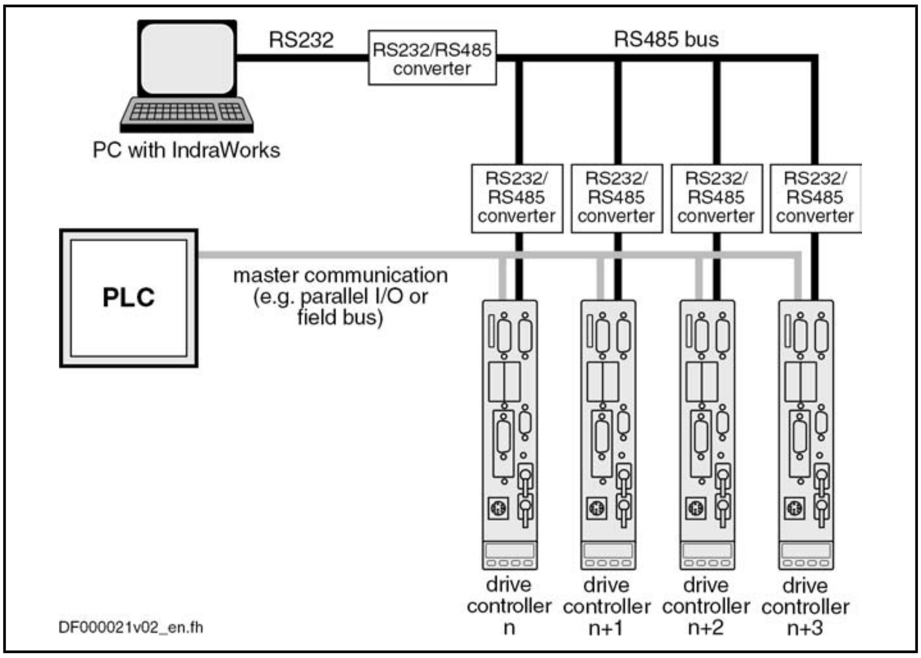

Fig. 10-45: Operating Several Drives With IndraWorks D

☞ Using IndraWorks D via the RS485 interface is only possible as of version 05.

Parameterization and Diagnosis Via PLC

Advantages for Application

- Parameters can be changed via PLC (e.g. adjustment of positioning blocks)
- Extended diagnostic possibilities for the PLC by reading in the error code

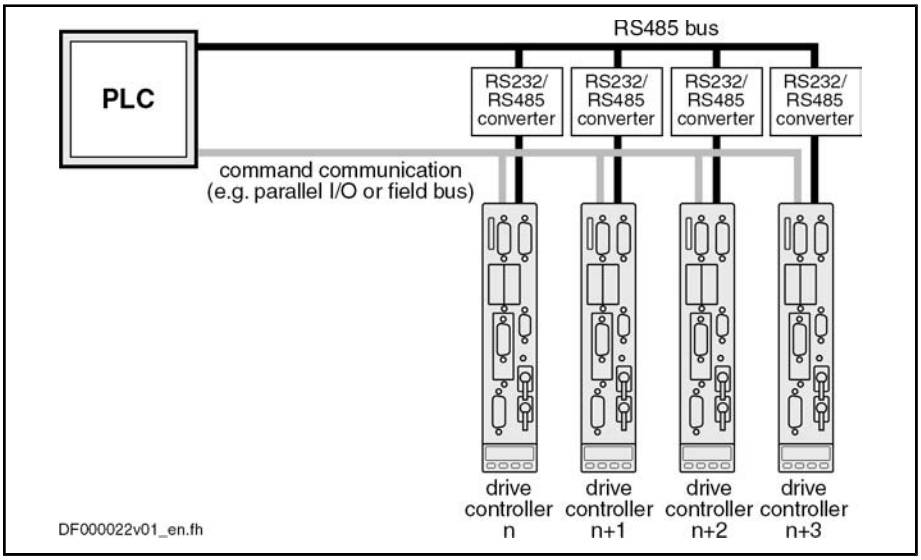

Fig. 10-46: Parameterization and Diagnosis Via PLC

Parameterization and Diagnosis of Drive Groups by an Operator Unit

Advantages for Application

- Realizing a central visualization unit

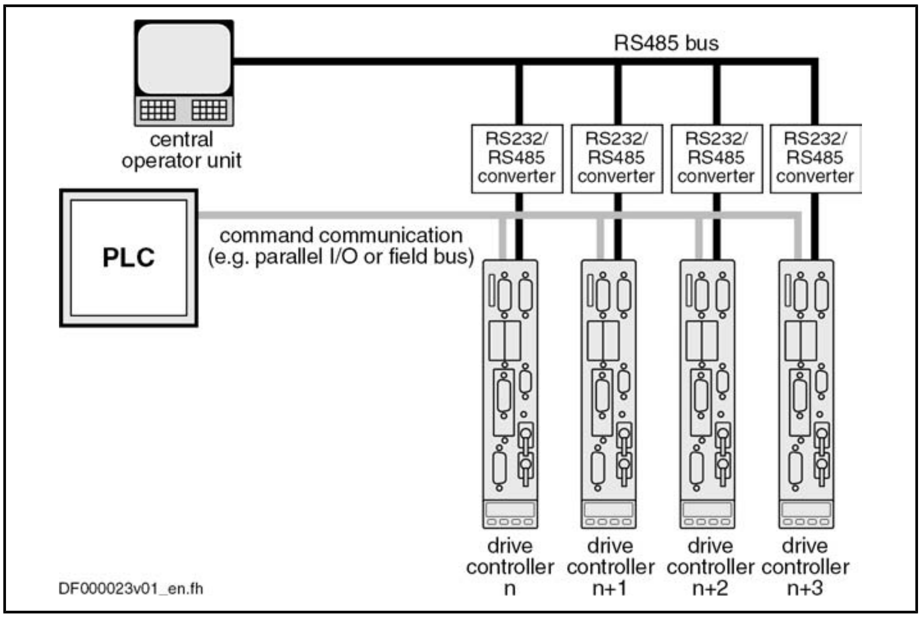

Fig.10-47: Parameterization and Diagnosis of Drive Groups by an Operator Unit

Connection System

See separate documentation "Drive Controllers, Control Sections; Project Planning Manual"

Error Messages With Serial Communication

The error codes defined in the SERCOS interface specification are used for the different errors (see "Specification SERCOS interface", section 4.3.2.3 "Service channel error messages"). These codes are also used in the case of incorrect access to control and system parameters.

Error code	Explanation
0x1001	No IDN
0x1009	Invalid access to element 1
0x2001	No name
0x2002	Name transmission too short
0x2003	Name transmission too long
0x2004	Name cannot be changed (read only)
0x2005	Name is write-protected at this time
0x3002	Attribute transmission too short
0x3003	Attribute transmission too long
0x3004	Attribute cannot be changed (read only)
0x3005	Attribute is write-protected at this time
0x4001	No units
0x4002	Unit transmission too short
0x4003	Unit transmission too long
0x4004	Unit cannot be changed (read only)

Error code	Explanation
0x4005	Unit is write-protected at this time
0x5001	No minimum input value
0x5002	Minimum input value transmission too short
0x5003	Minimum input value transmission too long
0x5004	Minimum input value cannot be changed (read only)
0x5005	Minimum input value is write-protected at this time
0x6001	No maximum input value
0x6002	Maximum input value transmission too short
0x6003	Maximum input value transmission too long
0x6004	Maximum input value cannot be changed (read only)
0x6005	Maximum input value is write-protected at this time
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 (reason: communication phase or mode)
0x7006	Operation data is smaller than the min. input value
0x7007	Operation data is greater than the max. input value
0x7008	Invalid operation data (e.g. IDN not supported, invalid bit number, invalid bit combination, invalid list length)
0x7009	Operation data write protected by a password
0x700A	Operation data is write protected, it is configured cyclically (IDN is configured in the MDT or AT. Therefore writing via the service channel is not allowed).
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)

Fig.10-48: Error Specification According to SERCOS

10.11.3 Communication With ASCII Protocol

Addressing a Specific Bus Node

In order to start the communication with a bus node, this node has to be specifically addressed by a CHANGE DRIVE command (CD command) indicating the drive address. With each CD command, the drive addressed via the indicated address is activated; all other drives are thereby switched to the passive mode. The drive that has been addressed responds with its prompt. As from now, the communication with the activated drive continues until another CD command causes the switching to another drive.

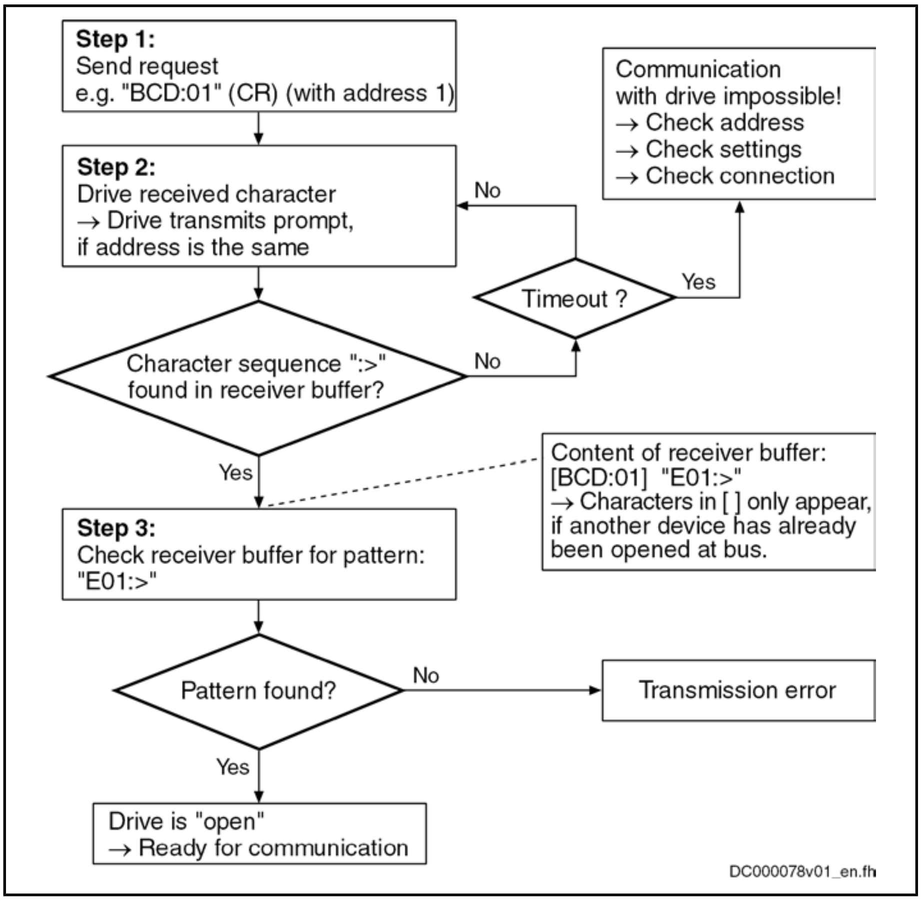

Fig. 10-49: Addressing a Bus Node

Write Access to a Parameter

As a basic principle, write access to a parameter is carried out as follows:

- **IDN of the parameter, data block element number, w, operating data (Carriage Return)**

After the writing operation has been carried out, the drive responds with its prompt again.

In order to access the parameter value of parameter P-0-4037, for example, the following input is required:

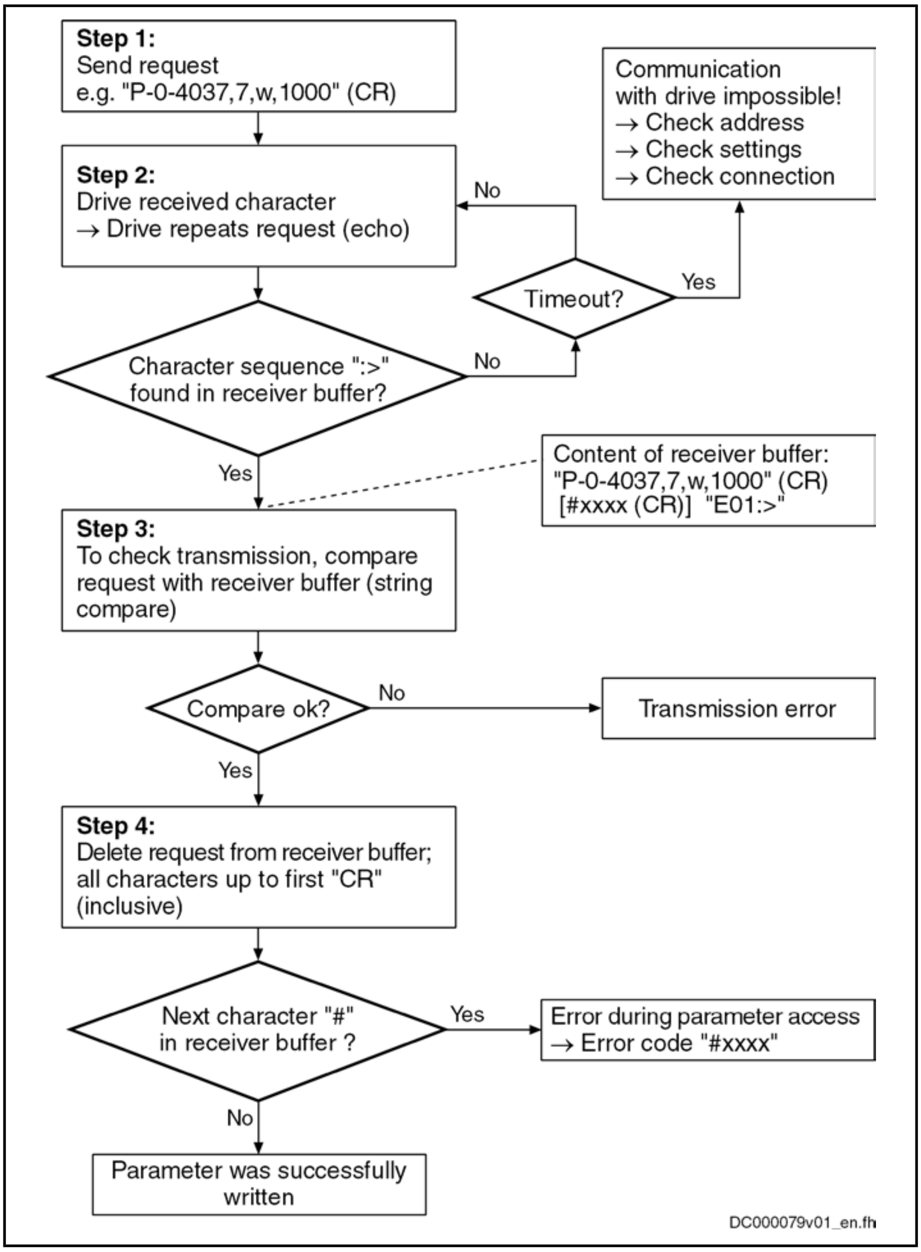

Fig. 10-50: Write Access to a Parameter

☞ The entered data must correspond to the data type defined in the attribute (HEX, BIN or DEC).

See also "Error Messages With Serial Communication"

Read Access to a Parameter

As a basic principle, read access to a parameter is carried out as follows:

- **IDN of the parameter, data block element number, r (Carriage Return)**

The drive then displays the content of the data block element that was addressed.

In order to access the operating data of parameter P-0-4040, for example, the following input is required:

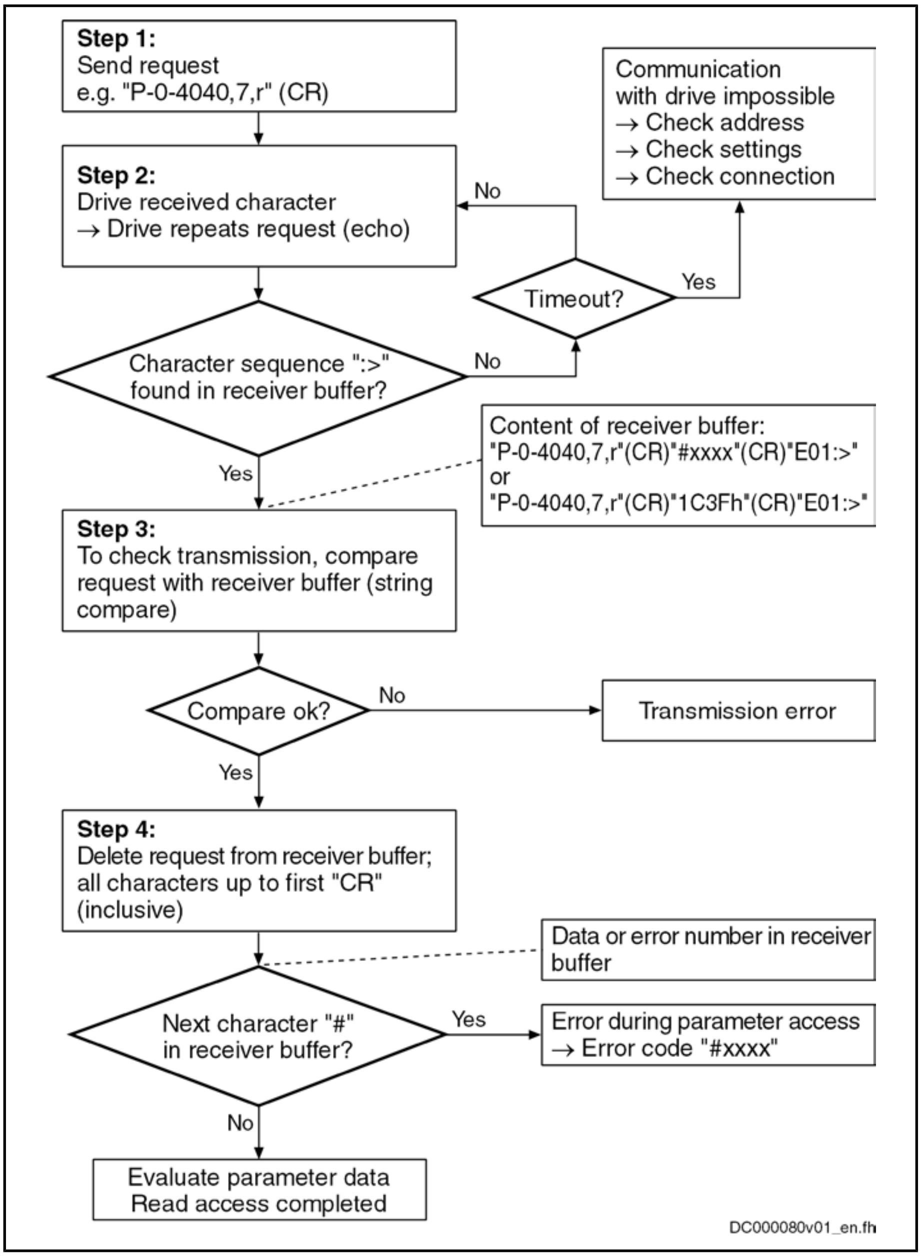

Fig. 10-51: Read Access to a Parameter

Write Access to List Parameters

There are some list parameters in the drive. To write data, these parameters have to be addressed in modified form:

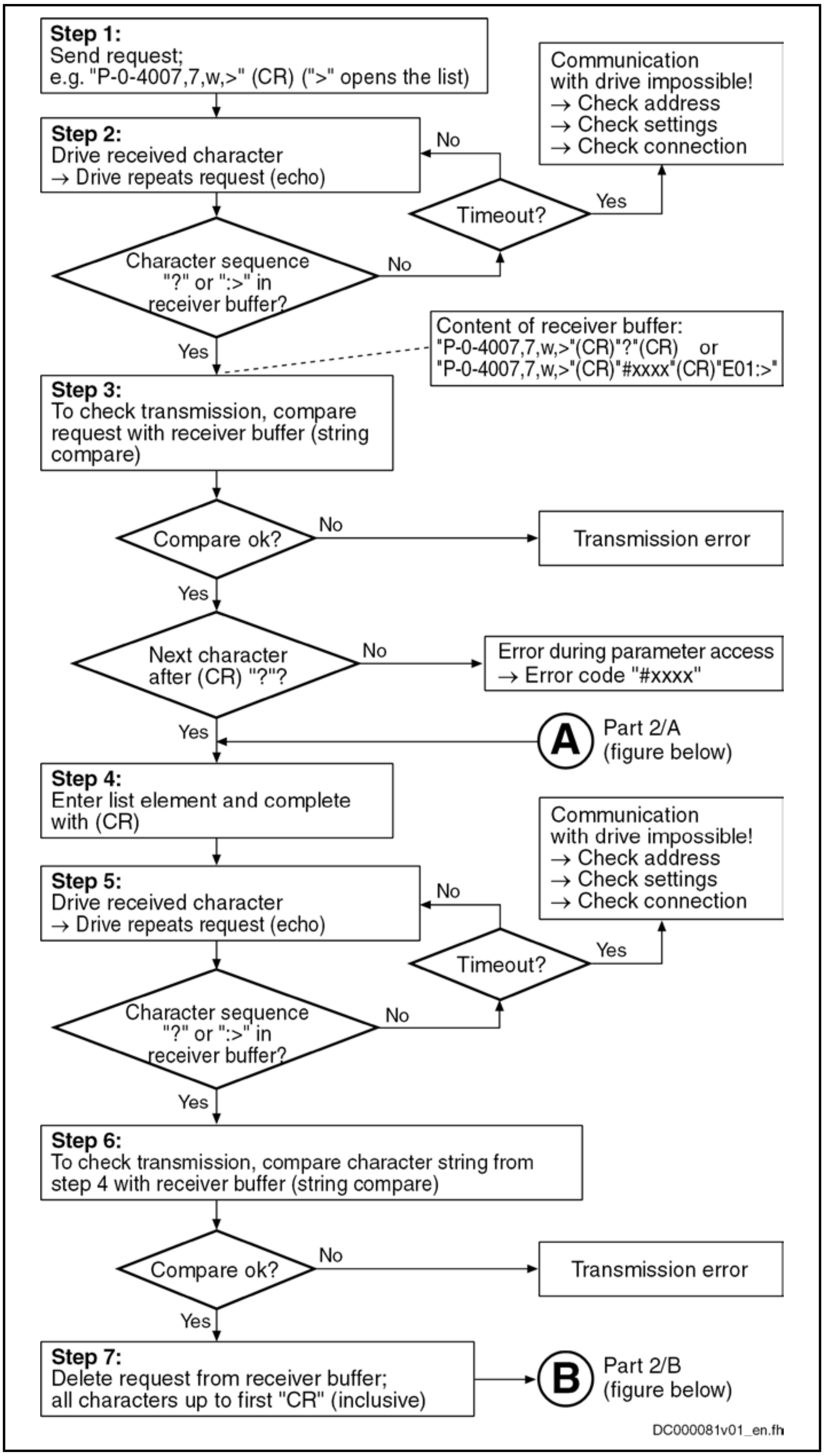

Fig.10-52: Write Access to List Parameters (Part 1)

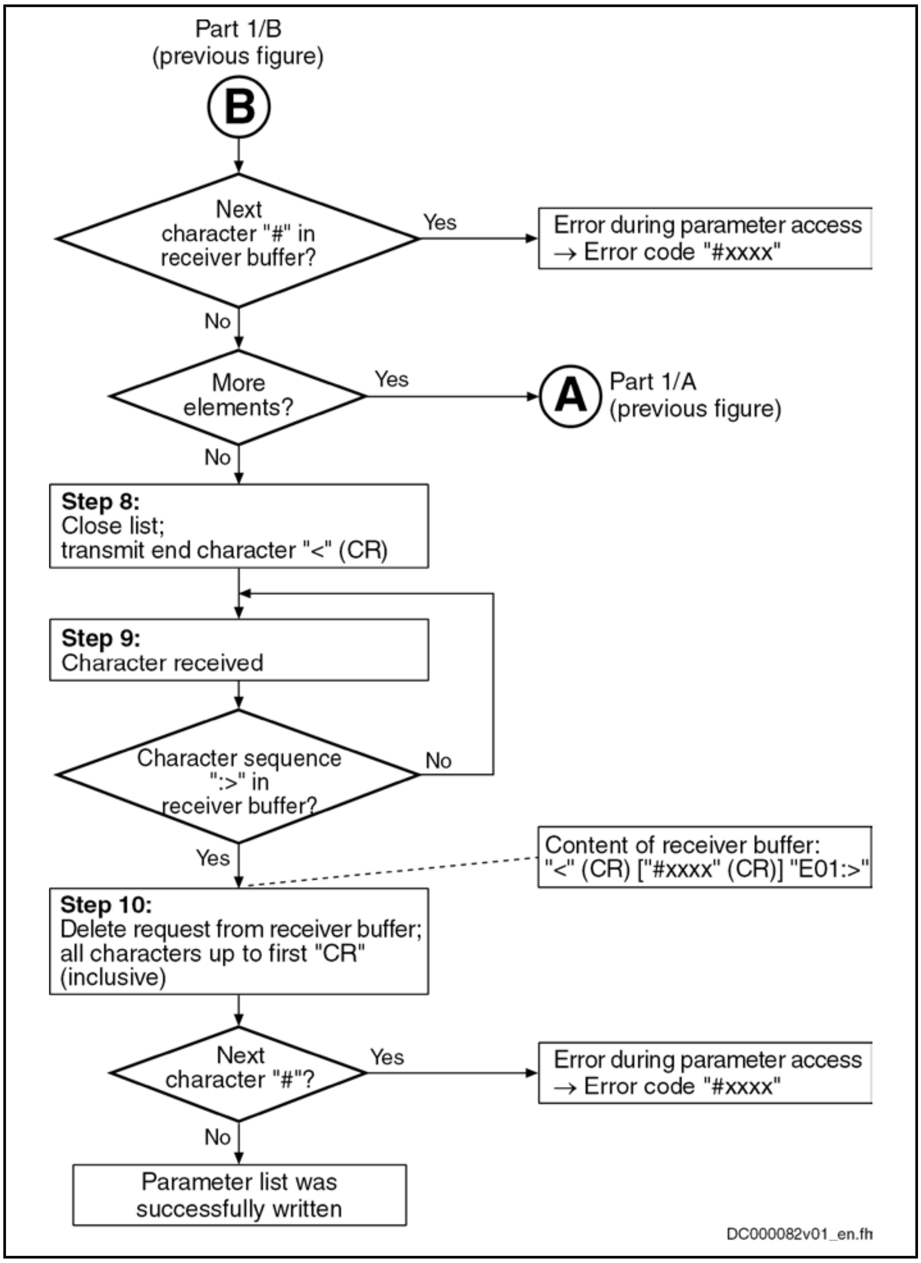

Fig. 10-53: Write Access to List Parameters (Part 2)

☞ It is important to complete the input with the "<" character, because only then are the data applied in the drive.

Read Access to List Parameters

The read access to list parameters is carried out in the same way as in the case of other parameters. The drive, however, provides all list elements as its response.

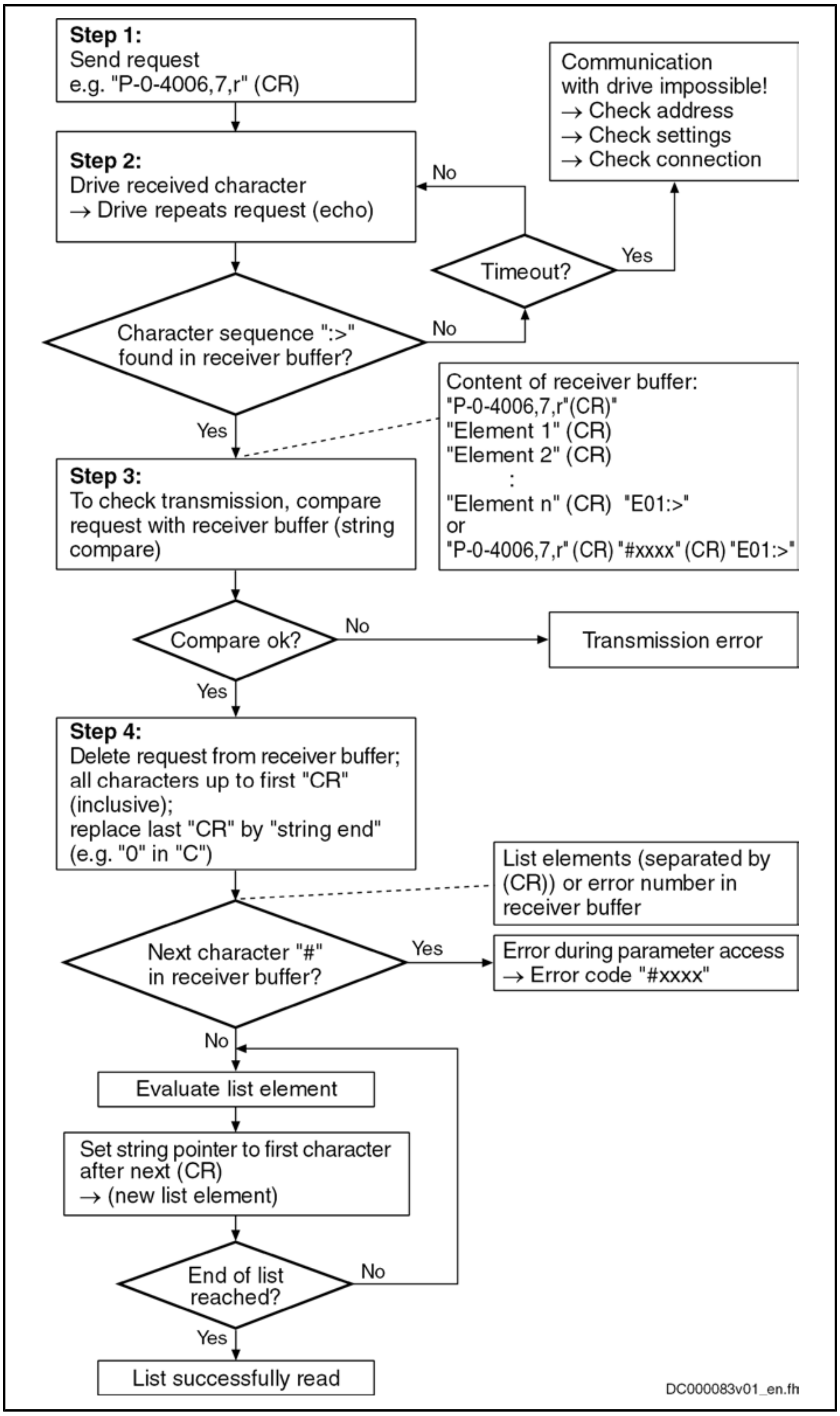

Fig. 10-54: Read Access to List Parameters

Triggering a Command

In the drive controller, a number of commands can be triggered the execution of which takes place automatically within the controller.

The following command parameters are available:

- Switching between operating mode and parameter mode:
  - S-0-0127, C0100 Communication phase 3 transition check
  - S-0-0128, C0200 Communication phase 4 transition check
  - P-0-4023, C0400 Communication phase 2 transition
- S-0-0099, C0500 Reset class 1 diagnostics
- S-0-0148, C0600 Drive-controlled homing procedure command
- S-0-0262, C07_x Load defaults procedure command
- P-0-0012, C0300 Command Set absolute measuring

Via the serial interface, it is possible to start, interrupt and complete the execution of a command. In addition, the status of the command execution can be read.

A command is triggered as follows:

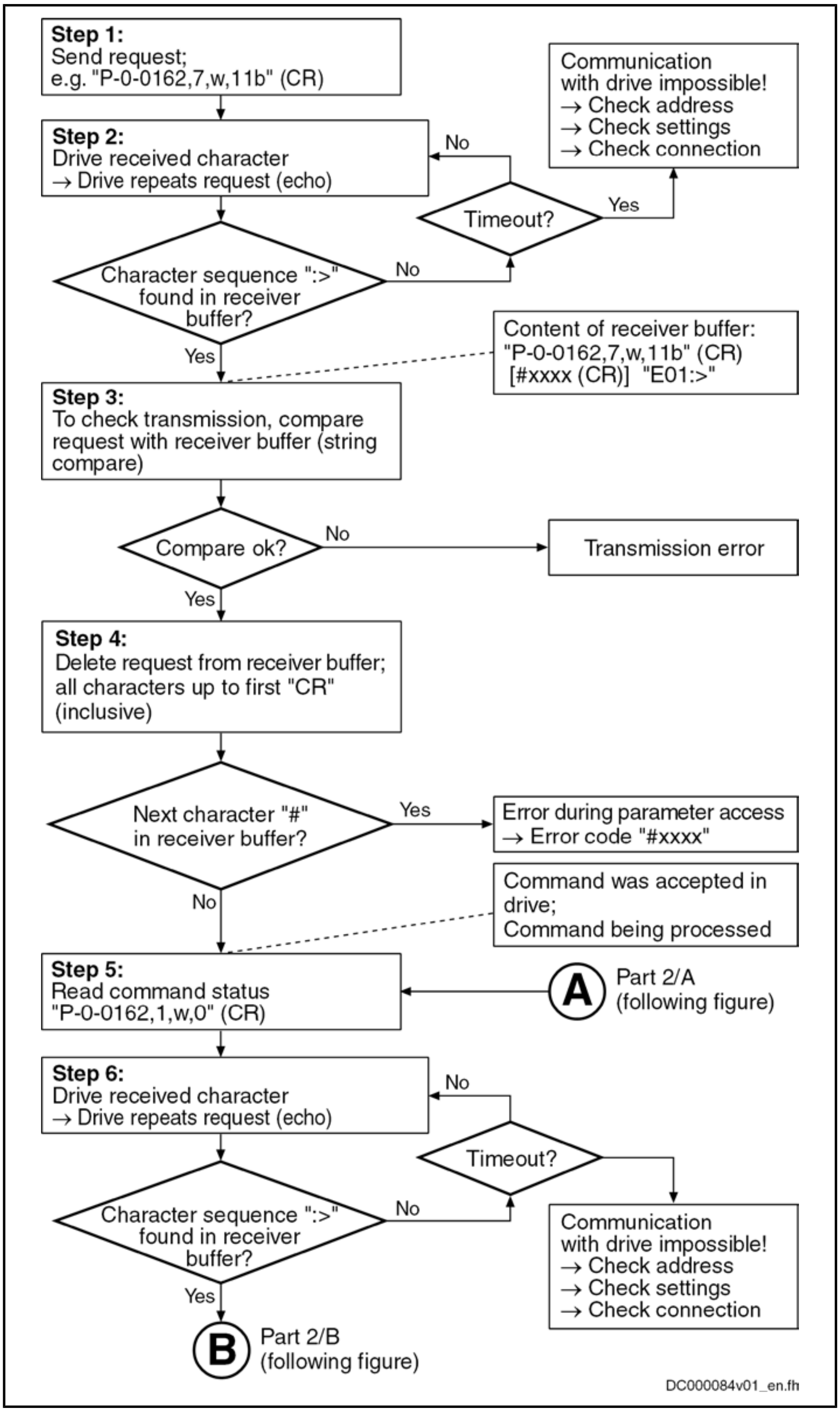

Fig. 10-55: Triggering a Command (Part 1)

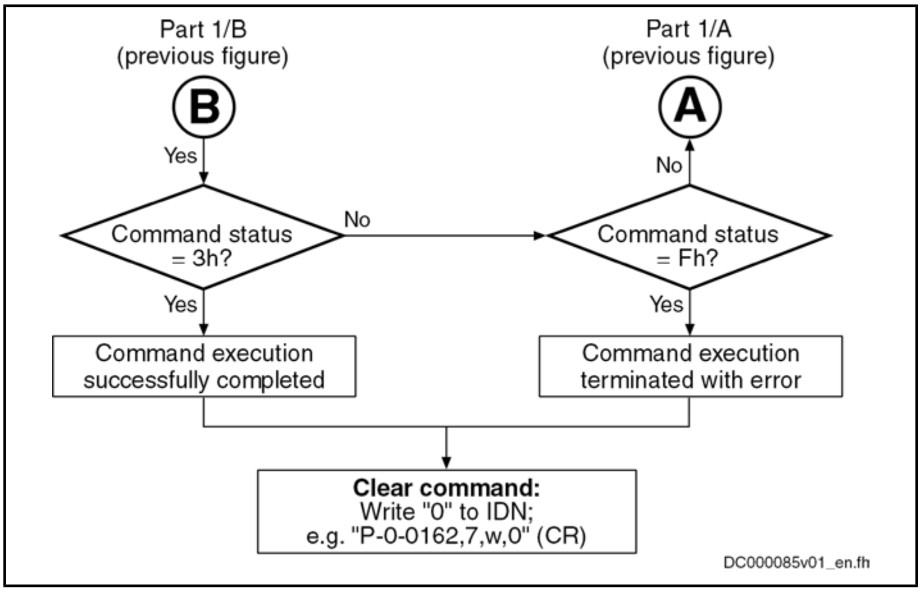

Fig.10-56: Triggering a Command (Part 2)

Querying the Command Status

The current status of a command can be queried. The query of the command status is used to make sure that the drive-side command execution is completed, before the connected control unit (or the PC) completes the command.

The command status is queried as follows:

- **IDN of the command,1,w,0 (Carriage Return)**

After the IDN of the command parameter was written, the drive signals the current command status.

Possible Status Messages

0 h	Command not set in the drive
1 h	Command set in the drive
3 h	Command set, enabled and correctly executed
5 h	Command set and enabled in the drive
7 h	Command set and enabled, but not yet executed
F h	Command set and enabled, but not executed due to error

Fig.10-57: Status Messages

The command status is transmitted in the form of a bit list. The significance of the individual bits is illustrated below.

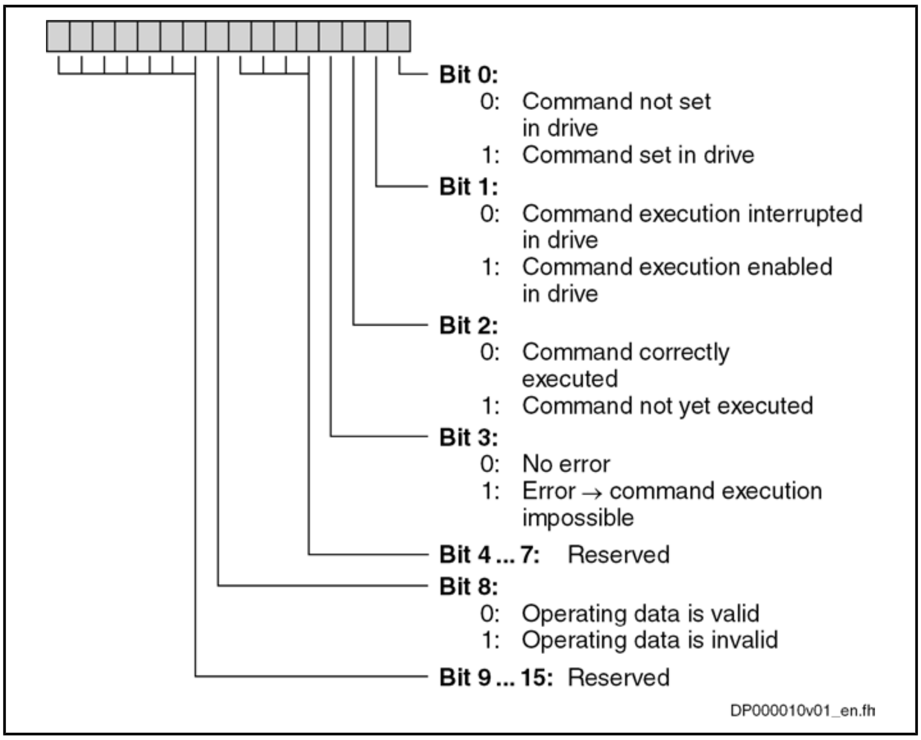

Fig. 10-58: Command Acknowledgment (Data Status)

Completing a Command

A command is completed as follows:

- **IDN of the command,7,w,0 (Carriage Return)**

Example of Application (Changing the Assign List for the Signal Status Word)

Assumption:

Several drives are connected to a PLC via an RS485 interface. The address of the drive we consider is "01".

→ Establishing the communication with the respective axis

BCD: 01 (CR)

Command for switching to drive **A01:>**

Echo of the connected drive (all other drives are passive)

☞ The drive does not send an echo after each character, but it is only after having received the "CR" that the drive returns the complete sequence that was input.

→ Writing the assign list for the signal status word to the drive

The assignment of the relevant bits for the signal status word (S-0-0144) is stored in the form of a list in parameter "S-0-0328, Assign list signal status word". In order to change one or more values in this list, it is necessary to always write all relevant values of this list. That is to say if four elements are used, it is necessary to write all 4 bits, even if only one element (bit) is to be changed.

Input:

S-0-0328,7,w,> (CR)

? 1 (CR) bit 1

? 2 (CR) bit 2

etc.

? <(CR)

E01:>

Error Messages With ASCII Communication

The following error messages specifically occur in the case of communication with ASCII protocol:

Error code	Explanation
0x9001	Fatal error (characters cannot be identified)
0x9002	Parameter type error
0x9003	Invalid data set number
0x9004	Input cannot be identified
0x9005	Data element number not defined
0x9006	Error in the write-read identifier (r/w)
0x9007	Invalid character in the data

Fig. 10-59: Error Messages With ASCII Communication

10.11.4 Communication with SIS Protocol

Telegram Structure, Telegram Scope

Basic Telegram Structure

In principle, a SIS telegram is devided into 3 blocks:

- Telegramm header
- Useful data header
- Useful data

Telegramm header	Useful data header	Useful data

Fig. 10-60: Structure of a SIS telegram

Structure of the Telegram Header

The SIS telegram header consists of a static and a dynamic part.

Static Part of the Telegram Header

The static part of the telegram header comprises of 8 byte and is contained in every SIS telegram.

Byte	Name	Description of the bytes in the static part of the telegram header
1	**StZ**	Start character: STX (0x02)
2	**CS**	Checksum byte → The checksum is generated in three steps: 1. The "CS" byte is cleared 2. All characters in the telegram are added byte by byte 3. The negated sum is stored in the "CS" byte The result if the byte-by-byte addition of all characters in a SIS telegram will always have the value zero!
3	**DatL**	Data length → The "DatL" byte contains the length of a telegram without the static telegram header. **The total length of a SIS telegram is limited to 255 byte.** Therefore, only a maximum of 247 byte of useful data can be transmitted.
4	**DatLW**	Data length repetition

Byte	Name	Description of the bytes in the static part of the telegram header
5	**Ctrl**	Control byte (Control) → In the control byte, the type structure of the dynamic telegram header are declared: • Bit 0…2 → number of subaddresses in the dynamic part of the telegram header • Bit 3 → specifying whether dynamic telegram header contains "PaketN" (package number) byte Bit 3 = 0 → without package number Bit 3 = 1 → with package number • Bit 4 → determining the telegram type Bit 4 = 0 → command telegram Bit 4 = 1 → reaction telegram • Bit 5 → reserved • Bit 6 → reserved in command telegrams; in reaction telegrams bit 6 signals a system warning in the slave • Bit 7 → reserved in command telegrams; in reaction telegrams bit 7 signals a system error in the slave
6	**service**	SIS service → The byte specifies the SIS service of the telegrams. Subservices are defined in some SIS services. In these cases the subservice is specified in the useful data header. The useful data of the command and reaction telegrams can be defined in a different way for every SIS service and its subservice.
7	**AdrS**	Address of the transmitter: • In command telegrams: → address of the master, valid from 0 to 126 • In reaction telegrams: → address of the slave
8	**AdrE**	Address of the receiver: • In command telegrams: → address of the slave, valid from 0 to 126 Address 128: → special address for a "point-to-point" connection; Each slave reacts to the special address independent of its station number. Address 254: → collective message to all slaves in the direct hierarchical level Address 255: → collective message to all slaves in the SIS network below the master Slaves do not respond to collective messages! • In reaction telegrams: → address of the master

Fig.10-61: SIS telegram header, static part

Dynamic Part of the Telegram Header

The dynamic part of the telegram header can contain up to 8 byte. The telegram number (‘PaketN‘ byte), when it was declared in the control byte (‘Ctrl‘ byte in the static part), is always in the last place in the dynamic part of the telegram header. If not all subaddresses are required, they are not available in the telegram. When a command telegram is transmitted from one hierarchical level to the hierarchical level below, the subaddress block is reduced by one address. On the way back, one address is added to the subaddress block in the reaction telegram.

Byte	Name	Description of the bytes in the dynamic part of the telegram header
9	**AdrES1**	slave address in the 1st sublevel
10	**AdrES2**	slave address in the 2nd sublevel
11	**AdrES3**	slave address in the 3rd sublevel
12	**AdrES4**	slave address in the 4th sublevel

Handling, Diagnostic and Service Functions

Byte	Name	Description of the bytes in the dynamic part of the telegram header
13	**AdrES5**	slave address in the 5th sublevel
14	**AdrES6**	slave address in the 6th sublevel
15	**AdrES7**	slave address in the 7th sublevel
16	**PaketN**	Package number (when bit 3 was set in "CTRL" byte): ● At the first request with a package number ≠ 0 the request is processed. The reaction telegram is stored and sent by the slave. ● When the request is repeated (with the same package number), it is not processed. The slave sends the stored reaction telegram. ● When there is another request with a new package number ≠ 0 or when there is a changed request (static telegram header), the request is processed. The stored reaction telegram is overwritten with the new reaction telegram and the new reaction telegram is sent by the slave. ● When there is a request with package number = 0, it is always processed. The reaction telegram is sent by the slave but not stored. Reaction telegrams that still are stored are cleared (re-initialization)! ● When there is a request without package number, it is always processed. The reaction telegram is sent by the slave but not stored. Reaction telegrams that are still stored are maintained! Only with the package monitor is it possible to repeat individual sequential telegrams that were incorrectly transmitted, without canceling the running sequential telegram cycle!

Fig. 10-62: SIS telegram header, dynamic part

Structure of the Useful Data Header

General Information on the Useful Data Header

☞ The structure of the useful data header depends on the direction of transmission. The useful data headers described below are only valid for the services 0x80 … 0x8F.

In the structure of the useful data header we distinguish between command telegram and reaction telegram.

Command Telegram

The command telegram is the telegram the master (drive) sends to the slave (master → slave).

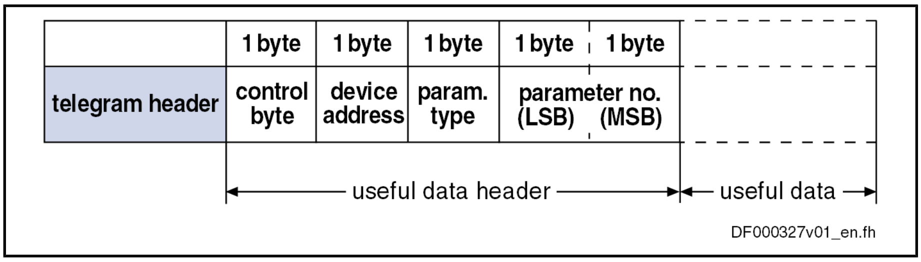

Fig. 10-63: Structure of the useful data header in the command telegram

Significance of the Useful Data Header In the command telegramm the useful data header describes the kind of request.

Control Byte The control byte indicates the parameter element (date, name, ...) that is to be read or written. In addition, the control byte indicates whether other telegrams (sequential telegrams) are required for reading or writing.

Device Address The device address that has been set at the address switches has to be entered in the block "Device Address".

Parameter Type and Number

The parameter number has the format defined in the specification for the SERCOS interface. In order to be able to address the control parameters, a byte for characterizing the parameter type precedes the address.

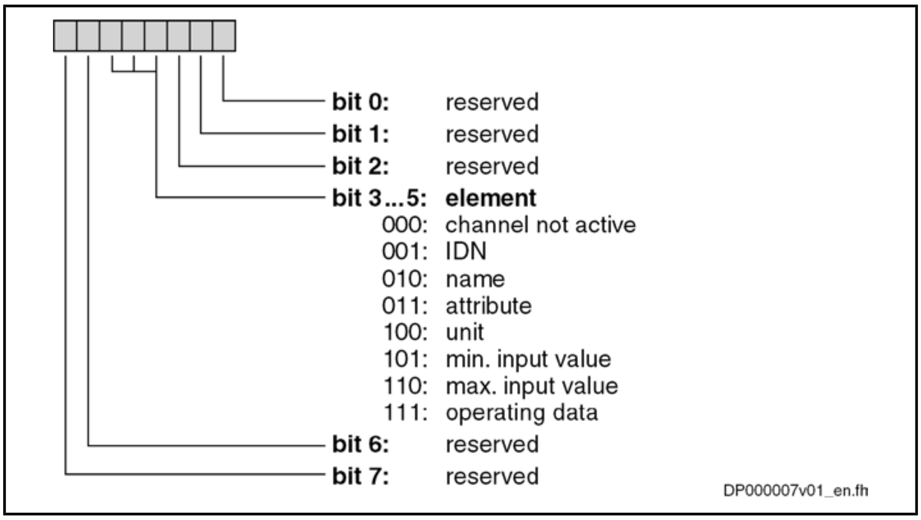

Fig. 10-64: Structure of the control byte

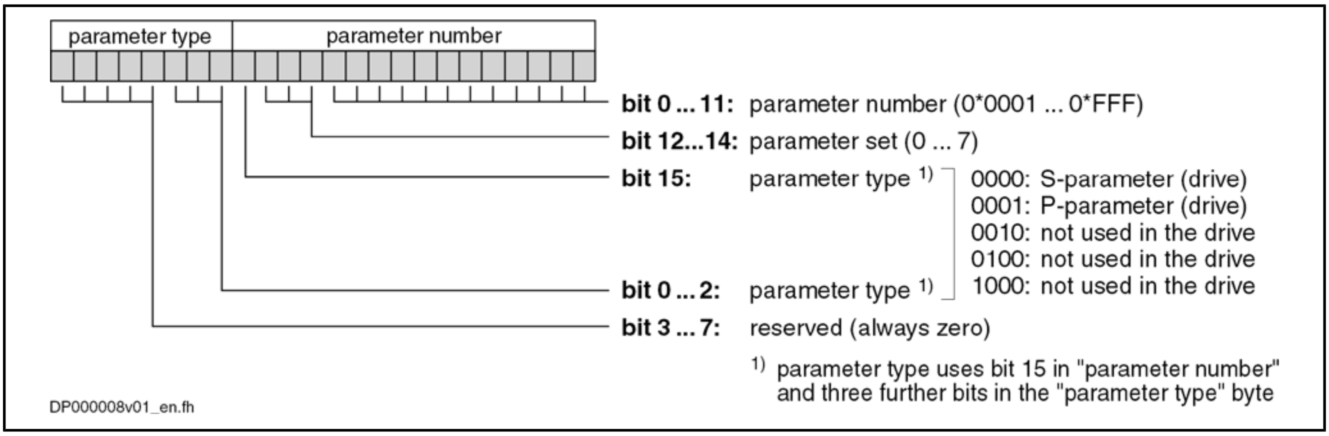

Fig. 10-65: Parameter type and number in the useful data header

Reaction Telegram

The reaction telegram is the telegram the slave (drive) sends to the master (slave → master).

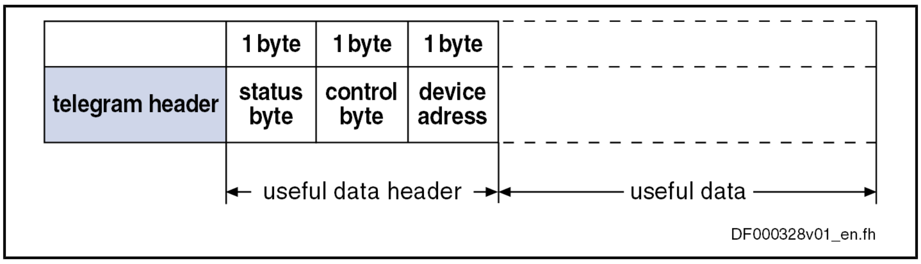

Fig. 10-66: Structure of the useful data header in the reaction telegram

Status Byte

In the status byte an error code is returned, if necessary. In the case of an error-free transmission, a 0x00 is returned in the status byte.

Control Byte

The control byte contains the information regarding which data block element of a parameter is accessed. Bit 2 controls the transmission of the sequential telegrams (writing lists in several steps).

Device Address

In the block "Device Address" the device address set in the parameter "P-0-4022, Drive address of serial interface" has to be entered.

Structure of the Useful Data Field

In the useful data bytes it is possible to enter any value that is interpreted in a different way according to service. For flash programming, for example, binary characters are entered in the useful data and when writing a parameter the decimal numeric value is entered.

The number of bytes in the useful data field and of the useful data header are entered in the "DatL" and "DatLW" bytes.

Status Messages

Status Byte	Description	Kind of error
0x00	Error-free transmission	without error
0x01	During the execution of the requested service an error occured. The **service-specific error code** is contained in the useful data of the reaction telegram.	execution error
0xF0	The requested service is not supported by the addressed slave.	telegram error
0xF8	In the sequential telegram, data in the useful data header, the transmitter address or the service have changed.	telegram error
0xF9	The command telegram contains subaddresses. The routing of telegrams is not supported by the slave.	telegram error
0xFA	Useful data are missing in the command telegram. The telegram cannot be executed.	telegram error
0xFB	The requested subservice is not supported by the addressed slave.	telegram error
0xFC	The requested component is not available in the addressed slave. The component address is invalid.	telegram error

Fig.10-67: List of the defined telegram states

Error Codes

Error code	Service	Description
0x0700	0x03	baud rate not supported
0x0800	0x03	baud rate not supported
0x800C	0x80,0x81, 0x8E,0x8F	Access to parameter denied; the parameter is occupied by the sequential telegram channel.
0x9002	0x02	firmware was deleted
0x9004	0x02	Shutdown not allowed in phase 4 (in FWA-MTx01VRS instead of 0x9010).
0x9010	0x02	Shutdown not allowed in operating mode (as of FWA-MPx02VRS).
0x9102	0x02	firmware was deleted
0x9104	0x02	Reboot not allowed in phase 4 (in FWA-MTx01VRS instead of 0x9010).

Error code	Service	Description
0x9110	0x02	Reboot not allowed in operating mode (as of FWA-MPx02VRS).
0x9200	0x02	error when reading
0x920Bh	0x02	The requested data volume exceeds the maximum useful data volume in the reaction telegram.
0x9400	0x02	timeout during deleting procedure
0x940A	0x02	deleting only possible in loader
0x96E0	0x02	verify error when programming the flash
0x96E1	0x02	timeout when programming the flash
0x96FF	0x02	error when writing to the flash
0x9701	0x02	additional checksum incorrect
0x9702	0x02	CRC32 checksum incorrect
0xA001	0x02	error when reading table
0xA002	0x02	incorrect table type
0xA003	0x02	no backup medium available
0xA201	0x02	error when reading the Hex header
0xA202	0x02	incorrect header number
0xA501	0x02	error when writing
0xA502	0x02	creating the file is not allowed
0xA503	0x02	not enough memory space
0xA601	0x02	error when writing
0xA602	0x02	access to file not allowed

Fig. 10-68: List of the defined error codes

Communication via SIS Protocol

Addressing a Drive

In the case of communication with SIS protocols we distinguish between command telegrams and reaction telegrams, according to the direction of transmission. A node can only be addressed under its address (see program module) when a specific telegram format (frame) is observed.

☞ Only when the drive has received at least one valid SIS telegram is the SIS channel enabled for further communication.

Read Access

When the reading of a parameter is started in a command telegram, a check is run in the drive to determine whether a sequential telegram is required. In this case, bit 2 (current/last transmission) is kept at "0" in the control byte of the reaction telegram until the last reaction telegram is sent. In the last reaction telegram, bit 2 is set to "1".

The sending of a sequential reaction telegram is activated by the repeated sending of the unchanged command telegram.

Sequential Telegram Access

When the writing or reading of a parameter with sequential telegrams was started in the drive, it is necessary to complete or cancel this process before another service with sequential telegrams can be started. If another service was started nevertheless, the "0x800C unauthorized access" error code is sent in the reaction telegram. The service with sequential telegram started before can then be normally processed or cancelled with the next command telegram.

Supported Services and Subservices

SIS service	Description	Subservices	Subservices description	Notes
0x00	**node identification**	0x01	reading SIS version	subservice is implemented but not active
		0x02	reading firmware version	supplies content of S-0-0030
		0x03	reading controller type	supplies content of S-0-0140
		0x04	reading supported baud rates	9600 baud, 19200 baud, 38400 baud, 57600 baud, 115200 baud
0x01	**data transmission canceled**	none		
0x02	**flash operations**	0x90	shutdown	switches drive firmware to the loading mode
		0x91	reboot	causes restart
		0x92	read flash	reads content of the flash
		0x93	find header	supplies header address of the first IBF module
		0x94	erase flash	deletes content of the flash
		0x96	program flash	programs content of the flash
		0x97	build checksum	supplies CRC32 checksum of the indicated IBF module
		0x9F	error reset in the slave	clears error in loading mode
		0xA0	read configuration	supplies configuration table
		0xA2	read header	reads header of the corresponding module
		0xA5	write file information	generates corresponding file
		0xA6	write file data	writes content to the opened file
0x03	**initialization of the SIS communication**	0x01	determining TrS	initializes max. reaction time in the slave
		0x02	determining TzA	initializes max. character interval on the bus
		0x03	determining Tmas	subservice is implemented but not active
		0x07	determining the baud rate	initializes the baud rate of the serial transmission
		0x08	time-controlled baud rate test	allows temporary change of the baud rate
		0xFF	accepting the determined values	activates the values initialized with the subservices 0x01, 0x02 and 0x07
0x10	**reading parameter**	none		0x10 = 0x80
0x11	**reading list segment**	none		segment information in byte
0x1E	**writing list segment**	none		segment information in byte
0x1F	**writing parameter**	none		0x1F = 0x8F
0x80	**reading parameter**	none		0x80 = 0x10
0x81	**reading list segment**	none		segment information in word

SIS service	Description	Subservices	Subservices description	Notes
0x8E	writing list segment	none		segment information in word
0x8F	writing parameter	none		0x8F = 0x1F

Fig. 10-69: Supported services and subservices

Service 0x01 Cancelling a Data Transmission

With this service it is possible to cancel a sequential telegram sequence. The sequential telegram channel is unlocked with the "Cancelling a data transmission" service when the device address and the service to be cancelled correspond with the sequential telegram sequence. When the command telegram is transmitted without the device address and without service to be cancelled, this service is always executed.

Command Telegram

- Enter 0x01 in the service of the telegram header.
- Enter the service to be cancelled in the useful data.

Reaction Telegram

If there isn't any error, the reaction telegram has the following structure:

Telegramm header	Useful data header

Fig. 10-70: Structure of the reaction telegram

In the case of an error, the useful data that contain the error code are transmitted. The useful data header corresponds to the SIS specification.

Telegramm header	Useful data header	Useful data

Fig. 10-71: Structure of the reaction telegram in the case of error

☞ When there wasn't any sequential telegram processed and this service was transmitted nevertheless, there isn't any error reaction telegram transmitted!

Service 0x80: Reading a Parameter

Command Telegram

A one-time read access is completed with one transmission step. The master enters the following information in the command telegram:

- In the control byte the desired element is selected in the bits 3...5 ("element"). Bit 2 is set to "1" (last transmission).
- The device address is entered.
- Parameter type and number are entered.
- There aren't any useful data entered.

Reaction Telegram

The answer to a read access contains the following data:

- In the Ctrl byte of the telegram header bit 4 is set to "1" in order to identify it as a reaction telegram.
- The status byte of the useful data header contains the information whether an error occurred during the processing of the command telegram.
- The control byte is read from the command telegram and copied to the reaction telegram.
- The device address is read from the command telegram and copied to the reaction telegram.
- The requested data is written to the useful data.

Example

The following example illustrates reading the "S-0-0044, Velocity data scaling type" parameter from the drive with the address "3". The parameter has the value "0x0042".

Command Telegram:

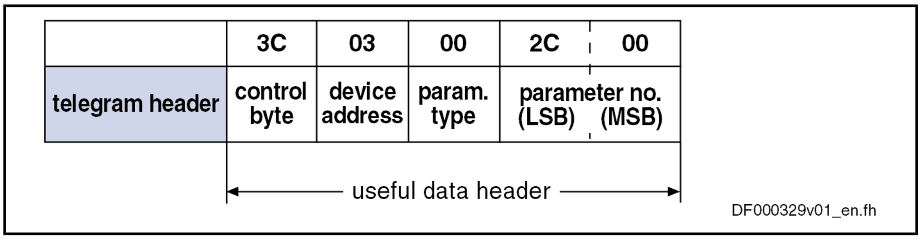

Fig. 10-72: Reading the S-0-0044 parameter (command telegram)

Reaction Telegram:

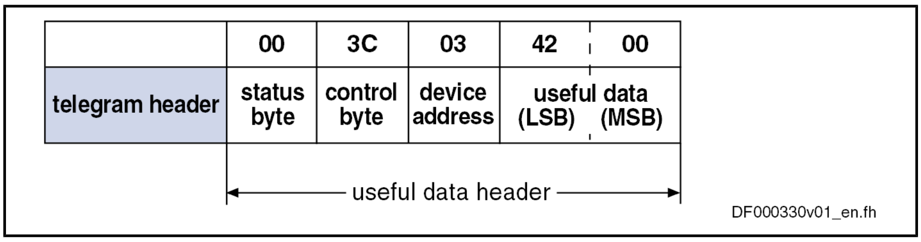

Fig. 10-73: Reading the S-0-0044 parameter (reaction telegram)

Service 0x8F: Writing a Parameter

☞ By means of this service, all available commands can be started in the drive.

Command Telegram

A one-time write access is completed with one transmission step. The master enters the following information in the command telegram:

- Enter "0x8F" in the service of the telegram header.
- Enter the parameter to be written in the "parameter type" and "parameter no." bytes of the useful data header.
- Enter the value to be written in the useful data.
- The device address is entered.
- In the control byte the operating date is selected in the bits 3...5 ("element"). Bit 2 is set to "1" (last transmission).
- The IDN of the parameter to be written is written to the parameter number.
- The value of the operating data is written to the useful data.

Reaction Telegram

The answer to a write access contains the following data:

- In the Ctrl byte of the telegram header bit 4 is set to "1" in order to identify it as a reaction telegram.
- The status byte of the useful data header contains the information whether an error occurred during the processing of the command telegram.
- The control byte is read from the command telegram and copied to the reaction telegram.
- The device address is read from the command telegram and copied to the reaction telegram.
- There aren't any useful data entered.

Example

The following example illustrates transmitting the "S-0-0044, velocity data scaling type" parameter to the drive with the address "03". The value "0x0042" is written to the parameter.

Command Telegram:

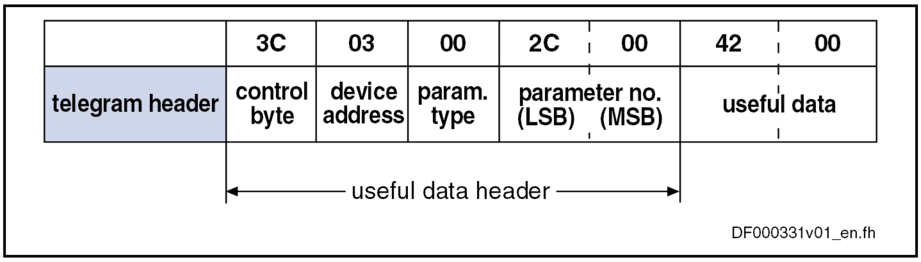

Fig. 10-74: Writing the S-0-0044 parameter (command telegram)

Reaction Telegram:

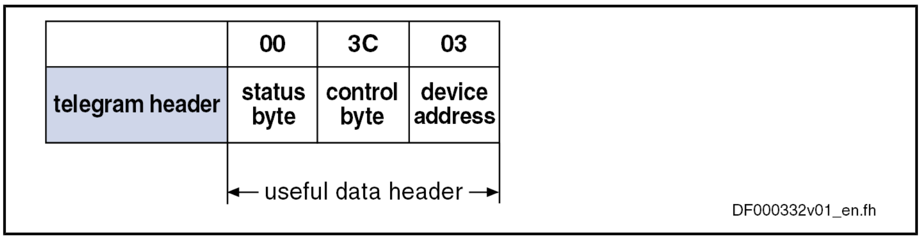

Fig. 10-75: Writing the S-0-0044 parameter (reaction telegram)

Starting a Command

With the service 0x8F "Writing a parameter" all commands can be started in the drive via the SIS protocol.

Telegramm header	Useful data header	2 byte useful data

Fig. 10-76: Structure of the command telegram

- Enter the value "0x8F" in the service of the telegram header.
- Enter the command to be activated in the "parameter type" and "parameter number" bytes of the useful data header.
- Enter the input of the command in the useful data byte.

Service 0x81: Reading a List Segment

Command Telegram

- Enter the value "0x81" in the service of the telegram header.
- Enter the parameter type and parameter no. of the parameter to be read in the useful data header.
- Enter the offest in the useful data bytes 0 and 1 within the list as a word (=16 bit).
- Enter the number of words to be read in the useful data bytes 2 and 3.

Reaction Telegram

- In the control byte of the reaction telegram the current/last transmission is marked with bit 2.

☞ The output of a sequential telegram is activated by the repeated sending of the unchanged command telegram.

Service 0x8E: Writing a List Segment

Command Telegram

- Enter the value "0x8E" in the service of the telegram header.
- Enter the parameter type and parameter no. of the parameter to be read in the useful data header.

- Enter the offest in the useful data bytes 0 and 1 within the list as a word (=16 bit).
- Enter the number of words to be written in the useful data bytes 2 and 3.

Reaction Telegram

- A possible error is entered in the useful data in the reaction telegram.

☞ With this service it is only possible to process list segments that are contained in the list currently available. If the actual list length is to be changed this list must specifically be written. Operation in the sequential telegram mode is not possible.

Examples of Application (Sequential Telegrams)

Service 0x8F: Write Access (with Sequential Telegrams)

Parameters of elements longer than 243 byte are read in several steps. The transmission of such lists is carried out in several steps. Bit 2 in the control byte marks the current transmission step as the current or last transmission.

The figures below illustrate the control word for a transmission in several steps.

1st Step

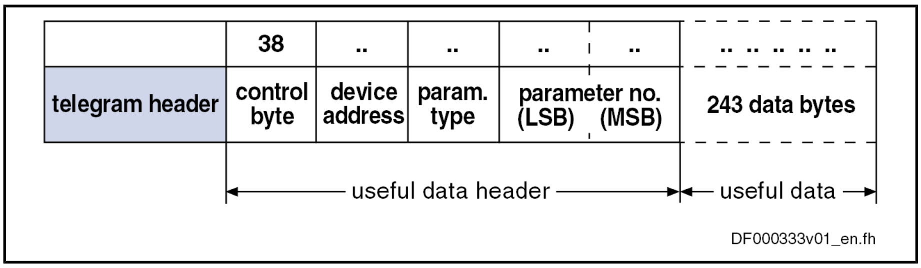

Fig. 10-77: Writing with sequential command telegram (step 1)

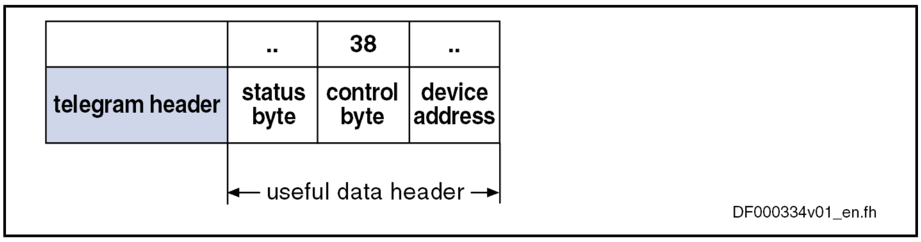

Fig. 10-78: Writing with sequential reaction telegram (step 1)

2nd Step

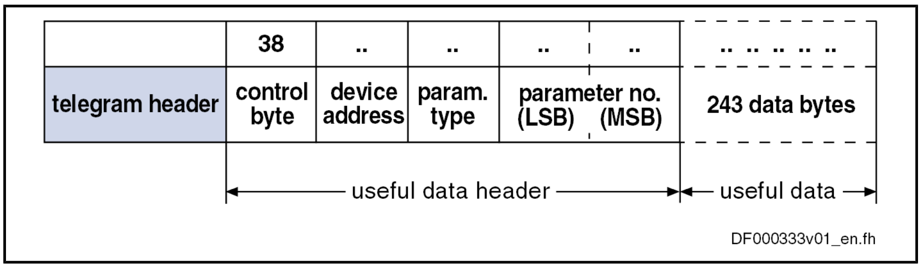

Fig. 10-79: Writing with sequential command telegram (step 2)

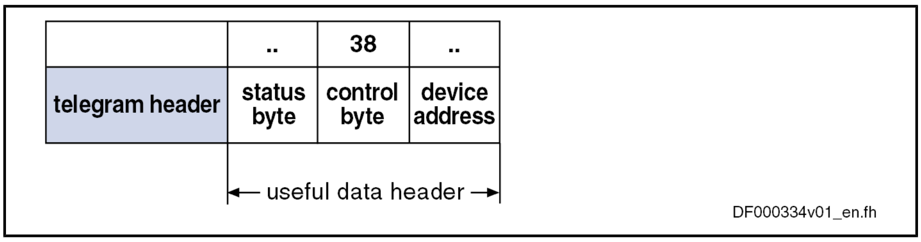

Fig. 10-80: Writing with sequential reaction telegram (step 2)

3rd Step

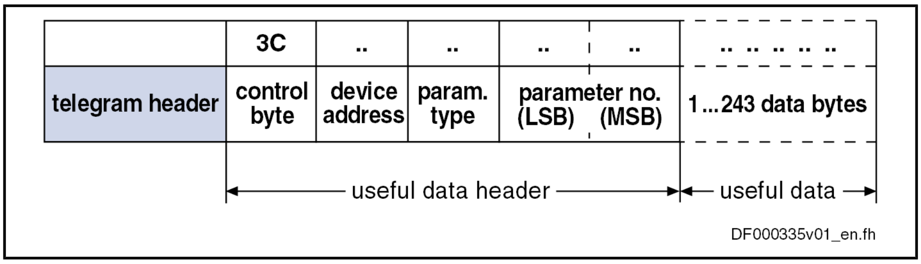

Fig. 10-81: Writing with sequential command telegram (step 3)

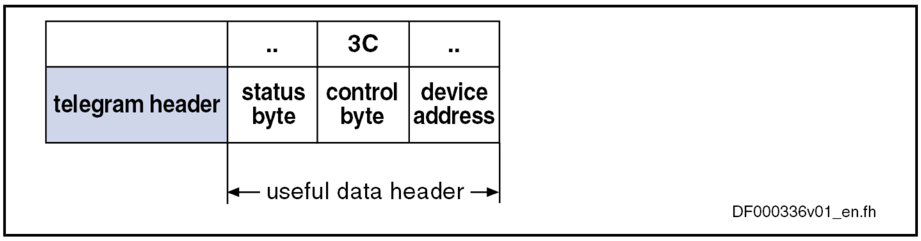

Fig. 10-82: Writing with sequential reaction telegram (step 3)

Service 0x80: Read Access (with Sequential Telegrams)

Parameters of elements whose length exceeds the maximum data field length of 245 byte are read in several steps. Bit 2 in the control byte of the reaction telegram marks the current transmission step as the current or last transmission.

The figures below illustrate the control word for a transmission in several steps.

1st Step

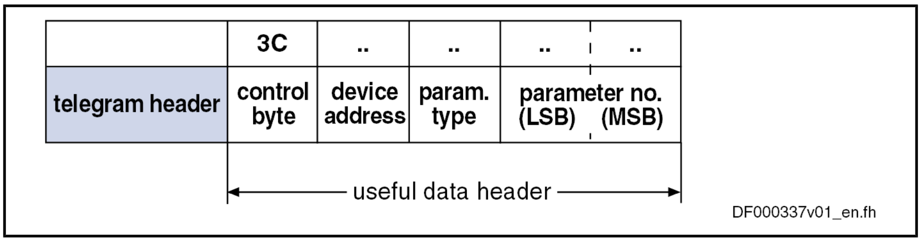

Fig. 10-83: Reading with sequential command telegram (step 1)

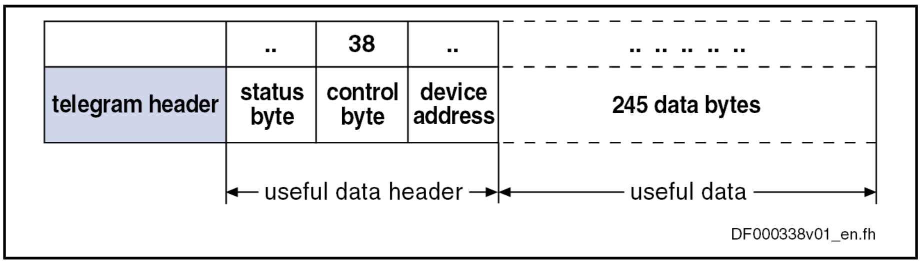

Fig. 10-84: Reading with sequential reaction telegram (step 1)

2nd Step

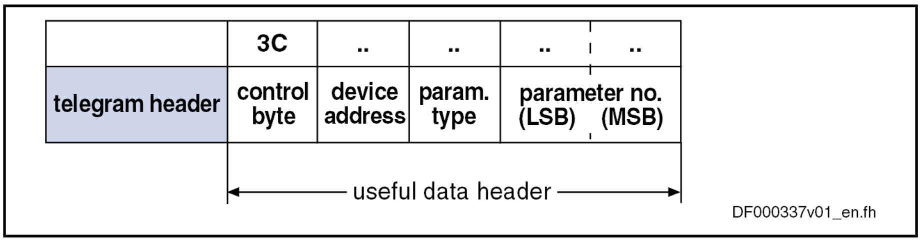

Fig. 10-85: Reading with sequential command telegram (step 2)

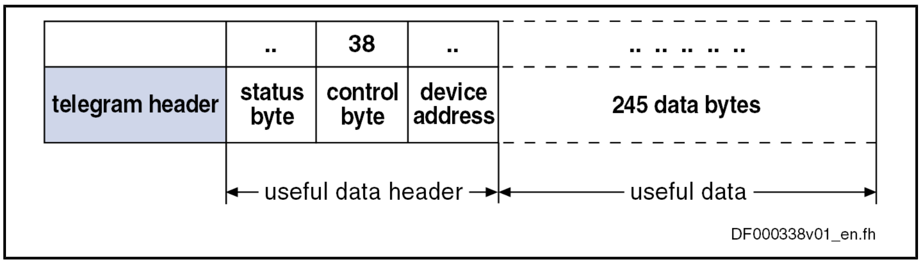

Fig. 10-86: Reading with sequential reaction telegram (step 2)

3rd Step

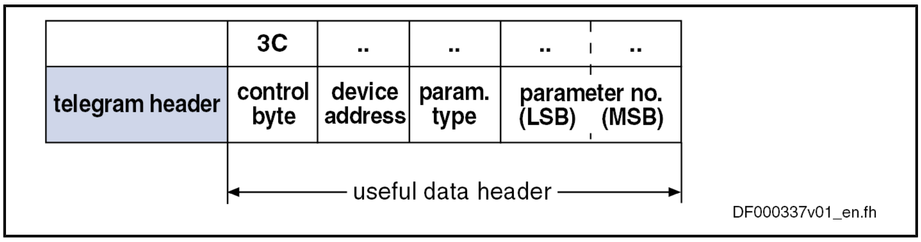

Fig. 10-87: Reading with sequential command telegram (step 3)

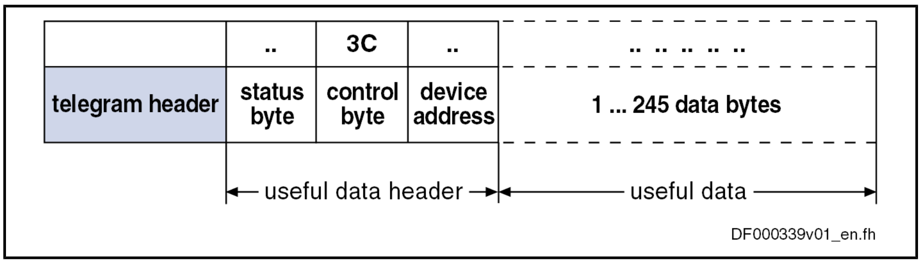

Fig. 10-88: Reading with sequential reaction telegram (step 3)

Error in the Case of SIS Communication

Error During Parameter Transmission

If an error occurs during the parameter transmission, an "error during parameter transmission" is signaled in the status byte.

The first two bytes of the useful data transmit an error code that describes the kind of error.

During the parameter transmission the following errors can occur:

Error code	Explanation
0x0000	no error
0x0001	service channel not open
0x0009	invalid access to element 0
0x8001	"Service channel currently occupied (BUSY)" → The desired access is currently impossible because the service channel is occupied.
0x8002	"Failure in service channel" → It is currently not possible to access the desired drive.
0x800B	"Transmission canceled (higher priority)"
0x800C	"Unauthorized access (service channel still active)" → A new request is started before the last transmission was completed.

Fig. 10-89: Error messages in the serial protocol

Execution and Protocol Acknowledgement

With each reaction telegram a status byte is transmitted. The status byte provides the result of a transmission in the form of a code number.

In general, the following applies:

Result of the transmission	Code number in the status byte
transmission without error	0x00
protocol error	0xF0 … 0xFF
execution error	0x01 … 0xEF

Fig. 10-90: Definition of the status byte

Protocol error	Code number	Description of error
invalid service	0xF0	The requested service is not specified or ist not supported by the addressed node.

Fig. 10-91: Definition of the protocol error

Execution error	Code number	Description of error
error during parameter transmission	0x01	When reading or writing a parameter an error occurred.

Fig. 10-92: Definition of the execution error

Example

The following example illustrates a write access to the read-only parameter "S-0-0106, Current loop proportional gain 1".

The master tries to write the value "0" to the parameter. The drive acknowledges with the "0x7004" ("Data cannot be changed") error message.

Command Telegram:

	3C	00	04	0B	00	00	00
telegram header	control byte	device address	param. type	parameter no. (LSB)	(MSB)	useful data	

← useful data header →

DF000340v01_en.fh

Fig. 10-93: Writing the S-0-0106 parameter (command telegram)

Reaction Telegram:

	01	3C	00	04	70
telegram header	status byte	control byte	device address	useful data	

← useful data header →

DF000341v01_en.fh

Fig. 10-94: Reading the S-0-0106 parameter (reaction telegram)

11 Commissioning

11.1 Commissioning Motors

11.1.1 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".

11.1.2 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 D" commissioning tool by Bosch Rexroth connected to the drive via SERCOS interface or via a serial interface,
- 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

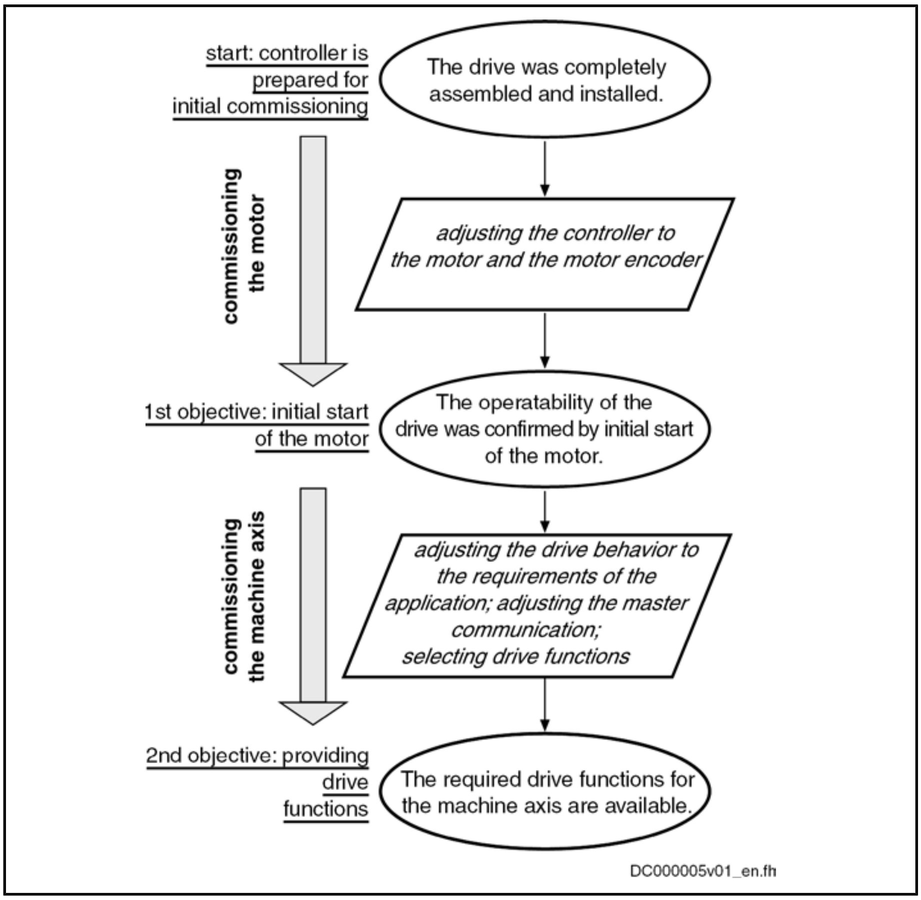

Fig.11-1: Two-step drive commissioning (schematic)

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 D or in the "Easy Startup" mode!

See 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 original status 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!

CAUTION

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, Selected IDN list of operation data to backup" 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. MMC and IndraWorks D only work with the content of the list parameter S-0-0192!

In its original status, 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 the parameters 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 (parameter "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 parameter 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 drive address (see "Basic Functions of Master Communication: Setting the Axis Address")
- "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"

11.1.3 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 **emergency operation when the control unit has failed**.

Features

- **Activation of the easy startup mode** is possible in two ways:
  - By activating the command parameter "P-0-4085, C4700 Command Activate easy startup mode" via serial interface or digital input
  - Via control panel of controller (pressing the corresponding keys in a certain order triggers activation of command parameter P-0-4085)
- Automatic **deactivation of master communication interface** (see P-0-4077, S-0-0134) and activation of "P-0-4028, Device control word"
- Activation of **drive enable** (P-0-4028, bit 15) via:
  - Digital input I_2 (default status)
  - Serial 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 (see parameter 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")
- **Control of motor potentiometer** via digital input signals (see parameter "P-0-1200, Control word 1 velocity control", bit 8 and bit 9)

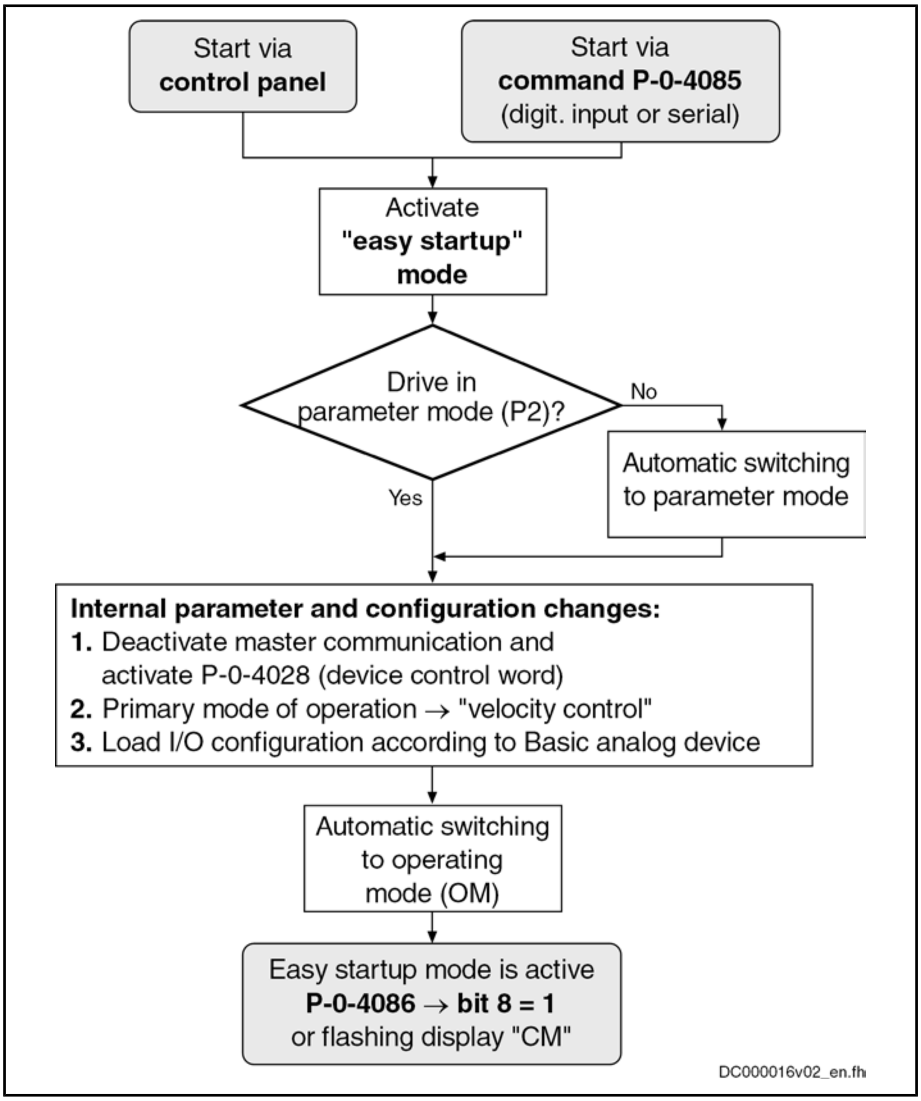

Fig. 11-2: Activating the Easy Startup Mode, Overview

Hardware Requirements

Control sections BASIC SERCOS, BASIC PROFIBUS, BASIC UNIVERSAL, BASIC UNIVERSAL double-axis and ADVANCED

For using the easy startup mode, the digital inputs and outputs (X31, X32) must be connected as follows:

- Connect 24V/0V power supply to respective terminal connectors
- X31/4: +24 V for activating drive enable
- X32/7 and X32/8: 0V/+24V for activating positive or negative rotational direction
- As an alternative to X32/7 and X32/8, it is possible to connect X31/3 and X31/7 to control the motor potentiometer.

Control sections BASIC OPENLOOP and BASIC ANALOG

For drives with these control sections, the easy startup mode actually is not required, because these drives can easily be moved with an analog command value.

See "Analog Interface"

Pertinent Parameters

- S-0-0032, Primary mode of operation
- S-0-0091, Bipolar velocity limit value

- P-0-0300, Digital I/Os, assignment list
- P-0-0301, Digital I/Os, bit numbers
- P-0-0302, Digital I/Os, direction
- P-0-1200, Control word 1 velocity control
- P-0-1206, Memory of velocity command values
- P-0-4028, Device control word
- P-0-4085, C4700 Command Activate easy startup mode
- P-0-4086, Master communication status

Pertinent Diagnostic Messages

There is the following diagnostic command message for the easy startup mode:

- C4700 Command Activate easy startup mode

When the easy startup mode is used, 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 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

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 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 "Easy active"!

The easy startup mode can be activated in the following ways:

- Via the control panel of the controller
- Via a digital input
- Via the serial interface

> ☞ By activating the parameter "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:

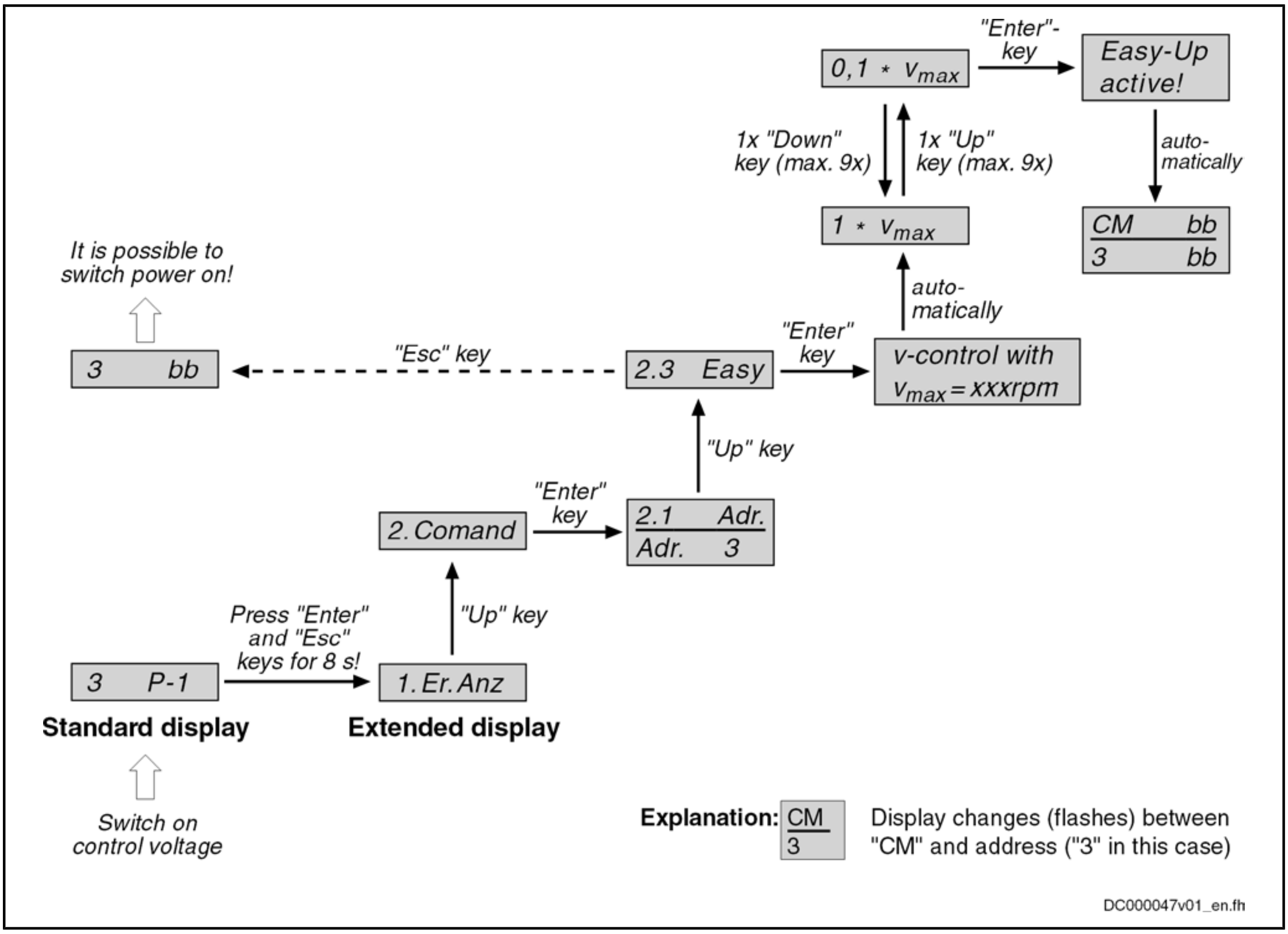

Fig. 11-3: Activating the Easy Startup Mode Via the Control Panel

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 Serial Interface

If the easy startup mode is activated via the serial interface, parameter P-0-4085 has to be written via SIS telegrams.

See "Serial Communication"

☞ The parameter "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 case the master would deactivate itself!

Acknowledging the Active Easy Startup Mode

The active 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

Influenced Settings and Parameters

By activating the easy startup mode, the following settings are automatically made:

- Activation of "volatile storage" of parameters so that the changes in the parameters made for the easy startup mode are not stored and get lost by switching the control voltage off.
- Deactivation of the master communication interface and activation of "P-0-4028, Device control word" for setting "drive enable".
- Assignment of the command velocity selected via the control panel in percent of "S-0-0091, Bipolar velocity limit value" to elements 1 and 2 of "P-0-1206, Memory of velocity command values" (with positive sign to element 1, with negative sign to element 2).

  Note: The content of parameter "P-0-1206, Memory of velocity command values" is not influenced by the command execution. The velocity values can either be adjusted via the control panel or the serial interface.
- Assignment of input E3 (X31/5) to the "drive enable" bit (bit 15) in parameter "P-0-4028, Device control word".
- Assignment of EA9 (X32/7) to bit 0 and of EA10 (X32,8) to bit 1 in parameter "P-0-1200, Control word 1 velocity control" for reversal of direction.
- Assignment of E1 (X31/3) to bit 8 and of E5 (X31,7) to bit 9 in parameter "P-0-1200, Control word 1 velocity control" for controlling the motor potentiometer.
- Activation of the "velocity control" mode in parameter "S-0-0032, Primary mode of operation" and switching to "bb".

☞ The assignments are made in "P-0-0300, Digital I/Os, assignment list", "P-0-0301, Digital I/Os, bit numbers" and "P-0-0302, Digital I/Os, direction".

See "Digital Inputs/Outputs"

"Load Basic Parameters" With Invalid Parameter Settings

After activating the easy startup mode, 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 parameter 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 parameter "P-0-0116, Device control: control word".

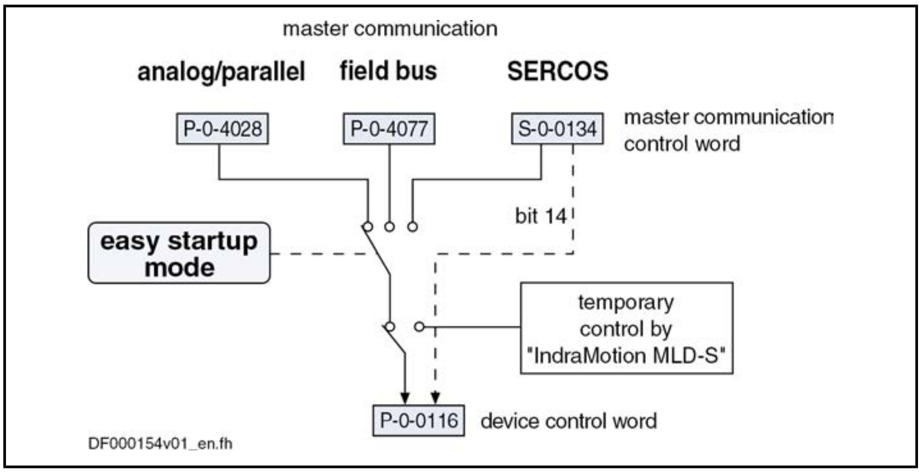

Fig.11-4: Controlling the Drive in the Easy Startup Mode

☞ 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-0-4028, Device control word" active in the easy start-up mode can be changed or influenced in the following ways:

- Via digital inputs, if they were accordingly configured before
- Via the serial interface by directly writing parameter P-0-4028

  → In this case, the parameter has to be actively written at least every 2 s, otherwise the drive will automatically clear drive enable!

Terminating the Easy Startup Mode

The easy startup mode can only be terminated by switching the controller off!

After the easy startup mode was terminated, the controller is in its initial status again and all configurations specifically made for this mode were undone.

After successful command execution, the drive is automatically switched to the operating mode again, if it had been in phase 4 before the start of the command!

☞ If required, the easy startup mode has to be activated again.

Notes on Commissioning

Invalid Commands

The commands for backup of 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!

Initial Commissioning

In the easy startup mode, initial commissioning of Rexroth motors with encoder data memory is easily done without commissioning tool, because the required parameter settings for motor control and motor encoder are automatically made via the command "load defaults procedure - load controller parameters".

For "load defaults procedure" see "Default Settings in the Motor Encoder Data Memory" under "Drive Control: Overview"

Initial commissioning of Rexroth motors without encoder data memory or of third-party motors is only possible in the easy startup mode in conjunction with a commissioning tool (DriveTop or IndraWorks D), 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 "P2" → "P4".

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"

CAUTION

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 transition "P2" → "P4"!

CAUTION

Property damage caused by errors when controlling motors!

⇒ The digital input signals have to be applied with due caution!

The figure below summarizes the commissioning sequence with the easy start-up mode:

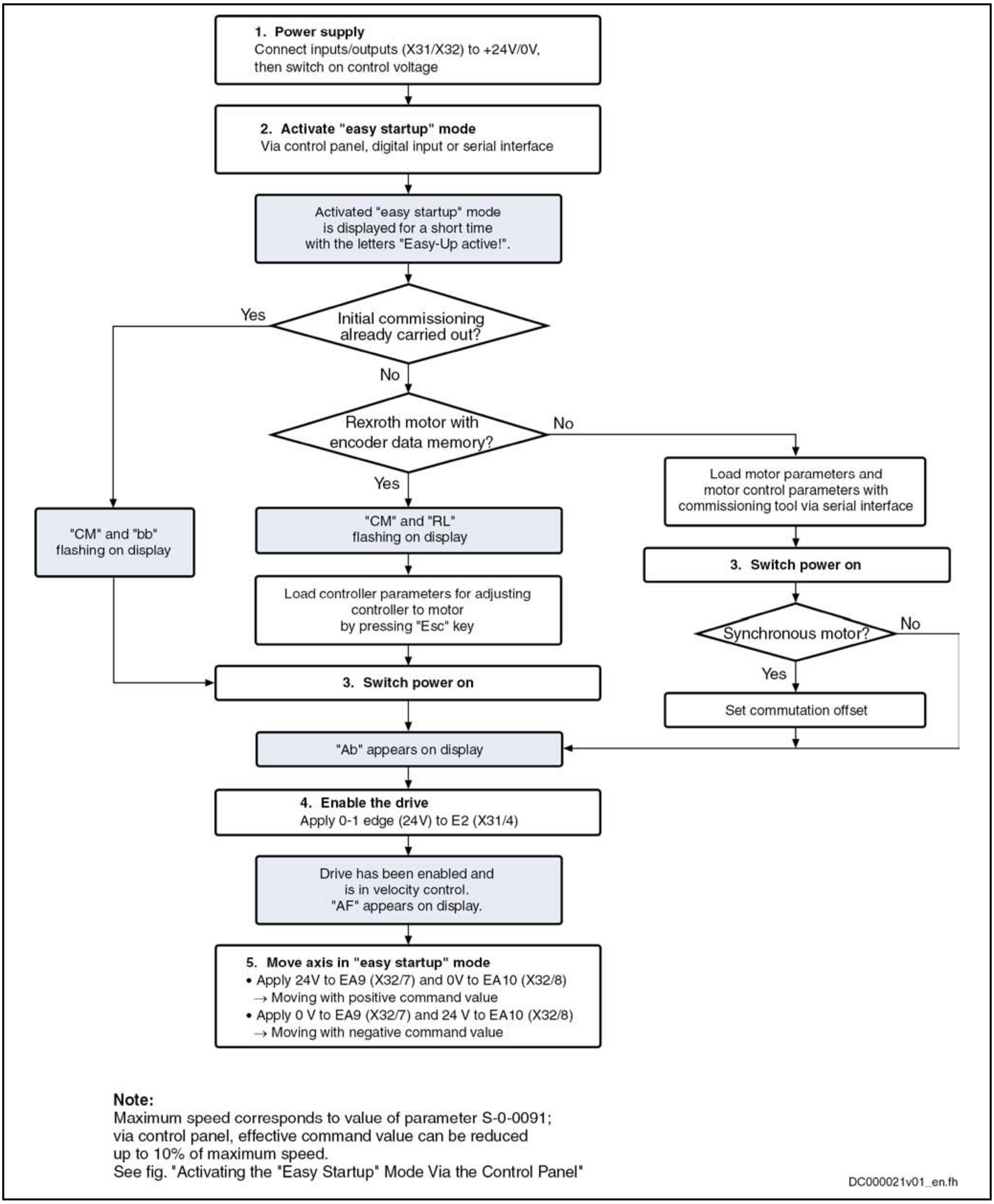

Fig.11-5: Commissioning Sequence With Easy Startup Mode

11.1.4 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. This is very easily done by means of initial start in the "easy startup" mode (velocity-controlled operation, master communication master not required), if possible in conjunction with the Rexroth commissioning tool "IndraWorks D" or via SERCOS interface in conjunction with the Rexroth commissioning tool "DriveTop" and the Rexroth SERCOS master SYSDA02.2.

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.
- 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 data base of the commissioning tool to the controller via the serial interface. This allows initial commissioning in the "easy startup" mode for these motors, too.
- If a PC with the commissioning tool "DriveTop" (version 16VRS) and SYSDA02.2 are available, drives with SERCOS interface can be conveniently commissioned and moved via command values of SYSDA02.2.

Available Commissioning Tools

For IndraDrive devices, Bosch Rexroth makes available the following commissioning tools (software):

- DriveTop (version 16VRS)

  - and -
- IndraWorks D

DriveTop

"DriveTop" is a tool for parameterizing and commissioning drives. It supports the Rexroth SERCOS master SYSDA02.2 by means of which it is possible to move drives with SERCOS interface. The communication with the drive or with SYSDA02.2 is established via the serial interface RS232/RS485.

IndraWorks D

"IndraWorks D" is a component of the software range "IndraWorks" which supports parameterization and commissioning of control units and drives by Bosch Rexroth. IndraWorks D has been designed for interaction with the SERCOS master SYSDA02.2. The communication with the drive is established via the serial interface RS232/RS485.

The commissioning tools "DriveTop" and "IndraWorks D" provide the following possibilities 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.

In conjunction with SYSDA02.2 the commissioning tool "DriveTop" (version 16VRS) provides further possibilities:

- The drive can be commissioned and moved.
- For the purpose of commissioning, commands can be started via DriveTop.

Functional Description

For the initial start of the motor the following steps have to be carried out:

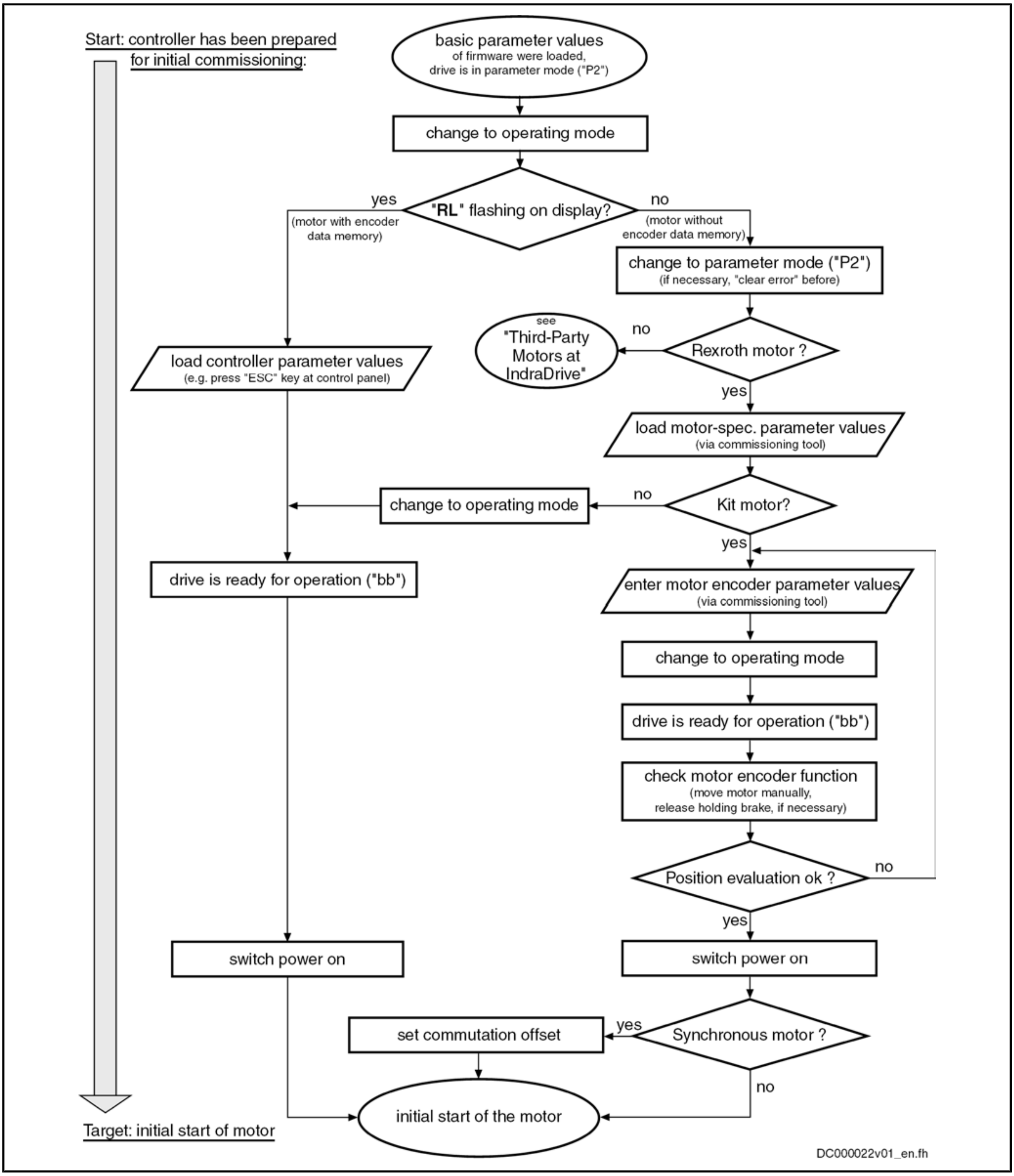

Fig. 11-6: Commissioning steps for initial start of Rexroth motors

Notes on Commissioning for Using DriveTop and SYSDA02.2

The steps for initial start illustrated in the figure (above) are described below as a detailed sequence for a Rexroth motor in conjunction with DriveTop and SYSDA02.2 (SERCOS interface).

Basic actions:

1. Connect "SYSDA02.2" hardware according to installation instructions:

   Voltage supply must be available! Establish serial communication with PC that makes DriveTop available and establish fiber optic SERCOS connection to controller (observe Tx → Rx!) (see technical documentation of SYSDA02.2)!

2. Switch on supply voltage of the controller(s):

   Display of controller(s) first shows boot phases. Then drive address and communication phase "P-1" will be displayed.

3. In DriveTop, enter drive address appearing on display:

   Enter drive address or addresses in "System overview" (open "System overview" dialog under menu item "Setup" – "SERCANS basic configuration")!

4. From communication phase "P-1" change to parameter mode "P2":

   Activate "parameterization mode" ("P2") (press right mouse key, activate with cursor)!

5. Now select drive in the SERCOS ring that is to be commissioned:

   Have list of drives connected by SERCOS ring displayed and select a drive (to do this, activate "System overview" in menu item "Overview" and select a drive with cursor)!

   The drive to be commissioned can now be addressed via DriveTop.

6. First prepare loading of basic firmware parameters:

   Write value "0x001" to parameter "P-0-4090, Index for C07 Load defaults procedure" (Select dialog "Drive commands" under menu item "Tools". Press right mouse key, select "Single parameters" with cursor, call "p4090" and write data)!

7. Now load basic firmware parameters:

   Start "C0700 Load defaults procedure command" (select command "S-0-0262, C07_x Load defaults procedure command" from list with cursor, start with corresponding button)!

   After command execution message, basic firmware parameter values (default parameter values) were loaded to drive parameters, drive now is in an operable initial state.

8. From communication phase "P2" change to phase "bb" (operating mode, P4):

   Activate "Operating mode" (press right mouse key, select with cursor)!

   If controller now requests loading of controller parameter values by "RL" flashing, continue with no. 9, if a different diagnostic message is displayed, continue with no. 11!

Rexroth motor with encoder data memory:

9. When "RL" is flashing on the display, a Rexroth motor with encoder data memory was connected to controller. Now adjust controller to motor:

   Start "Clear error" command (press right mouse key, activate with cursor or "Esc" at control panel)!

   Drive now is ready for operation, display of drive addressed by DriveTop reads "bb".

   If there are other drives in the SERCOS ring, repeat steps from no. 5 onward!

10. Continue sequence with no. 16!

Rexroth motor with motor encoder without data memory:

11. If "RL" is not flashing on right side next to drive address at controller display, a five-digit diagnostic message text appears in most cases. In this case, motor does not have an encoder memory. Therefore, there aren't any motor-specific parameter values made available on motor side. If connected motor is a Rexroth motor, motor-specific parameter values can be loaded to controller via DriveTop:

    Activate "Parameter mode" (press right mouse key, select with cursor)!

    On right side next to drive address display reads "P2".

12. Load motor-specific parameter values:

    Select Rexroth motor type in "Motor parameters" dialog (Open "Drive functions – motor parameters" dialog. Select tab page "Kit motor" or "without feedback data memory". Enter type designation of stator and rotor. Then activate "Edit motor parameters", if necessary, and activate "Set motor parameters").

    Motor-specific parameter values are now loaded to drive. If the motor is a Rexroth housing motor without encoder data memory", change to operating mode (cf. no. 14), then continue with no. 16, if it is a Rexroth kit motor, continue with no. 13!

Rexroth kit motor:

13. Control motor encoder parameters, adjust to encoder used, if necessary:

    Select motor encoder used in "Encoder settings" dialog, set line count, negation if necessary and encoder interface used (open "Drive functions – encoder settings" dialog)!

14. From communication phase "P2" change to phase "bb" (operating mode, P4):

    Activate "Operating mode" (press right mouse key, select with cursor)!

    Drive now is ready for operation, display of drive addressed by DriveTop reads "bb".

15. Now check function of motor encoder:

    To do this, manually move motor shaft or linear motor slide in positive direction (see requirements regarding direction of movement in Project Planning Manual of respective motor!). (to do this, select "Drive status" in "Overview" menu item with cursor)

    When actual position values of motor are increasing and traveled distance corresponds to actual position value difference displayed, motor encoder evaluation is okay; if not, return to no. 13 of sequence!

Switching power on:

When displays of all drives in SERCOS ring read "bb", power can be switched on via supply unit.

When DC bus voltage was supplied, controller displays read "Ab" (ready for power output).

Configuring and activating command value box:

16. Each drive in SERCOS ring can be individually addressed with command values via DriveTop.

    Select respective drive in system overview (to do this, activate "System overview" in menu item "Overview" and select a drive with cursor)!

    Note: In the case of synchronous kit motors, commutation setting has to be carried out first; see "Rexroth Kit Motors, Synchronous". This process is also supported by DriveTop (see "Drive commands" dialog under menu item "Tools")!

Configure command value box of SYSDA02.2 via DriveTop (via menu bar "Tools" – "Command value box" – "Command value box selection" select command value function "configured" and the desired operating mode)!

Note: For initial start of kit motors, it is important first to check correct direction of movement in torque/force control! For moving the drive during initial start a velocity-controlled operating mode is useful.

Activate command value box of SYSDA02.2 via DriveTop (via DriveTop menu bar "Tools" – "Command value box" – "Command value box adjustments" set travel profile of selected operating mode)!

Note: Reduce velocity and torque/force limits to safe values!

Put drive into operation:

17. Set drive enable (activate "Enable" button with cursor)!

    Negatively acknowledge warning dialog for possibly dangerous movements if requirements for safe drive functioning have not been fulfilled (activate "Cancel" button with cursor)!

    Positively acknowledge warning dialog if requirements for safe drive functioning have been fulfilled (activate "OK" button with cursor)!

    Caution! Possible damage caused by errors when controlling motors and moving parts! ⇒ Only enable axis from safe initial position; E-Stop pushbutton must be available in position easy to reach!

18. Correctly moving the drive according to preset command values confirms operatability of drive.

    If drive does not follow command values, shut it down as fast as possible (activate "Drives OFF" button with cursor or press E-Stop pushbutton)!

    If drive follows command values, this is the basis for further commissioning steps regarding master communication via NC and further machine-axis-related functions.

☞ DriveTop does not provide dialogs for parameter set switching! If it is necessary to switch parameters, the individual parameters have to be called (e.g. with the right mouse button) and directly written!

Notes on Commissioning for Using IndraWorks D

For Rexroth motors without encoder data memory in conjunction with IndraWorks D (without SERCOS master), the steps illustrated in the figure "Commissioning steps for initial start of Rexroth motors" (see above) can only be carried out in the "easy startup" mode (initial start without active master communication)!

With IndraWorks D 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 serial interface of the controller.

☞ In the case of synchronous kit motors, commutation setting has to be carried out first (see "Commutation Setting"), and the sequence required for this 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"

11.2 Commissioning Machine Axes

11.2.1 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 D" by Bosch Rexroth (see "Initial Start With the Commissioning Tool").

The commissioning of machine axis-specific functions should also be carried out via IndraWorks D, 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:

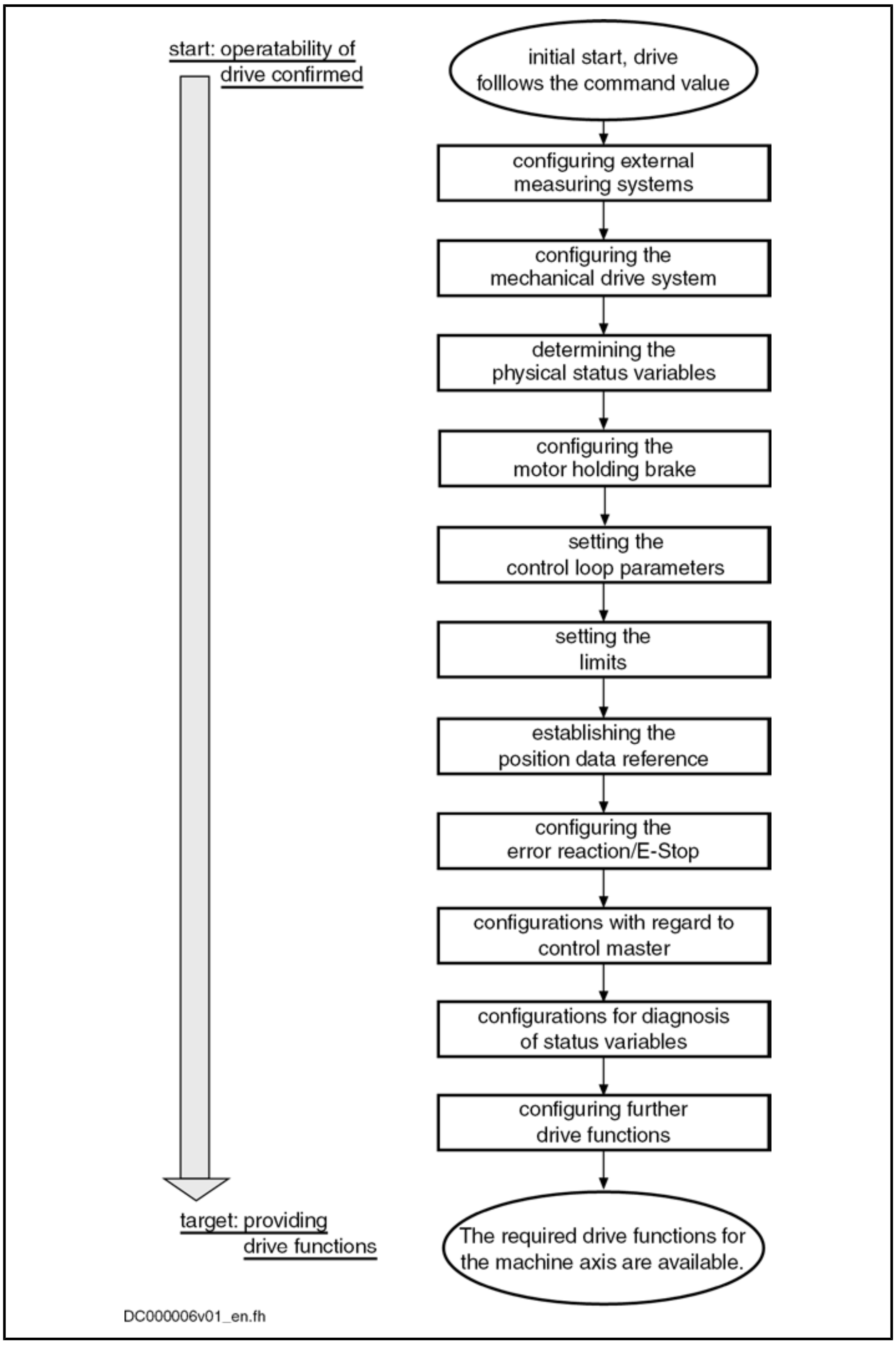

Fig. 11-7: Steps of machine axis-related commissioning

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 about parameters is only contained in the separate documentation "Rexroth IndraDrive, Parameter Description" (reference list of all IndraDrive parameters).

Configuring the Measuring Systems

Basic Settings Configure controller and encoder (set travel range, if necessary)

See "Notes on Commissioning" in the section "Basics on Measuring Systems, Resolution"

Relative Encoders Set initial position value; configure distance-coded measuring systems

See "Notes on Commissioning" in the section "Relative Measuring Systems"

Absolute Encoders Check whether absolute encoder evaluation is possible (depending on travel range), set initial position value

See "Notes on Commissioning" in the section "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" in the section "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" in the section "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" in the section "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, functioning principle and monitor of brake in holding brake control word

See "Notes on Commissioning" in the section "Motor Holding Bake"

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" in the section "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 generating 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 descriptions of the respective parameters 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 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)

are available on the user side.

See also "Torque/Force Control"

Limiting the Velocity Command Value

In the "velocity control" mode, the 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)

are available on the user side.

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 Switch"

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" in the section "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" in the section "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 mode of operation and secondary operating modes)

  See "General Information on the Operating Modes: Operating Mode Handling"
- Settings for the determined primary or secondary operating modes

  See description of the respective operating mode in chapter "Operating Modes"

With regard to the master communication interface used by the control master, you can make presettings for:

- SERCOS interface

  → When using the "IndraWorks D" commissioning tool, this is only appropriate via serial communication!
- PROFIBUS-DP
- Parallel interface
- 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

  See "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" to digital outputs

  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 Service and Support

12.1 Helpdesk

Our service helpdesk at our headquarters in Lohr, Germany, will assist you with all kinds of inquiries.

Contact us:

- By phone through the Service Call Entry Center,

  Monday to Friday 7:00 am - 6:00 pm CET

  +49 (0) 9352 40 50 60
- By fax

  +49 (0) 9352 40 49 41
- By e-mail: service.svc@boschrexroth.de

12.2 Service Hotline

Out of helpdesk hours please contact our German service department directly:

+49 (0) 171 333 88 26

or

+49 (0) 172 660 04 06

Hotline numbers for other countries can be found in the addresses of each region (see below).

12.3 Internet

Additional notes regarding service, maintenance and training, as well as the current addresses of our sales and service offices can be found on

http://www.boschrexroth.com

Outwith Germany please contact our sales/service office in your area first.

12.4 Helpful Information

For quick and efficient help please have the following information ready:

- Detailed description of the fault and the circumstances
- Information on the type plate of the affected products, especially type codes and serial numbers
- Your phone and fax numbers as well as your e-mail address so we can contact you in case of questions

Index

Index

Index

Notes

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