Electric Drives
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Hydraulics

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Assembly Technologies

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Service

Rexroth
Bosch Group

Rexroth IndraDrive
Firmware for Drive Controllers
MPH-, MPB-, MPD-, MPC-08

R911332643
Edition 01

Functional Description

Title	Rexroth IndraDrive Firmware for Drive Controllers MPH-, MPB-, MPD-, MPC-08
Type of Documentation	Functional Description
Document Typecode	DOK-INDRV*-MP*-08VRS**-AP01-EN-P
Internal File Reference	RS-c562f6b15967f8970a6846a000828e47-1-en-US-9
Purpose of Documentation	This documentation describes all the functional properties of the IndraDrive firmware in the variants MPH-08, MPB-08, MPD-08 and MPC-08.

Record of Revision

Edition	Release Date	Notes
DOK-INDRV*-MP*-08VRS**-AP01-EN-P	2011-09-23	First edition

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1   System Overview

1.1   General Information

1.1.1   About This Documentation

Means of Representation in This Documentation

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

What?	How?	For example...
Important facts which are to be highlighted in continuous text	Boldface	Transmission of freely configurable external **process data** (command values and actual values of the external control unit)
Parameter names, diagnostic message names, function designations	Quotation marks	The device function "cross communication (CCD)" is characterized by the following features:

Fig.1-1:   *Conventions of Notation*

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

⚠ DANGER   ...

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

⚠ WARNING   ...

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

⚠ CAUTION   ...

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

NOTICE   ...

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

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

☞   This box contains important information which you should take into consideration.

💡   This symbol highlights useful tips and tricks.

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

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

Dokusupport@boschrexroth.de

We need the following information to handle your feedback:

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

1.1.2   How to Use This Documentation

Structure of the Functional Description

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

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

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

Within one subject, these sections are always contained in the mentioned order, but for practical and formal reasons they 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.

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

ℹ️ The detailed description of the diagnostic messages, their causes and measures for remedy 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

System Overview

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.

> ℹ The detailed description of the diagnostic messages, their causes and measures for remedy 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 operation modes have a marker containing information on the availability of this functionality in the respective functional package of the firmware, e.g.:

> 💡 Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

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
- Firmware **variant** e.g. MP**H**, MP**B**, MP**D**, MP**C**
- Firmware **version** e.g. MPH-**08**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 of more detailed information.

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

- References to sections within this documentation are specified by indicating the title of the respective section and the designation of the superordinate topic, if necessary (both can be easily found via the index).

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- ℹ️ References to another documentation are additionally signaled by the "info icon", unless contained in a note, in a table or in brackets.

Reference Documentations

Drive Systems, System Components

Title Rexroth IndraDrive …	Kind of documentation	Document typecode[1)] DOK-INDRV*-…	Part number R911…
Drive Systems With HMV01/02 HMS01/02, HMD01, HCS02/03	Project Planning Manual	SYSTEM*****-PRxx-EN-P	309636
Mi Drive Systems	Project Planning Manual	KCU+KSM****-PRxx-EN-P	320924
Supply Units, Power Sections HMV, HMS, HMD, HCS02, HCS03	Project Planning Manual	HMV-S-D+HCS-PRxx-EN-P	318790
Drive Controllers Control Sections CSB01, CSH01, CDB01	Project Planning Manual	CSH********-PRxx-EN-P	295012
Additional Components and Accessories	Project Planning Manual	ADDCOMP****-PRxx-EN-P	306140
C Drive Controllers HCS02.1, HCS03.1	Operating Instructions	FU**********-IBxx-EN-P	314905

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

Fig.1-2:   Documentations – Overview

Title	Kind of documentation	Document typecode[1)]	Part number R911…
Automation Terminals Of The Rexroth Inline Product Range	Application Manual	DOK-CONTRL-ILSYSINS***-AWxx-EN-P	317021

1) In the document typecodes, "xx" is a wild card for the current edition of the documentation (example: AW01 is the first edition of an Application Manual)

Fig.1-3:   Documentations – Overview

Motors

Title Rexroth IndraDyn …	Kind of documentation	Document typecode[1)] DOK-MOTOR*-…	Part number R911…
A Asynchronous Motors MAD / MAF	Project Planning Manual	MAD/MAF****-PRxx-EN-P	295781
H Synchronous Kit Spindle Motors	Project Planning Manual	MBS-H******-PRxx-EN-P	297895
L Synchronous Linear Motors	Project Planning Manual	MLF********-PRxx-EN-P	293635

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Title Rexroth IndraDyn …	Kind of documentation	Document typecode[1) DOK-MOTOR*-…	Part number R911…
S MSK Synchronous Motors	Project Planning Manual	MSK********-PRxx-EN-P	296289
T Synchronous Torque Motors	Project Planning Manual	MBT********-PRxx-EN-P	298798

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

Fig.1-4:   *Documentations – Overview*

Cables

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

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

Fig.1-5:   *Documentations – Overview*

Firmware

Title Rexroth IndraDrive …	Kind of documentation	Document typecode[1) DOK-INDRV*-…	Part number R911…
Firmware for Drive Controllers MPH-08, MPB-08, MPD-08, MPC-08	Functional Description	MP*-08VRS**-APxx-EN-P	332643
Firmware for Drive Controllers MPH-07, MPB-07, MPD-07, MPC-07	Functional Description	MP*-07VRS**-FKxx-EN-P	328670
Firmware for Drive Controllers MPH-06, MPB-06, MPD-06, MPC-06	Functional Description	MP*-06VRS**-FKxx-EN-P	326766
Firmware for Drive Controllers MPH-05, MPB-05, MPD-05	Functional Description	MP*-05VRS**-FKxx-EN-P	320182
Firmware for Drive Controllers MPH-04, MPB-04, MPD-04	Functional Description	MP*-04VRS**-FKxx-EN-P	315485
Firmware for Drive Controllers MPH-03, MPB-03, MPD-03	Functional Description	MP*-03VRS**-FKxx-EN-P	308329
Firmware for Drive Controllers MPH-02, MPB-02, MPD-02	Functional Description	MP*-02VRS**-FKxx-EN-P	299223
Drive Controllers MPx-02 to MPx-08	Parameter Description	GEN-**VRS**-PAxx-EN-P	297317
MPx-02 to MPx-08 and HMV	Troubleshooting Guide	GEN-**VRS**-WAxx-EN-P	297319
Integrated Safety Technology	Functional and Application Description	SI*-**VRS**-FKxx-EN-P	297838

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Title Rexroth IndraDrive …	Kind of documentation	Document typecode[1)] DOK-INDRV*-…	Part number R911…
Integrated Safety Technology According to IEC61508	Functional Description	SI2-**VRS**-FKxx-EN-P	327664
Rexroth IndraMotion MLD	Application Manual	MLD-**VRS**-AWxx-EN-P	306084
Rexroth IndraMotion MLD Library	Library Description	MLD-SYSLIB*-FKxx-EN-P	309224

1)   In the document typecodes, "xx" is a wild card for the current edition of the documentation (example: FK02 is the second edition of a Functional Description)

Fig.1-6:   Documentations – Overview

Title	Kind of documentation	Document typecode[1)]	Part number R911…
Productivity Agent Extended Diagnostic Functions With Rexroth IndraDrive	Application Manual	DOK-INDRV*-MLD-PAGENT*- AWxx-EN-P	323947

1)   In the document typecodes, "xx" is a wild card for the current edition of the documentation (example: AW01 is the first edition of an Application Manual)

Fig.1-7:   Documentations – Overview

1.1.3   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:

- **MPx**: drives for general automation (incl. machine tool applications) with SERCOS interface, field bus interfaces, parallel and analog interface (the variants of design are **MPH**, **MPB**, **MPD** and **MPC**; 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, field bus interface 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 B, D, H and C**):

- **B**: **Single-axis** firmware with **Basic** performance and functionality

- **D**: **Double-axis** firmware with **Basic** performance and functionality

- **H**: **Single-axis** firmware with **Advanced** performance and functionality

- **C**: **Single-axis** firmware with **Advanced** performance and functionality plus CCD + MLD-M functions

This documentation describes the functionality of the following firmware types:

- **FWA-INDRV*-MPB-08VRS-D5**
- **FWA-INDRV*-MPD-08VRS-D5**
- **FWA-INDRV*-MPH-08VRS-D5**
- **FWA-INDRV*-MPC-08VRS-D5**

The "IndraWorks Ds/D/MLD" 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".

1.2   Terms, Basic Principles

1.2.1   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

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- 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.

1.2.2 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.

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 Ds/D/MLD" 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 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)

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Options for 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 Ds/D/MLD" 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.

1.2.3   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 the 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.

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

- **Customer Password**

  The parameter values of a parameter group combined by the customer can be protected.

- **Control Password**

  Parameters protected by a customer password 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.

1.2.4   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".

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Types of Commands   We distinguish 3 different types of commands:

- **Drive control commands**
  - Can cause automatic drive motion
  - Can only be started when drive enable has been set
  - Deactivate the active operation mode during its execution
- **Monitor commands**
  - Activate or deactivate monitorings or functions in the drive
- **Administration commands**
  - Carry out administration tasks
  - Cannot be interrupted

See also section "Command Processing"

1.2.5   Operation Modes

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

One of the eight (for SERCOS) operation modes that are defined in parameters is always active if the following conditions have been fulfilled:

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

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

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

See also chapter "Operation Modes"

1.2.6   Warnings

Depending on the active operation mode and the parameter settings, many monitoring functions are carried out. If a state is detected that still allows correct operation but in case this state 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).

Warning Classes   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.

We distinguish the following warning classes:

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

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

1.2.7 Errors

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

Error Classes   Errors are assigned to different error classes which are distinguished by different error reactions of the drive.

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

Diagnostic message number	Error class
F2xxx	Non-fatal error
F3xxx	Non-fatal safety technology error
F4xxx	Interface error
F6xxx	Travel range error
F7xxx	Safety technology error
F8xxx	Fatal error
F9xxx	Fatal system error
E-xxxx	Fatal system error "Processor exception"

Fig. 1-8:   *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 means of a procedure depending on the severity of the error, see separate documentation "Troubleshooting Guide" (description of diagnostic messages).

If the error status persists, the error message is immediately generated again.

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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 parameter "P-0-0192, Error memory of diagnostic numbers" and can be displayed by means of the control panel. By means of the "IndraWorks Ds/D/MLD" commissioning tool, it is possible to display the diagnostic message numbers and the respective times at which the errors occurred.

1.3   Drive Controllers

1.3.1   Overview

Standard Design of the IndraDrive Controllers

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

- Power Section
- Control Section
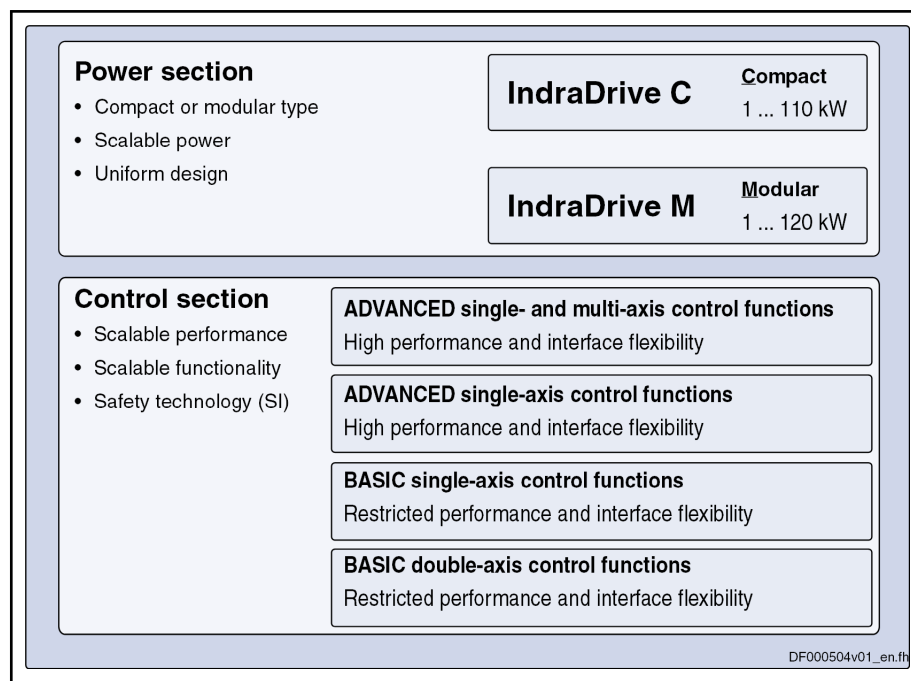
Fig. 1-9:   Design of the IndraDrive Controllers

Power Section

The following are connected to the power section:

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

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☞   Each of the two types of the power section is described in a separate documentation; e.g. "Supply Units and Power Sections, Project Planning Manual" (DOK-INDRV*-HMV-S-D+HCS-PR**-EN-P; part number: 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 the control section. The control section may only be replaced by a qualified service engineer.

☞   The available control sections are described in the separate documentation "Control Sections for Drive Controllers, Project Planning Manual" (DOK-INDRV*-CSH********-PR**-EN-P; part number: 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
    - Distributed servo drives **KSM**

        ⇒ Synchronous servo motors with integrated inverter and control section

    - Distributed drive controllers **KMS**

        ⇒ Very compact inverters with control control sections

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.

Implementing the SERCOS analog converter requires the following individual components:

- Housing for control sections **HAC01.1-002** (CDB, double-axis design) or **HAC01.1-001** (CSB, CSH, single-axis design)
- 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-06VRS**-**-*-***-**

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IndraDrive Mi (KSM01.2-B, Distributed Servo Drive)	In KSM (distributed servo drive), the control section and the power section are integrated in the motor (synchronous servo motor), configuration of the control section is not possible. The converter can be operated with the IndraDrive firmware **as of** version **FWA-INDRV*-MPB-04VRS**.
IndraDrive Mi (KMS01.2-B, Distributed Drive Controller)	In KMS (distributed drive controller), the control section and the power section are integrated and remote from the motor. Configuration of the control section is not possible. This variant of IndraDrive Mi has a HIPERFACE® encoder interface. The converter can be operated with the IndraDrive firmware **as of** version **FWA-INDRV*-MPB-06VRS**.

See also separate documentation "Rexroth IndraDrive – Drive System, Project Planning Manual" (DOK-INDRV*-SYSTEM*****-PR**-EN-P; part number: R911309636)!

1.3.2 Power Sections

The following power sections for the standard design of IndraDrive controllers can be operated with the **MPx-08VRS** firmware:

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.	Single-axis converters
HMS01.1N-W… HMS02.1N-W…	HMD01.1N-W…	HCS02.1E-W… HCS02.1E-F…	HCS03.1E-W… HCS04.1E-W… HCS03.1E-F…	HCS04.2E-W....

Fig.1-10:   Power Sections for IndraDrive Firmware

1.3.3 Control Sections

Available Control Section Designs

The following control sections can be operated with the appropriate **MPx-08VRS** firmware variant:

Control section characteristic	Basic device range	Firmware variant
MPC, Advanced, high-performance drive functions as well as single- and multi-axis control functions	CSH01.3	MPC08
MPH, Advanced, high-performance drive functions as well as single-axis control functions	CSH01.1	MPH08
MPB, Basic single-axis, medium-performance drive functions, designs	CSB01.1C CSB01.1N KSM01.2-B (distributed servo drive) KMS01.2-B (distributed drive controller)	MPB08
MPD, Basic double-axis,	CDB01.1	MPD08

Fig.1-11:   Control Section Support

- Configurable control sections
  - ADVANCED (single-axis; type CSH01.1)
  - ADVANCED (single-axis; type CSH01.3)
  - BASIC UNIVERSAL (single-axis; type CSB01.xC...)
  - BASIC UNIVERSAL double-axis (type CDB01.xC...)

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- Non-configurable control sections
  - BASIC OPENLOOP (single-axis; type CSB01.xN-FC-...)
  - BASIC SERCOS (single-axis; type CSB01.xN-SE-...)
  - BASIC PROFIBUS (single-axis; type CSB01.xN-PB-...)
  - BASIC ANALOG (single-axis; type CSB01.xN-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-08VRS** 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 →		CSH01.1	CSH01.3	CSB01.xC...	CDB01.xC...
Firmware variant →		MPH-08VRS	MPC-08VRS	MPB-08VRS	MPD-08VRS
Optional modules for master communication					
AN	Analog interface	–	–	■	–
CO	CANopen/DeviceNet™ (connected via spring terminal), only with CSB01.xB, not with CxB01.xC	■	■	■	–
CD	CANopen/DeviceNet™ (connected via D-SUB connector)	■	■	■	–
ET	EtherCAT®/SERCOS III	■	■	■	■
ET	PROFINET®/Ethernet	■	■	■	-
PB	PROFIBUS-DP	■	■	■	■
PL	Parallel interface	■	■	■	–
S3	SERCOS III	■	■	■	■
SE	SERCOS II	■	■	■	■
CCD [1]	Cross communication	–	■	–	–
Optional modules for encoder evaluation and I/O extension					
EN1	Encoder interface for HSF, resolver	■	■	■	■
EN2	Encoder interface for EnDat2.1, 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)	■	■	–	–

System Overview

Control section type →		CSH01.1	CSH01.3	CSB01.xC...	CDB01.xC...
Firmware variant →		MPH-08VRS	MPC-08VRS	MPB-08VRS	MPD-08VRS
MEM	Encoder emulation	■	■	■	■
Optional modules for safety technology					
L2	Starting lockout	■	■	■	■
S2	Safety technology	■	■	–	■

1)   Only required for CCD master
Fig. 1-12:   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-P; part number: R911295012).

1.4   Supported Motors and Measuring Systems

1.4.1   Supported Motors

The following table 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	MAL	MBSxx2 (IndraDyn H)	
MKE		MBT (IndraDyn T)	
MSP			
SF (by Bosch)			

Fig. 1-13:   Appropriate Rexroth Motors for IndraDrive

1.4.2   Supported Measuring Systems

Motor Encoders 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)

System Overview

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, MAD, MAF motors
- SSI encoders

☞   Resolvers cannot be evaluated as measuring encoders!

1.5 Overview of Master Communication

The **MPx-08VRS** firmware supports the following interfaces for master communication:

- SERCOS II
- SERCOS III
- PROFIBUS-DP
- EtherCAT®
- EtherNet/IP™
- PROFINET®
- CANopen interface
- DeviceNet™ interface
- Parallel interface (not for double-axis design MPD)
- Analog interface

1.6 Overview of Functions/Functional Packages

1.6.1 Overview

General Information

The application-specific scope of usable functions of the **FWA-INDRV*-MP*-08VRS** 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 6 optional card slots and a master communication slot. Depending on the availa-

System Overview

ble optional cards, it is possible to activate certain functions (incl. the corresponding parameters), e.g.:

- **Master communication**
- **Safety technology** (Safe Torque Off, Safe Motion)
- **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)
  - 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:
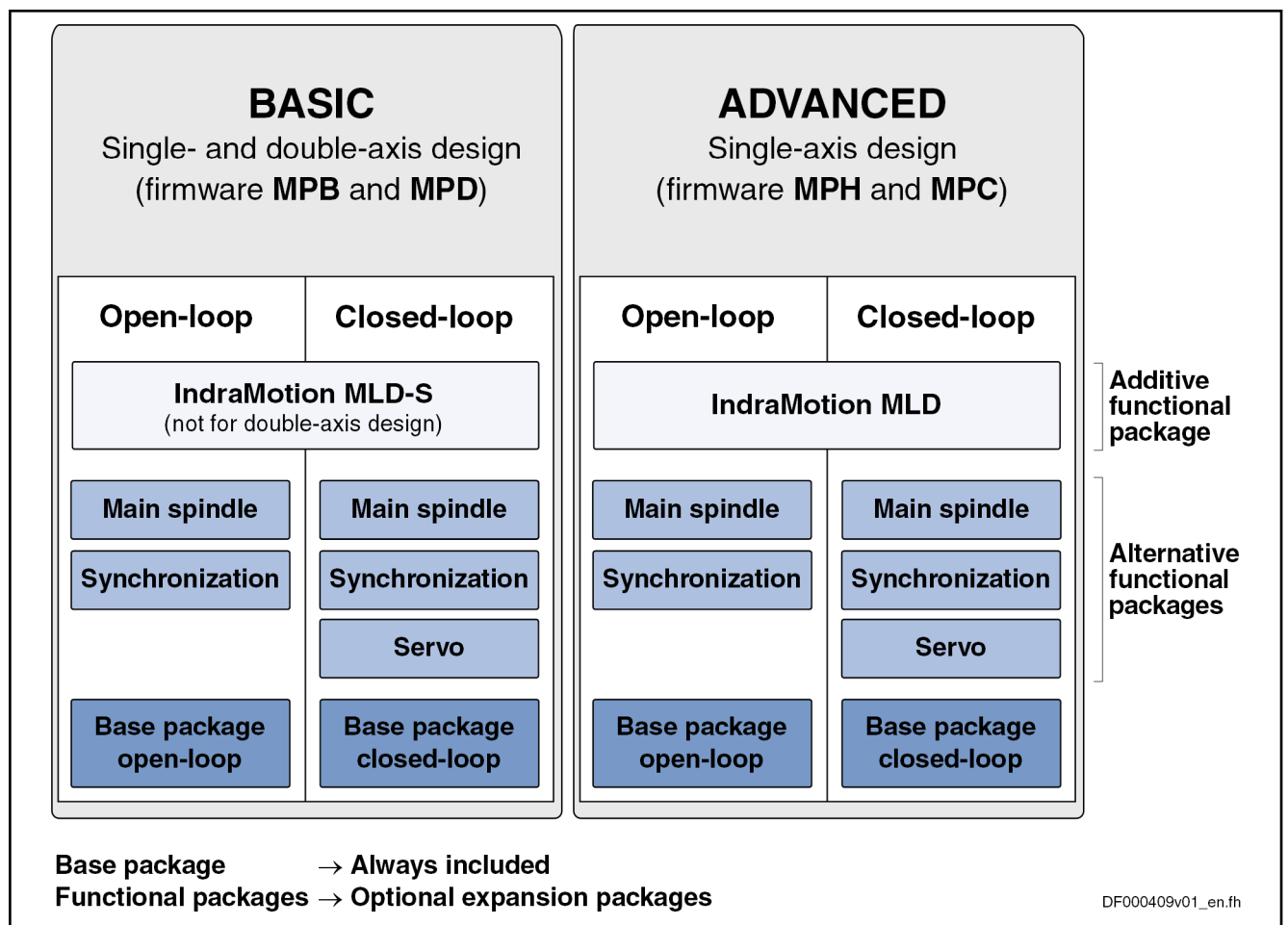
Fig.1-14: Functional Packages of IndraDrive Firmware MPx08 Depending on Control Performance

☞ 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*-08VRS** 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:

System Overview

- **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 synchronization possibilities 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 depend on the respective hardware and the firmware type:

Firmware variant →			MPB		MPD		MPH		MPC	
Control section design →			CSB01.1 CSB01.1N KSM01.2-B KMS01.2-B		CDB01.1		CSH01.1		CSH01.3	
Control section range ↓			OL	CL	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	–	–	–	–	■	■	■	■

System Overview

Firmware variant →			MPB		MPD		MPH		MPC	
Control section design →			CSB01.1 CSB01.1N KSM01.2-B KMS01.2-B		CDB01.1		CSH01.1		CSH01.3	
Control section range ↓			OL	CL	OL	CL	OL	CL	OL	CL
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
MPC	Single-axis firmware with Advanced performance and CCD + MLD-M functions
KSM01.2-B	Basic device range IndraDrive, distributed servo drive
KMS01.2-B	Basic device range IndraDrive, distributed drive controller
OL	Open-loop characteristic
CL	Closed-loop characteristic
1)	No free programming and only MLD-S

Fig.1-15:   Dependency of Functional Packages on Hardware and Firmware Variant

1.6.2   Firmware Types

Structure of the Firmware Type Designation

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

	IndraDrive firmware	Base package of variant (depending on control section)	Version	Release	Language	OL/CL	Alternative expansion packages	Additive expansion packages
Basic single-axis	FWA-INDRV*	-MPB-	08	VRS-	D5-	x-	xxx-	xx
Basic double-axis	FWA-INDRV*	-MPD-	08	VRS-	D5-	x-	xxx-	xx
Advanced single-axis	FWA-INDRV*	-MPH-	08	VRS-	D5-	x-	xxx-	xx
Advanced single-axis	FWA-INDRV*	-MPC-	08	VRS-[1]	D5-	x-	xxx-	xx

OL	Open-loop characteristic
CL	Closed-loop characteristic

Fig.1-16:   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
- **MPC** → Single-axis firmware with Advanced performance

Firmware characteristic:

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- **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)
- **MA** → IndraMotion MLD Advanced (only for MPH firmware)

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

1.6.3   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 Operation Modes" in section "Operation Modes: General Information"

See "Availability of the Extended Axis Functions"

See "Availability of the Optional Device Functions"

1.6.4   Alternative Functional Packages

General Information

Apart from the base packages that are always available, we provide 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:

Firmware variant →	MPB		MPD		MPH		MPC	
Functions of the expansion package "Servo function"	OL	CL	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	–	▪	–	▪	–	▪	–	▪
Set/shift coordinate system	–	▪	–	▪	–	▪	–	▪
Parameter set switching (without motor/gear switching)	▪	▪	–	–	▪	▪	▪	▪

OL   Open-loop characteristic
CL   Closed-loop characteristic
Fig. 1-17:   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***).

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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		MPC	
Functions of the expansion package "Synchronization"	OL	CL	OL	CL	OL	CL	OL	CL
Velocity synchronization	▪	▪	▪	▪	▪	▪	▪	▪
Phase synchronization	–	▪	–	▪	–	▪	▪	▪
Electronic cam	–	▪	–	▪	–	▪	▪	▪
Motion profile	–	▪	–	▪	–	▪	–	▪
Cogging torque compensation	–	–	–	▪	–	▪	–	▪
Measuring wheel mode	–	▪	–	▪	–	▪	–	▪
Virtual master axis generator	▪	▪	▪	▪	▪	▪	▪	▪
Programmable position switch	–	▪	–	▪	–	▪	–	▪
Measuring encoder	▪ [1]	▪ [1]	▪	▪	▪	▪	▪	▪
Parameter set switching (without motor/gear switching)	▪	▪	–	–	▪	▪	▪	▪

OL   Open-loop characteristic
CL   Closed-loop characteristic
1)   Only with control section BASIC UNIVERSAL
Fig.1-18:   *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		MPC	
Functions of the expansion package "Main spindle"	OL	CL	OL	CL	OL	CL	OL	CL
Spindle positioning	–	▪	–	▪	–	▪	–	▪
Parameter set switching	▪	▪	–	–	▪	▪	▪	▪
Drive-controlled oscillation	▪	▪	–	–	▪	▪	▪	▪

OL   Open-loop characteristic
CL   Closed-loop characteristic
Fig.1-19:   *Overview Expansion Package "Main Spindle"*

1.6.5　　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 (in different designs):

- **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)

Depending on its performance (type designation), the extension package "IndraMotion MLD" provides 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

- **IndraMotion MLD Advanced** (type designation "MA")

Firmware variant →	MPB	MPD	MPH	MPC
Integrated logic control	■	–	■	■
Integrated multi-axis motion control	■	–	–	■
Integrated single-axis motion control	■	–	■	■
Basis for technology functions	■	–	■	■
IndraMotion MLD Advanced	–	–	■	■

Fig.1-20:　　Overview Expansion Package "IndraMotion MLD"

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 "L2" or "S2" depending on the control section configuration.

By using the optional safety technology module "Safe Torque Off" (L2), the safety function "Safe torque off" can be implemented.

The following safety functions can be implemented in the different operating states by using the optional safety technology module "Safe Motion" (S2) or PROFIsafe:

System Overview

- In **normal operation** and in **special mode**
  - Safe maximum speed
  - Safely-limited position
  - Safe direction
- In **special mode "safe standstill"**
  - Safe torque off
  - Safe stop 1
  - Safe stop 2
  - Safe stop 1 (Emergency stop)
  - Safe braking and holding system
- In **special mode "safe motion"**
  - Safely-limited speed
  - Safe direction
  - Safely-limited increment
  - Safely-monitored position
- **Additional or auxiliary functions**
  - Safely-monitored stopping process
  - Safe homing procedure
  - Safe brake check
  - Safe parking axis
- **Safety functions for "safe feedback"**
  - Safe diagnostic outputs
  - Safe door locking (not PROFIsafe)
  - Safe inputs/outputs

1.7   Performance Data

1.7.1   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	250	500	2000	500
Economy	83,3/125/250	500	1000	2000	1000 [1]

1)   With half the quantity of cyclic data

Fig.1-21:   *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** (SH, CSB or CDB) and the corresponding drive **firmware** (MPH, MPB, MPD and MPC)

- **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 "Overview of Drive Control"

1.7.2   Control Section Design and Performance

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

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

System Overview

Control section/ firm-ware [1]	Functional packages [1]	Perform-ance level	f_{PWM} [2]	P-0-0556 Bit 2	Bit 5	PWM reduc. [4]	Rotor-syn-chro-nous PWM	$T_{A\_current}$	$T_{A\_velocity}$	$T_{A\_posi-tion}$	T_{MLD}	$T_{Mast-Com}$
CHS01.3/MPC		Basic	2 kHz [3]	0	0	No	No	250	500	500 µs	1000 µs	500 µs
		Basic	4 kHz	0	0	No	No	125	250	500 µs	1000 µs	500 µs
		Basic	8 kHz	0	0	Yes	Yes	125	250	500 µs	1000 µs	500 µs
		Basic	12 kHz	0	0	Yes	Yes	83.3 µs	250	500 µs	1000 µs	500 µs
		Basic	16 kHz	0	0	Yes	Yes	62.5 µs	250	500 µs	1000 µs	500 µs
		Advanced	4 kHz	1	0	No	No	125 µs	125 µs	250	1000 µs	250
		Advanced	8 kHz	1	0	Yes	Yes	62.5 µs	125 µs	250	1000 µs	250
		Advanced	16 kHz	1	0	Yes	Yes	62.5 µs	125 µs	250	1000 µs	250
CSH01.1/MPH	All	Basic	2 kHz [3]	0	0	No	No	250 µs	500 µs	500 µs	1000 µs	500 µs
		Basic	4 kHz	0	0	No	No	125 µs	250 µs	500 µs	1000 µs	500 µs
		Basic	8 kHz	0	0	Yes	Yes	125 µs	250 µs	500 µs	1000 µs	500 µs
		Basic	12 kHz	0	0	Yes	Yes	83.3 µs	250 µs	500 µs	1000 µs	500 µs
		Basic	16 kHz	0	0	Yes	Yes	62.5 µs	250 µs	500 µs	1000 µs	500 µs
		Advanced	4 kHz	1	0	No	Yes	125 µs	125 µs	250 µs	1000 µs	250 µs
		Advanced	8 kHz	1	0	Yes	Yes	62.5 µs	125 µs	250 µs	1000 µs	250 µs
		Advanced	16 kHz	1	0	Yes	Yes	62.5 µs	125 µs	250 µs	1000 µs	250 µs
CSB01.1/MPB	All, except SY and MLD	Basic	2 kHz [3]	0	0	No	No	250 µs	250 µs	500 µs	--	500 µs
		Basic	4 kHz	0	0	No	No	125 µs	250 µs	500 µs	--	500 µs
		Basic	8 kHz	0	0	Yes	No	125 µs	250 µs	500 µs	--	500 µs
		Economy	2 kHz [3]	0	1	No	No	250 µs	500 µs	1000 µs	--	1000µs [5]
		Economy	4 kHz	0	1	No	No	125 µs	500 µs	1000 µs	--	1000µs [5]
		Economy	8 kHz	0	1	Yes	No	125 µs	500 µs	1000 µs	--	1000µs [5]
		Economy	12 kHz	0	1	Yes	No	83.3 µs	500 µs	1000 µs	--	1000 µs [5]
	SY and MLD	Economy	2 kHz [3]	0	1	No	No	250 µs	500 µs	1000 µs	2000 µs	1000 µs [5]
		Economy	4 kHz	0	1	No	No	125 µs	500 µs	1000 µs	2000 µs	1000 µs [5]
		Economy	8 kHz	0	1	Yes	No	125 µs	500 µs	1000 µs	2000 µs	1000 µs [5]
		Economy	12 kHz	0	1	Yes	No	83.3 µs	500 µs	1000 µs	2000 µs	1000 µs [5]

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Control section/ firm- ware	Functional packages [1]	Perform- ance level	f_{PWM} [2]	P-0-0556 Bit 2 Bit 5		PWM reduc. [4]	Rotor- syn- chro- nous PWM	$T_{A\_current}$	$T_{A\_velocity}$	$T_{A\_posi-tion}$	T_{MLD}	$T_{Mast-Com}$
CDB01. 1/MPD	All	Basic	4 kHz	0	0	No	No	125 µs	250 µs	500 µs	--	500 µs
		Basic	8 kHz	0	0	No	No	125 µs	250 µs	500 µs	--	500 µs

1)	SY … Synchronization; MLD … IndraMotion MLD
2)	Switching frequency of the power output stage (can be set via P-0-0001)
3)	Only with power section HCS04.1… and MAD/MAF
4)	Reduction of PWM frequency depending on load or PWM switching depending on speed
5)	With half the quantity of cyclic data
P-0-0556	Config word of axis controller

Fig. 1-22: *Performance Depending on the Control Section Design*

1.7.3 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.

ℹ️   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".

1.7.4 PWM Frequency Reduction Depending on Load

For switching frequencies of 8kHz, 12 kHz or 16 kHz and corresponding performance settings in the parameters "P-0-0556, Config word of axis controller and P-0-0045, Control word of current controller"

reduction of the switching frequency depending on the thermal load of the controller is possible.

☞   When the load-dependent reduction of the PWM frequency is used, the switching frequency of the power output stage is changed, but not the cycle times!

See "Current Limitation: Dynamic Current Limitation"

1.7.5 PWM Frequency Reduction Depending on Speed

For switching frequencies of 8kHz, 12 kHz or 16 kHz and corresponding performance settings in the parameters "P-0-0556, Config word of axis controller" and "P-0-0045, Control word of current controller"

System Overview

reduction of the switching frequency depending on the electric output frequency of the controller is possible.

☞ When the speed-dependent reduction of the PWM frequency is used, the switching frequency of the power output stage is changed, but not the cycle times!

See "Motor Control"

1.7.6   Rotor-Synchronous PWM

For switching frequencies of 8kHz,12 kHz or 16 kHz and corresponding performance settings in the parameters "P-0-0556, Config word of axis controller" and "P-0-0045, Control word of current controller"

reduction of the switching frequency depending to the electric output frequency of the controller is possible.

☞ When the speed-dependent reduction of the PWM frequency is used, the cycle time of the current loop and the switching frequency of the power output stage are changed!

See "Motor Control"

1.7.7   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 or MPC), 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 can be taken from the table "Performance Depending on the Control Section Design" in section "Control Section Design and Performance".

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

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

Drive controllers have to be programmed before commissioning, 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.

Important Directions for Use

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

Typical applications include, for example:

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

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

2.2   Inappropriate Use

Using the Drive controllers outside of the operating conditions described in this documentation and outside of the 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!

☞   Components of the drive system Rexroth IndraDrive are **products of category C3** (with restricted distribution) according to IEC 61800-3. These components are not provided for use in a public low-voltage mains supplying residential areas. If these components are used in such a mains, high-frequency interference is to be expected. This can require additional measures of radio interference suppression.

3   Safety Instructions for Electric Drives and Controls

3.1   Definitions of Terms

Application Documentation	Application documentation comprises the entire documentation used to inform the user of the product about the use and safety-relevant features for configuring, integrating, installing, mounting, commissioning, operating, maintaining, repairing and decommissioning the product. The following terms are also used for this kind of documentation: User Guide, Operation Manual, Commissioning Manual, Instruction Manual, Project Planning Manual, Application Manual, etc.
Component	A component is a combination of elements with a specified function, which are part of a piece of equipment, device or system. Components of the electric drive and control system are, for example, supply units, drive controllers, mains choke, mains filter, motors, cables, etc.
Control System	A control system comprises several interconnected control components placed on the market as a single functional unit.
Device	A device is a finished product with a defined function, intended for users and placed on the market as an individual piece of merchandise.
Electrical Equipment	Electrical equipment encompasses all devices used to generate, convert, transmit, distribute or apply electrical energy, such as electric motors, transformers, switching devices, cables, lines, power-consuming devices, circuit board assemblies, plug-in units, control cabinets, etc.
Electric Drive System	An electric drive system comprises all components from mains supply to motor shaft; this includes, for example, electric motor(s), motor encoder(s), supply units and drive controllers, as well as auxiliary and additional components, such as mains filter, mains choke and the corresponding lines and cables.
Installation	An installation consists of several devices or systems interconnected for a defined purpose and on a defined site which, however, are not intended to be placed on the market as a single functional unit.
Machine	A machine is the entirety of interconnected parts or units at least one of which is movable. Thus, a machine consists of the appropriate machine drive elements, as well as control and power circuits, which have been assembled for a specific application. A machine is, for example, intended for processing, treatment, movement or packaging of a material. The term "machine" also covers a combination of machines which are arranged and controlled in such a way that they function as a unified whole.
Manufacturer	The manufacturer is an individual or legal entity bearing responsibility for the design and manufacture of a product which is placed on the market in the individual's or legal entity's name. The manufacturer can use finished products, finished parts or finished elements, or contract out work to subcontractors. However, the manufacturer must always have overall control and possess the required authority to take responsibility for the product.
Product	Examples of a product: Device, component, part, system, software, firmware, among other things.
Project Planning Manual	A project planning manual is part of the application documentation used to support the sizing and planning of systems, machines or installations.
Qualified Persons	In terms of this application documentation, qualified persons are those persons who are familiar with the installation, mounting, commissioning and operation of the components of the electric drive and control system, as well as with the hazards this implies, and who possess the qualifications their work

Safety Instructions for Electric Drives and Controls

requires. To comply with these qualifications, it is necessary, among other things,

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

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

3) to attend a course of instruction in first aid

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

3.2   General Information

3.2.1   Using the Safety Instructions and Passing Them on to Others

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

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

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

3.2.2   Requirements for Safe Use

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

- Rexroth is not liable for damages resulting from failure to observe the safety instructions.

- Read the operating, maintenance and safety instructions in your language before commissioning. If you find that you cannot completely understand the application documentation in the available language, please ask your supplier to clarify.

- Proper and correct transport, storage, mounting and installation, as well as care in operation and maintenance, are prerequisites for optimal and safe operation of the component.

- Only qualified persons may work with components of the electric drive and control system or within its proximity.

- Only use accessories and spare parts approved by Rexroth.

- Follow the safety regulations and requirements of the country in which the components of the electric drive and control system are operated.

- Only use the components of the electric drive and control system in the manner that is defined as appropriate. See chapter "Appropriate Use".

- The ambient and operating conditions given in the available application documentation must be observed.

- Applications for functional safety are only allowed if clearly and explicitly specified in the application documentation "Integrated Safety Technolo-

Safety Instructions for Electric Drives and Controls

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

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

  The machine and installation manufacturers must

  – make sure that the delivered components are suited for their individual application and check the information given in this application documentation with regard to the use of the components,

  – make sure that their individual application complies with the applicable safety regulations and standards and carry out the required measures, modifications and complements.

- Commissioning of the delivered components is only allowed once it is sure that the machine or installation in which the components are installed complies with the national regulations, safety specifications and standards of the application.

- Operation is only allowed if the national EMC regulations for the application are met.

- The instructions for installation in accordance with EMC requirements can be found in the section on EMC in the respective application documentation.

  The machine or installation manufacturer is responsible for compliance with the limit values as prescribed in the national regulations.

- The technical data, connection and installation conditions of the components are specified in the respective application documentations and must be followed at all times.

National regulations which the user must take into account

- European countries: In accordance with European EN standards

- United States of America (USA):
  – National Electrical Code (NEC)
  – National Electrical Manufacturers Association (NEMA), as well as local engineering regulations
  – Regulations of the National Fire Protection Association (NFPA)

- Canada: Canadian Standards Association (CSA)

- Other countries:
  – International Organization for Standardization (ISO)
  – International Electrotechnical Commission (IEC)

3.2.3   Hazards by Improper Use

- High electrical voltage and high working current! Danger to life or serious injury by electric shock!

- High electrical voltage by incorrect connection! Danger to life or injury by electric shock!

- Dangerous movements! Danger to life, serious injury or property damage by unintended motor movements!

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

Safety Instructions for Electric Drives and Controls

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

3.3 Instructions with Regard to Specific Dangers

3.3.1 Protection Against Contact With Electrical Parts and Housings

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

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

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

- Only qualified persons are allowed to operate, maintain and/or repair the components of the electric drive and control system.

- Follow the general installation and safety regulations when working on power installations.

- Before switching on, the equipment grounding conductor must have been permanently connected to all electric components in accordance with the connection diagram.

- Even for brief measurements or tests, operation is only allowed if the equipment grounding conductor has been permanently connected to the points of the components provided for this purpose.

- Before accessing electrical parts with voltage potentials higher than 50 V, you must disconnect electric components from the mains or from the power supply unit. Secure the electric component from reconnection.

- With electric components, observe the following aspects:

  Always wait **30 minutes** after switching off power to allow live capacitors to discharge before accessing an electric component. Measure the electrical voltage of live parts before beginning to work to make sure that the equipment is safe to touch.

- Install the covers and guards provided for this purpose before switching on.

- Never touch electrical connection points of the components while power is turned on.

- Do not remove or plug in connectors when the component has been powered.

- Under specific conditions, electric drive systems can be operated at mains protected by residual-current-operated circuit-breakers sensitive to universal current (RCDs/RCMs).

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

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

- Before switching on and before commissioning, ground or connect the components of the electric drive and control system to the equipment grounding conductor at the grounding points.

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- Connect the equipment grounding conductor of the components of the electric drive and control system permanently to the main power supply at all times. The leakage current is greater than 3.5 mA.

- Establish an equipment grounding connection with a minimum cross section according to the table below. With an outer conductor cross section smaller than 10 mm^2 (8 AWG), the alternative connection of two equipment grounding conductors is allowed, each having the same cross section as the outer conductors.

Cross section outer conductor	Minimum cross section equipment grounding conductor Leakage current ≥ 3.5 mA	
	1 equipment grounding conductor	2 equipment grounding conductors
1,5 mm^2 (AWG 16)	10 mm^2 (AWG 8)	2 × 1,5 mm^2 (AWG 16)
2,5 mm^2 (AWG 14)		2 × 2,5 mm^2 (AWG 14)
4 mm^2 (AWG 12)		2 × 4 mm^2 (AWG 12)
6 mm^2 (AWG 10)		2 × 6 mm^2 (AWG 10)
10 mm^2 (AWG 8)		-
16 mm^2 (AWG 6)	16 mm^2 (AWG 6)	-
25 mm^2 (AWG 4)		-
35 mm^2 (AWG 2)		-
50 mm^2 (AWG 1/0)	25 mm^2 (AWG 4)	-
70 mm^2 (AWG 2/0)	35 mm^2 (AWG 2)	-
...	...	...

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

3.3.2   Protective Extra-Low Voltage as Protection Against Electric Shock

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

On components of an electric drive and control system provided by Rexroth, all connections and terminals with voltages between 5 and 50 volts are PELV ("Protective Extra-Low Voltage") systems. It is allowed to connect devices equipped with basic insulation (such as programming devices, PCs, notebooks, display units) to these connections.

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

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

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3.3.3   Protection Against Dangerous Movements

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

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

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

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

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

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

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

To avoid accidents, injury and/or property damage:

*   Keep free and clear of the machine's range of motion and moving machine parts. Prevent personnel from accidentally entering the machine's range of motion by using, for example:
    –   Safety fences
    –   Safety guards
    –   Protective coverings
    –   Light barriers
*   Make sure the safety fences and protective coverings are strong enough to resist maximum possible kinetic energy.
*   Mount emergency stopping switches in the immediate reach of the operator. Before commissioning, verify that the emergency stopping equipment works. Do not operate the machine if the emergency stopping switch is not working.
*   Prevent unintended start-up. Isolate the drive power connection by means of OFF switches/OFF buttons or use a safe starting lockout.
*   Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.

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

3.3.4   Protection Against Magnetic and Electromagnetic Fields During Operation and Mounting

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

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

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

3.3.5   Protection Against Contact With Hot Parts

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

Safety Instructions for Electric Drives and Controls

- Do not touch hot surfaces of, for example, braking resistors, heat sinks, supply units and drive controllers, motors, windings and laminated cores!

- According to the operating conditions, temperatures of the surfaces can be **higher than 60 °C** (140 °F) during or after operation.

- Before touching motors after having switched them off, let them cool down for a sufficient period of time. Cooling down can require **up to 140 minutes**! The time required for cooling down is approximately five times the thermal time constant specified in the technical data.

- After switching chokes, supply units and drive controllers off, wait **15 minutes** to allow them to cool down before touching them.

- Wear safety gloves or do not work at hot surfaces.

- For certain applications, and in accordance with the respective safety regulations, the manufacturer of the machine or installation must take measures to avoid injuries caused by burns in the final application. These measures can be, for example: Warnings at the machine or installation, guards (shieldings or barriers) or safety instructions in the application documentation.

3.3.6   Protection During Handling and Mounting

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

- Observe the relevant statutory regulations of accident prevention.

- Use suitable equipment for mounting and transport.

- Avoid jamming and crushing by appropriate measures.

- Always use suitable tools. Use special tools if specified.

- Use lifting equipment and tools in the correct manner.

- Use suitable protective equipment (hard hat, safety goggles, safety shoes, safety gloves, for example).

- Do not stand under hanging loads.

- Immediately clean up any spilled liquids from the floor due to the risk of falling!

3.3.7   Battery Safety

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

Risk of injury by improper handling!

- Do not attempt to reactivate low batteries by heating or other methods (risk of explosion and cauterization).

- Do not attempt to recharge the batteries as this may cause leakage or explosion.

- Do not throw batteries into open flames.

- Do not dismantle batteries.

- When replacing the battery/batteries, do not damage the electrical parts installed in the devices.

- Only use the battery types specified for the product.

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

3.3.8   Protection Against Pressurized Systems

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

Risk of injury by improper handling of pressurized lines!

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

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

3.4   Explanation of Signal Words and the Safety Alert Symbol

The Safety Instructions in the available application documentation contain specific signal words (DANGER, WARNING, CAUTION or NOTICE) and, where required, a safety alert symbol (in accordance with ANSI Z535.6-2006).

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

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

> ### ⚠ DANGER

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

Safety Instructions for Electric Drives and Controls

⚠ **WARNING**

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

⚠ **CAUTION**

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

NOTICE

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

4   Master Communication

4.1   Basic Functions of Master Communication

4.1.1   Brief Description

General Information

Section Safety Messages

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

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

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 parameters "P-0-4025, Drive address of master communication" and "S-0-1040, 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 a 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, S-0-1045).

  – The device state machine is independent of the variant of master communication and maps the device-specific states to parameter "S-0-0424, Status parameterization level". We always distinguish between the operating mode (OM) and the parameter mode (PM).

- **Extended possibilities of control**

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

  – Multiplex channel

  See section "Control Options / Additional Functions"

Master Communication

☞ The state machine of the master communications is briefly out-
lined 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 com-
munication:

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

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

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
The following **additional** parameters are used for the "SERCOS interface":
- S-0-0021, IDN-list of invalid operation data for CP2
- S-0-0022, IDN-list of invalid operation data for CP3
- S-0-0127, C0100 Communication phase 3 transition check
- S-0-0128, C5200 Communication phase 4 transition check
- S-0-1044, SERCOS III: Device Control (C-Dev)
- S-0-1045, SERCOS III: Device Status (S-Dev)
- S-0-0134, Master control word
- S-0-0135, Drive status word

Field-Bus-Specific Parameters
The following **additional** parameters are used for field buses:

Master Communication

- 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   The following **additional** parameters are used for the parallel/analog interface:
- P-0-4028, Device control word
- P-0-0115, Device control: status word

Pertinent Commands

- 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
- C5300 SERCOS III: Command SYNC delay measurement

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:

- Direct writing to parameters "P-0-4025, Drive address of master communication" and "S-0-1040, Drive address of master communication" via 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".
>
> For SERCOS III, the parameter "S-0-1040, Drive address of master communication" always takes effect immediately, as it is already required in P0.

Condition as Supplied   In the condition as supplied the address "99" is 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.

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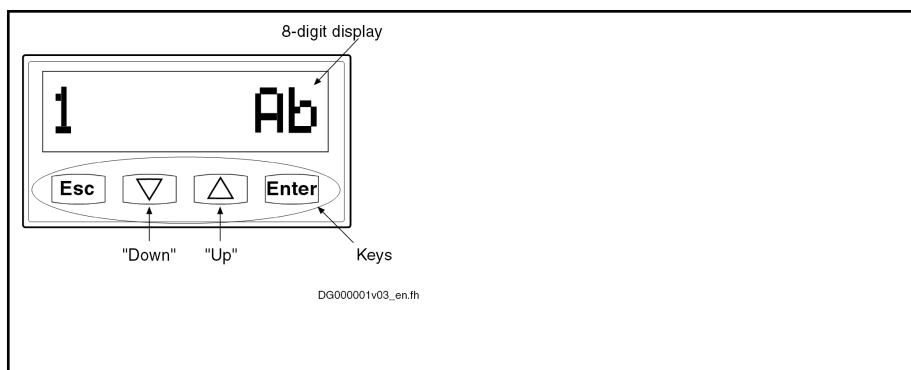
Fig.4-1:   *Standard Control Panel (Example of Display)*

The address is set via the control panel as follows:

1. Change to "commands/settings" mode
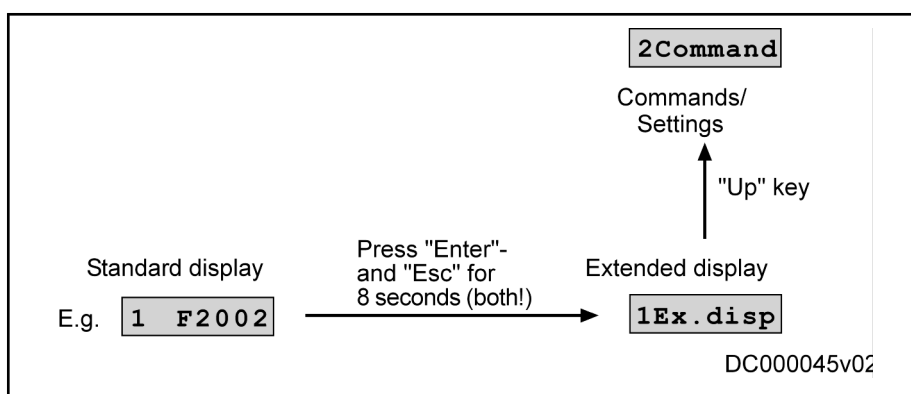
Fig.4-2:   *Activating the "Commands/Settings" Mode*

2. Select element "2.1 drive address" by means of "Up/Down" keys, 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.
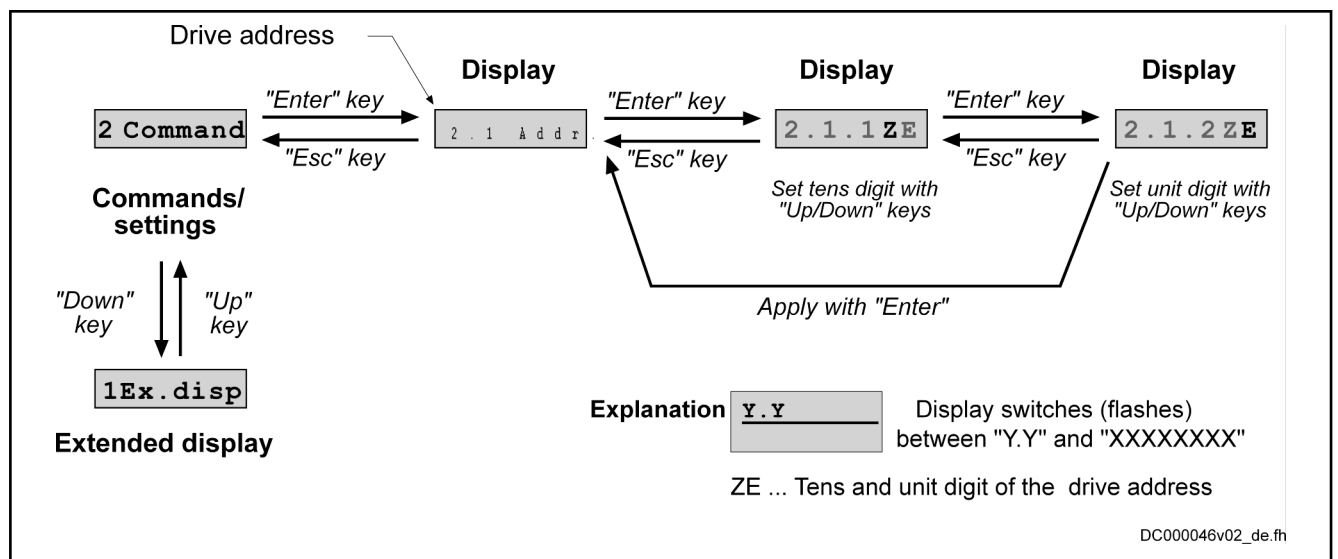
Fig.4-3:   Selecting and Setting the Drive Address

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".

Types of Commands We distinguish 3 types of commands:

- **Drive control commands**
  - Can cause automatic drive motion
  - Can only be started when drive enable has been set
  - Deactivate the active operation mode during its execution
- **Monitor commands**
  - Activate or deactivate monitorings or functions in the drive
- **Administration commands**
  - Carry out administration tasks
  - Cannot be interrupted

Master Communication

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.

NOTICE	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 Reset class 1 diagnostics, error reset"), data are written to the internal memory (flash), too. This memory, however, only allows a limited number of write accesses. Therefore, you should make sure that such write access is not carried out too often (a maximum of approx. 100,000 writing cycles).

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

Commands are started or terminated by:

- Directly writing data to the respective command parameter (e.g. 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

Master Communication

- **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 "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.

DK000024v01_en.fh
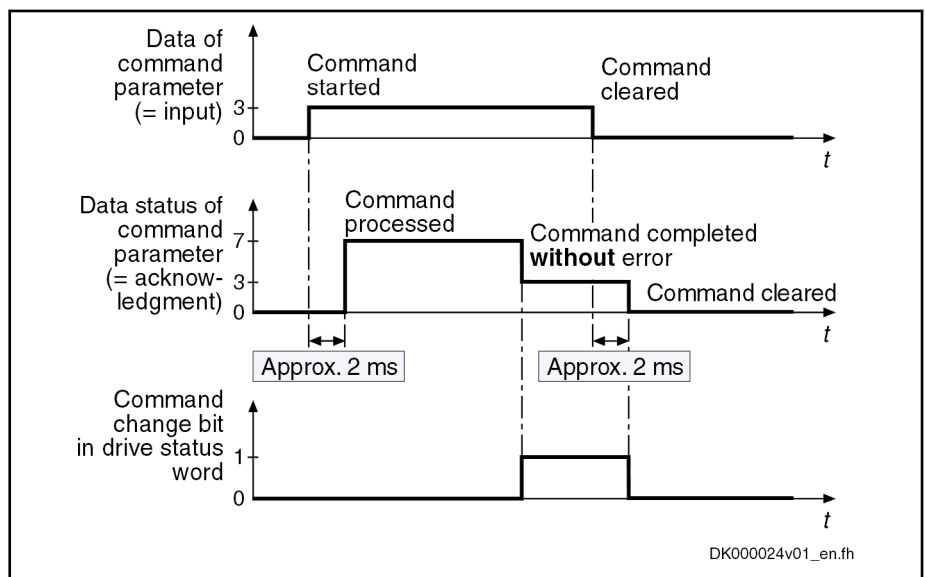
Fig.4-4:   *Input, Acknowledgment and Command Change Bit in the Case of Correct Execution*

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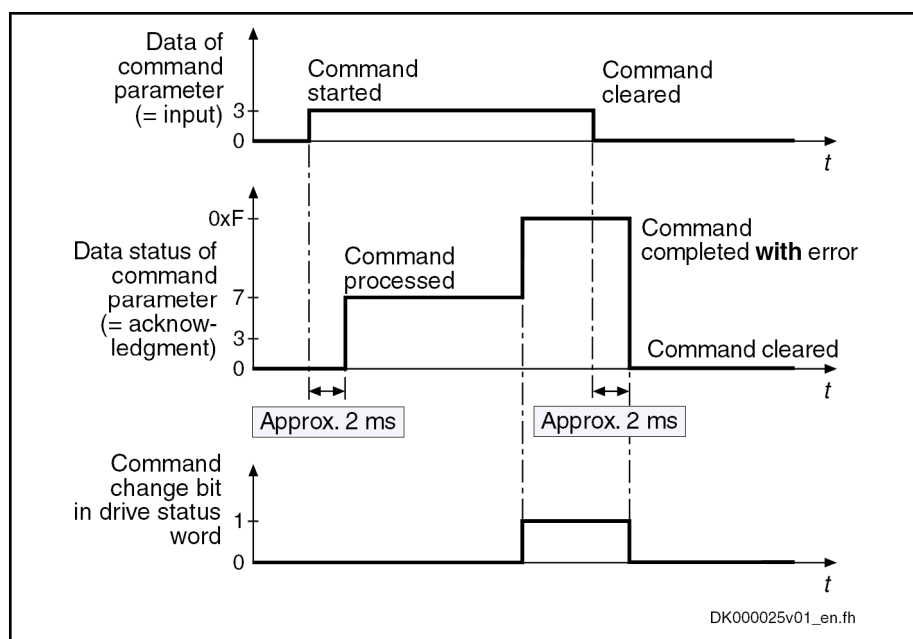
Fig.4-5:   *Input, Acknowledgment and Command Change Bit in the Case of Incorrect Execution*

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 operation modes). Corresponding state 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
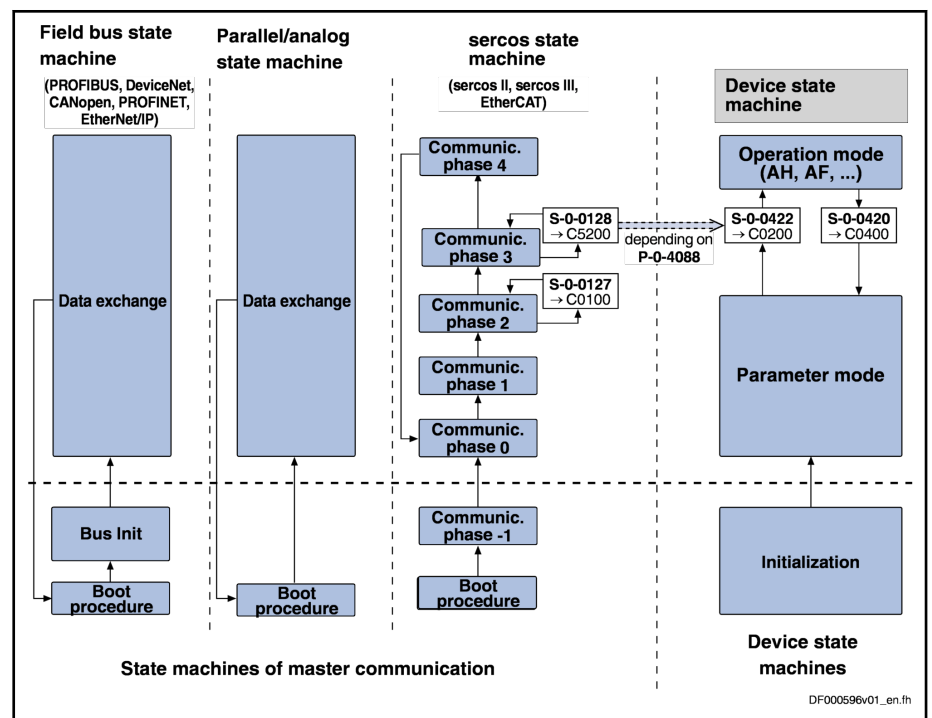
S-0-0127	C0100 Communication phase 3 transition check
S-0-0128	C5200 Communication phase 4 transition check
S-0-0420	C0400 Activate parameterization level procedure command
S-0-0422	C0200 Exit parameterization level procedure command
P-0-4088	Master communication, configuration
Fig.4-6:	Overview: State 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 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"

- For 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. Via the parameter "P-0-4088, Master communication: Drive configuration", this dependence can be deactivated.

Master Communication

- In the case of master communication other than SERCOS interface, the device-internal state machine changes to the operating mode after the booting process. This behavior, too, can be set via the parameter "P-0-4088, Master communication: Drive configuration".

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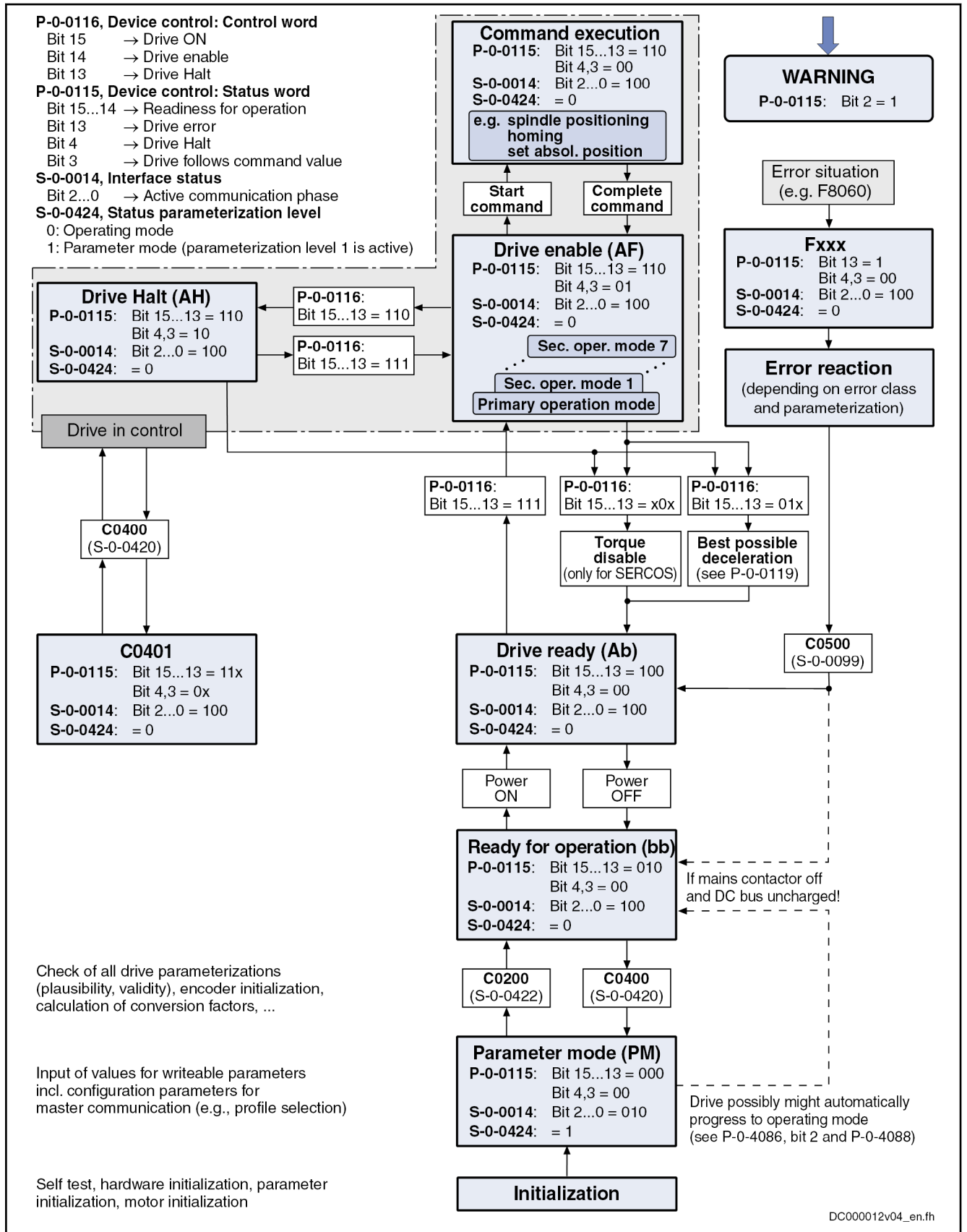
Fig.4-7:   Device Control (General State Machine)

Master Communication

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

- SERCOS State Machine (SERCOS II, SERCOS III, EtherCAT®)
- Field Bus State Machine (PROFIBUS DP, DeviceNet[TM], CANopen, PROFINET®, EtherNet/IP[TM])
- 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 (SERCOS II, SERCOS III, Ether-CAT®)

For the master communication "SERCOS interface", we distinguish the following states specific to this type of communication:
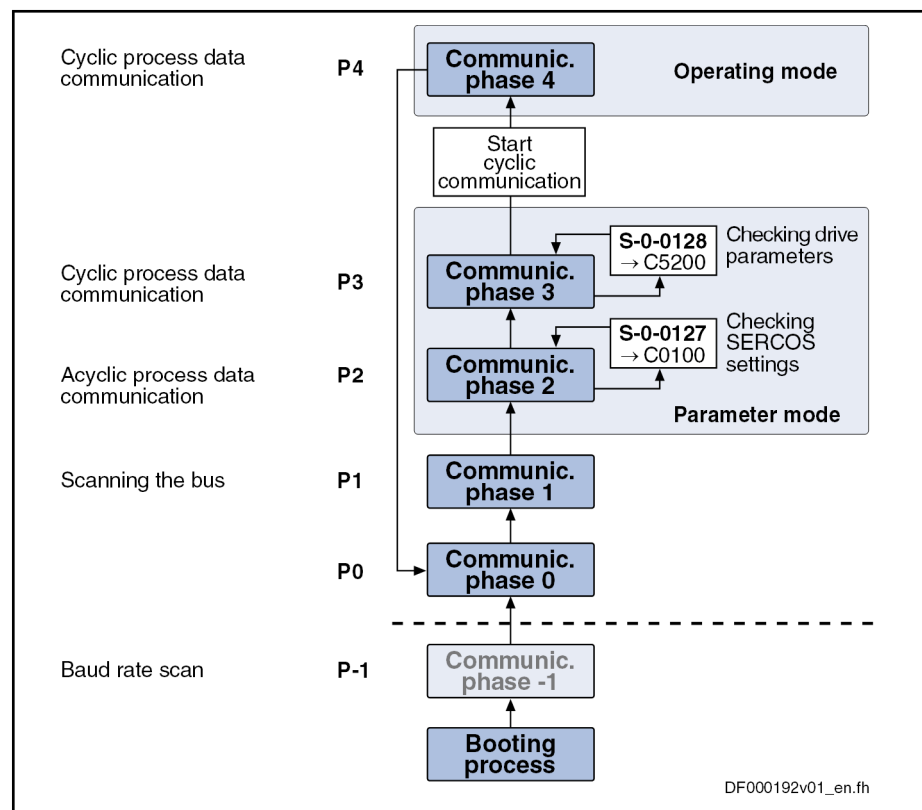
Fig.4-8:   State Machine of the Communication Phases of the Drive According to **SERCOS II** Specification

See also "SERCOS interface"

Master Communication
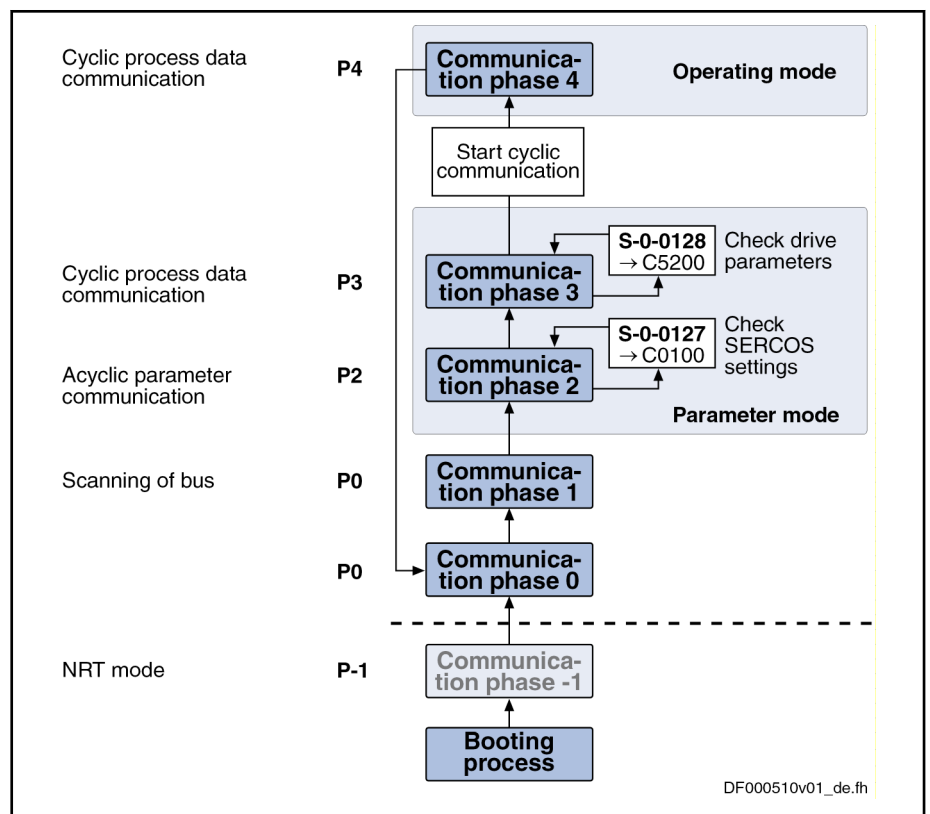
Fig.4-9:   *State Machine of the Communication Phases of the Drive According to **SERCOS III** Specification*

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

Field Bus State Machine (PROFIBUS®, DeviceNet™, CANopen, PROFINET®, EtherNet/IP™)   For the field bus master communication, we distinguish the following states specific to this type of communication:

Master Communication
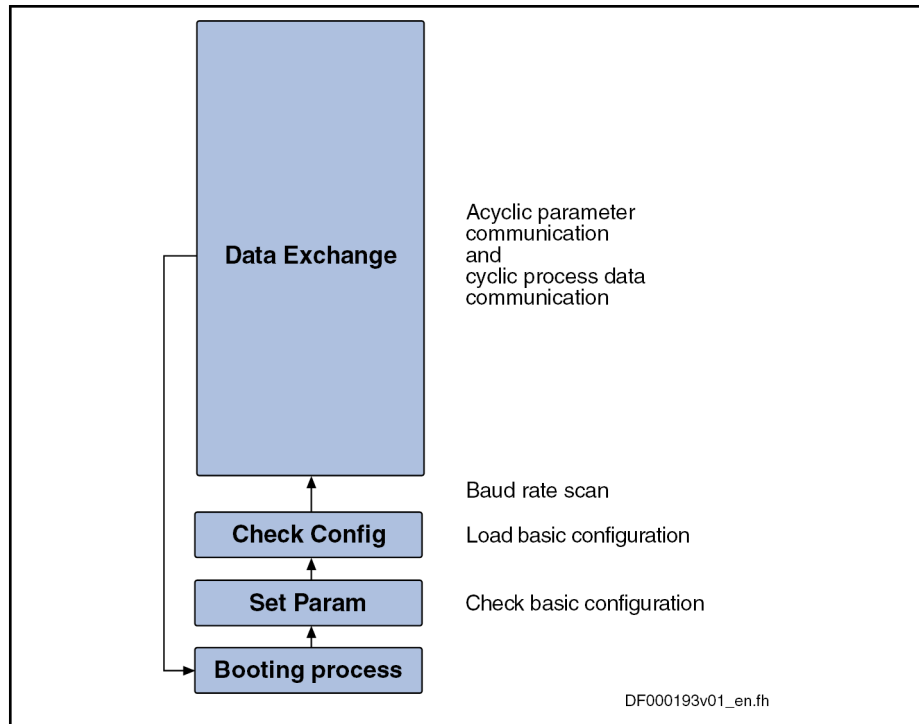
Fig.4-10:   *State Machine for Field Bus Interfaces*

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 drive can be completely parameterized.

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

  – Communication parameters (according to SERCOS)

  – Configuration of axis control (sampling times)

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

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

  In phase 3, the following parameters can be changed:

  – Parameters for operation mode configuration

  – Error reaction settings

  – Motor configuration parameters, holding brake parameters

  – Encoder configuration parameters

  – Mechanical transmission elements (gear, feed constant)

  – Scaling and polarity parameters, position data format, modulo value

  – Configuration of analog and digital inputs/outputs

  – Configuration of switch-on / switch-off sequence of drive enable (waiting times, …)

☞ 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 the 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. Switching to the operating mode always causes a new initialization of all functions available in the drive.

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

- After the controller has been switched on, it does not automatically go to the operating mode, but must be switched to this mode by the master.

- This switching of the drive controller to the operating mode is closely connected to establishing the readiness for operation.

- The procedure comprises several steps and is controlled by the master by presetting communication phases -1 to 4 and starting/completing the following commands:

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

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

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

Communication Phases for Field Bus Interface

For devices with **field bus interface**, there only is the 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.

Master Communication

> ☞ 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, EtherCAT®:
  - S-0-0134, Master control word
  - S-0-0135, Drive status word
- SERCOS III:
  - S-0-0134, Master control word
  - S-0-0135, Drive status word
- Field bus interface (e. g. PROFIBUS®, CANopen, DeviceNet^{TM}, PROFINET®, EtherNet/IP^{TM}):
  - 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:
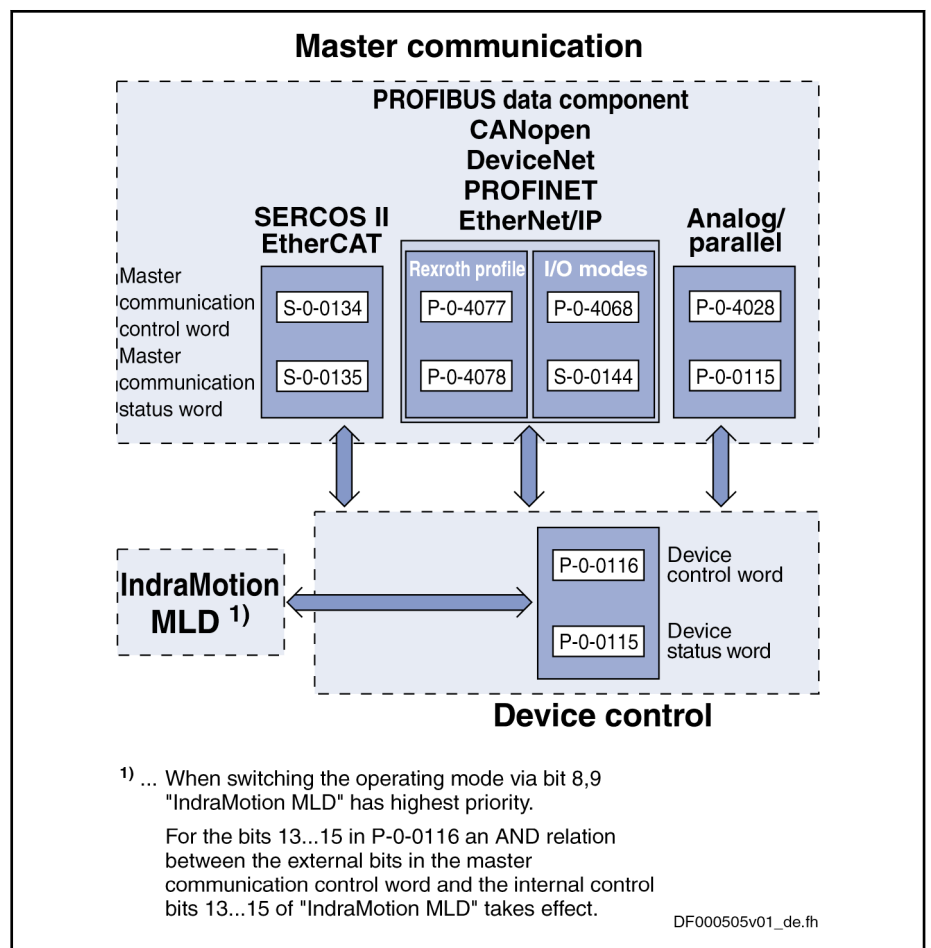
Fig.4-11:   Interaction of the Existing Control and Status Words According to
              SERCOS II Specification

Master Communication
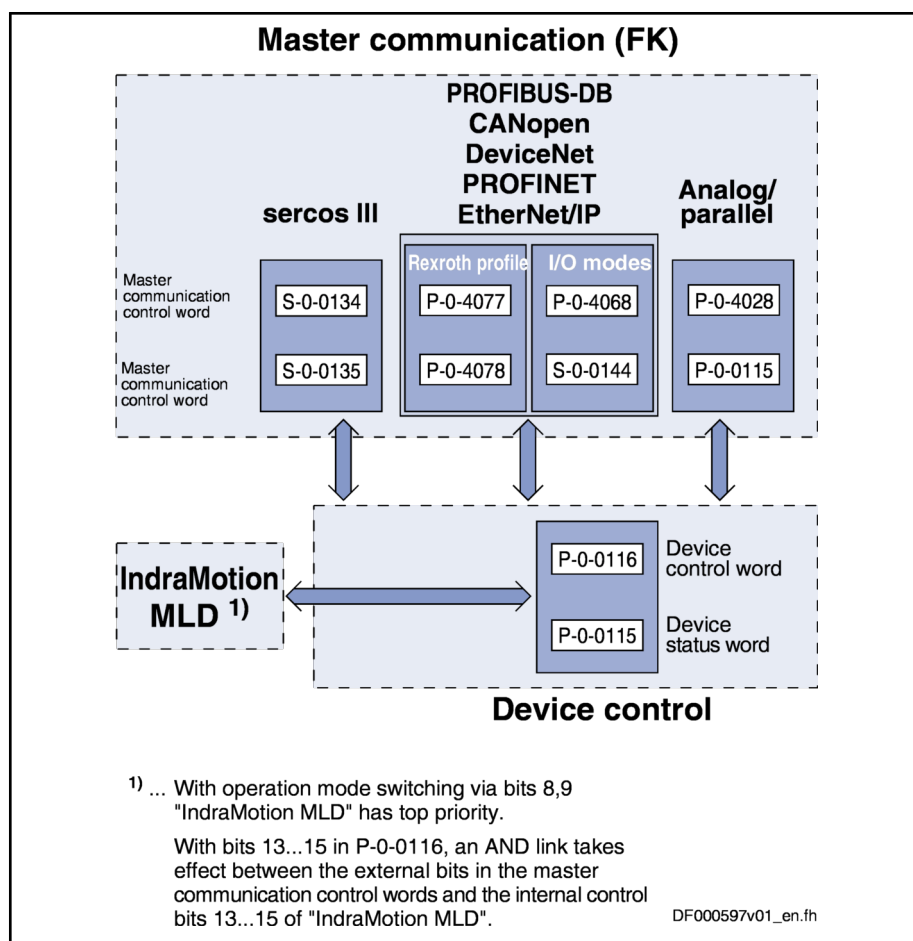
Fig.4-12:   *Interaction of the Existing Control and Status Words According to* **SERCOS III** *Specification*

ℹ️ 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 an 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)!

Master Communication

Bit Sequence During Switch-On Process
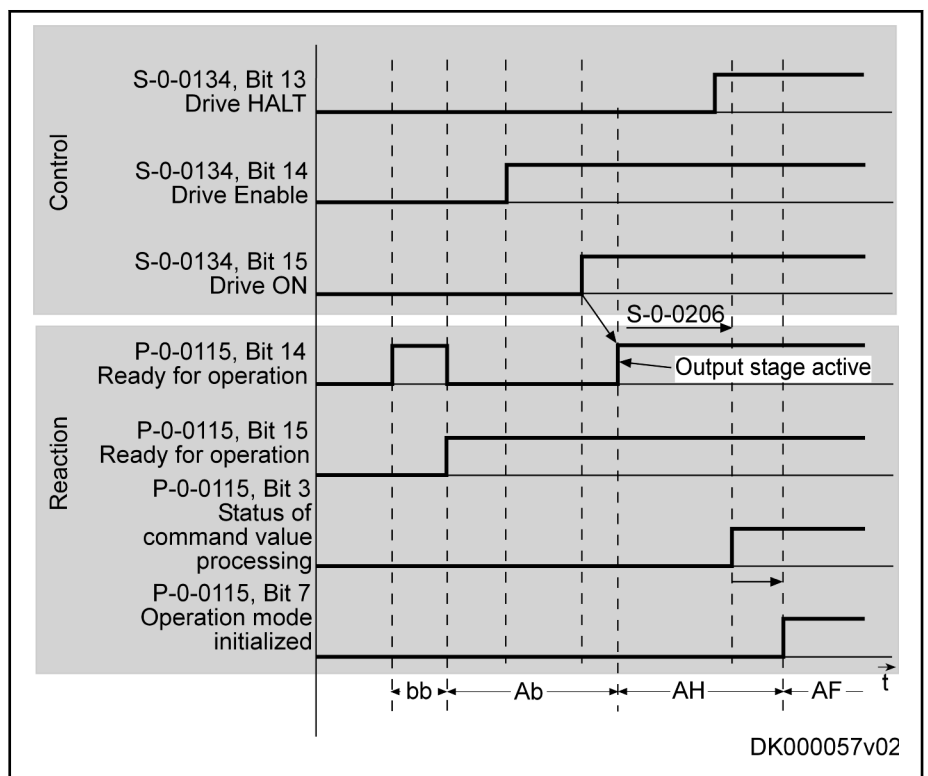
S-0-0206   Drive on delay time

Fig.4-13:   *Bit Sequence During Switch-On Process*

Master Communication

Bit Sequence During Switch-Off Process


```
DK000058v02_de.fh
```
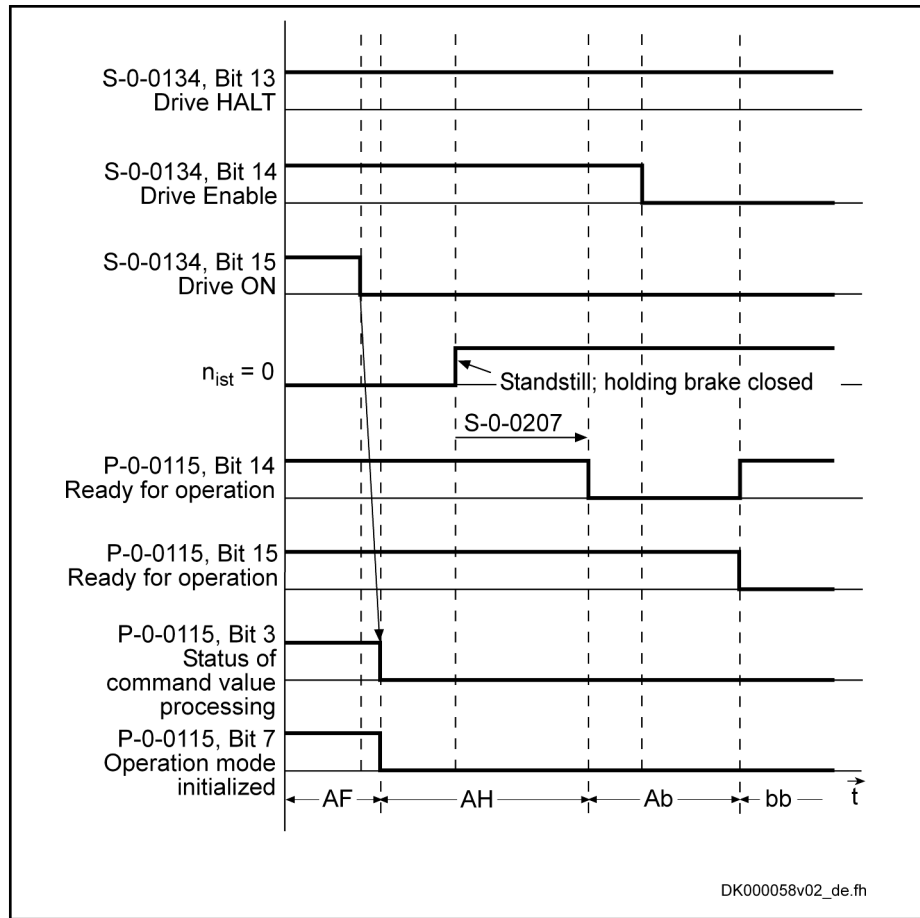
S-0-0207   Drive off delay time

Fig.4-14:   *Bit Sequence During Switch-Off Process*

Master Communication

Bit Sequence During Error Reaction

DK000059v02_de.fh
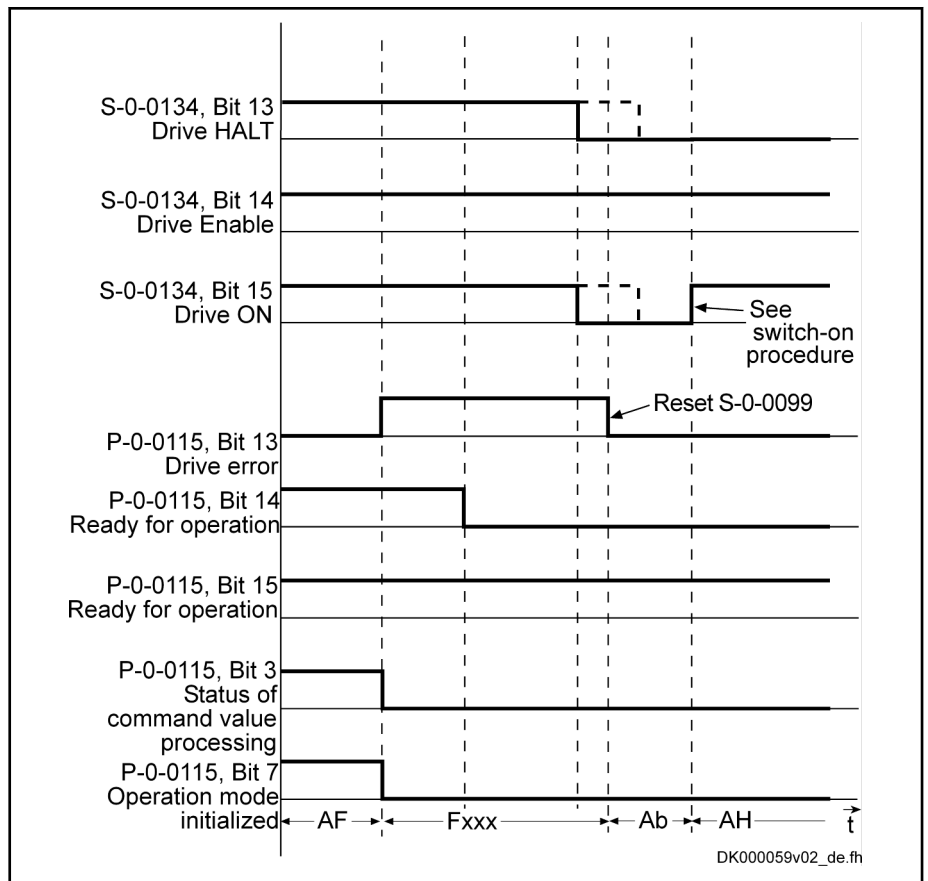
S-0-0099   C0500 Reset class 1 diagnostics

Fig.4-15:   Bit Sequence During Error Reaction

Master Communication

Bit Sequence During Change of Operation Modes
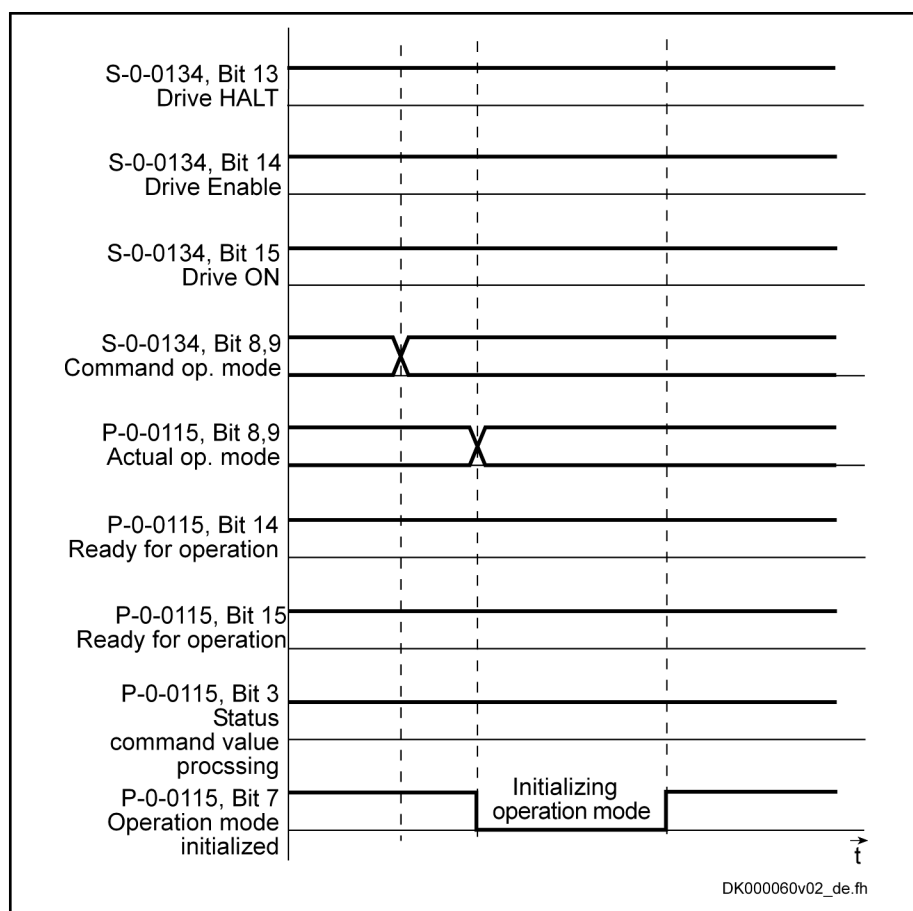
Fig.4-16:   Bit Sequence During Change of Operation Modes

Commands and Diagnostic Messages for Mode Change and Phase Switch

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

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

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

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

- Checking validity of parameters required for switching to phase 3

Master Communication

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 operation data for CP2". These parameters must 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

   – C0170 Config. IDNs for connection not configurable

   – C0171 Maximum length for connections exceeded

   – C0173 Connections (number) not configurable

   – C0174 Connection configuration not allowed

- 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 Telegram offset unsuitable

   – 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)

   – C0175 Producer cycle time of a connection not correct

- 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

   – C0172 Delay measurement (S-0-1024) not carried out

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

Master Communication

- C0299 Configuration changed. Restart

  → Drive must be rebooted before it is possible to switch to the operating mode (OM)

- Checking validity of parameters required for subsequent initializations
  - C0201 Invalid parameters (->S-0-0423)
  - C0212 Invalid control section data (->S-0-0423)
- Checking device configuration
  - C0223 Invalid settings for controller cycle times
- If necessary, checking parameters for field bus communication for validity and compliance with requirements
  - C0229 Field bus: IDN for cycl. command val. not configurable
  - C0230 Field bus: Max. length for cycl. command val. exceeded
  - C0231 Field bus: IDN for cycl. actual val. not configurable
  - C0232 Field bus: Length for cycl. actual values exceeded
  - C0233 Field bus: Tcyc (P-0-4076) incorrect
  - C0234 Field bus: P-0-4077 missing for cycl. command values
- Checking configuration of multiplex channel
  - C0238 Order of cyclic command value configuration incorrect
  - C0239 IDN for command value data container not allowed
  - C0240 IDN for actual value data container not allowed
- Checking motor and encoder configuration
  - C0210 Feedback 2 required (->S-0-0423)
  - C0219 Max. travel range too large
  - C0270 Error when reading encoder data => motor encoder
  - C0271 Incorrect parameterization of motor encoder (hardware)
  - C0272 Incorr. parameteriz. of motor enc. (mechanical system)
  - C0273 Modulo value for motor encoder cannot be displayed
  - C0274 Motor encoder unknown
  - C0275 Error when reading encoder data => optional encoder
  - C0276 Incorrect parameterization of optional enc. (hardware)
  - C0277 Incorr. parameteriz. of opt. enc. (mechanical system)
  - C0278 Modulo value for optional encoder cannot be displayed
  - C0279 Optional encoder unknown
  - C0280 Maximum travel range cannot be displayed internally
  - C0284 Invalid motor data in encoder memory (->S-0-0423)
  - C0285 Type of construction of motor P-0-4014 incorrect
  - C0286 Several motor encoders connected
  - C0287 Error during initialization of motor data (->S-0-0423)
  - C0288 Rotary scaling not allowed
  - C0289 Error at init. of synchr. motor with reluctance torque
  - C0290 Error when reading encoder data => measuring encoder
  - C0291 Incorr. prarmeterization of measuring enc. (hardware)
  - C0292 Measuring encoder unknown

Master Communication

- – C0293 Modulo value for measuring encoder cannot be displayed
- – C0294 Incorrect measuring encoder configuration
- Checking modulo range
  - – C0244 Act. modulo value cycle greater than max. travel range
- Checks during encoder initialization
  - – C0220 Error when initializing position of encoder 1
  - – C0221 Initialization velocity encoder 1 too high
  - – C0224 Error when initializing position of encoder 2
  - – C0225 Initialization velocity encoder 2 too high
  - – C0227 Error when initializing position of measuring encoder
  - – C0228 Initialization velocity measuring encoder too high
- Initializing optional additional functions (digital I/Os)
  - – C0243 Brake check function not possible
  - – C0250 Probe inputs incorrectly configured
  - – 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 Error in safety technology encoder initialization
- Limit value check
  - – C0202 Parameter limit error (->S-0-0423)
  - – C0203 Parameter conversion error (->S-0-0423)
- General system checks
  - – C0245 Operation mode configuration (->S-0-0423) not allowed
- Initializing fine interpolator
  - – C0258 Error in relation TNcyc (S-0-0001) to fine interpol.
- Initializing digital inputs/outputs
  - – C0246 Trav. range lim. switch not ass. to dig. input
  - – C0247 Dig. output already assigned to other axis
  - – C0248 Dig. input assigned differently to axes
  - – C0249 Dig. I/Os: Bit number too large
- 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

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

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

Notes on Commissioning of the Signal Control Word

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

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

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

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

☞   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 specified.

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

Exceptions
- If the assigned parameter is a command, the bit number in parameter "S-0-0329, Assign list signal control word" is irrelevant.
- 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" "S-0-0145, Signal control word" is used to map the control bits which are not contained in "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 for signal control word" and "S-0-0329, Assign list signal control word", the following checks are run:

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

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

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

Notes on Commissioning of the Signal Status Word

Configuring the IDNs   In parameter "S-0-0026, Configuration list for signal status word", the IDNs of those parameters are indicated that contain the original bits (sources). The parameters that can be entered into the configuration list are contained in pa-

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rameter "S-0-0398, IDN-list of configurable data in signal status word". The position of an IDN in the list determines the bit in the signal status word to which the IDN applies. For example, the 1st list element determines from which parameter bit 0 of the signal status word is taken.

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

☞   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 specified.

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.4-17:   *Example of Configuration of the Signal Status Word*

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

☞   When cross communication is used in the "CCD system mode", the parameter "S-0-0144, Signal status word" is used to map the status bits which are not contained in parameter "S-0-1135, 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 for signal status word", the following checks are run:

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

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

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

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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 use the "multiplex channel" mechanism, it is necessary to use a 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 operation-mode-dependent configuration of the cyclic data by index switching in case the operation 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: command value 1
- S-0-0450, Data container A: command value 2
  - to -
  S-0-0456, Data container A: command value 8

Parameters for actual value channel:
- S-0-0366, Data container A: list index feedback values
- S-0-0364, Data container A: feedback value 1
- S-0-0480, Data container A: feedback value 2
  - to -
  S-0-0486, Data container A: feedback value 8

Configuration lists of the command value data containers:
- S-0-0370, Data container A: configuration list command value-1
- S-0-0490, Data container A: configuration list command value 2
  - to -

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

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

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

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

The following assignment applies to S-0-0368:

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

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

☞ Only the bits 0…4 (for MDT) and the bits 8…12 (for AT) are used for addressing via the parameter S-0-0368. The other bits are ignored. This is why no value greater 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.
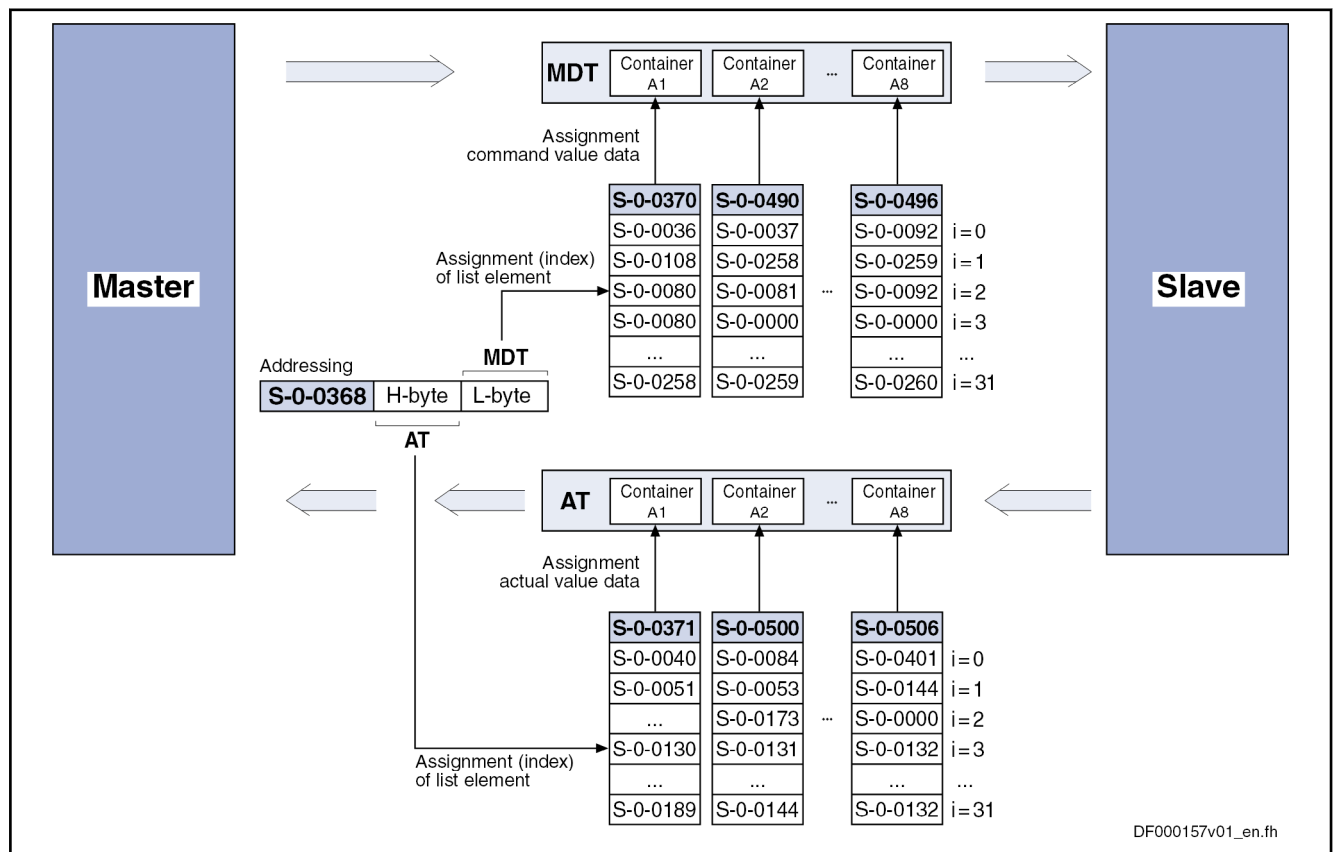
i	Index (= list element no.)
S-0-0368	Data Container A: Addressing
S-0-0370	Data Container A: Configuration list command value-1
S-0-0490	Data Container A: Configuration list command value-2
S-0-0496	Data Container A: Configuration list command value-8
S-0-0371	Data Container A: Configuration list feedback 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.4-18:   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.

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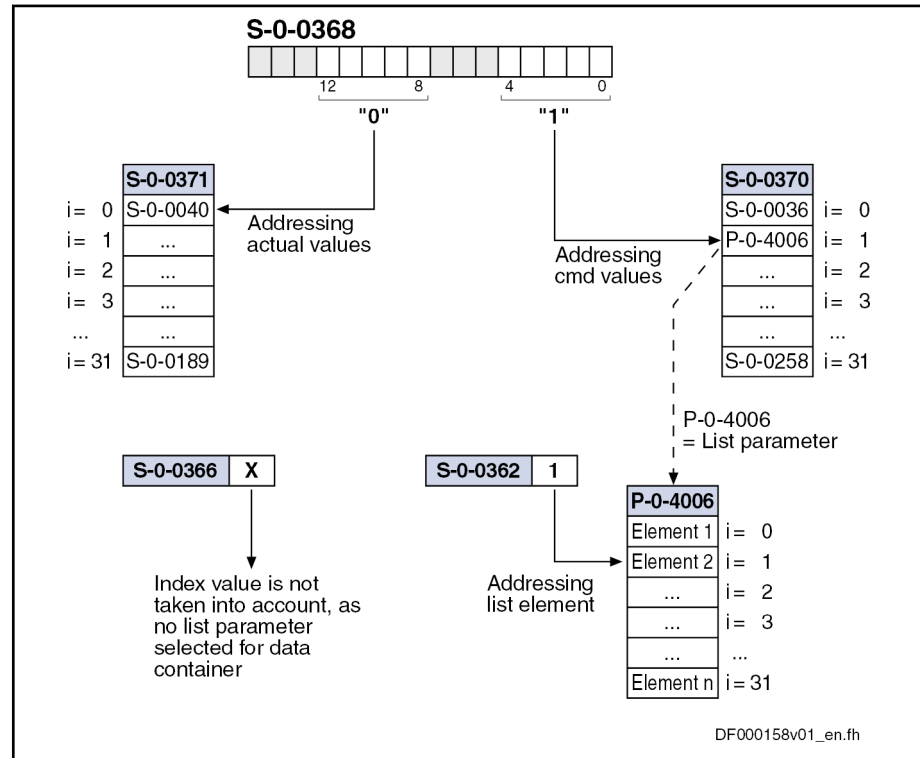
i	Index (= list element no.)
S-0-0368	Data Container A: Addressing
S-0-0362	Data Container A: List index command values
S-0-0366	Data Container A: List index feedback values
S-0-0370	Data Container A: Configuration list command value-1
S-0-0371	Data Container A: Configuration list feedback value-1
P-0-4006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

Fig.4-19: *Access to Elements of a List Parameter via Multiplex Channel (Example of Command Values → MDT Data Container)*

Notes on Commissioning

Activation

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

Data Container A: Command Value-x

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

- **Single parameters**

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

- **List parameters**

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

☞   The display format is hexadecimal without decimal places.

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

Data Container A: Feedback Value-x

For determining the source parameter 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 parameters:

- **Single parameters**

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

- **List parameters**

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

☞   The display format is hexadecimal without decimal places.

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

Diagnostic and Status Messages

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

Checking the Configured IDN Order

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

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

To make sure the correct order is followed when configuring the cyclic command values, the drive during the execution of "S-0-0127, C0100

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Communication phase 3 transition check" checks whether IDN S-0-0368 was configured before the IDNs S-0-0360 or S-0-0450 to S-0-0456. If this was not the case, the drive generates the error message "C0118 Order of cyclic command value configuration incorrect".

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

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

There are the following possible error messages:

- If a **command value configuration list** contains one or several IDNs that do not exist or are not contained in "S-0-0188, List of configurable data in the MDT", the following error message is generated:

    – C0151 IDN for command value data container not allowed

- If an **actual value configuration list** contains one or several IDNs that do not exist or are not contained in "S-0-0187, List of configurable data in the AT", the following error message is generated:

    – C0152 IDN for actual value data container not allowed

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

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

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

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

4.3   Operating Modes of Master Communication

4.3.1   Introduction and Overview

Overview of Operating Modes and Possibilities of Command Triggering

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

The figure below contains an overview of the possibilities of drive command triggering.
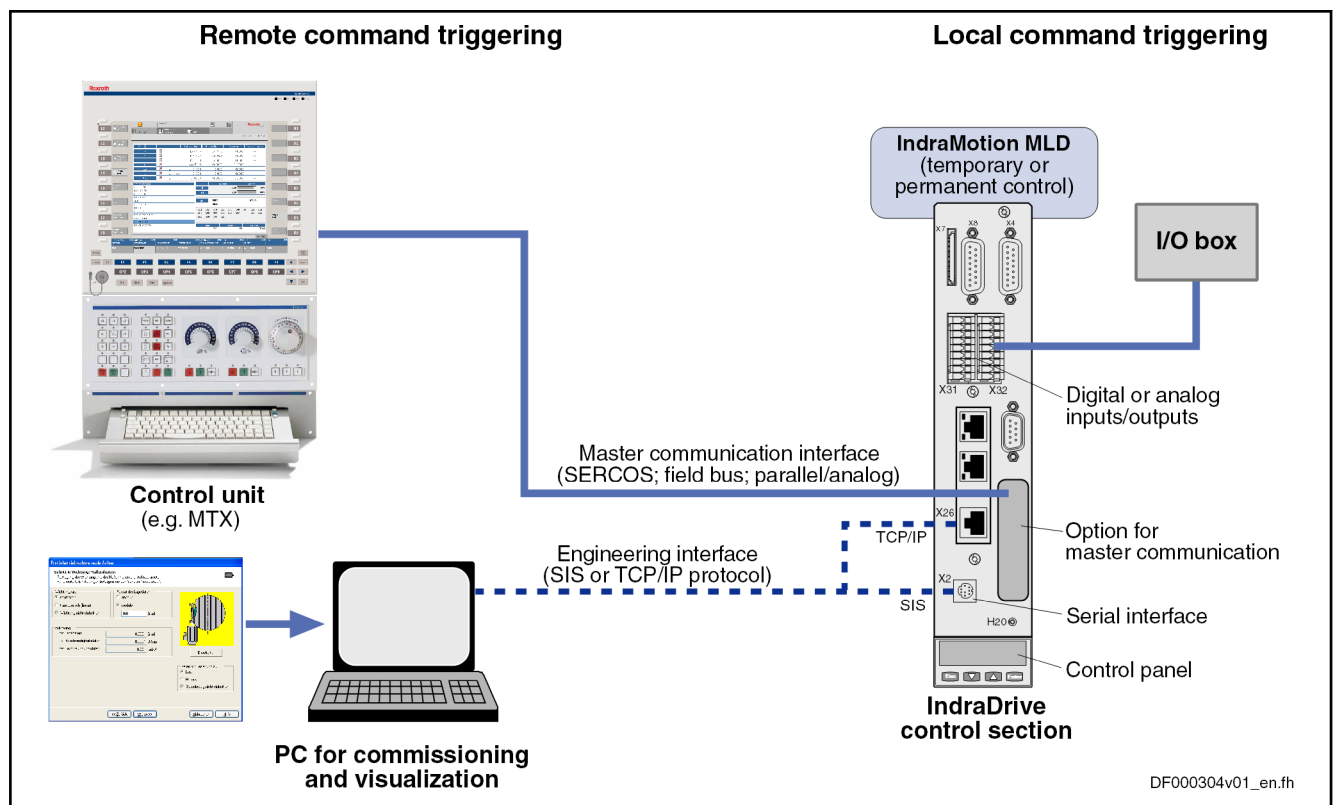
Fig.4-20:   Overview of Possibilities of Command Triggering for an IndraDrive Device

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

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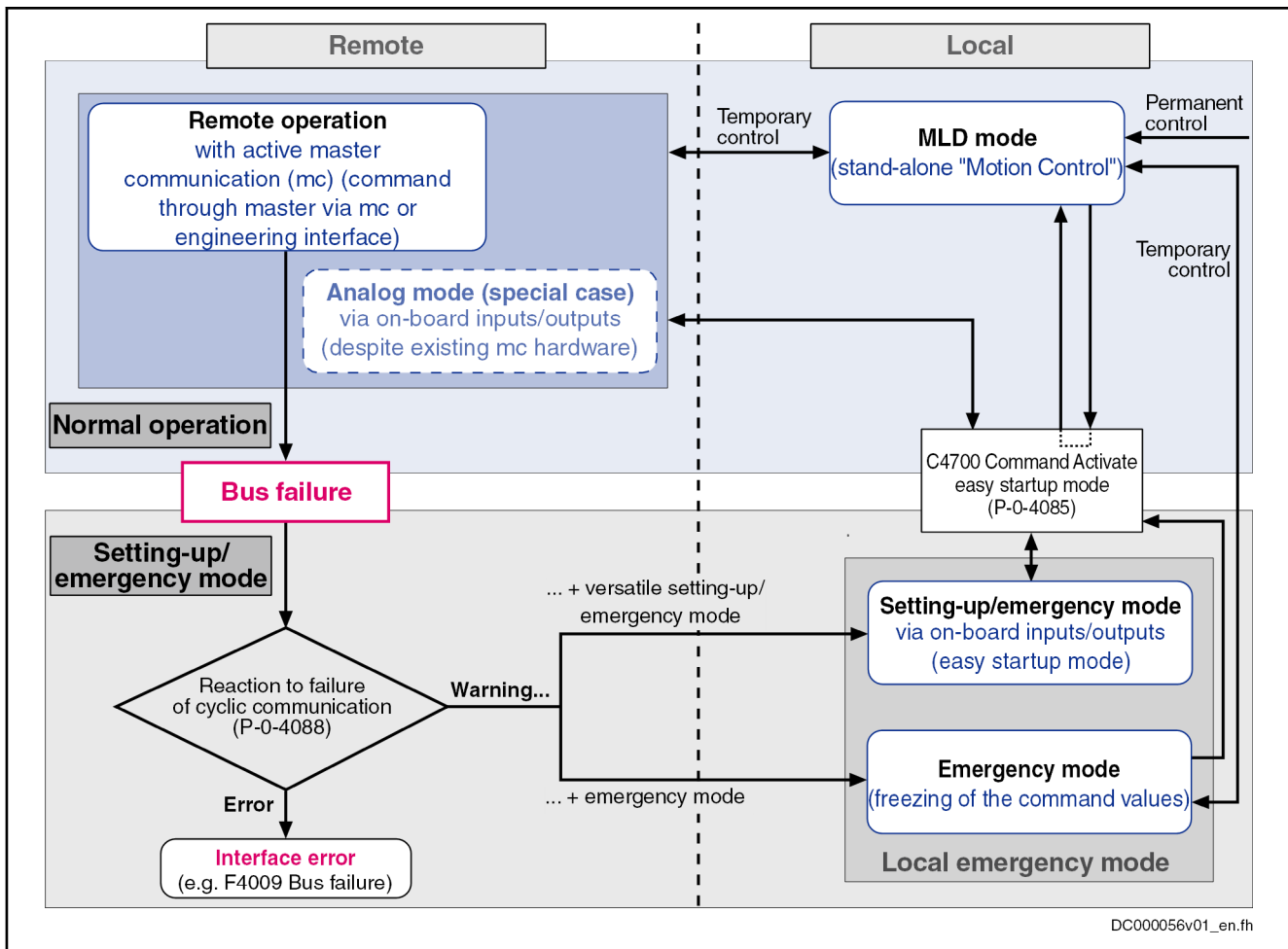
Fig.4-21:   *Operating States and Operating Modes of Master Communication*

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

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

Normal Operation (via Internal or External Control Unit)

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

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

→ Command triggering for the axis takes place via the master communication (SERCOS, field bus, analog/parallel).

Special cases (respective configuration via parameter P-0-4088):

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

–   **EtherNet/IP^{TM} communication** via the engineering interface

Master Communication

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

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

  → Configuration via parameter P-0-1367 (see also "Stand-Alone Motion Control" in the separate documentation "IndraMotion MLD, Application Manual")

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

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

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

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

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

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

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

4.3.2   Normal Mode (Remote or Local)

Remote Mode with External Control Unit and Active Master Communication

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

See description of the respective master communication:

- SERCOS interface
- SERCOS III
- PROFIBUS-DP
- EtherNet/IP(TM) interface
- CANopen interface
- DeviceNet™ interface
- Parallel Interface
- Analog interface

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

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

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

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

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

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

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

4.3.3   Setting-Up Mode (Easy Startup Mode)

Brief Description of Easy Startup Mode

The setting-up mode as so-called "easy startup mode" allows moving the drive without 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.

Fields of Application   The easy startup mode is particularly suited for

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

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

Features   The easy startup mode has the following features:

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

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    –   Selecting the **travel direction** (positive/negative) via digital input signals

    –   Activating and changing the fixed velocity command values via standard control panel

- **Switching off command triggering** by master communication interface (see "P-0-4077, Interface status", "S-0-0134, Interface status") and possibly available drive-integrated PLC (IndraMotion MLD)

Pertinent Parameters

- S-0-0014, Interface status
- P-0-0120, Control word easy startup
- P-0-0300, Digital 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-0-4085, C4700 Command Activate easy startup mode
- P-0-4086, Master communication status
- P-0-4088, Master communication: Drive configuration

Pertinent Diagnostic Messages

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

- When the easy startup mode has been activated, the display changes between the drive address and the message "CM" (Commissioning Mode).

- During commissioning, the relevant messages appear on the display (see fig. "Activating the Easy Startup Mode via the Control Panel").

Functional Description of Easy Startup Mode

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

Control via Digital or Analog Inputs

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

- Automatically by activating the easy startup mode

- or -

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

Automatic Configuration of the Inputs

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

- Deactivation of master communication interface and activation of drive enable in parameter "P-0-0120, Control word easy startup"

- Setting of operation mode "velocity control" with values from memory of fixed command values (P-0-1206)

- Assignment of the command velocity selected via the control panel (in percent) of "S-0-0091, Bipolar velocity limit value" to element 1 or 2 of parameter "P-0-1206, Memory of velocity command values" (with positive sign to element 1, with negative sign to element 2).

- Assignment of allocation of inputs

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

Master Communication

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

IndraDrive single-axis control sections (CSB, CSH)			
Connection	Signal	Function	I/O assignment
X31.3	I_1	Motor potentiometer, ramp +	P-0-1200, Control word 1 velocity control (bit 8)
X31.4	I_2	Drive enable	P-0-0120, Control word easy startup (bit 15)
X31.7	I_5	Motor potentiometer, ramp –	P-0-1200, Control word 1 velocity control (bit 9)
X32.7	I/O_9	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 0)
X32.8	I/O_10	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 1)

Fig.4-22:   *Automatic I/O Configuration for Easy Startup Mode with Single-Axis Control Sections*

IndraDrive double-axis control sections (CDB)				
Connection	Signal	Axis	Function	I/O assignment
X33.4	I_15	1	Motor potentiometer, ramp +	P-0-1200, Control word 1 velocity control (bit 8)
X33.1	I_12	1	Drive enable	P-0-0120, Control word easy startup (bit 15)
X33.5	I_16	1	Motor potentiometer, ramp –	P-0-1200, Control word 1 velocity control (bit 9)
X33.2	I_13	1	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 0)

IndraDrive double-axis control sections (CDB)				
Connection	Signal	Axis	Function	I/O assignment
X33.3	I_14	1	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 1)
X34.4	I_21	2	Motor potentiometer, ramp +	P-0-1200, Control word 1 velocity control (bit 8)
X34.1	I_18	2	Drive enable	P-0-0120, Control word easy startup (bit 15)
X34.5	I_22	2	Motor potentiometer, ramp –	P-0-1200, Control word 1 velocity control (bit 9)

Master Communication

IndraDrive double-axis control sections (CDB)				
Connection	Signal	Axis	Function	I/O assignment
X34.2	I_19	2	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 0)
X34.3	I_20	2	Selection of memory of fixed command values	P-0-1200, Control word 1 velocity control (bit 1)

Fig.4-23:   *Automatic I/O Configuration for Easy Startup Mode with Double-Axis Control Sections*

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

Fig.4-24:   *Automatic I/O Configuration for Easy Startup Mode with IndraDrive Mi*

☞   IndraDrive Mi (distributed servo drive "KSM") only has a limited number of digital inputs/outputs (4 inputs/outputs), it has no analog input and no control panel!

ℹ️   See also "Optional Modules for Control Sections" in the separate documentation "Control Sections for Drive Controllers; Project Planning Manual"

Manual Configuration of the Inputs   **Necessary** manual configuration of the digital/analog inputs (see also "Digital Inputs/Outputs" or "Analog Inputs"):

- Connect 24V/0V power supply to respective terminal connectors
- +24 V for activation of drive enable (P-0-0120, bit 15)

Alternatively, you can additionally set the following manual configurations:

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- Input of analog speed command value (P-0-1460), if command value input is to take place via analog value

- Setting of source for velocity command values in parameter "P-0-1200, Control word 1 velocity control":

  → Selection of memory of fixed command values, if command value input is to take place via predefined fixed values

  - or -

  → Setting that command value input is to take place via motor potentiometer function

Operating the Drive via Serial Interface or Ethernet
The drive can also be controlled via the commissioning interface (serial or Ethernet) via which it is possible to write the control word and the command values.

Take the following aspects into account:

- The digital inputs must not have been assigned to the parameter "P-0-1200, Control word 1 velocity control".

- Parameter "P-0-1460, PLC/setting-up mode, velocity command value" must not have been assigned to any analog input

- Drive enable mustn't have been assigned to any digital input (P-0-0120).

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

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

Notes on Commissioning for Easy Startup Mode

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

- For Rexroth motors with encoder data memory there is no commissioning PC required; for motors without encoder data memory, the motor parameters have to be manually written during commissioning.

- Master communication or IndraMotion MLD should not be active, as the easy startup mode switches off any possibly active command triggering via master communication or IndraMotion MLD!

- There mustn't be any error message present in the drive, not even a transition command error (C01xx, C02xx).

- The drive must be ready for operation (bb).

  – In the case of conventional field bus interfaces (e.g. CANopen, PROFIBUS® or DeviceNet[TM]), the drive is automatically ready for operation (bb) after run-up, even if master communication is not active. In this way, the requirements for manual mode basically are always fulfilled!

  – With SERCOS interface, Ethernet interface, …, the drive after run-up is **not ready for operation** if master communication is not active (e.g. communication phase "P-1" with SERCOS).

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

- Activate the corresponding menu item on **standard control panel**

Master Communication

- **Set a digital input** on which the command parameter P-0-4085 has been configured

- **Write the parameter P-0-4085** via master communication, via serial interface or via EtherNet/IP^{TM} (if available)

- **Automatically by internal command start** in the case of bus failure, if configured accordingly (see P-0-4088)

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

Activation via Control Panel　The command P-0-4085 can be activated and deactivated via the standard control panel of the IndraDrive controllers.

The figure below shows the sequence for activating the easy startup mode via the control panel:
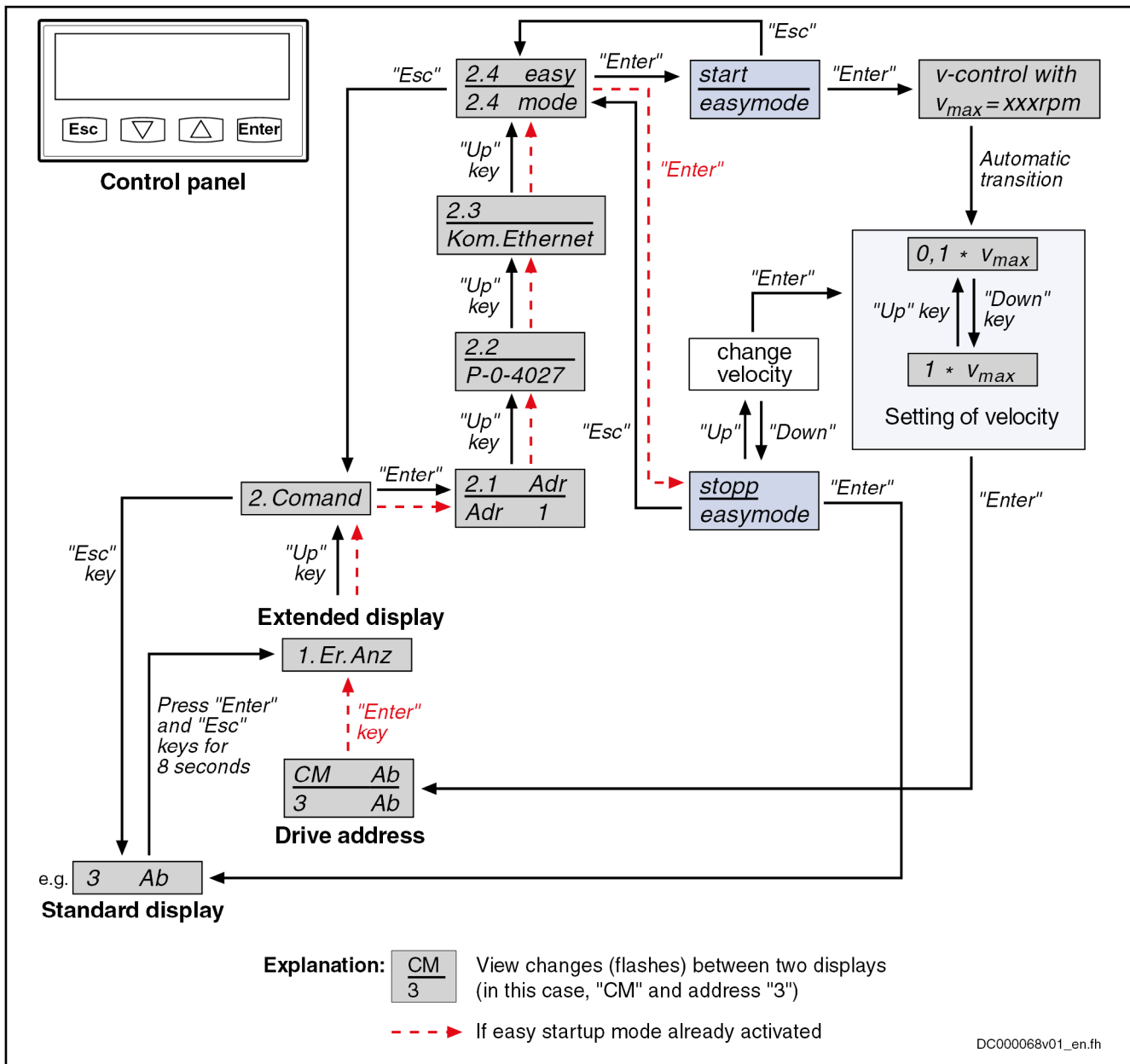
Fig.4-25:　　　Activating the Easy Startup Mode via the Control Panel

Master Communication

See also "Control Panels of the IndraDrive Controllers"

Activation via Digital Input

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

See "Digital Inputs/Outputs"

Activation via Serial Interface

To activate the easy startup mode via the serial interface, parameter P-0-4085 has to be written via SIS telegrams.

See "Serial Communication"

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

Acknowledgment of Activation

The activation of the easy startup mode is acknowledged by:

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

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

Deactivating/Exiting the Easy Startup Mode

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

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

Control Parameter P-0-0120

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

- Via digital inputs, if they were accordingly configured before
- Via the serial interface by direct writing of parameter P-0-0120

  → In this case, the parameter has to be actively written at least every 2 s, otherwise the drive will automatically clear drive enable!

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!

Commissioning with Easy Startup Mode

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

Master Communication
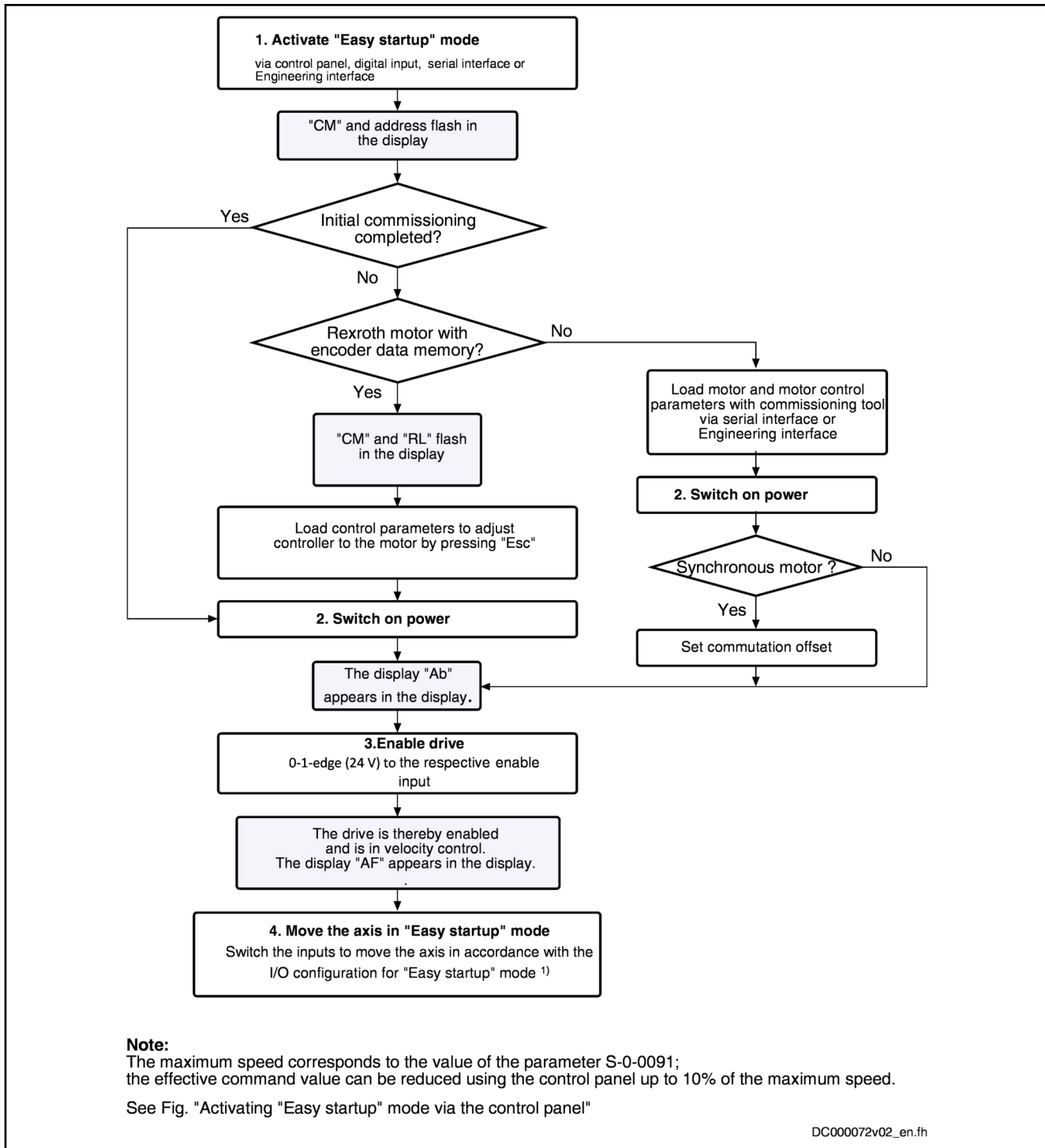
1)   See assignment tables for the different hardware designs under "Auto-
           matic Configuration of the Inputs"

Fig.4-26:   *Commissioning Sequence with the Easy Startup Mode*

For the "load defaults procedure", see "Default Settings in the Motor Encoder Data Memory" under "Overview of Drive Control".

Special case: Commissioning Motors without Encoder Data Memory

Initial commissioning of Rexroth motors without encoder data memory or of third-party motors is only possible in the manual mode in conjunction with the "IndraWorks Ds/D/MLD" commissioning tool, in order to load or enter the values for motor control parameters and motor encoder parameters. For syn-

chronous motors with absolute measuring system, the commutation offset only has to be determined at initial commissioning. For synchronous motors with relative measuring system, the commutation offset is automatically determined every time drive enable is set for the first time after transition "PM → OM".

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

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

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

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

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

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

4.3.4   Local Mode

Overview

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

- **MLD mode** with temporary control by IndraMotion MLD (intelligent servo axis) to carry out, for example, an intelligent error reaction.

- **Emergency run (local mode)** for bus failure → With the corresponding configuration, you can continue using the drive in an emergency mode, even if master communication (field bus, SERCOS, …) has failed.

MLD Mode with Temporary Control (Intelligent Servo Axis)

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

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

Emergency Mode (when Master Communication has Failed)

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

- **Bus failure as error**

Master Communication

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

- **Bus failure as warning**

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

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

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

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

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

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

4.3.5   Notes on Commissioning and Utilization

Using the Operating Modes

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

Place of command triggering	Mode	Usage	Execution of command triggering	Activation	Operation modes	Notes
Control unit (remote)	**Master comm. mode** (remote)	Field bus or SERCOS device is operated as usual via existing interface of master communication	Via external control unit (bus or inputs/outputs)	Not required	Standard operation modes 0…7 take effect and can be selected	Standard case
	Special case: Analog mode	Field bus device can be permanently operated as analog drive, if master comm. option deactivated (for mounting spare parts or emergency mode without master)	Only via digital onboard inputs/outputs and analog inputs	Configuration of parameter P-0-4088 **Note:** Activation requires complete booting process	Standard operating modes 0…7 take effect and can be defined according to application, if required	Special case in which master comm. option existing, but not active

Master Communication

Place of command triggering	Mode	Usage	Execution of command triggering	Activation	Operation modes	Notes
Control unit (internal)	MLD mode (permanent control)	For motion solutions with permanent control by MLD over the axis/axes	Internal via MLD with motion function blocks	Configuration of parameter P-0-1367	Standard operation modes 0…6 are automatically configured, operation mode 7 can be freely defined	No access by master communication (only E-Stop is possible)
Local	Setting-up mode	Setting-up and commissioning of axes, even without running master	Via digital inputs/outputs or acyclic channel with "IndraWorks Ds /D/MLD"	Control panel and command "easy startup mode"	Internal operation modes 8…12 take effect. **Note:** Operation modes 8…12 have been permanently configured	Control via MLD is impossible!
	Emergency mode	Moving the axes when master communication or MLD fails	Via MLD, digital inputs/outputs or acyclic channel with "IndraWorks Ds /D/MLD"	Command "easy startup mode", can be manually started in the case of bus failure	The operation modes last active take effect (0...7)	Control via MLD or activation of easy startup mode is possible
	Special case: Temporary control for intelligent error reaction	Preferably for use as intelligent servo axis (MLD has control only temporarily, e.g. for carrying out an intelligent error reaction)	Internal via MLD with motion function blocks	With function block "MX_Set-Control"	Internal operation modes 8…12 take effect. **Note:** Operation modes 8…12 have been permanently configured	Access by master communication with SERCOS. **Note:** With field bus, bit 14 in the control word does not take effect.

Master comm. option   Hardware option for master communication

MLD   IndraMotion MLD (drive-integrated PLC)

Fig.4-27:   Operation Criteria of the Operating Modes

Control Words of the Operating Modes and Master Communications

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

Master Communication
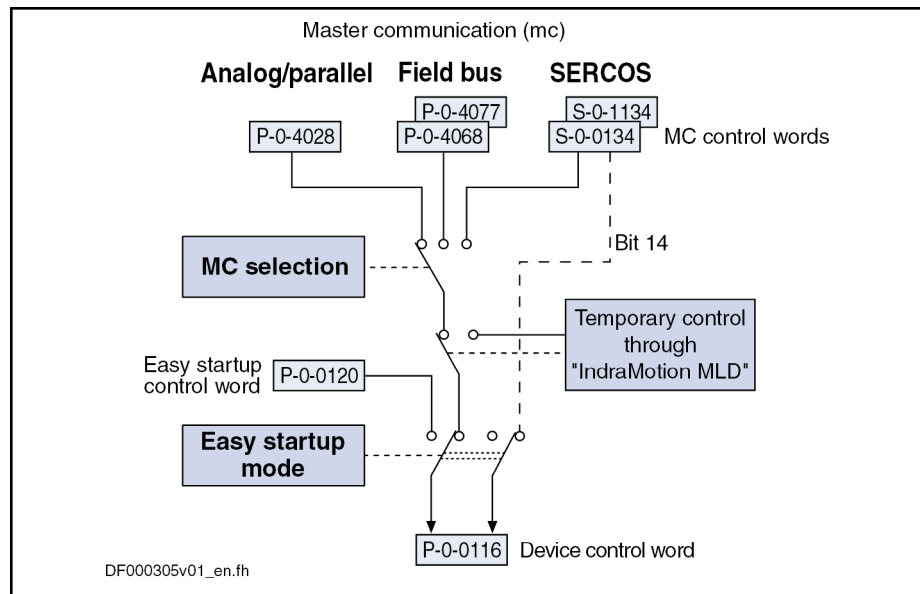
Fig.4-28:   *Overview of Control Words of Operating Modes and Master Communication*

Special Cases of Operation with External Control Unit

There are the following special cases of operation via an external master communication:

● Analog mode (with existing analog optional module)

● EtherNet/IP^{TM} communication via the engineering interface

Analog Mode with Existing Optional Module

You can **permanently** switch off a master communication interface (e.g. SERCOS or field bus) available in the control section and thereby use a SERCOS or field bus device like an analog device. In this case, the axis is controlled via the digital or analog inputs of the control section or a possibly available additional analog optional module (e.g. MA1).

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

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

● Deactivation of master communication and activation of the analog mode take place in the parameter "P-0-4088, Master communication: Drive configuration".

● The configuration will only take effect after repeated booting process, i.e. you have to switch off and on again the control voltage of the drive controller.

● In order to be able to control the device via the digital inputs, you have to assign the drive enable signal (see Parameter Description "P-0-0120, Control word easy startup") to a digital input of the control section.

See "Digital Inputs/Outputs"

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

See "Velocity Control" and "Positioning Block Mode"

Master Communication

- If analog inputs are available, they can be used for inputting a velocity command value (S-0-0036, S-0-0037) or, in the case of positioning block mode, a "feedrate override" (S-0-0108).

  See "Analog inputs"

EtherNet/IP(TM) via Engineering Interface It is possible to ignore a master communication interface (e.g. SERCOS or field bus) available in the control section and **operate the drive via the engineering interface**.

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

- Deactivation of master communication and activation of the analog mode take place in the parameter "P-0-4088, Master communication: Drive configuration".

- The configuration will only take effect after repeated booting process, i.e. you have to switch off and on again the control voltage of the drive controller.

- The axis is controlled via EtherNet/IP^{TM} communication. An optional module for parallel interface is available as an I/O extension.

See also "EtherNet/IP(TM) Interface"

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

4.4   Profile Types (with Field Bus Interfaces)

4.4.1   Supported Profile Types

Overview

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

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

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

Profile type: "No profile"			
Content of "P-0-4084, Field bus: profile type"	Master communication	Field bus or drive operation mode	Features
0x0000	PROFIBUS® CANopen DeviceNet^{TM} PROFINET® EtherNet/IP^{TM}	- With profile type "No profile", all settings relevant to the profile type are deactivated - The profile type "No profile" is mainly relevant to MLD applications with "permanent control" on the axis	- Profile type without field bus control and status words - Free configuration of real-time data - Free selection of the operation mode

Fig.4-29:   Profile Type "No Profile"

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

Fig.4-30:   Profile Type "I/O Mode Positioning"

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

Fig.4-31:   Profile Type "IO Mode Preset Velocity"

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

Fig.4-32:   Profile Type "Freely Configurable Mode"

Pertinent Parameters
- S-0-0026, Configuration list for signal status word
- S-0-0144, Signal status word
- S-0-0328, Assign list signal status word
- P-0-4068, Field bus: control word IO
- P-0-4071, Field bus: length of cyclic command value data channel

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- P-0-4074, Field bus: data format
- P-0-4077, Field bus: control word
- P-0-4078, Field bus: status word
- P-0-4080, Field bus: config. list of cyclic actual value data ch.
- P-0-4081, Field bus: config. list of cyclic command value data ch.
- P-0-4082, Field bus: length of cyclic actual value data channel
- P-0-4083, Field bus: length of 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 or P-0-4068) and of the field bus status word (P-0-4078),
- the structure and content of real-time channel (P-0-4080, P-0-4081),
- the active operation mode (S-0-0032, S-0-0033, S-0-0034, S-0-0035),
- the drive states and their transitions (state machine of IndraDrive profile type or I/O mode).

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

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

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

4.4.2   Profile Type "No Profile"

Brief Description

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

When the profile is activated for the first time,

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

Master Communication

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

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

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

Fig.4-33:   Structure of the Real-Time Channel for the Profile "No Profile"

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

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

Fig.4-34:   Example of the Data in the Real-Time Channel for the Profile "No Profile"

4.4.3   I/O Mode (Positioning and Preset Velocity)

Brief Description

We distinguish the following variants of the "I/O mode" profile type:
- I/O mode positioning (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 can be activated, if required, via "P-0-4083, Field bus: length of parameter channel" (max. 8 words)

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

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→ Configuration of "P-0-4081, Field bus: config. list of cyclic command value data ch."

– **Slave → master** (drive)

→ Configuration of "P-0-4080, Field bus: Config. list of cyclic actual value data ch."

● Freely configurable field bus status word (cf. S-0-0144)

● Relationship between profile type selection and operation mode which takes effect

– In the **I/O modes** there is a determined relationship between profile type (P-0-4084) and predefined primary operation mode (S-0-0032).

– The **freely configurable mode** allows free selection of the operation modes (S-0-0032, S-0-0033, …).

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

Structure of the Real-Time Channel

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

Fig.4-35:   Structure of the Real-Time Channel for the I/O Modes

Features "I/O Mode Positioning"

Specific features of "I/O mode positioning":

● The drive is operated in the "positioning block mode, lagless, encoder 1" (see also description of the operation mode "Positioning Block Mode").

● In this operation mode, 64 programmable positioning blocks can be selected and started via 6 bits (in the 16 bit wide control word).

● The jog function can be activated in "P-0-4068, Field bus: control word IO". "Drive-controlled positioning" was set as the 1st secondary operation mode (see also description of the operation mode "Drive-Controlled Positioning").

Features "I/O Mode Preset Velocity"

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

● The drive is operated in the "velocity control" mode (see also description of the operation mode "Velocity Control").

● In this operation 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):

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DC000013v02_en.fh
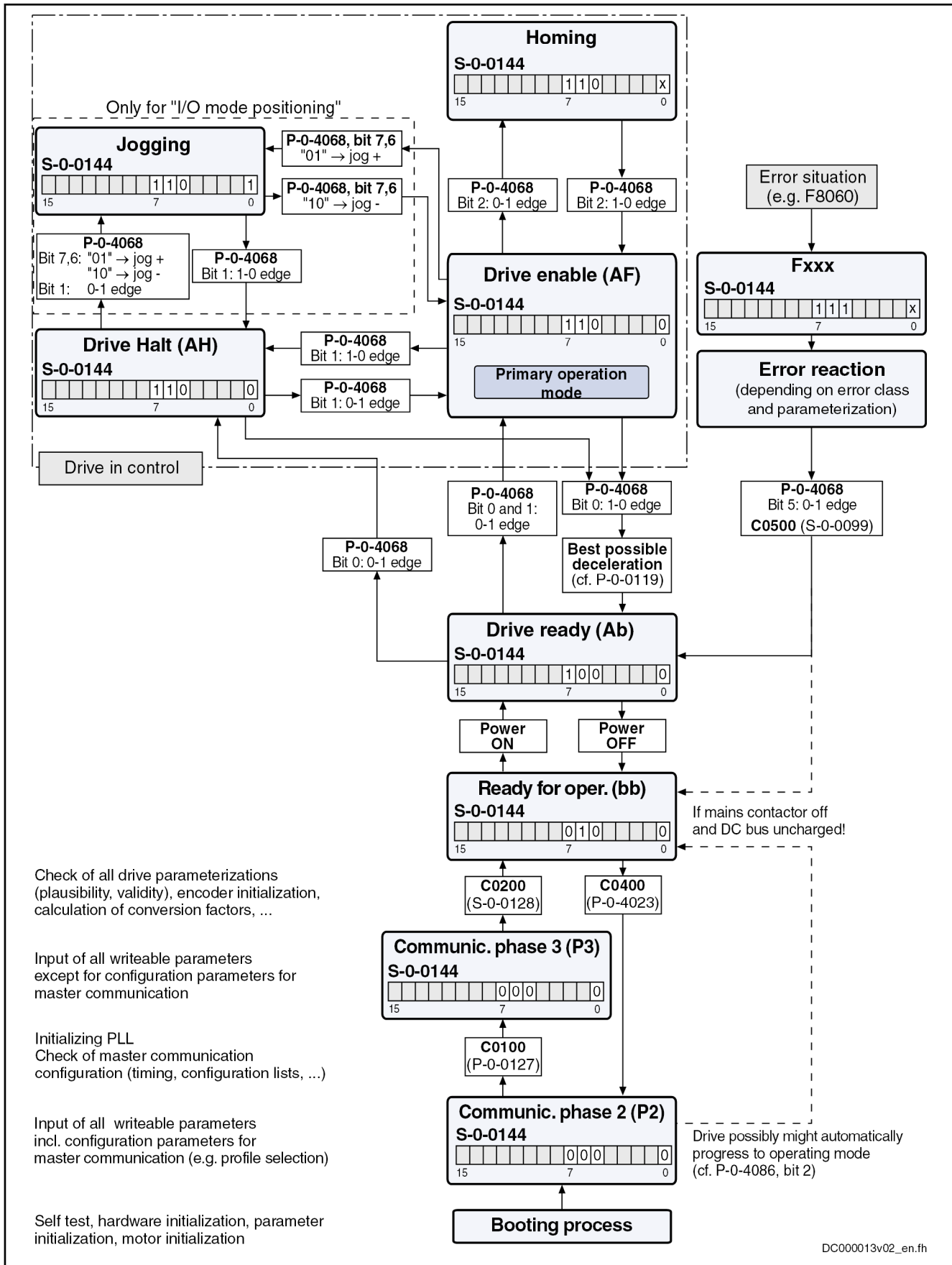
Fig.4-36:   *Device Control of Variants of I/O Mode (State Machine)*

Master Communication

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

_____

| *NOTICE* | **Automatic restart after bus failure!** |

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

_____

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

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

ℹ️ 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 sta-
  tus 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 de-
pend on the profile type:

Bit	Pin assignment	Significance
0	Active operation mode	**1:** Jogging (S-0-0437) **0:** Positioning
1	Position switch point (PSP)	**1:** To the right of PSP **0:** To the left of PSP (S-0-0060)
2	In reference	**1:** Drive has been homed (S-0-0403)
3	In motion	**0:** In motion (S-0-0331)
4	In position	**1:** Drive is in positioning window & no sequential block (P-0-4061)
5	Drive error (error flag)	**1:** Error (P-0-0115) **0:** No error
6	Readiness for operation; display "bb"	**1:** Ready for operation (P-0-0115)
7	Power switched on; display "Ab"	**1:** Power has been switched on (P-0-0115)

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Bit	Pin assignment	Significance
13...8	Positioning block acknowledgment	P-0-4051, Positioning block acknowledgment
15...14	Not assigned	

Fig.4-37:   Default Assignment of Parameter "S-0-0144, Signal Status Word" for "I/O Mode Positioning" (P-0-4084 = 0xFF82)

Bit	Pin 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.4-38:   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.

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

Notes on Parameterization/Commissioning

Features with Default Configuration   The following definitions apply to the default setting in the I/O modes:

- Fixed real-time channel length of 2 bytes. Thus the length of the real-time channel corresponds to the length of the cyclic data channel (P-0-4082 = P-0-4071 = 2)!

- "P-0-4068, Field bus: control word IO" und "S-0-0144, Signal status word" have been set to the above-mentioned default configuration.

- In the real-time channel, only "P-0-4068, Field bus: control word IO" and "S-0-0144, Signal status word" are transmitted.

Master Communication

Features/Settings with Free Configuration or Expansion

There are the following options for free configuration/expansion:

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

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

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

4.4.4   Freely Configurable Mode (IndraDrive Profile Type)

Brief Description

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

Features

- The structure (content) of the real-time data channel must be defined via the configuration parameters P-0-4080 and P-0-4081. No profile-dependent settings and checks are carried out!

- In this profile type, it is the Rexroth-specific definitions for the field bus control and status words which apply. Some bits in the parameters "P-0-4077, Field bus: control word" and "P-0-4078, Field bus: status word" can only be used in conjunction with certain operation modes.

- This profile type allows using the entire drive functionality (e.g. velocity synchronization, drive-controlled positioning, …).

- The primary operation mode and the secondary operation modes can be freely determined in the parameters S-0-0032, S-0-0033 etc.

- The operation mode "drive-controlled positioning" is set as default with the command values S-0-0282, S-0-0259 and twice S-0-0000 and the actual values S-0-0386, S-0-0040, S-0-0390 (see also below "Exemplary Configurations: Drive-Controlled Positioning").

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

Real-Time Channel

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

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

Master Communication

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

Fig.4-39:   Structure of the Real-Time Channel in the Freely Configurable Mode

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

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

Fig.4-40:   Content and Order of Data in Real-Time Channel in the Freely Configurable Mode

State Machine in Freely Configurable Mode (IndraDrive Profile Type)

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

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

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

Interaction of control and status bits (state machine):

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Jogging
P-0-4078
`1 1 0 0 x     0 0       1 0`
15   7   0

P-0-4077
Bit 6 or 7 = 1

P-0-4077
Bit 6 and 7 = 0

P-0-4077
Bit 6 or 7 = 1
Bit 13 = 1

P-0-4077
Bit 13 = 0

Drive Halt (AH)
P-0-4078
`1 1 0 0 x     1 0       1 0`
15   7   0

Homing
P-0-4078
`1 1 0 0 x       1 0       1 0`
15   7   0

P-0-4077
Bit 2 = 1

P-0-4077
Bit 2 = 0

WARNING
P-0-4078
`1 1 0 1 x     x 0       x x`
15   7   0

Error situation
(e.g. F8060)

Drive enable (AF)
P-0-4078
`1 1 0 0 x     0 0       1 0`
15   7   0

11 | Sec. oper. mode 3
10 | Sec. oper. mode 2
01 | Sec. oper. mode 1
00 | Prim. oper. mode

P-0-4077
Bit 13 = 0

P-0-4077
Bit 13 = 1

Fxxx
P-0-4078
`1 1 1 0 x     1 0       1 0`
15   7   0

Error reaction
(depending on error class
and parameterization)

Drive in control

P-0-4077
Bit 1: 0-1 edge

P-0-4077
Bit 1: 1-0 edge

P-0-4077
Bit 13 and 15:
0-1 edge

P-0-4077
Bit 15: 1-0 edge

Best possible
deceleration
(cf. P-0-0119)

P-0-4077
Bit 5: 0-1 edge
C0500 (S-0-0099)

C0401
P-0-4078
`1 1 0 0 x     x 1       1 0`
15   7   0

Drive ready (Ab)
P-0-4078
`1 0 0 0 x     1 0       1 0`
15   7   0

Power
ON

Power
OFF

P-0-4077
Bit 1: 0-1 edge
C0100 + C0200

Ready for oper. (bb)
P-0-4078
`0 1 0 0 x     1 0       1 0`
15   7   0

If mains contactor off
and DC bus uncharged!

Check of all drive parameterizations
(plausibility, validity), encoder initialization,
calculation of conversion factors, ...

C0200
(S-0-0128)

C0400
(P-0-4023)

Input of all writeable parameters
except for configuration parameters for
master communication

Communic. phase 3 (P3)
P-0-4078
`0 0 0 0 x     1 0       0 1`
15   7   0

P-0-4077
Bit 1: 1-0 edge
C0400 (P-0-4023)

Initializing PLL
Check of master communication
configuration (timing, configuration lists, ...)

C0100
(P-0-0127)

Input of all writeable parameters
incl. configuration parameters for
master communication (e.g. profile selection)

Communic. phase 2 (P2)
P-0-4078
`0 0 0 0 x     1 0       0 0`
15   7   0

Drive possibly might automatically
progress to operating mode
(cf. P-0-4086, Bit 2)

Self test, hardware initialization, parameter
initialization, motor initialization

Booting process

DC000014v01_en.fh

Fig.4-41:   Device Control in the Freely Configurable Mode (State Machine)

Master Communication

| NOTICE | Automatic restart after bus failure! |

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

Field Bus Control Word and Field Bus Status Word

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

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

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

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

See also "Device Control and State Machine"

Exemplary Configurations

General Information

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

Velocity Control

Features/Settings

- "Velocity control" must have been set as the primary operation mode in parameter S-0-0032 (see also description of the operation mode "velocity control").

- The contents of the parameter "S-0-0036, Velocity command value" are cyclically transmitted via the field bus in the command value data channel and "S-0-0040, Velocity feedback value", "S-0-0051, Position feedback value 1" and "S-0-0393, Command value mode" in the actual value data channel.

- The Rexroth-specific definitions for the field bus control and status words are applying (see also section "Freely Configurable Mode (IndraDrive Profile Type)"). Some bits in the parameters "P-0-4077, Field bus: Control word" and "P-0-4078, Field bus: Status word" are irrelevant for this configuration (or operation mode).

- The length of the cyclic data channel has been defined with:
    - P-0-4082 = 14 bytes
    - P-0-4071 = 6 bytes

Structure of the Real-Time Channel

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

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

Fig.4-42:   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.4-43:   Content and Order of Data in Real-Time Channel in Velocity Control (and Freely Configurable Mode)

Drive-Internal Interpolation

Features/Settings
- "Drive-internal interpolation, encoder 1, lagless" must have been set as the primary operation mode in parameter S-0-0032 (see also description of the operation mode "drive-internal interpolation").

- Via the field bus, the contents of parameters "S-0-0258, Target position" and "S-0-0259, Positioning velocity", as well as "S-0-0051, Position feedback value 1" and "S-0-0040, Velocity feedback value", are cyclically transmitted.

  → The configuration of P-0-4081 or P-0-4080 has to be adjusted accordingly!

- The Rexroth-specific definitions for the field bus control and status words are applying (see also section "Freely Configurable Mode (IndraDrive Profile Type)"). Some bits in the parameters "P-0-4077, Field bus: Control word" and "P-0-4078, Field bus: Status word" are irrelevant for this configuration (or operation mode).

- The length of the cyclic data channel has been defined with:
  - P-0-4082 = 14 bytes
  - P-0-4071 = 10 bytes

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

Structure of the Real-Time Channel

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

Master Communication

rameter "P-0-4080, Field bus: config. list of cyclic actual value data ch." are transmitted from drive to master.

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

Fig.4-44:   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.4-45:   Content and Order of Data in Real-Time Channel in Drive-Internal Interpolation (and Freely Configurable Mode)

Drive-Controlled Positioning

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

Structure of the Real-Time Channel

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

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

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

Fig.4-46: 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.4-47: Content and Order of Data in Real-Time Channel in Drive-Controlled Positioning (and Freely Configurable Mode)

Using the Signal Control Word and the Signal Status Word

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

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

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

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

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

Master Communication

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 value 1	i32 (2 words)
	S-0-0040, Velocity feedback value	i32 (2 words)
	S-0-0390, Diagnostic message number	u32 (2 words)
	S-0-0144, Signal status word	u16 (1 word)

Fig.4-48:   Structure of the Real-Time Channel when Using Signal Control Word and Signal Status Word (and Freely Configurable Mode)

Data di-rection	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.4-49:   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"

4.5   SERCOS Interface (SERCOS II)

4.5.1   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
- Transmission rate: Optionally 2, 4, 8 or 16 MBaud
- Automatic baud rate detection; active baud rate displayed in a parameter
- Transmitting power can be set via indication of transmission length (setting via control panel)

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- Max. quantity of configurable data in the MDT: 48 bytes
- Max. quantity 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

---

ℹ   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 value 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, Configuration list of MDT
- 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

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- 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 Telegram offset unsuitable
- 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 Sync telegram failure
- F4002 RTD telegram failure
- F4003 Invalid communication phase shutdown
- F4004 Error during phase progression
- F4005 Error during phase regression
- F4006 Phase switching without ready signal

4.5.2   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
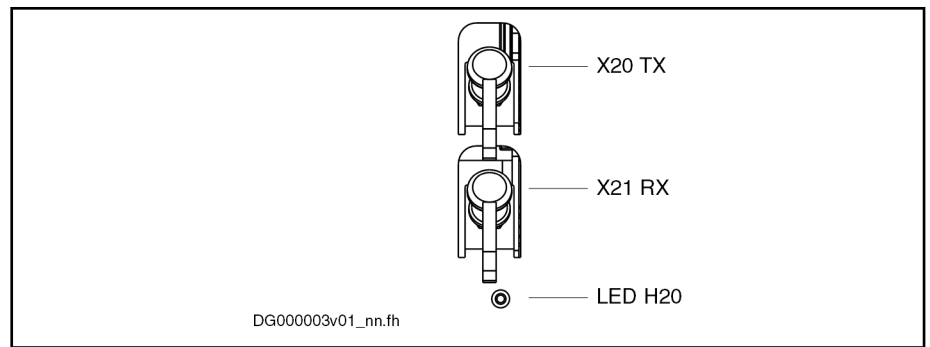
X20 TX	Optical output (transmitter)
X21 RX	Optical input (receiver)
H20	Distortion indicator LED
Fig.4-50:	*SERCOS interface*

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).

Master Communication
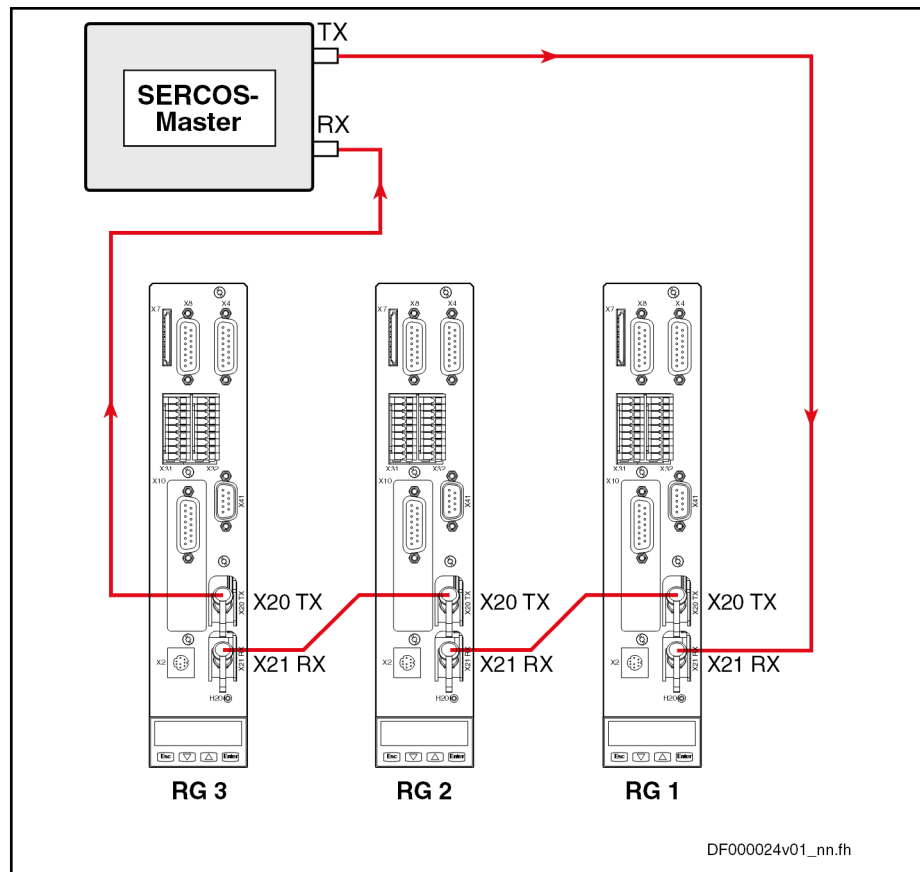
RG   Controller

Fig.4-51:   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

Due to great tolerances (transmitting power, cable, receiver), the distortion LED sometimes glows or flashes in spite of correct settings. In this case, the transmitting level must be increased or reduced.

Example: You use a cable of 35 m, the selected distance is level 3 (30 m to 45 m), but the LED keeps flashing. This is either caused by a combination of negative tolerances (input signal is distorted in negative direction) - in this case, switch the transmitter to the next higher level 4. If the cause is due to a combination of positive tolerances (input signal is distorted in positive direction), switch the transmitter to the next smaller level 2 (15 m - 30 m). As it is impossible to ascertain the degree of distortion from the outside without investing much effort, you must find out the correct setting by trial and error. If this causes the receiver's light level to be too low or too high, the receiver won't be damaged!

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".

Master Communication

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.

4.5.3   Cyclic Data Transfer

General Information

To synchronize the drives in a ring, the master synchronization telegram (MST) is transmitted 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 transmitted 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 operation 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 transmitted 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 operation 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 operation 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"

Master Communication

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 operation mode (e.g. "A0101 Velocity control").

Drive Halt

The "Drive Halt" signal is status-controlled and active when the signal = 0 V; this means that for signal =0 V the drive is in status "Drive Halt". 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 operation 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 input in the drive status word of the drive telegram. Bits 14 and 15 change from "10" (control and power section

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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 means of 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.
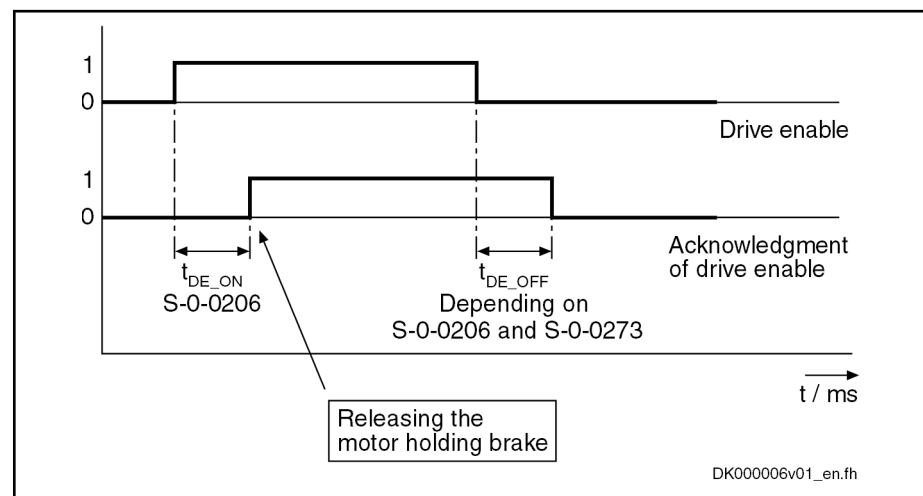
Fig.4-52:   *Acknowledging Drive Enable (DE)*

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")!

4.5.4   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.

4.5.5   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 pro-

Master Communication

grammed 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 Sync telegram failure
- F4002 RTD telegram failure
- F4003 Invalid communication phase shutdown
- F4004 Error during phase progression
- F4005 Error during phase regression
- F4006 Phase switching without ready signal

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.

4.5.6　　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 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.

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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!

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)".

4.6   PROFIBUS-DP

4.6.1   Brief Description

IndraDrive controllers with PROFIBUS interface (PB) can be operated as PROFIBUS slaves in a PROFIBUS system. Via these PROFIBUS components, it is possible to exchange real-time data with a PROFIBUS-DP master.

We distinguish the following communication channels:

- **Cyclic data channel** (PROFIBUS-DP)

  The field bus provides data containers in which useful data can be cyclically transmitted. This section is referred to as cyclic data channel. The cyclic data channel is divided as follows:

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

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

  – One (optional) **safe**, 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) which 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
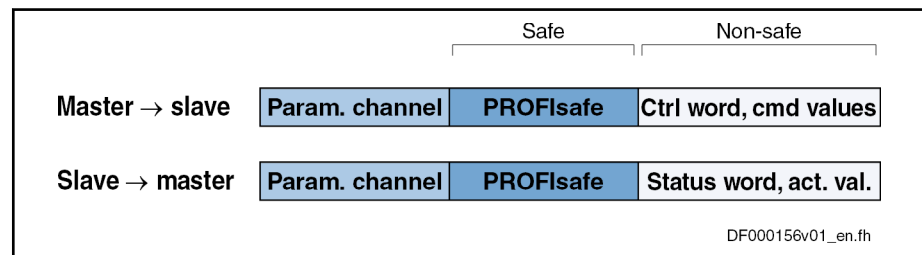
Fig.4-53:   *Overview of Cyclic Data Channel*

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> ☞ To simplify field bus communication, Rexroth makes available PLC function blocks for different programmable logic controllers (PLCs). The function blocks support the basic functionalities axis-specific process data channel and device-specific parameter channel. The principles applied can be easily used for other field bus masters.

Features   The slave PROFIBUS-DP interface with PROFIBUS-Interface (PB) master communication module has the following 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)
- Possible settings for P-0-4076: Min. 2 ms, max. 65 ms (can be adjusted in steps of 1 ms)

> ☞ Via the parameter "P-0-4076, Field bus: Process data - updating clock", you can set in which updating clock the process data are applied from the PROFIBUS interface to the drive or from the drive.

- Additional optional parameter channel in the cyclic channel with up to 16 bytes (8 words)
- Monitoring of the cyclic data exchange (watchdog function)
- LED for diagnosing the PROFIBUS interface
- Supported DPV0 services:
  - Slave_Diag (read diagnostic data)
  - Get_Cfg (read configuration data)
  - Set_Prm (transmit 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 access with DPV1-class-1 services
  - DDLM_Initiate (establishment of connection)
  - DDLM_Read (acyclic read access)
  - DDLM_Write (acyclic write access)
  - DDLM_Abort (abortion of connection)
  - DDLM_Idle (connection monitoring)
- Support of up to two DPV1 class 2 connections
- Supported field bus profiles:

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- 0x0000: "No profile selected"
- 0xFF82: I/O mode "positioning" with configurable real-time data
- 0xFF92: I/O mode "preset velocity" with configurable real-time data
- 0xFFFD: Freely configurable mode "operation mode neutral"
- 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 with the following configurable control sections, if they are equipped with the optional module "PB":

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

Axis Addressing   The axis address can be set directly via the control panel of the drive. This can be done via the so-called Easy Menu.
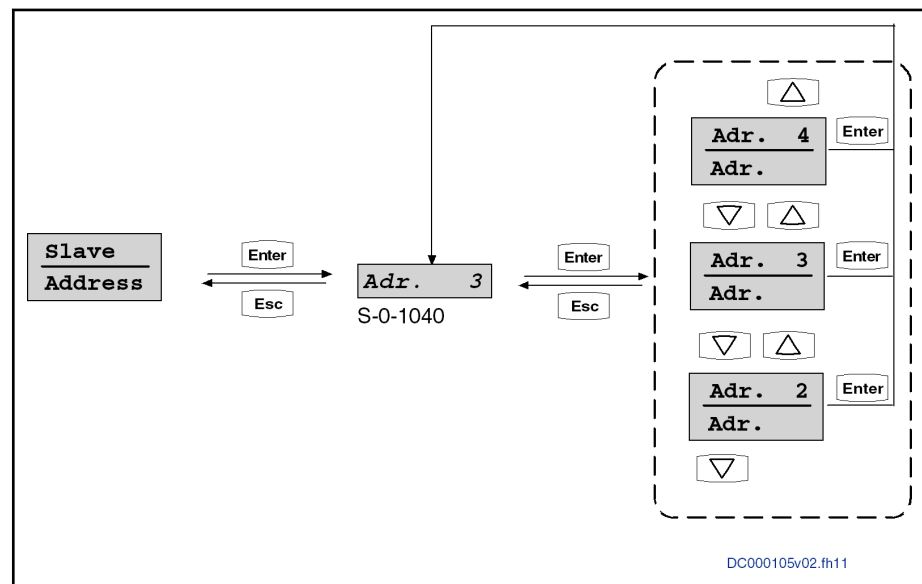
Fig.4-54:   Submenu of "Slave___" "_Address"

As an alternative, the address can be directly changed or displayed via the parameter "S-0-1040, Drive address of master communication".

The axis address is displayed at any time in the standard display on the left of the control panel.

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: diagnostic message
- P-0-4074, Field bus: data format

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- P-0-4075, Field bus: watchdog
- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: baud rate
- P-0-4083, Field bus: length of parameter channel
- P-0-4083.0.1, Master communication: Parameter channel configuration

Profile type parameters

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

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

Parameters for extended communication

We use additional parameters for extended communication.

See the following sections:

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

Pertinent Diagnostic Messages
- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable
- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- E4005 No command value input via master communication
- F4009 Bus failure
- F4012 Incorrect I/O length

4.6.2   Configuring the PROFIBUS-DP Slave

Device Data Sheet for IndraDrive

Like every other PROFIBUS slave, IndraDrive controllers must be configured in the field bus master. This requires the corresponding device data sheet (GSD) **"RX**0107.GSD"** that has to be included in the project ("*****" represents the version number of the GSD file). This GSD file, when configuring the bus master, is required for each node.

☞   The device data sheet (GSD) for IndraDrive controllers supports all hardware types and enabling of functional packages.

IndraDrive controllers assign their data to four slots (for single-axis devices), seven slots (for double-axis devices) or up to 31 slots for devices operated via CCD group (1 CCD master + 9 CCD slaves), which might possibly have to be configured. Each drive in the CCD group has an F module, one input module and one output module: A slot is used for plugging in modules.

- Slot 1: Parameter channel
- Slot 2: F module axis 0 (optional for PROFIsafe)
- Slot 3: Inputs axis 0
- Slot 4: Outputs axis 0
- Slot 5: F module axis 1 (optional for PROFIsafe, double-axis devices or devices operated at the CCD group)

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- Slot 6: Inputs axis 1 (only for double-axis devices or devices operated at the CCD group)

- Slot 7: Outputs axis 1 (only for double-axis devices or devices operated at the CCD group)

- Slot X: F-module axis X (optional for PROFIsafe, according to number of CCD drives)

- Slot Y: Inputs axis X (according to number of CCD drives)

- Slot Z: Outputs axis X (according to number of CCD drives)

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

The device data sheet also contains the IDN assigned to the IndraDrive controller by the PROFIBUS User Organization (PNO):

- **Ident. no. 107 hex**

☞   During the installation of "IndraWorks Ds/D/MLD", the device data sheet as a standard is stored in the "C:\Program Files\REXROTH \IndraWorks\DeviceDataSheets\IndraDrive\Profibus" directory.

Module 1: Parameter Channel   These modules are marked with "ParamCh" and are of the input/output module type. If no parameter channel is required, the module "ParamCh not used" has to be selected.

When IDN parameters or EIDN parameters are to be written via the parameter channel, observe the following aspects:

- IDN parameters

  To write a 2-byte IDN parameter (e.g. P-0-4006), include the "ParamCh 5 Words" module and configure it accordingly in the parameter "P-0-4083.0.1, Master communication: Parameter channel configuration".

- EIDN parameters

  To write a 4-byte EIDN parameter (e.g. P-0-4006.0.0), include the "ParamCh 6 Words" module and configure it accordingly in the parameter "P-0-4083.0.1, Master communication: Parameter channel configuration".

☞   The parameter channel length is displayed in parameter "P-0-4083, Field bus: length of parameter channel" in bytes.

          With the wrong configuration of the command values / actual values, the error "F4012 Incorrect I/O length" is displayed.

The drive automatically recognizes the configuration of the master and adjusts accordingly. Parameterization by the master is therefore always possible, even in the case of incorrect configuration of the command values/actual values. This allows parameter download from the master after a device was replaced.

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

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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.

> ☞ Even if the input data length is wrong, it is possible to communicate via the device-specific parameter channel.

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

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 has been set must correspond to the value of parameter "P-0-4071, Field bus: length of cyclic command value data channel".

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

Modules 5 to 7	The modules 5 to 7 are provided for double-axis devices or for 5 to 31 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 Safe)	The user can freely configure the cyclic data in the standard process data channel according to the process requirements.

> ☞ For the profile types "freely configurable mode" (P-0-4084 = 0xFFFE), "operating mode neutral" (P-0-4084 = 0xFFFD), "I/O mode" (P-0-4084 = 0xFF82), "I/O mode" (P-0-4084 = 0xFF92 preset velocity) or "no profile" (P-0-4084 = 0x0000), there is a default configuration that the user can change at any time.
> See also "Profile Types (with Field Bus Interfaces)"

Configuration List Cyclic Actual Value Data Channel	In parameter "P-0-4080, Field bus: config. list of cyclic actual value data ch.", the structure and 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 value data ch.", the structure of the process output data (master → slave) is mapped. This allows reading the current structure and thus the assignment in the field bus via the parameter channel.

> ☞ It is possible to configure up to 15 real-time parameters (incl. control word or status word) at the bus in each data direction (max. 48 bytes or 24 words).

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

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> ☞   Drives 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 module 5) have to be supported, too!

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

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

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

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

Standard Process Data Channel (Not Safe)   Within the cyclic channel, the parameter channel (optional) and the process data channel, in which the real-time data of the drive controller are transmitted, are arranged.

The PROFIBUS slave interface allows flexible configuration of the process data channel, the length of the process data channel thereby changes accordingly.

> ☞   The currently valid length can be seen from parameters "P-0-4082, Field bus: length of cyclic actual value data channel" and "P-0-4071, Field bus: length of cyclic command value data channel".

The process data channel (real-time data channel) can only have words or double words, but not bytes, as data types. Length, however, is specified in bytes for the sake of compatibility with other bus systems.

The length of the process data channel can range between 1…24 words or 2…48 bytes in either direction.

The length of the process data channel results from the content of the configuration lists "P-0-4080, Field bus: config. list of cyclic actual value data ch." or "P-0-4081, Field bus: config. list of cyclic command value data ch." and can be taken from the following parameters:

- P-0-4071, Field bus: length of cyclic command value data channel (master → slave)
- P-0-4082, Field bus: length of 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.

Master Communication

☞ Please note that a change in the length of the process data channel also requires a change in the master configuration. The length of the process data channel that was set must comply with the projected length in the master. If not, the error message "F4012 Incorrect I/O length" is generated.

PROFIsafe Process Data Channel (Safe)

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

4.6.3   Cyclic Communication via Process Data Channel

Communication Cycle Time

The communication cycle time results from the baud rate set in the master. This baud rate is transmitted to the slave and displayed in the parameter"P-0-4079, Field bus: baud rate".

Via the parameter "P-0-4076, Field bus: Process data - updating clock", you can set in which updating clock the data are applied from the PROFIBUS® interface to the drive and vice versa. For reasons of performance, the default setting should be maintained.

Valid values for "P-0-4076, Field bus: Process data - updating clock": Min. 2 ms, max. 65 ms (can be adjusted in steps of 1 ms)

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

Axis-Specific Process Data Channel
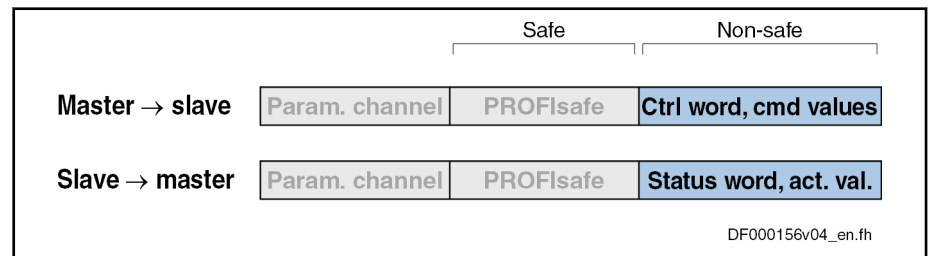
Fig.4-55:   Position of the Not Safe Process Data Channel in the Cyclic Data Channel

Processing the Cyclic Data

The internal processing of the command values and actual values is carried out synchronously with the control clock. As the communication via PROFIBUS-DP is not carried out in a synchronous way, this type of master communication is not suited for synchronous operation modes such as "position control with cyclic command value input", but only for positioning modes and the "velocity control" mode.

☞ There is no limit value check for the cyclically transmitted command values and they are stored in volatile form.

Configuring the Cyclic Data

The cyclic data must be configured in the parameter mode. The configuration of the cyclic data is described in the section "Configuring the PROFIBUS-DP Slave" (see above).

Master Communication

Safe, Axis-Specific Process Data Channel (PROFIsafe)

General Information

☞   Using the safe process data channel (PROFIsafe) with the firm-ware version MPx-08 requires the optional safety technology module "S2"!
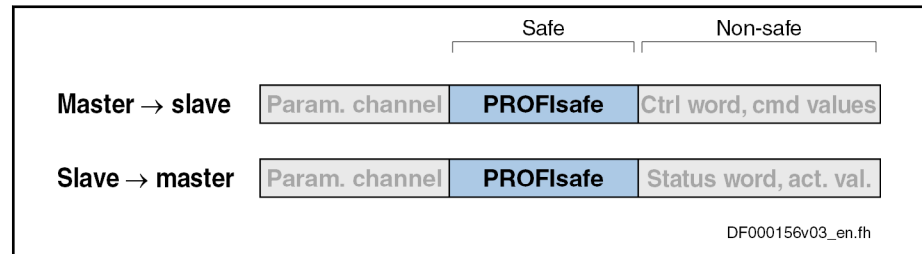
Fig.4-56:   *Position of the Safe Process Data Channel (PROFIsafe) in the Cyclic Data Channel*

☞   When the safe channel (PROFIsafe) is used, the minimum al-lowed 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 safe 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 Application Manual on integrated safety technology.

[i] See separate documentation "Rexroth IndraDrive - Integrated Safety Technology"

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

PROFIsafe Configuration

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

Configuring 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".

Configuring 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 following PROFIsafe modules (F-modules) are available for this purpose:

- **F module not used**

Master Communication

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

- **F module I/O**

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

ℹ️ See separate documentation "Rexroth IndraDrive - Integrated Safety Technology"

Parameter Channel in the Cyclic Channel (Device-Specific)
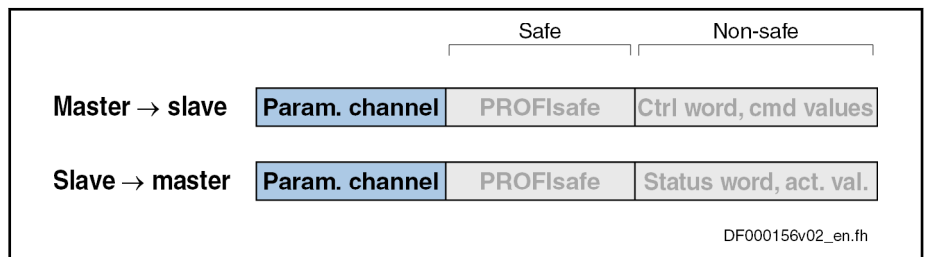
Fig.4-57:   Position of the Parameter Channel in the Cyclic Data Channel

Via the parameter channel, the drive or the drives can be parameterized via the field bus. The parameter channel is part of the cyclic data. For IndraLogic and Siemens S7, function blocks are available which implement the parameter channel protocol. This allows the user to ignore the parameter channel details. The parameter channel is described in the Technical Note "TN_40_Bosch_Rexroth PROFIBUS_PROFINET_Parameterkanal_V1.x".

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

4.6.4   Acyclic Data Exchange (DPV1)

Overview of Acyclic Communication

DP Master Class 1   An acyclic communication relationship of the "MSAC_C1" type to a DP master class 1 (MSAC_C1) is supported. The following DP services are available for this communication relationship:

- DDLM_Read (MSAC1_Read)
- DDLM_Write (MSAC1_Write)

DP Master Class 2   A maximum of two acyclic communication relationships of the "MSAC_C2" type to a DP master class 2 (MSAC_C2) are supported. The following DP services are available for this communication relationship:

- DDLM_Initiate (MSAC2_Initiate)
- DDLM_Abort (MSAC2_Abort)
- DDLM_Read (MSAC2_Read)
- DDLM_Write (MSAC2_Write)

Master Communication

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 entry
>
> "0" in parameter "P-0-4075, 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

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

Parameter for Diagnostic Field Bus Message
In parameter "P-0-4073, Field bus: diagnostic message", the status of the field bus master communication is stored in plain text. The contents of parameter P-0-4073 have the following significances:

Text	Significance
"OFFLINE"	Initialization value of the diagnostic message
"Power-On"	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.4-58:   Significances of the Entries in Parameter P-0-4073

Error Codes of PROFIBUS Communication

Parameter Channel Errors
The table below contains an overview of the possible parameter channel error messages and their significances:

Error code	Significance
0x0082	Quantity of all transmitted data is too small, i.e. less than 4 bytes
0x0083	Quantity of data still to be transmitted is greater than the internal buffer
0x0088	The length of the valid data indicated in the control word is longer than the parameter channel
0x008C	Status conflict, a new request was transmitted although there are still data to be retrieved
0x008D	Length of data still to be transmitted, which is indicated in the control word, is incorrect
0x008E	The type of EIDN/IDN access specified in the control word bit 15 does not match the type of access configured in P-0-4083.0.1

Fig.4-59:   Overview Parameter Channel Errors

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

Error code	Significance	Designation acc. to DPV1 standard
0x80 0xA0 0x00	The read request has a length of more than 10 bytes.	DPV1, access, read error
0x80 0xA1 0x00	The write request has a length of less than 11 bytes.	DPV1, access, write error
0x80 0xA9 0x00	DPV1 service not supported	DPV1, application, feature not supported
0x80 0xB0 0x00	No access to index 47.	DPV1, access, invalid index
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.4-60:   Overview DPV1 Errors

Parameter Access Errors   The table below contains an overview of the possible parameter access errors and their significances; the error values are transmitted in word format:

Error No. (hex)	Significance
0x1001	No IDN
0x1009	Invalid access to element 1
0x2001	No name
0x2004	Name cannot be changed (read only)
0x3004	Attribute cannot be changed (read only)
0x4001	No units

Master Communication

Error No. (hex)	Significance
0x4004	Unit cannot be changed (read only)
0x5001	No minimum input value
0x5004	Minimum input value cannot be changed (read only)
0x6001	No maximum input value
0x6004	Maximum input value cannot be changed (read only)
0x7002	Operation data transmission too short
0x7003	Operation data transmission too long
0x7004	Operation data cannot be changed (read only)
0x7005	Operation data is write-protected at this time (e.g. communication phase)
0x7006	Operation data is smaller than minimum input value
0x7007	Operation data is greater than maximum input value
0x7008	Invalid operation data: Configured IDN will not be supported, invalid bit number or bit combination
0x7009	Operation data write protected by a password
0x700A	Operation data is write protected, it is configured cyclically
0x700B	Invalid indirect addressing (e.g. data container, list handling)
0x700C	Operation data is write protected, due to other settings (e.g., parameter, operation mode, drive enable, drive on etc.)
0x7010	Procedure command already active
0x7011	Procedure command not interruptible
0x7012	Procedure command at this time not executable (e.g., in this phase the procedure command cannot be activated)
0x7013	Procedure command not executable (invalid or false parameters)
0x9001	Input cannot be identified as application
0x9002	Parameter type error
0x9003	Invalid data 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.4-61:   *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** (process data objects → PDO)

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

- **Acyclic data channel** (service data objects → SDO)

  The field bus provides data containers in which useful data (service data objects) can be acyclically transmitted.

☞　　　The process data are always transmitted via PDOs.

Features

- Simple configuration through use of "Predefined Connection Set" and "Minimal Boot-Up" according to DS301

- Baud rates of 20, 50, 125, 250, 500, 800 and 1000 kbit/s specified by CANopen according to DS301 are supported

- Configurable cyclic data up to 12 parameters (incl. field bus control word and field bus status word) in both data directions (max. 24 bytes or 12 words)

- Functional compatibility with EcoDrive functions through profile selection (I/O mode)

- Node monitoring (heartbeat function and node guard function)

- LED displays at the front panel of the master communication module for simple diagnosis of bus functions and most important communication relationships between drive and field bus (2 LEDs: "Run" status and "Error" status)

- All parameters of the drive can be directly read via SDO and, if permitted, can be written

- Upload/download function for all parameters of the drive possible with SDO services

- Event-controlled or synchronous transmission of process data

- CANopen Device profile DSP402 is not supported; field bus profiles according to DSP402 are partly supported (see "Profile Types (with Field Bus Interfaces)")

Hardware Requirements

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

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

- Single-axis ADVANCED (CSH01.xC)

Pertinent Parameters

Communication parameters

Specific parameters for CANopen communication:

- P-0-3610, CANopen: Heartbeat/NodeGuard Configuration

- P-0-3611, CANopen: COB-IDs

- P-0-3612, CANopen: Transmission Types

- P-0-3613, CANopen: List of the Event Parameters

Parameters for general field bus communication:

- P-0-4025, Drive address of master communication

Master Communication

- P-0-4073, Field bus: diagnostic message
- P-0-4074, Field bus: data format
- P-0-4075, Field bus: watchdog
- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: baud rate

Profile type parameters

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

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"

Pertinent Diagnostic Messages
- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable
- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- F4001Sync telegram failure
- F4002RTD telegram failure
- F4009Bus failure
- F4012Incorrect I/O length

4.7.2   Configuration CANopen Slave

EDS File

Due to the object directory, there is an individual EDS file for each firmware. These files comply with the specifications according to DSP306 and are checked according to versions V3.01, V3.02 and V4.01. Their names consist of the firmware designation and "…_Co.EDS":

- MPB08_Co.EDS
- MPH08_Co.EDS
- MPC08_Co.EDS

Setting the Node Address of the Slave

The bus address can be set within the range of 1 to 99. This range is smaller than the range allowed for CANopen, as only 2 digits can be displayed.

- Setting is either made via the display or by means of the "IndraWorks Ds/D/MLD" commissioning tool.
- The node address is stored in parameter "P-0-4025, Drive address of master communication".
- A new node address can only be set during baud rate search and in the CANopen states "Initialised" (with CAN warning present) and "Stopped". The corresponding diagnostic messages in parameter "P-0-4073, Field bus: diagnostic message" are:

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-    –   "CANopen: Auto Baudrate detection"
-    –   "CANopen: Initialised CAN-Warning"
-    –   "CANopen: Stopped"
-    –   "CANopen: Stopped CAN-Warning"

See also section " Setting the Axis Address"

Baud Rate Search/Baud Rate Input

Supported Transmission Rates

All transmission rates specified by CANopen are supported. The bit timing corresponds to DS301 (version 4.0.2) and must have been implemented accordingly in the master.

Baud rate	Max. network dimension	Description
10 kBaud	5,000 m	
20 kBaud	2,500 m	supported by baud rate search
50 kBaud	1,000 m	
125 kBaud	500 m	supported by baud rate search
250 kBaud	250 m	supported by baud rate search
500 kBaud	100 m	supported by baud rate search
800 kBaud	50 m	
1000 kBaud	25 m	supported by baud rate search

Fig.4-62:   CANopen transmission rates

Baud Rate Search

The automatic baud rate search is activated by writing the value "0" to parameter "P-0-4079, Field bus: baud rate" or by triggering the command "load defaults procedure". The search is carried out directly after switch-on. The first baud rate with which searching takes place after switching on again is the last one found. Baud rate search is signaled by both LED displays flickering. Baud rates which were found by baud rate search are displayed as negative numbers in parameter P-0-4079.

If baud rate search is not desired, it can be deactivated by writing the baud rate as a positive number to parameter P-0-4079. During operation it is possible to activate the baud rate search again or deactivate it after having switched on.

Baud Rate Input

Manual input of a different baud rate is possible during baud rate search and in the CANopen states "Initialised" (with CAN warning present) and "Stopped".

Configuring the Cyclic Data

The parameters for configuring the cyclic data (P-0-4080 and P-0-4081) contain 12 elements each of which four each have been reserved for each PDO. The data length of the configured PDOs may be 8 bytes as a maximum. "S-0-0000, Dummy parameter" as an empty parameter must be assigned to entries which are not used. If a PDO only consists of empty parameters, it is deactivated.

Master Communication

Element in P-0-4080	PDO (tx)		Element in P-0-4081	PDO (rx)
0			0	
1	PDO1 (tx)		1	PDO1 (rx)
2			2	
3			3	
4			4	
5	PDO2 (tx)		5	PDO2 (rx)
6			6	
7			7	
8			8	
9	PDO3 (tx)		9	PDO3 (rx)
10			10	
11			11	

Fig.4-63:   Configuring the Cyclic Data

4.7.3   Specifying the CANopen Interface

General Information

There are 11 bits "CAN Identifier" used for transmission.

Network Management Services

The network knows the following states:

* Initialising
* pre-operational
* operational
* stopped

A change of status is triggered by reception of an NMT telegram or a reset. The current status is transmitted in the NMT error telegram and displayed by the "Run" LED (H4) at the drive. In addition, it can be read from the parameter for the diagnostic field bus message (P-0-4073).

After having been switched on, the drive is in the "Initialising" state. After initialization has been completed, the drive transmits an NMT error telegram (boot-up telegram) and automatically goes to the "Pre-Operational" state.

Overview of Network States (Allowed Telegrams)

Telegram type	Initialising	pre-operational	operational	stopped
NMT	--	▪	▪	▪
SYNC	--	▪	▪	--
NMT_Error	▪	▪	▪	▪
EMCY	--	▪	▪	--
SDO	--	▪	▪	--
PDO	--	--	▪	--

Fig.4-64:   Network states and telegrams for CANopen

Master Communication

NMT Telegrams

The NMT telegram consists of 2 bytes. The first byte contains the command, the second byte the address. The node accepts all telegrams which either contain "0" (the command is destined for all nodes) or its own node ID in the second byte.

- Start Remote Node (command byte = 1)

  → Node is brought to "Operational" state.

- Stop Remote Node (command byte = 2)

  → Node is brought to "Stopped" state.

- Enter Pre-Operational (command byte = 128)

  → Node is brought to "Pre-Operational" state.

- Reset Node (command byte = 129)

  Reset Communication (command byte = 130)

  → Node is brought to "Initialising" state and after initialization goes to "Pre-Operational" state.

Node Monitoring

Types of Node Monitoring

Node monitoring is carried out by heartbeat telegrams or the so-called "Node-Guarding".

Heartbeat Mechanism

With the heartbeat mechanism, each node transmits an NMT error telegram in intervals which have been set. Monitoring takes place independently of the master, as the node number of the node it monitors can be set in each node.

The heartbeat mechanism used ensures the following conditions:

- The physical availability of the transmitter.
- The bus load, as transmission takes place with the lowest priority.
- The network status of the transmitter.
- The availability of the transmitter and its data (watchdog).

The heartbeat telegrams transmit a 1-byte data:

- 0 → Boot-up message
- 4 → Node is in "Stopped" state
- 5 → Node is in "Operational" state
- 127 → Node is in "Pre-Operational" state

Heartbeat Interval   The calculation of the heartbeat interval uses the number of nodes at the bus and the baud rate. As an estimated value, 1500 bit times can be provided for each node (including master). The interval is calculated according to the following relationship:

$$T = \frac{1500 \times n}{f}$$

T	interval
n	number of nodes in network (incl. master)
f	Baud rate

Fig.4-65:   *Calculating the heartbeat interval*

Master Communication

An interval should have a minimum duration of 10 ms. At least the double value should be selected as monitoring time for received heartbeat telegrams (consumer). The table below contains some combinations of node number and baud rate to determine the transmission interval.

Number of nodes	Baud rate (in kBaud)				
	20	125	250	500	1000
2	150 ms	24 ms	12 ms	10 ms	10 ms
3	225 ms	36 ms	18 ms	10 ms	10 ms
4	300 ms	48 ms	24 ms	12 ms	10 ms
5	375 ms	60 ms	30 ms	15 ms	10 ms
10	750 ms	120 ms	60 ms	30 ms	15 ms
15	1125 ms	180 ms	90 ms	45 ms	23 ms
20	1500 ms	240 ms	120 ms	60 ms	30 ms
30	2250 ms	360 ms	180 ms	90 ms	45 ms
40	3000 ms	480 ms	240 ms	120 ms	60 ms
50	3750 ms	600 ms	300 ms	150 ms	75 ms
60	4500 ms	720 ms	360 ms	180 ms	90 ms
70	5250 ms	840 ms	420 ms	210 ms	105 ms
80	6000 ms	960 ms	480 ms	240 ms	120 ms
90	6750 ms	1080 ms	540 ms	270 ms	135 ms
100	7500 ms	1200 ms	600 ms	300 ms	150 ms
127	9525 ms	1524 ms	762 ms	381 ms	191 ms

Fig.4-66:   Combinations of node number, baud rate and transmission interval

When the drive has been configured as heartbeat consumer and the transmitter is not in the "Operational" state, this is signaled by the "Error" LED (H5) flashing twice.

If after the Heartbeat Consumer Time there hasn't any NMT error telegram been received from the node to be monitored, a "Heartbeat Event" is triggered which in most cases results in the error message "F4009 Bus failure" (see Troubleshooting Guide for F4009).

Node Guarding

With the Node Guarding method, the master queries the individual nodes one after the other with an RTR request with regard to the NMT error telegram. The node replies with a Node Guard Telegram (NMT error).

The Node Guarding mechanism used ensures the following conditions:

- For the master:
    - Physical availability of the node which has been queried
    - Bus load, as transmission takes place with the lowest priority
    - Network status of the node which has been queried
    - Availability of the node which has been queried and its data (watchdog)
- For the node which has been queried:

–   Physical availability of the master

–   Bus load, as the request takes place with the lowest priority

–   Availability of the master and its data (watchdog)

The Node Guard Telegrams transmit a 1-byte data to the master with the following significance:

- 0 → Boot-up message

- 4 → Node is in "Stopped" state

- 5 → Node is in "Operational" state

- 127 → Node is in "Pre-Operational" state

Configuring the Node Monitoring

The behavior of node monitoring is configured in parameter "P-0-3610, CANopen: Heartbeat/NodeGuard Configuration". The required data are stored in this parameter as a 2-byte list containing 5 elements:

- Element 0

  → Heartbeat Producer Time (in ms); function is switched off with default value "0"

- Element 1

  → Heartbeat Consumer Time (in ms); monitoring is switched off with default value "0"

- Element 2

  → Node ID of the node to be monitored (valid values are 1 to 127); default value is "127"

- Element 3

  → Node Guard Time (in ms); function is switched off with default value "0"

- Element 4

  → Life Time Factor (valid values 1 to 255); default value is "3"

Only one of the two monitoring types may have been activated. Therefore, a check is run when writing data to the parameter P-0-3610 to find out whether either "Heartbeat" was switched off (elements 0 and 1 at "0") or "Node Guarding" was deactivated (element 3 at "0").

4.7.4   Cyclic Communication via Process Data Channel (PDO)

Characteristics of PDO Communication

The drive firmware supports 3 PDO(tx) and 3 PDO(rx) which can be freely configured:

- PDO1(tx) to PDO3(tx)

  → Data length 2 to 8 bytes; can be configured via P-0-4080

- PDO1(rx) to PDO3(rx)

  → Data length 2 to 8 bytes; can be configured via P-0-4081

List of Transmission Types

The transmission types are set in parameter "P-0-3612, CANopen: Transmission Types". The individual bits of the list parameter have the following significance:

Master Communication

Element	Designation	Valid values
0	PDO1 (tx)	0, 1, 252, 253 and 254
1	PDO1 (rx)	0, 1, 252, 253 and 254
2	PDO2 (tx)	0, 1, 252, 253 and 254
3	PDO2 (rx)	0, 1, 252, 253 and 254
4	PDO3 (tx)	0, 1, 252, 253 and 254
5	PDO3 (rx)	0, 1, 252, 253 and 254
6	--	Reserved
7	--	Reserved

Fig.4-67:   List of Transmission Types in Parameter P-0-3612

Transmission Type "254"   The transmission type corresponding to value "254" has the following characteristics:

- PDO(rx) is applied with every "command value copying cycle" on the time base of "P-0-4076, Field bus: Process data - updating clock".

- PDO(tx) is updated with every "actual value copying cycle" on the time base of "P-0-4076, Field bus: Process data - updating clock"; current data can be queried by means of RTR.

- PDO(tx) is transmitted in the following cases:

  – Data of an event parameter was changed, see "P-0-3613, CANopen: List of the Event Parameters"

  - or -

  – Fourfold heartbeat or node guard time has passed since last transmission (heartbeat or node guard time must have been set greater than zero)

  - or -

  – The application-related event was switched from "ChangeOfState" to "cyclic" ("P-0-4088, Master communication: Drive configuration"). In the case of a cyclic event, the corresponding PDOtx are transmitted in the clock of "P-0-4076, Field bus: Process data - updating clock", independent of any change in the data.

Transmission Type "253"   The transmission type corresponding to value "253" has the following characteristics:

- PDO(rx) is applied with every "command value copying cycle" on the time base of "P-0-4076, Field bus: Process data - updating clock"

- PDO(tx) is updated with every "actual value copying cycle" on the time base of "P-0-4076, Field bus: Process data - updating clock"

- PDO(tx) is transmitted as soon as data are queried by means of RTR

Transmission Type "252"   The transmission type corresponding to value "252" has the following characteristics:

- See transmission type "253"

- **Additionally**, SYNC telegram tries to synchronize internal clock of the drive controller

Transmission Type "1"   The transmission type corresponding to value "1" has the following characteristics:

- SYNC telegram tries to synchronize internal clock of the drive controller; in the case of double telegram failure, error message "F4001 Sync telegram failure" is generated

- PDO(rx) is applied with every "command value copying cycle" (is in last position loop clock before SYNC telegram) on the time base of "P-0-4076, Field bus: Process data - updating clock"

- PDO(rx) reception is monitored

   → In the case of one-time failure, new command values are calculated from the previous values; in the case of double failure, the error message "F4002 RTD telegram failure" is generated.

- PDO(tx) is updated with every "actual value copying cycle" (is in first position loop clock after SYNC telegram) on the time base of "P-0-4076, Field bus: Process data - updating clock"

- PDO(tx) is transmitted in interval of field bus cycle time; transmission starting time is directly after update of data

- Only PDO1 is supported

Transmission Type "0"   The transmission type corresponding to value "0" has the following characteristics:

- See transmission type "1" but PDO(rx) reception is **not monitored**

☞   With IndraDrive devices, the last position loop clock is considered as blocking time in which it is not allowed to transmit any synchronous process data object (PDO).

Minimum Supported Cycle Time (Bus Cycle Time)

Depending on the position loop clock, the IndraDrive firmware supports the following minimum cycle times:

Position loop clock (in ms)	Min. bus cycle time (in ms)
0,125	1
0,250	1
0,500	2
1	4

Fig.4-68:   Bus Cycle Time Depending on Position Loop Clock

List of the Event Parameters

All parameters of the drive which are suited for event-controlled transmission are listed in parameter "P-0-3613, CANopen: List of the Event Parameters". If one of these parameters has been configured as actual value, the corresponding PDO is immediately transmitted when the data is changed. The minimum possible interval between two telegrams is determined with the "P-0-4076, Field bus: Process data - updating clock".

List of COB-IDs

The COB-IDs used (the CAN identifiers used by these telegrams) are stored in parameter "P-0-3611, CANopen: COB-IDs". When the most significant bit (inactivity bit) has been set, the telegram is deactivated. This bit is set depending on the PDOs required for cyclic communication.

Element of parameter	PDO	Standard value
0	PDO1 (tx)	0x180 + node ID
1	PDO1 (rx)	0x200 + node ID

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Element of parameter	PDO	Standard value
2	PDO2 (tx)	0x280 + node ID
3	PDO2 (rx)	0x300 + node ID
4	PDO3 (tx)	0x380 + node ID
5	PDO3 (rx)	0x400 + node ID
6	--	Reserved
7	--	Reserved
8	EMCY	0x080 + node ID
9	SYNC	0x080 (rx) or 40000080 (tx)

Fig.4-69:   Assignment of Elements of Parameter P-0-3611

The drive can work both as SYNC consumer (rx) and as SYNC producer (tx).

SYNC Consumer   As soon as a synchronous transmission type has been selected and SYNC-COB-ID is at "0x80" (rx), the drive during the transition "PM → OM" switches to synchronous operation and tries to synchronize to a SYNC telegram. As soon as this has happened, the drive switches to operating status "bb".

If a different IndraDrive device is used as SYNC producer in the network, the bus runtime of the SYNC telegram can be corrected with a PLL offset. This PLL offset is activated via bit 8 of parameter "P-0-4088, Master communication: Drive configuration".

SYNC Producer   If the SYNC-COB-ID is at "0x40000080" (tx) and a synchronous transmission type has been selected, the drive during the transition "PM → OM" switches to synchronous operation and transmits a SYNC telegram to synchronize the other bus nodes to itself. As the drive itself is a SYNC producer, it immediately switches to the operating status "bb".

☞   In the network, only one node may have been configured as "SYNC producer".

4.7.5   Acyclic Parameter Access (SDO)

All parameters of the drive can be reached by means of SDO access. The following COB-IDs are assigned in a fixed way (standard conform):

- SDO(tx) → 0x580 + Node-ID
- SDO(rx) → 0x600 + Node-ID

The following SDO services are supported:

- **SDO Download**

  → To write a maximum of 4 bytes of data to the drive

- **Initiate SDO Download**

  → To write more than 4 bytes of data to the drive (with "Initiate" the length of the data is transmitted)

- **Download SDO Segment**

  → To transmit a fragment with data to the drive

- **SDO Upload**

  → To transmit a maximum of 4 bytes of data from drive to master

- **Initiate SDO Upload**

  → To transmit more than 4 bytes of data from drive to master (drive informs master of length of response data)

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- **Upload SDO Segment**

    → To transmit a fragment with data from drive to master

- **Abort SDO Transfer**

    → To report errors and abort SDO accesses

4.7.6   CANopen Objects

Communication Objects (0x1000 to 0x1FFF)

The communication objects are described in the CANopen standard DS301. Within the CANopen communication, these objects have one of the following functions:

- Access to Drive Parameters
- Constants
- Read-only objects

The table below contains an overview of the **objects specified** for CANopen communication:

Index	Subindex/ SubNumber	Description	Parameters
0x1000	0x00	ParameterName = Device Type ObjectType = 0x7 DataType = 0x7 DefaultValue = 0x00000192 AccessType = ro	0x00FF0192
0x1001	0x00	ParameterName = Error Register ObjectType = 0x7 DataType = 0x5 AccessType = ro	
0x1018	5	ParameterName = Identity Object ObjectType = 0x9	
	0x00	ParameterName = Number Of Entries DataType = 0x5 DefaultValue = 4 AccessType = ro	
	0x01	ParameterName = Vendor ID DataType = 0x7 DefaultValue = 0x24 AccessType = ro	36
	0x02	ParameterName = Product Code DataType = 0x7 DefaultValue = 0x4 AccessType = ro	4

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Index	Subindex/ SubNumber	Description	Parameters
	0x03	ParameterName = Revision Number DataType = 0x7 AccessType = ro	P-0-1509: El- ement 5 (release)
	0x04	ParameterName = Serial Number DataType = 0x7 AccessType = ro	P-0-1509: El- ement 3 (serial no.)

Fig.4-70:   Specified CANopen Objects

☞   Other communication objects of the CANopen interface are listed in the annex of the separate documentation "Rexroth IndraDrive, Parameter Description" and the corresponding EDS file.

Manufacturer-Specific Objects (0x2000 to 0x3FFF)

Manufacturer-Specific Object   All parameters of the drive can be reached via the manufacturer-specific objects. The S-parameters are addressed via the objects 0x2000 to 0x2FFF, the P-parameters via the objects 0x3000 to 0x3FFF. The manufacturer-specific objects have the following structure:

Subindex	Description
0	Number of parameter sets (1 or 8)
1	Operating data block 0
2	Operating data block 1 (if available)
3	Operating data block 2 (if available)
4	Operating data block 3 (if available)
5	Operating data block 4 (if available)
6	Operating data block 5 (if available)
7	Operating data block 6 (if available)
8	Operating data block 7 (if available)
10	Index of list pointer
11	List element to which element 10 points (only for list parameter)
12...18	List element to which element 10 points (if 8 parameter sets available); only for list parameter
21	Name of parameter
22…28	Name of parameter (if 8 parameter sets available)
31	Attribute of parameter
32…38	Attribute of parameter (if 8 parameter sets available)
41	Unit of parameter
42…48	Unit of parameter (if 8 parameter sets available)
51	Minimum value of parameter
52…58	Minimum value of parameter (if 8 parameter sets available)

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Subindex	Description
61	Maximum value of parameter
62…68	Maximum value of parameter (if 8 parameter sets available)
71	Maximum length of list parameter
72…78	Maximum length of list parameter (if 8 parameter sets available)
81	Actual length of list parameter
82…88	Actual length of list parameter (if 8 parameter sets available)

Fig.4-71:   Structure of Manufacturer-Specific Objects

List Access   The complete list of a list parameter can be read or written by accessing the operating data of the parameter.

To access individual list elements, it is possible to set a list index (subindex 10) and access the respective list element of the list index via subindex 11 (to subindex 18). With each access via subindex 11 (to subindex 18), the list index is incremented by one element. This allows processing a continuous part of a list in the case of repeated access to subindex 11 (to subindex 18).

With one of the following actions, the list index is reset to the first element:

- Change of parameter set
- Change of parameter
- Abortion of connection

For each list element access which does not start from the first element, it is therefore necessary to set the list index.

If the length of the list has to be changed, this can be corrected by changing the actual length of the list parameter (subindex 81…88).

The maximum list length can be read via the subindices 71…78.

With one of the following actions, the parameter value is stored:

- Writing to last element
- Change to a different parameter
- Change of parameter set
- Reading the same parameter
- Abortion of connection

The changes are discarded when the control voltage fails.

4.7.7   Notes on Commissioning

Commissioning the CANopen interface requires the following individual steps:

1. Before switching drive on, set switch above CAN connector to "CAN". After that you can switch drive on.

2. To set address (see also section "Setting the Axis Address"), it is advantageous not yet to connect CAN connector to drive controller. In this case, drive always is in 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)").

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5. If node monitoring is desired, it should be configured (see "Node Monitoring" above).

6. Transmit a "Start Remote Node" telegram (see "NMT Telegrams" above) for drive or for all nodes. After that, cyclic data are exchanged by PDOs.

4.7.8 Diagnostic Messages and Monitoring Functions

Diagnostic LED

The diagnostic LED displays are controlled according to standard DS303-3 V1.2. There are two LEDs at the front of the optional module CO; with master communication "CANopen" their displays have the significances described below.

LED Display "Run" (H4, Green)   Behavior of "Run" LED (H4; green) according to DS303-3:

Behavior of LED "H4"	Status	Significance
LED flickers	Auto-baudrate	Drive searches baud rate.
LED flashes	pre-operational	Drive is in CANopen status "Pre-Operational".
LED flashes shortly	stopped	Drive is in CANopen status "Stopped"
LED permanently lit	operational	Drive is in CANopen status "Operational".

Fig.4-72:   Behavior and Significance of "Run" LED (H4)

LED Display "Error" H5 (H5, Red)   Behavior of "Error" LED (H5; red) according to DS303-3:

Behavior of LED "H5"	Status	Significance
LED off	No error	CANopen interface works without error.
LED flickers	Auto-baudrate	Drive searches baud rate.
LED flashes once	Warning	CAN controller detected many errors during transmission or reception of telegrams.
LED flashes twice	Node Monitoring	Master no longer transmits heartbeat telegram (or no longer transmits NodeGuard request) or is not in status "Operational" while drive is in "Operational".
LED permanently lit	Bus-Off	CAN controller detected too many errors during transmission or reception of telegrams and has switched off.

Fig.4-73:   Behavior and Significance of "Error"-LED (H5)

CANopen - Diagnostic Messages

Depending on the CANopen status and the transmission errors on the CAN bus, a diagnostic message is generated which can be read via parameter "P-0-4073, Field bus: diagnostic message".

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Diagnostic message	Significance
CANopen: Offline	CANopen task is initialized.
CANopen: Auto Baudrate Detection	Drive searches baud rate (see "Baud Rate Search/Baud Rate Input").
CANopen: Initialised	Initialization was run after switch-on or after a reset, a boot-up telegram is to be transmitted.
CANopen: Initialised CAN-Warning	In status "Initialized" too many errors were detected on CAN bus, CAN interface is in status "Warning". This status mostly means that boot-up telegram could not be transmitted. Possible causes: Drive (currently) is only node at bus or there is node with different baud rate at bus.
CANopen: pre-operational	Boot-up telegram was sent, drive now is in status "Pre-Operational". Parameters can be read and written by means of SDO.
CANopen: Pre-Operational CAN-Warning	In status "Pre-Operational", too many errors were detected on CAN bus, CAN interface is in status "Warning".
CANopen: operational	Drive exchanges cyclic data (see "List of Transmission Types").
CANopen: Operational (only producer)	By received heartbeat telegram, master detected that heartbeat transmitter does not send any PDO due to network status.
CANopen: Operational CAN-Warning	In status "Operational", too many errors were detected on CAN bus, CAN interface is in status "Warning".
CANopen: stopped	Drive is in status "Stopped". In this status, drive only receives NMT commands. It is now possible to change basic communication parameters, such as baud rate or address.
CANopen: Stopped CAN-Warning	In status "Stopped", too many errors were detected on CAN bus, CAN interface is in status "Warning".
CANopen: BUS-OFF	CAN interface detected too many transmission errors and received incorrect telegrams. Possible causes are, among other things, disturbances on bus cable, short circuits, interruptions of bus cable or nodes with different baud rates at bus.
CANopen: BUS-OFF (RxCounter = 0)	CAN interface detected too many transmission errors. Most likely there wasn't any telegram received or received telegrams were not error-free.

Fig.4-74:   Overview of Diagnostic Messages for CANopen Communication

Emergency Object

When an error occurs or is cleared, an EMCY telegram is transmitted. The EMCY telegram transports 8-byte data.

0	1	2	3	4	5	6	7
0xFF00		0x81	P-0-0009		S-0-0390 (three least significant bytes)		

Fig.4-75:   Error Telegram

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0	1	2	3	4	5	6	7
0x0000		0x00	P-0-0009		S-0-0390 (three least significant bytes)		

Fig.4-76:   Error-Cleared Telegram

IndraDrive - Diagnostic Error Messages

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

- F4001 Sync telegram failure

  → In two successive cycles, there hasn't any SYNC telegram been received.

- F4002 RTD telegram failure

  → In two successive cycles, there hasn't any cyclic PDO telegram been received.

- F4009 Bus failure

  → Within the "Heartbeat Consumer Time" there was not heartbeat telegram received.

  - or -

  → Within the "Life-Time-Counter"-fold "Node-Guarding-Time" there was no Node Guarding request received.

  Note: With the corresponding setting in parameter "P-0-4088, Master communication: Drive configuration" (bits 1 and 2), this error message can be replaced by the warning "E4005 No command value input via master communication" (see also "Emergency Mode (When Master Communication has Failed").

- F4012 Incorrect I/O Length

  → A PDO telegram was received which had a different length than the configured length.

4.8   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

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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: Process data - updating clock
- P-0-4079, Field bus: baud rate

Profile type parameters

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

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

Parameters for extended communication

We use additional parameters for extended communication.

See the following sections:

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

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Pertinent Diagnostic Messages
- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable
- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- 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 the status "BAUD SEARCH". 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 Ds/D/MLD".

☞ 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), "DeviceNet 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." und "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.4-77:   *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**

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- 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.4-78:   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.4-79:   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".

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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 quantity of data of the parameter (attribute 8). The real size is stored in the actual quantity of data of the parameter (attribute 9) and can be modified unless the list is write-protected. All data refer to the parameter format. The pointer to the data (attribute 10) determines which data in the list is processed. If 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

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- 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
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.4-80:   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 section "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)").

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> ☞ The communication parameters "P-0-4025, Drive address of 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"
LED flashes red	Device "Major Recoverable Fault"
LED permanently lit red	Device "Major Unrecoverable Fault"

Fig.4-81:   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.4-82:   Behavior and Significance of Network Status LED

DeviceNet - Diagnostic Messages

The parameter "P-0-4073, Field bus: diagnostic message" displays the current status of the DeviceNet master communication:

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.

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Diagnostic message	Significance
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.4-83:   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.4-84:   Concrete 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." was 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. The active master communication parallel interface is displayed in parameter "P-0-4089.0.1, Master communication: Protocol" = 15.

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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 for signal status word
- S-0-0027, Configuration list for 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 signal control word
- S-0-0437, Positioning status
- 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
- P-0-4089.0.1, Master communication: Protocol

Pertinent Diagnostic Messages

- F2044 External power supply X15 error

Deactivation   In the condition as supplied, the "master communication parallel interface" has always been activated. The active "master communication parallel interface" is displayed in "P-0-4089.0.1, Master communication: Protocol" = 15. The active master communication requires the 24 V control voltage to have been connected; otherwise, the error "F2044 External power supply X15 error" is signaled. If the control section is to be used without using the parallel interface, the "master communication parallel interface" can be deactivated with P-0-4089.0.1 = 2. When the "master communication parallel interface" has been deactivated, F2044 is no longer signaled and the parameters "S-0-0144, Signal status word" and "S-0-0145, Signal control word" are no longer assigned to the parallel interface, but freely available via the communication interfaces.

4.9.2   Functional Description

Control

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"

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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 the operating mode (phase 4).
- Power must have been switched on and the DC bus voltage must be above the defined minimum threshold.

  The drive displays this status on the control panel with "Ab". The diagnostic drive message in parameter "S-0-0095, Diagnostic message" is "A0012Control and power sections ready for operation".

- The signal "Ready" in parameter "P-0-0115, Device control: status word" must have been 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; this means that for signal =0 V the drive is in status "Drive HALT"

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.

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

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

☞   The digital inputs of the parallel interface are mapped to the bits 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

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Bit number in signal control word	Digital input of the parallel interface
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.4-85:   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 section "I/O Extensions".

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

☞   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
5	X15, pin 31
6	X15, pin 13
7	X15, pin 32
8	X15, pin 33
9	X15, pin 15
10	X15, pin 34

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Bit number in signal status word	Digital output of the parallel interface
11	X15, pin 16
12	X15, pin 17
13	X15, pin 36
14	X15, pin 18
15	X15, pin 37

Fig.4-86:   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 section "I/O Extensions".

4.9.3   Notes on Commissioning/Parameterization

Positioning Block Mode With Parallel Interface

See also operation mode "Positioning Block Mode"

☞ With the device configuration "parallel interface " (PL), the signal control word and the signal status word are configured appropriately when the command "Load defaults procedure (factory settings)" is executed.

Positioning Block Selection, Start Signal   With a positive edge (0 → 1) at the strobe input (bit 0 of "P-0-4060, Positioning block 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 Select 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" (bits 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

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Bit number in signal control word	Configured parameter	Function/significance
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.4-87:   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	Device control status "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	Device control status "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
14	P-0-4051, bit 6	Positioning block acknowledgment
15	P-0-4051, bit 7	Positioning block acknowledgment

Fig.4-88:   Default Configuration for Positioning Block Mode via Digital Outputs

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Change of Operating Mode via Parallel Interface

To change the operation 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 operation mode selection (primary operation mode and secondary operation 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:

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

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.4-89:   Example of Configuration for Main Spindle Drive via Digital Inputs

The following messages are relevant for main spindle drives:

- Speed reached ("S-0-0330, Status "n_feedback = n_command"")
- Spindle has stopped ("S-0-0331, Status "n_feedback = 0"")
- Speed value has fallen below threshold ("S-0-0332, Status "n_feedback < nx"")
- In target position during spindle positioning ("S-0-0336, Status "In position"")
- Torque limit value reached ("S-0-0334, Status "T >= Tlimit"")
- Torque threshold exceeded ("S-0-0333, Status "T >= Tx"")
- Speed value exceeded ("S-0-0335, Status "n_command > n_limit"")
- Power threshold exceeded ("S-0-0337, Status "P >= Px"")

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ℹ️ 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	Device control status "Ready"
1	S-0-0330, bit 0	n_feedback = 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	n_feedback < nx
5	P-0-0115, bit 2	Device control status "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.4-90:   *Exemplary 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

With the parallel interface activated, 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

Overview   Apart from the digital master communication interfaces (SERCOS, PROFIBUS, …), the drive controllers of the IndraDrive range provide an interface for analog master communication (analog interface). This allows assigning an analog command value to a drive parameter (e.g. "S-0-0036, Velocity command value").

In conjunction with encoder emulation (SSI or incremental encoder), the position control loop can be closed in a higher-level control unit. The drive pro-

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vides 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.
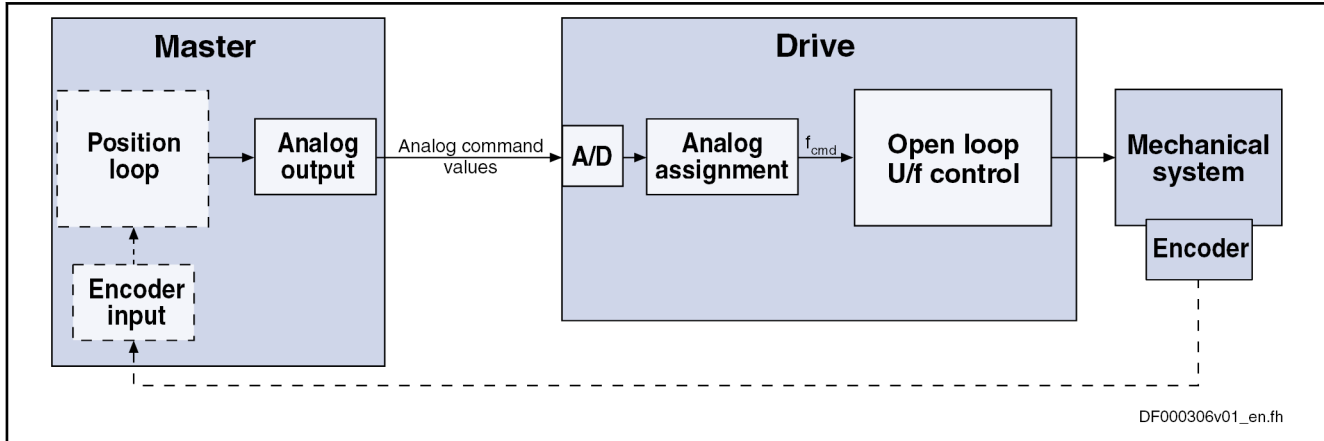
Fig.4-91:   Open-Loop Operation with Analog Interface (with Optional Position Feedback to Open-Loop Control)
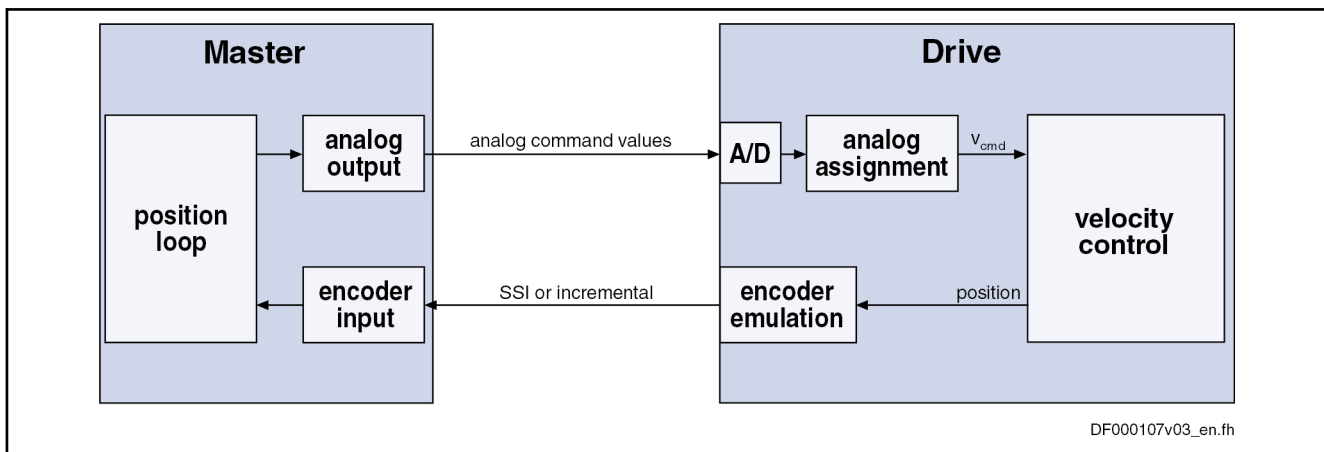
Fig.4-92:   Closed-Loop Operation with Analog Interface (with Analog Command Value Input and SSI Emulation)

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

Hardware Requirements

Master communication with analog interface is possible via the following control sections or control section designs:

- Analog command value input **for open-loop operation** (also for closed-loop operation):
    - Single-axis BASIC for open-loop operation (CSB01.1N-FC)
    - Single-axis BASIC ANALOG (CSB01.1N-AN)
    - Single-axis ADVANCED (CSH01.xC)
    - Double-axis BASIC UNIVERSAL (CDB01.1C)

    In addition, the following (configurable) control sections are possible, when they are equipped with the optional module for analog inputs/outputs (MA1):
    - Single-axis BASIC UNIVERSAL (CSB01.1C)
- Analog command value input **for closed-loop operation** with position feedback via encoder emulation:
    - Single-axis BASIC ANALOG (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):

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–   Single-axis ADVANCED (CSH01.xC)

–   Double-axis BASIC UNIVERSAL (CDB01.1C)

☞   With double-axis devices the function "analog interface" is availa-
ble once per axis.

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, inputs
- 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 adjustment
- P-0-0220, C2800 Analog input adjustment 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, Adjustment values of control section
- P-0-3904, Adjustment values analog I/O interface 3-4

Encoder emulation:

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- 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.

ℹ️ 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.

ℹ️ See also "Overview of Functions and Interfaces" in the documentation "Control Sections for Drive Controllers; Project Planning Manual"

Drive Enable
The activation of the drive requires a positive edge of the "drive enable" signal (connector pin assignment see corresponding section in the documentation "Control Sections for Drive Controllers; Project Planning Manual").

☞ The "drive enable" signal is mapped to the parameters "P-0-4028, Device control word" and "P-0-0116, Device control: control word".

See also "Device Control and State Machines"

The enable signal is accepted, i.e. the drive switches from its de-energized 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 the operating mode (phase 4).
- Power must have been switched on and the DC bus voltage must be above the defined minimum threshold.

  The drive displays this status on the control panel with "Ab". The diagnostic drive message in parameter "S-0-0095, Diagnostic message" is "A0012Control 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),

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- the display of the control panel changes to "AF" and

- the diagnostic drive message depends on the active operation mode (see description of the respective diagnostic message in the separate documentation "Troubleshooting Guide (description of diagnostic messages)")

☞   The "Drive HALT" signal is status-controlled and active when the signal = 0 V; this means that for signal =0 V the drive is in status "Drive HALT".

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

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

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"

Master Communication

☞   If the higher-level master and the drive have not been synchronized, beat effects can occur during sampling due to the different clock 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, Status "n_feedback = n_command"")
- Spindle has stopped ("S-0-0331, Status "n_feedback = 0"")
- Speed value has fallen below threshold ("S-0-0332, Status "n_feedback < nx"")
- In target position during spindle positioning ("S-0-0336, Status "In position"")
- Torque limit value reached ("S-0-0334, Status "T >= Tlimit"")
- Torque threshold exceeded ("S-0-0333, Status "T >= Tx"")
- Speed value exceeded ("S-0-0335, Status "n_command > n_limit"")
- Power threshold exceeded ("S-0-0337, Status "P >= Px"")

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

Master Communication

Bit in signal status word	Configured pa-rameter	Configured bit in parameter	Function/significance
1	S-0-0330	0	n_feedback = n_command
2	S-0-0331	0	n_feedback = 0
3	S-0-0332	0	n_feedback < 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.4-93:   Exemplary Configuration for Main Spindle Messages via Digital Out-puts

Command   The following command is relevant for main spindle drives:

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

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

Fig.4-94:   Exemplary 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 pa-rameter P-0-0115 provides information on the current status of the drive.

ℹ️ See Parameter Description "P-0-0115, Device control: status word"

Status of Digital Inputs/Outputs and Analog Inputs

All digital and analog input values can already be read via parameters before they are assigned to the internal drive parameters. The following applies:

Master Communication

- 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"

4.11   MultiEthernet

4.11.1   Brief Description, Basic Function

General Information

Operating IndraDrive controllers with a MultiEthernet-Interface is possible. This allows operation of the following master communications:
- SERCOS III
- EtherCAT®
- PROFINET®
- EtherNet/IP™

The protocol is selected or deactivated via "P-0-4089.0.1, Master communication: Protocol". The change will only take effect after the device has been restarted.

Engineering via master communication (TCP/IP communication) can also be made via the MultiEthernet interface. This function is maintained, even if the master communication is deactivated.

Features
- Protocol selection via control panel or "P-0-4089.0.1, Master communication: Protocol"
- SERCOS III, EtherCAT®, PROFINET®, EtherNet/IP™ protocols are supported
- IP engineering (TCP/IP communication) is supported, depending on the protocol
- Master communication engineering is supported depending on the protocol

Hardware Requirements   The description used for the MultiEthernet interface in the type codes is ET.
- Single-axis ADVANCED (CSH01.xC)
- Single-axis BASIC UNIVERSAL (CSB01.1C)
- Double-axis BASIC UNIVERSAL (CDB01.xC)

Note on Parameter Access   For control units that are not able to access 4-byte EIDN parameters, the following mechanisms are available:

Master Communication

- 4-byte EIDNs available in the drive with SERCOS element and SERCOS instance = 0, can be accessed as 2-byte IDNs. Example: Parameter P-0-4006.0.0 via P-0-4006

- The 4-byte EIDNs below with SERCOS element or SERCOS instance unequal 0, are mapped to the assigned 2-byte IDN parameters.

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

Fig.4-95:   Parameters for Configuring the Master Communication

> Therefore, all parameters can be accessed via 2-byte IDN with the above-mentioned mechanisms. The only exception are the CCD configuration parameters.

Pertinent Diagnostic Messages
- C0299 Configuration changed. Restart

Notes on Commissioning

Protocol Selection

Protocol Selection   The protocol is selected via parameter P-0-4089.0.1. The setting is either made in a menu-controlled way via the "display" or via the "IndraWorks" commissioning tool.
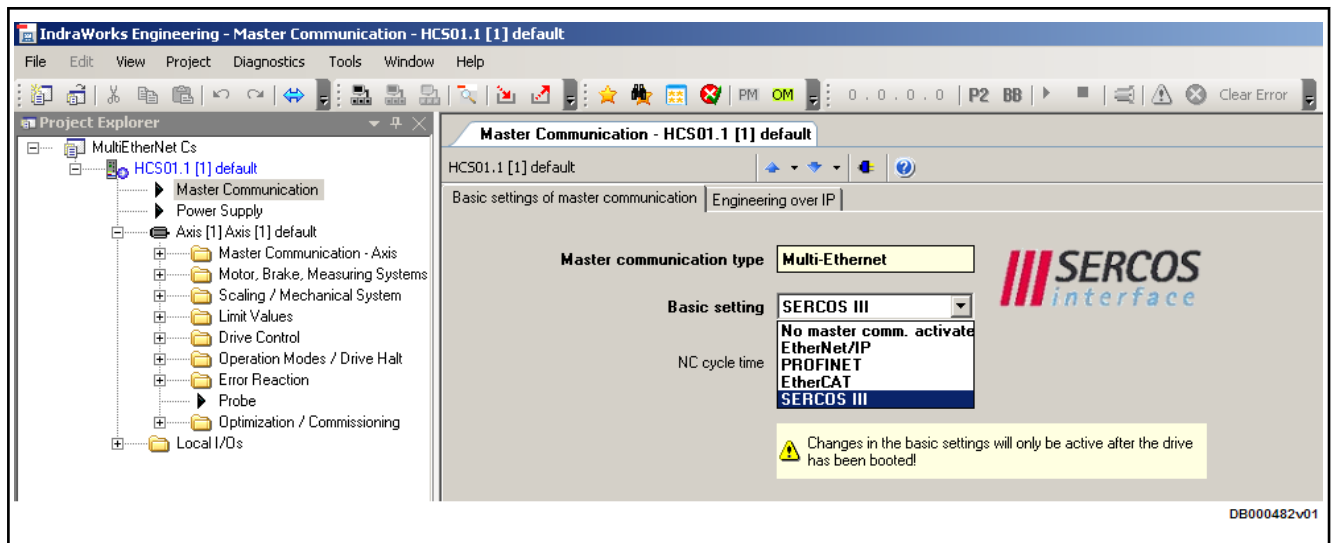
Fig.4-96:   MultiEthernet, Protocol Selection

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

4.11.2   SERCOS III

Brief Description

Topology

Master Communication
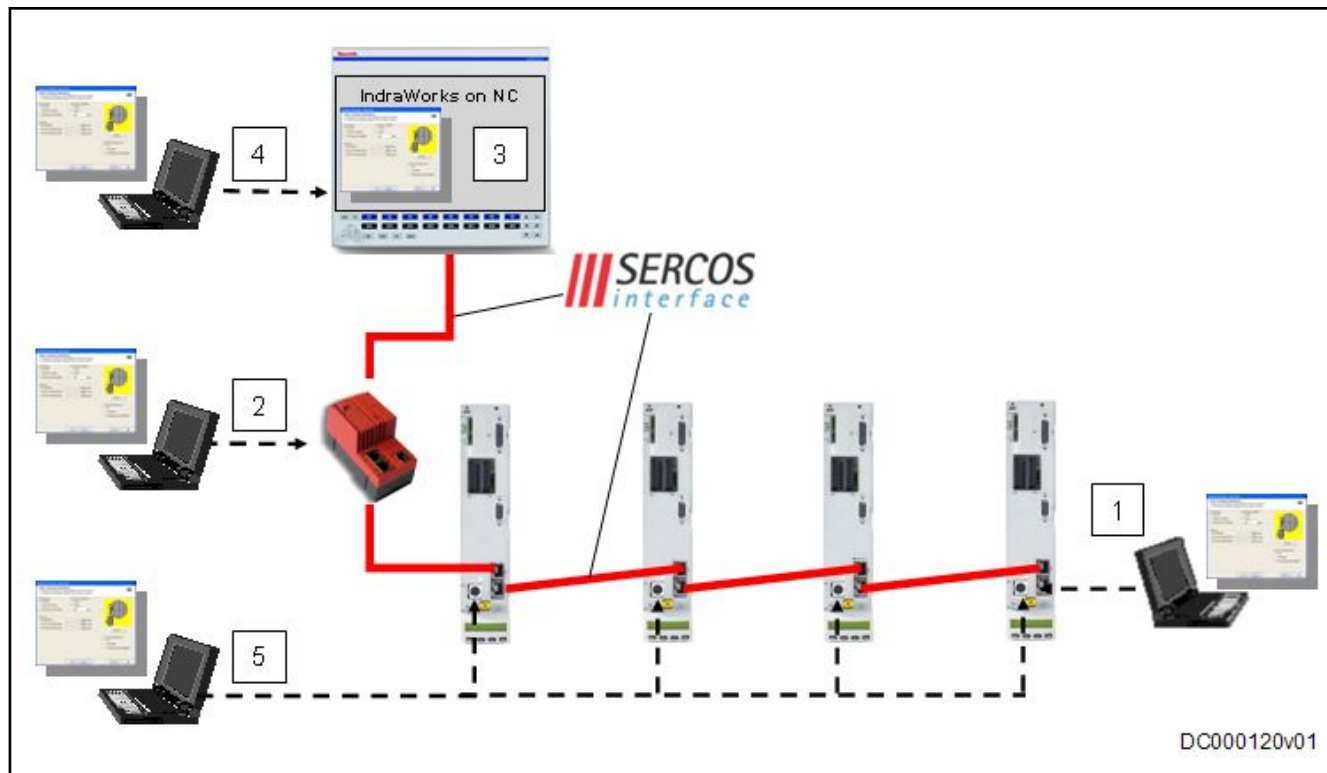
1	Engineering via unassigned SERCOS III port of a node at the bus
2	Engineering via optional SERCOS III netSWITCH
3	Engineering via IndraWorks on SERCOS III control
4	Via routing via control (if routing available in control)
5	Engineering via RS232 or existing engineering port at CSH01.3

Fig.4-97:   SERCOS III - Topology

It is possible to operate IndraDrive controllers with a MultiEthernet interface (ET) or the optional module "SERCOS III" (S3) as SERCOS III master communication. Via these modules, it is possible to exchange real-time data with a SERCOS III master.

We distinguish the following communication channels:

- **Cyclic data channel** (consumer, producer)

  → 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**).

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

  → Defined time slot within the cycle time for transmission of standard Ethernet telegrams

General Features
- Transmission rate 100 Mbit/s
- Cyclical data exchange of command values and actual values in equal time intervals
- Topologies: "Line" (= simple ring) or "ring" (= contra-rotating double ring)
- Data transmission via Ethernet cable (CAT5e copper)
- Service channel for parameterization and diagnosis
- Free configuration of telegram contents

Master Communication

- 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

			BASIC MPB-08VRS	Advanced MPH-08VRS
Position loop cycle	$T_{Position}$	µs	500	250
Master communication cycle time	min	µs	500	250
	max	ms	65	65
MotionData in each case for MDT/AT [excl. 2-byte connection control word (C_Con)]	$T_{Sercos}=T_{Position}$	Byte	26	26
		IDN	12	12
	$T_{Sercos}>T_{Position}$	Byte	50	50
		IDN	16	16
CC connections [excl. 2-byte connection control word (C_Con)]		Byte	8	8
		IDN	2	2

Fig.4-98:   Characteristic SERCOS III Values

- IndraDrive supports 4 connections, 2 between master and drive (typical of Motion data) and 2 CC connections (typical between 2 slaves)

☞ CC connections have been implemented in this firmware version, but not in accordance with the complete SERCOS specification. Therefore, incompatible changes as compared to subsequent versions might exist. For usage and configuration, see Technical Note "TN_332_CC_Verbindung_SERCOS3_EIDN.pdf".

- Cycle time: Min. 250 µs, max. 65 ms (multiples of position clock 250 µs can be set)
- Max. quantity of configurable consumer data: 50 bytes/16 IDNs
- Max. quantity of configurable producer - consumer data: 50 bytes/16 IDNs

☞ The number of configurable bytes in the consumer/producer connections depends on the relation of the position cycle time (P-0-0556, bit 2) to the SERCOS cycle time:

- SERCOS cycle time = position cycle time → max. length 26 bytes / 12 IDNs
- SERCOS cycle time > position cycle time → max. length 50 bytes / 16 IDNs

The NRT channel is only possible, if a time slot of more than 125 µs is available.

Hardware Requirements

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

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

Master Communication

The option ET or S3 must be available as master communication module.

Pertinent Parameters   Specific parameters for SERCOS III communication:

- S-0-1000, SERCOS III: SCP Type & Version
- S-0-1002, SERCOS III: Communication Cycle time (tScyc)
- S-0-1005, SERCOS III: Minimum feedback processing time (t5)
- S-0-1006, SERCOS III: AT0 transmission starting time (t1)
- S-0-1007, SERCOS III: Feedback acquisition capture point (t4)
- S-0-1008, SERCOS III: Command value valid time (t3)
- S-0-1009, SERCOS III: Device Control (C-Dev) offset in MDT
- S-0-1010, SERCOS III: Lengths of MDTs
- S-0-1011, SERCOS III: Device Status (S-Dev) offset in AT
- S-0-1012, SERCOS III: Length of ATs
- 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 (P/S)
- S-0-1017, SERCOS III: NRT transmission time
- S-0-1019, Master comm. engineering over IP: MAC address
- S-0-1020, Master comm. engineering over IP: IP address
- S-0-1021, Master comm. engineering over IP: Network mask
- S-0-1022, Master comm. engineering over IP: Gateway address
- S-0-1023, SERCOS III: SYNC jitter
- S-0-1024, C5300 SERCOS III: SYNC delay measuring procedure command
- S-0-1026, SERCOS III: Version of communication hardware
- S-0-1027.0.1, SERCOS III: Requested MTU
- S-0-1027.0.2, SERCOS III: Effective MTU
- S-0-1031, SERCOS III: Signal assignment TSx
- S-0-1035, SERCOS III: Error counter Port1 & Port2
- S-0-1040, Drive address of master communication
- S-0-1041, SERCOS III: AT Command value valid time (t9)
- S-0-1044, SERCOS III: Device Control (C-Dev)
- S-0-1045, SERCOS III: Device Status (S-Dev)
- S-0-1046, SERCOS III: List of SERCOS addresses in device
- S-0-1050.x.1, SIII-Connection: Connection setup
- S-0-1050.x.2, SIII-Connection: Connection number
- S-0-1050.x.3, SIII-Connection: Telegram assignment
- S-0-1050.x.4, SIII-Connection: Max. length of connection
- S-0-1050.x.5, SIII-Connection: Current length of connection
- S-0-1050.x.6, SIII-Connection: Configuration list
- S-0-1050.x.8, SIII-Connection: Connection control (C-Con)
- S-0-1050.x.10, SIII-Connection: Producer cycle time

Master Communication

- S-0-1050.x.11, SIII-Connection: Allowed data losses
- S-0-1050.x.12, SIII-Connection: Error counter data losses
- S-0-1050.x.20, SIII-Connection: IDN allocation of real-time bit
- S-0-1050.x.21, SIII-Connection: Bit allocation of real-time bit
- S-0-1051, SIII-Connection: Image of connection setups

Additional pertinent parameters according to "SERCOS interface":

- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0097, Mask class 2 diagnostics
- S-0-0134, Master control word
- S-0-0135, Drive status word
- S-0-0187, List of configurable data in the AT
- S-0-0188, List of configurable data in the MDT
- P-0-1044, Master comm. engineering over IP: Status IP communication

Pertinent Diagnostic Messages

- C0108 Time slot parameter > Sercos cycle time
- C0109 Telegram offset unsuitable
- C0112 TNcyc (S-0-0001) or TScyc (S-0-0002) error
- C0113 Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error
- C0170 Config. IDNs for connection not configurable
- C0171 Maximum length for connections exceeded
- C0172 Delay measurement (S-0-1024) not carried out
- C0173 Connections (number) not configurable
- C0174 Connection configuration not allowed
- C0175 Producer cycle time of a connection not correct
- C5301 SERCOS III: Delay measurement failed
- E4001 Double MST failure shutdown
- E4005 No command value input via master communication
- E4007 SERCOS III: Consumer connection failed
- E4010 Slave not scanned or address 0
- F4001 Sync telegram failure
- F4002 RTD telegram failure
- F4003 Invalid communication phase shutdown
- F4004 Error during phase progression
- F4005 Error during phase regression
- F4006 Phase switching without ready signal
- F4017 S-III: Incorrect sequence during phase switch

4.11.3 EtherCAT®

Brief Description

Topology

Master Communication
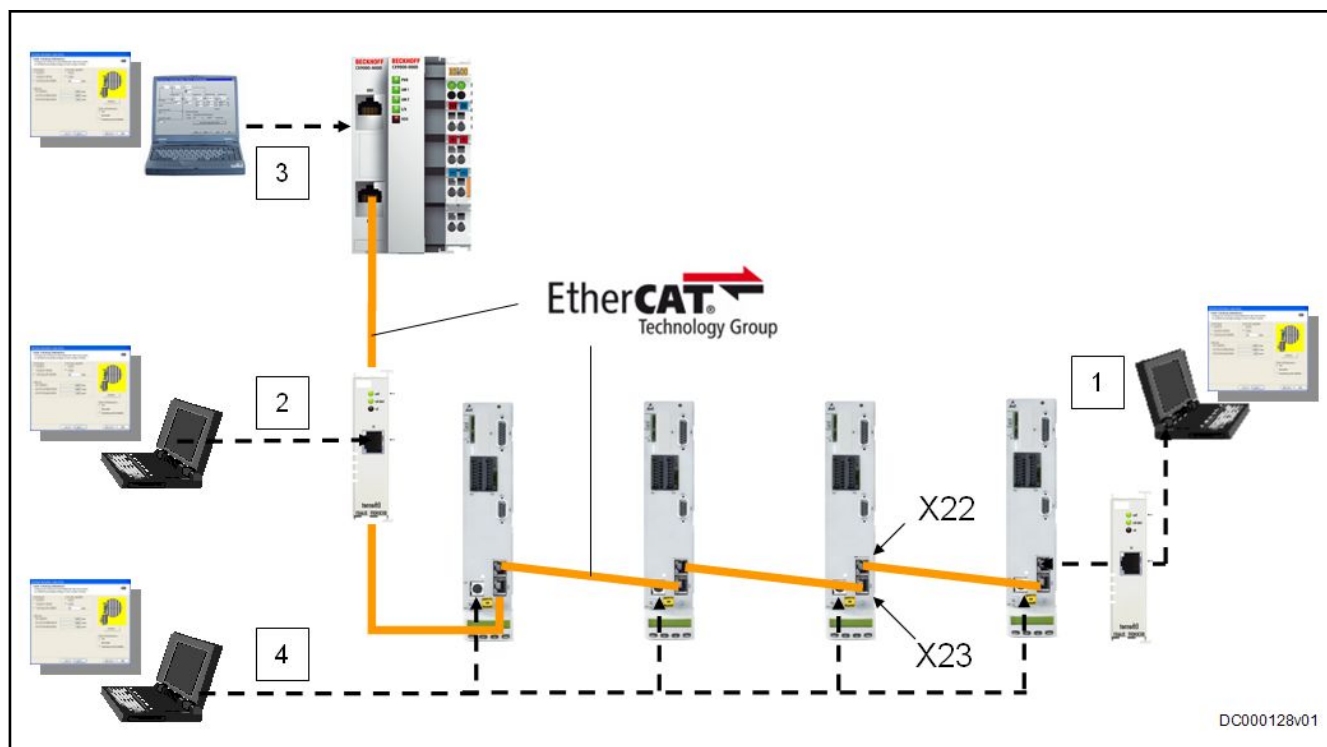
1	Engineering by means of EoE via optional Ethernet switch port
2	Engineering by means of EoE via optional Ethernet switch port
3	Engineering by means of ADS interface via third-party control unit or Engineering by means of EoE (control unit contains switch port)
4	Engineering via RS232 or existing engineering port at CSH01.3

Fig.4-99:   Engineering Options with EtherCAT®

IndraDrive controllers with MultiEthernet interface (ET) can be operated as EtherCAT® master communication. Via these modules, it is possible to exchange real-time data with an EtherCAT® master. "Servo Drive Profile over EtherCAT®" is supported, which is based on the SERCOS II specification.

We distinguish the following communication channels:

- **Cyclic data channel** (process data)

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

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

  → EtherCAT® mailbox method for acyclic transmission of useful data (**service data**)

  → Transmission of Ethernet telegrams via an EtherCAT® mailbox method [Ethernet over EtherCAT® (EoE)]

General Features
- Transmission rate 100 Mbit/s
- Data transmission via Ethernet cable (CAT5e copper)
- Topology: "Line"
- Access to 16-bit SERCOS parameters of the drive via "SoE" protocol (Servo Drive Profile over EtherCAT®)
- EtherCAT® mailbox method for parameterization and diagnosis
- Cyclic data exchange of command values and actual values
- Free configuration of telegram contents

- Max. length of the configurable MDT/AT data 15 IDNs with max. 48 bytes; with bus cycle = position cycle, the max. length is halved to 24 bytes
- Cycle time: Min. 500 µs (multiples of position cycle time can be set)
- "Distributed clock synchronization" (exact adjustment of distributed clocks)
- Synchronization between time command value takes effect and measurement starting time of the actual values for all drives on a ring
- Overall synchronization of all connected drives to the master
- No support of "CAN over EtherCAT®" (CoE)
- Only released in connection with "Beckhoff TwinCAT"

Hardware Requirements

Using the "EtherCAT®" master communication requires the following control section design:

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

The option ET must be available as master communication module.

Axis Addressing

☞ There isn't any relation between the master communication address shown on the display (S-0-1040) and the address assigned in the master (e.g. SystemManager by BECKHOFF). The drives only identify themselves by means of the order in the bus (example: address = "1" in master corresponds to "1st drive" in the line).

Pertinent Parameters

- S-0-0001, NC cycle time (TNcyc)
- S-0-0002, SERCOS cycle time (TScyc)
- S-0-0005, Minimum feedback acquisition time (T4min)
- S-0-0007, Feedback acquisition starting time (T4)
- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0016, Configuration list of AT
- S-0-0024, Configuration list of MDT
- S-0-0029, MDT error counter
- S-0-0097, Mask class 2 diagnostics
- S-0-0098, Mask class 3 diagnostics
- S-0-0134, Master control word
- S-0-0135, Drive status word
- S-0-0185, Length of the configurable data record in the AT
- S-0-0186, Length of the configurable data record in the MDT
- S-0-0187, List of configurable data in the AT
- S-0-0188, List of configurable data in the MDT
- S-0-0301, Allocation of real-time control bit 1
- S-0-0303, Allocation of real-time control bit 2
- S-0-0305, Allocation of real-time status bit 1
- S-0-0307, Allocation of real-time status bit 2
- S-0-0413, Bit number allocation of real-time control bit 1

Master Communication

- S-0-0414, Bit number allocation of real-time control bit 2
- S-0-0415, Bit number allocation of real-time status bit 1
- S-0-0416, Bit number allocation of real-time status bit 2

Pertinent Diagnostic Messages
- C0101 Invalid parameters (-> S-0-0021)
- C0104 Config. IDN for MDT not configurable
- C0105 Maximum length for MDT exceeded
- C0106 Config. IDNs for AT not configurable
- C0107 Maximum length for AT exceeded
- C0108 Time slot parameter > Sercos cycle time
- C0112 TNcyc (S-0-0001) or TScyc (S-0-0002) error
- C0113 Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error
- C0114 T4 > TScyc (S-0-0002) - T4min (S-0-0005)
- C0201 Invalid parameters (->S-0-0423)
- C0299 Configuration changed. Restart
- E4005 No command value input via master communication
- F4002 RTD telegram failure
- F4009 Bus failure

Notes on Commissioning

Rexroth provides a commissioning description which explains the essential steps for commissioning an IndraDrive with EtherCAT® at a BECKHOFF TwinCAT (IndraDrive mit EtherCAT® an BECKHOFF TwinCAT.pdf).

☞ When setting up an EtherCAT® network with IndraDrive C/M controllers, make sure to use
- slot X23 as an input and
- slot X22 as an output.

☞ There isn't any relation between the master communication address shown on the display (S-0-1040) and the address assigned in the master (e.g. SystemManager by BECKHOFF). The drives only identify themselves by means of the order in the bus. (Example: address = "1" in master corresponds to "1st drive" in the line).

Diagnostic LEDs
☞
- The LED H22 at the drive controller is used to diagnose the EtherCAT® communication.
- The PHY LEDs at the RJ45 connectors of the master communication module are used to diagnose the physical EtherCAT® connection.

Master Communication
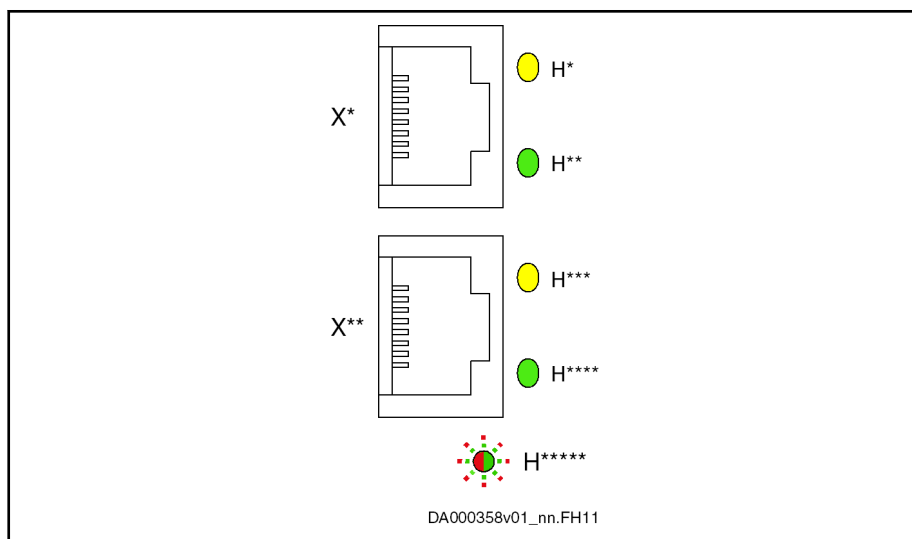
Fig.4-100:   ET, Display Elements

Display elements of the optional module ET:

- Two LEDs (H10, H11 and H12, H13) at each connection point
- One bicolor LED (H22)

The significance of the LED displays depends on the field bus system.

LED	Significance	Color / flashing pattern	Description
H10, H12	None	-	With EtherCAT, these LEDs do not have any function
H11, H13	Link	◯ Off	No connection to the network
		🟢 On, green	Connection to the network available, but no telegram traffic (EtherCAT bus inactive)
		🟢 Flickering green	Connection to the network available with telegram traffic (EtherCAT bus active)

Master Communication

LED	Significance	Color / flashing pattern	Description
H22	Status INIT	⚪ Off	• Cyclic process data and acyclic data channel are not transmitted • No error
	Status PRE-OPERATIONAL	 GN |--| ↰ 1) Flashing green	Acyclic data channel is transmitted
	Status SAVE-OPERATIONAL	 GN |--|--|--|--|--| ↰ 1) Green, flashing once	Acyclic data channel is transmitted
	Status OPERATIONAL	 On, green	Cyclic process data and acyclic data channel are transmitted
	Configuration error	 RD |--| ↰ 1) Flashing red	General EtherCAT configuration error
	Synchronization error	 RD |--|--|--|--|--| ↰ 1) Red, flashing once	• The drive controller has not been synchronized to the EtherCAT master • Communication error of the drive controller
	Timeout - watchdog	 RD |--|RD|--|--|--|--|--| ↰ 1) Red, flashing twice	• Timeout while cyclic process data are monitored • Watchdog of the EtherCAT master

1)   Flashing pattern: One division corresponds to a duration of 200 ms; the arrow identifies the end of a cycle; identifications of the divisions: GN = LED On, green, RD = LED On, red, -- = LED Off

Fig.4-101:   *EtherCAT® Display Elements*

☞   The yellow PHY LED is not used with EtherCAT®

**Pulse-Pause Relation of the Diag-
nostic LEDs**

Master Communication
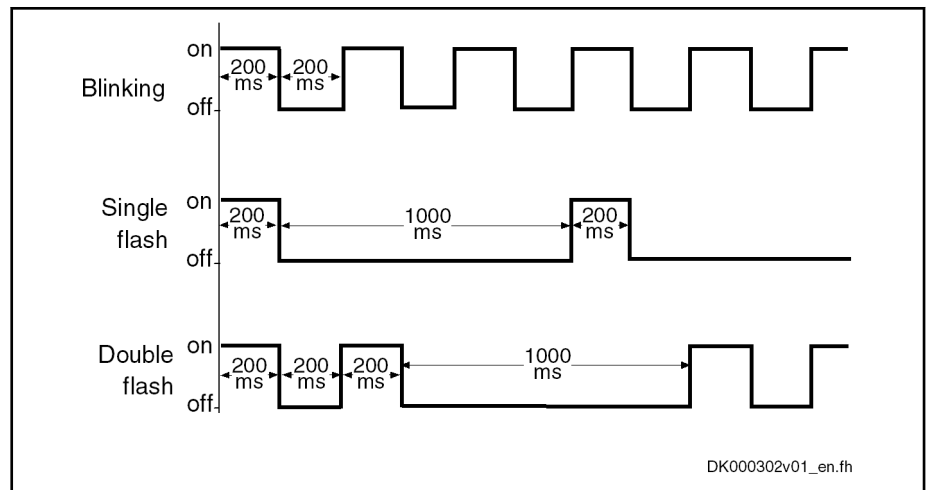
Fig.4-102:   *Pulse-Pause Relation*

4.11.4   PROFINET®

Brief Description

Topology
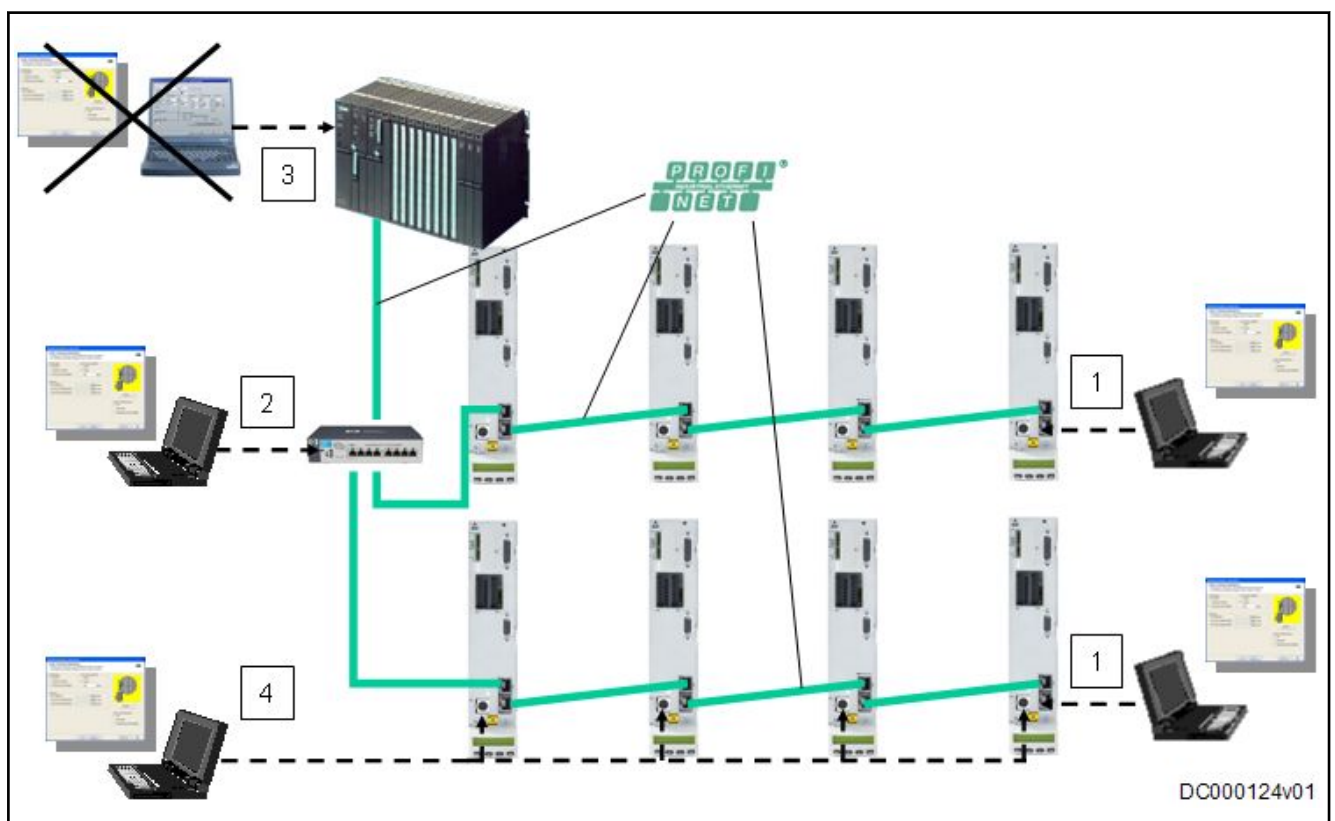
1	Engineering via unassigned PROFINET® port of a node at the bus
2	Engineering via optional Industrial Ethernet switch
3	Engineering via third-party control unit by means of TCI is impossible
4	Engineering via RS232 or existing engineering port at CSH01.3

Fig.4-103:   *Engineering Options with PROFINET®*

Master Communication

IndraDrive controllers with MultiEthernet interface (ET) can be operated as PROFINET® master communication. Via this module, it is possible to exchange real-time data with a PROFINET® controller.

The field bus provides data containers in which useful data can be cyclically transmitted. This section is referred to as **cyclic data channel** (PROFINET®).

The cyclic data channel is divided as follows:

● (Optional) **device-specific parameter channel** for reading and writing of all parameters via PROFINET®.

☞ The **device-specific parameter channel** does not fulfill "real-time properties"!

● One (optional) **safe, axis-specific process data channel** (PROFIsafe).

☞ The **safe, axis-specific process data channel** is not available in MPx08VRS. For configuration you must, however, integrate the "F module not used" module!

● One **axis-specific process data channel** (real-time channel) which contains fixed information that can be directly interpreted by the receiver.
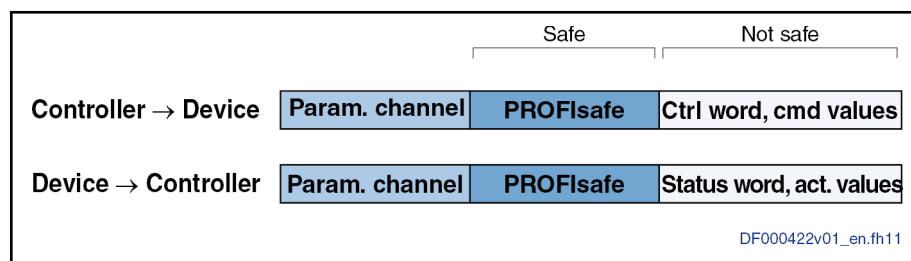
Fig.4-104:   Overview of Cyclic Data Channel

☞ To simplify field bus communication, there are PLC function blocks for different programmable logic controllers (PLCs) available. The function blocks support the basic functionalities axis-specific process data channel and device-specific parameter channel. The principles applied can be easily used for other PROFINET® controllers.

Features   The PROFINET® device interface with MultiEthernet interface has the following features:

● Ethernet according to IEEE 802.3 and prioritization according to IEEE 802.1Q

● Transmission rate 100 Mbit/s

● Data transmission via Ethernet cable (CAT5e copper)

● Topologies: "Star", "line" (by means of integrated cut-through switch)

● Assignment of the IP addresses via DCP protocol (**D**iscovery and **B**asic **C**onfiguration)

● The smallest supported cycle time (I/O cycle updating time) is 2 ms.

☞　　　The I/O cycle updating time is written by the control unit and is the time in which clock the process data are applied from the PROFINET network to the MultiEthernet interface and are written vice versa.

- 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)

- Possible settings via "P-0-4076, Field bus: Process data - updating clock", min. 2 ms, max. 65 ms (can be adjusted in steps of 1 ms)

☞　　　Via the parameter "P-0-4076 Field bus: Process data - updating clock", you can set in which updating clock the process data are applied from the MultiEthernet interface to the drive and vice versa.

☞　　　For the planning, cabling and assembly, as well as commissioning of a system, please see the following recommendations (denomination: PROFINET Trilogy):

- Recommendation for Planning

- Recommendation for Cabling and Assembly

- Recommendation for Commissioning

The recommendations can be ordered from the PNO (PROFIBUS Nutzerorganisation e. V. [PROFIBUS User Organization]).

☞　　　It is recommended

- that you do not connect the Industrial Ethernet network to a commercial network (office communication). (As an alternative, you can use a Level 3 router to connect the Industrial Ethernet network to a commercial network.)

- that you only use switches with cut-through technique for the Industrial Ethernet communication

- that you use a star topology with cable type AWG22 or shielded cables, especially for cables leading out of the control cabinet, as well as with cable lengths of more than 10 meters

- Additional optional parameter channel in the cyclic channel with up to 16 bytes (8 words)

- LED for diagnosing the PROFINET® status (network status)

- LEDs for display of link/activity status

- Support of CCA and RT_CLASS_1

- For reasons of compatibility with IndraDrive drive controllers with PROFIBUS® master communication module, diagnoses and alarms are not used.

- PROFINET® IRT is not supported.

- Operation in PROFINET® IRT networks not possible

- Supported field bus profiles:
  - 0x0000: "No profile" selected

Master Communication

    –   0xFF82: I/O mode "positioning" with configurable real-time data

    –   0xFF92: I/O mode "preset velocity" with configurable real-time data

    –   0xFFFD: Freely configurable mode "operation mode neutral"

    –   0xFFFE: Freely configurable mode

Hardware Requirements

Using the "PROFINET®" master communication requires the following control section design:

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

The option ET must be available as master communication module.

Axis Addressing

In PROFINET, a node is addressed via the so-called device name. The name is stored in the parameter P-0-4089.0.2 and can be changed in this parameter. The address displayed at the drive is irrelevant to PROFINET.

Pertinent Parameters

Communication parameters

Specific parameters for communication via PROFINET®:

- P-0-4089.0.11, Master communication: MAC address Port1
- P-0-4089.0.12, Master communication: MAC address Port2

Parameters for general communication via field bus interfaces:

- P-0-4073, Field bus: diagnostic message
- P-0-4074, Field bus: data format
- P-0-4075, Field bus: watchdog
- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: baud rate
- P-0-4083, Field bus: length of parameter channel
- P-0-4083.0.1, Master communication: Parameter channel configuration
- P-0-4088, Master communication: Drive configuration
- P-0-4089.0.2, Master communication: Device name
- P-0-4089.0.10, Master communication: MAC address device
- P-0-4089.0.13, Master communication: IP address
- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

Profile type parameters

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

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

Parameters for extended communication

We use additional parameters for extended communication.

See the following sections:

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

Pertinent Diagnostic Messages

- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable

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- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- C0299 Configuration changed. Restart
- E4005 No command value input via master communication
- E4006 Communication module overload
- E4011 Communication watchdog: Overload of cyclic communication
- F4009 Bus failure
- F4011 Communication watchdog: Overload of cyclic communication
- F4012 Incorrect I/O length

Configuring the PROFINET®-Slave

Device Data Sheet for IndraDrive

Like every other PROFINET® device, IndraDrive controllers must be configured in the field bus controller. This requires the corresponding device data sheet (DDS) **"GSDML-V2.1-Bosch Rexroth AG-011F-Indradrive_xxVxx-xxxxxxxx.xml"** that has to be included in the project ("YYYYMMDD" represents the creation date of the DDS file). This DDS file, when configuring the bus controller, is required for each node.

☞   The device data sheet for IndraDrive controllers supports all hardware types and enabling of functional packages.

IndraDrive controllers assign their data to four slots (for single-axis devices) or up to 31 slots for devices operated via CCD group (1CCD master + 9 CCD slaves), which have to be configured, if necessary. Each drive in the CCD group has an F module, one input module and one output module: A slot is used for plugging in modules.

Each slot has a certain module assignment which must be complied with for correct configuration.

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

The default configuration stored in the device data sheet is "Input 1 Word" and "Output 1 Word" (single-axis device) without safety technology and without parameter channel. For IndraDrive, this setting is active after the load defaults procedure.

☞   During the installation, "IndraWorks Ds/D/MLD" as a standard stores the device data sheet in the "C:\Program Files\REXROTH\IndraWorks\DeviceDataSheets\IndraDrive\Profinet" directory.

Master Communication

Module 1: Parameter Channel

These modules are marked with "ParamCh" and are of the input/output module type. If no parameter channel is required, the module "ParamCh not used" has to be selected.

When IDN parameters or EIDN parameters are to be written via the parameter channel, observe the following aspects:

- IDN parameters

  To write a 2-byte IDN parameter (e.g. P-0-4006), include the "ParamCh 5 Words" module and configure it accordingly in the parameter "P-0-4083.0.1, Master communication: Parameter channel configuration".

- EIDN parameters

  To write a 4-byte EIDN parameter (e.g. P-0-4006.0.0), include the "ParamCh 6 Words" module and configure it accordingly in the parameter "P-0-4083.0.1, Master communication: Parameter channel configuration".

☞   The parameter channel length is displayed in parameter "P-0-4083, Field bus: length of parameter channel" in bytes.

With the wrong configuration of the command values / actual values, the error "F4012 Incorrect I/O length" is displayed.

F Module

The blank module "F module not used" is assigned to slot 2.

Inputs Module

With these modules, the length of the input data is set in words. The module identifier is "Input". For the successful data exchange of the axis-specific process data channel, the length that has been set must correspond to the value in parameter "P-0-4082, Field bus: length of cyclic actual value data channel", specifying the length in bytes.

☞   Even if the input data length is wrong, it is possible to communicate via the device-specific parameter channel.

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

Outputs Module

With these modules, the length of the output data is set in words. The module identifier is "Output". The length of the output data that has been set must correspond to the value of parameter "P-0-4071, Field bus: length of cyclic command value data channel".

☞   If the configuration of the controller 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 31

The modules 5 to 31 are provided for devices operated at the CCD group.

Displaying the Device Name/IP Address of the IndraDrive Device

The device name of the IndraDrive device assigned with the "device baptism" is displayed in parameter "P-0-4089.0.2, Master communication: Device name". When exchanging a device, the device name can be set manually via this parameter using IndraWorks (see "Notes on How to Replace the Devices"). The IP settings permanently assigned to the device during configuration are displayed in the following parameters:

- P-0-4089.0.13, Master communication: IP address

Master Communication

- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

When "temporary assignment" (assignment by the controller during run-up) has been configured, the IP address "0.0.0.0" is displayed in the parameters.

☞　　The IP address is only relevant for communication with the controller! For engineering (e.g. IndraWorks), the engineering address (S-0-1020, Master comm. engineering over IP: IP address) must be used.

Configuring the Process Data Channel

Standard Process Data Channel (Not Safe)　The user can freely configure the cyclic data in the standard process data channel according to the process requirements.

☞　　For the profile types "freely configurable mode" (P-0-4084 = 0xFFFE), "I/O mode positioning" (P-0-4084 = 0xFF82) or "I/O mode" (P-0-4084 = 0xFF92 preset velocity), there is a default configuration that the user can change at any time.

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

Configuration List Cyclic Actual Value Data Channel　In parameter "P-0-4080, Field bus: config. list of cyclic actual value data ch.", the structure and therefore the number of words and their assigned objects (indices) for the process input data (device → controller) are mapped. The controller can use this configuration in order to locate 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 value data ch.", the structure of the process output data (controller → device) is mapped. This allows reading the current structure and thus the assignment in the field bus via the parameter channel.

☞　　It is possible to configure up to 15 real-time parameters (incl. control word or status word) at the bus in each data direction (max. 48 bytes or 24 words).

PROFIsafe Process Data Channel (Safe)　☞　　The **safe, axis-specific process data channel** is not available in MPx08VRS. For configuration you must, however, integrate the "F module not used" module!

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

Standard Process Data Channel (Not Safe)　Within the cyclic channel, the parameter channel (optional) and the process data channel, in which the real-time data of the drive controller are transmitted, are arranged.

The PROFINET® device interface allows flexible configuration of the process data channel, the length of the process data channel thereby changes accordingly.

☞　　The currently valid length can be seen from parameters "P-0-4082, Field bus: length of cyclic actual value data channel" and "P-0-4071, Field bus: length of cyclic command value data channel".

The process data channel (real-time data channel) can only have words or double words, but not bytes, as data types. Length, however, is specified in bytes for the sake of compatibility with other bus systems.

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The length of the process data channel results from the content of the configuration lists "P-0-4080, Field bus: config. list of cyclic actual value data ch." or "P-0-4081, Field bus: config. list of cyclic command value data ch." and can be taken from the following parameters:

- P-0-4071, Field bus: length of cyclic command value data channel

- P-0-4082, Field bus: length of cyclic actual value data channel

The setting is calculated from the contents of the parameters P-0-4080 and P-0-4081 and takes effect as the drive controller runs up to the operating mode.

☞   Please note that a change in the length of the process data channel also requires a change in the controller configuration. The length of the process data channel that was set has to be in accordance with the projected length in the controller. Otherwise the error message "F4012 Incorrect I/O length" is generated.

Cyclic Communication via Process Data Channel

Communication Cycle Time

The smallest supported cycle time (I/O cycle updating time) is 2 ms and preset by the control unit. It is the time in which clock the data are applied from the PROFINET network to the MultiEthernet interface or written to the PROFINET network.

Possible settings via "P-0-4076, Field bus: Process data - updating clock", min. 2 ms, max. 65 ms (can be adjusted in steps of 1 ms).

☞   Via the parameter "P-0-4076, Field bus: Process data - updating clock", you can set in which updating clock the data are applied from the MultiEthernet interface to the drive and vice versa.

Axis-Specific Process Data Channel
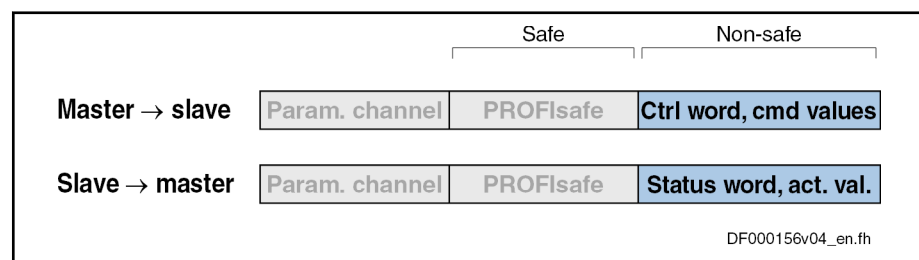
Fig.4-105:   Position of the Not Safe Process Data Channel in the Cyclic Data Channel

Processing the Cyclic Data   The internal processing of the command values and actual values is carried out synchronously with the control clock. As the communication via PROFINET® RT is not carried out in a synchronous way, this type of master communication is not suited for synchronous operation modes such as "position control with cyclic command value input", but only for positioning modes and the "velocity control" mode.

☞   There is no limit value check for the cyclically transmitted command values and they are stored in volatile form.

Configuring the Cyclic Data   The cyclic data must be configured in the parameter mode. The configuration of the cyclic data is described in the section "Configuring the PROFINET®-DP Slave".

Safe, Axis-Specific Process Data Channel (PROFIsafe)

General Information

☞   The **safe, axis-specific process data channel** is not available in MPx08VRS.

Parameter Channel in the Cyclic Channel (Device-Specific)
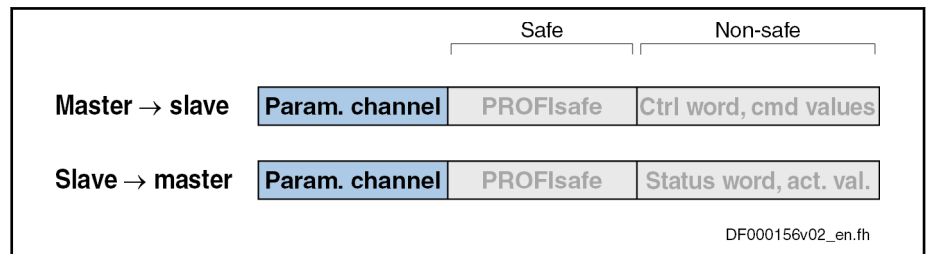
Fig.4-106:   *Position of the Parameter Channel in the Cyclic Data Channel*

Via the parameter channel, the drive can be parameterized via the field bus. The parameter channel is part of the cyclic data.

For IndraLogic and Siemens S7, function blocks are available which implement the parameter channel protocol. This allows the user to ignore the parameter channel details.

The parameter channel is described in the Technical Note "TN_40_Bosch_Rexroth PROFIBUS_PROFINET_Parameterkanal_V1.x".

☞   The parameter channel is always at the beginning of the cyclic data channel. The length of the parameter channel is configured in the controller and in the drive. For this purpose, use the parameter "P-0-4083.0.1, Parameter channel: Configuration".

Monitoring Functions and Diagnostic Functions

Diagnostic Possibilities

For simple diagnosis of network status a network status LED is provided.

The following table shows the possible states:

Message on display	Significance
Permanently off	The device does not have any valid IP address or has been switched off
Flashing green	The device has run up with a valid IP address, but has no cyclic connection
Permanently green	The I/O connection has been established without error.
Flashing red	The existing I/O connection was unexpectedly interrupted (e.g. watchdog)
Permanently red	During "Duplicate IP Address Check", the IP address which was set was detected to already exist in the network.
Flashing green/red	The device is currently initializing and performs a self test.

Fig.4-107:   *Overview of Diagnostic Messages for PROFINET® Communication*

Master Communication

Error Codes of PROFINET® Communication

Parameter Channel Errors

The table below contains an overview of the possible parameter channel error messages and their significances:

Error code	Significance
0x0082	Quantity of all transmitted data is too small, i.e. less than 4 bytes
0x0083	Quantity of data still to be transmitted is greater than the internal buffer
0x0088	The length of the valid data indicated in the control word is longer than the parameter channel
0x008C	Status conflict, a new request was transmitted although there are still data to be retrieved
0x008D	The length of data still to be transmitted that is indicated in the control word is incorrect
0x008E	The type of EIDN/IDN access specified in the control word bit 15 does not match the type of access configured in P-0-4083.0.1

Fig.4-108:   Overview Parameter Channel Errors

Parameter Access Errors

The table below contains an overview of the possible parameter access errors and their significances; the error values are transmitted in word format:

Error No. (hex)	Significance
0x1001	No IDN
0x1009	Invalid access to element 1
0x2001	No name
0x2004	Name cannot be changed (read only)
0x3004	Attribute cannot be changed (read only)
0x4001	No units
0x4004	Unit cannot be changed (read only)
0x5001	No minimum input value
0x5004	Minimum input value cannot be changed (read only)
0x6001	No maximum input value
0x6004	Maximum input value cannot be changed (read only)
0x7002	Operation data transmission too short
0x7003	Operation data transmission too long
0x7004	Operation data cannot be changed (read only)
0x7005	Operation data is write-protected at this time (e.g. communication phase)
0x7006	Operation data is smaller than minimum input value
0x7007	Operation data is greater than maximum input value
0x7008	Invalid operation data: Configured IDN will not be supported, invalid bit number or bit combination
0x7009	Operation data write protected by a password

Error No. (hex)	Significance
0x700A	Operation data is write protected, it is configured cyclically
0x700B	Invalid indirect addressing (e.g. data container, list handling)
0x700C	Operation data is write protected, due to other settings (e.g., parameter, operation mode, drive enable, drive on etc.)
0x7010	Procedure command already active
0x7011	Procedure command not interruptible
0x7012	Procedure command at this time not executable (e.g., in this phase the procedure command cannot be activated)
0x7013	Procedure command not executable (invalid or false parameters)
0x9001	Input cannot be identified as application
0x9002	Parameter type error
0x9003	Invalid data 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.4-109:   Overview Parameter Access Errors

4.11.5   EtherNet/IP(TM) Interface

Brief Description

Topology

Master Communication
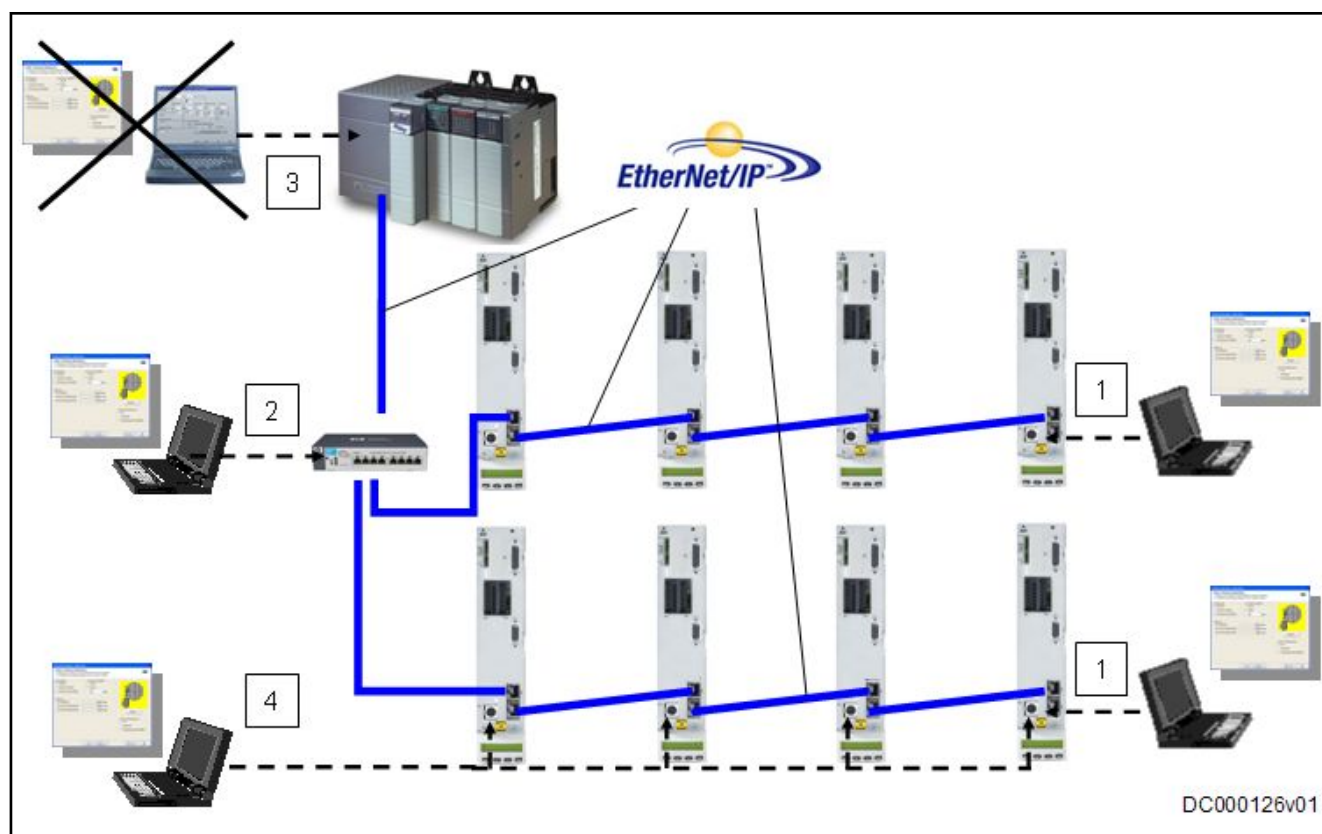
1	Engineering via unassigned EtherNet/IP™ port of a node at the bus
2	Engineering via optional Industrial Ethernet switch
3	Engineering via third-party control unit is impossible
4	Engineering via RS232 or existing engineering port at CSH01.3

Fig.4-110:   Engineering Options with EtherNet/IP(TM)

IndraDrive controllers with MultiEthernet interface can also be operated as EtherNet/IP™ master communication. Via this module it is possible to exchange real-time data with an EtherNet/IP™ scanner.

Via this interface, real-time data can be transmitted by means of I/O connection (class 1 connection).

To achieve high system flexibility, all data are accessible via objects. With Ethernet/IP™ interface, these objects can be addressed through class, instance and attribute. Some of these objects can be assigned to the I/O connection as real-time data and thus be cyclically transmitted. There is also the option of transmitting via "Explicit Message", but no objects defined in the real-time channel (P-0-4081) may be written by the master via "Explicit Message".

Features
- Transmission rate 100 Mbit/s (full duplex)
- Data transmission via Ethernet cable (CAT5e copper)
- Topologies: "Star", "line" (by means of integrated cut-through switch)
- Auto negotiation is supported; the prerequisite is the transmission rate specified above
- Profile type is "Generic Device", specified in ODVA 2.0 (**O**pen **D**evice-Net **V**endors **A**ssociation)
- EtherNet/IP™ Level 2 server
- Cyclic exchange via "EtherNet/IP™ I/O messaging" (class 1)

- Acyclic data exchange via "Ethernet/IP™ Unconnected Explicit Messaging" and "Explicite Messaging" (Class 3)
- The smallest supported cycle time (API → Actual Packet Interval) is 2 ms.
- Configurable cyclic data up to 15 parameters (incl. field bus control word and field bus status word) in both data directions
  (max. 48 bytes or 24 words)

☞   It is recommended

- that you do not connect the Industrial Ethernet network to a commercial network (office communication). (As an alternative, you can use a Level 3 router to connect the Industrial Ethernet network to a commercial network.)
- that you only use switches with cut-through technique for the Industrial Ethernet communication
- that you use a star topology with cable type AWG22 or shielded cables, especially for cables leading out of the control cabinet, as well as with cable lengths of more than 10 meters

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- Supported field bus profiles:
  – 0x0000: "No profile selected"
  – 0xFF82: I/O mode "positioning" with configurable real-time data
  – 0xFF92: I/O mode "preset velocity" with configurable real-time data
  – 0xFFFD: Freely configurable mode "operation mode neutral"
  – 0xFFFE: Freely configurable mode

Hardware Requirements   Using the master communication "EtherNet/IP™" requires the following control section design:

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

The option ET must be available as master communication module.

Pertinent Parameters
- P-0-4073, Field bus: diagnostic message
- P-0-4074, Field bus: data format
- P-0-4075, Field bus: watchdog
- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: baud rate
- P-0-4088, Master communication: Drive configuration
- P-0-4089.0.2, Master communication: Device name
- P-0-4089.0.10, Master communication: MAC address device
- P-0-4089.0.13, Master communication: IP address
- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

Profile type parameters

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

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

Master Communication

Parameters for extended communication

We use additional parameters for extended communication.

See the following sections:

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

Pertinent Diagnostic Messages

- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable
- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- C0299 Configuration changed. Restart
- E4005 No command value input via master communication
- E4006 Communication module overload
- E4011 Communication watchdog: Overload of cyclic communication
- F4009 Bus failure
- F4011 Communication watchdog: Overload of cyclic communication

Configuring the EtherNet/IP(TM) Slave

EDS File

For each EtherNet/IP™ device, it is necessary to have an EDS file (*.EDS) which contains the data required for operating the device on the field bus. When configuring bus masters supported by the EDS file, this file is required for each node.

The EDS file for IndraDrive is an ASCII file with the name "IndraDrive_EIP_MPx08.eds".

Setting the IP Address of the Slave

Setting is either made manually, in a menu-controlled way via the display or by means of the "IndraWorks" commissioning tool.

The IP address for the EtherNet/IP™ adapter is saved in parameter "P-0-4089.0.13, Master communication: IP address", the subnet mask in parameter "P-0-4089.0.14, Master communication: Network mask", and the gateway address in parameter "P-0-4089.0.15, Master communication: Gateway address".

☞   This IP address is only relevant for the communication with the scanner! For engineering (e.g. IndraWorks), the engineering address (S-0-1020, Master comm. engineering over IP: IP address) must be used.

Configuring the Cyclic Data

The parameters for configuring the cyclic data (P-0-4080 and P-0-4081) can contain a maximum of 15 elements each. The maximum length is limited to 24 words.

Possible settings via "P-0-4076, Field bus: Process data - updating clock", min. 2 ms, max. 65 ms (can be adjusted in steps of 1 ms).

Master Communication

> ☞ Via the parameter "P-0-4076, Field bus: Process data - updating clock", you can set in which updating clock the data are applied from the MultiEthernet interface to the drive and vice versa.

For configuration of cyclic data of a possible subordinate CCD system see also "Cross Communication (CCD)"

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

Specification of the EtherNet/IP(TM) Interface

The drive works with EtherNet/IP™ interface switched on as a level 2 device. This means that the drive makes available one server each for implicit messages (Class 1) and explicit messages (Class 3). The explicit messages are limited to the standard objects.

The implemented EtherNet/IP™ object directory contains the objects specified for a "Generic Device":

- Identity object (0x01)
- Message router object (0x02)
- Ethernet link object (0xF6)
- TCP/IP object (0xF5)
- Port object (0xF4)
- Connection manager object (0x06)
- Assembly object (0x04)

Cyclic Communication via the Process Data Channel (Class 1)

EtherNet/IP(TM) Connection Types

With an IndraDrive device as EtherNet/IP™ slave, parameters can be cyclically transmitted via an I/O container. This can be done via an "Exclusive Owner Connection" (Transport-Class-1) or a "Listen Only Connection" (Transport-Class-1).

With the "Exclusive Owner Connection", the EtherNet/IP™ input image is transmitted to the drive by means of "point-to-point connection". The output image can be transmitted by means of "point-to-point" or "multicast" connection.

With an already existing "Multicast-Exclusive Owner Connection", a second master can, with a "Listen Only Connection", read the EtherNet/IP™ output image of the IndraDrive device. In this case, a "Heartbeat Connection Point" is used as Consuming Connection Point, and the same Connection Point as with the "Exclusive Owner Connection" is used as Producing Connection Point.
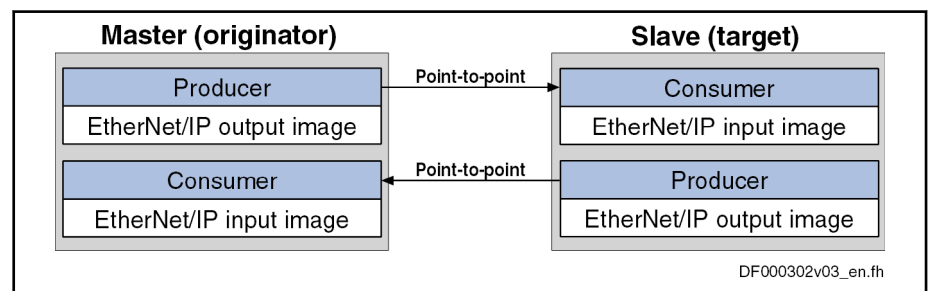
Fig.4-111:   EtherNet/IP™ Connection Type "Point-to-Point"

Master Communication
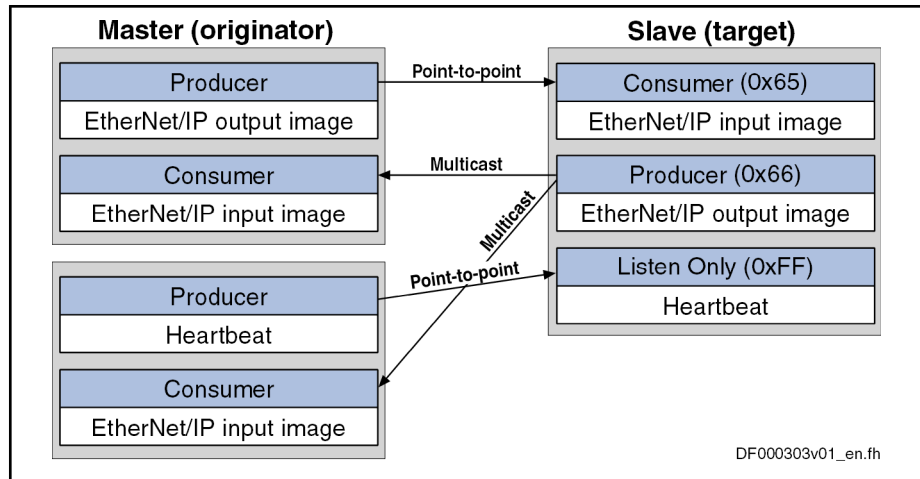
Fig.4-112: *EtherNet/IP^{TM} Connection Type "Multicast"*

For the cyclic I/O data channel (Implicit Message), the drive makes available a Consumer and Producer, i.e. it consumes the command values of the master and produces the actual values for the master.

Communication in this case runs via a UDP protocol; the direction from master to slave is transmitted with unicast telegrams, the opposite direction is transmitted with multicast telegrams.

Characteristic of the Cyclic Data Transmission

Features
- The smallest cycle time IndraDrive supports (API → Actual Packet Interval) is 2 ms.

- The "Idle/Run Header" of the EtherNet/IP^{TM} interface is supported (32 bits). The header is not visible in the cyclic I/O image of the IndraDrive device. The reaction of the IndraDrive device to the Idle/Run Header is defined via the settings of the setting-up mode (easy startup mode).

- The consumer instance of the IndraDrive device monitors the cyclic transmission of the master output image via a so-called "TimeOut" which the master determines when the connection is established.

The monitoring time is calculated according to the formula below:

$$t = TM \times API$$

$$TM = 2^{(TMV + 2)}$$

t   Monitoring time (in ms)
TM   TimeOut Multiplier
API   Actual Packet Interval
TMV   TimeOut Multiplier value

Fig.4-113: *Calculating the Monitoring Time in two Steps*

Examples

TMV	TM	API (in ms)	t (in ms)
0	4	2	8
0	4	5	20
1	8	2	16
1	8	5	40

TMV	TM	API (in ms)	t (in ms)
2	16	2	32
3	32	2	64
4	64	5	320
2	16	10	160

Fig.4-114:   Exemplary Values for the Monitoring Time

In most of the configuration user interfaces it is possible to directly enter the "TimeOut Multiplier", the user then does not have to take the first formula into account.

Configuring the Cyclic Process Data

The cyclic channel is configured by parameterizing "P-0-4080, Field bus: config. list of cyclic actual value data ch." and "P-0-4081, Field bus: config. list of cyclic command value data ch.".

On the level of EtherNet/IP™ communication, a static Output Assembly Instance (Class 4, instance 101) and a static Input Assembly Instance (Class 4, instance 102) are created in the cyclic channel. The data direction in this case is written from the master's point of view. If the parameter setting of P-0-4080 and P-0-4081 or the data length of a CCD slave is changed, new assembly instances are created during the transition from parameter mode (PM) to operating mode (OM). This results in a short interruption of communication.

Specific Features Cross Communication (CCD) in System Mode

For communication via EtherNet/IP™ with a CCD system, the configurable I/O data of the individual axes are copied one after the other to the data container of the assembly or removed. This means that the length of the assembly results from the sum of the individual lengths of the local axis and the CCD slave axes (see also "Cross Communication (CCD)").

Acyclic Parameter Access via "Explicit Message" (Class 3 / UCM)

General Information on Parameter Setting

To allow parameter setting via Ethernet/IP interface, all IDN parameters can be reached via a manufacturer-specific class object with the corresponding instances for each IDN parameter. The IDN parameters can be addressed either via an "Unconnected Explicit Message" (UCM) or via a "Connected Explicit Message" (Class 3).

> 💡 The acyclic parameter access via "Explicit Message" (Class 3/ UCM) only allows accessing IDN parameters, e.g. "P-0-4006 Positioning block target position". EIDN see also "Note on Parameter Access"

Addressing

For Ethernet/IP communication, the objects are addressed according to the following scheme:

Class → instance → attribute

Class   All parameters of a sub-device (e.g. drive) are mapped to the manufacturer-specific classes 100 (0x64) + sub-device index, i.e. sub-device 0 --> class 100, sub-device 1 --> class 101,…, sub-device 98 --> class 198.

Master Communication

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.4-115:   Structure of the IDN

The instance number can be calculated with the following formula:

$$\text{Inst} = (32768 \times \text{type}) + (4096 \times \text{set}) + \text{block}$$

Inst   instance number
type   parameter type (0 for S-parameters and 1 for P-parameters)
set   set number
block   data block number

Fig.4-116:   Calculating the instance number

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

The operating data can have four different formats:

- Data length 2 bytes → **W**
- Data length 4 bytes → **L**
- ASCII text with max. length of 64 bytes → **T**

There are three types of parameters:

- Single parameters
- Command parameters
- List parameters

Independent of its type, each parameter has these attributes (read-only):

No.	Name	Function	Format
0	Number of elements	Number of supported elements	W
1	IDN	SERCOS 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.4-117:   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

No.	Name/function	Format
10	Pointer to the element starting from which the elements 11 – 20 are accessed at the next access	L
11	Action for 1 list element (pointer to the list element is transferred)	W/L/T
12	Action for 2 list elements (pointer to the list element is transferred)	W/L/T
13	Action for 3 list elements (pointer to the list element is transferred)	W/L/T
14	Action for 4 list elements (pointer to the list element is transferred)	W/L/T
15	Action for 5 list elements (pointer to the list element is transferred)	W/L/T
16	Action for 6 list elements (pointer to the list element is transferred)	W/L/T
17	Action for 7 list elements (pointer to the list element is transferred)	W/L/T
18	Action for 8 list elements (pointer to the list element is transferred)	W/L/T
19	Action for 9 list elements (pointer to the list element is transferred)	W/L/T
20	Action for 10 list elements (pointer to the list element is transferred)	W/L/T

Fig.4-118:   Type-Dependent Attributes of a Drive Parameter

Accessing Single Parameters

The value can be accessed by writing and reading the operating data of the parameter. For single parameters, the number of attributes is the value "7".

Accessing Texts

The value can be accessed by writing and reading the operating data of the parameter. The maximum length of the text and the actual length of the text can be read with attributes 8 and 9. In addition, a text can be handled like a 1-byte list. With access to parameter texts, the number of attributes is the value "20".

Accessing Command Parameters

A command can be started by writing "3" to the operating data, the command status is obtained by read-accessing the operating data. With access to command parameters, the number of attributes is the value "7".

Accessing List Parameters

The maximum list size can be determined by reading the maximum quantity of data of the parameter (attribute 8). The real size is stored in the actual quantity of data of the parameter (attribute 9) and can be modified unless the list is write-protected. All data refer to the parameter format. The pointer to the data (attribute 10) determines which data in the list is processed. If the value of the data is zero, the pointer is automatically modified in the following situations:

Master Communication

- Zero is loaded when changing from another parameter to this parameter.
- After each access to the operating data, the pointer is incremented by the number of elements which were read.

By access to attribute 11 one element is processed, to attribute 12 two elements are processed etc. up to attribute 20 for processing 10 elements. The pointer is increased by the processed elements. With access to list parameters, the number of attributes is the value "20".

☞   For successful access to the operating data, the pointer must be smaller than the actual length.

Example   The parameter "P-0-0072, Cam table 1" has 18 list elements and is to be read:

- Calculate instance with formula

  Input:

  – P-parameter → type = 1

  – Parameter set 0 → set = 0

  – Data block number 72 → block = 72

  → Instance = 32840

- Read: Class 100, instance 32840, attribute 9 = 18 (actual length)
- Write: Class 100, instance 32840, attribute 10 = 0 (list pointer)
- Read: Class 100, instance 32840, attribute 11 = element 0

  → List pointer now automatically pointing to 1

- Read: Class 100, instance 32840, attribute 20 = elements 1 to 10

  → List pointer now automatically pointing to 11

- Read: Class 100, instance 32840, attribute 12 = element 11, 12

  → List pointer now automatically pointing to 13

- Read: Class 100, instance 32840, attribute 15 = elements 13 to 17

  → List pointer now automatically pointing to 18

- Read: Class 100, instance 32840, attribute 10 = 18 (pointer)

Another access to the operating data would not supply any data without loading the list pointer again (list pointer = actual length). The number of attributes supplies the value "20".

Storing List Elements

List elements are not directly stored in permanent form. Storage takes place by one of the following actions:

- Writing the last element of the list
- Read-accessing the list
- Accessing a different parameter
- Abortion of connection

When the control voltage fails, all changes which were not stored are cleared!

Error Codes at Parameter Access

When a vendor-specific error occurs during parameter access, the additional error code provides hints at the cause of the error.

The following table lists the most important error codes.

Master Communication

Error No. (hex)	Significance
0x03	Invalid parameter value • Value is smaller than minimum input value • Value is greater than maximum input value • Incorrect value • Invalid indirect addressing • Procedure command not executable (invalid or false parameters)
0x0E	Parameter cannot be changed
0x0F	Parameter is password-protected
0x10	Parameter write-protected • Parameter is write-protected at this time • Parameter write-protected, as cyclically configured in MDT • Parameter is write protected at this time, due to other settings (parameter, operation mode, drive enable…) • Procedure command at this time not executable (e.g., in this phase procedure command cannot be activated)
0x13	Parameter transmitted too short
0x15	Parameter transmitted too long
0x1F	• Procedure command already active • Procedure command not interruptible

Fig.4-119:   Error Codes and Their Significances at Parameter Access

Notes on Commissioning

In preparation

Diagnostic and Status Messages

Diagnostic Messages via Display

The diagnostic displays via LED (module status, network status), required according to EtherNet/IP™ specification, have been realized by the corresponding display messages and the network status LED.

Master Communication
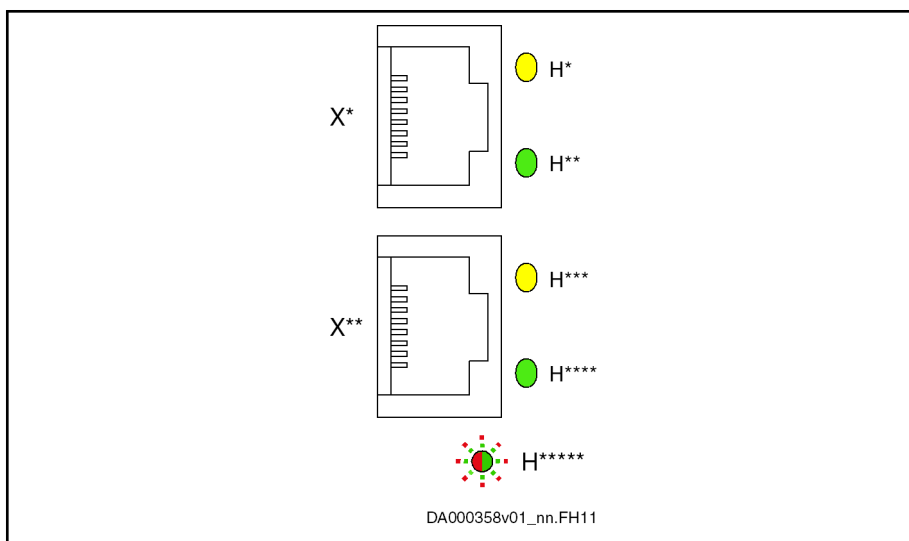
Fig.4-120:   ET, Display Elements

Display elements of the optional module ET:

- Two LEDs (H10, H11 and H12, H13) at each connection point
- One bicolor LED (H22)

The significance of the LED displays depends on the field bus system.

Module Status   As the EtherNet/IP[TM] functionality is not an individual module, the module status is covered by the error messages of the drive.

Network Status   The network status of the EtherNet/IP[TM] unit is displayed via the corresponding "network status LED".

LED	Significance	Color	Description
H10, H12	Status	On, yellow	Data transmission running
H11, H13	Link	On, green	Connection to the network available

Master Communication

LED	Significance	Color	Description
H22	Not active	○ Off	Interface has been switched off (24V supply) or has no IP address
	Not connected	Flashing green	Interface has received an IP address, but no connection
	Connected	On, green	Connection to the network available, data transmission running
	Timeout	Flashing red	Existing connection was aborted
	Invalid IP address	On, red	Assigned IP address is already used by another device
	Self test	Flashing red-green	After the device has been switched on, the interface performs a self test

Fig.4-121:   *EtherNet/IP^{TM} Display Elements*

Diagnostic Messages of IndraDrive

Diagnostic messages of IndraDrive and their significances in conjunction with EtherNet/IP^{TM} master communication:

- E4005 No command value input via master communication

  → The master is in the stop mode and the EtherNet/IP^{TM} stack thereby is in the status "IDLE" or the master has specifically aborted the I/O connection and the EtherNet/IP^{TM} stack thereby is in the status "CLOSED".

- F4009 Bus failure

  → The master hasn't received any telegram within the watchdog time. The watchdog time is calculated by the formula for the "timeout" time explained under 1.4.2.

DOK-INDRV*-MP*-08VRS**-AP01-EN-P   Bosch Rexroth AG   235/1183
Rexroth IndraDrive Firmware for Drive Controllers MPH-, MPB-, MPD-, MPC-08

Motor, Mechanical Axis System, Measuring Systems

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

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

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!

Diagnostic Data of Motor Operation

The firmware provides the option to collect dynamic operating data of the motor and store them in the motor or the controller (operating hours counter, thermal and mechanical operating data, operational performance).

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.

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- 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 clamping 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, 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

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

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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"!

☞ The 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 "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 "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

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- Allowed thermal effect on the machine design, etc.

If the temperature sensor has not been connected, this is detected by the motor temperature monitor, too.

Depending on the sensor type, motor temperature monitoring has the following states:

Thermal state	Motor temperature...	Message and reaction
Thermal range not allowed, temperature sensor possibly not connected.	... for 30 s ≤ -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 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, 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 S-0-0201 and S-0-0204!

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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 "P-0-0512, Temperature sensor". The respective resistance temperature characteristic then has to be input manually as a table of values in "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   Rexroth motors with the characteristic temperature sensor number "1" (MHD, MKD, MLP, MBT, MBS motors) or "4" (MKE motors):

→ No parameter settings regarding the temperature sensor are required!

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

→ An adjusted value has to be written to the following parameter during commissioning:

- S-0-0201, Motor warning temperature

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

→ The following parameters have to be replaced by an adjusted value during commissioning:

- 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 S-0-0201 has to be lower than the value of S-0-0204!

Activating/Deactivating the Function   The motor temperature monitoring is activated by entering the sensor type in "P-0-0512, Temperature sensor". The value "0" deactivates motor temperature monitoring.

When the function has been activated, the following diagnostic messages are possible:

- E2021 Motor temperature outside of measuring range
- E2051 Motor overtemp. prewarning
- F2019 Motor overtemperature shutdown
- F2021 Motor temperature monitor defective

Querying the current motor temperature (not in the case of the characteristic temperature sensor numbers "1" or "4"):

- S-0-0383, Motor temperature

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5.2   Rexroth Motors

5.2.1   Basics on Rexroth Motors

Brief Description

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 Ds/D/MLD" commissioning tool.

The motor parameter values determined by the manufacturer guarantee that the motor can be loaded in accordance with its operating characteristic, if the required current and the corresponding power are provided by controller and supply unit.

Thermal Motor Monitoring

Rexroth motors are thermally monitored by the controller and protected against overheating. For this purpose, the current motor temperature is determined by thermo sensors installed in the motor winding. Depending on temperature thresholds that can be set, the controller generates a warning or switches the motor off.

☞   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 lines have different measuring systems which allows offering cost-efficient motors depending on the application.

The following measuring systems are used:

● Encoders with sine signals (1 Vpp) and HIPERFACE® interface ● Encoders with sine signals (1 Vpp) and EnDat2.1 interface ● Encoders with sine signals (1 Vpp)

- Encoders with sine signals (1 Vpp) and HIPERFACE® interface
- Encoders with sine signals (1 Vpp) and EnDat2.1 interface
- Encoders with sine signals (1 Vpp)
- HSF ("high-resolution servo feedback"), single- or multi-turn type
- Resolver, single- or multi-turn type

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

- Encoders with sine signals (1 Vpp) and EnDat2.1 interface, Heidenhain standard

- Encoders with sine signals (1 Vpp) and HIPERFACE® interface [IndraDrive-compatible HIPERFACE® encoders (FAQ_IndraDrive_unterstützte_Geber...) or HIPERFACE® encoders with type ID "0xFF"]

- Encoders with sine signals, 1 Vpp, Heidenhain standard

- Hall sensor box and encoders with sine signals, 1 Vpp, Heidenhain standard (only for Rexroth linear kit motors)

- Hall sensor box and encoders with square-wave signals, TTL, Heidenhain standard (only for Rexroth linear kit motors)

Functional Description

Application-Dependent Motor Parameters for Asynchronous Motors

The Rexroth motor lines MAD and MAF are asynchronous motors. For asynchronous motors, a value adjusted to the application has to be written to "P-0-0532, Premagnetization factor".

The premagnetization factor influences the "magnetizing current" motor parameter:

$$\text{Effective magnetizing current} = \frac{(P\text{-}0\text{-}0532)}{100\ \%} \times (P\text{-}0\text{-}4004)$$

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.
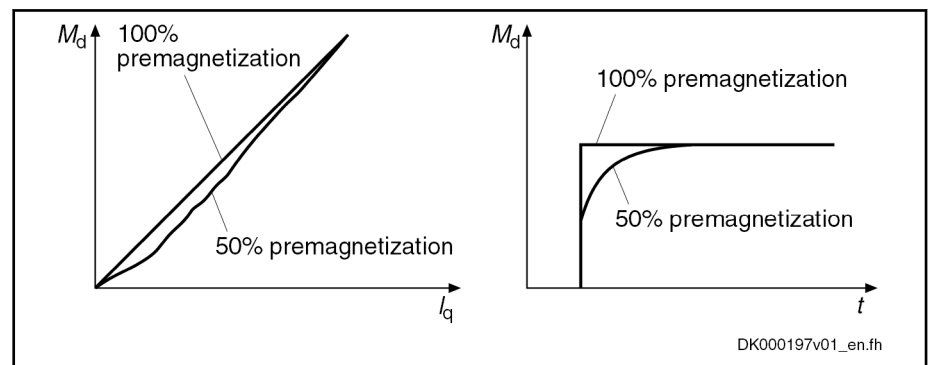
Md   Torque at the motor shaft
Iq   Torque-generating component of the motor current
Fig.5-3:   *Influence of the Premagnetization Factor on the Torque*

Notes on Commissioning

Parameter Values Made Available

For Rexroth motors, the manufacturer-side, motor-specific parameter values, such as

- motor parameters

- parameters of the measuring system

- parameters of the motor holding brake

- temperature sensor parameters

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can be automatically loaded from the encoder data memory, if available. Otherwise, they are loaded from a database via the "IndraWorks Ds/D/MLD" commissioning tool or input manually by means of a list (e.g., via the control terminal).

Setting the Premagnetization Factor

The following table contains the recommended setting for "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 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 (1MB, MAD, MAF), published by Rexroth, refer to a premagnetization of 100%.

       With lower values, you have to expect deviation from these data!

5.2.2   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, MSP, KSM
* MAD, MAF

☞   The Bosch motor of 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

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- 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 loop 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

- C0700 Load defaults proced. command (motor-spec. controller val.) (C07_0)
- 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.

During the initial commissioning of a drive, the error message "F2008 RL The motor type has changed." is shown first. 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"), "S-0-0262, C07_x Load defaults procedure command" is automatically started. Default control loop parameter values for this motor are thereby loaded.

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> ☞ Depending on the setting in "P-0-4090, Configuration for loading default values", 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 must be corrected!

Diagnostic Messages   In conjunction with the loading and verifying of parameter values from the encoder data memory, the following messages might possibly be generated:

- When the default control loop parameter values and the motor type parameter are loaded

  → C0700 Load defaults proced. command (motor-spec. controller val.) (C07_0)

- 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 motor does not have an encoder data memory:

- 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.

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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:

- Linear motor MLF
- Rotary motors MBS and MBT

As the motor is assembled in the machine, stator, rotor and measuring system can only be put together on site. The electric-magnetic-mechanical allocation of the synchronous motor is therefore only to be made on site. This is done by determining and setting the commutation offset.

> 💡 The measuring system should be realized with high resolution and as a motor encoder to be evaluated in absolute form (see also "Absolute Measuring Systems"). If it is necessary to use an incremental measuring system, 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)

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- **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 from a database via the "IndraWorks Ds/D/MLD" commissioning tool.

Premagnetization factor   A value adjusted to the application has to be written only to "P-0-0532, Premagnetization factor".

See section "Basics on Rexroth Motors"

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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 suppliers 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 their 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.

For the suitability test of the motor, keep the completed "Forms for Required Manufacturer-Side Motor Data" ready!

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

How to Commission?

The motor parameter values must be determined first (see section "Determining the Parameter Values for Motor and Motor Control"). The parameter values of motor control are calculated by means of a 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.

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5.3.3   Determining the Parameter Values of Third-Party Motors

General Information on How to Determine the Parameter Values

As Rexroth cannot make available parameter values for motor control of third-party motors, these values have to be determined before or during the commissioning of the third-party motor. The determination of these parameter values is supported by commands:

- Asynchronous motors
  - Recommendation:

    "C3200 Command Calculate motor data", drive-internal calculation of the values for the motor and motor control parameters from the type plate data

    "C3600 Command Motor data identification", optimization of the parameter values calculated via C3200 by experimentally supplying current and, if necessary, motor motion
  - Alternative:

    "C4600 Command Calculate motor control parameters", calculation of the motor and motor control parameters from motor-specific data (see forms for "Motor Parameters for Asynchronous Motors")

- Synchronous motors
  - Recommendation:

    "C3600 Command Motor data identification", drive-internal determination of the values for the motor and motor control parameters from few characteristic motor data by means of calculation, experimentally supplying current and, if necessary, motor motion
  - Alternative:

    "C4600 Command Calculate motor control parameters": Calculation of the motor and motor control parameters from motor-specific data (see forms for "Motor Parameters for Synchronous Motors")

The specific motor data must be made available by the motor manufacturer. To collect all required manufacturer-side data of the motor, use the appropriate forms to copy below.

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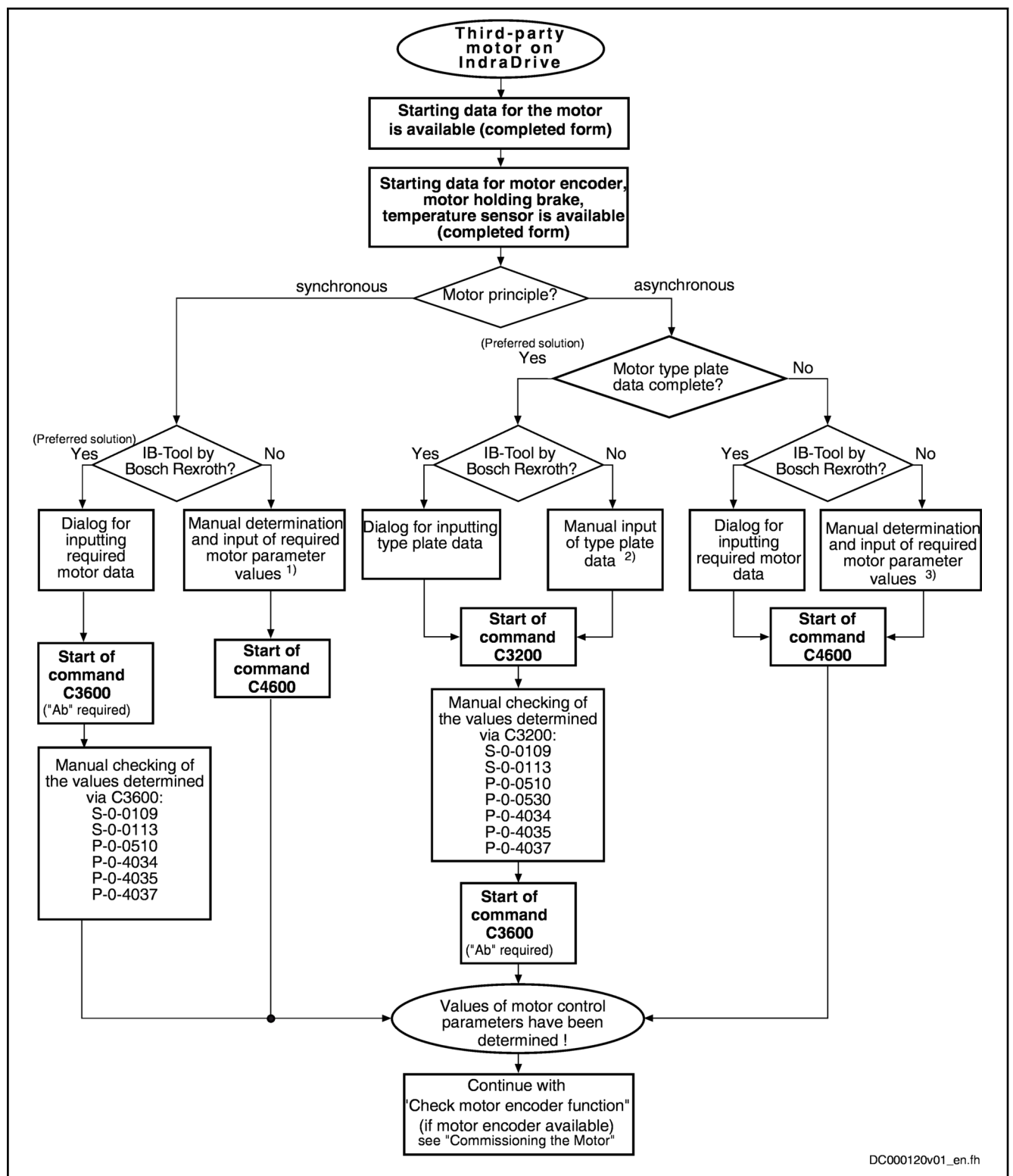
1)   According to form "Motor Parameters for Synchronous Motors"
2)   In parameter "P-0-4032, Motor type plate data"
3)   According to form "Motor Parameters for asynchronous Motors"
C-tool   Commissioning tool (e.g. IndraWorks Ds/D/MLD)
Fig.5-5:   *Determining the Values for the Motor Control Parameters*

For detailed explanations on the scope of functions of the mentioned commands see "Automatic Setting of Motor Control"!

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Determining the Motor Parameter Values for Manual Input (for Command C4600 as an Alternative Solution)

On the basis of the motor-specific data made available by the manufacturer, you have to determine the motor parameter values for third-party motors.

Procedure without "IndraWorks Ds/D/MLD"

The collection of the motor parameter values to be determined is supported by the forms "Motor Parameters for Synchronous Motors" and "Motor Parameters for Asynchronous Motors".

Procedure with "IndraWorks Ds/D/MLD"

If you use the "IndraWorks Ds/D/MLD" commissioning tool, the motor parameters, after the required data have been input (according to the completed form "Manufacturer-Side Data of Synchronous Motors" or "Manufacturer-Side Data of Asynchronous Motors"), are input by means of the corresponding dialog.

Type of Construction of Motor

The functional principle and type of the third-party motor has to be entered in parameter "P-0-4014, Type of construction of motor".

☞ In parameter P-0-4014, the bits for further settings have to be set to "0", because the respective functions generally cannot be used for third-party motors!

Number of Pole Pairs/Pole Pair Distance

Take the value for parameter "P-0-0018, Number of pole pairs/pole pair distance" from the completed form "Manufacturer-Side Data of Synchronous Motors" or "Manufacturer-Side Data of Asynchronous Motors".

Rotor Inertia

For the setting of parameter "P-0-0510, Rotor inertia" take the values from the completed form "Manufacturer-Side Data of Synchronous Motors" or "Manufacturer-Side Data of Asynchronous Motors".

Motor Peak Current

The rms value of the maximum allowed total motor current (magnetic-field-generating and torque-generating current) has to be set in parameter "S-0-0109, Motor peak current".

For asynchronous motors, there usually isn't any value given for the maximum allowed peak current.

☞ For synchronous motors, see manufacturer's specification for the value of the maximum allowed peak current.

If there hasn't any value been specified for the maximum allowed peak current, we recommend its limitation according to the following relationships for thermal reasons:

Rotary motors	$(S\text{-}0\text{-}0109) = f \times I_N$
Linear motors	$(S\text{-}0\text{-}0109) = f \times I_d$

S-0-0109   Motor peak current (rms value of maximum total motor current in A)
f   Safety factor 1.1 … 2.5
I_N Rated current (rms value in A)
I_d Continuous current at standstill (rms value in A)
Fig.5-6:   *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).

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$$\text{Rotary synchronous motors } (\text{S-0-0111}) = I_N$$
$$\text{Linear synchronous motors } (\text{S-0-0111}) = I_d$$

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*

$$\text{Rotary asynchronous motors } (\text{S-0-0111}) = I_N \times \cos\varphi$$

S-0-0111   Motor current at standstill (rms value)
I_N Rated current (rms value, acc. to motor data)
$\cos\varphi$ Power factor
Fig.5-8:   *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:

$$\text{Rotary synchronous motors } (\text{P-0-0051}) = \frac{M_N}{I_N}$$
$$\text{Linear synchronous motors } (\text{P-0-0051}) = \frac{F_N}{I_d}$$

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*

$$\text{Rotary asynchronous motors } (\text{P-0-0051}) = \frac{M_N}{I_N \times \cos\varphi}$$

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)
$\cos\varphi$ Power factor
Fig.5-10:   *Calculating the Value of Parameter P-0-0051 for Asynchronous Motors*

Stator Resistance   Calculating the value of parameter "P-0-4048, Stator resistance":

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$$(\text{P-0-4048}) = (R_{\text{U-V}} + 2 \times R_{\text{Dr}} + 2 \times R_{\text{Lt}})$$

P-0-4048	Stator resistance (total resistance of the connected motor in Ω)
$R_{\text{U-V}}$	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 "IndraWorks Ds/D/MLD" commissioning tool supports the input of the motor parameter values of third-party motors by means of the forms "Manufacturer-Side Data of Synchronous Motors" and "Manufacturer-Side Data of Asynchronous Motors" completed by the motor manufacturer!

Manual Input of the Motor Parameter Values for Synchronous Motors (for Command C4600 as an Alternative Solution)

Based on the motor-specific data made available by the manufacturer, the motor parameter values specific to synchronous motors are determined.

Direct-Axis Inductance of Motor and Quadrature-Axis Inductance of Motor

For motors with reluctance property, different values are observed when the inductance is measured, depending on the position of the primary part of the motor with regard to the secondary part of the motor. The values are fluctuating between a minimum and a maximum value:

● The minimum value is relevant to the direct-axis inductance of the motor.

● The maximum value is relevant to the quadrature-axis inductance of the motor.

💡   Even if the reluctance property of synchronous third-party motors cannot be used (respective bit in parameter "P-0-4014, Type of construction of motor" must not have been set!), it is advantageous to use the mentioned values for current control!

Direct-Axis Inductance of Motor

To determine the parameter value for "P-0-4016, Direct-axis inductance of motor", use the minimum value of motor inductance for calculation, as indicated in the completed form "Manufacturer-Side Data of Synchronous Motors":

$$(\text{P-0-4016}) = L_{\text{(U-V)min}} \times 0{,}5$$

P-0-4016	Direct-axis inductance of motor
$L_{\text{(U-V)min}}$	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":

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$$(P\text{-}0\text{-}4017) = L_{(U\text{-}V)max} \times 0{,}5$$

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*

Charact. of Quadrature-Axis Induct. 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

Charact. 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 (Value with Smaller Absolute Value has to be Entered with Negative Sign in Parameter P-0-4005)*

☞   By menu prompt via dialogs, the "IndraWorks Ds/D/MLD" commissioning tool supports the input of the motor parameter values of synchronous third-party motors by means of the form "Manufacturer-Side Data of Synchronous Motors" completed by the motor manufacturer!

Manual Input of the Motor Parameter Values for Asynchronous Motors (for Command C4600 as an Alternative Solution)

Based on the motor-specific data made available by the manufacturer, the motor parameter values specific to asynchronous motors can also be manually determined.

Magnetizing Current

The value for parameter "P-0-4004, Magnetizing current" is the rms value of the motor magnetizing current:

$$(P\text{-}0\text{-}4004) = I_{Mag}$$

P-0-4004	Magnetizing current (rms value in A)
I_{Mag}	Indicated magnetizing current (rms value in A)

Fig.5-15:   *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:

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$$(P\text{-}0\text{-}4004) = \sqrt{1 - (\cos \varphi)^2} \times I_N$$

P-0-4004	Magnetizing current (rms value in A)
I_N	Rated current of the motor (rms value in A)
cos φ	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 Parameters P-0-4039, P-0-4040 and P-0-4041 acc. to Manufacturer's Specification

DF000236v01_nn.fh
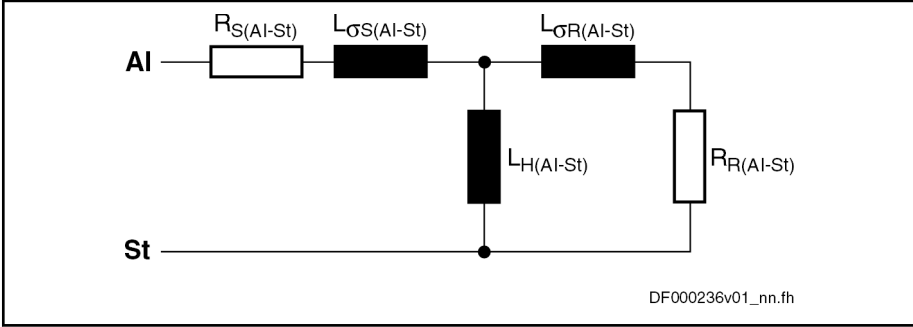
Al	Outer conductor
St	Star point
$R_{S(Al\text{-}St)}$	Ohmic resistance of stator at 20°C
$R_{R(Al\text{-}St)}$	Ohmic resistance of rotor at 20°C
$L_{\sigma S(Al\text{-}St)}$	Leakage inductance of stator
$L_{\sigma R(Al\text{-}St)}$	Leakage inductance of rotor
$L_{H(Al\text{-}St)}$	Motor magnetizing inductance

Fig.5-18:   Equivalent Circuit Diagram of Asynchronous Machine, Single-Phase, with Star Point Reference

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Characteristic of Motor Magnetizing Inductance

List parameter "P-0-4042, Characteristic of motor magnetizing inductance":

→ Unless otherwise specified, enter the value "1,0" in each of the five lines

Rotor Time Constant

Take the value for parameter "P-0-4043, Rotor time constant" from the completed form "Manufacturer-Side Data of Asynchronous Motors".

If the value is not available, it can be calculated by means of approximation:

$$(\text{P-0-4043}) = \frac{L_{\sigma R(\text{Al-St})} + L_{H(\text{Al-St})}}{R_{R(\text{Al-St})}} = \frac{(\text{P-0-4040}) + (\text{P-0-4041})}{R_{R(\text{Al-St})}}$$

P-0-4043	Rotor time constant (in ms)
$L_{H(\text{Al-St})}$	Motor magnetizing inductance
$R_{R(\text{Al-St})}$	Ohmic resistance of rotor at 20°C
$L_{\sigma R(\text{Al-St})}$	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 "IndraWorks Ds/D/MLD" commissioning tool supports the input of the motor parameter values of asynchronous third-party motors by means of the form "Manufacturer-Side Data of Asynchronous Motors" completed by the motor manufacturer!

☞   For project planning and commissioning of a third-party motor the required, manufacturer-specific motor data must always be available!

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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_{rms}	
Rated speed or rated velocity [1]	n_N / v_N	min^{-1} / m/min	
Rated voltage	U_N	V_{rms}	
Continuous current at standstill [1]	I_d	A_{rms}	
Inertia or mass	J / m	_	
Rated force [1]	F_N	N	
Allowed maximum current (magn. saturation effects?)	I_{max}	A_{rms} (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 (see "Limitations")	T_{Motor}	min	
Thermal time constant of winding (see "Limitations")	$T_{Winding}$	s	
Thermal short-time overload of winding (see "Limitations")	$k_{Overload}$	--	
Type of construction of motor (rotary/linear)	--	--	
Type of winding (distributed winding/toothed winding)	--	--	
Winding body material (iron/ironless)	--	--	

1)   Only for linear motor

Fig.5-20:   Motor Data of Synchronous Motors

_____   _____   _____
Name   Date   Signature

☞   Take form "Manufacturer-Side Data of Motor Temperature Sensor, Motor Encoder and Motor Holding Brake" into account, too!

Motor, Mechanical Axis System, Measuring Systems

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 $_{rms}$	
Power factor [1]	cos φ	--	
Magnetizing Current	I_{Mag}	A $_{rms}$	
Rated speed [1]	n_N	min^{-1}	
Rated frequency [1]	f_N	Hz	
Rated voltage [1]	U_N	V_{rms}	
Inertia	J	_	
Maximum speed	n_{max}	min^{-1}	
Number of pole pairs	PPZ	--	
Insulation class	Isol.Kl.	--	
Motor inductance (minimum/maximum/average value)	$L_{U-V, min}/L_{U-V, max}/L_{U-V}$	mH	
Stator leakage inductance [2]	$L_{\sigma S(Al-St)}$	mH	
Rotor leakage inductance [2]	$L_{\sigma R(Al-St)}$	mH	
Motor magnetizing inductance [2]	$L_{H(Al-St)}$	mH	
Stator resistance (20°C) [2]	$R_{S(Al-St)}$	Ω	
Rotor resistance (20°C) [2]	$R_{R(Al-St)}$	Ω	
Rotor time constant [2]	T_R	ms	
Winding resistance (20°C)	R_{U-V}	Ω	
Allowed periodic peak voltage	$\hat{u}_{max\_zul.}$	$V_{pp/2}$	
Allowed rate of rise of voltage	$du/dt_{zul.}$	kV/µs	
Cooling type (without/with blower, liquid cooling)	--	--	
Thermal time constant of motor (see "Limitations")	T_{Motor}	min	
Thermal time constant of winding (see "Limitations")	$T_{Winding}$	s	
Thermal short-time overload of winding (see "Limitations")	$k_{Overload}$	--	
Type of construction of motor (rotary/linear)	--	--	
Does rotor/secondary part have closed slots?	--	Yes/no	

1)	Data on type plate of rotary motor	
2)	Helpful but not obligatory data	
Fig.5-21:	*Motor Data of Asynchronous Motors*	

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Name	Date	Signature

☞   Take form "Manufacturer-Side Data of Motor Temperature Sensor, Motor Encoder and Motor Holding Brake" into account, too!

Form for Manufacturer-Side Data of Motor Temperature Sensor, Motor Encoder and Motor Holding Brake

Temperature sensor data

PTC? NTC? Switch contact?	
Type designation?	
How many and where installed?	
Characteristics available?	

Fig.5-22:   *Data of Temperature Sensor*

Motor encoder data (if available)

Type/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	kgm²/kg	
Clamping delay	ms	
Release delay	ms	
Mass	kg	

Fig.5-24:   *Data of Motor Holding Brake*

Name	Date	Signature

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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 as an Alternative Solution)".

Manufacturer, Motor type: _____   Customer, Installation, Axis designation: _____

Parameter IDN	Parameter name	Input value	Unit
P-0-4014	Type of construction of motor		
P-0-0018	Number of pole pairs/pole pair distance		PPZ / mm
P-0-0510	Rotor inertia		(Scaling-dependent)
S-0-0109	Motor peak current		A
S-0-0111	Motor current at standstill		A
S-0-0113	Maximum motor speed		(Scaling-dependent)
P-0-0051	Torque/force constant		(Scaling-dependent)
P-0-4048	Stator resistance		Ω
P-0-4016	Direct-axis inductance of motor		mH
P-0-4017	Quadrature-axis inductance of motor		mH
P-0-4002	Charact. of quadrature-axis induct. of motor, inductances	[0] [1] [2] [3]	
P-0-4003	Charact. of quadrature-axis inductance of motor, currents	[0] [1] [2] [3]	
P-0-4005	Flux-generating current, limit value		A

Fig.5-25:   Motor Parameters for Synchronous Motors

Form "Motor Parameters for Asynchronous Motors"

☞ After having entered the data from the type plate (in P-0-4032) and executed the command C3200, the parameter values contained in this list are automatically determined. If you want to enter the data manually, determine the values according to the description in the section "Determining the Motor Parameter Values for Manual Input (for Command C4600 as an Alternative Solution)".

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Manufacturer, Motor type: _____ Customer, Installation, Axis designation: _____			
Parameter IDN	Parameter name	Input value	Unit
P-0-4014	Type of construction of motor		--
P-0-0018	Number of pole pairs/pole pair distance		PPZ / mm
P-0-0510	Rotor inertia		(Scaling-dependent)
S-0-0109	Motor peak current		A
S-0-0111	Motor current at standstill		A
S-0-0113	Maximum motor speed		(Scaling-dependent)
P-0-0051	Torque/force constant		(Scaling-dependent)
P-0-4048	Stator resistance		Ω
P-0-4004	Magnetizing current		A
P-0-4036	Rated motor speed		1/min
P-0-4039	Stator leakage inductance		mH
P-0-4040	Rotor leakage inductance		mH
P-0-4041	Motor magnetizing inductance		mH
P-0-4042	Characteristic of motor magnetizing inductance	[0] [1] [2] [3] [4]	
P-0-4043	Rotor time constant		ms

Fig.5-26:   Motor Parameters for Asynchronous Motors

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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 "IndraWorks Ds/D/MLD" commissioning tool simplifies the commissioning of third-party motors.

See also "Commissioning Motors"

Basic Commissioning Steps for Third-Party Motors   The commissioning of a third-party motor (synchronous or 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 motors with motor encoder (closed-loop operation), make the settings in the corresponding parameters:

   •   S-0-0116, Resolution of feedback 1
   •   S-0-0277, Position feedback 1 type

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- P-0-0074, Encoder type 1 (motor encoder)

3. Settings for motor temperature sensor and motor temperature model have to be made in the corresponding parameters:
   - S-0-0201, Motor warning temperature
   - S-0-0204, Motor shutdown temperature
   - P-0-0512, Temperature sensor
   - P-0-4034, Thermal time constant of winding
   - P-0-4035, Thermal time constant of motor
   - P-0-4037, Thermal short-time overload of winding

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
   - standard control panel or of the small operator terminal (optional additional component).

Synchronous Third-Party Motors

After the basic commissioning steps (1 to 4; see above), there are further steps required for synchronous third-party motors:

1. The following motor data have to be entered in motor parameters by means of completed form " Form for Manufacturer-Side Data of Synchronous Motors":
   - P-0-0018, Number of pole pairs/pole pair distance
   - P-0-4036, Rated motor speed
   - S-0-0111, Motor current at standstill

2. Afterwards, start drive-internal determination of motor and motor control parameters with "P-0-0565, C3600 Command Motor data identification". For this purpose, drive must be in "ready for power output" state ("Ab").

☞ The command C3600 can be configured for turning motors or motors in standstill (P-0-0601, Configuration motor data identification). If necessary, the motor is actively put into rotation. This increases the precision of the determined values.

3. By executing command C3600, some parameters are set to default values, as they require data that cannot be identified by the command. Before continuing commissioning of drive, these parameters have to be checked and, if necessary, set to correct value by means of data of completed form:
   - S-0-0109, Motor peak current
   - S-0-0113, Maximum motor speed
   - P-0-0510, Rotor inertia

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- P-0-4034, Thermal time constant of winding
- P-0-4035, Thermal time constant of motor
- P-0-4037, Thermal short-time overload of winding

Initial commissioning for initial start of motor can now be continued.

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

When synchronous third-party motors are operated in "field-oriented current control (FOC, with motor encoder)", it is obligatory that you set the commutation offset before the initial start. In this case, the motor is only operational and safe to operate when the commutation offset has been set correctly!

See also "Commutation Setting"

If the procedure with C3600 does not result in operational motor and motor control parameters, the procedure with C4600 can be used as an alternative. For this purpose, the completed form "Motor Parameters for Synchronous Motors" must be available!

If the motor ultimately is not operational, carry out the "validation check" (C3600, P-0-0601). During this procedure, the controller checks whether the motor and the motor encoder match and it checks their rotational direction.

Asynchronous Third-Party Motors

After the basic commissioning steps (1 to 4; see above), there are further steps required for asynchronous third-party motors:

1. Rated data according to completed form or type plate have to be entered in "P-0-4032, Motor type plate data" (data can already be entered in communication phase "P2").

2. With "P-0-4033, C3200 Command Calculate motor data", start calculation of values of motor and motor control parameters.

3. Then optimize parameter values calculated via command C3200 with "P-0-0565, C3600 Command Motor data identification". To do this, put drive in "ready for power output" state ("Ab"); then start command.

The command C3600 can be configured for turning motors or motors in standstill. If necessary, the motor is actively put into rotation. This increases the precision (P-0-0601, Configuration motor data identification) of the determined values.

---

4. By executing command C3200, some parameters are set to default values, as they require data that cannot be identified by the command. Before continuing commissioning of drive, these parameters have to be checked and, if necessary, set to correct value by means of data of completed form:

- S-0-0109, Motor peak current
- S-0-0113, Maximum motor speed
- P-0-0510, Rotor inertia
- P-0-0530, Slip increase
- P-0-4034, Thermal time constant of winding
- P-0-4035, Thermal time constant of motor
- P-0-4037, Thermal short-time overload of winding

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Initial commissioning for initial start of motor can now be continued. See Commissioning Motors: "Initial Start with the Commissioning Tool"

☞   If the procedure with C3200, C3600 does not result in operational motor and motor control parameters, the procedure with C4600 can be used as an alternative. For this purpose, the completed form "Motor Parameters for Asynchronous Motors" must be available!

If the motor ultimately is not operational, carry out the "validation check" (C3600, P-0-0601). During this procedure, the controller checks whether the motor and the motor encoder match and it checks their rotational direction.

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.

NOTICE	Holding brakes at Rexroth motors normally are not 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 clamping 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. Power supply is realized by the controller via the 24V control voltage. The holding brake must be suited for the voltage that is output, the holding brake current 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 must be controlled separately.

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☞   The optionally available holding brakes of Rexroth motors can be directly controlled via the controller!

Pertinent Parameters	

Pertinent Parameters

- S-0-0206, Drive on delay time
- S-0-0207, Drive off delay time
- S-0-0273, Maximum drive off delay time
- P-0-0525, Holding brake control word
- P-0-0539, Holding brake status word
- P-0-0540, Torque of holding brake
- P-0-0542, C2000 Command Release holding brake
- P-0-0543, C3800 Command Apply holding brake

Pertinent Diagnostic Messages

- C2000 Command Release motor holding brake
- C2001 Command not enabled
- C3800 Command Apply motor holding brake
- F6024 Maximum braking time exceeded

Functional Description

With IndraDrive it is possible to control both self-releasing (electrically clamping) and self-clamping (electrically releasing) motor holding brakes. The controller is informed of the brake type via the respective bit in "P-0-0525, Holding brake control word".

Releasing the Holding Brake

When drive enable (AF = "Antriebsfreigabe") is set by the control unit, the releasing of the holding brake is activated. The brake is released with a delay, due to the inductance of the brake winding. The controller is informed of this delay via "S-0-0206, Drive on delay time".

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"

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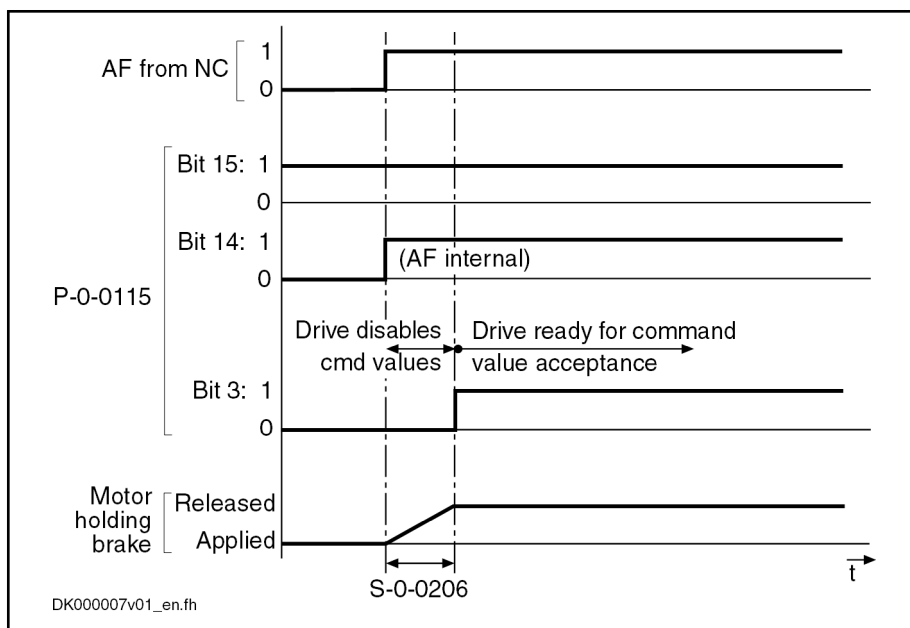
Fig.5-28:   Time Response when Releasing the Holding Brake

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 of this delay via "S-0-0207, Drive off delay time".

In order to avoid, for example, that a non-equilibrated vertical axis in standstill moves down because of the force due to weight, "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 of this time via parameter "S-0-0273, Maximum drive off delay time".

☞   The "maximum drive off delay time" is the time that the drive needs 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" was set as the error reaction (F2xxx, F4xxx, F6xxx error or NC-side drive enable reset in the case of axis motion).

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Error Situation 2

- Drive defect (F8xxx error) or "torque or force disable of the motor ("coasting")" was set as the error reaction (F2xxx, F4xxx, F6xxx error or NC-side rive enable reset in the case of axis motion).

☞ The error reaction is set in parameter "P-0-0119, Best possible deceleration".

Errors can possibly cause damage to machines or drive components. Depending on the application, the following strategies are used to minimize damage:

Holding Brake Control for Servo Drives

In the case of servo drives that mostly drive linear axes with limited travel distances, the protection of the machine is preferred to the drive in the case of error situation 2. The controller, according to the setting made by the customer (in "P-0-0525, Holding brake control word"), therefore tries to realize the shortest possible braking distances, even if this damages the holding brake.

Holding Brake Control for Main Drives

Main drives are rotary axes with "unlimited" travel distance, such as spindle motors of milling and turning machines. Due to high speed and high inertia most of these axes produce kinetic energies in operation that often exceed the allowed energy absorption capacity of holding brakes integrated in the motor. In the case of error situation 2, shutdown realized by the holding brake only could destroy the brake very easily. Due to the unlimited travel distance there normally isn't any danger of damaging the machine. The controller therefore, when determined by the customer (P-0-0525), prevents the holding brake from applying and gives priority to friction braking.

Parameter "P-0-0525, Holding brake control word"

The required functionality of the holding brake, depending on the application type of the drive (servo or main drive), is determined by the respective bit in parameter P-0-0525.

Holding Brake Control with Error Situation 1

If the drive cannot shut down the mechanical system within the time after occurrence of the error entered in parameter S-0-0273, the motor holding brake is applied after motor standstill, independent of the application (servo or main drive).

Depending on the error reaction, motor standstill means:

- Falling below a velocity threshold (in the case of "velocity command value reset" error reaction, with or without ramp)
- Target position reached and actual velocity value lower than the value of "S-0-0124, Standstill window"

See also "Error Reactions"

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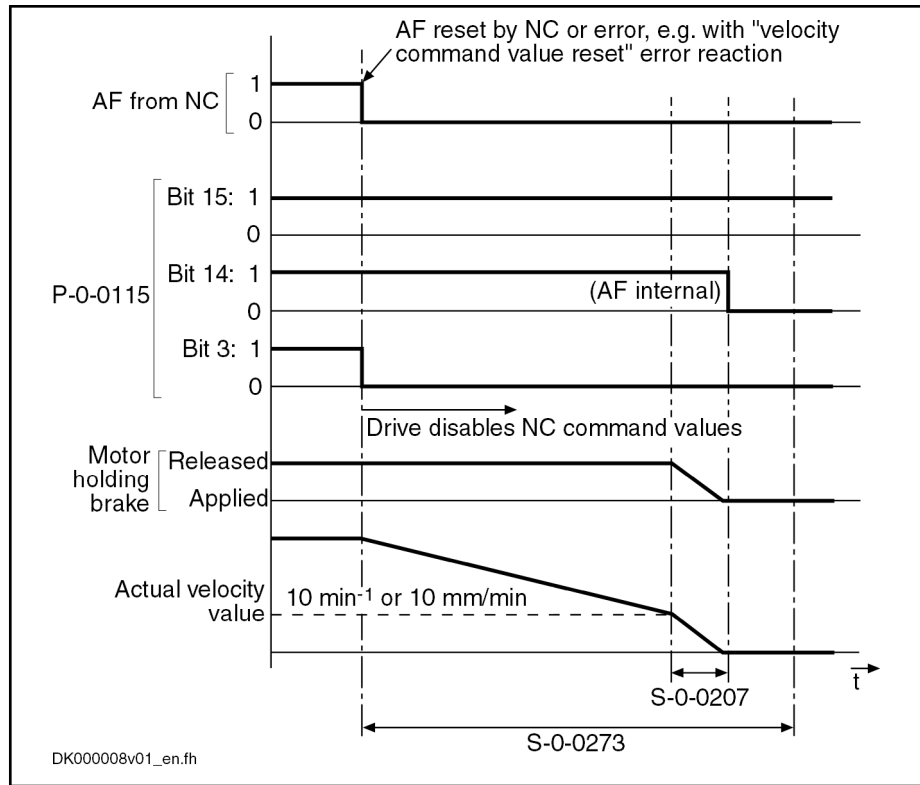
Fig.5-29:   *Holding Brake Control with Error Situation 1 and Braking*
            Time < S-0-0273 (Error Reaction "Velocity Command Value Reset")

If the drive cannot shut down the mechanical system within the time after oc-
currence of the error entered in parameter S-0-0273, the motor holding brake
is controlled depending on the application (servo or main drive):

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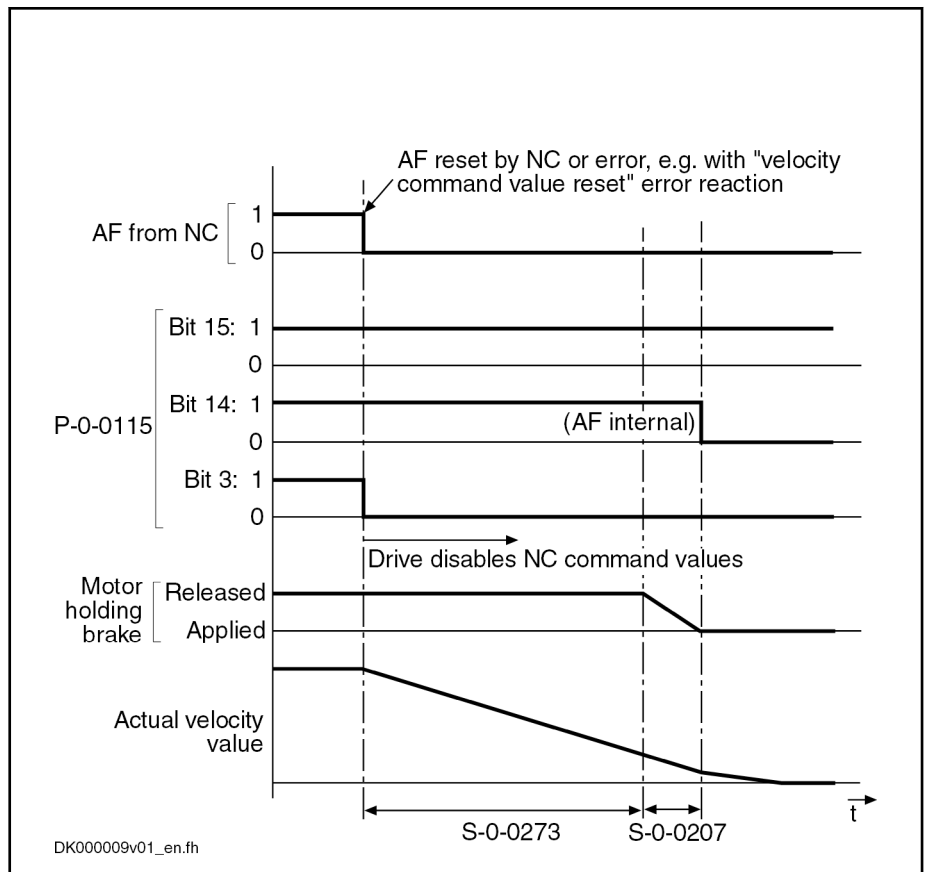
Fig.5-30:   Holding Brake Control with Error Situation 1 and Braking Time > S-0-0273 for Servo Drives
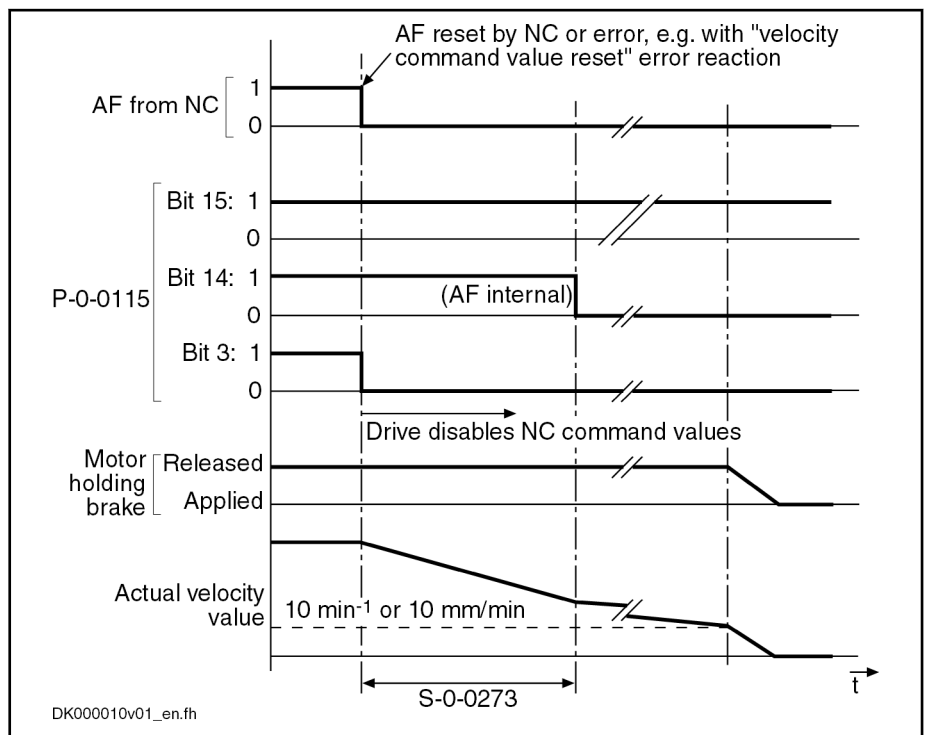
Fig.5-31:   Holding Brake Control with Error Situation 1 and Braking Time > S-0-0273 for Main Drives

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Holding Brake Control with Error Situation 2

In the case of error situation 2, the drive becomes torque-free or force-free after the error event. The braking effect, in addition to the axis friction, can only be achieved by means of the holding brake. To limit the damage the holding brake is controlled depending on the application (servo or main drive).
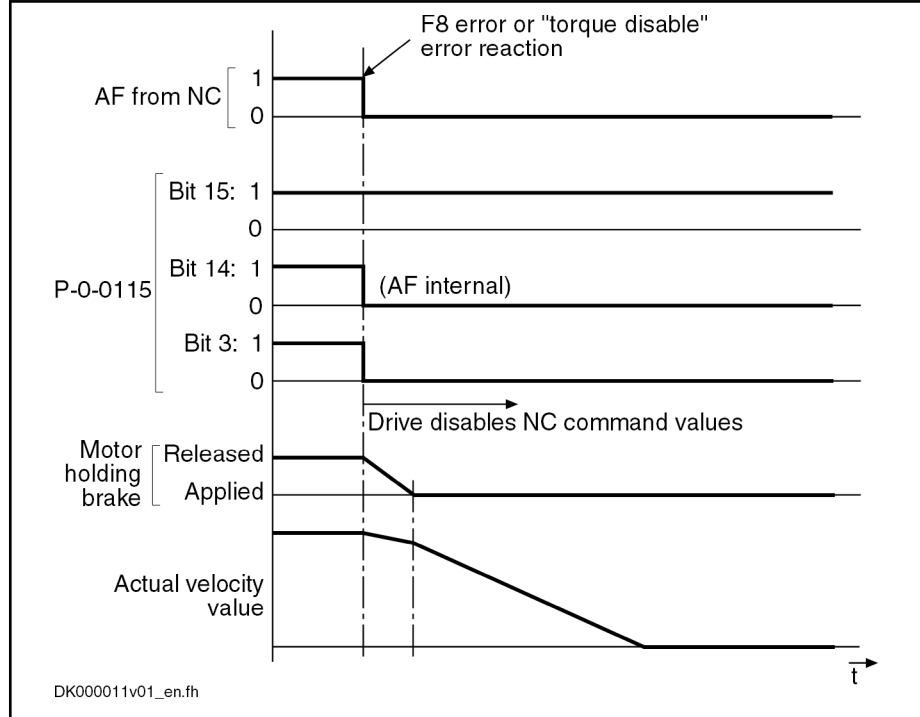
Fig.5-32:   *Holding Brake Control with Error Situation 2 for Servo Drives*
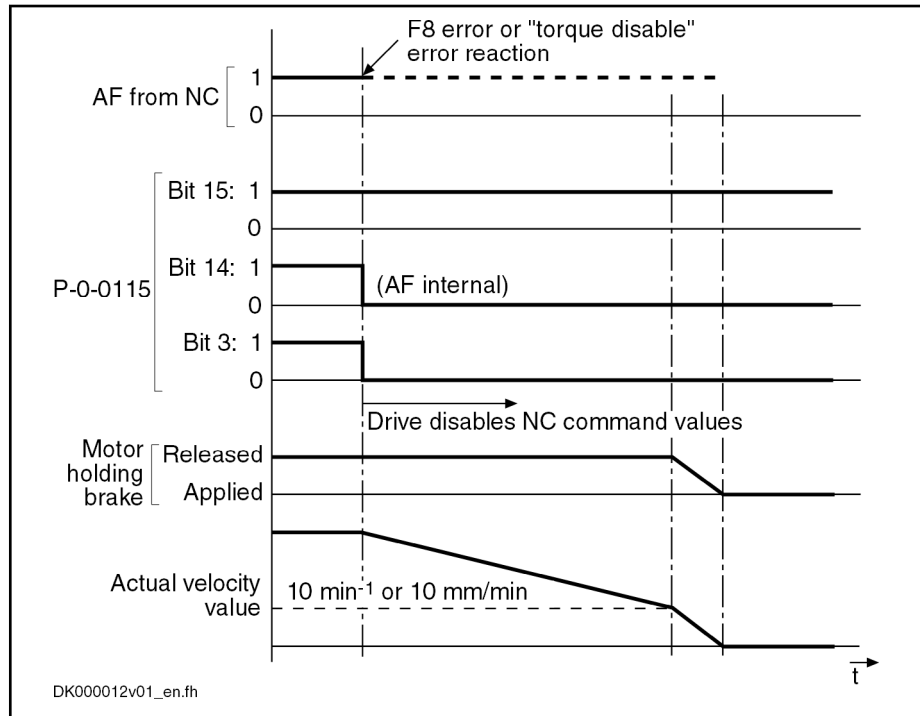
Fig.5-33:   *Holding Brake Control with Error Situation 2 for Main Drives*

"Release Holding Brake" Command

In special cases, it can be convenient to release the holding brake even if the drive is not in "AF" (drive enable). This is possible by activating "P-0-0542,

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C2000 Command Release holding brake". This command, however, must firstly be enabled by the respective bit in "P-0-0525, Holding brake control word"!

NOTICE	Property damage caused by movement of non-equilibrated axes when releasing the holding brake!

⇒ Before starting the command, move the axis to a noncritical position!

Upon completion of the command, the brake is applied again. When drive enable is set and then reset with the command being active, the holding brake is applied again when resetting "AF" (drive enable)!

☞ The command for releasing the holding brake can also be started via the control panel, when the corresponding bit has been set in parameter "P-0-0525, Holding brake control word".

"Apply Holding Brake" Command

In special cases, it can be convenient to apply the holding brake if the drive is in an active state ("AF", drive enable). This is possible by activating "P-0-0543, C3800 Command Apply holding brake"!

NOTICE	Damage to the holding brake!
	If the axis is moved with the holding brake applied, the brake can become prematurely worn!

⇒ In case of doubt start "P-0-0541, C2100 Holding system check command"!

Influence of Drive Enable on Command "Apply Holding Brake"

If drive enable ("AF") is reset and set again when the command is active, the brake releases when drive enable is set although the command is still active!

When the command is completed, the brake releases again if the drive is still active ("AF").

When the command is completed, the brake remains applied if drive enable was reset during the execution of the command!

Notes on Commissioning

Relevant Parameters

Enter application-dependent parameter values:

- S-0-0273, Maximum drive off delay time

In this parameter, enter the determined time that the drive needs in order to stop the axis out of maximum velocity at maximum inertia or inertial mass with maximum allowed brake torque or brake force. If necessary, increase the determined time to make sure the axis really stops!

NOTICE	Danger of damaging the motor brake when value in S-0-0273 is too low!

⇒ The value for "S-0-0273, Maximum drive off delay time" must always be set higher than the time needed to decelerate the axis by velocity command value reset (if necessary with ramp), taking the maximum possible velocity into account.

Enter data of holding brake:

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- 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 database of the "IndraWorks Ds/D/MLD" 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.

"Release Holding Brake" Command The control unit can release the holding brake by means of the following command:

- P-0-0542, C2000 Command Release holding brake

NOTICE	Property damage caused by movement of non-equilibrated axes when releasing the holding brake!

⇒ Before starting the command, move the axis to a noncritical position!

"Apply Holding Brake" Command The control unit can apply the holding brake by means of the following command when the drive is active:

- P-0-0543, C3800 Command Apply holding brake

NOTICE	Damage to the holding brake!
	If the axis is moved with the holding brake applied, the brake can become prematurely worn!

⇒ In case of doubt start "P-0-0541, C2100 Holding system check command"!

Operating Status Displaying the operating status:

- P-0-0539, Holding brake status word

Signaling the readiness to accept command values:

- S-0-0135, Drive status word

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 installa-

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tions. 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 13849-1, cat. 2 or dynamization/check of one of two redundant holding systems according to EN 13849-1, cat. 3.

In the case of corrosion, the effectiveness of the holding brake can be re-established by a drive-controlled "resurfacing procedure".

Pertinent Parameters	- P-0-0525, Holding brake control word
	- P-0-0526, Displacement during brake check
	- P-0-0539, Holding brake status word
	- P-0-0540, Torque of holding brake
	- P-0-0541, C2100 Holding system check command
	- P-0-0544, C3900 Command Holding brake resurfacing
	- P-0-0545, Test torque for releasing holding system
	- P-0-0546, Starting torque for releasing holding system
	- P-0-0547, Nominal load of holding system
	- P-0-0549, Oper. hours control sec. at last succ. holding system check
	- P-0-0550, Time interval holding system check
	- P-0-0551, Current load torque
	- P-0-0553, Test torque factor for brake check
	- P-0-0554, Current torque value of the motor holding brake
Pertinent Diagnostic Messages	- C2100 Command Holding system check
	- C2101 Holding system check only possible with drive enable
	- C2103 Holding brake: Torque too low
	- C2104 Command execution impossible
	- C2105 Load of holding system greater than test torque
	- C2106 Test torque of holding system not reached
	- C2108 Error when releasing the holding system
	- C3900 Command Holding brake resurfacing
	- C3901 Resurfacing of holding brake only possible with drive enable
	- C3902 Error during resurfacing of holding brake
	- C3903 Command execution impossible
	- E2069 Holding brake torque too low
	- E3115 Prewarning, end of brake check time interval
	- F2069 Error when releasing the motor holding brake
	- F3115 Brake check time interval exceeded

Functional Description

Monitoring the Holding Brake   The controller can check the effectiveness of the holding brake and its released state by starting a routine:

- Automatically each time drive enable is set and reset

- or -

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- Depending on the situation via "P-0-0541, C2100 Holding system 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 holding system" (described in the Notes on Commissioning for function check of holding brake).

If the test was successful, the drive starts operations.

☞   When the safety function "Safe braking and holding system" is active, the automatic monitoring function is not available, the holding system check must always be carried out via the command "P-0-0541, C2100 Holding system check command".

If the motor does not move during this test, 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 is set with the parameters "P-0-0547, Nominal load of holding system" and "P-0-0553, Test torque factor for brake check". The value for the nominal load "P-0-0547, Nominal load of holding system" can be determined during initial commissioning. (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 Holding 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

The check can be made in both force directions or in one preselected direction only. This can be preselected in parameter "P-0-0525, Holding brake control word".

☞   To test the displacement during the brake check, the encoder selected by "S-0-0520, Axis control word" is used. To check the motor brake, the motor encoder should be used. The actual displacement during the brake check is recorded in "P-0-0526, Displacement during brake check".

⚠ CAUTION	Possible property damage caused by vertical axis moving down!

⇒ Take constructional precautions!

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"Brake Check" Command

The brake is monitored every time drive enable is switched on and off which considerably delays this procedure. Therefore, it is normally better to activate the monitoring function only via the command. When "P-0-0541, C2100 Holding system check command" is started, the drive must be in "AF". Freedom of movement and the required holding torque are monitored in direct succession.

When the safety function "Safe braking and holding system" is active, the brake check parameters are set by the safety technology parameterization. This means that it is not the standard parameters which take effect, but:

- "P-0-3303, SBS: Nominal load" replaces "P-0-0547, Nominal load of holding system"
- "P-0-3310, SBS: Travel range brake check" replaces the fixed range of 2 degrees
- "P-0-3311, SBS: Duration test torque injection brake check" replaces the fixed duration of the test torque injection
- "P-0-3316, SBS: Test torque factor motor holding brake" replaces "P-0-0553, Test torque factor for brake check"

The routine corresponds to that of automatic monitoring (see above).

Detection of Wear

To increase the availability of the axis and detect wear or defects of the holding system at an early stage, the following value must be determined:

- The presently maximum holding torque of the brake

or

- The maximum distance by which the axis was moved with the holding brake applied

For this purpose, the following data are determined during the holding system check and made available to the user:

- "P-0-0546, Starting torque for releasing holding system": Evaluating this parameter allows detecting at an early stage whether the friction of the axis has increased, or whether the holding brake is still entirely released. To evaluate "P-0-0546, Starting torque for releasing holding system", the value of the error-free axis must be determined during initial commissioning.
- "P-0-0526, Displacement during brake check": This parameter indicates the distance by which the axis moved during the holding system check with the holding brake applied. (The movement is recorded separately for each direction and each brake (with the safe braking and holding system)). As holding brake wear increases, this erroneous distance will increase. To evaluate P-0-0526, the value of the error-free axis must be determined during initial commissioning.
- "P-0-0554, Current torque value of the motor holding brake": This parameter displays the torque which the holding brake held during the holding system check. To determine the current maximum holding torque of the holding brake, the factor in "P-0-0553, Test torque factor for brake check" can be increased. In this case, the drive in P-0-0554 records the torque starting from which the holding brake no longer holds the axis.

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> 💡 When the safe braking and holding system is used, the monitoring of the holding system is derived from the safety technology parameterization and mustn't be changed after safety technology acceptance test. To temporarily increase the test torque for detection of wear, the test torque factor P-0-0553 can be added to one of the two brakes via the "P-0-3212, Safety technology control word, channel 1".

Load Torque Monitoring

Within the scope of the holding system check, the current load torque of the axis is determined and displayed in "P-0-0551, Current load torque". If the determined load torque is greater than the test torque for the holding system check, the holding system check is aborted with the command error "C2105 Load of holding system greater than test torque".

Time Interval of Holding Brake Check

At the activation of the time interval for brake check (in parameter "P-0-0525, Holding brake control word"), the interval since the last successful brake check is measured and compared to the value of parameter "P-0-0550, Time interval holding system check". The monitoring function with regard to this value might possibly generate the following messages:

- If the measured interval draws up to 15 min nearer to the interval set in parameter P-0-0550, the warning "E3115 Prewarning, end of brake check time interval" is output.

- If the measured interval exceeds the value in parameter P-0-0550, the error message "F3115 Brake check time interval exceeded" is generated.

> ☞ The output of the warning "E3115" and of the error "F3115" can be deactivated in the parameter "P-0-0525, Holding brake control word". In this case, only the "status of holding brake check" is set to "not successful" after the time interval has expired.

The warning E3115 disappears automatically when the brake check is successfully carried out within 15 min after the message had been generated. The brake check is carried out, for example, by starting "C2100 Command Holding system check" 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 Command Holding system check". After successful execution the "status of holding brake check" and the "status of holding torque check" is set to "1" in "P-0-0539, Holding brake status word". The time of the brake check is stored in "P-0-0549, Oper. hours control sec. at last succ. holding system check" and the time interval measurement is restarted!

If the brake check is not carried out or cannot be successfully carried out, the drive switches off with the error message "F3115 Brake check time interval exceeded", at the latest 15 min after drive enable had been set.

> ☞ 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!

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☞   When the safety technology function "Safe braking and holding system" has been activated, the time interval monitoring is obligatory. The time interval is parameterized in the parameter"P-0-3302, SBS: Time interval brake check", the parameters P-0-0550 and bit 6 in the parameter P-0-0525 are therefore irrelevant.

Reestablishing the Holding Brake Torque

For re-establishing the brake torque, "C3900 Command Holding brake resurfacing" (P-0-0544) can be started. To do this, drive enable ("AF") must have been set! After the command was started, the drive is accelerated to 100 rpm or 100 mm/min. Active acceleration and deceleration ramps, as well as filters (P-0-1201, P-0-1202, P-0-1203, P-0-1211, P-0-1213 and P-0-1222) are taken into account! When the motor has reached the command velocity, the brake is applied for 400 ms. After the command has been completed, the motor has been stopped by velocity control with command value "0".

With the execution of command C3900 there is no check run as to whether the resurfacing of the brake was successful! It is therefore recommended to execute command C2100 (brake check) after command C3900!

⚠ 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

"Brake Check" Command

The control unit can activate the brake check by means of a command:

- P-0-0541, C2100 Holding system 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 holding system.

The appropriate value for P-0-0545 can be determined on the basis of the value displayed in

- P-0-0546, Starting torque for releasing holding system.

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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 test torque or force can be preset via the parameters

- P-0-0547, Nominal load of holding system and
- P-0-0553, Test torque factor for brake check

The criterion for which the check is to be carried out is decisive for determining an appropriate value for P-0-0547 and P-0-0553:

- Nominal torque or force of the holding brake
- Holding torque or force for fixing the axis
- Increased holding torque or force

Criterion "Nominal Torque" or "Nominal Force"

The nominal torque or force of the holding brake from "P-0-0540, Torque of holding brake" can be activated for the check. To do this, enter the value "0" in parameter P-0-0547 (or leave it at "0")!

ℹ️ See Parameter Description "P-0-0547, Nominal load of holding system". With the configuration of P-0-0547 = "0", the factor in P-0-0553 is no longer taken into account for the holding system check.

Criterion "Fixing the Axis"

The torque or force required for fixing the axis can be determined on the basis of "S-0-0084, Torque/force feedback value". To do this, bring the axis to the position with the highest load due to weight and write the value of (S-0-0084 × safety factor (>1)) to parameter "P-0-0547, Nominal load of holding system"!

> ☞ 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 "Increased holding force"

The safety-relevant dimensioning of the holding brake normally requires a higher holding torque than the holding torque necessary to fix the axis. In this case, the holding torque or holding force must be entered in the parameter P-0-0547 and the safety factor for the holding system check in P-0-0553!

> ☞ The maximum value for "P-0-0547, Nominal load of holding system" is limited by the value of "P-0-0540, Torque of holding brake"! The "test torque" (P-0-0547 x P-0-0553) may not be greater than the value of the parameter P-0-0540; otherwise, the holding system check is aborted with the error message "C2103 Holding brake: Torque too low"!

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Criterion "Time Interval Brake Check"
: 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 holding system check".

Brake Resurfacing "Command"
: By starting a command it is possible to reestablish, by removing the oxide film (resurfacing of the brake), the holding torque or the holding force of a holding brake that has not yet become worn.

- P-0-0544, C3900 Command Holding brake resurfacing

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 Holding brake torque too low

Errors
- F2069 Error when releasing the motor holding brake

Command Errors
- C2101 Holding system check only possible with drive enable
- C2103 Holding brake: Torque too low
- C2104 Command execution impossible
- C2105 Load of holding system greater than test torque
- C2106 Test torque of holding system not reached
- C3901 Resurfacing of holding brake only possible with drive enable
- C3902 Error during resurfacing of holding brake
- C3903 Command execution impossible

5.5 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.

We distinguish the following drive control loops:

- 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:

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- • 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 Construction 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 dedicated 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"

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Hardware Requirements | For connecting the measuring systems to the controller there are three optional interfaces available. "P-0-0077, Assignment motor encoder->optional slot" and "P-0-0078, Assignment optional encoder->optional slot" determine the interface to which the respective encoder is connected. It must be equipped with the encoder input appropriate for the encoder.

ℹ️ See also separate documentation "Control Sections for Drive Controllers; Project Planning Manual"

☞ The following rules apply to P-0-0077 and P-0-0078:

- In the case of motors with encoder data memory (MHD, MKD, MKE), the value for P-0-0077 is automatically set correctly.
- In the case of motors without encoder data memory (rotary and linear kit motors), the value for 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 value 1
- S-0-0053, Position feedback value 2
- S-0-0115, Position feedback 2 type
- S-0-0116, Resolution of feedback 1
- S-0-0117, Resolution of feedback 2
- S-0-0256, Multiplication 1 (motor encoder)
- S-0-0257, Multiplication 2 (optional encoder)
- S-0-0277, Position feedback 1 type
- S-0-0278, Maximum travel range
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0075, Encoder type 2 (optional encoder)
- P-0-0129, Internal position data format

Functional Description

Absolute Encoder Precision | The absolute precision is a feature of the encoder and is determined by its construction and the quality of its components. The data for the absolute precision are given by the manufacturer of the encoder.

Resolution (Division Periods) | The resolution of the measuring system (division periods) is entered in the following parameters:
- S-0-0116, Resolution of feedback 1
- S-0-0117, Resolution of feedback 2

☞ Generally, the following applies:

→ **Encoder 1** refers to "motor encoder"

→ **Encoder 2** refers to "external or optional encoder"

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)

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- 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 "P-0-4014, Type of construction of motor" (rotary or linear motor).

☞ For Rexroth housing motors with motor encoder data memory and for Rexroth kit motors with EnDat2.1 encoder, or for IndraDrive-compatible HIPERFACE® encoders (FAQ_IndraDrive_unterstützte_Geber...) or HIPERFACE® encoders with the type ID "0xFF", the correct value is automatically written to the parameter S-0-0116!

Maximum Encoder Resolution after Digitalization

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)!

$$\text{Motor encoder (rotary)} \quad (S\text{-}0\text{-}0116) \times 2^{15}$$
$$\text{External encoder (rotary)} \quad (S\text{-}0\text{-}0117) \times 2^{15}$$

S-0-0116   Feedback 1 resolution
S-0-0117   Feedback 2 resolution
Fig.5-34:   Maximum Possible Resolution of Rotary Encoders

$$\text{Motor encoder (linear)} \quad \frac{(S\text{-}0\text{-}0116)}{2^{15}}$$
$$\text{External encoder (linear)} \quad \frac{(S\text{-}0\text{-}0117)}{2^{15}}$$

S-0-0116   Feedback 1 resolution
S-0-0117   Feedback 2 resolution
Fig.5-35:   Maximum Possible Resolution of Linear Encoders

☞ Depending on the type of motion of the encoder, the "maximum encoder resolution after digitalization" is given in different units:

- Rotary encoders → Position information/encoder revolution
- Linear encoders → mm (length of the shortest measurable distance)

Internally, the value range of the encoder position data is "$\pm 2^{31}$", i.e. the encoder position range can be resolved to "2^{32}" data. By digitalization, a multitude of position data results from one division period. By means of adjusted multiplication, the range of encoder position data of "$\pm 2^{31}$" values, referring to the travel range of the axis (S-0-0278), is complied with.

The resulting drive-internal encoder resolution is as follows:

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Internal Encoder Resolution, Rotary Encoders

Motor encoder (rotary)   (S-0-0116) $\times$ (S-0-0256)
External encoder (rotary) (S-0-0117) $\times$ (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 (motor encoder)
S-0-0117	Feedback 2 resolution
S-0-0257	Multiplication 2 (optional encoder)
S-0-0278	Maximum travel range (± travel range)
$c_{\_axis\_G1}$	Axis motion range / motor encoder revolution
$c_{\_axis\_G2}$	Axis motion range / revolution of external encoder
Fig.5-36:	*Drive-Internal Resolution of Rotary Encoders*

Internal Encoder Resolution, Linear Encoders

Motor encoder (linear) $\dfrac{(S\text{-}0\text{-}0116)}{(S\text{-}0\text{-}0256)}$

External encoder (linear) $\dfrac{(S\text{-}0\text{-}0117)}{(S\text{-}0\text{-}0257)}$

Auxiliary calculation and internal limitation:

$$(S\text{-}0\text{-}0256) = \frac{2^{30} \times (S\text{-}0\text{-}0116)}{(S\text{-}0\text{-}0278)} \leq 2^n \qquad\qquad n \leq 15 \text{ (in round numbers)}$$

$$(S\text{-}0\text{-}0257) = \frac{2^{30} \times (S\text{-}0\text{-}0117)}{(S\text{-}0\text{-}0278)} \leq 2^n \quad \text{(load reference)} \quad n \leq 15 \text{ (in round numbers}$$

$$(S\text{-}0\text{-}0257) = \frac{2^{30} \times (S\text{-}0\text{-}0117)}{(S\text{-}0\text{-}0278) \times c_{\_bef\_M}} \leq 2^n \qquad \text{(motor reference)} \qquad n \leq 15 \text{ (in round numbers}$$

S-0-0116	Feedback 1 resolution
S-0-0256	Multiplication 1 (motor encoder)
S-0-0117	Feedback 2 resolution
S-0-0257	Multiplication 2 (optional encoder)
S-0-0278	Maximum travel range (± travel range)
$c_{\_bef\_M}$	Infeed length / motor revolution
Fig.5-37:	*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.

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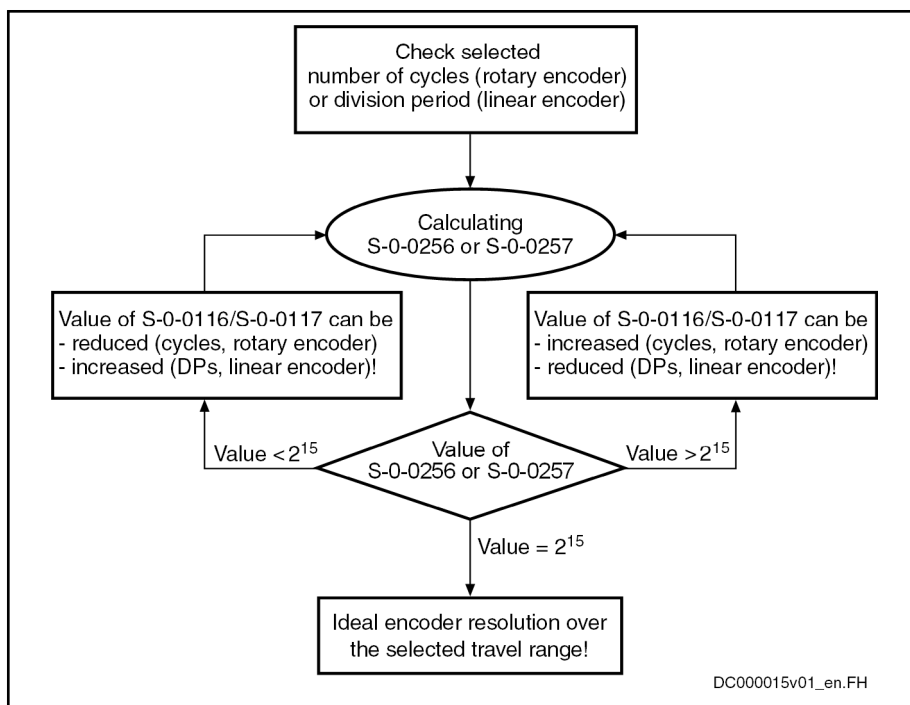
S-0-0116   Feedback 1 resolution
S-0-0117   Feedback 2 resolution
Fig.5-38:   *Checking the Selected Resolution and Determining the Ideal Resolution for Encoder 1 (or Encoder 2)*

☞   The calculated value of S-0-0256 or S-0-0257 normally will never exactly correspond to "2^{15}" (= 32768). With results "$=2^{15}$", the conditions with regard to the possibilities of encoder evaluation are ideal!

Internal Resolution of the Position Data   The position control itself works with the resolution displayed in "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 "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.5-39:   *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.5-40:   *Drive-Internal Resolution of the Position Data for Linear Motors*

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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 greater 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, Resolution of feedback 1

Set the resolution (number of lines, division period) of the optional encoder:

- S-0-0117, Resolution of feedback 2

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, 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 EnDat2.1 encoder, the correct value is automatically written to 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 value 1

Current actual position value of the optional encoder:

- S-0-0053, Position feedback value 2

Position status of the connected encoders:

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- 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 value "32768" is contained in "S-0-0256, Multiplication 1 (motor encoder)" and in "S-0-0257, Multiplication 2 (optional encoder)", where applicable, he encoder evaluation is ideal. When the value is lower, the maximum travel range (S-0-0278) has to be checked for correct 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 Motor control methods with encoder are only safe to operate if the motor encoder is connected to the movable part without slip. Slip and too little stiffness in the motor encoder connection are detected and indicated with a tolerance to be specified.

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-0-0115, Position feedback 2 type
- S-0-0277, Position feedback 1 type
- 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

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- 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-0-0328, Type of position encoder for measuring encoder
- P-0-0391, Actual position value difference encoder1 - encoder2
- P-0-0520, Encoder validation error threshold factor
- P-0-0620, Encoder validation monitoring signal
- P-0-0621, Encoder validation upper monitoring threshold
- P-0-0622, Encoder validation lower monitoring threshold

Pertinent Diagnostic Messages
- E2074 Encoder 1: Encoder signals disturbed
- E2075 Encoder 2: Encoder signals disturbed
- F2036 Excessive position feedback difference
- F2042 Encoder 2: Encoder signals incorrect
- F2048 External power supply X15 error
- F2074 Actual pos. value 1 outside absolute encoder window
- F2075 Actual pos. value 2 outside absolute encoder window
- F2174 Loss of motor encoder reference
- F2175 Loss of optional encoder reference
- F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)
- F8023 Error mechanical link of encoder or motor connection

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:

$$0,2 \times U_{A,B\_nom} \leq \sqrt{U_A^2 + U_B^2} \leq 1,4 \times U_{A,B\_nom}$$

U_{A,B_nom} Nominal amplitude value of the encoder tracks, in this case 1.0 Vpp
U_A Amplitude of encoder track A
U_B Amplitude of encoder track B
Fig.5-41:   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:

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- • E2074 Encoder 1: Encoder signals disturbed
- • E2075 Encoder 2: Encoder signals disturbed

The warning remains active until the drive is switched off or switched to communication phase P2!

Incorrect counts caused by injected noise and permanently reduced signal amplitudes caused by dirty code disks can be the reason why an error message for the motor encoder or the external encoder is generated:

- • F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)
- • F2042 Encoder 2: Encoder signals incorrect

The drive then reacts with the error reaction that has been set.

Signal Monitoring for 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.5-42:   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!

The reference marker can also be monitored for failure or distance. For this purpose, the "cyclic reference marker detection" function has to be activated (position encoder type motor encoder: "S-0-0277, Position feedback 1 type", bit 9; position encoder type external encoder: "S-0-0115, Position feedback 2 type", bit 9; position encoder type measurement encoder: "P-0-0328, Type of position encoder for measuring encoder", bit 9). This activates the monitoring function and an encoder error is output, if applicable.

Marker distance monitoring: The difference of the last two markers must be equal to the defined marker distance.

Marker failure monitoring: The distance between the encoder position and the last marker position must not exceed 1.5 * marker distance.

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

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- 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 motor control methods with encoder the motor encoder must be without slip and be rigidly connected to the moving part of the motor The current quality of the motor encoder coupling is represented by the value of "P-0-0620Encoder validation monitoring signal". The mechanical connection is error-free if the value lies between the upper and the lower monitoring threshold ("P-0-0621, Encoder validation upper monitoring threshold" and "P-0-0622, Encoder validation lower monitoring threshold"). The sensitivity of the monitoring is set in "P-0-0520Encoder validation error threshold factor".

☞   This function is particularly relevant in connection with safety technology. In the case of Rexroth housing motors, the monitoring function for reliable behavior is preset (medium sensitivity).

For axis drives that are equipped with an external encoder, the controller provides the possibility of monitoring the difference of the actual position values of motor encoder and external encoder with regard to a maximum value that can be set.

The maximum allowed difference of the actual position values of both encoders is defined in parameter "S-0-0391, Monitoring window feedback 2". When this value is exceeded the "F2036 Excessive position feedback difference" error message is generated. This monitoring function is active as of communication phase 4 and can be deactivated!

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. If the maximum input frequency was exceeded, the reference will be cleared.

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☞   For positioning processes, the reference must be reestablished with relative measuring systems, e.g. by means of "C0900 Position spindle command" or by means of "C0600 Drive-controlled homing procedure command".

The external encoder is only required for C-axis operation, but would make regular spindle operation impossible. The encoder monitor can therefore be switched off in this case by the respective value in parameter "P-0-0185, Control word of encoder 2 (optional encoder)".

Determining the maximum frequency of the encoder (encoder output frequency):

$$f_{out} = \frac{TP \times n_{max}}{60000 \frac{s}{min}}$$

f_{out}	Encoder output frequency in kHz
DP	Number of lines of encoder per revolution
n_{max}	Maximum speed of spindle in 1/min

Fig.5-43:   *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	Encoders with EnDat interface from Heidenhain	200 kHz

Fig.5-44:   *Maximum Frequencies 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 "Control Sections for Drive Controllers; Project Planning Manual").

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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 (recommended: 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.

In order to prevent the drive from exceeding the maximum input frequency during operation and switching off, the spindle encoder monitoring should be deactivated. To do so, enter the respective value in parameter "P-0-0185, Control word of encoder 2 (optional encoder)"

Setting the Motor Encoder Connection Monitor

In general, Rexroth housing motors with motor encoder do not require setting of "P-0-0520, Encoder validation error threshold factor". Medium sensitivity is preset.

In the case of Rexroth kit motors or third-party motors, this monitoring function has to be checked and "P-0-0520, Encoder validation error threshold factor" set to the appropriate sensitivity. See TN35, Encoder Validation Monitoring With IndraDrive Controllers

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.

NOTICE	The value in P-0-0095 or P-0-0096 has to be unequal zero; the value "0" deactivates the monitor!

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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 temporarily incorrect encoder signals are detected, the drive generates the warning

- E2074 Encoder 1: Encoder signals disturbed

- or -

- E2075 Encoder 2: Encoder signals disturbed.

The warning remains active until the drive is switched off or switched to communication phase P2!

When incorrect encoder signals are detected the drive generates the error message

- F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)

- or -

- F2042 Encoder 2: Encoder signals incorrect.

When the voltage of the battery of the encoder data memory has fallen below the determined limit value, the drive generates the following error message:

- F2048 External power supply X15 error.

See also "Error Reactions"

If the sensitivity of the encoder coupling monitor is too high, the motor encoder coupling is faulty or the motor power cable has not been connected, the drive will generate the error message

- F8023 Error mechanical link of encoder or motor connection

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).

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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 motors
- Motor encoder option S2 or M2: EnDat2.1 encoder, single- or multi-turn type
- 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:

- EnDat2.1 linear encoders (Heidenhain) or HIPERFACE® linear encoders [Stegmannn, IndraDrive-compatible types (FAQ_IndraDrive_unterstützte_Geber) or encoders with type ID "FF"] for linear motors or linear axes
- Rotary EnDat2.1 encoders (Heidenhain) or rotary HIPERFACE® encoders (Stegmannn, IndraDrive-compatible types (FAQ_IndraDrive_unterstützte_Geber...) or encoders with type ID "FF") for rotary kit motors or rotary axes

Establishing Axis-Related Absolute Position

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 the motor or the mechanical axis system, it is necessary to determine the position offset between encoder and axis zero point once at the initial commissioning (see also "Establishing the Position Data Reference:) Establishing Position Data Reference for Absolute Measuring Systems").

Hardware Requirements

For the signal specification of third-party encoders for position and homing signals with regard to amplitude and phase angle, see the documentation "Control Sections for Drive Controllers; Project Planning Manual".

☞   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.

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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 S-0-0277 or S-0-0115! The encoder can then only be evaluated in relative form!

Checking the Dimensioning Regarding Absolute Encoder Evaluation

To dimension absolute encoders it is necessary to check by the way of calculation whether the intended travel range of the axis, considering all mechanical transfer elements, can be displayed within the absolute encoder range.

The following condition must be fulfilled:

- Rotary encoders → Travel range of axis requires less encoder revolutions than preset in absolute encoder range!
- Linear encoders → Travel range of axis is smaller than preset in absolute encoder range!

Actual Position Value of Encoders To Be Evaluated in Absolute Form After Switching On

The actual position value of an absolute measuring system must be adjusted to the mechanical axis system once at initial commissioning.

☞　　　The adjustment is made by determining an actual position value, related to the axis zero point, given a defined axis position (P-0-0012, C0300 Set absolute position procedure command). Thereby the offset between the actual position value that first is encoder-related and the required axis-related actual position value is internally determined and permanently stored! The respective encoder then is "in reference".

If only one absolute encoder (motor encoder) is available, there are the following cases to be distinguished for the actual position value after the drive has been switched on:

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Absolute evaluation (S-0-0277, bits 6 and 7)	Actual pos. value of motor encoder when switching on (S-0-0051)	Notes on the commissioning status	Current position status (S-0-0403, bit 0 … 2)
Active → Evaluation as absolute measuring system	**Original position** of motor encoder	Initial commissioning not yet carried out, motor encoder not "in reference".	0b … 000
	Absolute value of motor encoder	Initial commissioning was carried out, the motor encoder was set "in reference".	0b … 01x
Inactive → Evaluation as relative measuring system intended	P-0-0019	Initial commissioning not yet carried out, motor encoder is not "in reference".	0b … 000
Not possible → Evaluation as relative measuring system, e.g. due to length of travel range	P-0-0019	Initial commissioning not yet carried out, motor encoder is not "in reference".	0b … 000

P-0-0019   Initial position value (can be defined by user)

Fig.5-45:   *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 "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 "P-0-0019, Initial position value" in conjunction with bit 6, bit 7 and bit 8 of the corresponding parameter for the type of position encoder.

If the drive, apart from the motor encoder, is equipped with an external encoder and at least one encoder can be evaluated in absolute form, the following actual position values, depending on the reference status of the encoder, are resulting after switching on:

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Absolute evaluation		Actual position values when switching on			
Motor encoder (S-0-0277) Bit 8/7/6	External encoder (S-0-0115) Bit 8/7/6	Motor encoder (S-0-0051)	External encoder (S-0-0053)	Notes on the commissioning status	Current position status (S-0-0403)
001 or 100 (active)	001 or 100 (active)	Original position of motor encoder	Original position of external encoder	Initial commissioning has not been carried out, none of the encoders has "reference".	0b … 000
		Absolute value of motor encoder	Absolute value of motor encoder	During the initial commissioning only the motor encoder was set "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 of motor encoder	Absolute value ext. encoder	During the initial commissioning both encoders were set "in reference".	0b … 111
001 or 100 (active)	011 (inactive)	Original position of motor encoder	Original position of motor encoder	Initial commissioning not yet carried out, motor encoder not "in reference".	0b … 000
		Absolute value of motor encoder	Absolute value of motor encoder	Initial commissioning was carried out, the motor encoder was set "in reference".	0b … 01x
001 or 100 (active)	000 (not possible)	Original position of motor encoder	Original position of motor encoder	Initial commissioning has not been carried out, none of the encoders has "reference".	0b … 000
		Absolute value of motor encoder	Absolute value of motor encoder	During the initial commissioning only the motor encoder was set "in reference".	0b … 10x
011 (inactive)	001 or 100 (active)	Original position of external encoder	Original position of external encoder	Initial commissioning has not been carried out, none of the encoders has "reference".	0b … 000
		Absolute value ext. encoder	Absolute value ext. encoder	During the initial commissioning the external encoder was set "in reference".	0b … 010x
000 (not possible)	001 or 100 (active)	Original position of external encoder	Original position of external encoder	Initial commissioning has not been carried out, none of the encoders has "reference".	0b … 000
		Absolute value ext. encoder	Absolute value ext. encoder	During the initial commissioning the external encoder was set "in reference".	0b … 10x
000 (not possible)	000 (not possible)	P-0-0019	P-0-0019		0b … 000

P-0-0019   Initial position value (can be defined by user)
Fig.5-46:   *Actual Position Values when Switching on a Drive with Encoders to be Evaluated in Absolute Form*

☞   "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.

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☞   After the measuring systems to be evaluated in absolute form were set "in reference" during the initial commissioning of the drive, their actual position values in the operational status of the drive, related to the mechanical system, are always absolute values. This is so, even when the drive is switched off and on again!

Notes on Commissioning

☞   The Notes on Commissioning for "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems" must be observed, too!

Setting the Travel Range

Enter the travel range of the axis:

- S-0-0278, Maximum travel range

Check the absolute encoder range of the respective control encoder:

- S-0-0378, Absolute encoder range of motor encoder
- S-0-0379, Absolute encoder range of optional encoder

☞   The travel range and the absolute encoder ranges have the same position reference! They refer, depending on the scaling that was set, to the motor or to the load!

Absolute Encoder Evaluation Possible?

When the travel range is smaller than the absolute encoder range of the control encoder (determined by the active operating mode) the encoder can be evaluated as an absolute encoder. This is also displayed in the respective bits of the following parameters:

- S-0-0277, Position feedback 1 type
- S-0-0115, Position feedback 2 type

By means of these parameters, it is possible to deactivate the absolute evaluation of an encoder. The actual position values then are only relative, i.e. the encoder has to be homed again each time the machine is restarted!

If the absolute encoder range of the control encoder is smaller than the value of S-0-0278 you have to check whether the travel range was correctly input or whether the default value is active!

Setting the Initial Position Value

If desired, it is possible to enter a defined initial position value for the actual position value of the encoder or the encoders in "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

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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 Position

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 position:

- Moving to a defined axis position with reproducible precision.

- or -

- detecting a defined axis position by "passing" two distance-coded reference marks of the encoder.

At a defined position, the actual position value of the encoder to be homed is written with the corresponding absolute value of the axis (see "Establishing the Position Data Reference: Establishing Position Data Reference for Relative Measuring Systems").

Hardware Requirements

For the signal specification for position and homing signals with regard to amplitude and phase angle, see the documentation "Control Sections for Drive Controllers; Project Planning Manual".

Pertinent Parameters

- S-0-0115, Position feedback 2 type
- S-0-0116, Resolution of feedback 1
- S-0-0117, Resolution of feedback 2
- S-0-0165, Distance-coded reference offset A
- S-0-0166, Distance-coded reference offset B
- S-0-0277, Position feedback 1 type
- S-0-0440, Marker position feedback 1
- S-0-0441, Marker position feedback 2
- S-0-0442, Counter marker position feedback 1
- S-0-0443, Counter marker position feedback 2
- P-0-0019, Initial position value

Functional Description

Initial position value

When the drive is switched on, the actual position values of relative encoders are written with the initial position value (P-0-0019), if none of the encoders is an absolute value encoder that has already been set in reference.

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Absolute evaluation possible?		Actual position values when switching on			Current position status
Motor Encoder	External encoder	Motor encoder (S-0-0051)	External encoder (S-0-0053)	Notes on the operating status	(S-0-0403, bit 0..2)
No	No	P-0-0019	P-0-0019	Axis has not moved after switching on, axis has not yet been homed.	0b … 000
		Absolute value of motor encoder	Absolute value of motor encoder	Axis was homed via motor encoder; at the home point, S-0-0053 is set to the value of S-0-0051.	0b … 01x
		Absolute value ext. encoder	Absolute value ext. encoder	Axis was homed via external encoder; at the home point, S-0-0051 is set to the value of S-0-0053.	0b … 10x
		Absolute value of motor encoder	Absolute value ext. encoder	Axis was homed via motor encoder and external encoder.	0b … 111

P-0-0019   Initial position value
Fig.5-47:   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, Signal status word" are in reference.

Reference Marks   In order to establish the axis-related absolute distance ("reference") the controller monitors the signals of the relative encoder or of the axis sensors that contain absolute position information regarding the axis:

- Reference marks of the encoder, if necessary in combination with home point switch of the axis

- Distance-coded reference marks of the encoder

- Home point switch of the axis

The controller is told via the parameters "S-0-0277, Position feedback 1 type" and "S-0-0115, Position feedback 2 type" which homing signals the connected measuring system makes available.

Reference Marks, Not Distance-Coded   During the homing procedure, the controller automatically detects the reference mark if its signal corresponds to the specification and the reference mark is to be evaluated to establish the reference (see "Establishing the Position Data Reference: Establishing Position Data Reference for Relative Measuring Systems").

If a relative encoder has several reference marks over the travel distance, a reference mark is to be identified by means of a home point switch at the axis for establishing the position reference (see "Establishing the Position Data Reference: Establishing Position Data Reference for Relative Measuring Systems").

Cyclic Marker Evaluation   In the position feedback 1 type (S-0-0277, bit 9 = "1", cyclic marker evaluation active) or position feedback 2 type (S-0-0115, bit 9 = "1", cyclic marker evaluation active), the marker evaluation for the motor encoder or for the external encoder can be enabled. After the marker has been detected, the calculated position value is entered in the parameter "S-0-0440, Marker position feedback 1" or in the parameter "S-0-0441, Marker position feedback 2". To detect overflow during marker transmission, the counter "S-0-0442, Counter

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marker position feedback 1" or the counter "S-0-0443, Counter marker position feedback 2" is incremented with every error-free marker. Therefore, the control unit can make sure to process two successive marker positions, even in the case of telegram failure.

Distance-Coded Reference Marks

In the case of relative encoders with distance-coded reference marks, several reference marks are distributed in equal distances over the entire travel distance. There is a "shorter distance" and a "longer distance" between one reference mark and the mark after the next. The values of these two distances are available to the controller in the parameters "S-0-0165, Distance-coded reference offset A" and "S-0-0166, Distance-coded reference offset B".
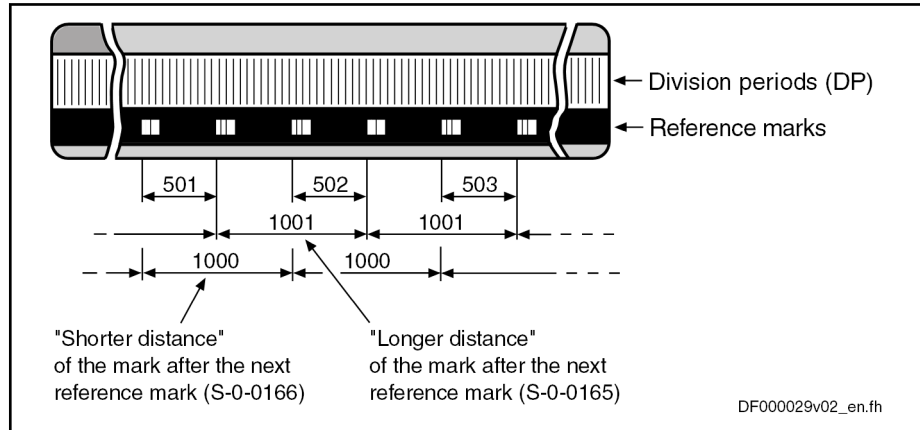
| S-0-0165 | Distance-coded reference offset A |
| S-0-0166 | Distance-coded reference offset B |

Fig.5-48:   Reference Mark Distances in the Case of a Distance-Coded Linear Encoder with a Distance Difference of 1 DP

☞   The values for "distance-coded reference distance A" and "distance-coded reference distance B" have to be indicated by the manufacturer!

Determining the "Distance-Coded Reference Distance A"

If the value of "distance-coded reference offset A" is not directly given in the data sheet of the distance-coded encoder, the value can also be determined by means of calculation if the travel distance for establishing the absolute position data reference is given in the data sheet of the encoder:

Linear encoders

$$\text{General} \qquad \text{S-0-0165} = \frac{x_{ref} + n \times DP}{DP}$$

$$\text{Motor encoder} \qquad \text{S-0-0165} = \frac{x_{ref} + n \times (\text{S-0-0116})}{(\text{S-0-0116})}$$

$$\text{External encoder} \qquad \text{S-0-0165} = \frac{x_{ref} + n \times (\text{S-0-0117})}{(\text{S-0-0117})}$$

S-0-0165	Distance-coded reference offset A (in number of DP)
x_{ref}	Travel distance for establishing the absolute position data reference (in mm)
n	Number of DP of the distance difference (longer-shorter distance)
DP	Division period of the relative linear encoder (in mm)
S-0-0116	Feedback 1 Resolution (division period in mm)
S-0-0117	Feedback 2 Resolution (division period in mm)

Fig.5-49:   Determining the Value for the "Longer Distance" of the Distance-Coded Reference Marks with a Relative Linear Encoder

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Rotary Encoders

$$\text{General} \qquad \text{S-0-0165} = \frac{N_{cyc} \times \varphi_{ref}}{360°} + z$$

$$\text{Motor encoder} \qquad \text{S-0-0165} = \frac{(\text{S-0-0116}) \times \varphi_{ref}}{360°} + z$$

$$\text{External encoder} \qquad \text{S-0-0165} = \frac{(\text{S-0-0117}) \times \varphi_{ref}}{360°} + z$$

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.5-50:	*Determining the Value for the "Longer Distance" of the Distance-Coded Reference Marks with a Relative Rotary Encoder*

Determining the "Distance-Coded Reference Distance B"

If the value of "distance-coded reference offset B" is not directly given in the data sheet of the distance-coded encoder, the value can only be determined by means of calculation if the distance difference (longer distance – shorter distance) is given in the data sheet of the encoder:

Linear encoders

$$\text{General} \qquad \text{S-0-0166} = \frac{x_{ref}}{DP}$$

$$\text{Motor encoder} \qquad \text{S-0-0166} = \frac{x_{ref}}{(\text{S-0-0116})}$$

$$\text{External encoder} \qquad \text{S-0-0166} = \frac{x_{ref}}{(\text{S-0-0117})}$$

S-0-0166	Distance-coded reference offset B (in number of DP)
x_{ref}	Travel distance for establishing the absolute position data reference (in mm)
DP	Division period of the relative linear encoder (in mm)
S-0-0116	Feedback 1 Resolution (division period in mm)
S-0-0117	Feedback 2 Resolution (division period in mm)
Fig.5-51:	*Determining the Value for the "Shorter Distance" of the Distance-Coded Reference Marks with a Relative Linear Encoder*

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Rotary Encoders

$$\text{General} \qquad S\text{-}0\text{-}0166 \; = \; \frac{N_{cyc} \; \times \; \varphi_{ref}}{360°}$$

$$\text{Motor encoder} \qquad S\text{-}0\text{-}0166 \; = \; \frac{(S\text{-}0\text{-}0116) \; \times \; \varphi_{ref}}{360°}$$

$$\text{External encoder} \quad S\text{-}0\text{-}0166 \; = \; \frac{(S\text{-}0\text{-}0117) \; \times \; \varphi_{ref}}{360°}$$

S-0-0166	Distance-coded reference offset B (in number of cycles)
N_{cyc}	Number of cycles of the rotary encoder (per 360°)
φ_{ref}	Travel angle for establishing the absolute position data reference (in degrees)
S-0-0116	Feedback 1 Resolution (per 360°)
S-0-0117	Feedback 2 Resolution (per 360°)

Fig.5-52:   Determining the Value for the "Shorter Distance" of the Distance-Coded Reference Marks with a Relative Rotary Encoder

Notes on Commissioning

☞   The Notes on Commissioning in the sections "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems" must be observed, too!

Setting the Initial Position Value   If the actual position value of relative encoders is not to be written with the default value "0" when the drive is switched on, "P-0-0019, Initial position value" has to be changed to have the desired value.

In the Case of Distance-Coded Measuring System   If the relative encoder possesses distance-coded reference marks, the controller is informed on this by the respective bit in the following parameters:

- S-0-0277, Position feedback 1 type
- S-0-0115, Position feedback 2 type

The value for the "longer distance" of the distance-coded reference marks has to be entered in parameter "S-0-0165, Distance-coded reference offset A".

The value for the "shorter distance" of the distance-coded reference marks has to be entered in parameter "S-0-0166, Distance-coded reference offset B".

5.5.5   Establishing the Position Data Reference

General Information on Establishing the Position Data Reference

Brief Description

During the initial commissioning of a drive the actual position values transmitted by the measuring systems do not yet have any reference to the machine axis. This applies to

- Relative measuring systems and
- Absolute measuring systems.

For more detailed information on relative and absolute evaluation of measuring systems, see "Absolute Measuring Systems".

Relative Measuring Systems   The position data reference of a relative measuring system to the axis has to be reestablished after each time the drive is switched on or after the position data reference is lost. For this purpose, it is necessary to move to a defined

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axis position and set the actual position value to an axis-related value at a defined position (Exception: For relative encoders with distance-coded reference marks, movement is only required over two marks!).

Absolute Measuring Systems
The position data reference of an absolute measuring system to the axis has to be established once during initial commissioning after replacing the motor or encoder (motor encoder or external encoder) and changes in the mechanical axis system. The position data reference still is maintained and the actual position values are axis-related immediately after the drive is switched on.

Establishing the Position Data Reference, Drive-Controlled
For establishing the position data reference in a drive-controlled way, the position data reference is automatically established by the drive by master-side triggering of a command. The procedure depends on the kind of measuring system:

- In the case of a relative measuring system without distance-coded reference marks, the axis moves to the reference point or to a dedicated point and then automatically switches to axis-related actual position values.

- In the case of a relative measuring system with distance-coded reference marks, the axis moves between two reference marks and then automatically switches to axis-related actual position values.

- In the case of an absolute measuring system, the automatic switching to the axis-related actual position value is carried out with the axis in standstill.

The presettings for establishing the position data reference are made via assigned parameters.

Establishing the Position Data Reference, NC-Controlled
For establishing the position data reference in an NC-controlled way, the drive makes available three commands to the master. The master has to generate the travel motion for searching the marker:

- The master starts the command "NC-controlled homing" and for searching the reference point or dedicated point must move the axis by inputting command values.

- To calculate the offset and switch to axis-related actual position values it is necessary to start further commands.

The presettings for establishing the position data reference are made via assigned parameters.

Displaying the Position Data Reference
A position status parameter shows whether the position data reference of a measuring system evaluated by the controller has been established.

Motor Encoders 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:

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- "Establishing Position Data Reference for Absolute Measuring Systems"
- "Establishing Position Data Reference for Relative Measuring Systems"

Pertinent Parameters
- S-0-0115, Position feedback 2 type
- S-0-0175, Offset parameter 1
- S-0-0176, Offset parameter 2
- S-0-0277, Position feedback 1 type
- S-0-0403, Position feedback value status
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0075, Encoder type 2 (optional encoder)

Functional Description

Supported Encoder Types

IndraDrive controllers can evaluate a multitude of 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 type of encoder and the travel range that has been set (S-0-0278) determine whether absolute evaluation is possible for this encoder. This is displayed by the respective bits of the following parameters:
- S-0-0277, Position feedback 1 type
- S-0-0115, Position feedback 2 type

Depending on relative or absolute evaluation of the motor encoder or external encoder, the controller makes available different procedures for establishing the position data reference:
- "Set absolute position" for encoders to be evaluated in absolute form
- "Drive-controlled homing procedure" for relative encoders
- "NC-controlled homing procedure" for relative encoders

> ☞ After having successfully established the position data reference, the actual position value of the respective encoder refers to the axis. The encoder then is 0 "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:

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- The position data reference was only established for one of the two encoders. The actual position value of the other, non-homed encoder is set to the value of the homed encoder.

- The position data reference was established for both encoders. The actual position value of each encoder is an individual value that can be identical, but does not need to be identical.

Encoder evaluation		Current position status	Actual position values when switching on		
Motor Encoder	External encoder	(S-0-0403, bit ..2,1,0)	Motor encoder (S-0-0051)	External encoder (S-0-0053)	Notes on the commissioning status
Relative/ absolute	Relative/ absolute	0b … 01x	Absolute value of motor encoder	Absolute value of motor encoder	Position data reference only established for motor encoder.
Relative/ absolute	Relative/ absolute	0b … 10x	Absolute value ext. encoder	Absolute value ext. encoder	Position data reference only established for external encoder.
Relative/ absolute	Relative/ absolute	0b … 11x	Absolute value of motor encoder	Absolute value ext. encoder	Position data reference established for motor encoder and external encoder.
Relative/ absolute	Relative/ absolute	0b … 000	See also "Absolute Measuring Systems" or "Relative Measuring Systems"		Position data reference was established neither for motor encoder nor for external encoder.

Fig.5-53:   *Actual Position Values After Establishing the Position Data Reference for Motor Encoder and External Encoder*

Actual Position Value Offset Before/After Establishing Position Data Reference

When the position data reference was established for an encoder there mostly is a step change of the actual position value. The difference between the new and the old actual position value is displayed in the following parameters:

- S-0-0175, Offset parameter 1
- S-0-0176, Offset parameter 2 (external encoder)

The respective values are written to the offset parameters each time the position data reference is established. After the drive was switched on the value, however, is undefined, even if the position data reference has already been established!

Notes on Commissioning

Checking the Possibility of Absolute Encoder Evaluation

The possibility of absolute evaluation of motor encoder or external encoder is displayed by the respective bits of the following parameters:

- S-0-0277, Position feedback 1 type(Motor encoder)
- S-0-0115, Position feedback 2 type (external encoder)

Checking whether Position Data Reference was Established

The position status of motor encoder and external encoder is displayed in:

- S-0-0403, Position feedback value status

If required by the master, the position status of one of the two encoders can be mapped to bit 0 of S-0-0403. This is done by setting the bit for encoder selection in "S-0-0147, Homing parameter".

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☞   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.

Establishing Position Data Reference for Absolute Measuring Systems (Set Absolute Position)

Brief Description

💡   **Base package** of all variants in **closed-loop** characteristic

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 position" 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 position"

- 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

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systems, both actual position values are equal at the position at which the position data reference was established.

☞ If the position data reference was only set for one encoder, the actual position values of both encoders remain equal as long as mechanical axis system and encoder systems are mechanically connected without slip (slip control is possible!).

"Set Absolute Position" Command

It is recommended to start the "set absolute position" command when the axis is in standstill without drive enable. In case the axis, for establishing the position data reference, is to be brought to a defined position on the master side and be held in this position by the drive, "set absolute position" can also be executed with active drive.

"Drive-Controlled Homing" Command

When the command "drive-controlled homing procedure" (without previous start of "set absolute position") 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 Position"

By starting the "set absolute position" command, the previous actual position value of an encoder at a dedicated position of the axis is set to a new value. This value is the current axis position related to the coordinate system of the machine.

The dedicated position is defined by:

- The current axis position

- or -

- The positioning of the axis at a "striking" axis position (e.g. value "0")

The required assignments and configurations for "setting absolute position" are realized via parameter settings.

Assigning the Axis-Related Actual Position Value with "Drive-Controlled Homing Procedure"

By starting the "drive-controlled homing procedure" command the previous actual position value of an encoder at a dedicated position of the axis is set to a new value. This value is the current axis position related to the coordinate system of the machine.

The required assignments and configurations for "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 Set absolute position procedure command
- P-0-0177, Absolute encoder buffer 1 (motor encoder)
- P-0-0178, Absolute encoder buffer 2 (optional encoder)
- P-0-0612, Set absolute position control

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- P-0-1002, Absolute encoder offset 1, encoder memory
- P-0-1012, Absolute encoder offset 2, encoder memory

Pertinent Diagnostic Messages
- C0300 Set absolute position procedure command
- C0301 Measuring system unavailable
- C0302 Absolute evaluation of measuring system impossible
- C0303 Absolute encoder offset cannot be saved

Functional Description

"Drive-Controlled Homing Procedure" Command 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, Set absolute position control".

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.

"Set Absolute Position" Command

Dedicated Position
By starting the "set absolute position" command, the previous actual position value of an encoder at a dedicated position of the axis is set to a new value. The dedicated position corresponds to the current axis position at the start of the command.

The new actual position value at the dedicated position after "set absolute position" is the value of parameter

- S-0-0052, Reference distance 1 (for motor encoder)

- or -

- S-0-0054, Reference distance 2 (for external encoder).

| Motor encoder | $S\text{-}0\text{-}0051_{new}$ | = | S-0-0052 |
| External encoder | $S\text{-}0\text{-}0053_{new}$ | = | S-0-0054 |

S-0-0051   Position feedback 1 value
S-0-0052   Reference distance 1
S-0-0053   Position feedback 2 value
S-0-0054   Reference distance 2
Fig.5-54:   *Actual Position Values after "Set Absolute Position"*

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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, Set absolute position control", the encoder for which the "set absolute position" command is to take effect.
Storing the Absolute Encoder Off-set	In order that an encoder to be evaluated in absolute form maintains the position data reference to the axis after "set absolute position", the absolute encoder offset is stored in the encoder data memory (P-0-1002/P-0-1012) and in the parameter memory (P-0-0177/P-0-0178).

> ☞ Storing the absolute encoder offset in the encoder data memory and in the parameter memory allows recognizing whether the absolute encoder that was homed was replaced!

Possible Operating States Before "Set Absolute Position"	The "set absolute position" 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")

"Set Absolute Position" Procedure	When the "set absolute position" 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 position""). 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 position"").

- 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 position"") and the "drive-controlled homing procedure" command is signaled by the drive to have been executed. The master now has to "synchronize" to the new actual position value of the encoder used in the active operation mode. After the master cleared the "drive-controlled homing procedure" command, the drive returns to master-controlled operation.

… 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 position" command has to be cleared by the master!

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Fig.5-55:   Sequence of "Set Absolute Position" Command Execution

Notes on Commissioning

See also Notes on Commissioning under "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 position" by determining the encoder for "set absolute position" in "P-0-0612, Set absolute position control". Also set in

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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 Position"   Start command "P-0-0012, C0300 Set absolute position procedure command".

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 Position" Command Execution").

See also "Command Processing"

Checking Whether Position Data Reference was Established   The respective bit of parameter "S-0-0403, Position feedback value status" displays whether the encoder selected via S-0-0612 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 position" was executed again for an absolute encoder, a value for the "offset" of the actual position values before and after command execution is entered in:

- S-0-0175, Offset parameter 1 (motor encoder)
- S-0-0176, Offset parameter 2 (external encoder)

Clearing the Executed Commands   After the commands have been executed (diagnosis possible via parameter "S-0-0403, Position feedback value status"), the commands started have to be cleared again in reverse order when "set absolute position" is carried out via 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 must be established again!

Establishing Position Data Reference for Relative Measuring Systems (Homing)

Brief Description

💡   **Base package** of all firmware versions in **closed-loop** characteristic.

See also section "General Information on Establishing the Position Data Reference"

Actual Position Value of Relative Measuring Systems when Switching On   After the drive has been switched on, the actual position values signaled by relative measuring systems do not yet have any reference to the machine axis. Measuring systems can be installed at the motor (motor encoder) and directly at the mechanical axis system (external or optional encoder).

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For the encoder arrangement and mechanical axis system, see also "Mechanical Axis System and Arrangement of Measuring Systems"

The position data reference of relative measuring systems to the axis has to be established again each time after the drive was switched on or after all procedures that cause the position data reference to get lost (homing procedure).

Establishing the Position Data Reference, Drive-Controlled

After start of the respective command by the master, the drive can automatically establish the position data reference.

To do this, the drive moves the axis until the controller can detect a dedicated point. The actual position values then are automatically switched to axis reference. The presettings for the sequence for establishing the position data reference are made via assigned parameters.

Establishing the Position Data Reference, NC-Controlled

As an alternative to establishing the position data reference in a drive-controlled way, the NC ("master") can control the homing procedure.

In this case, the master inputs the command values for moving the axis to the dedicated point and controls the homing procedure via commands and assigned parameters.

The NC-controlled homing procedure can be advantageous for drives with a rigid mechanical connection (e.g. for Gantry axes), because the master can input coordinated command values for the drives for the homing motion.

Dedicated Point for Establishing the Position Data Reference

The dedicated point for establishing the position data reference, in the case of linear axes, is at one end of the travel range. This allows finding the dedicated point from any axis position (situation when switched on) by moving in a defined direction. Rotary axes do not have an axis end position, the dedicated point is at a defined position within the travel range.

Reference Mark for Relative Measuring Systems

The precision with which this dedicated point is detected considerably influences the absolute precision of the axis. Apart from the signals for position detection, relative measuring systems therefore also provide a signal for exact determination of a dedicated point. This signal is called "reference marker". 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 operating status 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.

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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, Bipolar jerk limit
- S-0-0400, Home switch
- S-0-0403, Position feedback value status
- P-0-0153, Optimum distance home switch-reference mark

Parameters for NC-controlled homing:
- S-0-0146, C4300 NC-controlled homing procedure command
- S-0-0171, C4400 Calculate displacement procedure command
- S-0-0172, C4500 Displacement to referenced system procedure command
- S-0-0175, Offset parameter 1
- S-0-0176, Offset parameter 2
- S-0-0404, Position command value status
- S-0-0407, Homing enable
- S-0-0408, Reference marker pulse registered

Parameters for relative measuring systems, distance-coded:
- S-0-0165, Distance-coded reference offset A
- S-0-0166, Distance-coded reference offset B
- S-0-0177, Absolute offset 1
- S-0-0178, Absolute offset 2

Parameters for homing at travel range limit switches:
- P-0-0090, Travel range limit parameter
- P-0-0222, Travel range limit switch inputs

Parameters for homing at positive stop:

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- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0331, Status "n_feedback = 0"
- S-0-0333, Status "T >= Tx"

Pertinent Diagnostic Messages   Diagnostic messages for drive-controlled homing:

- C0600 Drive-controlled homing procedure command
- C0601 Homing only possible with drive enable
- C0602 Distance home switch - reference mark erroneous
- C0604 Homing impossible with absolute encoder
- C0606 Reference mark not detected
- C0607 Reference cam input not assigned

Diagnostic messages for NC-controlled homing:

- C4302 Distance home switch - reference mark erroneous
- C4304 Homing impossible with absolute encoder
- C4306 Reference mark not detected
- C4307 Reference cam input not assigned
- C4308 Pos. stop a. HW lim. switch not allowed f. modulo axes
- C4400 Calculate displacement procedure command

Functional Description

General Information

Type and Arrangement of Refer-ence 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**

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→ 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 through an automated sequence, 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)

For example for manual purposes, the position data reference of a relative measuring system (group 1, 2, 3) can also be established without identifying the dedicated point, i.e. without motion, if the precise axis position of the axis slide in standstill or locked in place. In this case neither the reference marker of the encoder nor an axis-side additional device (home switch) are required. Via command "S-0-0148, C0600 Drive-controlled homing procedure command" the position data reference can be established with the drive being in standstill and inactive (without AF).

☞   In this connection, adequate values have to be selected for the reference distance and the reference offset!

Motion Range for Homing

The motion range required for homing depends on the encoder used:

- For encoders of group 1, 2 or 3, motion over the entire travel distance of the axis might be required.

- 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)

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- Positive stop at the end of the axis (if there isn't any switch to be used)

☞ The mentioned axis-side additional devices are also used for detecting the end of the axis during the homing procedure.

| | Number of reference mark signals occurring over the travel range | | | |
| | One signal | | Several signals | |
Relative encoder of …	Rotary axis	Linear Axis	Rotary axis	Linear Axis
… group 1, 2 (rotary encoder)	AD: No	AD: Yes	AD: Yes (home switch)	AD: Yes
… group 3 (linear encoder)	---	AD: Yes	---	AD: Yes
… group 4 (rotary/linear encoder)	---	---	AD: No	AD: Yes

TU   Additional device

Fig.5-56:   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 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.

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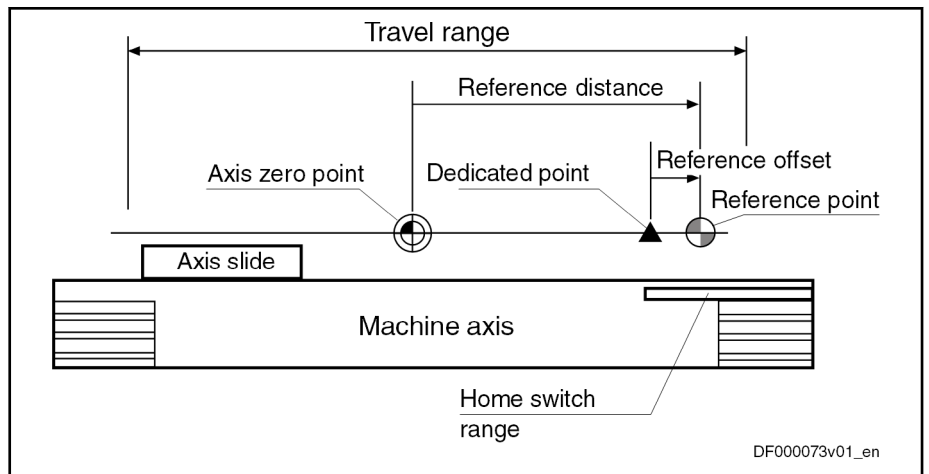
Fig.5-57:   Example of Positions of Axis Zero Point, Dedicated Point and Refer-
              ence Point for Encoders of Groups 1, 2, 3

As the position data reference can be established both for the motor encoder
and for the external encoder, there is one independent parameter available
for the respective reference offset of both encoders:

- S-0-01750 Reference offset 1 (motor encoder)

- S-0-0151, Reference offset 2 (external encoder)

The reference distance is the distance between the reference point and the
axis zero point. There is one independent parameter available for the respec-
tive 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 En-coders 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 posi-
tion difference of two neighboring distance-coded reference marks. The posi-
tion difference between axis zero point and encoder zero point is transmitted
to the controller via the so-called absolute offset.
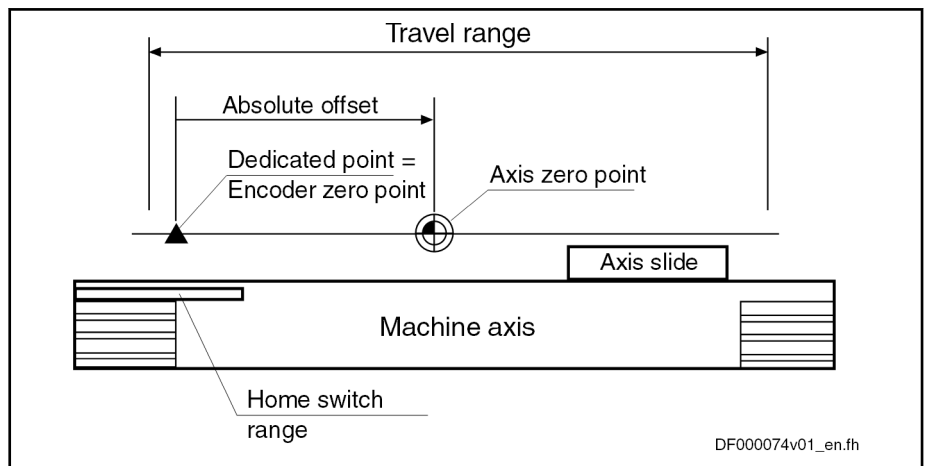
Fig.5-58:   Example of Positions of Axis Zero Point and Dedicated Point for En-
              coders of Group 4

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:

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- S-0-0177, Absolute offset 1 (motor encoder)
- S-0-0178, Absolute offset 2 (external encoder)

☞   Only one distance-coded measuring system can be connected!

Motion Range for Encoders with Distance-Coded Reference Marks   For the homing procedure, relative measuring systems with distance-coded reference marks require a motion range corresponding as a maximum to the double distance of two neighboring reference marks.

Reference Mark Distance of Linear Encoders   Distances of neighboring reference marks of encoders with distance-coded reference marks:

$$\text{Motor encoder} \quad s_{RefMarks} = \text{S-0-0165} \times \text{S-0-0116}$$

$$\text{External encoder} \quad s_{RefMarks} = \text{S-0-0165} \times \text{S-0-0117}$$

$s_{RefMarks}$ 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.5-59:   *Distance of Neighboring Reference Marks of Linear Encoders with Distance-Coded Reference Marks*

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.5-60:   *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" has been selected in 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, a   Homing acceleration (S-0-0042)
Fig.5-61:   *Maximum Motion Range for Homing Encoders with Distance-Coded Reference Marks in Case of "Stop" (S-0-0147)*

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☞ 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:

$$\text{Linear scaling} \quad s_{\text{Ref\_max}} = 2 \times s_{\text{RefMarks}} + \frac{v^2}{2 \times a}$$

$$\text{Rotary scaling} \quad s_{\text{Ref\_max}} = 2 \times s_{\text{RefMarks}} + \frac{\omega^2}{2 \times \alpha}$$

$s_{\text{Ref\_max}}$	Maximum motion range
sRefMarks	Distance of neighboring reference marks
v, ω	Homing velocity (S-0-0041)
a, α	Homing acceleration (S-0-0042)

Fig.5-62: *Maximum Motion Range for Homing Encoders with Distance-Coded Reference Marks in Case of "Run Path" (S-0-0147)*

☞ The motion range of the axis in the case of "run path" is always the same! This is advantageous for homing Gantry axes!

Detecting the End of the Travel Range

When homing relative measuring systems, the axis always has to be moved in defined direction so that the dedicated point can be reliably identified. As a prerequisite the axis has to be within the allowed travel range.

But the axis, when the search of the dedicated point is started, can also already be at that end of the axis at which the dedicated point is situated. For fail-safe detection of the dedicated point the drive has to be able to recognize this situation. This is only possible by means of axis-side additional devices (AD):

- Home switch at end of axis
- Travel range limit switches
- Positive stop at end of axis for axis blocking (detection of positive stop)

One of these devices must be mounted at the end of axis of the dedicated point and its signals must be evaluated by the drive controller.

💡 For NC-controlled homing a home switch is obligatory! For NC-controlled homing, travel range limit switches and positive stop can neither be used for detecting the end of the travel range nor for identifying the dedicated point.

The 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")

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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 marker.

For using the NC-controlled homing an axis-side home switch is obligatory!
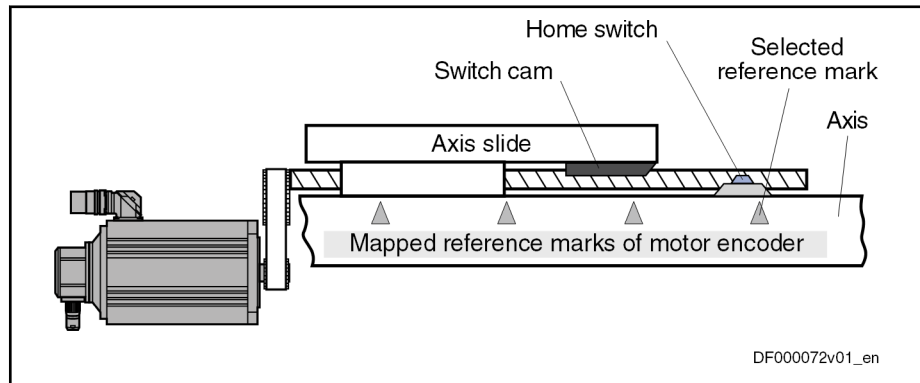
Fig.5-63:   Selecting a Reference Mark via Home Switch in the Case of a Linear Axis

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
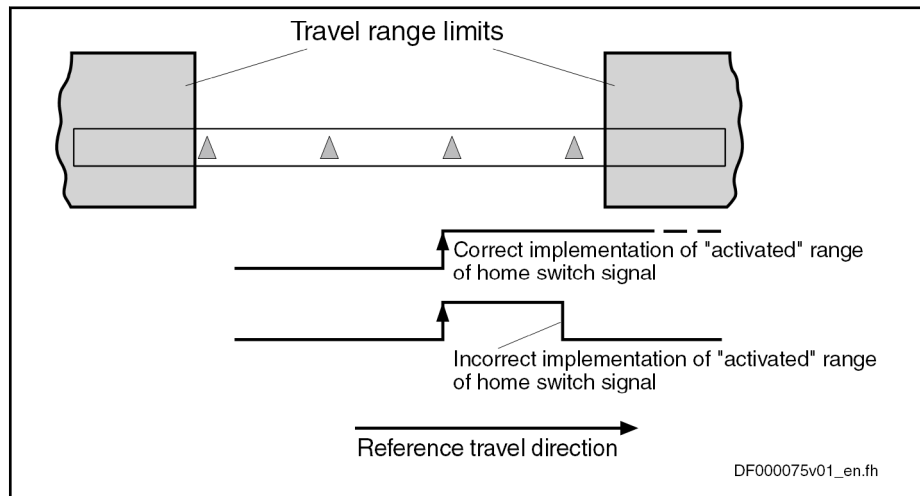
Fig.5-64:   Arranging the Home Switch with Regard to Travel Range Limits in the Case of Linear Axes

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

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travel range. The following applies to the minimum distance home switch-travel range limit:

$$x_{RS\_VbLimit} \geq x_{RefMarks} + \frac{v^2}{2 \times a}$$

$x_{RS\_VbLimit}$	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.5-65:   *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

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Determined edge evaluation (S-0-0147)	Signal status of home switch (bit in S-0-0400)	Drive action
Negative	0 ("Activated")	Motion against reference travel direction until home switch is not activated, then reversal of motion; search for dedicated point after negative signal edge was detected
Positive	1 ("Activated")	Motion against reference travel direction until home switch is not activated, then reversal of motion; search for dedicated point after positive signal edge was detected

Fig.5-66:   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 "S-0-0173, Marker position A", the non-homed position of the neighboring reference mark is stored in "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.5-67:   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)

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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 "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 "").
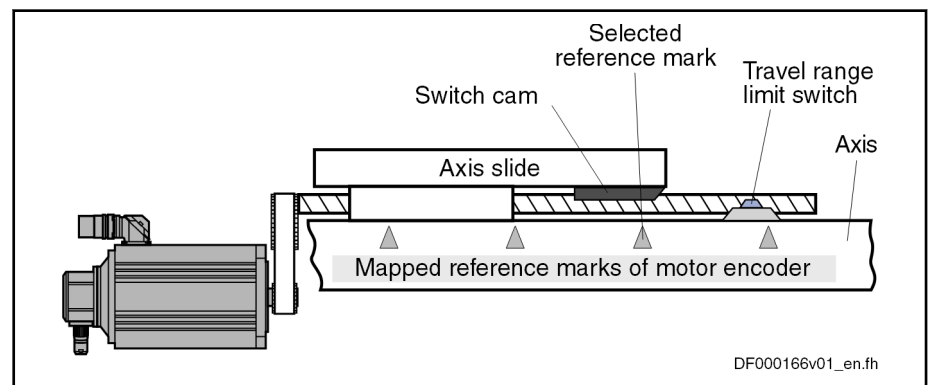
Fig.5-68:   Selecting a Reference Mark via Travel Range Limit Switch

After the start of drive-controlled homing (command C0600), the axis is moved in the determined direction of motion until the travel range limit switch is activated. The drive then changes the direction of motion, the dedicated point is detected when the first reference mark signal occurs.

☞   If the travel range limit switches for hardware-side limitation of the allowed travel range have been activated, this monitoring function is deactivated during the homing procedure!

Axis Position When Switching On; Detecting the End of the Travel Range

When the axis drive is switched on, the moving part of the axis can be at any position within the travel range, but it can also be at the end of the travel range. The travel range limit switch mounted at the end of the axis can be activated.

It must be possible to carry out the homing procedure even from this start position. In the case of drive-controlled homing, the drive, independent of the signal status and the settings for the "activated" signal of the travel range limit switches, automatically passes the dedicated point.

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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.5-69:   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.5-70:   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 switches is displayed in "P-0-0222, Travel range limit switch inputs":

See "Digital Inputs/Outputs"

Activating the Evaluation of Reference Marks and Travel Range Limit Switch

The evaluation of the reference marks and the travel range limit switch as additional devices for homing has to be activated in the respective bit of "S-0-0147, Homing parameter".

> The evaluation of home switch and/or positive stop mustn't be activated at the same time!

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☞ If the evaluation of the reference marks has not been activated, the dedicated point is determined only by the signal of the travel range limit switch!

Identifying the Dedicated Point by Means of Reference Mark and Positive Stop

Positive Stop for Selecting a Reference Mark

A positive stop at an axis, too, can be used as axis-side additional device (AD) for selecting a reference mark, if several reference mark signals can occur over the travel distance of an axis and the dedicated point is to be determined by one of the marks (see table "chapter "General Information" on page 314").
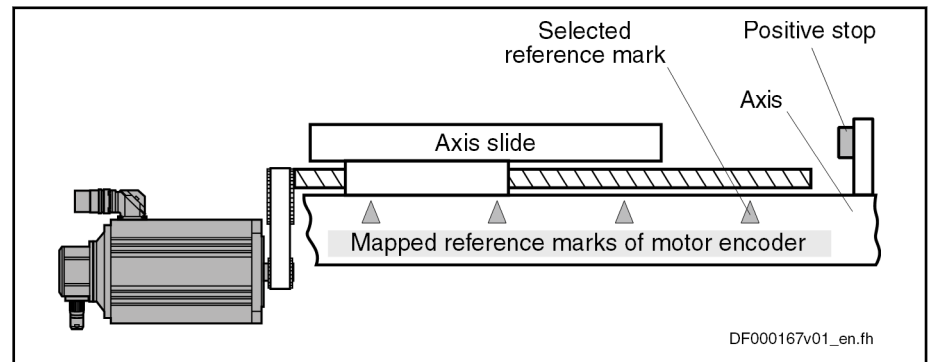
Fig.5-71:   Selecting a Reference Mark via Positive Stop at the end of the Axis

Detecting the End of Travel Range by Axis Blocking (Positive Stop)

After the start of drive-controlled homing (command C0600), the drive first moves the moving part of the axis in the determined reference travel direction (see S-0-0147). There is no switch signal required for identifying the end of the axis!

Search for Dedicated Point for Non-Distance-Coded Encoders

In the case of non-distance-coded encoders, the axis moves until it is blocked by positive stop. After the actual torque value (S-0-0084) of the drive has exceeded the torque limit value (minimum of S-0-0092 and S-0-0082 or S-0-0092 and S-0-0083) that was set and standstill of the drive was detected ("S-0-0331, Status "n_feedback = 0""), the drive changes the direction of motion; the dedicated point is determined by the occurrence of the first reference mark signal.

Search for Dedicated Point for Distance-Coded Encoders

In the case of distance-coded encoders, the axis only moves to positive stop, if there is none or only one distance-coded reference mark in the determined reference travel direction before blocking. After blocking was detected (see paragraph above), the drive changes the direction of motion and over the next two reference marks determines the axis position with regard to the dedicated point.

☞ If evaluation of the reference marks has not been activated, the dedicated point is only determined by detection of positive stop (S-0-0333, S-0-0331, see above).

Activation of Axis Blocking Detection (Positive Stop) for Homing Procedure

The evaluation of the reference marks and the positive stop as additional devices for homing has to be activated in the respective bit of "S-0-0147, Homing parameter". The evaluation of home switch and/or travel range limit switch mustn't be activated at the same time!

☞ The monitoring of position command value, actual position value and acceleration is switched off during the homing procedure!

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☞   If travel range limit switches for hardware-side limitation of the al-
      lowed travel range have been activated, the monitoring of this lim-
      itation 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 ref-
erence 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 sig-
nal that is evaluated by the controller for detecting the position of the dedica-
ted 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 trav-
   el 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 proce-
   dure

Within the range of inaccuracy of the position detection there mustn't occur
any encoder reference mark, because reliably reproducible detection of the
dedicated point is impossible within this range!
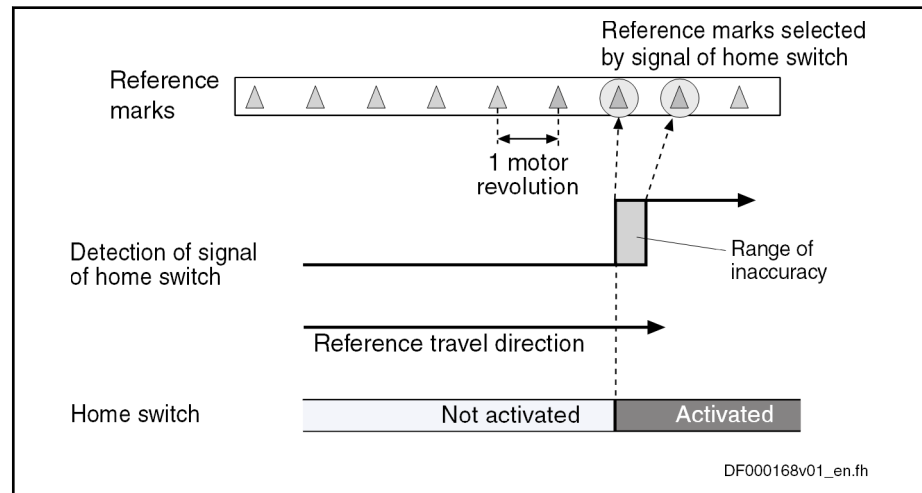
Fig.5-72:   Ambiguous Detection of Reference Marks in Range of Inaccuracy of
             Home Switch Detection

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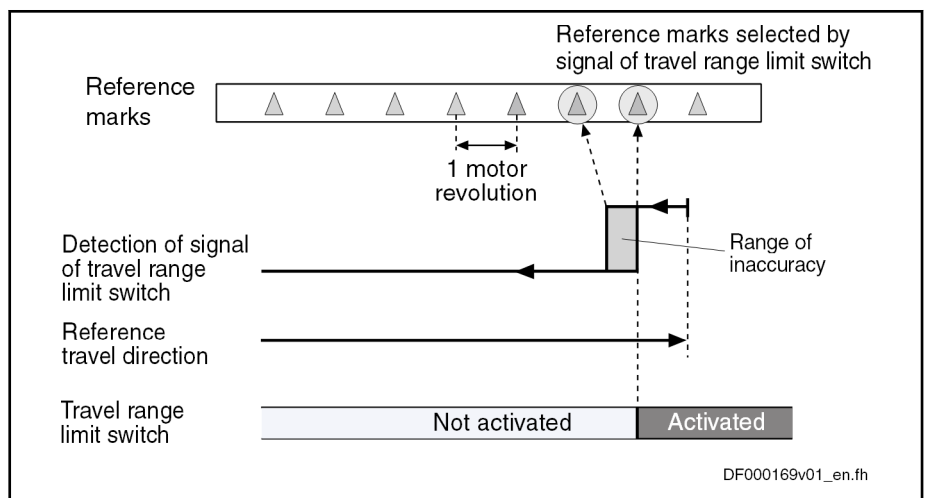
Fig.5-73:   Ambiguous Detection of Reference Marks in Range of Inaccuracy of Travel Range Limit Switch or Positive Stop Detection

Distance Monitoring Switch Edge or Positive Stop Detection/Reference Mark

Due to the range of position inaccuracy of the switch edge or positive stop detection, the distance to the position of the next reference mark is monitored. If the distance falls below a certain value, the error message "C0602 Distance home switch - reference mark erroneous" will be generated.

Classification of distance	Distance	Drive reaction
Critical distance	< 0.25 × reference mark distance	Shutdown with message C0602
Optimum distance	0.5 × reference mark distance	--
Allowed distance range	(0.25 … 0.75) × reference mark distance	--

Fig.5-74:   Data Regarding the Distance Between Switch Edge or Positive Stop Detection and Reference mark
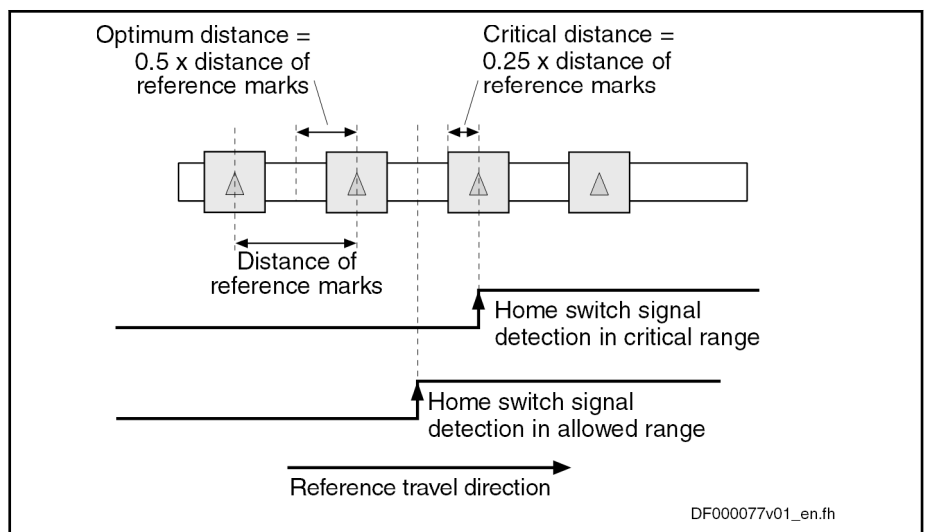
Fig.5-75:   Critical and Optimum Distance of Switch Edge and Reference Mark in the Case of the home Switch

For monitoring the distance the optimum distance has to be specified in "P-0-0153, Optimum distance home switch-reference mark".

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☞ 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!

ℹ For default values of P-0-0153 for distance monitoring to the next reference mark in the case of switch edge or positive stop detection, see separate documentation "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 "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 "S-0-0299, Home switch offset". For this purpose, the value of S-0-0298 has to be entered in S-0-0299.
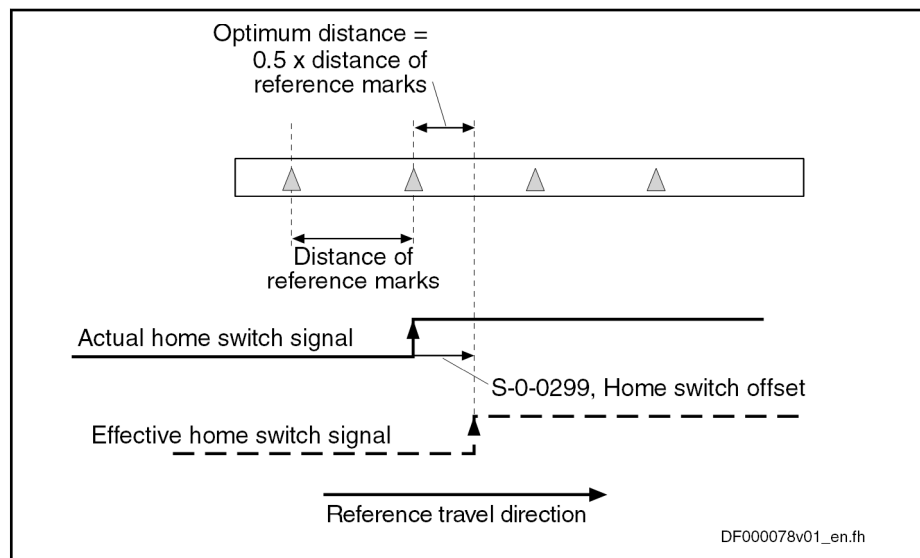
Fig.5-76:   Operating Principle of Parameter S-0-0299 in the Case of Home Switch Signal

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

☞ 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!

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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 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!

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Jerk Limitation

To limit acceleration jumps it is possible to additionally activate a jerk limit. This is made by the input in "S-0-0349, Bipolar jerk limit".

Motion Range for Homing

The process for searching the dedicated point requires axis motion. The axis motion to be expected depends on the selected measuring system and on the position of the axis at the start of drive-controlled homing (for information on axis motion see above under the description of the respective paragraph "Identifying the Dedicated Point by Means of …").

Maximum Velocity

As in the case of all drive-controlled functions, the maximum velocity can be directly influenced with a feedrate factor when executing the homing procedure. The effective maximum velocity then results from the product of the values of "S-0-0041, Homing velocity" and "S-0-0108, Feedrate override".

Shutdown

After the controller has detected the dedicated point of the axis by the homing procedure, the actual position values are switched to axis-related values. The drive then shuts down the axis with the homing acceleration (S-0-0042). Shutdown can be carried out as:

- "Stopping"

  → Non-target-oriented immediate braking motion that possibly is of shorter duration

- or -

- "Positioning"

  → Target-oriented motion to the reference point (axis-related value in "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".
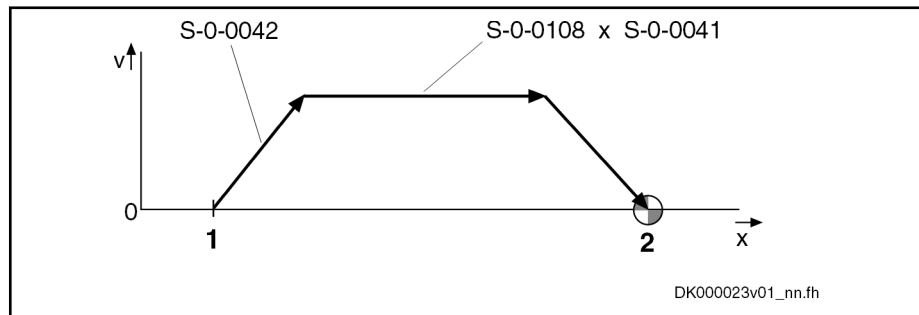
1	Start point
2	Reference point
S-0-0041	Homing velocity
S-0-0042	Homing acceleration
S-0-0108	Feedrate override

Fig.5-77:   Command Value Profile for Drive-Controlled Homing with Constant Feedrate Factor and "Positioning" Shutdown

☞   If "S-0-0108, Feedrate override" starts with zero, the warning "E2055 Feedrate override S-0-0108 = 0" will be output.

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Actions of the Control Unit in the Case of Drive-Controlled Homing

Starting Command C0600
The control master starts the command by writing to "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 "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

- S-0-0146, C4300 NC-controlled homing procedure command

and presets the command value for axis motion, according to the active operation mode.

When the drive has detected the dedicated point, it informs the master of this fact and stores the position of the dedicated point. The master then completes the execution of command C4300 and afterwards activates

- 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

- 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 "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 S-0-0147), it has to be detected as "activated". For distance-coded encoders, the master-side hom-

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ing 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 "S-0-0408, Reference marker pulse registered". The position of the dedicated point or the detected reference marks is stored:

- For non-distance-coded encoders, the detected dedicated position is stored in "S-0-0173, Marker position A".

- For distance-coded encoders, the first detected reference mark is stored in "S-0-0173, Marker position A", the second one in "S-0-0174, Marker position B".

The correct, time-optimized sequence of the execution of command C4300 requires the following assignments:

- Bit "homing enable" (S-0-0407) in real-time control bit of "S-0-0134, Master control word"

- Bit "reference mark detected" (S-0-0408) in real-time status bit of "S-0-0135, Drive status word"

When the bit "reference mark detected" (S-0-0408) has been set, the master can complete the execution of the command C4300.

Drive-Side Calculation of Actual Position Value Displacement for Zero Point Reference

By master-side activation of "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 "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.

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The calculated displacement value (S-0-0175 or S-0-0176) is now added to the non-homed actual position value; the new actual position value is displayed in:

- S-0-0051, Position feedback value 1

- or -

- S-0-0053, Position feedback value 2.

The homing status of the encoders connected to the drive is also displayed in "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 "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 -

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> – Travel range limit switch as a replacement for home switch (option-al for drive-controlled homing, not possible for NC-controlled hom-ing)
>
> - or -
>
> – Activation of detection of axis blocking for positive stop drive proce-dure (optional for drive-controlled homing, not possible for NC-con-trolled 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 "S-0-0092, Bipolar torque/force limit value", or "S-0-0082, Torque/force limit value positive" or "S-0-0083, Torque/force limit value negative"

- Setting of standstill threshold for detection of blocking in "S-0-0124, Standstill window"

Distance Monitoring of Reference Mark Signals

With active reference mark evaluation (obligatory for NC-controlled homing, optional for drive-controlled homing), encoder-specific values for the monitoring of the reference mark signals have to be entered in "P-0-0153, Optimum distance home switch-reference mark". Monitoring takes place during the homing procedure (see Parameter Description P-0-0153).

NOTICE	**Property damage at the installation caused by home switch edge incorrectly set!**

⇒ Make sure the home switch edge was correctly set and is within the travel range!

Distance Control Home Switch Edge - Travel Range Limit

In the case of home switch evaluation, first control whether the minimum distance between home switch edge and travel range limit has been complied with:

- Search for switch point of home switch, e.g. by jogging the axis to switch cam; control switch status in "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 ve-locity 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"

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- 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 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 has been entered in "P-0-0153, Optimum distance home switch-reference mark"

  Note: The value in P-0-0153 refers to the encoder to be homed as determined in parameter S-0-0147. If a second encoder has to be homed that requires different values in P-0-0153, this parameter has to be adjusted to the respective encoder to be homed before the C0600 command is started!

- Execution of the drive-controlled homing procedure (command C0600) with "S-0-0299, Home switch offset" = 0 and the setting "Stop" in 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 from "S-0-0298, Reference cam shift" in "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 "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

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- or -

–   Use of a travel range limit switch as a replacement for home switch

- or -

–   Activation of blocking detection for positive stop drive procedure

Note: Only one of the possible axis-side additional devices for drive-controlled homing may be selected!

● Setting for shutting axis down after detection of dedicated point ("stop", "positioning" or "run path")

Axis-Related Settings for Establishing the Position Data Reference

Depending on the kind of reference marks of the encoder, the axis-related parameter settings for establishing the position data reference are explained in the following sections.

Notes on Commissioning for Drive-Controlled Homing with Relative Encoders (Reference Marks Non-Distance-Coded)

Manual Establishment of Position Data Reference

If the position data reference of an encoder (according to group 1, 2, 3) is to be established, for example, during initial commissioning of an axis in a simple manner, this can be made with the axis slide in standstill without "AF". To do so, perform the following steps:

1. Enter correct actual position value of the axis slide at the current axis position n S-0-0052, Reference distance 1 or S-0-0054, Reference distance 2

2. Enter value "0" in S-0-0150, Reference offset 1/S-0-0151, Reference offset 2

3. Do not activate encoder reference marker evaluation or evaluation of home switch or travel limit switch or positive stop of axis in "S-0-0147, Homing parameter"

4. Execute "C0600 Drive-controlled homing procedure command" (S-0-0148), the drive does not have to be in "AF".

The position data reference of the axis has now been established via the current position of the axis slide.

☞   Before repeating the manual homing procedure, ensure that the value in S-0-0052, reference distance 1 or S-0-0054, Reference distance 2 receives the correct position of the current axis slide position!

Search for the Dedicated Point of the Axis (for automated Sequence)

To establish the position data reference of an encoder (of groups 1, 2, 3) to the axis through an automated sequence, the distance between the dedicated point identified on the drive side and the reference point of the axis, as well as the position of the reference point compared to the axis zero point have to be entered.

To do this, the following steps have to be carried out:

1. First set the following parameters to value "0":

   ● S-0-0052, Reference distance 1/S-0-0054, Reference distance 2

   ● S-0-0150, Reference offset 1/S-0-0151, Reference offset 2

2. If encoder reference marks are not to be evaluated, but only either home switch or travel limit switch or the positive stop of the axis, make corresponding settings in "S-0-0147, Homing parameter" (default setting: encoder reference marks are evaluated!).

3. For initial commissioning, set parameters for automated search of dedicated point of axis to small values:

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- 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 operation mode becomes active again. When the "drive-internal interpolation" mode was set, for example, the drive immediately moves to the position according to the value in "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 "S-0-0051, Position feedback value 1" or "S-0-0053, Position feedback value 2" now has absolute reference to this preliminary axis zero point.

Settings for the Reference Point

The reference point normally has an actual position value determined on the axis-side and related to the axis zero point. Ideally, the dedicated point identified on the drive-side has the same position as the reference point. As the dedicated point position is considerably influenced by the mounting situation of the encoder, dedicated point and reference point are different. The distance between dedicated point and reference point for the motor encoder or external encoder is entered in the parameter for reference offset 1 or reference offset 2.

To determine the reference offset the following steps have to be carried out, based on the initial 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 "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 "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

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- S-0-0042, Homing acceleration

For the purpose of control carry out 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, this too has to be set in S-0-0147. The position can be preset via "S-0-0150, Reference offset 1" or "S-0-0151, Reference offset 2".

NOTICE	Property damage 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"

NOTICE	Property damage caused by step change of actual position value!

⇒ By clearing the command, the original operation mode becomes active again. When the "drive-internal interpolation" mode was set, for example, the drive immediately moves to the value in "S-0-0258, Target position". Take change in actual position value into consideration!

Axis Zero Point and Dedicated Point

After the command was executed, the axis zero point is at the same axis position as the dedicated point, because the absolute offset (S-0-0177/S-0-0178) was set to the value "0". The actual position value in "S-0-0051,

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Position feedback value 1" or "S-0-0053, Position feedback value 2" now has absolute reference to this preliminary axis zero point.

Settings for the Axis Zero Point

An axis-side reference point possibly available is not used for establishing the position data reference for distance-coded measuring systems. In order to establish the position reference to the real axis zero point, enter the desired axis-related actual position value of the dedicated point in "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

For the purpose of control carry out "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 S-0-0147, if the axis is in the "activated" range of the home switch!

For distance-coded encoders, drive-controlled homing can be completed with "stop", "positioning" or "run path":

"Stop" at the End of the Homing Procedure

If the setting "stop" (default setting) was made in "S-0-0147, Homing parameter", the drive stops the axis as soon the controller has detected two neighboring reference marks. The motion range of the axis, depending on the initial position, is the single to double reference mark distance (S-0-0165).

"Positioning" at the End of the Homing Procedure

If the axis, after the dedicated point was detected, is to position to the reference point, this too has to be set in S-0-0147. The position can be preset via "S-0-0052, Reference distance 1" or "S-0-0054, Reference distance 2".

☞ When homing distance-coded encoders, the value in S-0-0052/ S-0-0054 is insignificant for establishing the position data reference! In this case, it can possibly be used for presetting a homing target position.

| **NOTICE** | **Property damage possible at the installation, if the reference point is outside the allowed travel range and the position limit hasn't been activated yet!** |

⇒ Make sure that reference point is within the travel range and activate the position limit!

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"Run Path" for Homing Procedure

If the setting "run path during homing procedure" has been 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 "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.

Notes on Commissioning "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 "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

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- "Notes on Commissioning for Drive-Controlled Homing with Relative En-coders with Distance-Coded Reference Marks", see above

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☞ The axis-related settings for establishing the position data refer-ence are basically the same for drive-controlled and NC-control-led homing! For determining the axis-related parameter values it is advantageous to use drive-controlled homing!

Searching for the Dedicated Point

The master starts "C4300 NC-controlled homing procedure command" and sets the command value for the homing motion (if drive in "AF").

Detection of dedicated point takes place when:

- Homing enable (S-0-0407) has been set

- or -

- "S-0-0407, Homing enable" has been set and the home switch is in the "activated" status (S-0-0400)

For non-distance-coded encoders, the non-homed position of the detected dedicated point is stored in:

- S-0-0173, Marker position A

For distance-coded encoders, the non-homed position of the detected dedi-cated 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 "S-0-0408, Reference marker pulse registered" and the master then com-pletes 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 deter-mined, 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 Displace-ment 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 dis-played in the following parameters:

- S-0-0051, Position feedback value 1
- S-0-0053, Position feedback value 2.

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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 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 "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 impossible with absolute encoder
- C0606 Reference mark not detected
- C0607 Reference cam 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 impossible with absolute encoder
- C4306 Reference mark not detected
- C4307 Reference cam input not assigned

Shifting the Position Data Reference for Absolute/Relative Measuring Systems (Shift Coordinate System Procedure)

Brief Description

> Expansion package **servo function** (order code **SRV**) of all firmware variants in **closed-loop** characteristic.

The existing position data reference of the measuring systems to the axis can be shifted if the respective command was activated by the master. It is possible to shift the data reference in standstill or while the axis is moving. This does not affect the position reference of the axis because it is only the actual position values output for the master that are displayed in "shifted" form. Internally, the original ("non-shifted") position data reference is maintained.

Shifting the position data reference affects the motor encoder and, if available, the external encoder, independent of which encoder is the active encoder for position control. If different actual position values are valid for the encoders (both encoders possibly have position data reference independent of each other), the actual position values of both measuring systems are shifted by the same difference.

Pertinent Parameters
- S-0-0197, C3300 Set coordinate system procedure command
- S-0-0198, Initial coordinate value
- S-0-0199, C3400 Shift coordinate system procedure command

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- 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 "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 after completion of shifting of actual position values (value in "S-0-0283, Current coordinate offset" unequal "0") the position data reference of the encoder to the axis is established ("C0300 Set absolute position procedure command" or "C0600 Drive-controlled homing procedure command"), the current offset of the coordinate system is cleared and the value "0" is displayed in S-0-0283.

"Set Coordinate System" Command

When the control master triggers the "C3300 Set coordinate system procedure command" (S-0-0197), the drive becomes independent of the command values preset by the master and goes to standstill in a drive-controlled way. Deceleration takes place according to the "A0010 Drive HALT" function.

ℹ️ See also description of diagnostic message "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 S-0-0283. The command then is acknowledged as having been "executed".

"Shift Coordinate System" Command

When the control master triggers "C3400 Shift coordinate system procedure command" (S-0-0199), the drive also becomes independent of the command values preset by the master but maintains the current velocity by internal input of the previous velocity command value. The actual position values now are shifted by addition of "S-0-0275, Coordinate offset value". The difference between the new and original actual position values is stored in S-0-0283. The command then is acknowledged as having been "executed".

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Action of Control Unit after Command Acknowledgment

After the command acknowledgment the control master has to adjust to the shifted actual position values. This can be done by means of the actual position values of the encoder active for position control (S-0-0051 or S-0-0053) or the current offset value (S-0-0283). When the control master has adjusted its command values to the new actual position values, it can clear the command. The master then sets the command values again. In spite of the actual position value having been shifted with the drive active, there is no jerk when controlled!

Change in Position Data by "Shifting Position Data Reference"

Measured position values, generated by probe evaluation, for example, refer to the actual position value system in which they were measured, i.e.:

- When measured after the shifting, they refer to the "shifted" measuring system.

- When measured before the shifting, they refer to the original measuring system.

Command values (cyclic command values, target position, spindle angle position etc.) have to refer to the current actual position value system, i.e. to the possibly shifted position data reference.

Unchanged Position Data after "Shifting Position Data Reference"

Travel range limit values (S-0-0049 or S-0-0050) and **position correction values** (e.g. axis error correction values) are always in their original position data reference, i.e. the control unit, before writing these parameters, has to take the current offset into account and calculate the original position reference again.

Notes on Commissioning

Shifting the position data reference during commissioning can cause incorrect command values after the shifting has been carried out! Commissioning basically makes sense only in conjunction with the control master. Check whether the command value handling of the master is correct!

NOTICE	Property damage caused by error in command value input after shifting the position data reference!

⇒ Protect the travel range of the axis, activate axis limit switches and make sure they are working!

"Set Coordinate System"

It is recommended to begin with "set coordinate system procedure". But first "S-0-0283, Current coordinate offset" should be read. When the shifting of the position data reference has not yet been carried out after the transition from "P2" to "AF" , the value has to be "0"!

With master-side command value input, the "S-0-0197, C3300 Set coordinate system procedure command" has to be started by the master.

See also "Command Processing"

Checking the Offset of Position Data Reference

When the command was acknowledged by the drive, the offset of the position data reference has to be checked:

- The actual position value (S-0-0051 and possibly S-0-0053) must correspond to "S-0-0198, Initial coordinate value".

- Read "S-0-0283, Current coordinate offset". 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.

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<table>
<tr><td>Checking the Command Value Input and Clearing the Command</td><td>To check the command value input the master has to preset a position command value that corresponds to the value of 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!</td></tr>
<tr><td>"Shift Coordinate System Procedure"</td><td>With "shift coordinate system procedure" it is recommended to control the axis on the master-side with velocity command value "0" or with very low velocity. In this context, you must, however, first read parameter "S-0-0283, Current coordinate offset". When the shifting of the position data reference has not yet been carried out after the transition from "P2" to "AF" , the value has to be "0"!

Subsequently, start "C3400 Shift coordinate system procedure command" on the master side.

See also "Command Processing"</td></tr>
<tr><td>Checking the Offset of Position Data Reference</td><td>When the command was acknowledged by the drive, the offset of the position data reference has to be checked:

- The values of "S-0-0283, Current coordinate offset" and "S-0-0275, Coordinate offset value" have to correspond.</td></tr>
<tr><td>Checking the Command Value Input and Clearing the Command</td><td>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!</td></tr>
</table>

Detecting the Marker Position

Brief Description

> 💡 **Base package** of all firmware versions in **closed-loop** characteristic.

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 performed:

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- "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 "S-0-0173, Marker position A" and then the command execution is signaled to be completed.

☞   The drive does not generate any command value. The operation mode active at the start of the command remains unchanged. In order to pass the reference mark the control master has to preset such command values (e.g. by means of jogging) that lead to a movement in direction of the reference mark to be detected.

☞   The position of the reference marker is stored in "S-0-0173, Marker position A", even while "C0600 Drive-controlled homing procedure command" (S-0-0148) is being carried out. This position, however, refers to the "old" coordinate system (before switching the coordinate system when executing the homing procedure).

5.6   Mechanical Axis System and Arrangement of Measuring Systems

5.6.1   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 backlash or a low degree of stiffness of the mechanical system, etc.

The external (optional) encoder can also be used as a measuring wheel encoder (frictionally engaged on transported material).

See "Measuring Wheel Mode"

For 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 motors of high precision requirements

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- EnDat2.1 encoder with 2048 increments for high accuracy requirements

- HIPERFACE® encoder with 128 increments for low accuracy 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 supplied as individual components and assembled in the machine to form the motor. It consists of a moving and a static part, the bearing and the motor encoder.

The following measuring systems can be used as a motor encoder:

- GDS/GDM encoders from Rexroth (rotary single-turn or multi-turn encoders with housing and shaft)

- Incremental encoders with sine signals (compatible with signal specification of Heidenhain)

- Encoders with EnDat2.1 interface from Heidenhain

- Encoders with HIPERFACE® interface from Stegmann [IndraDrive-compatible HIPERFACE® encoders (FAQ_IndraDrive_unterstützte_Geber...) or HIPERFACE® encoders with type ID "0xFF"]

- Combined encoders consisting of incremental encoder with sine signals (compatible with signal specification of Heidenhain) and "Hall sensor box SHL02.1" (Rexroth-compatible signal specification)

- Encoders with EnDat2.1 interface from Heidenhain

- Incremental encoders with square-wave signals (compatible with signal specification of Heidenhain)

- Combined encoders consisting of incremental encoder with square-wave signals
  (compatible with signal specification of Heidenhain) and "Hall sensor box SHL02.1" (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").

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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!

As of MPx06V08:

In two special cases, however, for synchronous motors with encoder gear and a motor that can be evaluated in absolute form (rotary encoders only) the commutation setting is performed only during initial commissioning. Then, when the drive is switched on again, it is immediately ready for operation; automatic commutation setting for initial drive enabling (AF) is not required, so it is not performed in the following cases:

Case 1, Single-turn (or multi-turn) encoder:

- if an n-fold motor revolution (n is an integer) yields exactly one encoder revolution

Case 2, Multi-turn encoder:

- if exactly one motor revolution yields an m-fold encoder revolution (m is an integer)

External Encoders at Machine Axes

IndraDrive controllers can evaluate the following measuring systems as external encoders:

- GDS/GDM encoders from Rexroth (rotary single-turn or multi-turn encoders with housing and shaft)

- Incremental encoders with sine signals (compatible with signal specification of Heidenhain)

- Encoders with EnDat2.1 interface from Heidenhain

- Encoders with HIPERFACE® interface from Stegmann [IndraDrive-compatible HIPERFACE® encoders (FAQ_IndraDrive_unterstützte_Geber...) or HIPERFACE® encoders with type ID "0xFF"]

- Incremental encoders with square-wave signals (compatible with signal specification of Heidenhain)

Possibilities of Arranging Measuring Systems

The figure below shows an overview of arrangement possibilities of mechanical drive system and measuring systems.

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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.5-78: *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 "P-0-0077, Assignment motor encoder->optional slot" and "P-0-0078, Assignment optional encoder->optional slot", you can determine 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

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- 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)

5.6.2   Functional Description

Motor Encoder   The motion type of the motor encoder can either be rotary or linear. The controller is told this via "S-0-0277, Position feedback 1 type".

If "linear motor encoder" is set in S-0-0277, the encoder 1 gear parameters are inactive, the actual position value reference (S-0-0076, Position data scaling type) has to be set to "motor-related" and "linear". As the actual position values are determined directly at the moving part of the axis it does not make sense to use another external encoder!
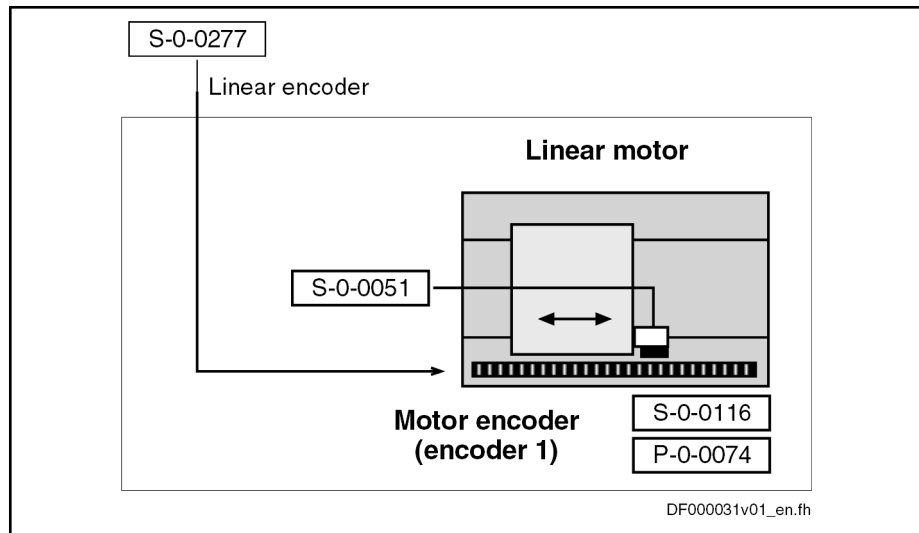
S-0-0051	Position feedback 1 value
S-0-0116	Feedback 1 resolution
S-0-0277	Position feedback 1 type
P-0-0074	Encoder type 1 (motor encoder)

Fig.5-79:   Motor Encoder Arrangement for Drive with Linear Motor

When "rotary motor encoder" has been set, the controller assumes an application with a rotary motor. This means:

- In the case of rotary kit motors, the motor encoder can be connected via a gear; Rexroth housing motors have a direct motor connection.
- The load side of the drive can be rotary or linear (S-0-0076).

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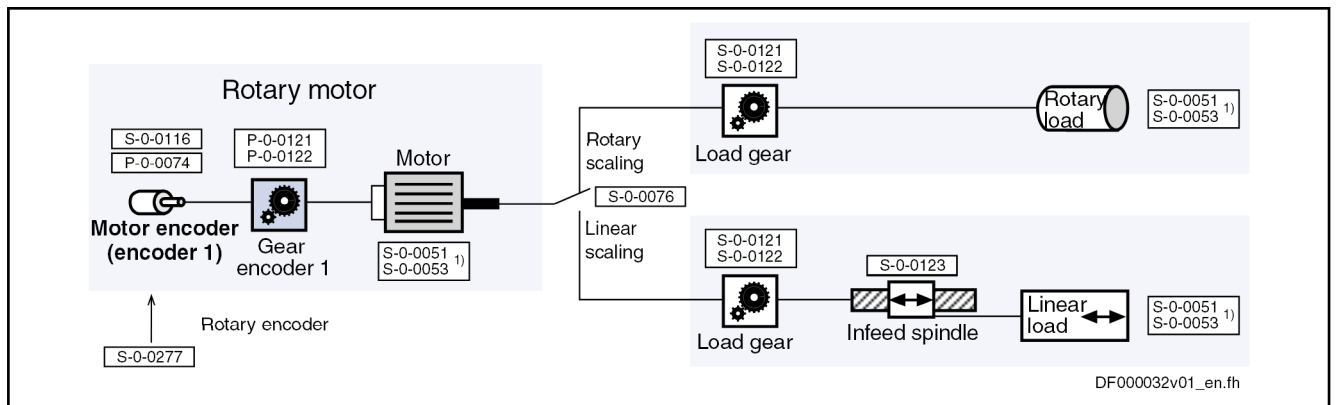
1)	S-0-0051 or S-0-0053, depending on scaling (S-0-0076)
S-0-0051	Position feedback 1 value
S-0-0053	Position feedback 2 value
S-0-0076	Position data scaling type
S-0-0116	Feedback 1 resolution
S-0-0121	Input revolutions of load gear
S-0-0122	Output revolutions of load gear
S-0-0123	Feed constant
S-0-0277	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.5-80: Possible Drive Arrangements with Rotary Motor (without External Encoder)

External encoder For drives with rotary motor, a rotary or linear load-side (external) encoder can be necessary, depending on the application:

- A rotary external encoder can be connected to the load via an encoder 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!

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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.5-81: *Possible Drive Arrangements with Rotary Motor and External Encoder*

5.6.3 Notes on Commissioning

☞ The Notes on Commissioning in the sections "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems" must be observed, too!

Basic Settings Set "linear" or "rotary" encoder type:

- S-0-0277, Position feedback 1 type

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Enter encoder type, hardware assignment and resolution:
- S-0-0116, Resolution of feedback 1
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0077, Assignment motor encoder->optional slot

Settings for Rotary 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 "linear" or "rotary" encoder type:
- S-0-0115, Position feedback 2 type

Enter encoder type, hardware assignment and resolution:
- P-0-0075, Encoder type 2 (optional encoder)
- P-0-0078, Assignment optional encoder->optional slot
- S-0-0117, Resolution of feedback 2

Enter gear ratio for the external (optional) encoder:
- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)

Settings for Measuring Wheel Encoder   Activate feed constant for measuring wheel:
- P-0-0185, Control word of encoder 2 (optional encoder)

Enter feed constant for measuring wheel:
- P-0-0123, Feed constant 2 (optional encoder)

5.7   Scaling of Physical Data

5.7.1   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.

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	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. Physical data, however, can also be exchanged in the control-internal format, i.e. without specific reference to physical units. For this purpose, the scaling for certain data can be freely set ("parameter scaling").

Linear and Rotary Data
Depending on the kind of motion of motor or load, the data can be displayed as follows:

- In linear form (linear axis or motor motion)

- or -

- In rotary form (rotary axis or motor motion)

Motor Reference/Load Reference
In the drive firmware there are mechanical transfer elements between motor and load mapped by means of mathematical models. The physical data can thereby be referred to

- the point where the load takes effect (load-side data reference)

- or -

- the point where the force is input (motor-side data reference).

Absolute/Modulo Evaluation
For technical reasons, the value range of the position data the controller can display is limited.

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
- S-0-0078, Linear position data scaling exponent

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- 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

5.7.2   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:

Physical Data	Preferred scaling		
	Linear	Linear	Rotary
	for unit "m"	for unit "inch"	
Position data	0.0001 mm	0.000025 mm	0.0001 dgr
Velocity data	0.001 mm/min	0.00001 inch/min	0.0001 1/min or 0.000001 1/s

Fig.5-82:   Overview: Preferred Scalings for Position Data and Velocity Data

Physical Data	Preferred scaling			
	Linear	Linear	Rotary	Ramp time
	for unit "m"	for unit "inch"	Unit "rad"	Unit "s"
Acceleration data	0.001 mm/s^2	0.00001 inch/s^2	0.001 rad/s^2	0.001 s
Jerk data	0.000001 mm/s^3	0.00001 inch/s^3	0.001 rad/s^3	0.001 s^2

Fig.5-83:   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:

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$$\text{reference vel. ramp} = \frac{\text{S-0-0446}}{\text{ramp reference time}}$$

$$= \frac{\text{S-0-0446}}{1.0 \text{ ms}} \quad \text{(with preferred scaling)}$$

S-0-0446   Ramp reference velocity for acceleration data

Fig.5-84:   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.5-85:   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.5-86:   Values of Scaling Parameters and Decimal Places of Velocity Data Determined by Preferred Scaling

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Physical data	Scaling type	Unit	S-0-0160	S-0-0161	S-0-0162	Attribute number of decimal places
Acceleration data	Linear	mm/s^2	..0x00.0001	1	-6	3
	Linear	inch/s^2	..0x01.0001	1	-5	5
	Rotary	rad/s^2	..0x00.0010	1	-3	3
	Ramp time	s	..0x00.0011	1	-3	3

S-0-0160   Acceleration data scaling type
S-0-0161   Acceleration data scaling factor
S-0-0162   Acceleration data scaling exponent
Fig.5-87:   *Values of Scaling Parameters and Decimal Places of Acceleration Data Determined by Preferred Scaling*

☞   For practical reasons, the metric measures of length in the case of preferred scaling are scaled in "mm". This when reading the respective parameter can also be seen from the corresponding "unit" data element. The decimal places are adjusted to the current unit.

Parameter Scaling (Individually Defined)   As an alternative to preferred scaling, it is possible to activate parameter scaling. For parameter scaling, the least significant bit (LSB) of the respective operating data can be individually defined.

☞   By means of parameter scaling, it is possible to modify the range of values of physical data!

Example: The maximum value for "S-0-0278, Maximum travel range" can be increased by reducing the number of decimal places of the position data.

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position data, linear	$\text{LSB} = \text{unit}^{1)} \times \text{scaling factor}^{1)} \times 10^{SE}$
position data, rotary	$\text{LSB} = \dfrac{360}{\text{rotational pos. resolution}^{2)}} \times \text{unit}^{2)}$
velocity data	$\text{LSB} = \dfrac{\text{unit (position data)}}{TU} \times \text{scaling factor} \times 10^{SE}$
acceleration data (linear, rotary)	$\text{LSB} = \dfrac{\text{unit (position data)}}{TU^2} \times \text{scaling factor} \times 10^{SE}$
acceleration data (ramp time scaling)	$\text{LSB} = \dfrac{\text{S-0-0446}}{\text{scaling factor} \times 10^{SE}}$
jerk data	$\text{LSB} = \dfrac{\text{unit (position data)}}{TU^3} \times \text{scaling factor} \times 10^{SE}$

1)	With scaling factor ≠ 1, the unit is no longer indicated as in 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.5-88:	*Defining the Least Significant bit (LSB) for Parameter Scaling*

☞ The jerk data scaling is derived from the acceleration data scaling.

Respective units of measurement and time defined in the parameters:
- S-0-0076, Position data scaling type
- S-0-0044, Velocity data scaling type
- S-0-0160, Acceleration data scaling type

Respective scaling factor and scaling exponent defined in the following parameters:
- S-0-0077, Linear position data scaling factor
- S-0-0078, Linear position data scaling exponent

- S-0-0045, Velocity data scaling factor
- S-0-0046, Velocity data scaling exponent

- S-0-0161, Acceleration data scaling factor
- S-0-0162, Acceleration data scaling exponent

For rotary position data, the value of the following parameter, in the case of parameter scaling, must be determined for defining the LSB:
- S-0-0079, Rotational position resolution

Torque/Force Data   For torque/force data there are the following basic scaling types:
- Linear
- Rotary
- Percentage-based

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It is possible to choose between preferred scaling (predefined scaling) and parameter scaling (scaling can be individually defined). With percentage-based scaling, parameter scaling is not allowed.

Preferred Scalings (Predefined)

Depending on the scaling type setting, there are the following predefined preferred scalings:

Physical value	Preferred scaling, decimal places and ranges of values		
	Linear	Rotary	Percentage-based
Torque	--	0.01 Nm... 327.67 Nm or 0.1 inlbf... 3276.7 inlbf	0,1%
Force	1 N...32767 N or 0.1 lbf...3276.7 lbf	--	0,1%

Fig.5-89:   *Preferred Scalings for Torque/Force Data*

The scaling types and units can be determined in the respective bits of parameter

- S-0-0086, Torque/force data scaling type

Respective scaling factor and scaling exponent defined in the following parameters:

- S-0-0093, Torque/force data scaling factor and
- S-0-0094, Torque/force data scaling exponent

Parameter Scaling (Individually Defined)

As an alternative to preferred scaling, it is possible to activate parameter scaling. For parameter scaling, the least significant bit (LSB) of the respective operating data can be individually defined.

Torque/force data LSB = unit x scaling factor x $10^{SE)}$

= unit x S-0-0093 x $10^{S-0-0094}$

There are the following maximum ranges of values for SI units:

Physical value	Parameter scaling with S-0-0093 = "1", S-0-0094 = 0....6; decimal places and ranges of values	
	Linear	Rotary
Torque	--	0.01 Nm...327.67 MNm
Force	1 N...32767 MN or	--

Fig.5-90:   *Parameter Scaling with Torque/Force Data, System of SI Units*

There are the following maximum ranges of values in the imperial system of units:

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Physical value	Parameter scaling with S-0-0093 = "1", S-0-0094 = 0....3; decimal places and ranges of values	
	Linear	Rotary
Torque	--	0.1 inlbf...3276.7 kinlbf
Force	0.1 lbf...3276.7 klbf	--

Fig.5-91:   *Parameter Scaling with Torque/Force Data, Imperial System of Units*

☞   The number of decimal places remains constant, the abbreviation of the thousandth power of ten (kilo or mega) results from the value to be displayed.

Temperature Data   For temperature data, only the following units can be selected:

- Degrees Celsius (°C)
- Fahrenheit (F)

☞   For temperature data is it only possible to select preferred scaling (predefined scaling)!

Physical value	Preferred scaling	
	Celsius	Fahrenheit
Temperature	0.1 °C	0.1 F

Fig.5-92:   *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)
- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)

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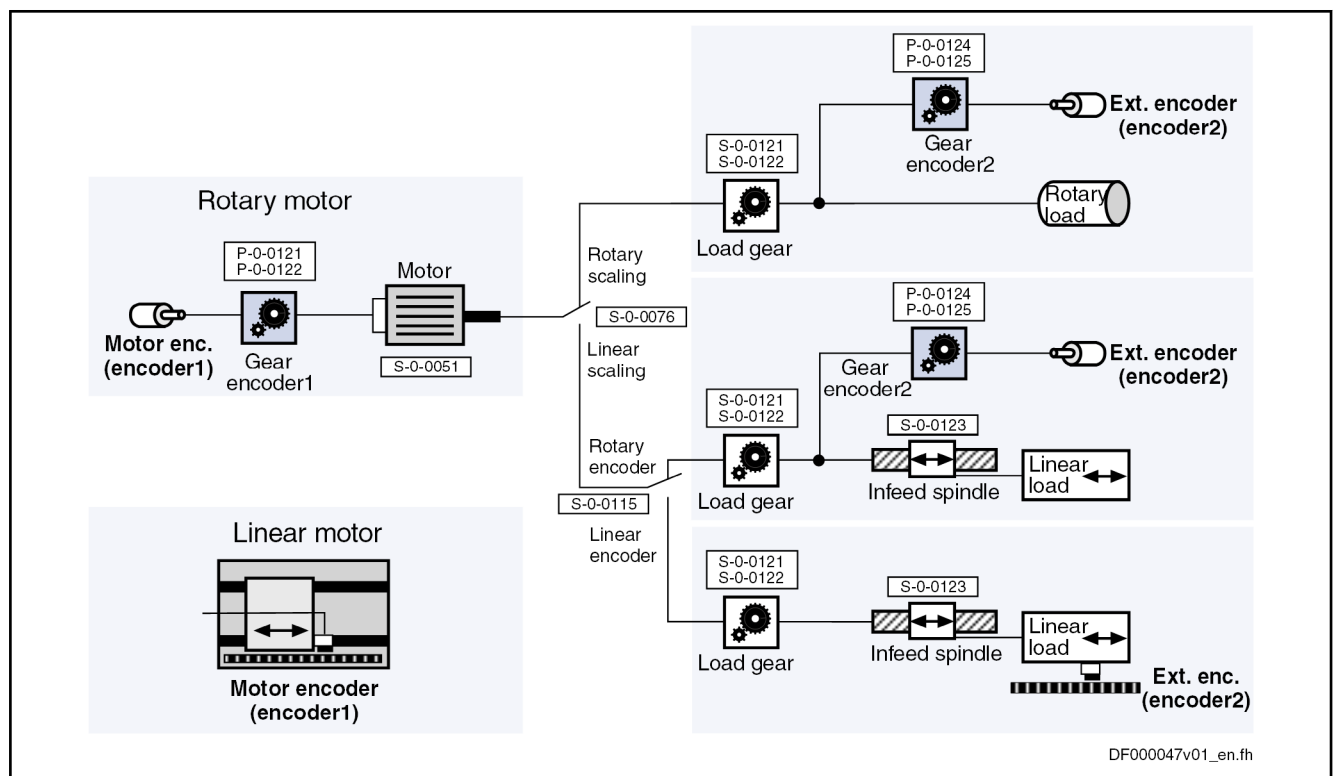
Fig.5-93: Mechanical Transfer Elements Between Motor, Encoders and Load

☞ For linear motors, the motor reference is the same as the load reference, because the point where the force is input and point where the load takes effect are identical. There aren't any mechanical transfer elements!

Polarity The polarity of the position, velocity and torque/force data can be changed from positive to negative polarity in the following parameters:

- S-0-0055, Position polarities
- S-0-0043, Velocity polarity parameter
- S-0-0085, Torque/force polarity parameter

Depending on the mounting situation (especially of kit motors and their respective motor encoder or external encoder), this allows determining the appropriate polarity of the respective data for the machine axis.

Modulo Scaling Via the respective bit of "S-0-0076, Position data scaling type", it is possible to select, for the position data format, between two formats:

- Absolute format
- Modulo format

If the position data of an axis with infinite travel range (e.g. rotary axis, spindle etc.) were processed in absolute format, the axis would risk to move beyond the value range of the position data. This would lead to invalid position data; operation modes with position control would not be safe to operate.

The value range for modulo format is limited, only position data between the value 0.00... and a maximum value to be determined in "S-0-0103, Modulo value" are possible.

When the measured actual position value exceeds the value range or falls below it, the actual position value displayed in parameter S-0-0051 or S-0-0053 behaves unsteadily, i.e. it changes by the absolute value of the

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modulo value range in such a way that the actual position value displayed always remains within the modulo value range.
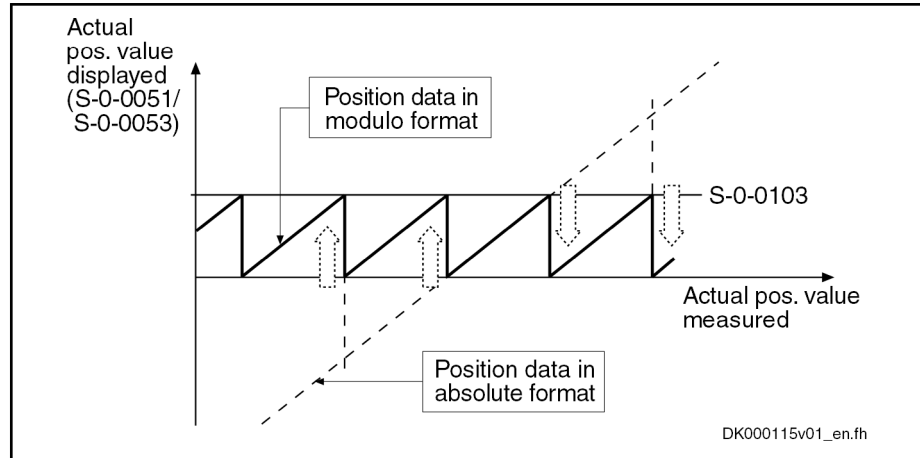
S-0-0051	Position feedback 1 value
S-0-0053	Position feedback 2 value
S-0-0103	Modulo value

Fig.5-94: *Actual Position Value for Axis Motion with Constant Velocity for Absolute and Modulo Format*

Modulo Format - Requirements   The "modulo format" setting for actual position values is only appropriate for rotary motors, because a mechanically unlimited travel range is only possible for axes with rotary motors. The "modulo format" therefore is only allowed for rotary motors, not for linear motors!

☞   The condition "rotary motor" for selecting "modulo format" is checked when the drive progresses to the ready-for-operation status. If the condition has not been fulfilled, an error is signaled!

Restrictions/Conditions for "Modulo Format"   When using the modulo format, you must observe and comply with the following restrictions and conditions:

● Due to the firmware-internal conversion of absolute format to modulo format, the allowed maximum velocity is as follows:

$$v_{max} = \frac{(S\text{-}0\text{-}0103)}{2\ ms}$$

| v_{max} | Maximum velocity or maximum angular velocity |
| S-0-0103 | Modulo value |

Fig.5-95: *Allowed Maximum Velocity for Modulo Format*

NOTICE   Possible property damage caused by errors when controlling motors and moving parts!

⇒ The value in "S-0-0091, Bipolar velocity limit value" mustn't be higher than the allowed maximum velocity for modulo format!

● In the case of encoders evaluated in absolute form, the mechanical drive system, with the drive switched off, may as a maximum be moved by a distance or angle corresponding to half the absolute encoder range ("S-0-0378, Absolute encoder range of motor encoder" or "S-0-0379, Drive Halt acceleration bipolar")! The actual position value after switch-

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ing on can otherwise be incorrect! This, however, cannot be diagnosed on the controller side!

NOTICE	Possible property damage caused by errors when controlling motors and moving parts!

⇒ Block the mechanical system with drive switched off by self-holding holding brake or self-locking gear!

See also "Absolute Measuring Systems"

- The following conditions must be complied with in the case of rotary modulo scaling:

Scaling type of position data →	Modulo scaling, rotary position reference		
External encoder →	External encoder available		No external encoder available
Type of motion of external encoder →	Rotary	Linear not possible!	
Conditions (No.) to be complied with →	1; 2; 3; 4; 5; 6	---	1; 2; 4; 5
Conditions → No. 1: $S\text{-}0\text{-}0079 \times S\text{-}0\text{-}0122 = 2^{64}$ No. 2: $S\text{-}0\text{-}0079 \times P\text{-}0\text{-}0121 \times S\text{-}0\text{-}0122 = 2^{64}$ No. 3: $S\text{-}0\text{-}0079 \times P\text{-}0\text{-}0124 \times S\text{-}0\text{-}0121 = 2^{64}$ No. 4: $S\text{-}0\text{-}0103 \times P\text{-}0\text{-}0129 \times S\text{-}0\text{-}0121 = 2^{64}$ No. 5: $S\text{-}0\text{-}0103 \times S\text{-}0\text{-}0116 \times P\text{-}0\text{-}0122 \times S\text{-}0\text{-}0121 = 2^{64}$ No. 6: $S\text{-}0\text{-}0103 \times S\text{-}0\text{-}0117 \times P\text{-}0\text{-}0125 \times S\text{-}0\text{-}0122 = 2^{64}$			

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.5-96:   Conditions for Modulo Scaling and Rotary Position Reference

☞   Rotary modulo scaling is impossible for linear external encoders!

- Only load reference is possible for linear modulo scaling. Depending on the use of an external encoder the following conditions have to be complied with:

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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: $S\text{-}0\text{-}0103 \times S\text{-}0\text{-}0121 \times P\text{-}0\text{-}0129 = 2^{64}$ No. 2: $S\text{-}0\text{-}0123 \times S\text{-}0\text{-}0122 = 2^{64}$ No. 3: $S\text{-}0\text{-}0103 \times S\text{-}0\text{-}0121 \times P\text{-}0\text{-}0122 \times S\text{-}0\text{-}0116 = 2^{64}$ No. 4: $S\text{-}0\text{-}0123 \times S\text{-}0\text{-}0122 \times P\text{-}0\text{-}0121 = 2^{64}$ No. 5: $S\text{-}0\text{-}0103 \times P\text{-}0\text{-}0125 \times S\text{-}0\text{-}0117 = 2^{64}$ No. 6: $S\text{-}0\text{-}0123 \times P\text{-}0\text{-}0124 = 2^{64}$ No. 7: $S\text{-}0\text{-}0103 \times S\text{-}0\text{-}0077 \times 10^{(S\text{-}0\text{-}0078)} = 2^{64}$			

S-0-0077	Linear position data scaling factor
S-0-0078	Linear position data scaling exponent
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.5-97:   Conditions for Modulo Scaling and Linear Position Reference

☞   Linear modulo scaling is impossible for motor reference!

5.7.3   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

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- S-0-0044, Velocity data scaling type
- S-0-0160, Acceleration data scaling type
- S-0-0086, Torque/force data scaling type

Settings and Tips for Modulo Scaling

When selecting "modulo format", the value range limit must be set in parameter "S-0-0103, Modulo value".

> ☞ For "modulo format", enter a value greater than or equal to the value of parameter S-0-0103 in "S-0-0278, Maximum travel range"!

NOTICE	Danger of incorrect actual position value of encoders evaluated in absolute form after switching the drive on, when the mechanical drive system, with the drive switched off, was moved in the case of modulo scaling!

⇒ Make sure that the mechanical drive system, with the drive switched off, is as a maximum moved by a distance or angle corresponding to half the absolute encoder range ("S-0-0378, Absolute encoder range of motor encoder" or "S-0-0379, Absolute encoder range of optional encoder")!

Temperature Scaling

In addition, make the scaling setting for temperature data in "S-0-0208, Temperature data scaling type".

Individual Settings for Parameter Scaling

Further Settings for Parameter Scaling

Position data:
- S-0-0077, Linear position data scaling factor
- S-0-0078, Linear position data scaling exponent
- or -
- S-0-0079, Rotational position resolution

Velocity data:
- S-0-0045, Velocity data scaling factor
- S-0-0046, Velocity data scaling exponent

Acceleration data:
- S-0-0161, Acceleration data scaling factor
- S-0-0162, Acceleration data scaling exponent

Diagnostic Messages of Scaling Setting

If inadmissible scaling settings were made, they are detected when switching from parameter mode (communication phase 2) to operating mode (communication phase 4). The drive in this case does not reach the operating mode and, according to setting, displays the following command errors:

- 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

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- C0140 Rotary scaling not allowed

Examples of Scaling Settings

There are many options to make settings for the scaling type. The table below shows useful settings for which there aren't any command errors to be expected.

Mechanical system			Encoder		Useful scaling type settings		
Motor	Load gear	Feed spindle	Motor Encoder	External encoder	Motor reference	Load reference	Modulo
Rotary	Available	Not available	Rotary	No	Rotary	Rotary	Possible
Rotary	Available/not available	Available	Rotary	No	Rotary	---	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.5-98:   Useful Scaling Type Settings Depending on Mechanical Drive System and Measuring Systems

6 Drive Control

6.1 Safety Instructions

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

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

6.2 Overview of Drive Control

6.2.1 Basic Principles and Terms

The IndraDrive firmware supports the following two basic principles of drive control:

- **Open-loop axis control** (U/f control, flux-controlled FXC operation)

  → Open-loop-controlled operation without encoder information

- **Closed-loop axis control** (various methods of control)

  → Closed-loop-controlled operation with encoder feedback (position, velocity and current)

☞   When selecting the functional packages, take the desired method of control into account as you have to choose between "open-loop" and "closed-loop base package"!

Operation mode / command value adjustment	Control mode	Functional principle of motor	Encoder available	Required base package	Method of control
U/f control with command value adjustment of the velocity control	Voltage-controlled operation	Asynchronous	Yes	Closed-loop	Not relevant
			No	Open-loop	U/f control
Torque/force control	Field-oriented current control	Asynchronous	Yes	Closed-loop	FOC control
			No	--	No method available
		Synchronous	Yes	Closed-loop	FOC control
			No	--	No method available

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Operation mode / command value adjustment	Control mode	Functional principle of motor	Encoder available	Required base package	Method of control
Velocity control / velocity synchronization	Velocity control	Asynchronous	Yes	Closed-loop	FOC control
			No	Open-loop	FXC control
		Synchronous	Yes	Closed-loop	FOC control
			No	Open-loop	FXC control
Position control, drive-controlled positioning, positioning block mode, phase synchronization, electronic cam	Position control	Asynchronous	Yes	Closed-loop	FOC control
			No	Closed-loop	FXC control [1]
		Synchronous	Yes	Closed-loop	FOC control
			No	Closed-loop	FXC control [1]

[1]   Only with external encoder

Fig.6-1:   *Overview: Operation Modes and Available Control Methods*

☞   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"

6.2.2   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 operation mode "velocity control" is configured, but only the command value processing specific to this operation mode takes effect. Closed-loop control (position and velocity) and functions and operation modes depending thereof are not possible.

See "Voltage-Controlled Open-Loop Operation (U/f Control)"
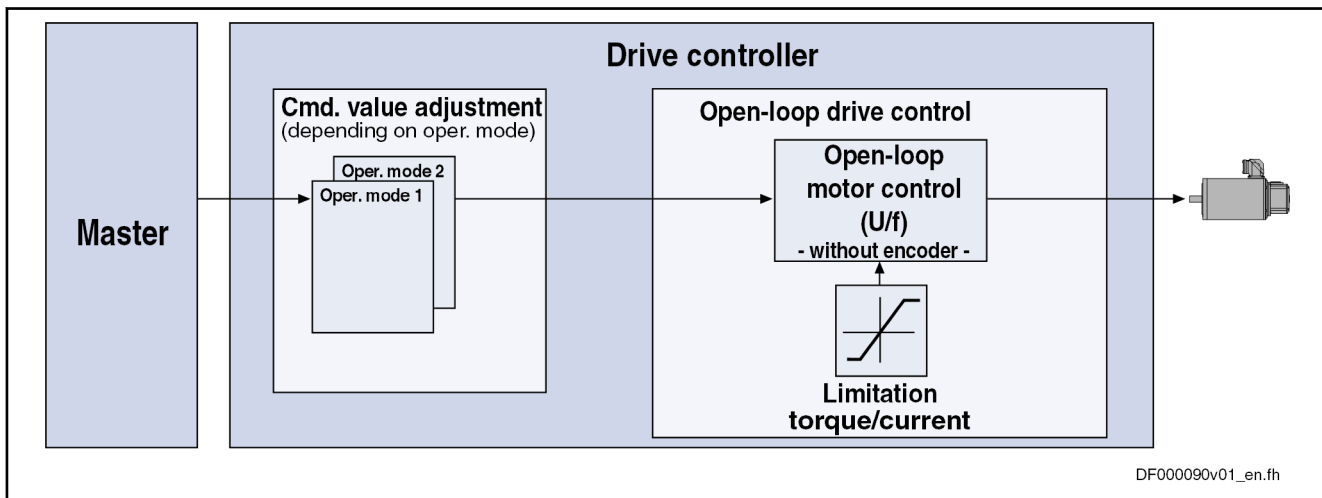
Fig.6-2:   *Principle of Drive Control (Open-Loop Operation)*

See also section "Closed-Loop Axis Control (Closed-Loop Operation)"

Drive Control

See also section "Overview of Functions/Functional Packages"

Overview of Closed-Loop Axis Control

☞ The "Closed-Loop" base package also contains the functions of the "Open-Loop" base package.

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 operation 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, positioning block mode)
  - 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"
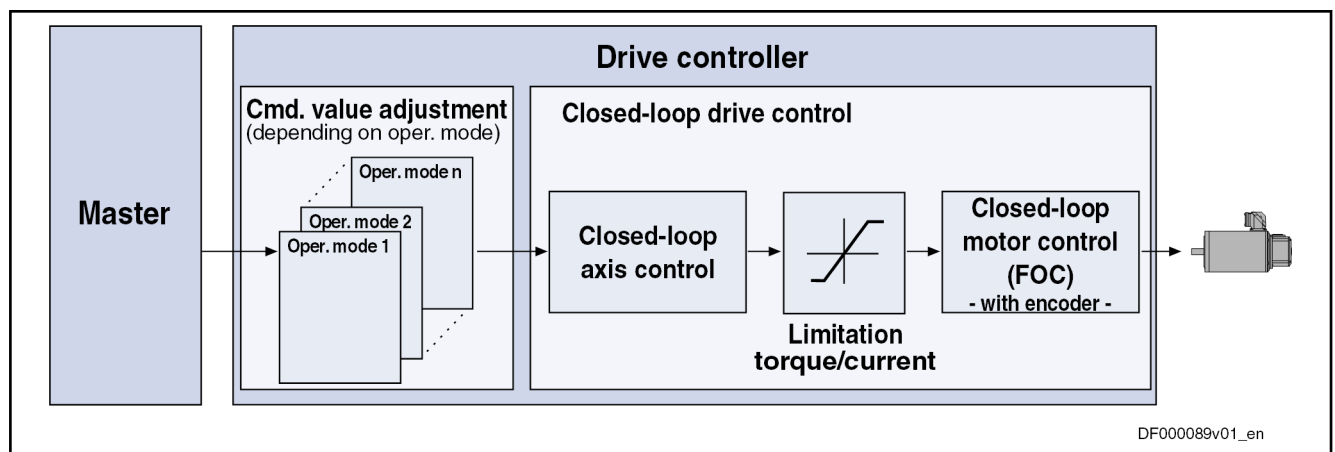
Fig.6-3:   Principle of Drive Control (Closed-Loop Operation)

See also section "Open-Loop Axis Control (Open-Loop Operation)"

See also section "Overview of Functions/Functional Packages"

6.2.3   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 operation mode, only the torque/force control loop, the torque/force control loop and the velocity control loop or, in addition to these two control loops, the position control loop are closed in the drive.

Torque/Force Control   The "torque/force control" mode actually isn't torque or force control, but current control. Therefore, only the current control loop is closed in the drive.

See also "Torque/Force Control"

Drive Control

Velocity Control   In the "velocity control" mode, the velocity control loop, apart form the current control loop, is closed in the drive, too.

See also "Velocity Control"

Position Control   For the following position control modes, the position control loop, apart from the current and velocity control loops, is closed internally (in the drive):

- Position control with cyclic command value input
- Drive-internal interpolation
- Positioning modes (e.g., drive-controlled positioning, positioning block mode)

See also description of the respective operation mode.

The figures in the following two paragraphs contain an overview of the structure and the interaction of the control loops (distinguished according to the illustration of the setting parameters and the display parameters).

Control Loop Structure with Setting Parameters

S-0-0032, Primary operation mode
S-0-0037, Additive velocity command value
S-0-0048, Additive position command value
S-0-0051, Position feedback value 1
S-0-0053, Position feedback value 2
S-0-0081, Additive torque/force command value
S-0-0082, Torque/force limit value positive
S-0-0083, Torque/force limit value negative
S-0-0091, Bipolar velocity limit value
S-0-0092, Bipolar torque/force limit value
S-0-0100, Velocity 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
S-0-0109, Motor peak current
S-0-0110, Amplifier peak current
S-0-0111, Motor current at standstill
S-0-0138, Bipolar acceleration limit value
S-0-0155, Friction compensation

S-0-0348, Acceleration feedforward gain
S-0-0380, DC bus voltage
P-0-0001, Switching frequency of the power output stage
P-0-0004, Velocity loop smoothing time constant
P-0-0040, Velocity feedforward evaluation
P-0-0043, Torque-generating current, actual value
P-0-0051, Torque/force constant
P-0-0059, Additive position command value, controller
P-0-0109, Torque/force peak limit
P-0-0180, Acceleration feedforward smoothing time constant
P-0-0556, Config word of axis controller
P-0-0640, Cooling type
P-0-0690, Additive velocity command value, process loop
P-0-0691, Additive position command value, process loop
P-1-1119, Velocity mix factor feedback 1 & 2
P-1-1120, Velocity control loop filter: Filter type
P-1-1126, Velocity control loop: Acceleration feedforward
E2059 Velocity command value limit active
E2070 Acceleration feedforward limit active
F8079 Velocity limit value exceeded
* only for operation mode position control with cyclic command value input

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 (Example for Field-Oriented Control with Encoder)

Drive Control

Control Loop Structure with Display Parameters

DF000625v02_en.th

P-0-0038, Torque-generating current, command value
P-0-0043, Torque-generating current, actual value
P-0-0048, Effective velocity command value
P-0-0049, Effective torque/force command value
P-0-0051, Torque/force constant
P-0-0059, Additive position command value, controller
P-0-0063, Torque-generating voltage, actual value
P-0-0070, Effective additive torque/force command value
P-0-0112, Actual velocity value of motor
P-0-0434, Position command value of controller
P-0-0453, Integral-action component velocity loop
P-0-0454, Velocity feedforward actual value
P-0-0455, Acceleration feedforward actual value
P-0-0690, Additive velocity command value, process loop
P-0-0691, Additive position command value, process loop
P-0-1119, Velocity mix factor feedback 1 & 2

P-0-4045, Maximum possible continuous current
P-0-4046, Effective peak current

S-0-0037, Additive velocity command value
S-0-0040, Velocity feedback value
S-0-0048, Additive position command value
S-0-0051, Position feedback value 1
S-0-0053, Position feedback value 2
S-0-0081, Additive torque/force command value
S-0-0155, Friction compensation
S-0-0156, Velocity feedback value 2
S-0-0189, Following distance
S-0-0347, Velocity error
S-0-0386, Active position feedback value
S-0-0535, Active velocity feedback value
* only for operation mode position control with cyclic command value input

Drive Control

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 (Example)*

6.2.4   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 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:

- PI loop that can be set via the following parameters: "S-0-0100, Velocity loop proportional gain"

  "S-0-0101, Velocity loop integral action time"

- Standardization of the output value at the velocity loop to Newton (N) or Newton meter (Nm); therefore, depending on the motor type, the following unit results for "S-0-0100, Velocity loop proportional gain":

  – Rotary motor → Nm * s/rad

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> – Linear motor → N * min/mm
> - Filter options for filtering encoder noise and resonance frequencies
>   – One filter of 1st degree (low pass of 1st order), can be parameterized via P-0-0004
>   – Four filters of 2nd degree (low pass of 2nd order, band-stop filter, 2nd order filter), can be activated via P-0-1120 with the setting parameters P-0-1121, P-0-1122, P-0-1123, P-0-1140, P-0-1141, P-0-1143
> - Acceleration feedforward can be set in parameter P-0-1126
> - Possibility of mixing the actual velocity value used for control from the actual value of the motor-side and load-side encoder by means of a "mix factor" P-0-1119
> - Limitation of command acceleration (change in velocity command value) in velocity control by setting in parameter "S-0-0138, Bipolar acceleration limit value"
> - Limitation of command velocity via the parameters S-0-0113, S-0-0038, S-0-0039, S-0-0091 and P-0-0113
>
> See also "Velocity Loop (Including the Respective Filters)"

Position Loop

The position loop is characterized by the following features:
- P-loop, can be set via "S-0-0104, Position loop Kv-factor"
- Velocity feedforward (degree of feedforward) can be set in parameter "P-0-0040, Velocity feedforward evaluation" (0% ... 100%)
- Acceleration feedforward can be set in parameter "S-0-0348 Acceleration feedforward gain"
- The actual value of the motor encoder or of the optional encoder can be used as the actual position value for control. It is possible, however, to use both actual position values for position control ("hybrid actual position value").

See also "Position Loop (with Respective Feedforward Functions and Actual Value Adjustment)"

6.2.5 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 operation mode, the following parameters are available to do this:

Operation 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	!	--	--	--

Drive Control

Operation mode	S-0-0081	S-0-0037	P-0-0059	S-0-0048
Velocity control / velocity synchronization	¦	¦	--	--
Position Control	¦	¦	¦	--
Drive-controlled positioning	¦	¦	¦	--
Positioning Block Mode	¦	¦	¦	--
Phase synchronization	¦	¦	--	¦
Electronic cam	¦	¦	--	¦

S-0-0081   Additive torque/force command value
S-0-0037   Additive velocity command value
P-0-0059   Additive position command value, controller
S-0-0048   Additive position command value
Fig.6-7:   *Overview of the Additive Command Values Depending on the Operation Mode*

In closed-loop operation, it is possible to access the outer control loops from a higher-level operation mode. The access options to the individual control loops are illustrated in the following example:

Drive Control
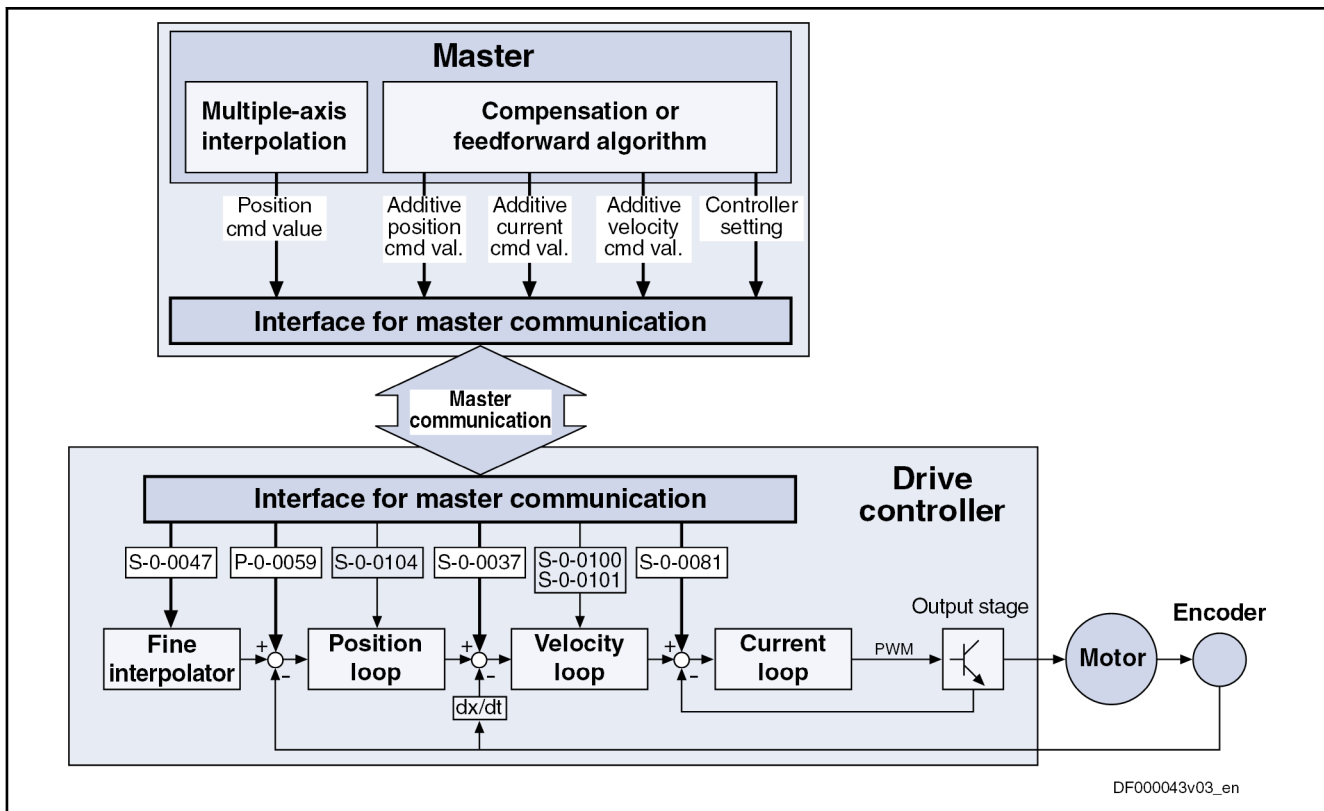
S-0-0037	Additive velocity command value
S-0-0047	Position command value
S-0-0081	Additive torque/force command value
S-0-0100	Velocity loop proportional gain
S-0-0101	Velocity loop integral action time
S-0-0104	Position loop Kv-factor
P-0-0059	Additive position command value, controller

Fig.6-8: Structural Overview Including Access Options (Example for Operation 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 database via the "IndraWorks Ds/D/MLD" commissioning tool.

   The commissioning of **third-party motors** (including control loop settings) is described in the respective sections on third-party motors in this documentation (see "Third-Party Motors at IndraDrive Controllers").

Drive Control

2. **Velocity control loop**

The settings of the velocity loop (S-0-0100 and S-0-0101) with the respective filters (P-0-0004 und P-0-1120, P-0-1121, P-0-1122, P-0-1123, P-0-1140, P-0-1141, P-0-1142, P-0-1143) on the one hand depend on the motor parameters (inertia and torque/force constant), on the other hand they strongly depend on the mechanical properties (load inertia/mass, friction, 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")

"Load Defaults Procedure" Command

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 "S-0-0262, C07_x Load defaults procedure command":

- Automatically when running up the drive by recognizing that the motor type (cf. S-0-0141) has changed. The display then reads "RL" and the "load defaults procedure" command is internally started by pressing the "Esc" key on the control panel, unless this was deactivated in "P-0-0556, Config word of axis controller".

- Starting the command by writing "11b" to S-0-0262.

See also "Loading, Storing and Saving Parameters"

☞   In order to start the "load defaults procedure" command, the value "0" must have been set in "P-0-4090, Configuration for loading default values" (default setting).

When the motor default values are loaded, the following control loop parameters are set to their default values optimized for the respective motor:

- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- S-0-0104, Position loop Kv-factor
- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- P-0-0004, Velocity loop smoothing time constant

☞   The default settings for the current loop (cf. S-0-0106 and S-0-0107) are automatically adjusted to the currently parameterized PWM frequency (cf. P-0-0001) and performance setting (cf. P-0-0556)!

In addition, the following control loop parameter is set to its firmware-side default values when the motor default values are loaded, although there hasn't any default value been stored for it in the motor data memory:

- S-0-0348, Acceleration feedforward gain

Drive Control

☞   In the majority of cases, the controller settings stored in the motor
          encoder data memory provide a useful and reliable control loop
          setting. In exceptional cases, however, it may be necessary to
          make the settings with regard to the specific application.

6.3   Motor Control

6.3.1   General Information on Motor Control

Overview of Motor Control Methods

Classification of Motor Control Methods

There are different methods available to control the motor; the main differ-
ence between these methods is the fact whether a motor encoder is required
or not.

Motor Control with Motor Encoder

Motor control with position feedback via a motor encoder (field-oriented cur-
rent control → FOC) is the highest-quality method of motor control providing
the best control performance. It can be used for synchronous and asynchro-
nous motors and, within the precision and performance of motor and control-
ler determined by the hardware, allows unrestricted motor operation in the
following operation modes:

- Position control modes
- Velocity Control
- Torque/Force Control

**Motor Control without Motor En-
coder**

For sensorless motor control, there are different model-based methods avail-
able for synchronous and asynchronous motors.

- For asynchronous motors:
  - Voltage-controlled open-loop operation (U/f control)
  - Flux-controlled operation ("FluX Control" → FXC)
- For synchronous motors:
  - Current-controlled closed-loop operation with indirect rotor position
    detection (field-oriented current control, sensorless → FOCsl)

Regarding the possible operation modes when using these methods, observe
the following restrictions:

- Position control modes ("positioning") can only be used with sensorless
  synchronous motors, or with asynchronous motors only in flux-controlled
  operation (FXC) and with an external encoder. In these cases, generally
  take the performance losses into account!
- Velocity control, too, can only be used with performance losses!

☞   Torque/force control cannot be used for motor control without mo-
          tor encoder!

**Motor Control Method and Func-
tional Principle of Motor**

The motor control method is defined in "P-0-0045, Control word of current
controller". Make sure that the requirements regarding functional principle of
motor and motor encoder have been fulfilled for the specified motor control
mode. The table below contains an overview for selecting the method.

Drive Control

Motor encoder?	Functional principle of motor	Motor control method	Specific information for use	Possible operation modes
With Motor Encoder	Synchronous motor / Asynchronous motor	FOC	Parallel operation of linear motors MLF is possible!	Position control modes / Velocity Control / Torque/Force Control
Without Motor Encoder	Synchronous motor	FOCsl	Difference in inductance between d- and q-axis is required!	Position control modes / Velocity Control
	Asynchronous motor	FXC	Only single-motor operation!	
		U/f control	Parallel operation of motors is possible!	Velocity Control

Fig.6-9:   Overview of Motor Operation with and without Motor Encoder

See also "Overview of Drive Control"

Pertinent Parameters
- P-0-0001, Switching frequency of the power output stage
- P-0-0045, Control word of current controller
- P-0-0556, Config word of axis controller

Field-Oriented Current Control with Motor Encoder (FOC)

Features and Use

Field-oriented current control with position feedback via motor encoder (FOC) is characterized by the following features:

- Highest-quality method of motor control

  → To be used when there are high demands on the quality of control and the dynamic response!

- Can be used for synchronous and asynchronous motors

Operation Modes with FOC

Within the hardware-side precision and performance of motor and controller, field-oriented current control with position feedback via motor encoder allows unrestricted motor operation in the following operation modes:

- Position control modes
- Velocity Control
- Torque/Force Control

See main section "Field-Oriented Current Control (FOC Control)"

Model-Based Current Control Without Motor Encoder (FXC, FOCsl)

Features and Use

Model-based current control without motor encoder is characterized by the following features:

- Cost-saving motors, compared to the FOC method, can be used, as no motor encoder is required (however, performance losses)
- With asynchronous motors → flux-controlled method (FXC) can be used without motor-specific restrictions
- For synchronous motors → FOCsl method; only applicable with motors that have a difference in inductance between d- and q-axis (few sizes of the MSK motor range)

Operating Modes With FXC and FOCsl

Current control without motor encoder allows using the following operating modes:

- Velocity control (only suited for single motors, parallel operation of motors is not possible)

Drive Control

- Position control modes depending on functional principle of motor
    - With synchronous motors, actual position value detection is possible without encoder
    - With asynchronous motors, actual position value detection via external encoder is required

☞   Torque/force control cannot be used for sensorless (model-based) motor control!

See main section "Motor Operation without Encoder, Flux-Controlled (FXC Control)"

Voltage-Controlled Open-Loop Operation (U/f Control)

Features and Use   Voltage-controlled motor operation without motor encoder is characterized by the following features:

- Cost-saving motors, compared to the FOC method, can be used, as no motor encoder is required (however, performance losses)
- Can only be used for asynchronous motors
- Linear or square U/f characteristic can be selected

Operation Mode with U/f Control   For voltage-controlled operation without motor encoder, you can only use the "velocity control" mode with the following features:

- Parallel operation of motors is possible
- Adjustment of motor control to velocity-proportional increase in load (e.g. with blowers) by adjusted ("square") U/f characteristic to reduce the motor losses
- Performance losses compared to velocity control with motor encoder

☞   Torque/force control and position control modes cannot be used for voltage-controlled operation without motor encoder!

See main section "Voltage-Controlled Open-Loop Operation (U/f Control)"

Notes on Selection of Motor Control Method

Motor Control Performance   The performance of motor control significantly depends on the type of control section including the corresponding firmware, as well as on the PWM frequency of the power output stage which has been set.

☞   An overview of the performance to be achieved and the clock rates depending on control section design and parameter settings is contained in the section "Performance Data".

Selecting the Motor Control Method   The motor control method is defined in "P-0-0045, Control word of current controller". By means of a dialog, the "IndraWorks Ds/D/MLD" commissioning tool supports the assignment of the motor control method.

Selection Criteria   The following criteria have to be taken into account when selecting the appropriate motor control method:

Drive Control

Motor type	Motor encoder available?	Parallel connection of motors?	Motor control method	Notes on use
Synchronous motor without reluctance torque	Yes	Rotary: No Linear: Yes [1]	Field-oriented current control	For standard applications with high demands on quality of control and dynamic response
Synchronous motor with reluctance torque	No	No	Field-oriented current control	Only allowed with approval by the drive development department
	Yes	Rotary: No Linear: Yes [1]		For standard applications with high demands on quality of control and dynamic response
Asynchronous motor	No	No	Flux-controlled current control	For standard applications with medium demands on quality of control and dynamic response
		Yes	U/f control	For standard applications with low demands on quality of control and dynamic response
	Yes	No	Field-oriented current control	For standard applications with high demands on quality of control and dynamic response

1)   Observe mechanical setup according to motor data

Fig.6-10:   *Basic Selection Criteria for the Motor Control Method*

See also "Overview of Drive Control"

Operating Properties for Control of Synchronous Motors   Observe the following differences for controlling synchronous motors in operation with and without motor encoder:

Motor characteristic		Control with encoder	Control without encoder
Speed working ranges	Basic Speed Range	Yes	Yes (with reduced maximum speed)
	Field weakening range	Yes	No (no field weakening range)
Supported operation modes	Torque/Force Control	Yes	No
	Velocity control (incl. synchronization)	Yes	Yes (with restrictions)
	Position control/positioning (incl. synchronization)	Yes	Yes (with restrictions)
Torque limitation		Yes	Yes

Drive Control

Motor characteristic	Control with encoder	Control without encoder
Maximum torque	High	Medium
Dynamic response	High	Low to medium
Running smoothness/speed quality	High (depending on measuring system, motor type, mechanical system)	Medium
Torque ripple	Low (< ± 5%)	High
Required precision of the motor parameters	Low	High
Robustness	High	Low
Sensitivity against disturbances	Low	High
Validity (availability) of the position information	Absolute encoder: in PM + OM Relative encoder: in OM	Only when motor supplied with current ("AF" in OM)

PM   Parameter mode
OM   Operating mode

Fig.6-11:   Comparison of Motor Control without Encoder and with Encoder for Synchronous Motors

Operating Properties for Control of Asynchronous Motors   Observe the following differences for controlling asynchronous motors as regards operation with and without encoder:

Motor characteristic		Control with encoder	Control without encoder	U/f control
Speed working ranges	Basic Speed Range	Yes	Yes	Yes
	Field weakening range	Yes	Yes	Yes
Supported operation modes	Torque/Force Control	Yes	No	No
	Velocity control (incl. synchronization)	Yes	Yes (with restrictions)	Yes (with restrictions)
	Position control/positioning (incl. synchronization)	Yes	Only with external position encoder	No
Torque limitation		Yes	Yes	No (only stall protection loop)
Maximum torque		High	Medium	Low
Dynamic response		High	Medium	Low
Running smoothness/speed quality		High (depending on measuring system, motor type, mechanical system)	Medium	Low
Torque ripple		Low (< ± 5%)	High	High
Required Accuracy of the motor parameters		Low	Low	High, if high performance must be reached
Robustness		High	Medium	Low

Drive Control

Motor characteristic	Control with encoder	Control without encoder	U/f control
Sensitivity against disturbances	Low	High	High
Validity (availability) of the position information	Absolute encoder: in PM + OM	Depending on load-side encoder type used	not available
	Relative encoder: only in OM		

PM   Parameter mode
OM   Operating mode

Fig.6-12:   *Comparison of Motor Control without Encoder and with Encoder for Asynchronous Motors*

6.3.2　Motor Control Frequency

Brief Description

General Information　The speed of three-phase a.c. motors depends on the frequency of the voltage applied at the motor. The maximum frequency of the motor voltage provided by the controller depends on the PWM frequency with which the power output stage is controlled (clocked).

The power output stage can be controlled in different ways. Depending on the relation of the motor control frequency to the output stage frequency, different procedures are possible for IndraDrive controllers:

- "Static PWM" for low and medium output frequency
- "Dynamic PWM" for high output frequency

Features　The maximum motor control frequency - and thereby the motor speed - can be considerably increased by the "dynamic PWM" as compared to the "static PWM"; in addition, dynamic PWM reduces the no-load losses at high speeds:

PWM frequency in Hz	Max. motor control frequency in Hz	
Value in P-0-0001	Static PWM[*]	Dynamic PWM
4000	400	--
8000	800	1330
12000	1200	2000
16000	1600	2660
[*]see also "Supply Units and Power Sections; Project Planning Manual"		

Fig.6-13:   *PWM Frequency Settings and Maximum Motor Control Frequency for Static and Dynamic PWM*

Note on Sizing　☞　Observe the required PWM frequency when selecting the controller, because the setting of the PWM frequency has an influence on the continuous current of the controller:

- Set the lowest possible PWM frequency due to continuous current of controller
- Set the highest necessary PWM frequency due to motor control frequency

Advantageous Behavior　Due to the reduction of the continuous current with PWM frequencies greater than 4kHz, the controller can automatically set the most advantageous PWM frequency, depending on the required motor control frequency.

Drive Control

Availability

Depending on the control section design and the setting of the PWM frequency, "dynamic PWM" or the "most favorable PWM", depending on the velocity, can be used

Control Section	Firmware	Possible PWM frequencies/Hz	Dynam. PWM or most favorable PWM depending on speed
CSB	As of MPB06VRS	4000	No
CDB	As of MPD06VRS	8000	Yes
CSH	As of MPH06VRS	4000	No
		8000	Yes
		12000	Yes
		16000	Yes

Fig.6-14:   Hardware and Firmware Dependencies

Pertinent Parameters

- P-0-0001, Switching frequency of the power output stage
- P-0-0045, Control word of current controller

Pertinent Diagnostic Messages

The PWM frequency switching is displayed in the corresponding bit of "P-0-0046, Status word of current controller".

Functional Description

Clocking Method

In general, IndraDrive controllers can control their power output stage via:

- "Static PWM" due to speed-independent, constant PWM frequency
- "Dynamic PWM" due to variable PWM frequency depending on speed

For the mentioned clocking methods the time period and transmission of the "support points" change for a sine wave of the motor voltage.

☞   A "support point" is a switching action of the power output stage with which the controller can influence the motor current.

The clocking method is selected in "P-0-0045, Control word of current controller".

Static PWM

"Static PWM" is characterized by a constant number of "support point" within a time interval. For different motor control frequencies the number of support points varies for a periodic time of the motor voltage.

- With increasing motor control frequency the number of support points decreases
- With decreasing motor control frequency the support point number increases
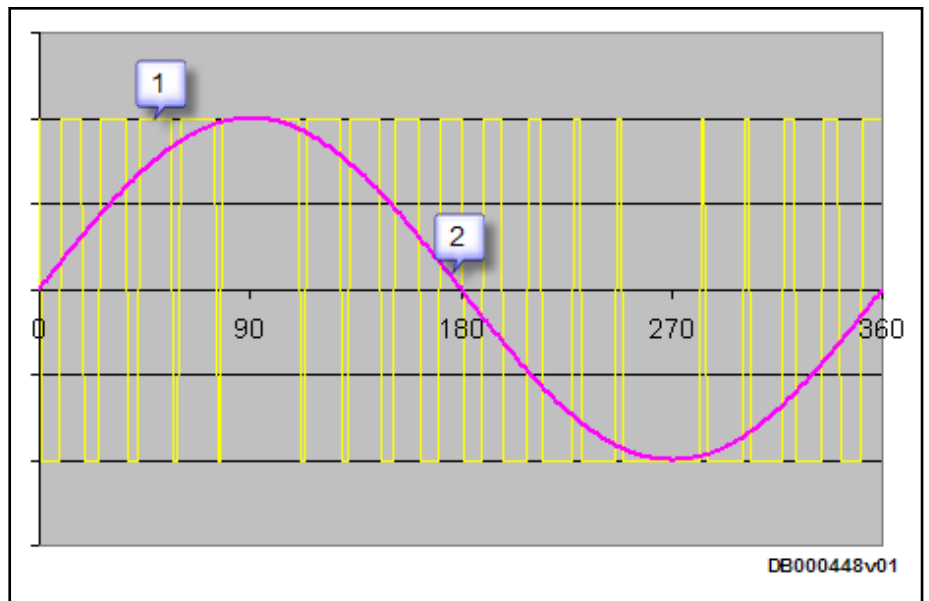
Drive Control

| 1: | Motor voltage support points, DC bus voltage is transmitted by the power output stage |
| 2: | Curve of the effective motor voltage |

Fig.6-15:   Control of Power Output Stage with "Static PWM", in Principle

Dynamic PWM   "Dynamic PWM" is characterized by a constant number of "support points" within a sine wave of the motor voltage. In different motor control frequency ranges the number of support points remains constant for a periodic time of the motor voltage.

● The "dynamic PWM" does not take effect until a motor control frequency threshold is exceeded

● The number of "support points" is reduced in stages from 21 to 6 in successive output frequency intervals in ascending order
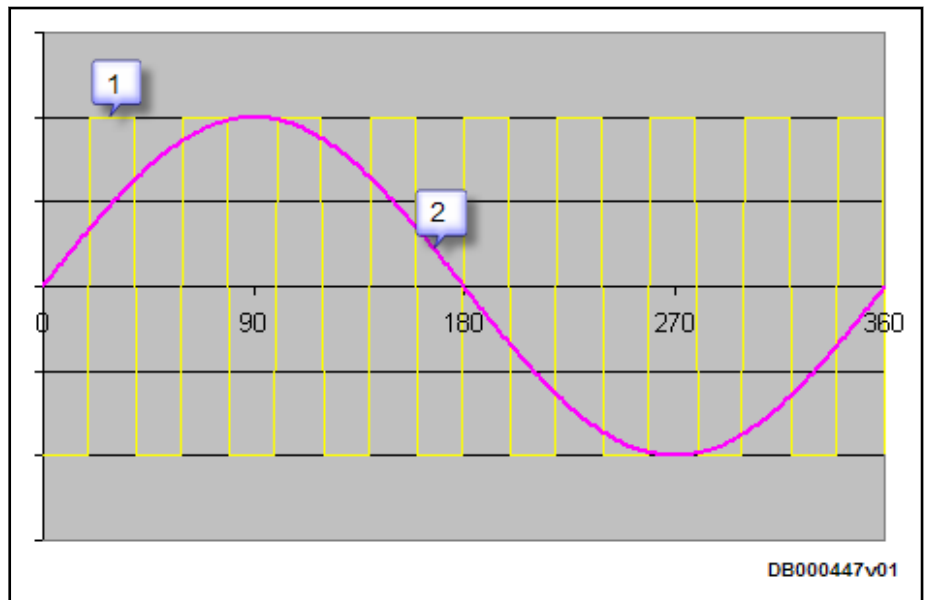
| 1: | Motor voltage support points, DC bus voltage is transmitted by the power output stage |
| 2: | Curve of the effective motor voltage |

Fig.6-16:   Control of Power Output Stage with "Dynamic PWM", in Principle

Drive Control

Automatic PWM Adjustment

"Most Advantageous PWM Frequency"

As the continuous current of the controller is reduced with increasing PWM frequency due to higher switching losses of the power output stage, the controller selects automatically the most favorable PWM frequency, depending on the actual motor control frequency.

- Dynamic PWM
- PWM switching depending on speed (static PWM)

The "PWM switching depending on speed" as well as the "dynamic PWM" can be set in "P-0-0045, Control word of current controller".

For the two variants the PWM frequency stage required for the maximum motor speed is set in "P-0-0001, Switching frequency of the power output stage". If P-0-0001 was set greater than 4kHz, half the switching frequency will takes effect below a motor control frequency threshold:

PWM frequency in Hz		PWM switching for [1]motor control frequency threshold in Hz	
Set value in P-0-0001/	Effective PWM frequency below [1]// above [1]	PWM switching depending on speed:	Dynamic PWM
4000	--	--	--
8000	4000 // 8000	400	190
12000[*]	6000[**] //12000	600	285
16000[*]	8000 //16000	800	381

[*]Depending on the design of the controller and the performance settings, these PWM frequencies might not be available!

[**]For PWM = 6000 Hz, the controller's continuous current data of 8000 Hz apply!

Fig.6-17:   PWM Frequency Settings and PWM Switching Thresholds

☞ The continuous current of a controller depends on the effective PWM frequency. Check whether the selected controller makes available sufficient continuous current for the motor or the application, both below and above the motor control frequency threshold for PWM switching!

Notes on Commissioning

Setting the PWM Frequency

The PWM frequency for controlling the power output stage is set in "P-0-0001, Switching frequency of the power output stage". Depending on the control section design, different PWM frequencies are available (see above).

Selecting the PWM Adjustment

PWM adjustment is only possible, when a higher PWM frequency than 4kHz was set. Vie the corresponding bits of P-0-0045, you can choose between:

- Static PWM (default)
- PWM reduction depending on load
- PWM reduction depending on velocity
- Dynamic PWM for maximum motor control frequency

IWD Dialogs for PWM Adjustment

According to the motor control mode that was set, there are different dialogs:
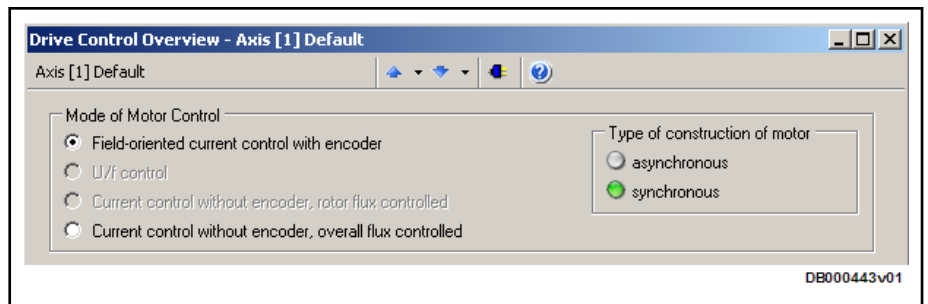
Fig.6-18: IWD Dialog "Motor Control, FOC Setting"
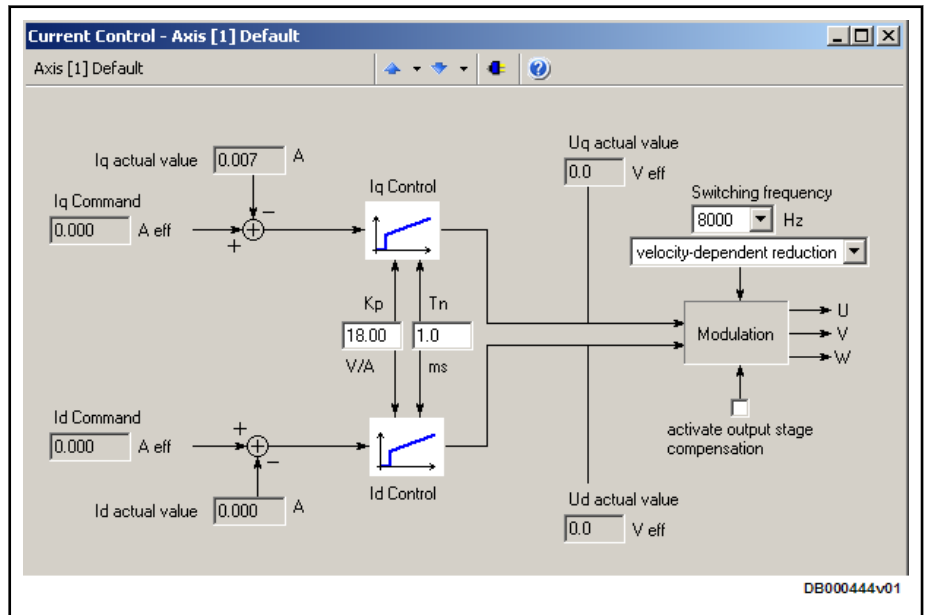
Fig.6-19: IWD Dialog for Setting the PWM Adjustment with FOC Operation
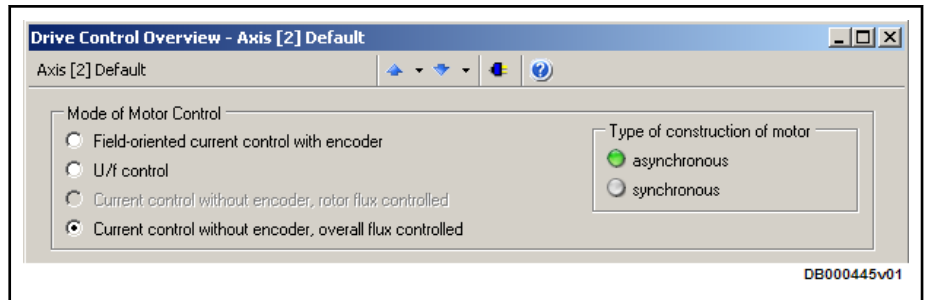
Fig.6-20: IWD Dialog "Motor Control, FXC Setting"

Drive Control
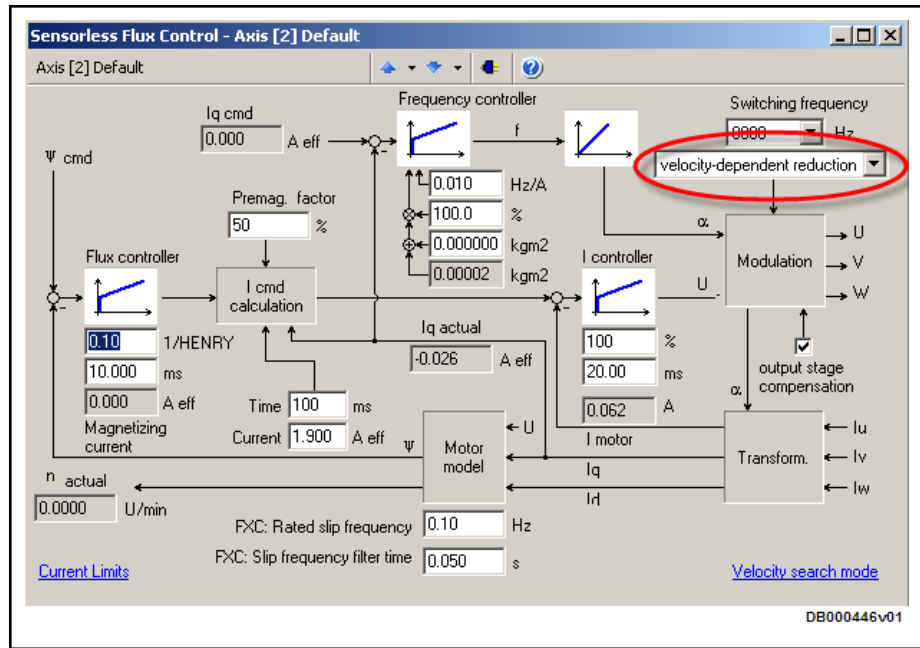
Fig.6-21:   IWD Dialog for Setting the PWM Adjustment with FXC Operation

Displaying the PWM Switching   The switching of the PWM frequency to half the value of P-0-0001 is displayed in the corresponding bit of "P-0-0046, Status word of current controller".

6.3.3   Voltage-Controlled Open-Loop Operation (U/f Control)

Brief Description

The drive function "voltage-controlled operation of asynchronous motors without encoder in open-loop 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 operation mode "velocity synchronization with real/virtual master axis" is additionally available.
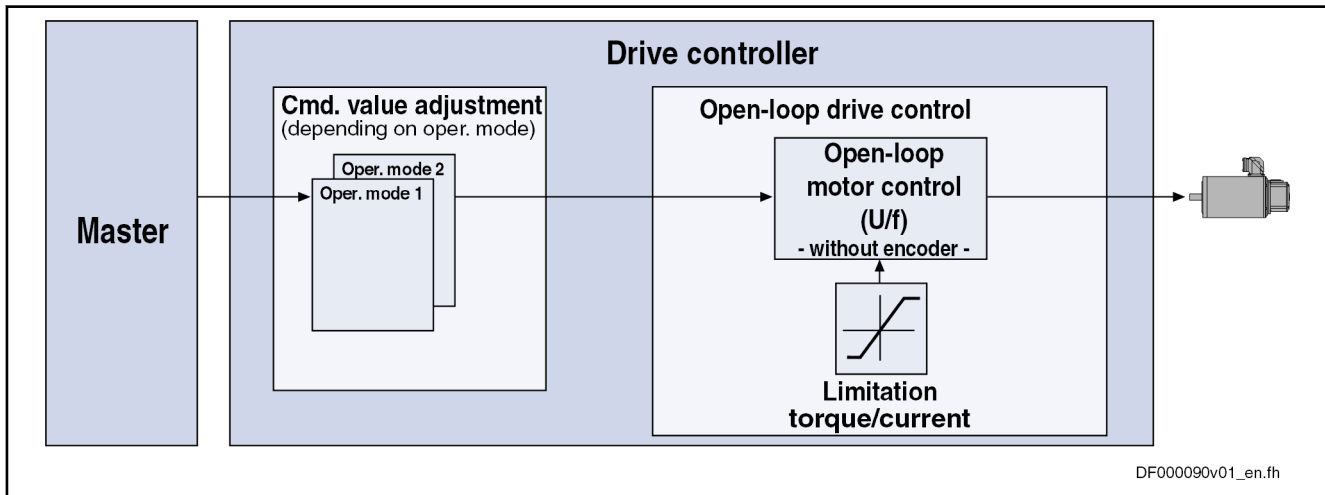
Fig.6-22:   Principle of U/f Control

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

Drive Control

- **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)
- **D.C. braking** to reach standstill more quickly
- 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

Drive Control

- P-0-0577, Square characteristic: lowering factor
- P-0-0578, Current for deceleration, absolute value
- P-0-0579, Current for deceleration, time period
- P-0-4036, Rated motor speed
- P-0-4046, Effective peak current

Pertinent Diagnostic Messages
- E8040 Torque/force actual value limit active
- E8041 Current limit active
- E8260 Torque/force command value limit active

Functional Description

Overview of Core Functions

The figure below illustrates the core functions of U/f control:
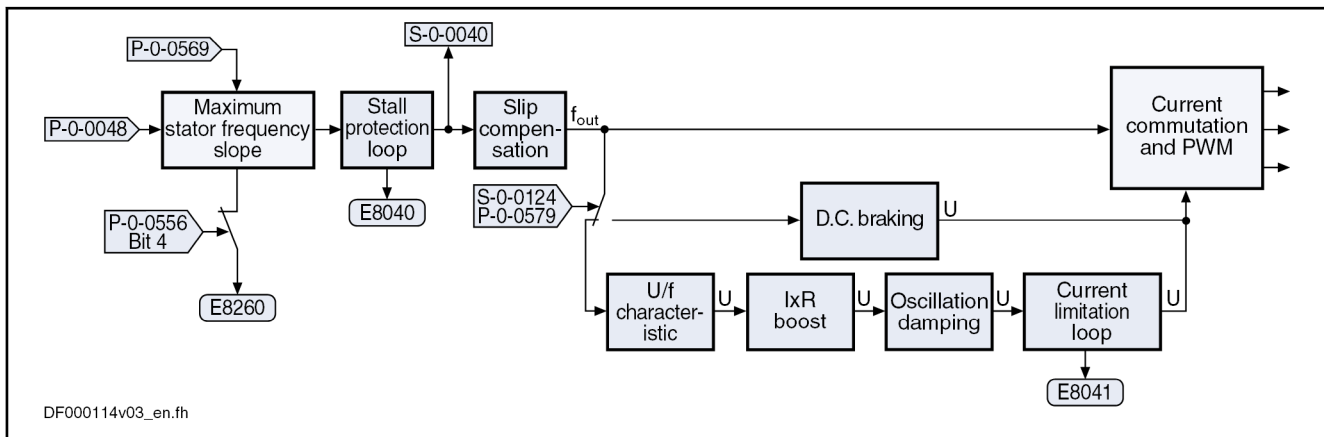
S-0-0040	Velocity feedback value
S-0-0124	Standstill window
P-0-0048	Effective velocity command value
P-0-0065	Absolute voltage value, actual value
P-0-0556	Config word of axis controller
P-0-0569	Maximum stator frequency slope
P-0-0579	Current for deceleration, time period

Fig.6-23:   *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 "P-0-0569, Maximum stator frequency slope". If the acceleration capability was exceeded, the diagnostic message "E8260 Torque/force command value limit active" is output.

This message can be masked via bit 4 of "P-0-0556, Config word of axis controller":

- Bit 4 = 0 → Message is displayed
- Bit 4 = 1 → Message is not displayed
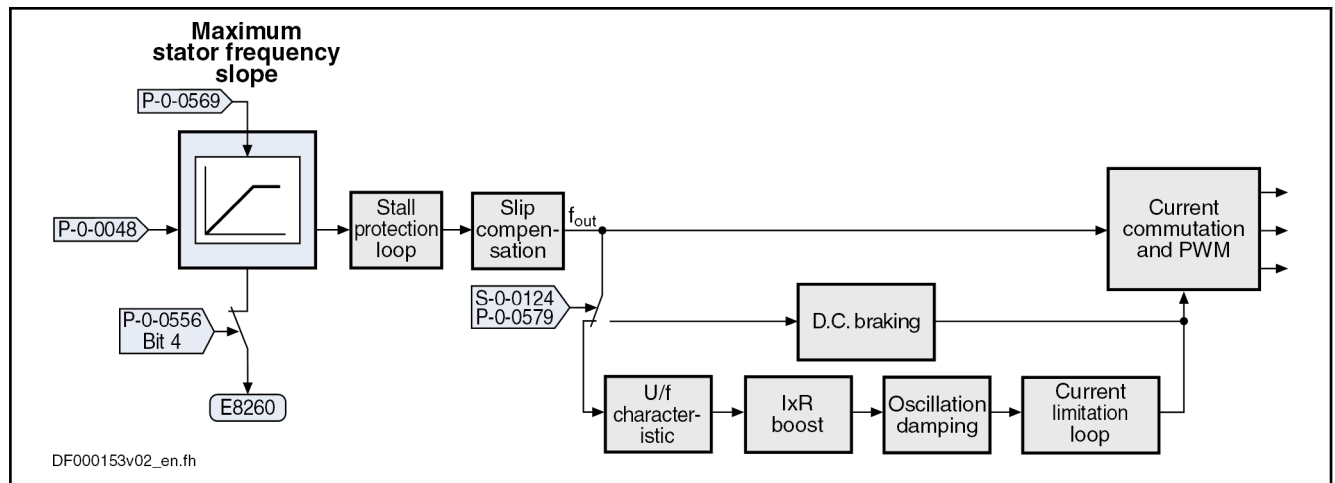
S-0-0124	Standstill window
P-0-0048	Effective velocity command value
P-0-0556	Config word of axis controller
P-0-0569	Maximum stator frequency slope
P-0-0579	Current for deceleration, time period

Fig.6-24:   *Core Function "Maximum Stator Frequency Slope"*

Stall Protection Loop

When the torque limits in the case of motive and generating 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 "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).

Drive Control
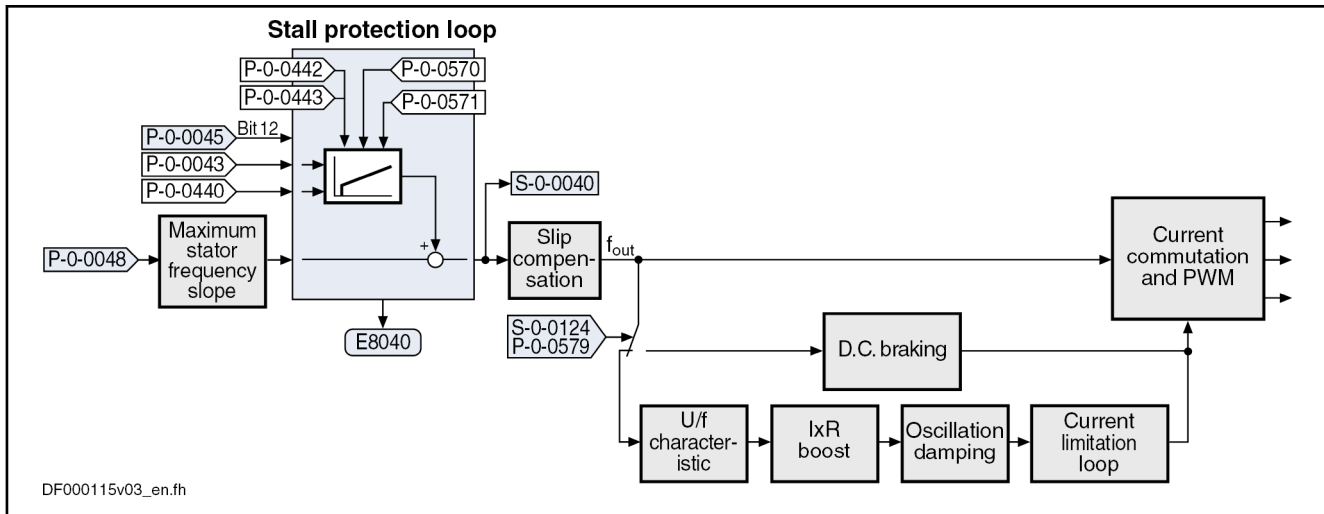
S-0-0124	Standstill window
S-0-0040	Velocity feedback value
P-0-0043	Torque-generating current, actual value
P-0-0045	Control word of current controller
P-0-0048	Effective velocity command value
P-0-0440	Actual output current value (absolute value)
P-0-0442	Actual value torque limit positive (stationary)
P-0-0443	Actual value torque limit negative (stationary)
P-0-0570	Stall protection loop proportional gain
P-0-0571	Stall protection loop integral action time
P-0-0579	Current for deceleration, time period

Fig.6-25:   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 "P-0-0043, Torque-generating current, actual value" and "P-0-0440, Actual output current value (absolute value)".

The controller is set via:

- P-0-0570 , Stall protection loop proportional gain

- P-0-0571 , Stall protection loop integral action time

The values of "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.

Drive Control
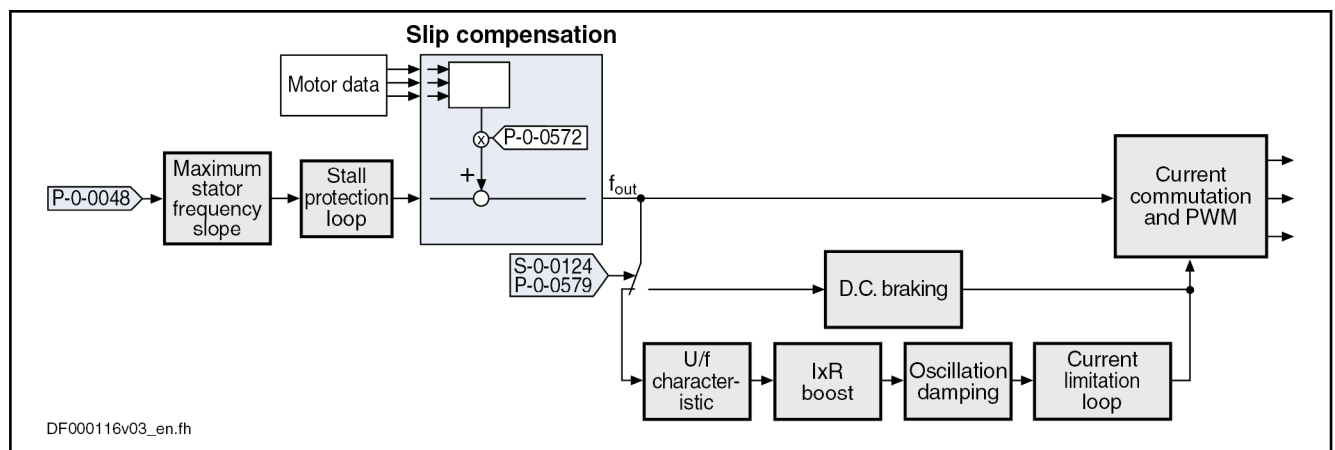
S-0-0124	Standstill window
P-0-0048	Effective velocity command value
P-0-0572	Slip compensation factor
P-0-0579	Current for deceleration, time period

Fig.6-26:   *Core Function "Slip Compensation"*

The output signal of the stall protection loop is used as the input value.

The feedforward can be set via "P-0-0572 , Slip compensation factor".

☞   With a value of "0.00%" in 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).

Drive Control
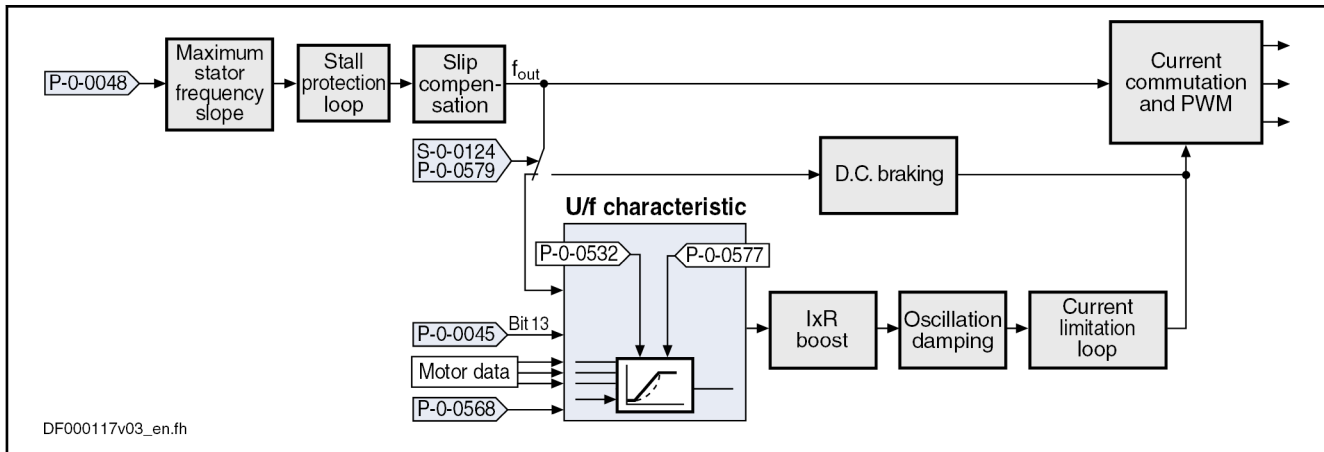
DF000117v03_en.fh

S-0-0124	Standstill window
P-0-0045	Control word of current controller
P-0-0048	Effective velocity command value
P-0-0532	Premagnetization factor
P-0-0568	Voltage boost
P-0-0577	Square characteristic: Lowering factor
P-0-0579	Current for deceleration, time period

Fig.6-27:   Core Function "U/f Characteristic"

The output signal of the slip compensation is used as the input value for the U/f characteristic.

With "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 "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 P-0-0577 corresponds to the linear characteristic.

The magnetization of the machine can be trimmed via "P-0-0532, Premagnetization factor". This corresponds to a change in the steepness of the U/f characteristic. P-0-0532 can be configured in 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 "P-0-0573, IxR boost factor" it is possible to influence the feedforward of the output voltage in a load-depending way. When the motor is under load, the output voltage can be increased by means of P-0-0573 in order to compensate for the enhanced voltage drop inside the motor.

☞   With a value of "0.00%" in P-0-0573 the feedforward is switched off.
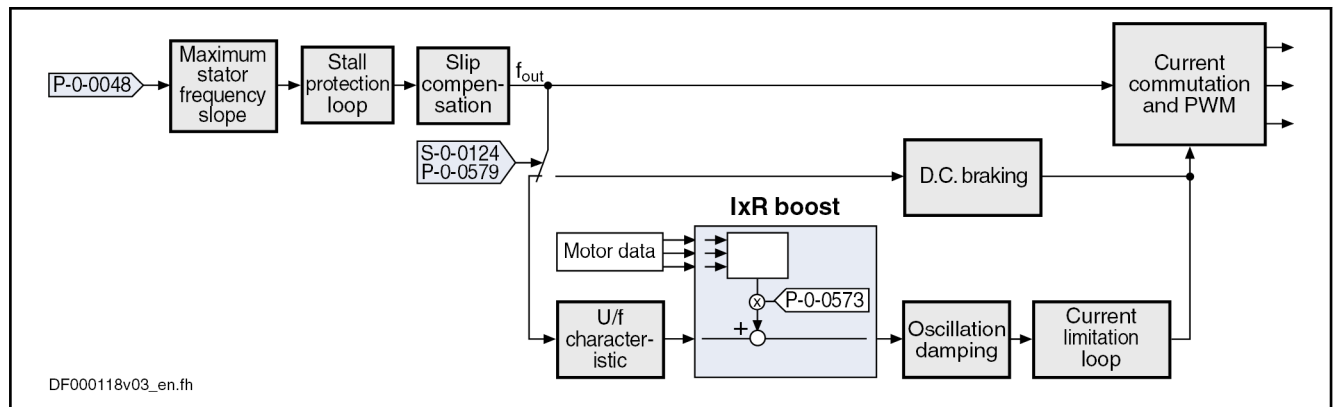
Drive Control

S-0-0124	Standstill window
P-0-0048	Effective velocity command value
P-0-0573	IxR boost factor
P-0-0579	Current for deceleration, time period
Fig.6-28:	*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 "P-0-0574, Oscillation damping factor".

☞   With a value of "0.00%" in P-0-057 the feedforward is switched off.
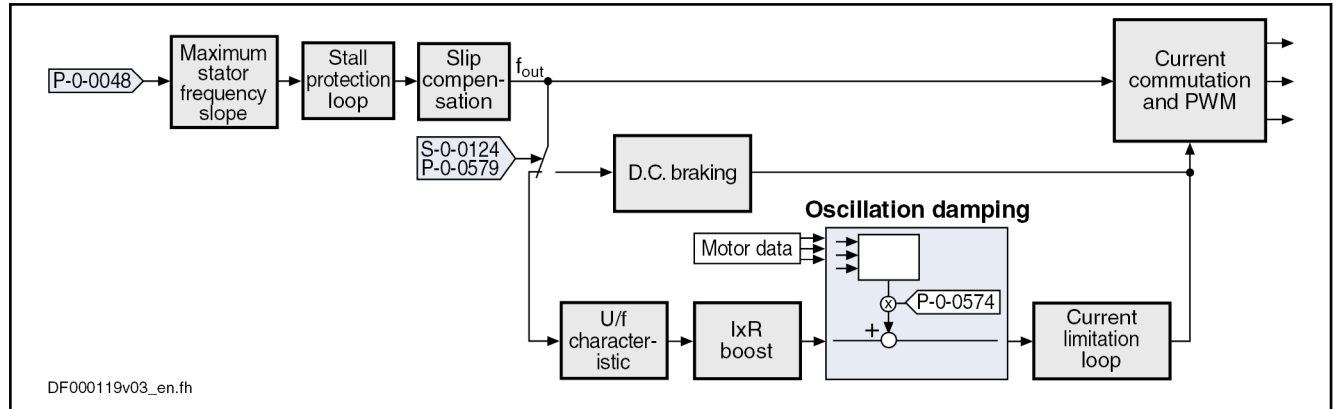
S-0-0124	Standstill window
P-0-0048	Effective velocity command value
P-0-0574	Oscillation damping factor
P-0-0579	Current for deceleration, time period
Fig.6-29:	*Core Function"Oscillation Damping"*

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 is activated if the current in the motor surpasses the maximum current of the motor or of the controller. Before the activation of the current limitation loop, the activated stall protection loop already tried to relieve the motor!

Drive Control
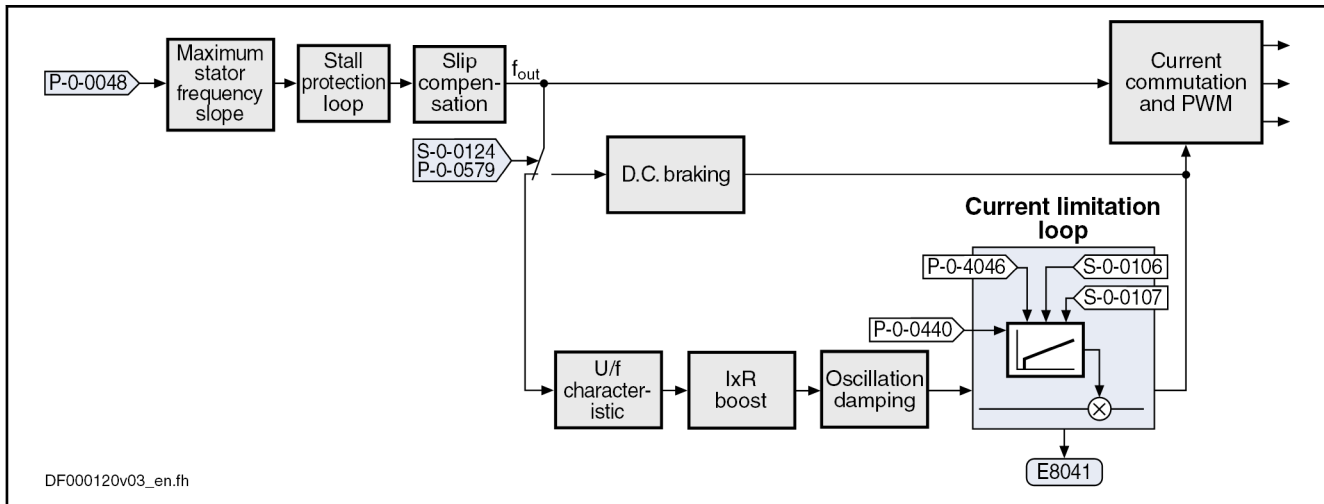
DF000120v03_en.fh

S-0-0124	Standstill window
S-0-0106	Current loop proportional gain 1
S-0-0107	Current loop integral action time 1
P-0-0048	Effective velocity command value
P-0-0440	Actual output current value (absolute value)
P-0-4046	Effective peak current
P-0-0579	Current for deceleration, time period

Fig.6-30:   *Core Function "Current Limitation Loop"*

D.C. Braking

D.C. braking, which can be activated, improves motor deceleration in case the velocity command value equals zero. If the absolute value of the velocity command value and actual value falls below the value in "S-0-0124, Standstill window", switching from open-loop voltage control (U/f operation) to closed-loop current control takes place and the current for deceleration is generated. The degree of current for deceleration is preset in "P-0-0578, Current for deceleration, absolute value".

☞   The value of P-0-0578 must at least comply with the value of "P-0-4004, Magnetizing current" and is limited to 90% of the motor peak current (S-0-0109). In addition, the thermal limitations of motor and controller take effect!

Due to sensorless motor operation, motor standstill cannot be definitively ascertained. Therefore, the current for deceleration can be maintained, with the value of "P-0-0579, Current for deceleration, time period", beyond the internally detected motor standstill (velocity command value and actual value equal zero), so that the deceleration of the motor is really completed.

☞   The default value of P-0-0579 is 0.5s. The parameter value must be adapted to the deceleration behavior. Inputting the value "0" deactivates d.c. braking!

Drive Control
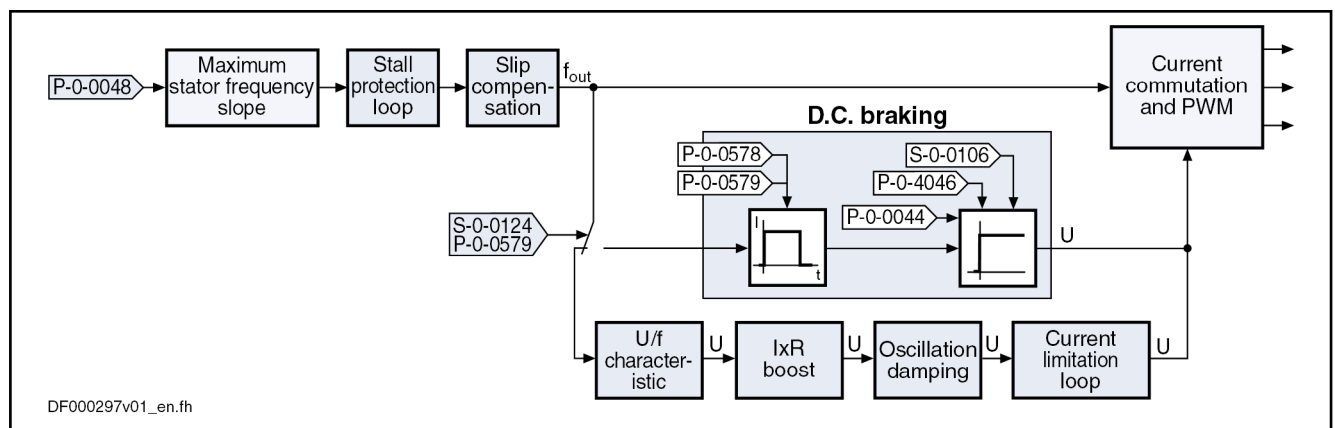
DF000297v01_en.fh

S-0-0106	Current loop proportional gain 1
S-0-0124	Standstill window
P-0-0044	Flux-generating current, actual value
P-0-0578	Current for deceleration, absolute value
P-0-0579	Current for deceleration, time period
P-0-4046	Effective peak current

Fig.6-31:   *Core Function "D.C. Breaking"*

D.C. braking is terminated when one of the following conditions has been fulfilled:

● During the deceleration process, the time period (P-0-0579) for activation of the current for deceleration has elapsed. Starting point of time is when the actual velocity value enters the standstill window (S-0-0124). After the deceleration time is over, the motor is in U/f control again. In the case of motor standstill "P-0-0568, Voltage boost" determines the current flowing in the motor.

● The absolute value of the velocity command value again exceeds the value of the standstill window (S-0-0124). The motor is accelerated in U/f control.

☞   The value for "S-0-0106, Current loop proportional gain 1" is determined when the command C3200 (calculate motor data) is executed!

Velocity Search Mode

The velocity search mode is selected and activated in "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 rota-

Drive Control

tional 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 "P-0-0569, Maximum stator frequency slope".

When the limitation of the maximum stator frequency change takes effect, "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 "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 "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 "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 "P-0-0046, Status word of current controller" (bit 14: search mode):

- Bit 14 = 1 → Search mode active
- Bit 14 = 0 → Search mode not active

6.3.4　Field-Oriented Current Control (FOC Control)

Brief Description

> 💡 **Base package** of all firmware versions in **closed-loop** characteristic

☞ 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 Ds/D/MLD).

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:
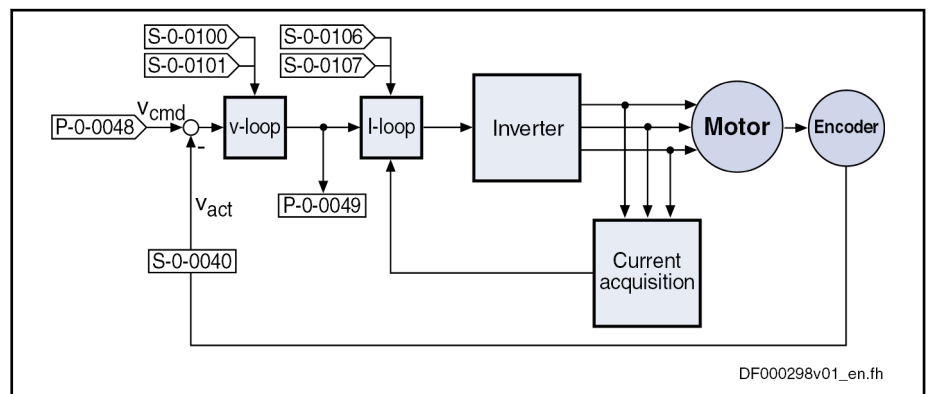
| v-loop | Velocity loop |
| I-loop | Current Loop |

Fig.6-32:   *Simplified Schematic Diagram for Field-Oriented Current Control with Higher-Level Velocity Control*

Working Ranges

Field-oriented current control of asynchronous and synchronous motors allows operation in the entire speed range.

The speed range is divided into the following working ranges:

- Basic speed range → **constant torque**
- Field weakening range 1 → **constant power**
- Field weakening range 2 → **power limit range**

General Features

Field-oriented current control has the following general features:

- Control of the motor current according to the principle of field orientation, i.e. separate control of the torque-generating current and the flux-generating current
- Compensation of the cross coupling of the d-axis and q-axis 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 when loading the default values (motor-spec. controller values)

Features of Synchronous Motor Control

In the case of **synchronous motors**, field-oriented current control additionally has the following features:

- Limitation of the I_q command value at the voltage limit for protection against too little control margin

Drive Control

- 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

Power monitoring:
- S-0-0158, Power threshold Px
- S-0-0337, Status "P >= Px"
- S-0-0382, DC bus power

Encoder monitoring (in operation with encoder):
- P-0-0520, Encoder validation error threshold factor

Display parameters:
- S-0-0380, DC bus voltage
- P-0-0046, Status word of current controller
- P-0-0063, Torque-generating voltage, actual value

Drive Control

- P-0-0064, Flux-generating voltage, actual value

- P-0-0065, Absolute voltage value, actual value

Pertinent Diagnostic Messages
- C0132 Invalid settings for controller cycle times

- E8025 Overvoltage in power section

- E8028 Overcurrent in power section

- F2077 Current measurement trim wrong

- F8023 Error mechanical link of encoder or motor connection

- F8060 Overcurrent in power section

General Function of Field-Oriented Current Control

Open-Loop Torque/Force Control In contrast to the functional principle called "torque/force control" mode, this actually is current control, as the actual current value is measured and not the force or the motor torque. This means that 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.

$$M_i = K_M \times I_q$$

The so-called torque/force constant "K_M", however, is not a static value, it is changed by:

- Amount of the actually flowing current: Reduction in currents larger $I_{nominal}$

- Temperature change of motor winding and rotor: Reduced when temperature rises

This causes deviations of the torque at the motor shaft compared with the value displayed on the drive side. In the case of torque/force scaling in the physical units "Nm" and/or "N", the value on the drive side differs from the actual effect of the motor; in the case of percentage-based scaling, the displayed value is only correct for the current ratio.

With synchronous motors, the specified influencing factors can be corrected on the drive side so that a precise torque/force constant is effective for the torque/force calculation. (Cross reference to the documentation on "Compensation functions / correction of the torque/force constant")

In the case of asynchronous motors, the torque constant is corrected according to the active rotor flux:

Field Weakening Operation With the firmware, it is possible to operate asynchronous and synchronous motors in the entire speed range (including field weakening range).

We basically distinguish 3 working ranges that are illustrated in the following figure and described below.

Drive Control
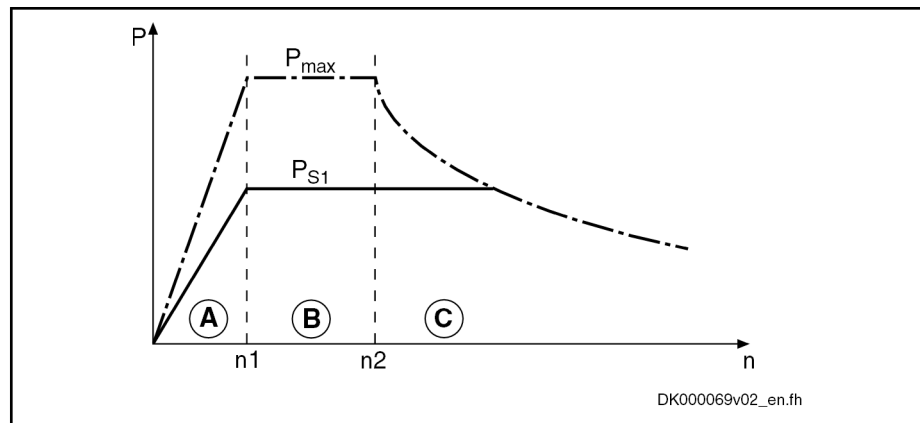
A	Basic Speed Range
B	Field weakening range 1
C	Field Weakening Range 2 (Power Limit Range)

Fig.6-33:   Three Working Ranges of the Speed Range

Basic Speed Range

The basic speed range is characterized by constant torque and speed-independent torque/force constant (P-0-0051).

In the case of asynchronous motors, the programmed, effective magnetizing current flows in no-load operation. The motor voltage is less than the maximum controller output voltage. The corner speed n1 is directly proportional to the DC bus voltage.

Field Weakening Range 1 (Constant Power)

The field weakening range 1 is characterized by constant power, the motor voltage is kept constant. In the case of asynchronous motors, the no-load current is reduced as the speed increases. This reduces the magnetization and the torque constant, the slip increases accordingly. The adjustment of magnetizing current and slip is automatically carried out by the voltage 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 this range, performance can only be increased by increasing the voltage of the DC bus!

In the following sections, we distinguish control of synchronous machines (with motor encoder) and asynchronous machines (with and without motor encoder).

Field-Oriented Current Control of a Synchronous Machine

☞   For synchronous motors, field-oriented current control is only possible with motor encoder (with closed-loop base package)!

Synchronous motors with a motor encoder in field-oriented current control can be operated in all available operating modes. The figure below illustrates the control loop structure and the points at which the individual parameters take effect for a synchronous machine.
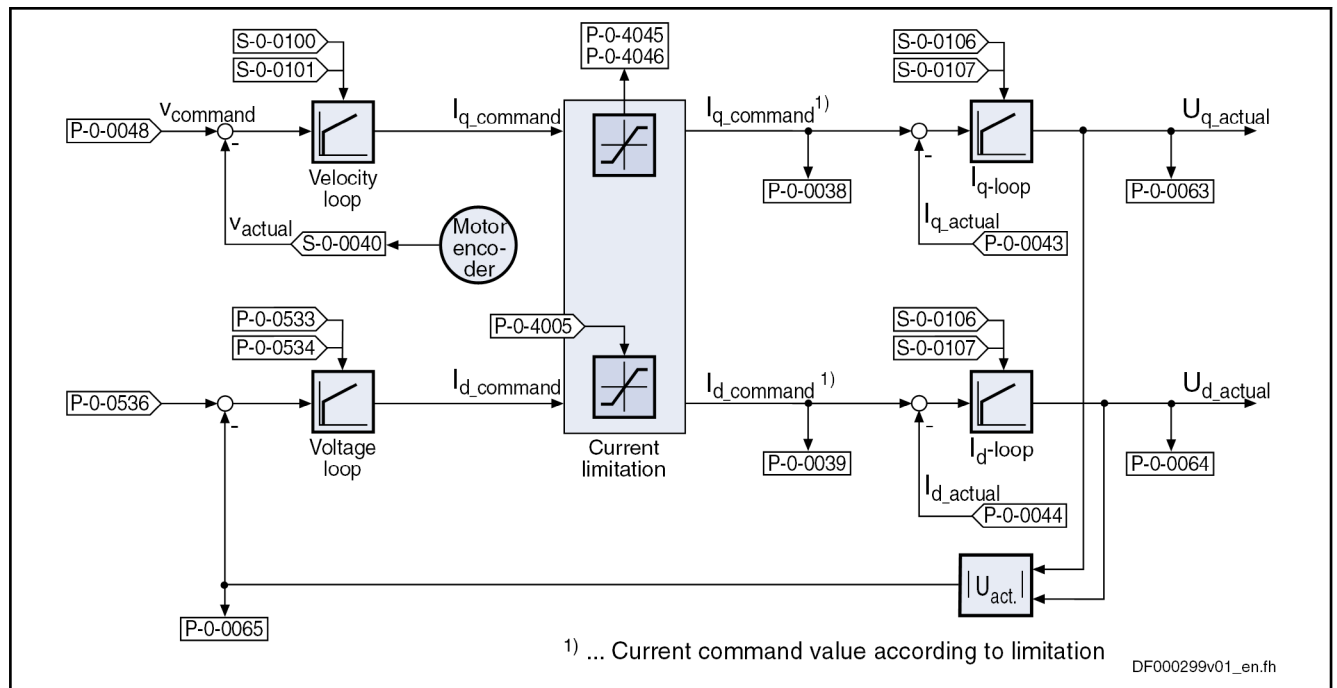
Fig.6-34:   *Simplified Schematic Diagram of the Current Control Loop for a Synchronous Machine*

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 ($\rightarrow$ 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 "chapter "Field-Oriented Current Control of a Synchronous Machine" on page 402"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-axis and q-axis, requires the separate input of L_d and L_q in the respective parameters:

- P-0-4016, Direct-axis inductance of motor (Ld)
- P-0-4017, Quadrature-axis inductance of motor (Lq)

Drive Control

> ☞ Utilization of the reluctance effect allows increasing the available torque in the basic speed range.

Field-Oriented Current Control of an Asynchronous Machine

Field-oriented control of the asynchronous machine differs from control of the synchronous machine in the additional function blocks "flux feedforward" and "flux loop incl. field model".

The figure below illustrates the control loop structure of field-oriented current control:
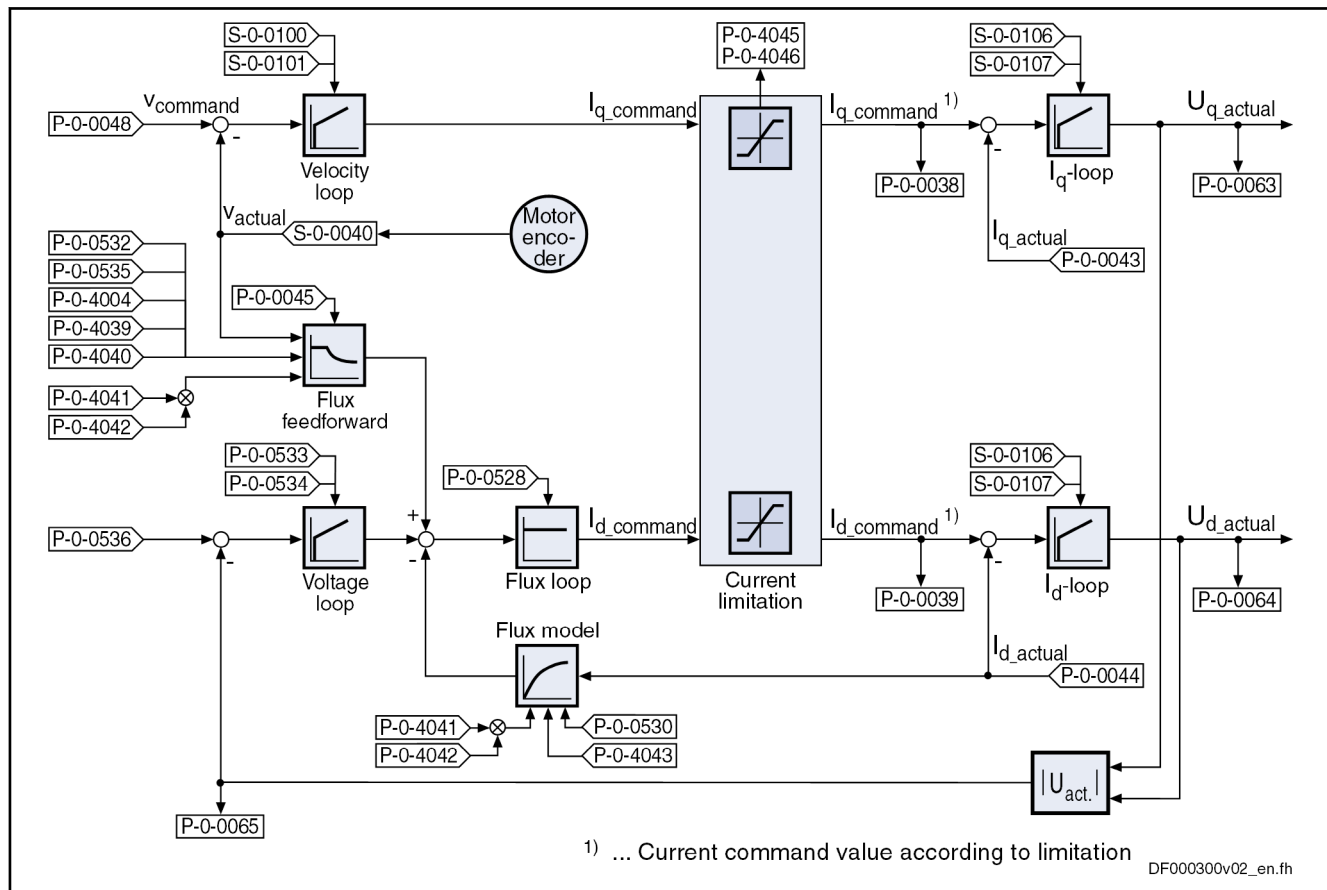
Fig.6-35:   *Simplified Schematic Diagram of the Current Control Loop for an Asynchronous Machine*

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

Drive Control

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 constant and 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-cmd} provides for rapid rotor flux generation. This is of importance for applications with dynamic speed response (field weakening range). The gain can be set in "P-0-0528, Flux control loop proportional gain".

☞   In the case of asynchronous motors, the field or rotor flux control has a decisive influence on the torque generation and dynamic response of the machine, particularly in the field weakening range.

☞   For Rexroth motors the corresponding value is stored in the "DriveBase" database.

Stall Current Limit

The stall current limit only takes effect in the power limit range of the field weakening range (C). The maximum allowed torque-generating current is calculated by means of the active rotor flux and the motor data. This absolute limit value can be relatively changed via the setting in "P-0-0529, Scaling of stall current limit" (in percent).

☞   When operating a motor without field weakening it is only the effective magnetizing current that is applied as 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.

Building up the Magnetic Field

Building up the magnetic field typically takes half the time an asynchronous motor has as its rotor time constant (P-0-4043, Rotor time constant). During this time, the command value acceptance is blocked because the torque output is not yet ensured.

The premagnetization factor (P-0-0532) influences the intensity of the magnetic field in the air gap of the asynchronous motor. With values smaller than "1", the immediate ability to output torque after command value acceptance is reduced to the entered percentage value. This effect is transient, i.e. the reduction is no longer effective in the case of stationary load.

Drive Control

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 "Automatic Setting of Motor Control" and "Third-Party Motors at IndraDrive Controllers").

See also "Commissioning Motors"

Inductance Characteristic for Synchronous Motors

It is possible to store a characteristic of the motor quadrature-axis inductance (L_q) in the drive depending on the torque-generating current (I_q). If required (e.g. saturation phenomena), it is thereby possible to achieve the reduction of the effective current loop gain for higher currents. This function is activated by setting bit 12 in "P-0-4014, Type of construction of motor".

☞ For motors with significant saturation phenomena, it is recommended to use the inductance characteristic to achieve adjustment of the effective current 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 P-0-4002 are factors which refer to the value in "P-0-4017, Quadrature-axis inductance of motor". The inductance values L_q of the characteristic are resulting by multiplication with this value. The values in P-0-4003 are factors which refer to the value in "S-0-0111, Motor current at standstill". The current values I_q of the characteristic are resulting by multiplication with this value.

Drive Control
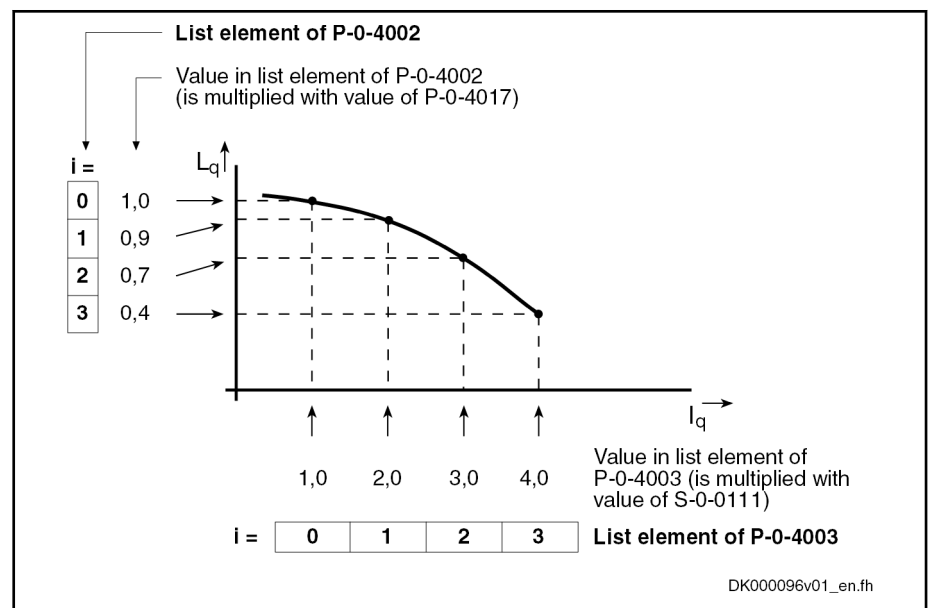
Fig.6-36: *Interaction of the Parameters for Defining the Inductance Characteristic (with Exemplary Values)*

Flux Feedforward for Asynchronous Motors

Due to higher magnetization (rotor flux), the motor produces higher torque. In no-load operation, however, the magnetization produces loss which is the reason why it is useful to reduce magnetization for less dynamic applications.

☞ For reducing magnetization, a value between 50% and 100% can be set in "P-0-0532, Premagnetization factor".

In addition, magnetization can be influenced via bit 2 in "P-0-0045, Control word of current controller":

- **Bit 2 = 0** (default setting)

  → According to required torque, magnetization is increased up to nominal value; 100% are reached at nominal motor torque

- **Bit 2 = 1**

  → Independent of load, magnetization remains at value set in P-0-0532

The value in "P-0-0535, Motor voltage at no load" is used as limit value for the flux feedforward. The motor voltage at no load is specified in a percentage-based way and also refers to the maximum possible output voltage of the inverter.

☞ It is advisable to **set 80%** in P-0-0535.

Flux Model for Asynchronous Motors

The slip frequency used in the flux model changes with the temperature of the motor. This is compensated by measuring the motor temperature (S-0-0383) and scaling with the factor in "P-0-0530, Slip increase".

☞ The factor in P-0-0530 has to be set depending on the motor cooling type!

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

Drive Control

☞ 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 determined by means of "P-0-0536, Maximum motor voltage".

The input in P-0-0536 is made in percent and refers to the maximum possible output voltage of the inverter that is determined by the current DC bus voltage (see "S-0-0380; DC bus voltage").

☞ It is advisable to **set 90%** in P-0-0536.

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 "P-0-0530, Slip increase" in asynchronous motors.

Diagnostic and Status Messages

Status Messages

- S-0-0158, Power threshold Px

  This parameter determines the power threshold above which the drive outputs the status message "power > = Px" in "S-0-0337, Status "P >= Px"".

- S-0-0337, Status "P >= Px"

  Only bit 0 of this parameter is used. It is set when the following applies:

  "S-0-0382, DC bus power" = "S-0-0158, Power threshold Px"

  Simultaneously, bit 7 is set in "S-0-0013, Class 3 diagnostics".

Display Values and Diagnostic Values

- The DC bus voltage is measured in the current loop clock and displayed in "S-0-0380, DC bus voltage".
- The effective electric power produced by the controller (taking the inverter losses into account) is displayed in "S-0-0382, DC bus power".

  The effective power (P_w) is calculated according to the following formula:

$$P_w = (U_d \times I_d + U_q \times I_q) \times 1,5$$

  The calculated value is displayed in filtered form (T = 8 ms). When the parameterized threshold value in "S-0-0158, Power threshold Px" is exceeded, bit 0 is set in "S-0-0337, Status "P >= Px"" and bit 7 in class 3 diagnostics.

- The measured value of the torque-generating current (I_q) detected in the current loop clock is displayed in "P-0-0043, Torque-generating current, actual value, actual value".

- The measured value of the field-generating current (I_d) detected in the current loop clock is displayed in "P-0-0044, Flux-generating current, actual value".

- "P-0-0046, Status word of current controller" displays the status of the current loop.

Drive Control

Errors, Warnings and Monitoring Functions

- C0132 Invalid settings for controller cycle times

  → An error was detected in the parameterization of the controller cycle times and PWM frequency.

- E8025 Overvoltage in power section

  → This warning is generated when the DC bus voltage exceeds a value of 870.0 V. In this case, the current 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).

- F2077 Current measurement trim wrong

  → During zero adjust of the current measurement, a deviation outside of the tolerance range occurred (hardware defect).

6.3.5 Sensorless Motor Operation, Flux-Controlled (FXC Control)

Brief Description

> 💡 **Base package** of all firmware variants in **open-loop and closed-loop** characteristic

For asynchronous and synchronous motors, flux-controlled, sensorless motor operation is available in the base packages "open-loop" and "closed-loop" of all firmware variants and can be used in the "velocity control" mode and in position-controlled operation modes which use position encoder 2 (external encoder).

When using the firmware expansion package "synchronization", you can also run the operation mode "velocity synchronization with real/virtual master axis".
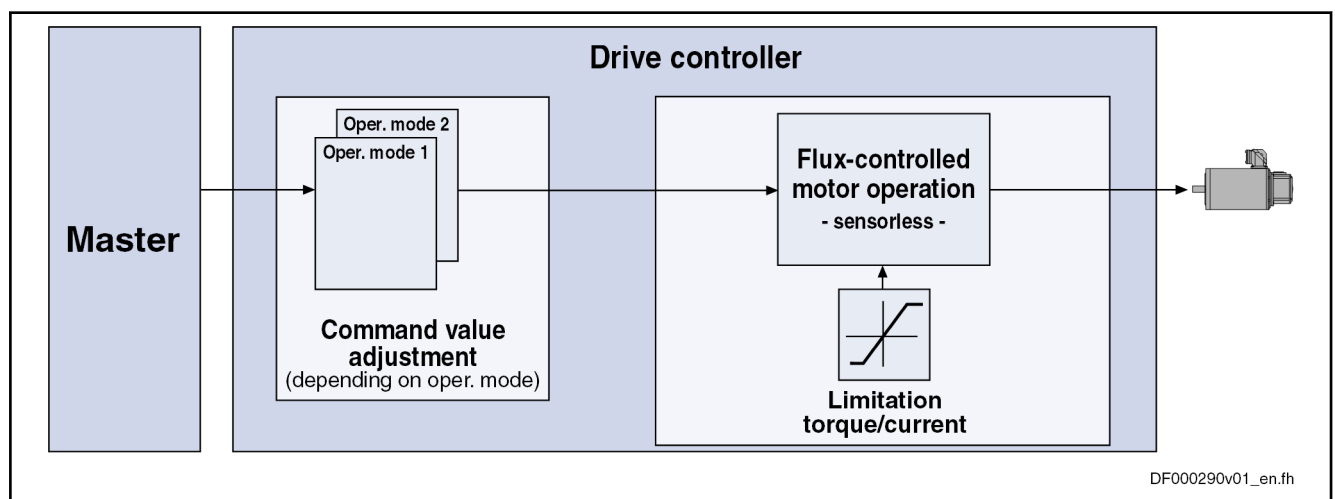
Fig.6-37:   Principle of Sensorless, Flux-Controlled Motor Operation

Features

- Limitation of the maximum **stator frequency slope** that results from the command velocity change

- "Stable" motor operation

  → To maintain the maximum possible torque

Drive Control

- **Slip compensation** for asynchronous motors (estimated motor slip taken into account for calculating actual velocity value)

  → To minimize the stationary speed deviations, due to slip, from the command value when the asynchronous motor is loaded

- Motor speed does not tend to oscillation in operation at partial load and no-load operation

- **Velocity search mode** of a coasting asynchronous motor after switching drive enable on

- Possibility of taking user-side **torque/force limitation** into account

Pertinent Parameters   Motor control parameters of sensorless, flux-controlled motor operation:

- P-0-4033, C3200 Command Calculate motor data
- P-0-0532, Premagnetization factor
- P-0-0565, C3600 Command Motor data identification
- P-0-0578, Current for deceleration, absolute value
- P-0-0579, Current for deceleration, time period
- P-0-0580, Motor frequency
- P-0-0593, FXC: Total flux loop proportional gain
- P-0-0594, FXC: Total flux loop integral action time
- P-0-0595, FXC: Frequency loop proportional gain
- P-0-0596, FXC: Frequency loop scaling factor of inertia
- P-0-0597, FXC: Current loop proportional gain
- P-0-0598, FXC: Current loop integral action time
- P-0-0599, FXC: Slip frequency filter time constant
- P-0-0600, FXC: Rated slip frequency
- P-0-0602, FXC: Minimum no-load current

Motor data parameters:

- P-0-0510, Rotor inertia
- P-0-4004, Magnetizing current
- P-0-4032, Motor type plate data

Axis data parameters:

- P-0-4010, Load inertia

Control parameters:

- P-0-0045, Control word of current controller
- P-0-0601, Configuration motor data identification

Functional Description
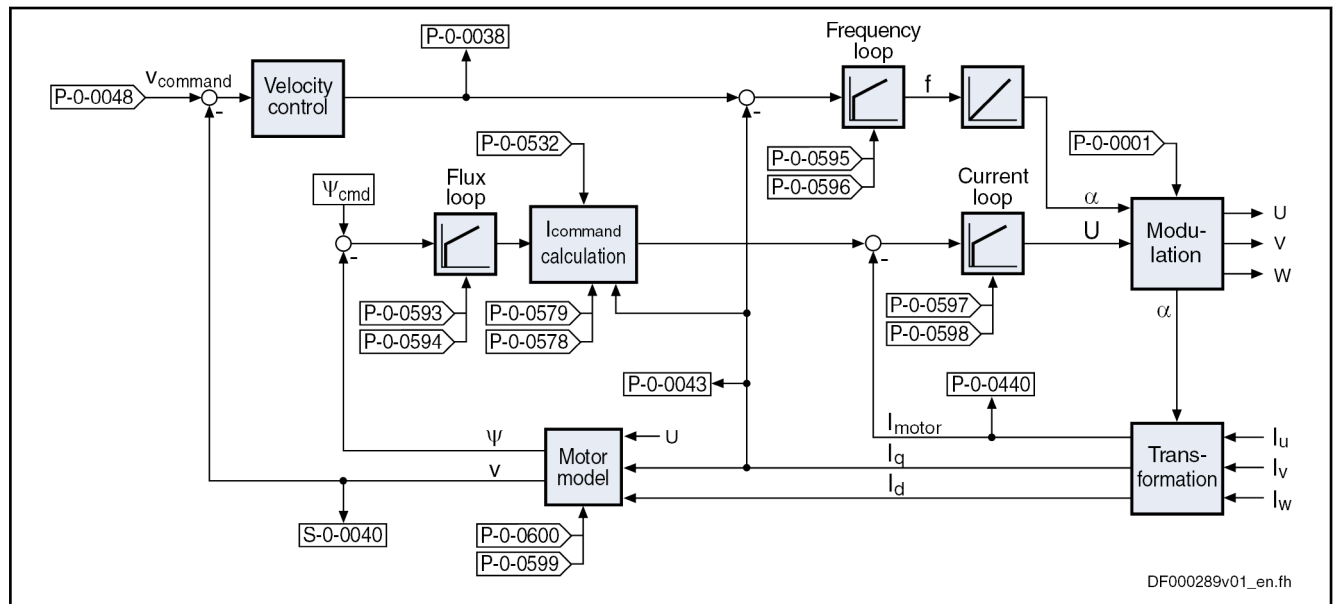
Fig.6-38: Block Diagram of Sensorless, Flux-Controlled Motor Operation

Control Method For controlling sensorless synchronous motors (SYM) or asynchronous motors (ASM), the control method generates a three-phase rotary field with variable voltage amplitude and rotary field frequency. The rotary field frequency depends on the velocity command value, the number of pole pairs of the motor and, in the case of ASM, on the motor load. The amplitude of the motor voltage depends on the impedances and on the magnetic flux in the motor.

The frequency of the motor voltage is given by a PI frequency loop, depending on the control difference of the torque-generating command current and actual current. It is the electrical equivalent of the velocity:

- For ASM, torque is generated by "slip" (deviation from velocity command value under load). This "slip" can be compensated for ASM via the calculated actual velocity value (motor model calculation). When the load exceeds the "pull-out slip" of the motor, it stops.

- For SYM (synchronous motors), the torque is generated by the "load angle". Its value is proportional to the load; when it remains smaller than 90° el., the actual velocity value follows the velocity command value without deviation. When the load causes a load angle greater than 90° el., the SYM stops abruptly.

The amplitude of the motor voltage is given by a PI current loop, depending on the control difference of the total motor current:

- For ASM, the required magnetic flux must be generated in the air gap. The optimum flux command value for the motor is preset drive-internally. From the current status variables, the motor model calculates the flux existing in the motor. By means of the flux deviation, the PI flux loop and a subsequent calculation function generate the command value for the total motor current.

- For SYM, the magnetic flux already exists in the air gap due to the permanent magnets. However, a command value for the total motor current is preset when the motor is in no-load operation. The impulse load stability is improved with increased no-load current, the no-load loss, however, is increased.

Drive Control

Deceleration, Standstill

At low speed, the determination of the actual velocity is highly inexact due to motor operation without encoder. At output frequencies below a threshold value, a current for deceleration (P-0-0578, Current for deceleration, absolute value) which can be set is therefore output during deceleration to bring the motor to standstill. During the determination of the motor parameters, the value is automatically set to the rated current of the motor.

As motor standstill cannot be reliably identified, the current for deceleration, after the velocity command value and the actual velocity value have been brought to zero, is maintained for a time which can be set (P-0-0579, Current for deceleration, time period) so that the motor really comes to standstill.

When this time is over, the current is reduced, with the drive having been enabled:

- For asynchronous motors to the magnetizing current (P-0-4004).
- For synchronous motors to the no-load current (P-0-0602).

In both cases, the current flowing in the motor when it is in standstill can be reduced more via a premagnetization factor (P-0-0532). This reduces the temperature rise of the enabled motor which is in standstill and the thermal load of the controller.

"Coasting" Motor

By means of the velocity search mode, a coasting asynchronous motor can be brought to deceleration mode and be decelerated, or run to a command value. When this is done, the control of the motor first synchronizes to the current rotational frequency of the motor, before the command value becomes active.

☞   For synchronous motors, this function is not available.

Working Ranges

The sensorless, flux-controlled synchronous or asynchronous motor works in a velocity-dependent way in the basic speed range (low speed) or in the field weakening range (high speed). For the field weakening range, it is not necessary to make any further settings.

Determining the Motor and Motor Control Parameters

On the basis of the type plate parameters, the controller can automatically determine the motor parameters for asynchronous motors by executing commands.

☞   For synchronous motors, this function is not yet available.

See "Automatic Setting of Motor Control"

Frequency Loop

The frequency loop has been designed as a PI loop. It limits the slope of the frequency change of the motor voltage, when accelerating and decelerating, to the steepest, stable characteristic. The slope is significantly determined by the total inertia of the axis. With the parameter "P-0-0596, FXC: Frequency loop scaling factor of inertia" it can be adjusted to the mechanical transmission performance of the load connection. If necessary, it can compensate lacking accuracy of the motor-shaft-related inertia value.

$$J_{axis\_MW\_FXC} = \frac{(P\text{-}0\text{-}0596)}{100\%} \times J_{axis\_MW} = \frac{(P\text{-}0\text{-}0596)}{100\%} \times \left[(P\text{-}0\text{-}0510) + (P\text{-}0\text{-}4010)\right]$$

$J_{Axis\_MW\_FXC}$	Effective inertia of the axis (in frequency loop)
J_{Axis_MW}	Inertia of the machine axis, motor-shaft-related
P-0-0596	Frequency loop scaling factor of inertia (FXC)
P-0-0510	Rotor Inertia
P-0-4010	Load inertia (motor-shaft-related)
Fig.6-39:	*Inertia of the Axis Effective in the Frequency Loop*

The maximum slope of the stator frequency can be calculated by means of the following formula:

Asynchronous motor:

$$\frac{\Delta f_{Stator}}{\Delta t} = \frac{PPZ \times M_{th}}{2 \times \pi \times J_{AXIS\_MW\_FXC}} = \frac{3 \times (P\text{-}0\text{-}0018)^2 \times (S\text{-}0\text{-}0111) \times (P\text{-}0\text{-}4004) \times (P\text{-}0\text{-}4041) * 10^{-3}}{2 \times \pi \times \frac{(P\text{-}0\text{-}0596)}{100\%} \times \left[(P\text{-}0\text{-}0510) + (P\text{-}0\text{-}4010)\right]} \left[Hz/s\right]$$

Synchronous motor:

$$\frac{\Delta f_{Stator}}{\Delta t} = \frac{PPZ \times M_{th}}{2 \times \pi \times J_{AXIS\_MW\_FXC}} = \frac{(P\text{-}0\text{-}0018) \times (P\text{-}0\text{-}0051) \times (S\text{-}0\text{-}0111)}{2 \times \pi \times \frac{(P\text{-}0\text{-}0596)}{100\%} \times \left[(P\text{-}0\text{-}0510) + (P\text{-}0\text{-}4010)\right]} \left[Hz/s\right]$$

Conversions:

$$\frac{\Delta \omega_{Rotor}}{\Delta t} = \frac{2 \times \pi}{(P\text{-}0\text{-}0018)} \times \frac{\Delta f_{Stator}}{\Delta t} \left[rad/s^2\right]; \qquad \frac{\Delta n_{Rotor}}{\Delta t} = \frac{60s/min}{(P\text{-}0\text{-}0018)} \times \frac{\Delta f_{Stator}}{\Delta t} = \frac{60s/min}{2 \times \pi} \times \frac{\Delta \omega_{Rotor}}{\Delta t} \left[min^{-1}/s\right]$$

f_{Stator}	Stator frequency
M_{th}	Theoretical maximum torque of the motor (internally calculated)
PPZ	Number of pole pairs of the motor
$J_{Axis\_MW\_FXC}$	Effective inertia of the axis (in frequency loop)
ω_{Rotor}	Angular frequency of the rotor (motor shaft)
n_{Rotor}	Speed of the rotor (motor shaft)
P-0-0018	Number of pole pairs/pole pair distance
S-0-0111	Motor current at standstill
P-0-4004	Magnetizing current
P-0-4041	Motor magnetizing inductance
P-0-0596	Frequency loop scaling factor of inertia (FXC)
P-0-0510	Rotor inertia
P-0-4010	Load inertia
P-0-0051	Torque/force constant

Fig.6-40:   Calculating the Stator Frequency Slope

Enter the motor inertia in the parameter "P-0-0510, Rotor inertia" and the axis inertia (motor-shaft-related) in the parameter "P-0-4010, Load inertia".

If the motor-shaft-related axis inertia is unknown, it can be determined by an acceleration test:
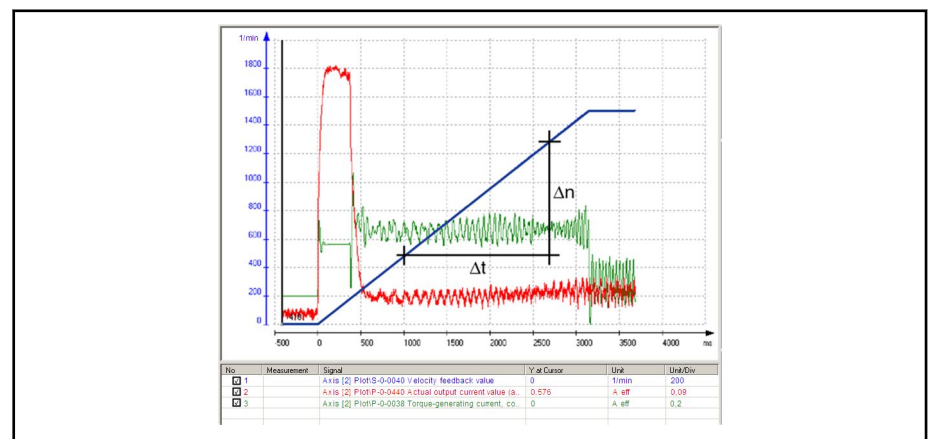
Fig.6-41:   Acceleration Curve of the Axis with the Required Status Variables

☞   Select the acceleration ramp such that the actual value of the torque-generating current (P-0-0043) is constant over the biggest possible velocity range. If applicable, a smaller ramp acceleration is to be selected!

Drive Control

$$J_{Axis\_MW} = \frac{3 \times (P\text{-}0\text{-}0018) \times (P\text{-}0\text{-}4041) \times (P\text{-}0\text{-}4004) \times (P\text{-}0\text{-}0043) \times 60s}{2 \times \pi \times 10^3 \times min} \times \frac{\Delta t}{\Delta n}$$

Asynchronous motor:

$$J_{Axis\_MW} = \frac{(P\text{-}0\text{-}0051) \times (P\text{-}0\text{-}0043) \times 60s}{2 \times \pi \times min} \times \frac{\Delta t}{\Delta n}$$

Synchronous motor:

J_{Axis_MW}	Inertia of the machine axis, motor-shaft-related
P-0-4041	Motor magnetizing inductance (in mH)
P-0-4004	Magnetizing current (in A)
P-0-0043	Torque-generating current, actual value (average value during the linear acceleration in A)
P-0-0018	Number of pole pairs/pole pair distance
P-0-0051	Torque/force constant
Δt	Run-up time in the range of the linear speed increase (in s)
Δn	Speed change during the run-up time (in min-1)

Fig.6-42:   Calculating the Motor-Shaft-Related Total Inertia of the Machine Axis

Enter the calculated value of the motor-shaft-related total inertia of the axis, less the rotor inertia (P-0-0510), in parameter "P-0-4010, Load inertia".

☞   If the rotor inertia is unknown, you can enter the total inertia in parameter P-0-0510 or P-0-4010.

Only in particular cases is it necessary to change the value of parameter "P-0-0595, FXC: Frequency loop proportional gain".

Flux Loop   The flux loop, too, has been designed as a PI loop. It is one of the input values for calculating the current command value. The values for the parameters "P-0-0593, FXC: Total flux loop proportional gain" and "P-0-0594, FXC: Total flux loop integral action time" remain at default. By means of run-up measurement with little acceleration, check the values and adjust them, if necessary (see below "Notes on Commissioning").

☞   Only in particular cases is it necessary to change the value of parameter "P-0-0593, FXC: Total flux loop proportional gain".

Speed Slip Compensation (Only for Asynchronous Motors)   For speed slip compensation, the slip of the asynchronous motor to be expected under load is taken into account in the motor model for the determined current velocity. By velocity control (PI loop), the slip in comparison to the velocity command value is compensated.

Speed slip compensation is only required for drives with high demands as regards the maintaining of the velocity command value under load. It does not need to be used for standard requirements!

In the default status, speed slip compensation is inactive. It can be activated by means of the motor-specific value in parameter "P-0-0600, FXC: Rated slip frequency". The theoretical value is calculated according to the formula below:

Drive Control

$$P\text{-}0\text{-}0600 \;=\; f_{nominal} \;-\; \frac{n_{nominal} \times (P\text{-}0\text{-}0018) \times min}{60s}$$

P-0-0600	Rated slip frequency (FXC)
$f_{Nominal}$	Rated frequency acc. to motor type plate (in Hz)
$n_{Nominal}$	Rated speed acc. to motor type plate (in 1/min)
P-0-0018	Number of pole pairs/pole pair distance

Fig.6-43:   *Calculating the Value for the Slip Frequency*

As it is not really possible to check the velocity of sensorless motors, it is only due to subjective assessment that you can deduce whether the command velocity has been maintained under load.

The value of parameter "P-0-0599, FXC: Slip frequency filter time constant" influences the reaction time of slip compensation at load impulse. Only in particular cases is it necessary to adjust the value in motor-specific form!

Current Loop   The current loop for sensorless, flux-controlled motor operation outputs the amplitude of the motor terminal voltage. It differs from the current loop of the methods for field-oriented motor control with motor encoder. The preset values of the parameters "P-0-0597, FXC: Current loop proportional gain" and

"P-0-0598, FXC: Current loop integral action time" only have to be adjusted in particular cases.

Notes on Commissioning

Establishing the Basic State   To establish a neutral state of the drive parameters, it is recommended that you execute the command "load basic parameters".

Sensorless, flux-controlled motor operation (FXC) is only possible when the motor encoder input (if available) has been deactivated.
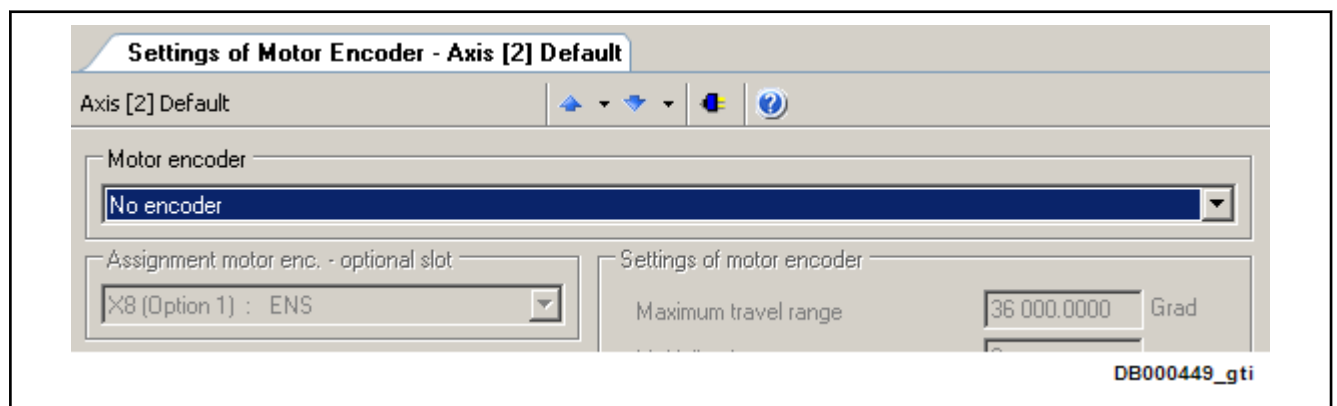
Fig.6-44:   *"IndraWorks Ds/D/MLD" Dialog "Motor Encoder", Deactivation*

Activating FXC Operation   When you set the type of construction of motor to "synchronous", sensorless, flux-controlled motor operation is automatically activated; with the type of construction of motor "asynchronous", you can choose between FXC operation and U/f operation.

☞   You can make the settings via dialogs in "IndraWorks Ds/D/MLD", or set the corresponding bits in the control word of the current controller (P-0-0045).

Drive Control
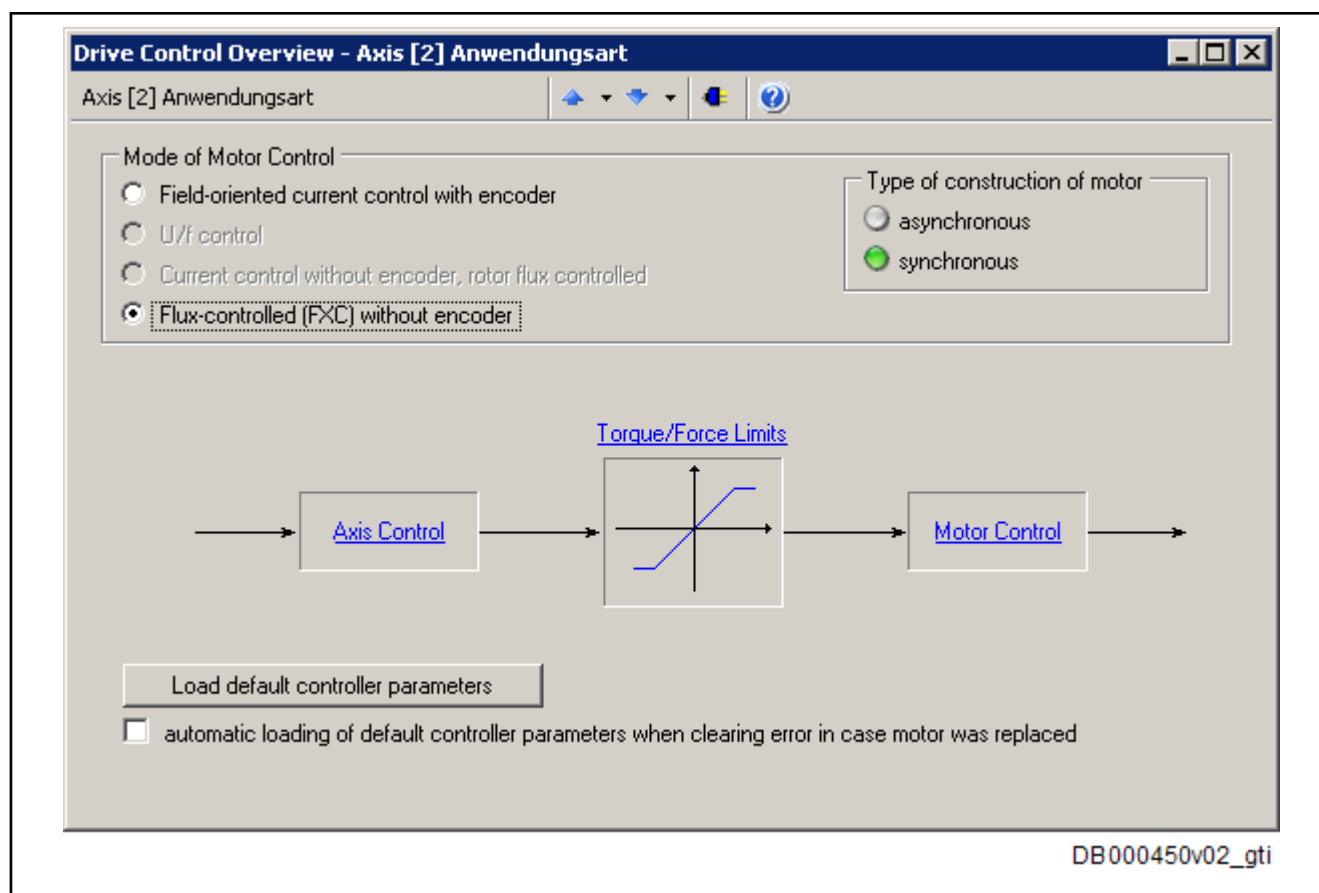
Fig.6-45:   "IndraWorks Ds/D/MLD" Dialog for Setting the Mode of Motor Control

Determining the Motor Parameters for Asynchronous Motors

For asynchronous motors, it is recommended that you have the motor parameters determined by the controller on the basis of the type plate data. For this purpose, enter the type plate data in the parameter "P-0-4032, Motor type plate data" and afterwards execute the commands "C3200 Command Calculate motor data" (P-0-4033) and "C3600 Command Motor data identification" (P-0-0565).

See also "Automatic Setting of Motor Control"

☞   When reading the type plate data, make sure the data correlate. Only enter data with the same frequency reference (in the case of data for 50Hz and 60Hz) or data with reference to the same winding connection (in the case of data for Y and Δ)!

Before you start "C3600 Command Motor data identification" (P-0-0565), check whether it is allowed to put the motor shaft into rotation. Enter the result in the parameter "P-0-0601, Configuration motor data identification". When the motor is turning, the magnetizing inductance can be determined more precisely; therefore, the motor shaft, if allowed, is brought to approx. 50% of the nominal speed by C3600.

☞   The default setting of parameter P-0-0601 is "Motor shaft **cannot** move freely".

Drive Control
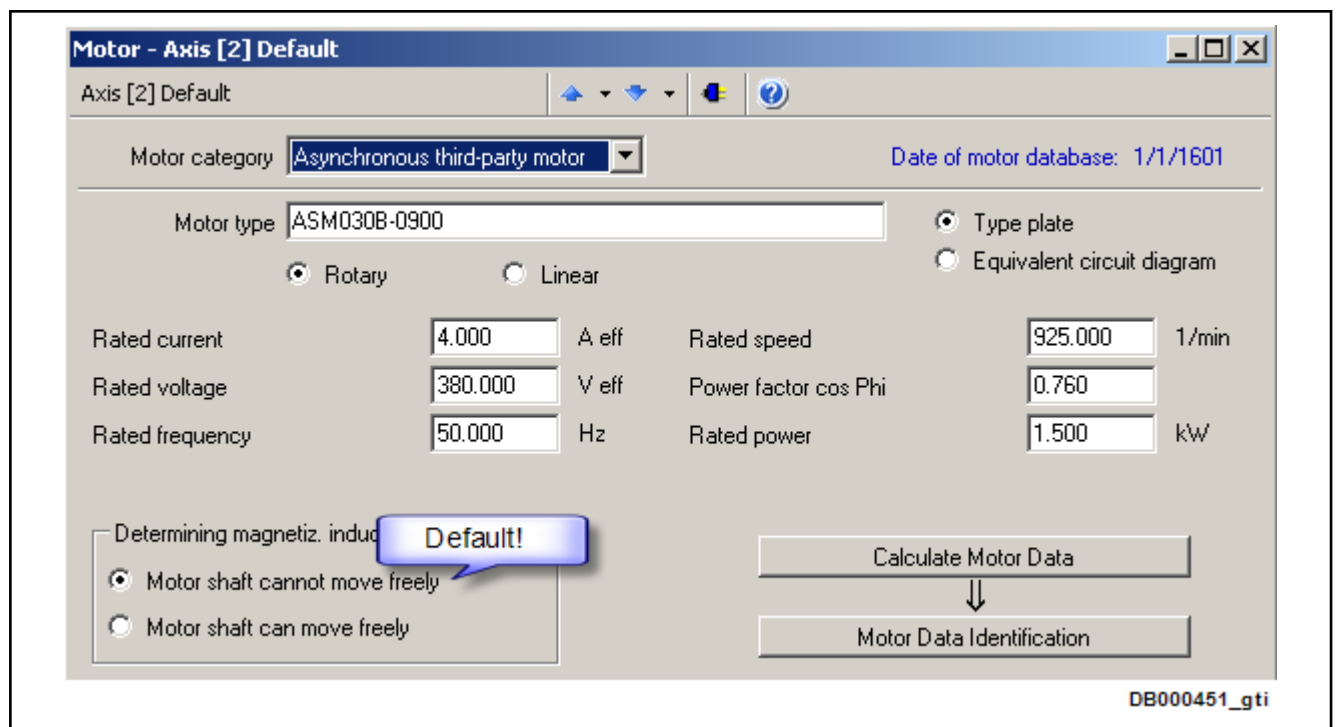
Fig.6-46:   *"IndraWorks Ds/D/MLD" Dialog "Motor", Setting Type of Construction of Motor, Entering Type Plate Data of ASM, Starting Commands "Calculate Motor Data" and "Motor Data Identification" with Exemplary Values*

Determining the Motor Parameters for Synchronous Motors

Enter the motor data of the synchronous motor in the "IndraWorks Ds/D/MLD" dialog "Motor", otherwise in the following parameters:

- P-0-0018, Number of pole pairs/pole pair distance
- S-0-0113, Maximum motor speed
- S-0-0111, Motor current at standstill
- S-0-0109, Motor peak current
- P-0-0051, Torque/force constant
- P-0-4005, Flux-generating current, limit value
- P-0-4016, Direct-axis inductance of motor
- P-0-4017, Quadrature-axis inductance of motor
- P-0-4048, Stator resistance
- P-0-0510, Rotor inertia

☞   The command "C4600 Command Calculate motor control parameters" is irrelevant for FXC operation of synchronous motors!

Drive Control
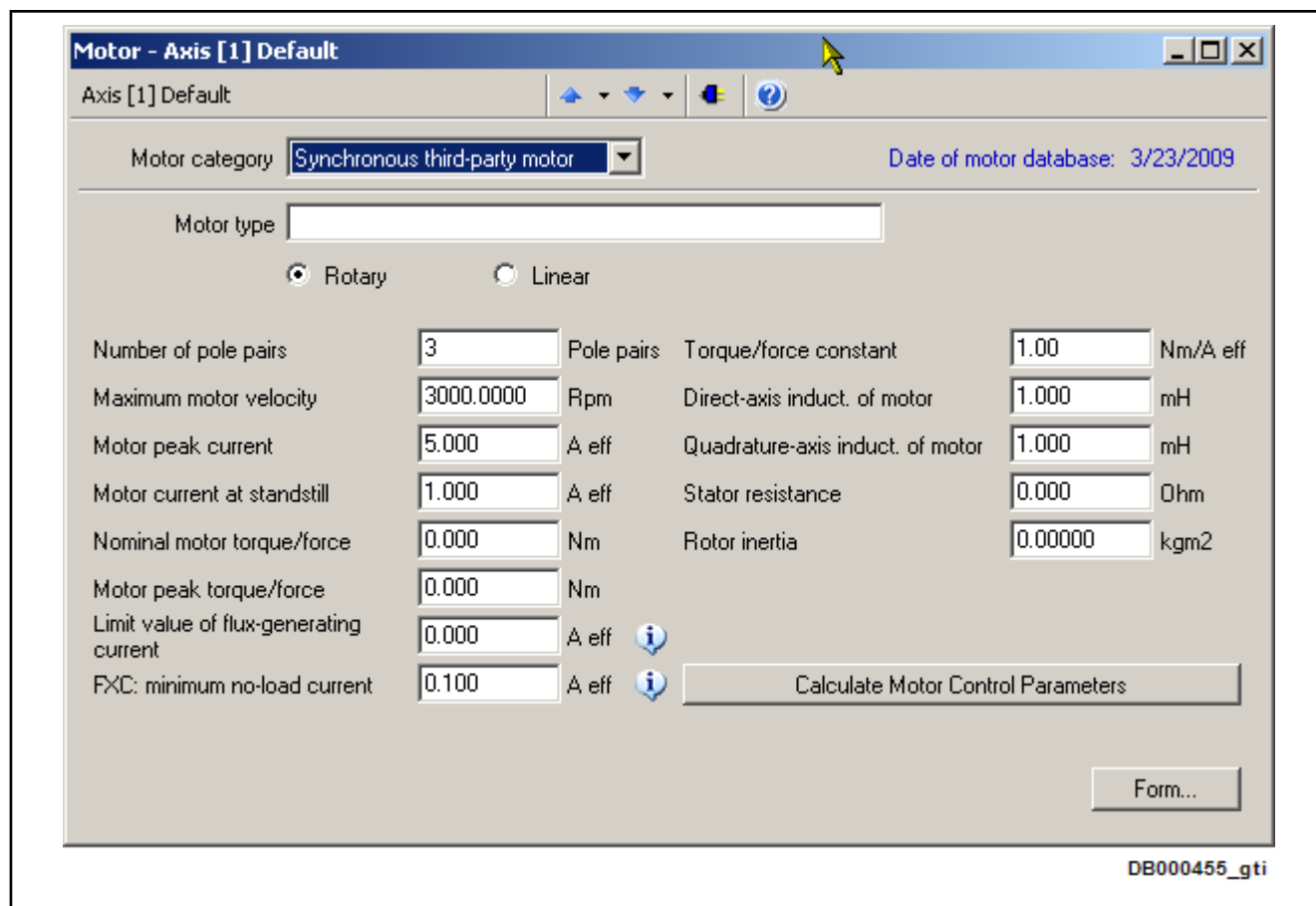
Fig.6-47:   "IndraWorks Ds/D/MLD" -Dialog "Motor", Setting Type of Construction
                 of Motor, Entering Motor Data of SM With Exemplary Values

Determining the Inertia   The frequency loop can only work correctly, if the inertia of the machine axis (motor-shaft-related) has been entered in the following parameters:

- P-0-0510, Rotor inertia
- P-0-4010, Load inertia

If the total inertia of the axis, which relates to the motor shaft, is unknown, it can be determined by means of an acceleration test. For this purpose, it is advisable to accelerate the motor with a flat ramp to approx. 75% of the nominal speed.

Recommendation for setting the appropriate velocity ramp with velocity control:

$$P\text{-}0\text{-}1201 \;=\; P\text{-}0\text{-}1211 \;=\; \frac{\pi}{30\,\text{s/min}} \times \frac{\Delta n}{\Delta t} \approx 0,1 \times \frac{0,75 * n_{nominal}}{2\,\text{s}} \times \frac{min}{s}$$

$$P\text{-}0\text{-}1202 \;\geq\; n_{nominal}$$

P-0-1201	Ramp 1 pitch (in rad/s2)
P-0-1211	Deceleration ramp 1 (in rad/s2)
Δt	Run-up time in the range of the linear speed increase (in s)
Δn	Speed change during the run-up time (in min-1)
P-0-1202	Final speed ramp 1
$n_{Nominal}$	Rated speed acc. to type plate

Fig.6-48:   Velocity Ramp to Determine the Total Inertia of the Axis

Drive Control

Setting the Acceleration/Deceleration Ramp
:   As regards data for calculating the total inertia of the axis, see above "Functional Description".

As a matter of principle, the acceleration and deceleration ramp (P-0-1201 et seq.) should be used for velocity-controlled FXC operation. It is recommended that you only use approx. 90% of the maximum possible acceleration. This results in steadier acceleration and deceleration behavior than is the case at the current limit (determining the acceleration/deceleration values).

Entering the No-Load Current
:   The no-load current which can be set influences the impulse load stability of the motor. The value of "P-0-0602, FXC: Minimum no-load current" can be set to values between 0.1....0.75*nominal current; via the sign, the no-load current behavior can be influenced in a speed-dependent way:
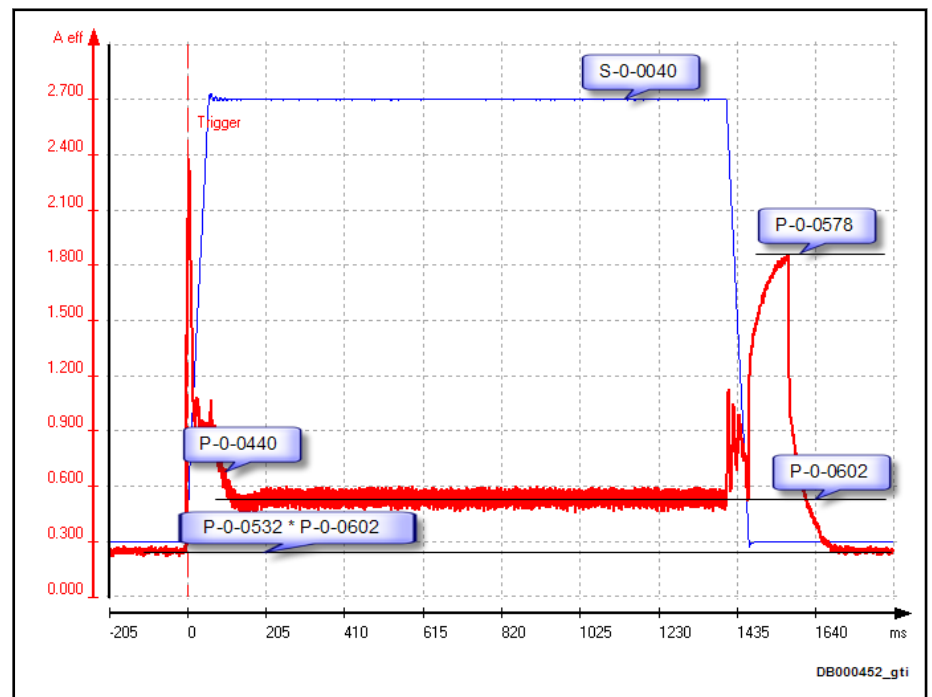
P-0-0602	FXC: Minimum no-load current
P-0-0532	Premagnetization factor
P-0-0578	Current for deceleration, absolute value
P-0-0440	Actual output current value (absolute value)
S-0-0040	Velocity feedback value

Fig.6-49:   *No-Load Current with Positive Sign of P-0-0602, P-0-0532 = 50%*

☞   With positive sign of P-0-0602, the no-load current of the motor is at least as high as the value of P-0-0602. At motor standstill, the no-load current can be reduced via factor P-0-0532.

Drive Control
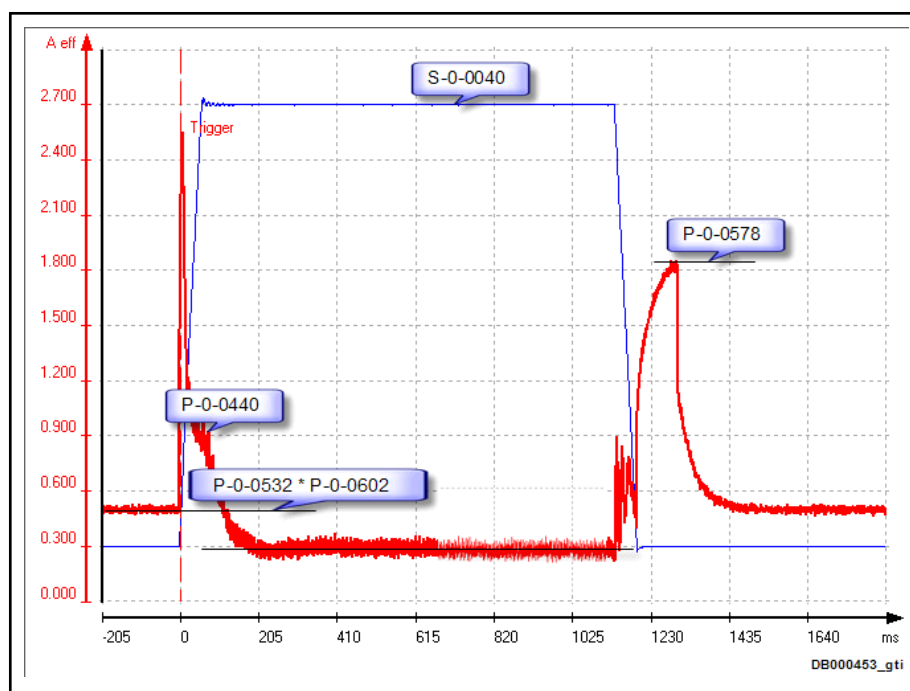
P-0-0602	FXC: Minimum no-load current
P-0-0532	Premagnetization factor
P-0-0578	Current for deceleration, absolute value
P-0-0440	Actual output current value (absolute value)
S-0-0040	Velocity feedback value
Fig.6-50:	*No-Load Current with Negative Sign of P-0-0602, P-0-0532 = 100%*

☞   With negative value of P-0-0602, the no-load current of the motor can be reduced to a minimum of 0.1* nominal current (S-0-0111) when the motor is turning; when the motor is in standstill, control takes place with regard to the absolute value of P-0-0602 * P0-0532. This improves the acceleration behavior and minimizes the no-load loss of the turning motor.

Checking Relevant Parameters   The parameters relevant to FXC operation are shown in a block diagram in "IndraWorks Ds/D/MLD".
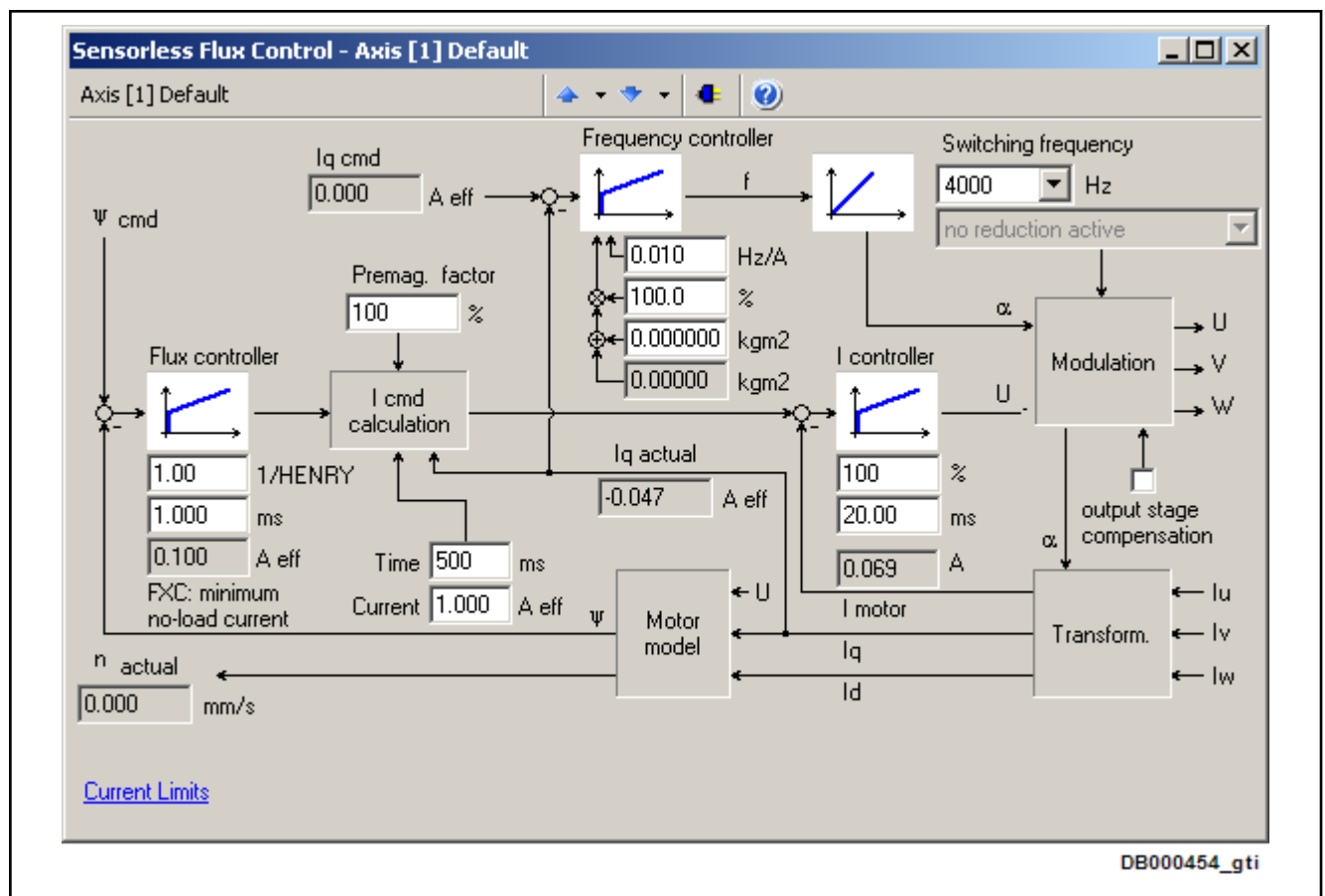
Fig.6-51:   "IndraWorks Ds/D/MLD" Dialog for FXC Operation, with Exemplary
                 Values

Setting the Frequency Loop   With the value of the parameter "P-0-0596, FXC: Frequency loop scaling factor of inertia", you can influence the pitch of the frequency ramp of the frequency loop. The optimum value has been reached at maximum acceleration of the motor. If you continue modifying the value, this will only cause the motor temperature to rise due to increased motor currents!

Leave the value of parameter "P-0-0595, FXC: Frequency loop proportional gain" unchanged!

Checking the Flux Loop   For the flux loop, you should check and, if necessary, adjust the value of the parameter "P-0-0594, FXC: Total flux loop integral action time". For this purpose, carry out an acceleration test with ramp-like velocity command value, for example to 75% of the rated speed in approx. 2 s (see above). After the flux loop has been activated, the total current (P-0-0440) should quickly fall to a stationary value (see above "Functional Description"). In order for the total current to fall more quickly, reduce the value of parameter P-0-0594.

Drive Control
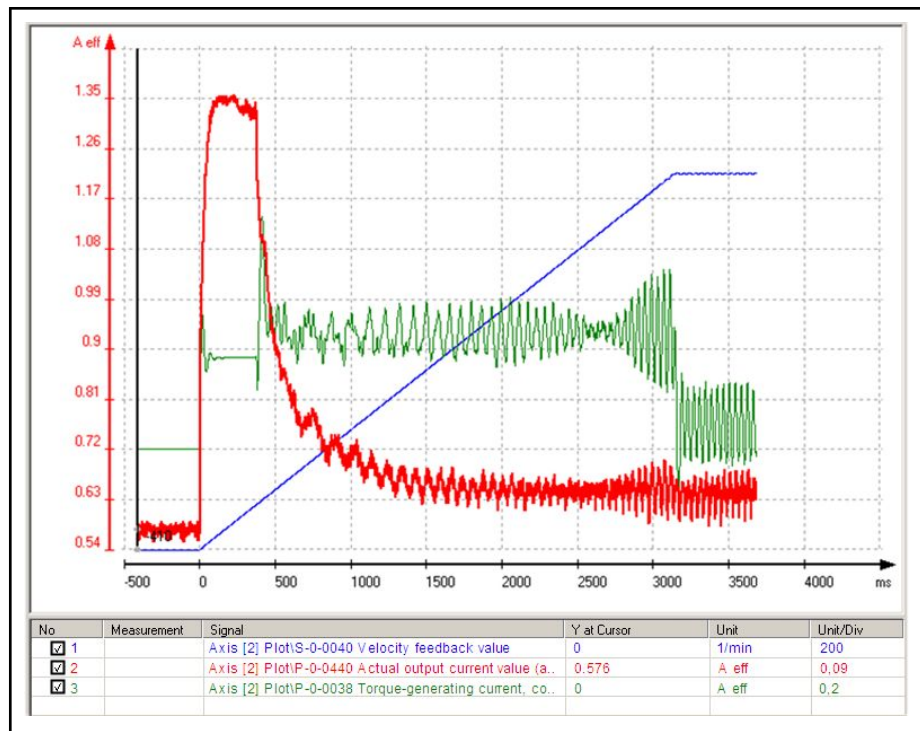
Fig.6-52:   Result of P-0-0594 Check → Value too High
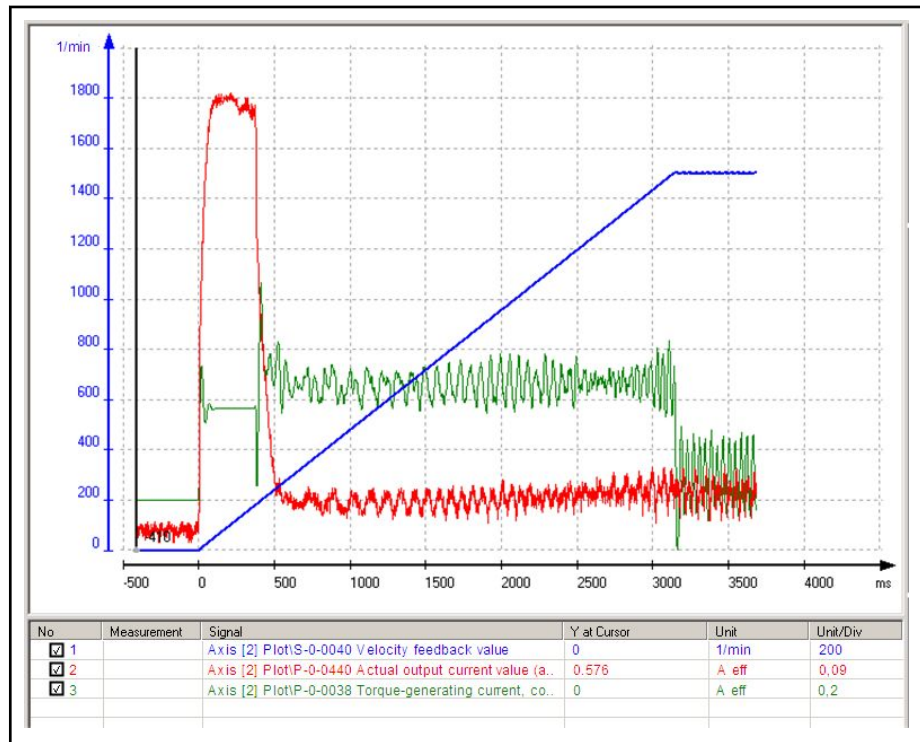
Fig.6-53:   Result of P-0-0594 Check → Value Correct

☞   The appropriate value for parameter "P-0-0594, FXC: Total flux loop integral action time" quickly causes the total current (P-0-0440) to fall to a horizontal current profile.

In most of the cases, the value of parameter "P-0-0593, FXC: Total flux loop proportional gain" can remain unchanged!

Drive Control

Current Loop	Only in particular cases does the current loop require motor-specific settings.

Leave the values of the parameters "P-0-0597, FXC: Current loop proportional gain" and "P-0-0598, FXC: Current loop integral action time" unchanged!

When the current oscillates under load, you should first try to attenuate the oscillation by increasing the value of P-0-0598.

☞   For motors with low ohmic resistance, unstable motor movement can be improved with higher values of P-0-0597 (compared to default value)!

When overcurrent occurs during acceleration from standstill (message "F8060 Overcurrent in power section"), you should reduce the value of the parameter P-0-0597.

Speed Slip Compensation (Only for Asynchronous Motors)   For the parameter "P-0-0600, FXC: Rated slip frequency", calculate and enter the value (see above "Functional Description").

Judge the slip compensation of the motor at constant speed under load:

- Motor speed audibly reduced → Increase value in P-0-0600

- Motor speed audibly increased → Reduce value in P-0-0600

Only in particular cases is it necessary to change the default setting of parameter "P-0-0599, FXC: Slip frequency filter time constant". You should increase the value when the motor, at load impulse, is "out-of-step" and possibly stops because the current limit of the device has been reached. The reaction time of speed slip compensation is slowed down as the values increase; this causes the current to rise less at load impulse (Requirement: The continuous current of the device must be sufficient for stationary load!).

☞   Using speed slip compensation is mainly advantageous in the "velocity control" mode!

Settings for Deceleration   The deceleration behavior of the drive is decisively influenced by the parameters "P-0-0578, Current for deceleration, absolute value" and "P-0-0579, Current for deceleration, time period".

When the velocity value falls below a firmware-internal threshold, the motor is taken to velocity value "zero" with the current amplitude from parameter P-0-0578. By entering a time period for the current for deceleration (P-0-0579) unequal zero, the current for deceleration is maintained for this time, after velocity command value and actual velocity value have reached "zero".

If the drive does not come to standstill, increase:

- Deceleration time (P-0-0579)

  - and/or -

- Current for deceleration (P-0-0578)

☞   When acceleration takes place out of standstill, the value of P-0-0578 takes effect, too, below the mentioned velocity threshold!

Using the Motor Search Mode (Only for Asynchronous Motors)   If a motor could already be in motion without control, you should activate the motor search mode in the control word of the current controller (P-0-0045). This leads the motor from uncontrolled motion to the preset command value.

Drive Control

| | NOTICE | Acceleration of the motor shafts of motors in standstill with activated motor search mode after drive enable! |

⇒ Only activate the motor search mode when arbitrary rotation of the motor shaft is safely possible!

Notes on Error Diagnosis

Sensorless, flux-controlled motor operation does not require any specific diagnosis!

Problems in the operating behavior can have the following causes:

- **Difference between actual value of no-load current and entered magnetizing current for asynchronous motors**

  Read the value of parameter "P-0-0440, Actual output current value (absolute value)" in no-load motor operation (without connected load) at 50% of the rated speed. This value must correspond to the value of the magnetizing current (P-0-4004).

  → The value of P-0-0440 can be proportionally adjusted to the value of P-0-4004 by the setting in parameter "P-0-4041, Motor magnetizing inductance".

  Note: Make sure that parameter P-0-4004 contains the **correct magnetization current** of the asynchronous motor!

- **Current limitation at motor standstill**

  If the warning "E8260 Torque/force command value limit active" appears in standstill with the drive having been enabled, the controller cannot continuously supply the required current at standstill of the motor.

  → Reduce current at standstill by smaller value in parameter "P-0-0532, Premagnetization factor".

  → Use controller with higher continuous current (type current).

6.3.6 Automatic Setting of Motor Control

Brief Description

| | 💡 | **Base package** of all firmware variants in **open-loop and closed-loop** characteristic |

For operating motors, it is necessary to collect the values for motor parameters (resistance values, inductances, ...), in order to determine the motor control parameters (flux 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**:

Drive Control

–   Loading the parameters 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

    Note: Appropriate start values already must 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
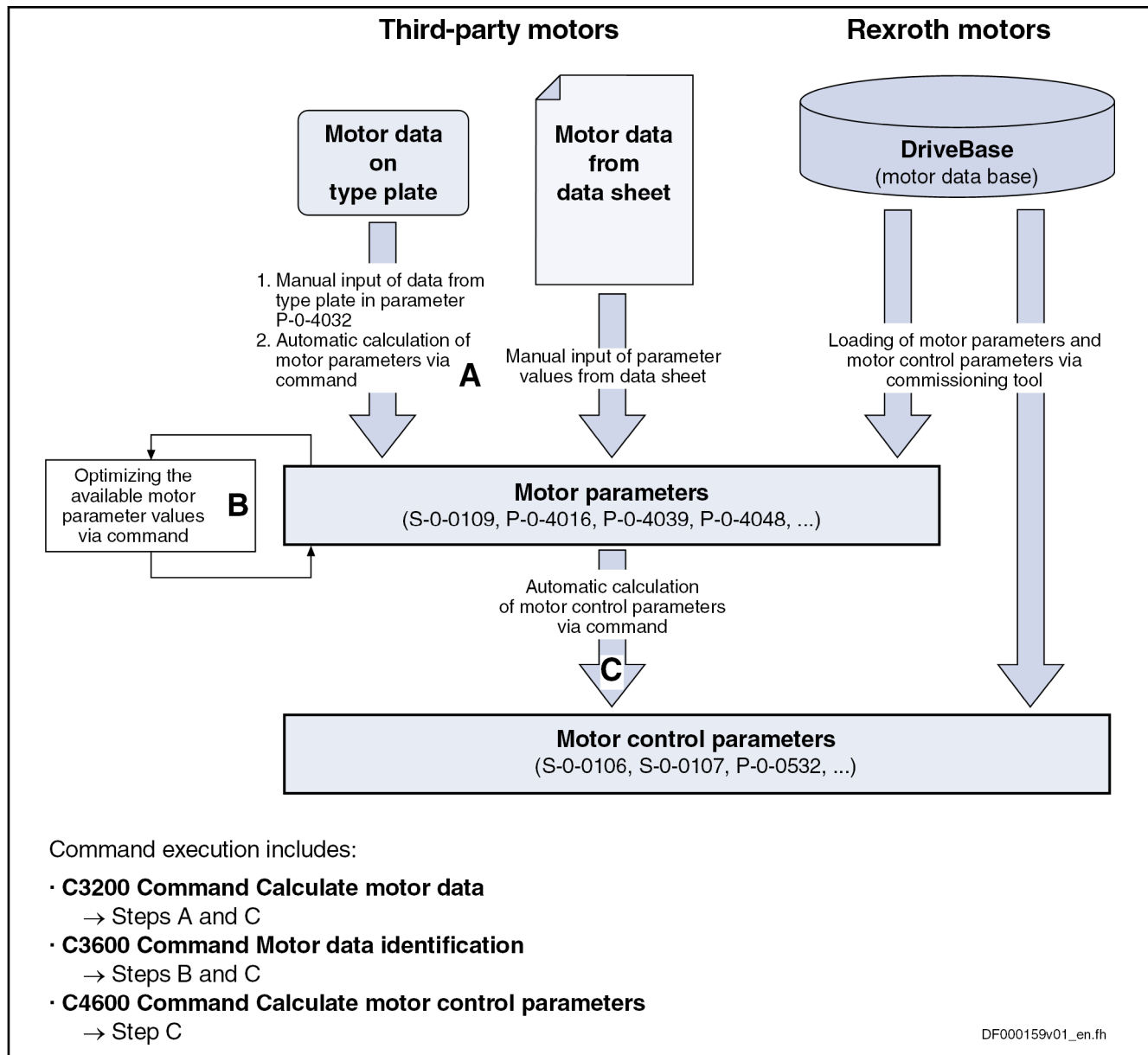
P-0-4032   Motor type plate data
Fig.6-54:   *Determining Motor and Motor Control Parameters for Motors without*
                  Motor Encoder Data Memory

☞   In addition to collecting or determining the motor and motor con-
           trol 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 the section "Third-Party Motors
           at IndraDrive Controllers"

Pertinent Parameters   • P-0-0565, C3600 Command Motor data identification
                           • P-0-0566, C4600 Command Calculate motor control parameters
                           • P-0-4032, Motor type plate data

Drive Control

Pertinent Diagnostic Messages
- P-0-4033, C3200 Command Calculate motor data
- C3200 Command Calculate motor data
- C3201 Incorrect input for current
- C3202 Incorrect input for voltage
- C3203 Incorrect input for frequency
- C3204 Incorrect input for speed
- C3205 Incorrect input for power factor
- C3206 Incorrect input for power
- C3207 Type plate list incomplete
- C3208 Error when writing parameters (->S-0-0423)
- C3600 Command Motor data identification
- C3601 Motor not or not correctly connected
- C3602 Determined values invalid
- C3603 Device current limit too low
- C3604 Error when writing parameters (->S-0-0423)
- C3605 Motor turning
- C3606 Type of construction of motor not allowed
- C4600 Command Calculate motor control parameters
- C4601 Error when writing parameters (->S-0-0423)

Overview of Motor and Motor Control Parameters

Motor Parameters   The table below contains an overview of the motor parameters for synchronous and asynchronous motors:

Motor parameters	
Synchronous motor	**Asynchronous motor**
P-0-4014, Type of construction of motor	P-0-4014, Type of construction of motor
S-0-0109, Motor peak current	S-0-0109, Motor peak current
S-0-0111, Motor current at standstill	S-0-0111, Motor current at standstill
S-0-0113, Maximum motor speed	S-0-0113, Maximum motor speed
P-0-0018, Number of pole pairs/pole pair distance	P-0-0018, Number of pole pairs/pole pair distance
P-0-0051, Torque/force constant	P-0-0051, Torque/force constant
P-0-0510, Rotor inertia	P-0-0510, Rotor inertia
P-0-4048, Stator resistance	P-0-4048, Stator resistance
P-0-4013, Current limit value of demagnetization	P-0-0530, Slip increase
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

Drive Control

Motor parameters	
Synchronous motor	**Asynchronous motor**
	P-0-4042, Characteristic of motor magnetizing inductance
	P-0-4043, Rotor time constant

Fig.6-55:   *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.6-56:   *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

Fig.6-57:   *Overview of Motor Control Parameters for Synchronous and Asynchronous Motors and Field-Oriented Current Control (FOC)*

Drive Control

Motor control parameters for sensorless motor operation, flux-controlled (FXC)	
Synchronous motor	Asynchronous motor
P-0-0532, Premagnetization factor	P-0-0532, Premagnetization factor
P-0-0578, Current for deceleration, absolute value	P-0-0578, Current for deceleration, absolute value
P-0-0579, Current for deceleration, time period	P-0-0579, Current for deceleration, time period
P-0-0593, FXC: Total flux loop proportional gain	P-0-0593, FXC: Total flux loop proportional gain
P-0-0594, FXC: Total flux loop integral action time	P-0-0594, FXC: Total flux loop integral action time
P-0-0595, FXC: Frequency loop proportional gain	P-0-0595, FXC: Frequency loop proportional gain
P-0-0596, FXC: Frequency loop scaling factor of inertia	P-0-0596, FXC: Frequency loop scaling factor of inertia
P-0-0597, FXC: Current loop proportional gain	P-0-0597, FXC: Current loop proportional gain
P-0-0598, FXC: Current loop integral action time	P-0-0598, FXC: Current loop integral action time
P-0-0599, FXC: Slip frequency filter time constant	P-0-0599, FXC: Slip frequency filter time constant
P-0-0600, FXC: Rated slip frequency	P-0-0600, FXC: Rated slip frequency
P-0-0602, FXC: Minimum no-load current	

Fig.6-58:   *Overview of Motor Control Parameters for Synchronous and Asynchronous Motors and Sensorless, Flux-Controlled Motor Operation (FXC)*

Determining the Parameter Values by Means of Type Plate Data

Command "Calculate Motor Data" (C3200)

For asynchronous motors it is possible via "C3200 Command Calculate motor data" to calculate the values for motor parameters from the type plate data and then the values of the motor control parameters. The activation of C3200 first requires manual input of the motor data from the type plate of the asynchronous motor in "P-0-4032, Motor type plate data".

ℹ️ See description of "P-0-4032, Motor type plate data"

☞ The command C3200 can only be used for asynchronous motors and can only be activated in communication phases "P2" or "P3"!

The figure below illustrates the scope of functions of the command C3200:

Drive Control

Third-party motors (asynchronous)

**Motor data
on
type plate**

1. Manual input of data from
   type plate in parameter
   P-0-4032
2. Automatic calculation of
   motor parameters via
   command **C3200**

Motor parameters
(S-0-0109, P-0-4016, P-0-4039, P-0-4048, ...)

Automatic calculation of motor control
parameters via already activated
command **C3200**

Motor control parameters
(S-0-0106, S-0-0107, P-0-0532, ...)

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Fig.6-59:   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 val-
ues are calculated from the data of the asynchronous motor entered in list
parameter P-0-4032:

● Motor parameters

  – Motor parameters, general

  – Specific motor parameters for asynchronous motors

● Motor control parameters

  – Motor control parameters for voltage-controlled operation (U/f) of
    sensorless asynchronous motors

  – Motor control parameters for field-oriented current control (FOC) of
    asynchronous motors

  – Motor control parameters for flux-controlled operation (FXC) of
    sensorless asynchronous motors

Drive Control

Notes on Operating Principle

As regards the operating principle of the command C3200, observe the following points:

- The input in P-0-4032 is irrelevant unless the command C3200 has been started.

- When the command was processed without error, the calculated values of motor and motor control parameters are operational.

Identifying and Optimizing the Motor Parameter Values

"Command Motor Data Identification" (C3600)

It is possible via "C3600 Command Motor data identification" to automatically identify and optimize the optimum motor and motor control parameters on the basis of appropriate start values.

☞ The command C3600 can only be activated in the operating mode (communication phase "P4")!

The figure below illustrates the scope of functions of the command C3600:
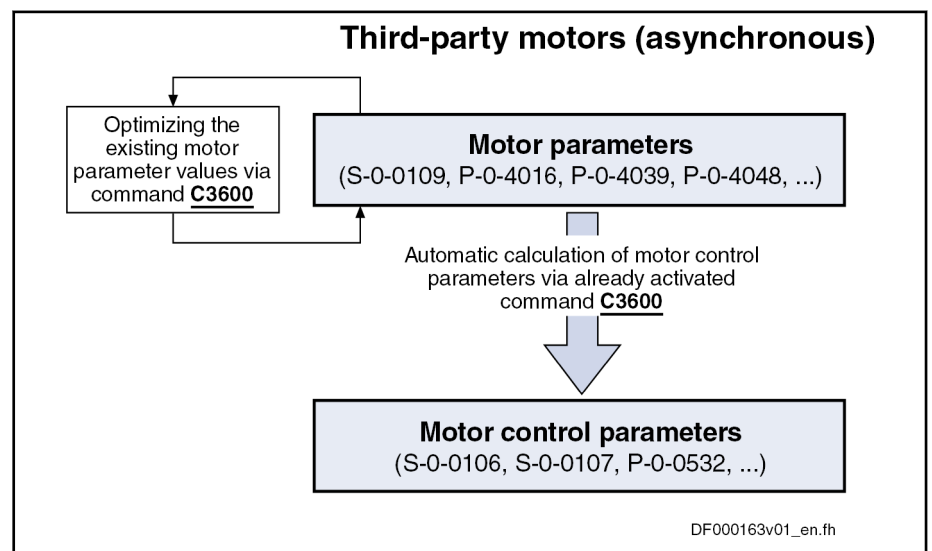
Fig.6-60:   Functions of "C3600 Command Motor Data Identification"
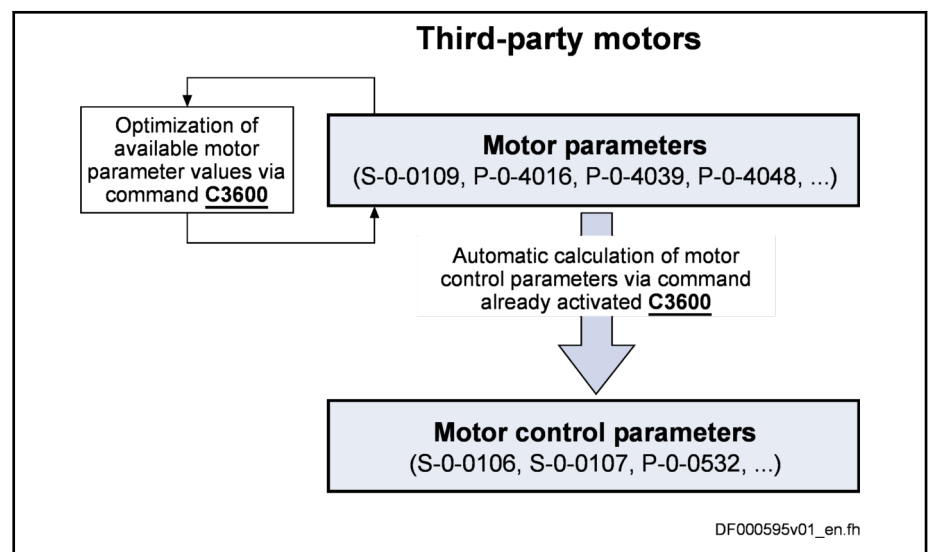
Fig.6-61:   Functions of "C3600 Command Motor Data Identification"

Drive Control

Requirements

To execute the command C3600, the following requirements must have been fulfilled:

- Manual input of the type plate data of asynchronous motors in "P-0-4032, Motor type plate data" and subsequent execution of "C3200 Command Calculate motor data"

  - or -

- Manual input of the motor data of synchronous or asynchronous motors acc. to manufacturer's specification (completed form) in the motor parameters

Procedure

In "ready for power output" state ("Ab"), current and voltage test signals are transmitted to the motor with the execution of command C3600. In this way, the motor parameters 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

- Motor control parameters for flux-controlled operation (FXC) of sensorless synchronous and asynchronous motors

Notes on Operating Principle

The command C3600 provides several options for identification and validation checks:

- Motor data identification with the motor being in standstill or moving

- Determination of the magnetization characteristic of asynchronous motors

- Validation check of the motor and motor encoder data

- Rotational direction check of motor and motor encoder

Any holding brake controlled by the controller is controlled, if necessary.

☞   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)

With "C4600 Command Calculate motor control parameters" it is possible 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:

Drive Control

<div align="center">

Third-party motors

Motor parameters
(S-0-0109, P-0-4016, P-0-4039, P-0-4048, ...)

Automatic calculation
of motor control parameters
via command **C4600**

Motor control parameters
(S-0-0106, S-0-0107, P-0-0532, ...)

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</div>
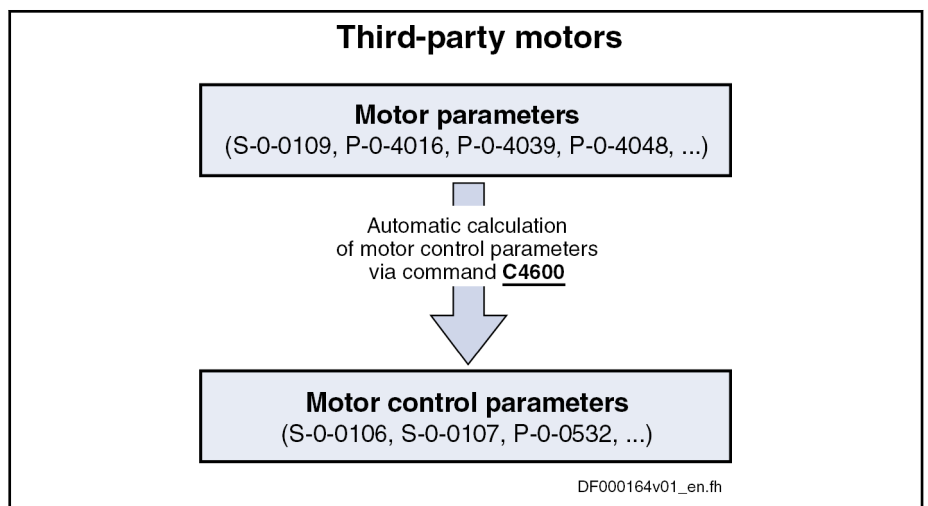
Fig.6-62:   Function of "C4600 Command Calculate Motor Control Parameters"

Requirements   To execute the command C4600, the motor data of synchronous or asynchronous motors must have been entered in the corresponding parameters:

- Motor data of the third-party motor must be available (completed form for manufacturer-side motor data)

- For **asynchronous third-party motors**, the command C4600 is only useful, if from specific, manually input motor parameters, conversion of the available motor data in the motor data parameters (forms for parameter values), see chapter "Determining the Parameter Values of Third-Party Motors"

☞   The command C4600 has been integrated in the command "C3600, Command Motor data identification". When C3600 is executed, it is not necessary to start C4600!

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 manufacturer	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
		MSD	No	M/D	M/D
	Kit	1MB, MBS, MBT, MBW, MLF, MBSxx2 (high speed)	No	M/D	M/D

Drive Control

Motor connected to controller				Parameter values made available	
Motor manufac-turer	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.6-63:   *Making Available Values for Motor Parameters and Motor Control Pa-
rameters*

Rexroth Motors   For Rexroth motors, both the motor and motor control parameters are opti-
mized by the manufacturer via the encoder data memory of the motor encod-
er 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 opti-
> mized by the manufacturer are overwritten with the values calcu-
> lated by means of command. This can modify the drive character-
> istics 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 database 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 re-
spective 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!

> ℹ️   See descriptions of the diagnostic messages in the separate documen-
> tation "Troubleshooting Guide (description of diagnostic messages)"

6.4   Open-Loop Axis Control (Open-Loop Operation)

6.4.1   Brief Description

In operation without encoder (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 selec-
> ted via bit 14 of parameter "P-0-0045, Control word of current
> controller".

See also section "Motor Control"
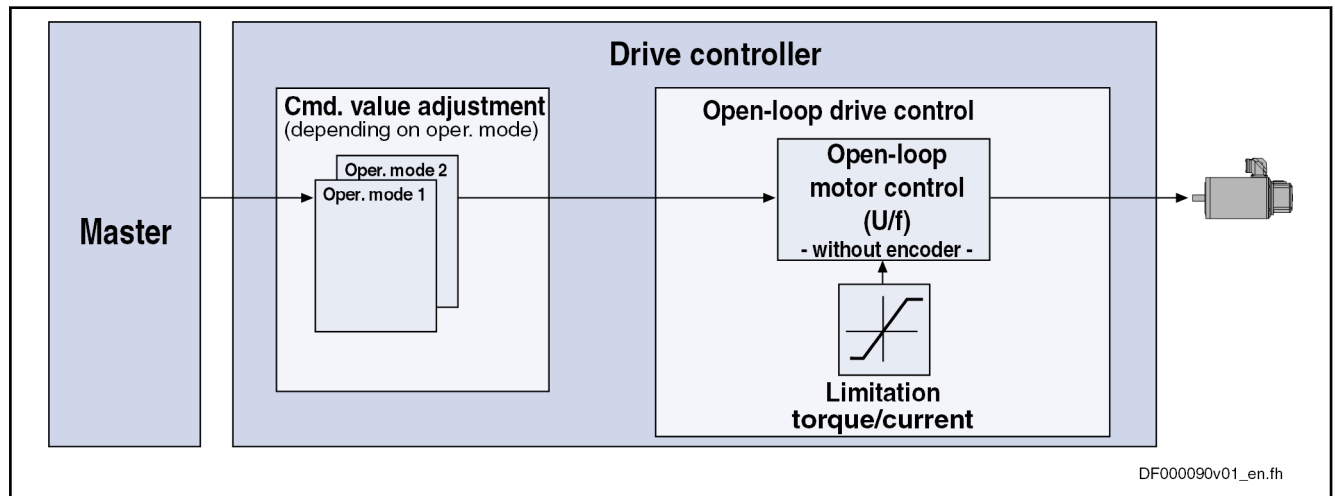
Fig.6-64:   Principle of Drive Control in Open-Loop Operation

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, axis controller messages
- P-0-0556, Config word of axis controller

Drive Control

Pertinent Diagnostic Messages   •   F8079 Velocity limit value exceeded (S-0-0091)

6.4.2   Functional Description
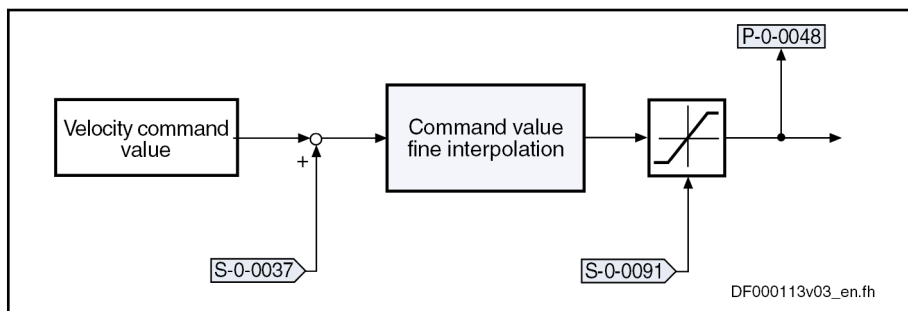
Fine Interpolator

S-0-0037	Additive velocity command value
S-0-0091	Bipolar velocity limit value
P-0-0048	Effective velocity command value

Fig.6-65:   Fine Interpolation of the Velocity Command Value

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 Open-Loop Operation".

6.4.3   Diagnostic and Status Messages

Monitoring the Velocity Limit Value   The actual velocity value, internally generated via the stall protection loop, is monitored for the limit value of 1.125 * S-0-0091 (bipolar velocity limit value) as soon as it is outside the standstill window S-0-0124. When this value is exceeded, the following error message is generated:

*   F8079 Velocity limit value exceeded

6.5   Closed-Loop Axis Control (Closed-Loop Operation)

6.5.1   General Information on Closed-Loop Axis Control

Control Loop Structure

The drive controller has a so-called cascade structure, i.e. the individual 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 operation mode, only the torque control loop, the torque control loop and the velocity control loop or, in addition to these two control loops, the position control loop can be closed in the drive.

The structure and the interaction of the control loops are illustrated in the two figures in the section "Overview of Drive Control" (see "Control Loop Structure with Setting Parameters" or "Control Loop Structure with Display Parameters").

Features of the Control Loops

For the simplification of the parameterization of the control loops and for an increase in performance, a number of standardizations and structural changes have been carried out.

Drive Control

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.6-66:   Cycle and Switching Times to be Achieved with IndraDrive

☞   All data on performance are summarized in the section "Performance Data".

Velocity Loop

The velocity loop is a PI loop which can be set via the following parameters: "S-0-0100, Velocity loop proportional gain", S-0-0101, Velocity loop integral action time

- Standardization of the output value at the velocity loop to Newton (N) or Newton meter (Nm). Therefore, depending on the motor type, the following unit results for S-0-0100 with IndraDrive:
- Rotary motor → Nm * s/rad
- Linear motor → N * min/mm
- Filter options for filtering encoder noise and resonance frequencies are available:
  - One filter of 1st degree (low pass of 1st order), can be parameterized via P-0-0004
  - Four filters of 2nd degree (low pass of 2nd order, band-stop filter, 2nd order filter), can be activated via P-0-1120 with the setting parameters P-0-1121, P-0-1122, P-0-1123, P-0-1140, P-0-1141, P-0-1143
- Acceleration feedforward can be set in parameter P-0-1126
- Possibility of mixing the actual velocity value used for control from the actual value of the motor-side and load-side encoder by means of a "mix factor" P-0-1119
- Limitation of command acceleration (change in velocity command value) in velocity control by setting in parameter "S-0-0138, Bipolar acceleration limit value"
- Limitation of command velocity via the parameters S-0-0113, S-0-0038, S-0-0039, S-0-0091 and P-0-0113

See also chapter "Velocity Loop (Including the Respective Filters)"

Position Loop

- P-loop, can be set via "S-0-0104, Position loop Kv-factor"

Drive Control

- Velocity feedforward, i.e. degree of feedforward, to be set via "P-0-0040, Velocity feedforward evaluation" (0% ... 100%)
- Acceleration feedforward can be set in parameter S-0-0348
- The actual value of the motor encoder or of the optional encoder can be used as the actual position value for control. It is possible, however, to use both actual position values for position control ("hybrid actual position value").

See also chapter Position Loop (with Respective Feedforward Functions and Actual Value Adjustment)

Possibilities of Accessing Outer Control Loops

In closed-loop operation it is possible to add command values in addition to the command values available in the control loop. Depending on the active operation mode, the following parameters are available to do this:

Operation mode	S-0-0081	S-0-0037	P-0-0059	S-0-0048
U/f control (command value processing in velocity control)	--	--	--	--
Torque/Force Control	■	--	--	--
Velocity control / velocity synchronization	■	■	--	--
Position Control	■	■	■	--
Drive-controlled positioning	■	■	■	--
Positioning Block Mode	■	■	■	--
Phase synchronization	■	■	--	■
Electronic cam	■	■	--	■

S-0-0081   Additive torque/force command value
S-0-0037   Additive velocity command value
P-0-0059   Additive position command value, controller
S-0-0048   Additive position command value
Fig.6-67:   Overview of the Additive Command Values Depending on the Operation Mode

In closed-loop operation, it is possible to access the outer control loops from a higher-level operation mode. The access options to the individual control loops are illustrated in the following example:

DOK-INDRV*-MP*-08VRS-AP01-EN-P**
Bosch Rexroth AG 439/1183
Rexroth IndraDrive Firmware for Drive Controllers MPH-, MPB-, MPD-, MPC-08

Drive Control
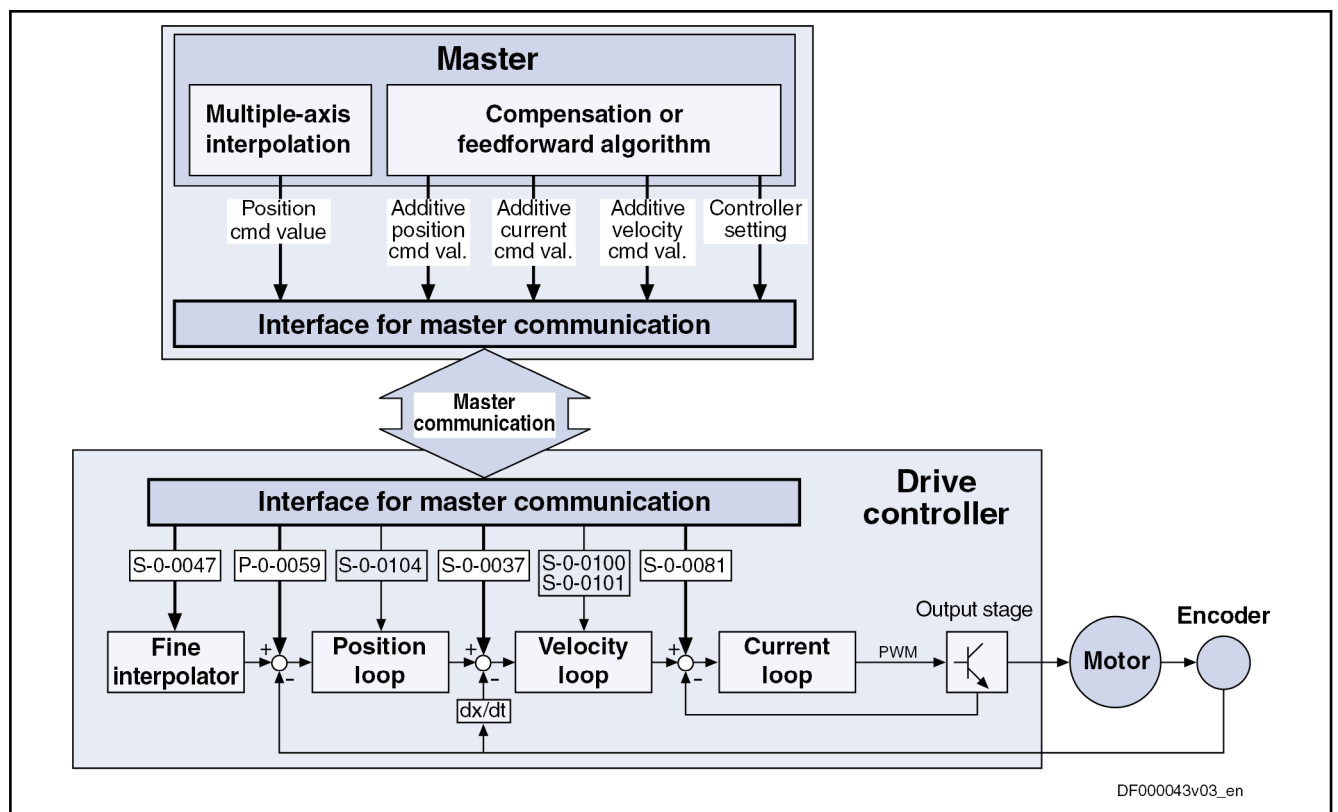
S-0-0037   Additive velocity command value
S-0-0047   Position command value
S-0-0081   Additive torque/force command value
S-0-0100   Velocity loop proportional gain
S-0-0101   Velocity loop integral action time
S-0-0104   Position loop Kv-factor
P-0-0059   Additive position command value, controller
Fig.6-68:   *Structural Overview Including Access Options*

Command Value Processing Depending on Operation Mode

Position Control   For the following operation modes, the position control loop is closed internally (in the drive) in addition to the velocity and the current control loops:

- Position control with cyclic command value input
- Drive-internal interpolation
- Drive-controlled positioning

See also Description of the Respective Operation Mode

Velocity Control   In the "velocity control" mode, the velocity control loop, apart form the current control loop, is closed in the drive, too.

See also "Velocity Control"

Torque/Force Control   The "torque/force control" mode actually is not torque or force control but current control. Therefore, only the current control loop is closed in the drive.

See also "Torque/Force Control"

Notes on Commissioning for Control Loop Setting

The control loop settings in a digital drive controller are very important for the features of the servo axis.

To optimize the control loop setting, application-specific controller parameters are available for all digital Rexroth drives.

Drive Control

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** (MHD, MKD and MKE lines), 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 taken from a central motor database 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 und P-0-1120, P-0-1121, P-0-1122, P-0-1123, P-0-1140, P-0-1141, P-0-1142, P-0-1143) on the one hand depend on the motor parameters (inertia and torque/force constant), on the other hand they strongly depend on the mechanical properties (load inertia/mass, friction, 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)

"Load Defaults Procedure" Command

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 "S-0-0262, C07_x Load defaults procedure command":

- Automatically when running up the drive by recognizing that the motor type (cf. S-0-0141) has changed. The display then reads "RL" and the "load defaults procedure" command is internally started by pressing the "Esc" key on the control panel, unless this was deactivated in "P-0-0556, Config word of axis controller".

- Starting the command by writing "11b" to S-0-0262.

See also "Loading, Storing and Saving Parameters"

☞   In order to start the "load defaults procedure" command, the value "0" must have been set in "P-0-4090, Configuration for loading default values" (default setting).

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

Drive Control

- 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 parameter is set to its firmware-side default values, although there haven't any default values been stored for it in the motor data memory:

- S-0-0348, Acceleration feedforward gain

☞　　In the majority of cases, the controller settings stored in the motor encoder data memory provide a useful and reliable control loop setting. In exceptional cases, however, it may be necessary to make the settings with regard to the specific application.

6.5.2　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. "P-0-0163, Damping factor for autom. controller setting" and "P-0-0164, Application for autom. controller setting" can be used to influence the result of the control loop setting (obtained control loop dynamics).

☞　　Depending on the settings in "P-0-0165, Drive optimization, control word", it is necessary to move the drive to carry out the automatic control loop setting. The drive is moved when the load inertia is determined and when 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 position limits for the travel range
  - or -
  - Entering a relative travel distance based on the current actual position
- Use of drive-internal interpolation and its parameters
- Via "P-0-0165, Drive optimization, control word" 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:
  - Calculation of velocity and/or position loop parameters (drive does not move)
  - Optimization of velocity and/or position loop parameters (drive moves)
  - Determination of acceleration feedforward (drive does not move)
  - Determination of load inertia (drive moves)
  - Determination of maximum acceleration (drive does not move)
  - Oscillating motion / unipolar motion

Drive Control

–   Absolute travel limits / relative movement around start position

Pertinent Parameters
- P-0-0162, C1800 Command Drive optimization / command value box
- P-0-0163, Damping factor for autom. controller setting
- P-0-0164, Application for autom. controller setting
- P-0-0165, Drive optimization, control word
- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive
- P-0-0168, Maximum acceleration to be parameterized
- P-0-0169, Drive optimization, travel distance
- P-0-0170, Drive optimization, acceleration
- P-0-0171, Drive optimization, velocity

Pertinent Diagnostic Messages
- C1800 Command Drive optimization / command value box
- C1801 Start requires drive enable
- C1802 Motor feedback data not valid
- C1803 Inertia detection failed
- C1804 Automatic controller setting failed
- C1805 Travel range invalid
- C1806 Travel range exceeded
- C1807 Determining travel range only via travel distance
- E2049 Positioning velocity >= limit value (S-0-0091)
- E2055 Feedrate override S-0-0108 = 0
- F2039 Maximum acceleration exceeded

Prerequisites for Starting the Automatic Control Loop Setting

NOTICE	Property damage and/or personal injury caused by drive motion!

During the execution of "C1800 Command Drive optimization / command value box", the drive might possibly move automatically, i. e. without external command value input.

⇒ Check and make sure that the E-Stop circuit and the travel range limit switches are working!

Loading the Default Controller Parameters   Before starting the command "automatic control loop setting", the default controller parameters stored in the motor encoder data memory should be loaded or the data of the motor data sheet should be entered in the respective parameters.

Drive Enable and Start of Automatic Control Loop Setting   The automatic control loop setting (with or without motion) is only carried out when the following requirements have been fulfilled:

- **Drive enable** is present
- The function "automatic control loop setting" must have been configured in parameter "P-0-0165, Drive optimization, control word". In this parameter, the presettings for a total of three functions are made which operate with internal command value input:
  1. Recording table for cogging torque compensation (highest priority)

Drive Control

2.   Drive-internal command value box (medium priority)

3.   Automatic control loop setting (lowest priority)

The functions mentioned above cannot be used simultaneously, although they can be selected simultaneously by means of the respective bits. Prioritization applies as stated in the list above.

☞   The bits 10, 8 and 9 in the parameter "P-0-0165, Drive optimization, control word" must be "0", because the "automatic control loop setting" has the lowest priority.

- Command "C1800 Command Drive optimization / command value box" started

Defining the Travel Range   As the axis moves when the load inertia is determined and the position loop and/or speed loop parameters are optimized, it is necessary to define the allowed travel range.

When defining the travel range, observe the following aspects:

- The required minimum travel range is:

  – For rotary motors > 2 motor revolutions

  – For linear motors > 100 mm

- As a matter of principle, there are two options for defining the travel range; they are set in "P-0-0165, Drive optimization, control word" (bit 15):

  – Entering the limits in "P-0-0166, Drive optimization, end position negative" and "P-0-0167, Drive optimization, end position positive"

    - or -

  – Entering a relative travel range in "P-0-0169, Drive optimization, travel distance" (required for modulo axes)

- For a successful automatic control loop setting, the minimum travel range must be run through approximately ten times. The required travel range of the axis depends on the selected motion type set in "P-0-0165, Drive optimization, control word" (bit 14):

  – Oscillating motion (reversing duty)

    → Through the reversing procedure, the travel range can be restricted to the minimum travel range.

  – Motion in one direction only (stepper mode)

    → Through the stepwise travelling of the travel range in the same direction, ten times the minimum travel range must be calculated for the travel range of the axis.

    → The direction of motion is set in "P-0-0165, Drive optimization, control word" (bit 13)

-

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 setting

  → Selection of the desired control loop dynamics

- P-0-0164, Application for autom. controller setting

Drive Control

→ Consideration of the mechanical properties for the controller optimization

- P-0-0165, Drive optimization, control word

→ Selection of the functionality (modes) of the automatic control loop setting and determination of requirements

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. Move to start position in accordance with settings in P-0-0165, Drive optimization, control word
   - The drive only moves to the start position, if motion is required to carry out the automatic control loop setting (determination of load inertia and/or control loop optimization).
   - The start position depends on the settings in P-0-0165, bit 15,14
     - P-0-0165 bit 15,14 = x1 or 1x: Start position equals current actual position
     - P-0-0165 bit 15,14 = 00 the middle of the negative (P-0-0166) and positive (P-0-0167) end positions
3. Determine total inertia
   - P-0-0165 Bit 4 = 1: By evaluating acceleration and deceleration processes; i.e. axis moves
   - P-0-0165 Bit 4 = 0: By applying parameter values P-0-0510 and P-0-4010

     Total inertia is the sum of P-0-0510 and P-0-4010; i.e. axis does not move
4. Calculate and activate control loop parameters in drive without axis motion
   - P-0-0165, bit 1: Calculate speed loop parameters (0: No , 1: Yes)
   - P-0-0165, bit 2: Calculate position loop parameters (0: No , 1: Yes)

   taking the following parameters into account:
   - P-0-0163, Damping factor for autom. controller setting
   - P-0-0164, Application for autom. controller setting
   - P-0-0510, Rotor inertia
   - P-0-4010, Load inertia
5. Optimize control loop parameters with axis motion

   The control loop parameters are only optimized with P-0-0165 bit 0 = 1 and at least one of the bits 2/1 set in P-0-0165
   - P-0-0165 bit 1 = 1: Check velocity control loop and optimize control loop parameters, until desired behavior occurs (depends on dynamics programmed)
   - P-0-0165 bit 2 = 1: Check position control loop and optimize control loop parameters, until aperiodic behavior occurs in position control loop
6. Move back to initial position (actual position at start of command)
7. Wait for possible restart or completion of command

Drive Control

During this step, the drive is idle (velocity = 0) and the display reads "C1800".

When command completed, save

- determined control loop settings
- determined load inertia
- max. acceleration that can be parameterized

Drive Control

Step 1:
```
Command start
```

Command start error free? → No → C1801 Start only possible with drive enable
C1802 No useful motor feedback data
C1805 Travel range invalid
C1807 Determination of travel range only via travel distance

Yes

Step 2:
```
Move to start position
```

Command start error free? → No → C1804 Automatic control setting failed
C1806 Travel range exceeded

Yes

Step 3:
```
Determine the inertia
(or use value from P-0-4010)
```

Determining of inertia successful? → No → C1803 Error in determination of the mass inertia
→ Save default control settings

Yes

Step 4:
```
Calculation of control parameters
```

Calculation successful? → No → C1803 Error in determination of the mass inertia
→ Save default control settings

Yes

Step 5:
```
Optimization of velocity control loop
```

Optimization successful? → No → C1804 Automatic control setting failed
C1806 Travel range exceeded
→ Save default control settings

Yes

Step 6:
```
Move to start position
```

```
Wait for restart of command end
```

Step 7:

Command end?

Yes

```
Save:
- Inertia (in P-0-4010)
- Max. parameterizable acceleration
- Determined control settings
```

DC000010v03_en.fh

P-0-4010   Load inertia
Fig.6-69:   *Steps of Automatic Control Loop Setting*

Drive Control

Result of Automatic Control Loop Setting

☞   The current control loop is not affected during the automatic control loop setting, as its setting is load-independent and optimum current controller parameters were already stored in the motor encoder data memory at the factory.

See also "Default Settings in the Motor Encoder Data Memory ("Load Motor Default Values")"

Selection Parameter for Automatic Control Loop Setting   Via "P-0-0165, Drive optimization, control word" 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.

ℹ️   See Parameter Description "P-0-0165, Drive optimization, control word"

Possible results of the automatic control loop setting (with respective bit set in P-0-0165):

- **Bit 1** → Calculation plus optimization (bit 0 = 1) of the velocity control loop parameters (cf. S-0-0100, S-0-0101, P-0-0004)
- **Bit 2** → Calculation plus optimization (bit 0 = 1) of the position control loop parameters (cf. S-0-0104)
- **Bit 3** → Determination of acceleration feedforward (cf. S-0-0348)
- **Bit 4** → Determination of load inertia (reduced to motor shaft) and input in P-0-4010
- **Bit 6** → Determination of maximum drive acceleration and input in P-0-0168

Notes on Commissioning

NOTICE	The execution of the automatic control loop setting is connected with a drive motion!

⇒ Select the travel range defined with P-0-0166 and P-0-0167 or P-0-0169 such that danger to man and machine resulting from drive motion is excluded.

☞   The parameter settings required to execute the command "automatic control loop setting" must be made prior to command start.

Drive Enable Missing   If at command start drive enable is not available, the error message "C1801 Start requires drive enable" will be displayed.

Starting the Automatic Control Loop Setting   The automatic control loop setting is started by writing the binary numeric value "3" (11b) to "P-0-0162, C1800 Command Drive optimization / command value box" (command start).

Triggering a Motion   An axis motion and thus the execution of the automatic control loop setting is only possible if the "Drive HALT" signal has not been set. If the "Drive HALT" signal has been set, the drive will acknowledge the start of "C1800 command automatic control loop setting", but the axis will not move.

Drive Control

Triggering the Motion by Starting the Command C1800
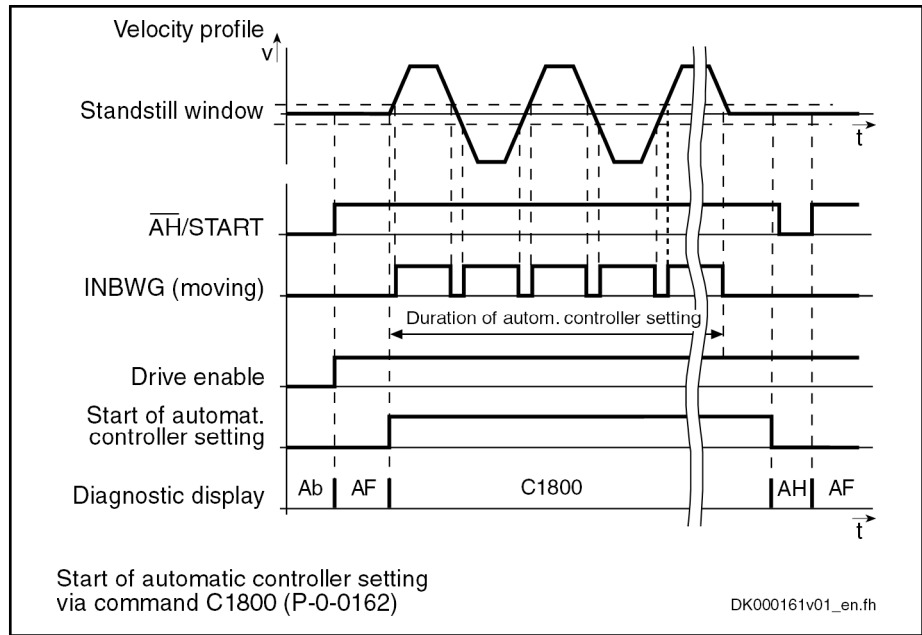
Fig.6-70:   Signal Flow Chart for Motion by Command Start

Triggering the Motion by "Drive Start"
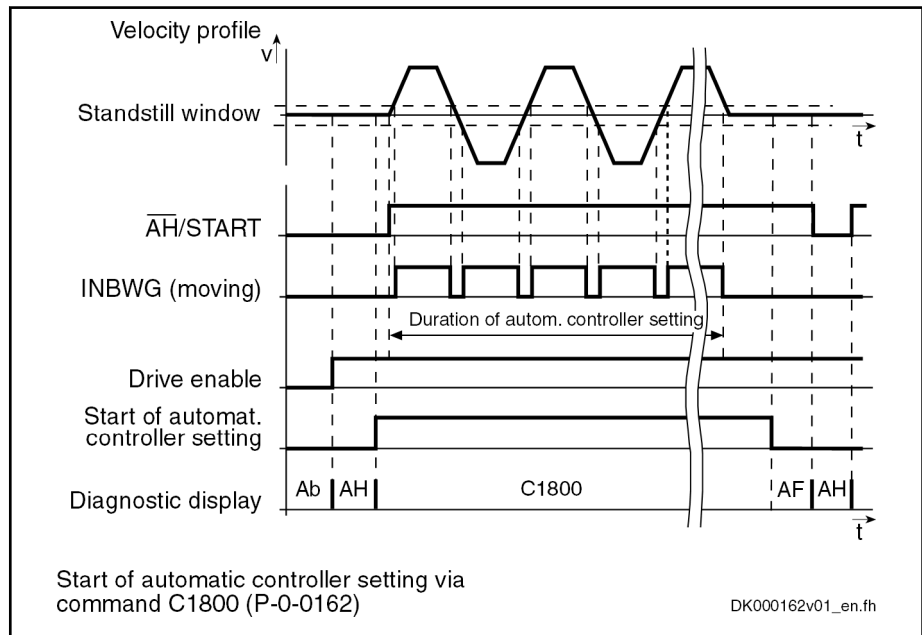
Fig.6-71:   Signal Flow Chart for Motion by "Drive Start"

Drive Control

Interrupting the Command with "Drive Halt"
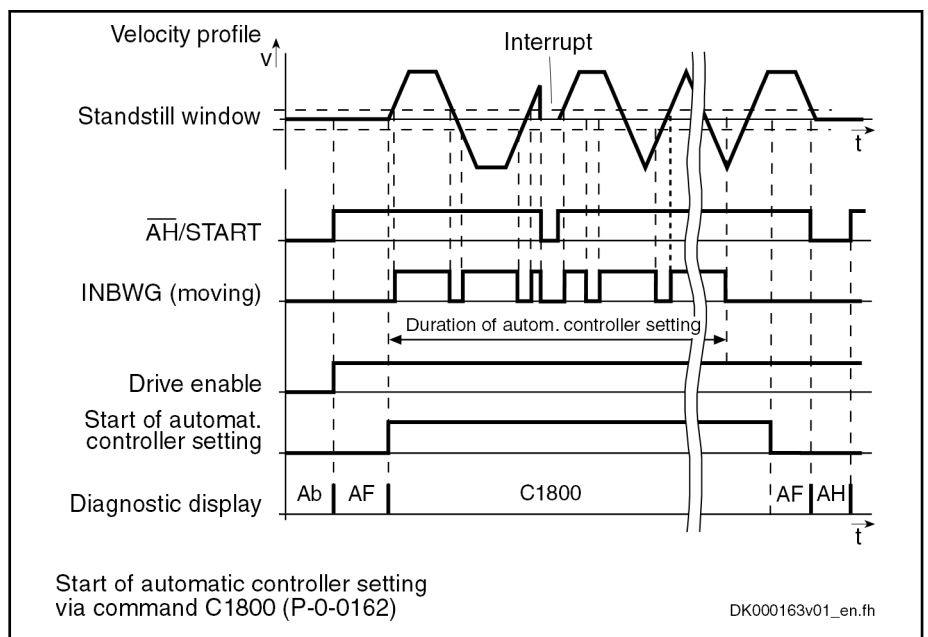
Fig.6-72:   *Signal Flow Chart for Interruption by "Drive HALT"*

☞   A repeated run with possibly changed settings can be carried out in two ways:

- By removing and then re-applying drive enable or the start signal ("drive start")

- By completing and then restarting command C1800

Start Position and Optimization Motion

At the start of the command, the axis from its current actual position moves to the start position for the optimization motion. After the optimization motion, the axis moves back to the actual position at which it was at the start of the command.

💡   The drive only moves to the start position, if motion is required to carry out the automatic control loop setting (determination of load inertia and/or control loop optimization;

The start position and the optimization motion depend on the type of motion (P-0-0165, bit 14) and on the settings made to determine the travel range (P-0-0165, bit 15).

Drive Control

Motion P-0-0165, bit 14	Determining travel range P-0-0165, bit 15	Start position	Optimization motion
Oscillating motion	Input of limits	Middle of P-0-0166, P-0-0167	Oscillation between the limits
	Input of travel distance		Oscillation around the start position +/- half the value of P-0-0169
Motion always in one direction	Input of limits	Actual position at start of the command	Stepwise motion in one direction until, as a maximum, one of the limits (P-0-0166, P-0-0167) has been reached [1] [2]
	Input of travel distance		Stepwise motion in one direction until, as a maximum, the defined travel distance (P-0-0169) has been covered [1]

1)   The direction of motion depends on the settings in P-0-0165, bit 13
2)   The pos. or neg. end position takes effect depending on the direction of motion (P-0-0165, bit 13)

Fig.6-73:   *Start Position and Optimization Motion Depending on the Motion and the Determined Travel Range*

☞   During the automatic control loop setting (optimization motion), the defined travel range is permanently monitored. When the travel range is exceeded, the command error "C1806 Travel range exceeded" is output and the drive is shut down in a speed-controlled way.

The defined travel range is only monitored during the execution of the "automatic control loop setting" command!

6.5.3 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 closed-loop operation (current and velocity) can be carried out with encoder for all types of motors and for asynchronous motors also without encoders.

☞   The motor control type is selected by means of "P-0-0045, Control word of current controller" (bit 14,15)
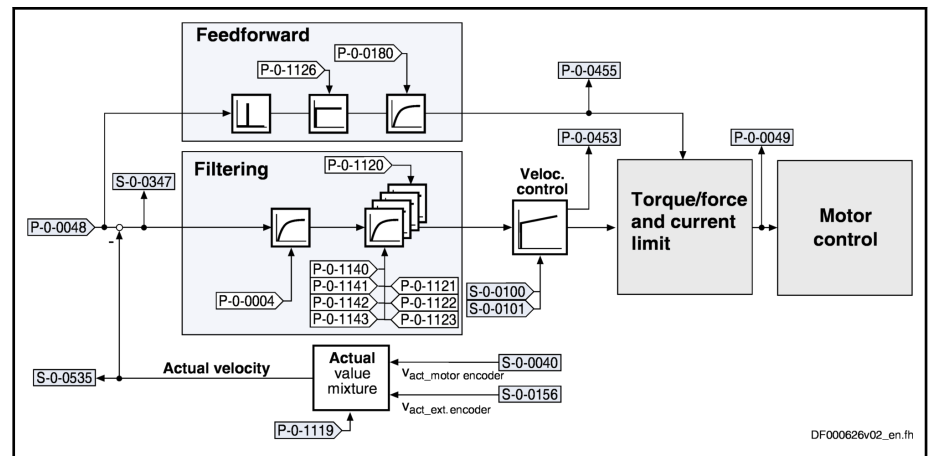
Fig.6-74:   Structure of the Velocity Loop

> ☞   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 operation mode "Velocity Control".

Features
- Digital PI loop 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
    - Once executing the function "load defaults procedure "
    - or -
    - Manual optimization (see description below)
    - or -
    - Automatic parameterization of the axis controller (see "Automatic Setting of Closed-Loop Axis Control").
- Depending on the control performance which has been set, the cycle time $T_{A\_Velocity}$ is used for velocity loop calculations (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
- Low-pass filter to attenuate interference frequencies, to be set via 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

Drive Control

- S-0-0081, Additive torque/force command value
- S-0-0084, Torque/force feedback value
- S-0-0091, Bipolar velocity limit value
- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- S-0-0149, C1300 Positive stop drive procedure command
- S-0-0155, Friction compensation
- S-0-0164, Acceleration feedback value 1
- S-0-0347, Velocity error
- P-0-0004, Velocity loop smoothing time constant
- P-0-0048, Effective velocity command value
- P-0-0049, Effective torque/force command value
- P-0-0180, Acceleration feedforward smoothing time constant
- P-0-0451, Actual acceleration torque/force value
- P-0-0452, Actual process torque/force value
- P-0-0555, axis controller messages
- P-0-0556, Config word of axis controller
- P-0-1119, Velocity mix factor feedback 1 & 2
- P-0-1120, Velocity control loop filter: filter type
- P-0-1121, Velocity control loop filter: limit frequency of low pass
- P-0-1122, Velocity control loop filter: bandwidth of band-stop filter
- P-0-1123, Vel. cont. loop filter: center frequency of band-stop filter
- P-0-1126, Velocity control loop: acceleration feedforward
- P-0-1140, Velocity control loop filter: Numerator natural frequency
- P-0-1141, Velocity control loop filter: Denominator natural frequency
- P-0-1142, Velocity control loop filter: Numerator damping
- P-0-1143, Velocity control loop filter: Denominator damping
- P-0-2100, Velocity loop proportional gain, encoder memory
- P-0-2101, Velocity loop integral-action time, encoder memory
- P-0-3004, Speed loop 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 velocity command value preset in the position loop clock can be linearly interpolated to the speed loop clock through a fine interpolator via 2 steps. This can be used, for example, in the case of great changes in the velocity command value per position loop clock in order to reduce the current command value noise. You must observe that, when using the fine interpolation, an additional phase shift has an effect on the control loop structure; in position-controlled operation modes, this phase shift might possibly have a negative effect on the contour precision (following distance).
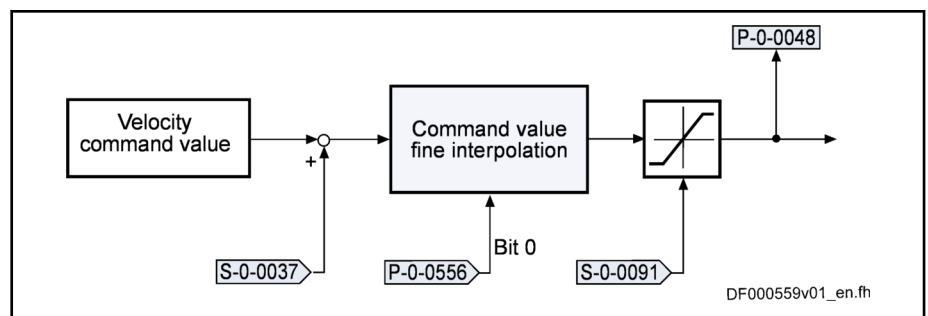
Drive Control

S-0-0037   Additive velocity command value
S-0-0091   Bipolar velocity limit value
P-0-0048   Effective velocity command value
Fig.6-75:   *Fine Interpolation of the Velocity Command Value*

☞   In the default setting, the fine interpolator is switched off. It can be
          activated via bit 0 of parameter "P-0-0556, Config word of axis
          controller".

Velocity Loop   The velocity loop designed as a PI loop can be set via the following parame-
          ters:

- 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 sys-
tem.

- For Rexroth motors with motor data memory (e.g., IndraDyn S motor
  line), a default controller setting that is suitable for most of the standard
  applications is stored in this memory.

- For Rexroth motors without motor data memory and for third-party mo-
  tors, the controller settings must be determined at the commissioning,
  as they are strongly dependent 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 en-
          coder 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 cur-
          rent 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 figure below illustrates the feedforward of the controller:

Drive Control
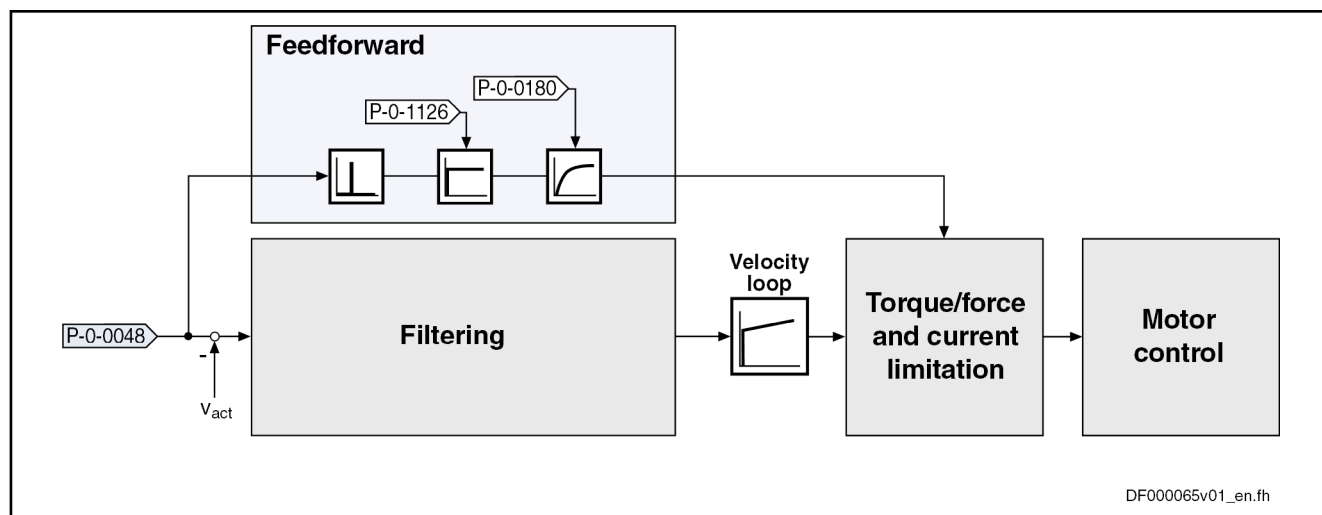
P-0-0048	Effective velocity command value
P-0-0180	Acceleration feedforward smoothing time constant
P-0-1126	Velocity control loop: Acceleration Feedforward
Fig.6-76:	*Acceleration Feedforward in the Velocity Control Loop*

☞   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:

● One low pass of 1st order
● Four freely configurable 2nd order filters

    The following setting options are available for each of these four filters:

    – Low pass of 2nd order
    – Band-stop filter
    – Filter of 2nd order

The figure below illustrates the position of the filters in the overall control loop:
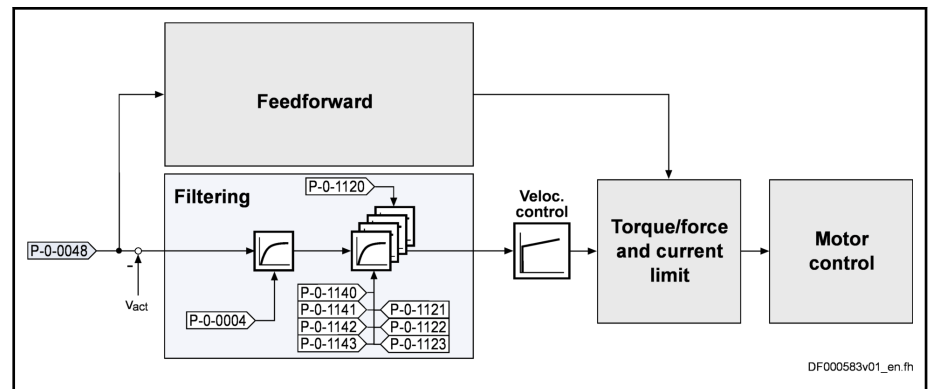
P-0-0004	Speed loop smoothing time constant
P-0-0048	Effective velocity command value
P-0-1120	Velocity control loop filter: Filter type
P-0-1121	Velocity control loop filter: Limit frequency of low pass
P-0-1122	Velocity control loop filter: Bandwidth of band-stop filter
P-0-1123	Velocity control loop filter: Center frequency of band-stop filter
P-0-1140	Velocity control loop filter: Numerator natural frequency
P-0-1141	Velocity control loop filter: Denominator natural frequency
P-0-1142	Velocity control loop filter: Numerator damping
P-0-1143	Velocity control loop filter: Denominator damping

Fig.6-77:   Filtering Options in the Velocity Control Loop

In practical application there often occur resonant oscillations that mostly result from deficiencies or restrictions of the mechanical system:

- Connection of limited stiffness of the mechanical system to the motor shaft

    → Resonances in the range of 100 Hz … 1000 Hz are possible (according to stiffness of the connection and mass ratio)

- Faulty 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 filters integrated in the drive. By means of the implemented filter cascade, it is possible to selectively suppress up to 4 different resonance frequencies.

☞ The implemented filters enable a suppression of resonance frequencies in the **frequency range 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 speed control loop and the dynamics of the position control loop can be considerably improved as compared to control without the use of a filter. This leads to improved movement according to contour and smaller cycle times for positioning processes with sufficient distance to the stability limit.

Band-Stop Filter Function   Both center frequency and bandwidth can be set for the band-stop filter. The attenuation of the center frequency is the strongest; the bandwidth determines the frequency range in which the attenuation is smaller than –3 dB.

Drive Control
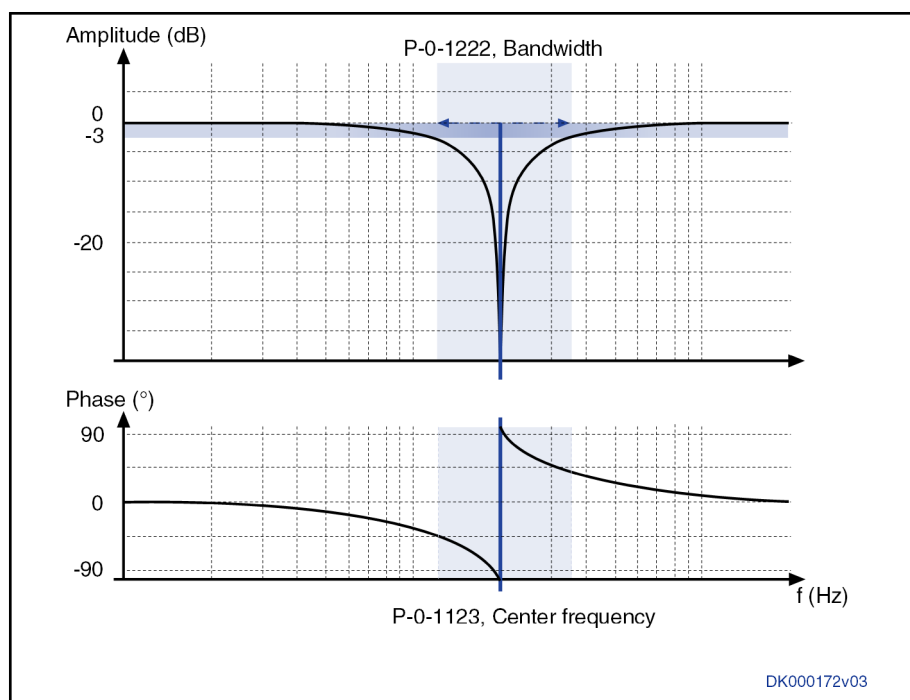
P-0-1122   Velocity control loop filter: Bandwidth of band-stop filter
P-0-1123   Velocity control loop filter: Center frequency of band-stop filter
*Fig.6-78:   Band-Stop Filter Bode Diagram (Amplitude in dB and Phase in De-
                grees)*

2nd Order Filter Function   For the 2nd order filter, it is possible to set the numerator natural frequency
(P-0-1140), the denominator natural frequency (P-0-1141), the numerator
damping (P-0-1142) and the denominator damping (P-0-1143). The figure be-
low shows the exemplary transmission behavior of the 2nd order filter.
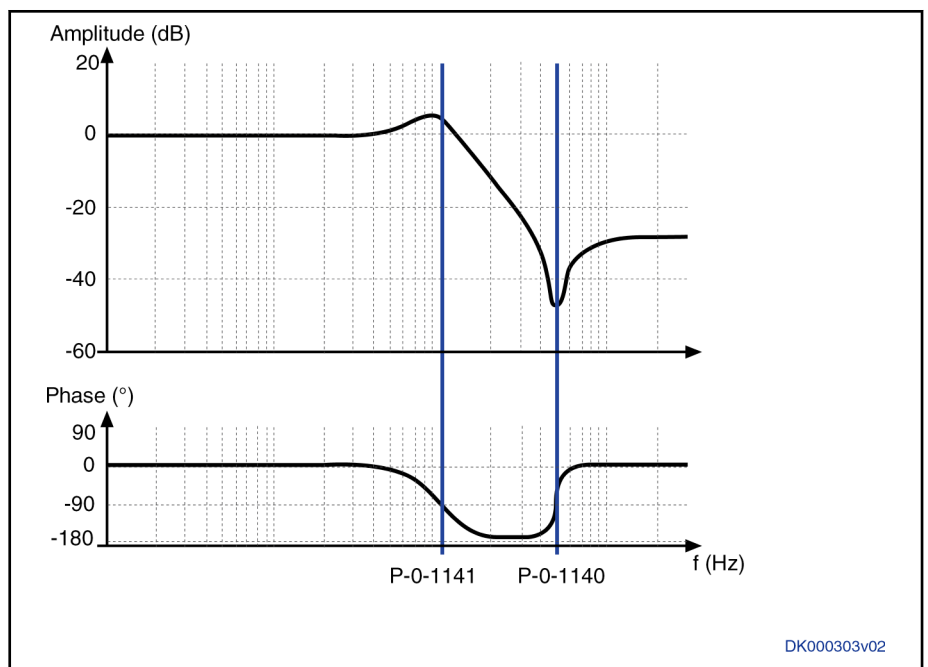
Drive Control

P-0-1140	Velocity control loop filter: Numerator natural frequency
P-0-1141	Velocity control loop filter: Denominator natural frequency
P-0-1142	Velocity control loop filter: Numerator damping
P-0-1143	Velocity control loop filter: Denominator damping

Fig.6-79: *2nd Order Filter Bode Diagram (Amplitude in dB and Phase in Degrees)*

Features of 2nd order filter:

- The relation between denominator frequency (f_D) and numerator frequency (f_N) defines the reduction (or overshoot) above the two frequencies. The reduction (Red in [dB]) is calculated as follows:

$$Abs = 40 * \log(f_N / f_Z); \qquad \begin{array}{l} f_N > f_Z \rightarrow Abs > 0 \rightarrow \text{Superelevation} \\ f_N = f_Z \rightarrow Abs = 0 \\ f_N < f_Z \rightarrow Abs < 0 \rightarrow \text{Fall} \end{array}$$

Fig.6-80: *2nd Order Filter - Reduction*

- The absolute value of the denominator frequency (f_D or P-0-1141) and the (f_N or P-0-1140) is calculated in this way:

Drive Control

$$\left|F(f{=}f_z)\right|_{\text{in dB}} = 20*\log 10\left(\sqrt{\frac{4D_z^{\,2}}{\left(1-\left(\frac{f_z}{f_N}\right)^2\right)^2+\left(\frac{2D_N*f_z}{f_N}\right)^2}}\right);$$

$$\left|F(f{=}f_N)\right|_{\text{in dB}} = 20*\log 10\left(\sqrt{\frac{\left(1-\left(\frac{f_N}{f_z}\right)^2\right)^2+\left(\frac{2D_z*f_N}{f_z}\right)^2}{4D_N^{\,2}}}\right);$$

Fig.6-81:   *Absolute Value of Denominator Frequency f_D and Numerator Frequency f_N*

- If the damping D_D or D_N is greater than 1/root(2), there is no overshoot or drop below the numerator frequency f_N or the denominator frequency f_D.

> The smaller the damping, the nearer the frequencies, at which the max. overshoot or the max. drop occurs, are to the denominator frequency or numerator frequency; i.e. when the damping equals zero, the frequencies are identical.

- It is possible to implement a band-stop filter with a defined reduction (Red in dB) and dimension to bottom of notch D (drop in dB at the center frequency f_C).

$$f_z = f_m;$$

$$f_N = f_m*10^{\frac{Abs}{40}};$$

$$D_z = 10^{\frac{K}{20}}*0.5*\sqrt{\left(1-\frac{1}{10^{\frac{Abs}{20}}}\right)^2+\frac{f_{BB}^{\,2}}{f_m^{\,2}*10^{\frac{Abs}{10}}}};$$

$$D_N = \frac{f_{BB}}{2*f_m*10^{\frac{Abs}{40}}};$$

Special case Abs = 0: $f_N = f_m;$

$$D_z = 10^{\frac{K}{20}}*0.5*\frac{f_{BB}}{f_m};\qquad D_N = \frac{f_{BB}}{2*f_m};$$

f_c	Center frequency [Hz]
f_{BW}	Bandwidth [Hz] (-3dB)
D	Dimension to bottom of notch [dB]
Red	Reduction [dB]

Fig.6-82:   *2nd Order Filter for Band-Stop Filter with Reduction Red and Dimension to Bottom of Notch D*

In the special case Red = "0" and D = "-infinite", the filter operates like the band-stop filter that can be parameterized via P-0-1122 and P-0-1123.

Drive Control

Filtering by Means of a Multiple Smoothing Filter

The optimization of the control loop by means of a band-stop filter or a 2nd order filter does not always sufficiently improve the quality of control. This is the case, for example, when the closed control loop has no distinctive resonance frequencies or when there are more than 4 resonance points. It is then possible to obtain the desired quality of control by activating several smoothing filters (with PT2 characteristics).

For this purpose, the 4 elements in "P-0-1120, Velocity control loop filter: filter type" are set to the value "1" or "0" (see description of Parameter P-0-1120).

Instead of the rejection filter, smoothing filters are activated in the control loop, the smoothing time constants of which (T_{gl}) are contained in "P-0-1121, Velocity control loop filter: limit frequency of low pass".

Together with the PT1 filter (P-0-0004, Velocity loop smoothing time constant) at the velocity loop input, you obtain filter characteristics with PT_N behavior. Frequencies higher than the limit frequency ($f_g = 1/2pTgl$) are suppressed much more and cannot excite the control loop oscillation.

The following applies to the filter effect:

*   P-0-0004, Velocity loop smoothing time constant

    → Attenuation of 20 dB/decade

*   P-0-1121, Velocity control loop filter: limit frequency of low pass

    → Attenuation of 40 dB/decade

When activating all low-pass filters, the maximum attenuation is 180 dB/decade. This corresponds to a very high filtering degree.
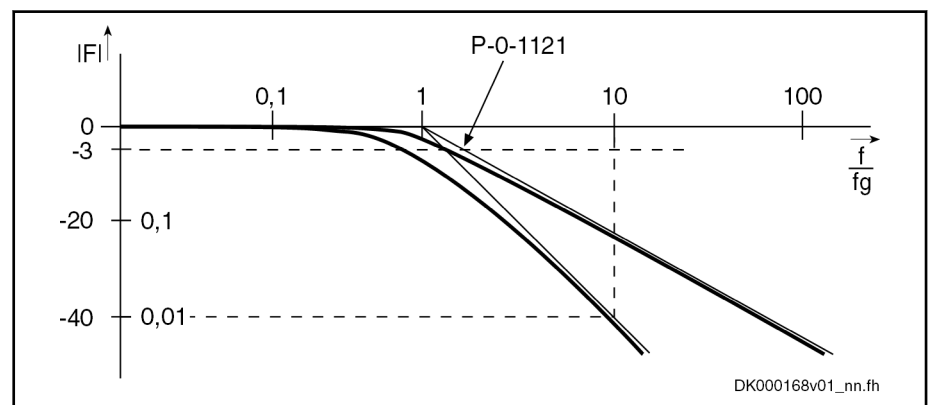
IFI	Absolute value of the transmission function (in dB)
P-0-1121	Velocity control loop filter: Limit frequency of low pass
Fig.6-83:	*Amplitude Characteristic of a PT1 and a PT2 Filter*

☞   When using the filters in the speed loop, take into account that each filter causes phase displacement in the control loop and therefore has a negative effect on the phase margin in the control loop (control loop stability).

Therefore, the following applies: "As little filtering as possible, but as much filtering as necessary!"

Notes on Commissioning

Preparations for 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:

Drive Control

- 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 have been selected.

Start Settings   For the parameterization of the controller, the start settings must be executed as described below:

- S-0-0100, Velocity loop proportional gain

    → Standard value of the connected motor

- S-0-0101, Velocity loop integral action time

    → For a value equal to zero → No I-component

- P-0-0004, Velocity loop smoothing time constant

    → For smoothing time constants smaller than or equal to the speed loop cycle time $T_{A\_velocity}$, the filter is switched off.

    →$T_{A\_velocity}$ = 125 µs (Advanced performance)

    →$T_{A\_velocity}$ = 250 µs (standard performance)

    →$T_{A\_velocity}$ = 500 µs (Economy performance)

    See also "Performance Data"

- P-0-1120, Velocity control loop filter: filter type

    → With value "0000" → Filter is switched off

☞   When determining the velocity 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:

Determining the Critical Proportional Gain

1. Have the drive moving with a low velocity after switching on drive enable.

    - Linear motor → 1000 … 2000 mm/min

    - Rotary motor → 10 … 20 rpm

2. Increase the value in "S-0-0100, Velocity loop proportional gain" until an instable ratio (continuous oscillation) occurs.

3. The frequency of the oscillation must be recorded by oscilloscoping the actual velocity (see also "Analog Outputs" or "Oscilloscope Function"). If the frequency of the oscillation is much higher than 500 Hz, increase the value in the parameter "P-0-0004, Velocity loop smoothing time constant" until the oscillation is reduced. Subsequently, increase the value in "S-0-0100, Velocity loop proportional gain" further, until an oscillation (instability) occurs anew.

4. Decrease the value in "S-0-0100, Velocity loop proportional gain" until the continuous oscillation ceases automatically.

    The value thus determined is the so-called

    "Critical velocity loop proportional gain".

Drive Control

☞ By utilization of the filter cascade (P-0-1120, P-0-1121, P-0-1122, P-0-1123,P-0-1140, P-0-1141, P-0-1142, P-0-1143), other filters can be activated to dampen resonances.

Determining the Critical Integral Action Time

To determine the

"critical integral action time", proceed as follows:

1. Set the parameter "S-0-0100, Velocity loop proportional gain" = 0.5 × "critical proportional gain"

2. Reduce the value in "S-0-0101, Velocity loop integral action time" starting with the maximum value, until an instable behavior (continuous oscillation) occurs.

3. Increase the value in "S-0-0101, Velocity loop integral action time" until the continuous oscillation ceases automatically. The value thus determined corresponds to the "critical integral action time". 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:

$$S\text{-}0\text{-}0100 = \frac{(P\text{-}0\text{-}0510) + (P\text{-}0\text{-}4010)}{T_s \times \alpha} \times \frac{1}{60 \times 1000} \quad \left(\text{in } \frac{N \times min}{mm}\right)$$

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 = 400 µs + (P-0-0004)
a	Optimization variable a = 2.5

Fig.6-84:   Calculating the Value for the Proportional Gain of the Velocity Loop for Linear Motors

$$S\text{-}0\text{-}0100 = \frac{(P\text{-}0\text{-}0510) + (P\text{-}0\text{-}4010)}{T_s \times \alpha} \quad \left(\text{in } Nm \times \frac{s}{rad}\right)$$

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 = 400 µs + (P-0-0004)
a	Optimization variable a = 2.5

Fig.6-85:   Calculating the Value for the Proportional Gain of the Velocity Loop for Rotary Motors

$$S\text{-}0\text{-}0100_{IndraDrive} = P\text{-}0\text{-}0051 \times S\text{-}0\text{-}0100_{EcoDrive} \quad \left(\text{in } \frac{N \times min}{mm}; \text{ in } \frac{Nm}{rad}\right)$$

S-0-0100	Velocity loop proportional gain
P-0-0051	Torque/force constant

Fig.6-86:   Correlation of the Proportional Gain Between the IndraDrive and the EcoDrive Firmware

Characteristics of the Control Loop Setting

From the calculated critical values (see above) a controller setting can be derived that has the following features:

• Independent of changes at the axis due to sufficient distance to the stability limit

• Properties can be reliably reproduced in series machines

Drive Control

In the following table some of the most frequent modes of application and the respective characteristics of the control loop settings are illustrated.

Application type	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.6-87:   Features of the Controller Settings

Parameterizing the Band-Stop Filters The band-stop filters are parameterized by means of the following parameters:

- P-0-1120, Velocity control loop filter: filter type
- P-0-1122, Velocity control loop filter: bandwidth of band-stop filter
- P-0-1123, Vel. cont. loop filter: center frequency of band-stop filter

Each of these parameters have 4 elements, which results in the following allocation of the relevant filter settings:

- **Band-stop filter 1:** P-0-1120 [0], P-0-1122 [0], P-0-1123 [0]
- **Band-stop filter 2:** P-0-1120 [1], P-0-1122 [1], P-0-1123 [1]
- **Band-stop filter 3:** P-0-1120 [2], P-0-1122 [2], P-0-1123 [2]
- **Band-stop filter 4:** P-0-1120 [3], P-0-1122 [3], P-0-1123 [3]

Presetting The following procedure is recommended for the setting of the band-stop filter:

1. First set the rejection filter inactive.
2. Enter the following values in "P-0-1120, Velocity control loop filter: filter type".
   - P-0-1120 [0] = 0 → Filter 1 is switched off
   - P-0-1120 [1] = 0 → Filter 2 is switched off
   - P-0-1120 [2] = 0 → Filter 3 is switched off
   - P-0-1120 [3] = 0 → Filter 4 is switched off

Determining the Resonance Frequency The following procedure is recommended 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 directly read by means of a fast Fourier transform (FFT) of the frequency response. For this purpose, the utilization of the "IndraWorks Ds/D/MLD" commissioning tool is required.
2. In reversing duty increase the value in "S-0-0100, Velocity loop proportional gain" until distinctive oscillation is noticed (resonant oscillation).
3. Record the time behavior of the oscillation with the oscilloscope 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

Drive Control

"IndraWorks Ds/D/MLD" commissioning tool by means of the frequency display.

4. Set the drive enable 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. Enter the frequency that emerged most noticeably in Hz in "P-0-1123, Vel. cont. loop filter: center frequency of band-stop filter".

    Enter a minimum bandwidth (e.g. 25 Hz) in "P-0-1122, Velocity control loop filter: bandwidth of band-stop filter".

    ⇒ Record the previous step response again!

    If the step response shows less overshooting and shorter period of oscillation:

7. Check if increasing the value in "P-0-1122, Velocity control loop filter: bandwidth of band-stop filter" causes another improvement, or if changing the value in "P-0-1123, Vel. cont. loop filter: center frequency of band-stop filter" causes another improvement.

    If the step response shows the same behavior:

8. Check the determined resonance frequency; if need be, considerably increase the value in "P-0-1122, Velocity control loop filter: bandwidth of band-stop filter":

9. Re-optimize the velocity loop using the pre-optimized values in "P-0-1122, Velocity control loop filter: bandwidth of band-stop filter" and "P-0-1123, Vel. cont. loop filter: center frequency of band-stop filter"

10. If necessary, carry out another optimization procedure for P-0-1122 and P-0-1123 due to the high-frequency or less attenuated resonance points that are now possibly occurring.

> ☞ If the rejection filter does not seem to show any effect, check whether the sampling time of the oscilloscope function might be too high, which means that the measured resonance frequency is merely the inverted version of the real frequency.

Diagnostic and Status Messages

Velocity Deviation   The velocity deviation (S-0-0347) is calculated by subtraction, from the effective velocity command value (P-0-0048) and the current actual velocity value (S-0-0040).

> ☞ The motor-related velocity (motor speed with rotary motors) is displayed in "P-0-0112, Actual velocity value of motor".

Acceleration Torque/Force   The acceleration torque is determined from the total inertia (P-0-0510 + P-0-4010) calculated from the automatic control loop setting and the value in "S-0-0164, Acceleration feedback value 1" and is displayed in "P-0-0451, Actual acceleration torque/force value".

Process Torque/Force   The current process torque is determined from the current total torque in "S-0-0084, Torque/force feedback value" and the determined "P-0-0451, Actual acceleration torque/force value" and displayed in "P-0-0452, Actual process torque/force value".

Drive Control

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 with S-0-0082, S-0-0083 and S-0-0092. At the output of the limitation, the effective torque / force command value (P-0-0049) can be read.

☞ If the limitation is activated, the corresponding warning "E8260 Torque/force command value limit active" is generated and the respective bit (positive / negative limit) in P-0-0555, axis controller messages

is set.

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 the case of error, the drive torque is immediately disabled and the error message "F8078 Speed loop error" is generated.

[i] See also description of diagnostic message "F8078 Speed loop error"

6.5.4   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).
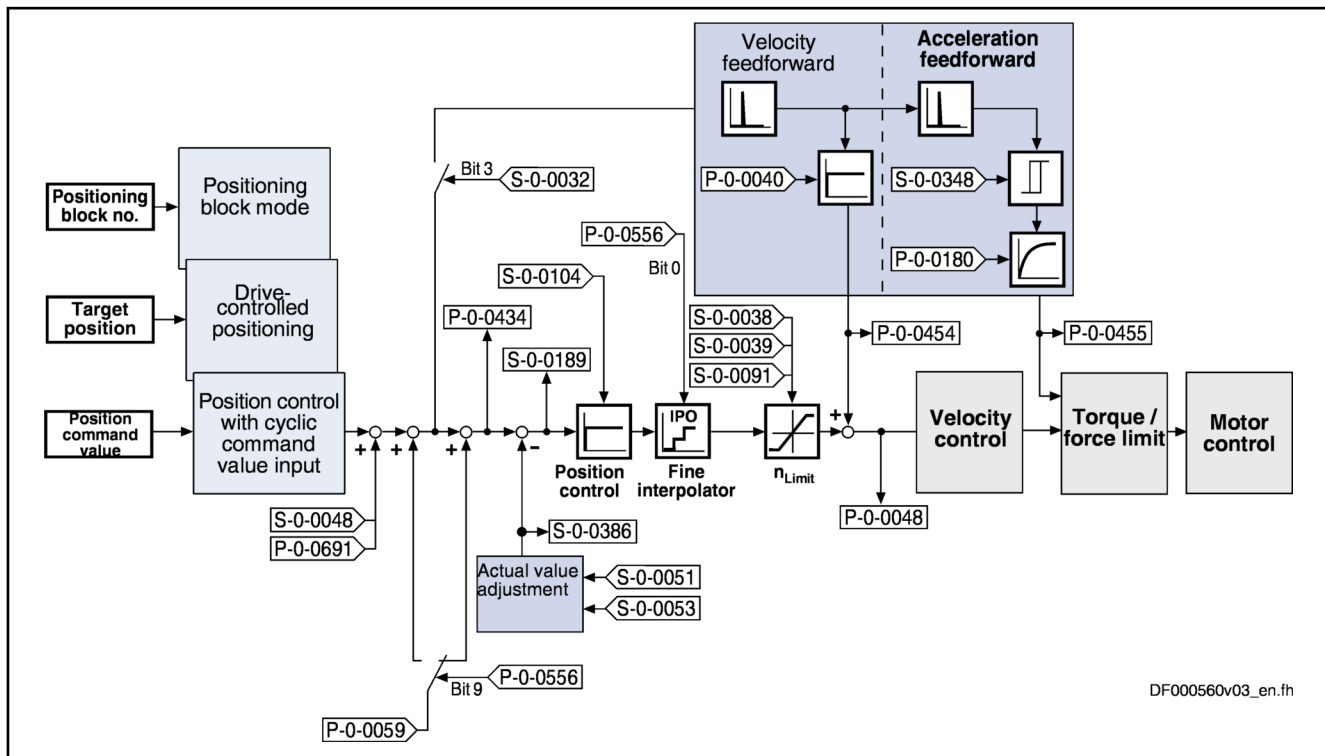
Fig.6-88:   Structure of the Position Loop

Drive Control

> ☞ 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 operation mode
  → Bit 3 = 1 → Activation of lagless operation
- S-0-0038, Positive velocity limit value
- S-0-0039, Negative velocity limit value
- S-0-0040, Velocity feedback value
- S-0-0048, Additive position command value
- S-0-0051, Position feedback value 1
- S-0-0053, Position feedback value 2
- S-0-0091, Bipolar velocity limit value
- S-0-0092, Bipolar torque/force limit value
- S-0-0104, Position loop Kv-factor
- S-0-0189, Following distance
- S-0-0348, Acceleration feedforward gain
- S-0-0386, Active position feedback value
- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0040, Velocity feedforward evaluation
- P-0-0048, Effective velocity command value
- P-0-0049, Effective torque/force command value
- P-0-0059, Additive position command value, controller
- P-0-0109, Torque/force peak limit
- P-0-0180, Acceleration feedforward smoothing time constant
- P-0-0241, Actual pos. smoothing time constant for hybrid pos. control
- P-0-0434, Position command value of controller

Drive Control

- P-0-0454, Velocity feedforward actual value
- P-0-0455, Acceleration feedforward actual value
- P-0-0556, Config word of axis controller
- P-0-0691, Additive position command value, process loop

Pertinent Diagnostic Messages
- F2028 Excessive deviation
- F2036 Excessive position feedback difference
- F2037 Excessive position command difference

Functional Description

☞   Activating the lagless operation causes a feedforward value determined from the position command value (velocity command value) to be added to the velocity command value at the position 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. To do this set bit 9 of "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 "S-0-0348, Acceleration feedforward gain":

- Linear motor → Total mass (motor + load) in kg
- Rotary motor → Total mass inertia (motor + load) in kgm^2

☞   Adjust the input value in "S-0-0348, Acceleration feedforward gain" in dependency of the respective local mechanical system!

The illustrations below exemplify the operating principle of the respective feedforward procedure.
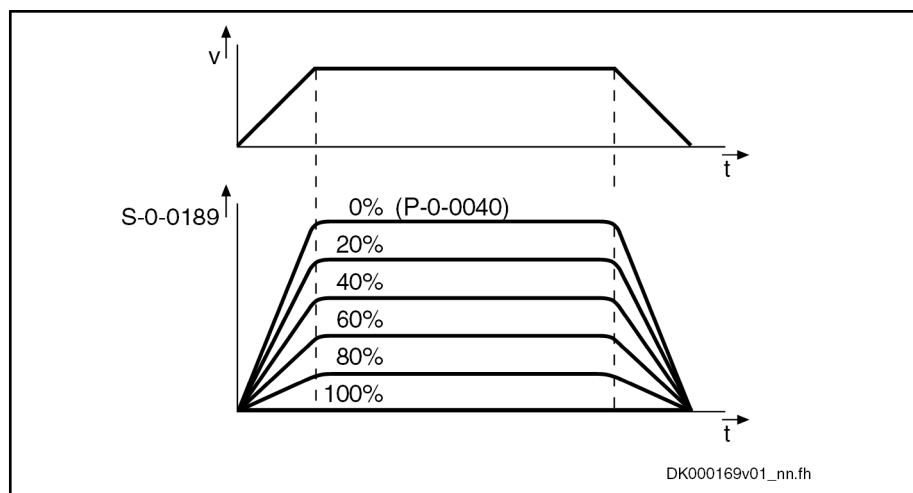
S-0-0189   Following distance
P-0-0040   Velocity feedforward evaluation
Fig.6-89:   *Operating Principle of the Velocity Feedforward*

Drive Control
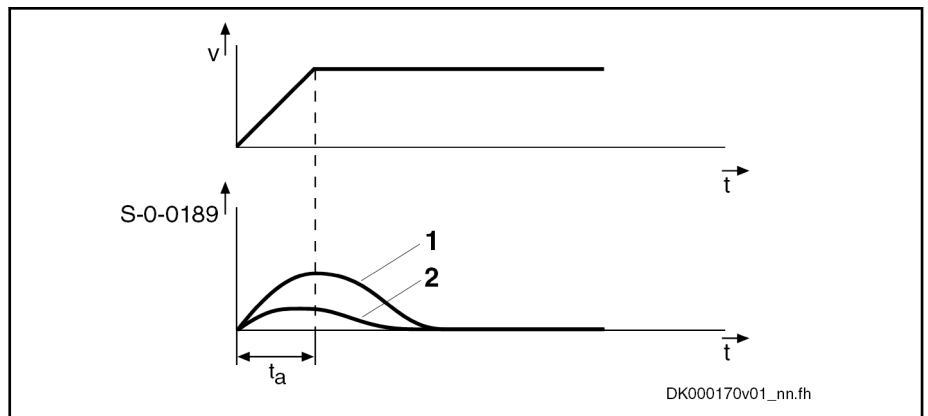
1	Without acceleration feedforward
2	With acceleration feedforward
t_a	Acceleration phase
S-0-0189	Following distance

Fig.6-90: Operating Principle of Acceleration Feedforward (with P-0-0040 = 100%)

Making the Actual Position Value Available

The actual value for the position control can be made available by the motor encoder or the optional encoder. It is possible, however, to use both actual position values for position control ("hybrid actual position value").

"Hybrid Actual Position Value"

The actual position value detected by the optional encoder is added to the actual position value of the motor encoder and is used for position control as the so-called "hybrid actual position value". The difference of both actual position values is smoothed via a filter which can be set (P-0-0241) and added to the actual position value of the motor encoder.

Using the hybrid actual position value is particularly advantageous if there only is a low degree of stiffness between motor encoder and external encoder. In the case of slip between motor encoder and external encoder, it is advantageous to activated the measuring wheel mode (see also "Measuring Wheel Mode").
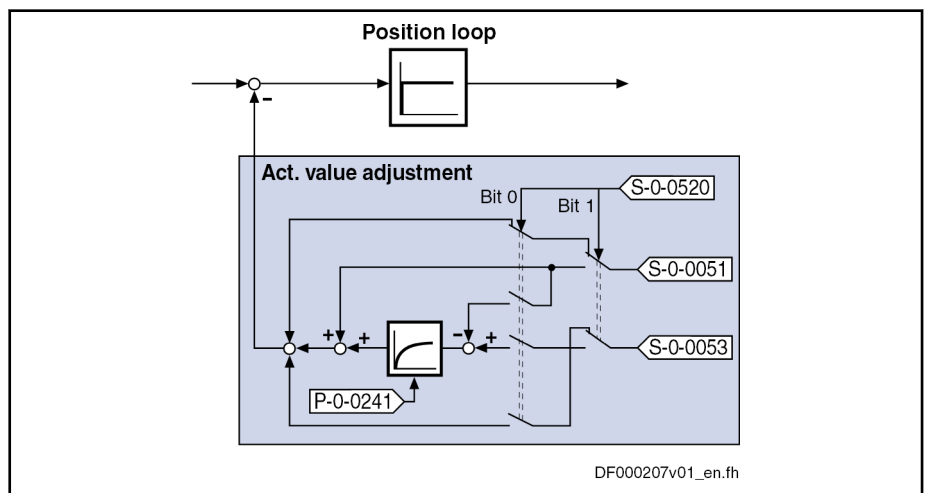
S-0-0051	Position feedback 1 value
S-0-0053	Position feedback 2 value
S-0-0520	Control word of axis controller
P-0-0241	Actual pos. smoothing time constant for hybrid pos. control

Fig.6-91: Generating the Hybrid Actual Position Value

Drive Control

The generation of the hybrid actual position value is configured in t"S-0-0520, Axis control word", its use for control tasks is activated in the same parameter.

To be noticed:

- By the value "0" in "P-0-0241, Actual pos. smoothing time constant for hybrid pos. control", the actual position value of the motor encoder is ignored and only the actual position value of the optional encoder is used for position control.

- If the values of S-0-0051 and S-0-0053 differ (might be the case for measuring systems to be evaluated in absolute form with different position data reference), abrupt changes in the velocity command value can occur when the hybrid actual position value is activated.

☞　　　The position data reference of motor encoder and optional encoder remains unchanged when the hybrid actual position value is activated. As a prerequisite the optional encoder **must not** have been activated as measuring wheel encoder in "P-0-0185, Control word of encoder 2 (optional encoder)"!

Notes on Commissioning

The cascade 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 "S-0-0104, Position loop Kv-factor" until instable behavior (continuous oscillation) occurs.

3. "Reduce S-0-0104, Position loop Kv-factor" until continuous oscillation decreases automatically.

   The value thus determined is the so-called "critical position 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. For this purpose, the following machine and application types have to be distinguished:

- **High-end machine tools** (e.g. grinding machines)

  → Optimization with regard to a minimum lag error characteristic by the highest possible Kv-factors

- **Standard positioning axes** (e.g. press transfer)

  → Optimization with regard to a minimum lag error characteristic is not required, the important thing is smoothest possible, jerk-free positioning.

Drive Control

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 "P-0-0185, Control word of encoder 2 (optional encoder)". Configure the hybrid actual position value in "S-0-0520, Axis control word".

Activating the Hybrid Actual Position Value

The hybrid actual position value can only be activated when the drive is ready for operation, by

- Activating "hybrid actual position value" in "S-0-0520, Axis control word"

  - and -

- position-controlled 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 "S-0-0520, Axis control word"

- Switching to communication phase P2 or parameter mode

- Switching the drive off

Setting the Jerk Attenuation for the Hybrid Actual Position Value

Abrupt position differences between motor encoder and optional encoder can be attenuated by inputting a value greater than zero in "P-0-0241, Actual pos. smoothing time constant for hybrid pos. control".

☞   The value "0" in P-0-0241 switches off the attenuation and causes only the actual position value of the optional encoder to be effective.

Procedure:

1. Enter value "0" in P-0-0241 and move axis at low velocity and little acceleration.

2. Increase 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 actual position value permanently exceeds the value of "S-0-0159, Monitoring window" it is obvious that the drive cannot follow the preset command value and the error message "F2028 Excessive deviation" is generated.

Excessive Position Feedback Difference (F2036)

- **Monitoring of position difference (encoder 1 and encoder 2)**

  When 2 measuring systems (1 motor encoder and possibly external length measuring system) are used simultaneously, the actual position value 1 and the actual position value 2, in cyclic operation (phase 4), are

Drive Control

monitored for a maximum allowed actual position value difference indicated in "S-0-0391, Monitoring window feedback 2". If the absolute value of the difference is greater than the value of the monitoring window, the error message "F2036 Excessive position feedback difference" is generated.

☞ The current position difference is displayed in "P-0-0391, Actual position value difference encoder1 - encoder2"!

The following limitation is carried out in the position 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"

6.6   Commutation Setting

6.6.1   Basics on Commutation Setting

Brief Description

General Information

Significance of Commutation Offset

Synchronous three-phase a.c. motors are only operational, when the current in the primary part has been correctly assigned to the permanent magnetic field in the secondary part. For this purpose, the position of the primary part (motor windings) in relation to the pole pairs of the secondary part must always be known to control. Depending on the primary part position signaled by the motor encoder, the current in the three-phase windings is generated in such a way by means of the "commutation offset" that force is generated in the motor.

A synchronous motor can only generate the maximum torque or the maximum force related to the motor current, when the value of the commutation offset is correct. Otherwise, the relation between torque/force and motor current (torque/force constant) would be minor and not optimal. A highly incorrect value implies the danger of the motor moving in an uncontrolled way.

If the motor encoder has not been mounted in a defined orientation with regard to the primary and secondary parts of the motor, an individual commutation offset value must be determined for each synchronous motor:

- For synchronous Rexroth motors with integrated motor encoder and encoder data memory (e.g., MSK motors), the commutation offset was already determined at the factory and is provided in the motor encoder data memory. The user does not need to set the commutation offset!

- Synchronous Rexroth kit motors consist of motor components (primary part, secondary part). It is only by mounting them in the machine axis that they are put together to form an operational motor and they are completed by a motor encoder on the customer side. The commutation offset can only be determined on the user side after the motor has been completed.

  The following Rexroth kit motors are manufactured according to the functional principle "synchronous motor":

Drive Control

– Linear motors LSF, MLF

– Rotary motors MBS and MBT

Motor Encoders for Synchronous Motors

Absolute motor encoders should ideally be used for synchronous Rexroth kit motors. The advantage in this case is the absolute position detection of the motor position which immediately ensures, when drive enable is set, the correct assignment of current in the primary part to the magnetic field in the secondary part when the commutation offset had been determined and stored in the drive during the initial commissioning of the motor.

For some applications it is necessary to use relative motor encoders, because the available length of absolute motor encoders is limited, for example. The disadvantage in this case is that absolute detection of the motor position is impossible. It is therefore necessary, after each time the drive is switched on again or after having changed the communication phase from "PM" to "OM" ("bb" or "Ab"), to set the commutation offset again. For linear motors, this disadvantage can be removed by using an additional Hall sensor component or option, because with regard to commutation setting the relative motor encoder then behaves like an absolute motor encoder.

☞ If you use a relative motor encoder, using the additional Hall sensor component is absolutely recommended for linear Rexroth motors! In this way, you achieve highest safety with regard to correct motor function and compliance with the power data!

Concerning operationally reliable drives with synchronous third-party motors and IndraDrive controllers, there are, with regard to the selected motor encoder, the same principles applying as to synchronous Rexroth kit motors (see above); the Hall sensor box SHL02.1, however, cannot be used for linear third-party motors!

Overview of the Motor Encoders to be Used for Synchronous Motors

Motor encoder	Synchronous Rexroth kit motor (rotary, linear)	Synchronous Rexroth kit motor (linear) with SHL02 or Hall unit	Synchronous third-party motor
Absolute	+	--	+
Relative	o	+	o

+   Advantageous combination
o   Combination possible, initial commissioning might possibly require especially trained staff
--   Combination not useful

Fig.6-92:   *Possible Combinations of Motor Encoders and Synchronous Motors for which Commutation Setting is Required*

Drive Control

☞ The motor encoder 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 motor encoder, you should avoid using encoders with square-wave signals!

In the case of synchronous motors with a gearbox between motor and motor encoder (**encoder gearbox**), an absolute motor encoder usually **cannot** be evaluated **as an absolute commutation encoder** (for special cases, see below)!

For synchronous motors with a relative motor encoder in combination with an **external encoder to be evaluated in absolute form** additionally installed at the axis, the external encoder, in case the mechanical axis system is without slip, can be used as an **absolute commutation encoder** for the motor (see special case below).

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, 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, type plate

Pertinent Diagnostic Messages

- C1200 Commutation offset setting command
- C1204 Error in offset calculation
- C1208 No adjustment with asynchronous motor
- C1209 Proceed to phase 4
- C1211 Commutation offset could not be determined.
- C1212 Motion range exceeded during commutation
- C1214 Command only possible with linear synchronous motor
- C1215 Command only possible in 'bb'
- C1216 Commutation determination not selected
- C1217 Setting only possible in 'Ab'
- C1218 Automatic commutation: Current too low
- C1219 Automatic commutation: Overcurrent
- C1220 Automatic commutation: Timeout
- C1221 Automatic commutation: Iteration without result
- C1222 Error when writing offset parameters
- C1223 Command execution impossible
- C5600 Command subsequent optimization of commutation offset
- C5601 Command requires drive enable

Drive Control

- C5602 Axis blocked
- C5603 Timeout: Axis in motion
- F2032 Validation error during commutation fine adjustment
- F8010 Autom. commutation: Max. motion range when moving back
- F8011 Commutation offset could not be determined
- F8012 Autom. commutation: Max. motion range
- F8013 Automatic commutation: Current too low
- F8014 Automatic commutation: Overcurrent
- F8015 Automatic commutation: Timeout
- F8016 Automatic commutation: Iteration without result
- F8017 Automatic commutation: Incorrect commutation adjustment

Overview of Methods for Determining the Commutation Offset

Methods for Determining the Commutation Offset

The commutation offset can be determined with different methods. The method is chosen in accordance with the axis geometry, the practicability and the chances of success of the respective method depending on motor and mechanical axis system.

The following methods are possible:

- **Calculation method**

  → For relative motor encoder when using the additional Hall sensor component SHL02 (distance measurement, currentless → only possible with Rexroth linear kit motors, see documentation "Hall Sensor Box SHL02.1")

- **Measuring method**

  → For motor encoder that can be evaluated in absolute form (distance measurement, currentless → only possible with Rexroth linear kit motors)

- **Saturation method** (axis needs to be blocked or at standstill, with current)

  → Possible with all types of motor 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 motor 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:

Drive Control

Motor type	Determination method (and motor encoder that can be used)			
	Calculation method (only relative linear encoder with additional Hall sensor component or option)	Measuring method (absolute linear encoder only)	Saturation method* (absolute or relative motor encoder)	Sine-wave method* (absolute or relative motor encoder)
MBSxx0	--	--	+	o
MBSxx2 (high speed)	--	--	o	+
MBT	--	--	+	o
LSF	+ (with SHL02)	+	+	o
MLF	+ (with SHL02)	+	+	o
MCL	(not required with "Hall unit, analog" option)	+	--	o
MSP	--	--	+	o
Sy. third-party motors (rot. and lin.)	--	--	+	o

+   Recommended method
o   Method not recommended
--   Method not possible
*   See application-related restrictions

Fig.6-93:   *Recommendations for Selecting Determination Method for Commutation Offset Depending on Motor Type (for Rexroth Motors)*

☞   For MCL motors, the "Hall unit, digital" option cannot be evaluated with MPx08!

☞   The sine-wave method (generally requires unrestricted movement of axis) should only be used if the saturation method cannot be used!

Restrictions for Saturation Method

Applications of synchronous motors	Restrictions for saturation method
Third-party motors without or with only little saturation effects (e.g., ironless motors or motors with high leakage flux)	Saturation method cannot be used for determining commutation offset!
Applications with relative measuring system (without using the optimum commutation offset value with regard to the reference point)	Max. torque/force can be reduced by approx. 20% compared to the optimum value (autom. determining the commutation offset for "AF")!
Applications with relative measuring system that are using the optimum commutation offset value with regard to the reference point	Max. torque/force until reference mark is passed can be reduced by approx. 20%!

Drive Control

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 is 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)!
Drives that mustn't move during the determination of the commutation offset (low-friction axes with little inertia)	Saturation method (with current) can cause motor motion!

Fig.6-94:   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" then must not be active at the other drive!
Axis with holding brake (e.g., vertical axis)	Holding brake must be released to successfully determine the commutation offset. Only balanced axes!
Rotary axes with single drive	Only balanced axes with little friction; high inertia can cause problems!
Rotary axes, mechanically connected	See above "Linear axes in Gantry arrangement"!

Fig.6-95:   Typical Applications and Restrictions for Sine-Wave Method

Identifying the Motor Encoder

Drive Control
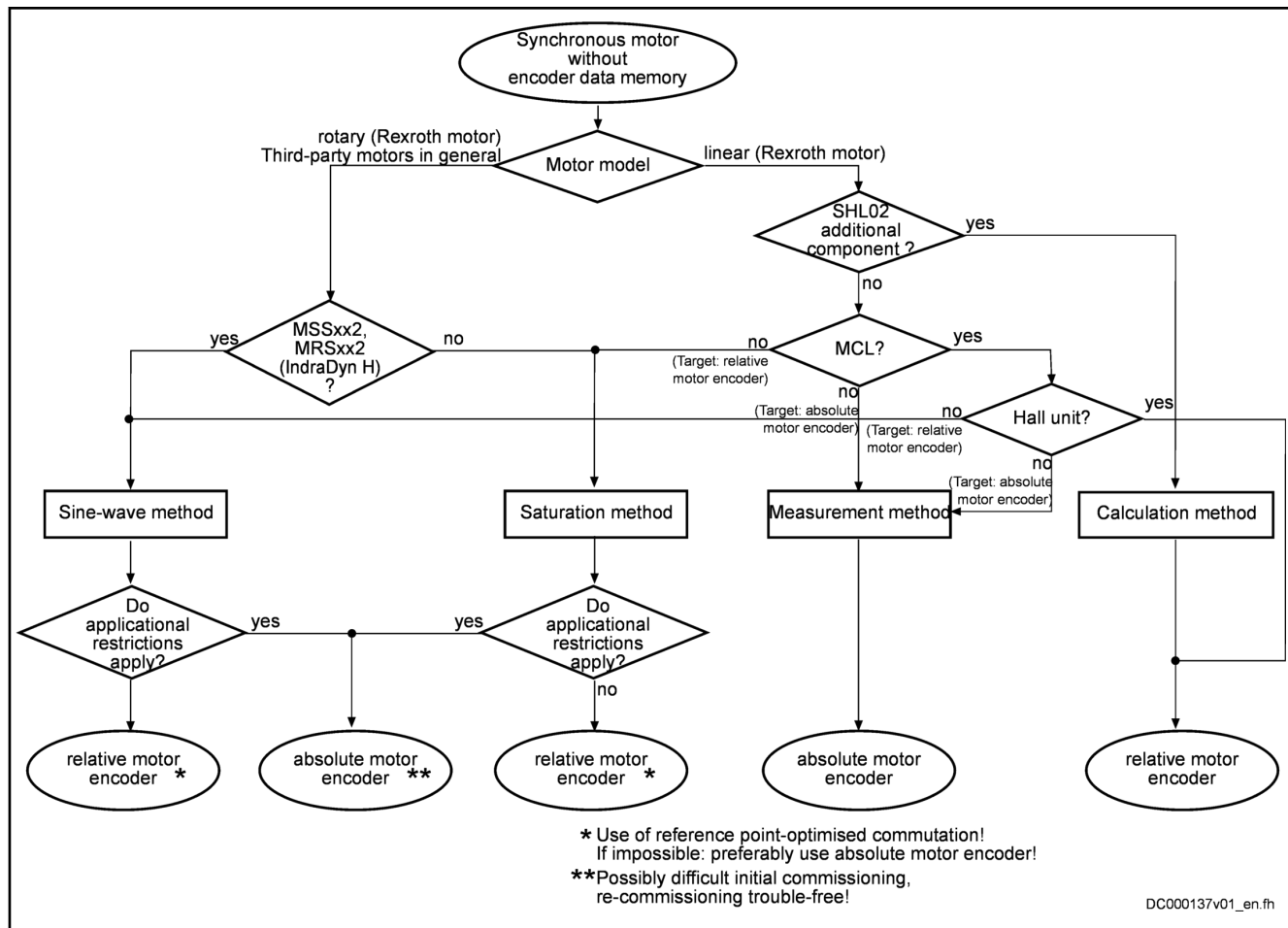
Fig.6-96:   *Identifying Absolute or Relative Motor Encoder Depending on Motor and Application-Related Restrictions*

Effect of an Encoder Gearbox

When a motor encoder to be evaluated in absolute form has been connected to a synchronous motor by means of an encoder gearbox, the assignment of electrical angle and absolute actual position value generally is not unequivocal. Therefore, the motor encoder to be evaluated in absolute form now behaves like a relative motor encoder as regards commutation.

In two special cases, however, absolute commutation encoder evaluation (rotary encoders only) is possible for synchronous motors with encoder gearbox:

- Case 1, single-turn (or multi-turn) encoder:

  - If n-fold motor revolution (n integral) causes exactly one encoder revolution

- Case 2, multi-turn encoder:

  - If exactly one motor revolution causes m-fold encoder revolution (m integral)

Effect of an External, Absolute Encoder

For synchronous motors with a relative motor encoder, the external encoder, in case the mechanical axis system is without slip, can be used as an absolute commutation encoder for the motor when an external encoder to be evaluated in absolute form is additionally installed at the axis. If this is the case, the external encoder can be assigned as commutation encoder in "P-0-0185, Control word of encoder 2 (optional encoder)". The data which then apply are those of a synchronous motor with a motor encoder that can be evaluated in absolute form.

Determining the Commutation Off-set

The active commutation offset value is contained in the parameter "P-0-0521, Effective commutation offset". Due to its relevance for the torque/force development of the motor and the operational safety, P-0-0521 as a matter of principle is write-protected.

Depending on the motor encoder used, you have to determine the commutation offset for the following situations:

- With absolute motor encoder only during **initial commissioning** of the motor

- With relative motor encoder both during **initial commissioning** of the motor and each time the drive has been switched on (**recommissioned**)

☞   For synchronous Rexroth motors with integrated motor encoder (e.g., MSK motors), initial commissioning was already carried out at the factory, the correct commutation offset value was determined and is provided in the motor encoder data memory. The user does not need to set the commutation offset!

Initial Commissioning and Recommissioning

During the initial commissioning of Rexroth kit motors and synchronous third-party motors, the commutation offset is determined during initial commissioning of the motor by means of an appropriate method made available by the drive. The quality of this determination of the commutation offset is subject to variations which can be caused by the current mechanical axis system and electromagnetic properties of the drive. But as the torque/force development of the motor mainly depends on the quality of the commutation offset value, this value should be thoroughly optimized during the initial commissioning of the motor.

For this purpose, however, it must be allowed to write the parameter "P-0-0521, Effective commutation offset", usually write-protected, so that it is possible, if required, to optimize the value manually. To optimize the value, the drive provides the "initial commissioning mode" (to be activated in "P-0-0522, Control word for commutation setting").

The optimum value of the commutation offset identified during initial commissioning is displayed in "P-0-0521, Effective commutation offset" and must also take effect after the drive has been switched on again (recommissioning). This value must be store in the proper way in the "initial commissioning mode" so that it is available for recommissioning:

- **For motors with absolute motor encoder, as well as with relative motor encoder and analog Hall sensors (SHL02 for MLF, analog Hall unit for MCL):**

  The value of the effective commutation offset (P-0-0521) is automatically stored in "P-0-0508, Commutation offset", too. When the drive is recommissioned, this stored value takes effect again. If the motor encoder has a data memory, the value of P-0-0521 is stored in "P-0-3008, Commutation offset, type plate", too.

- **For motors with relative motor encoder:**

  The value of the effective commutation offset (P-0-0521) is stored in "P-0-0508, Commutation offset"with relation to a fixed, reproducible motor or axis position. For this purpose, the appropriate actions of the drive must be carried out on the user side. When the drive is recommissioned, it is firstly the automatic commutation setting of the motor that takes place after drive enable ("AF") has been set for the first time. By the appropriate actions of the drive triggered on the user side, the value stored in P-0-0508 takes effect in an optimizing way for the automatical-

Drive Control

ly determined commutation offset (P-0-0521) as a correction value is determined and added.

☞ By the addition of a correction value, the effective commutation offset (P-0-0521), after the motor has been recommissioned, reaches the quality of the value effective during the initial commissioning of the drive. The resulting drive behavior is reproducible with regard to the torque/force development. The determination of the appropriate correction value is based on the reference mark of the motor encoder or on the dedicated position for homing the axis; therefore, the method is called "optimum commutation offset with regard to reference point".

Basic Notes on Commissioning

Explanations on Initial Commissioning

Determining the commutation offset during the initial commissioning of a synchronous motor is of particular relevance. Depending on the motor and motor encoder, there are different methods available or applicable for determining the commutation offset. The effectiveness of the determined value should be checked and, if necessary, optimized during initial commissioning.

Selecting the Method for Determining the Commutation Offset

After the motor had been selected and application-related restrictions of the methods for commutation setting had been checked, an absolute or relative motor encoder was selected and a method for commutation setting was determined. If the determined method is unknown at initial commissioning, the appropriate method can be identified by means of the selected motor and motor encoder:
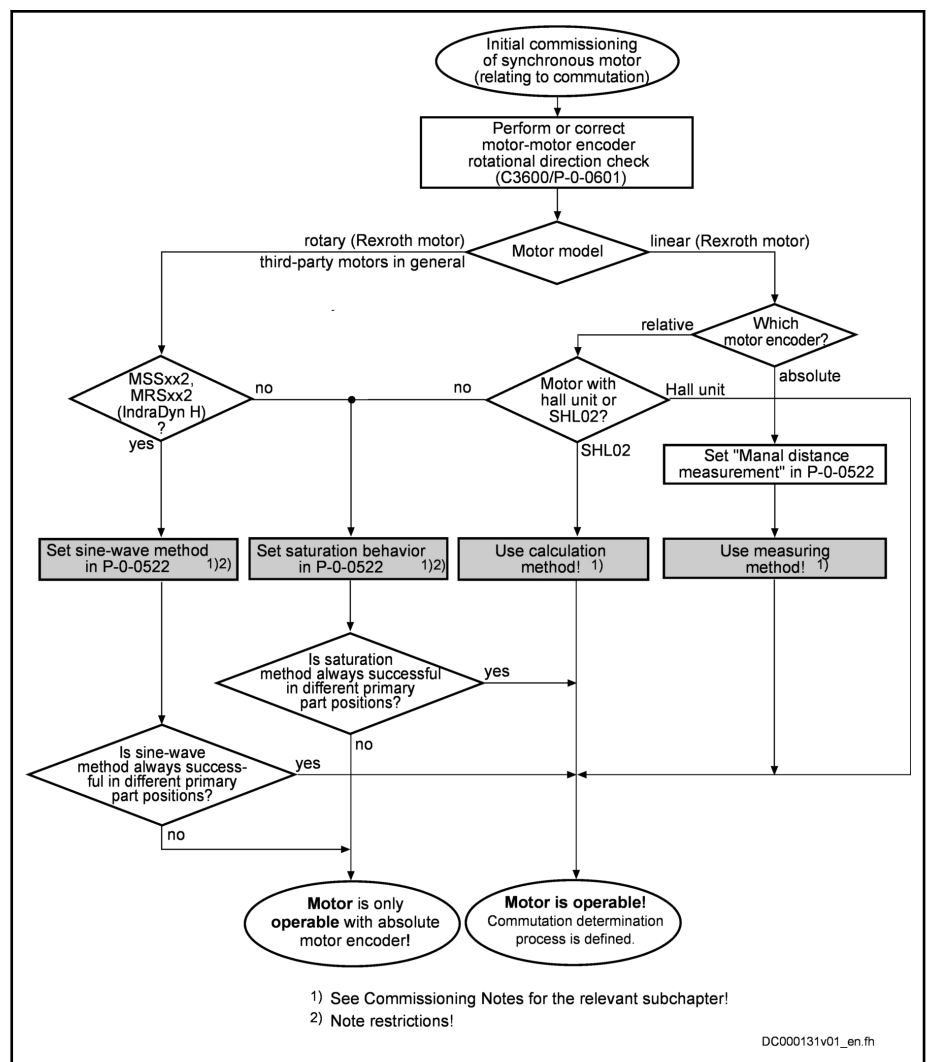
Drive Control

P-0-0521	Effective commutation offset
P-0-0522	Control word for commutation setting
P-0-0601	Configuration motor data identification

Fig.6-97: *Selecting the Method for Determining Commutation Offset During Initial Commissioning of Synchronous Motor*

Checking the Rotational Direction Motor - Motor Encoder

To successfully determine the commutation offset, it is imperative that the rotational direction of the motor matches the rotational direction of the motor encoder. This is the case, when the position feedback value of the motor encoder (S-0-0051) shows increasing position feedback values at positive torque/force command value (S-0-0080 or P-0-0049) (take possible negations of the polarity parameters into account!).

☞ If the rotational direction of the motor does not match the rotational direction of the motor encoder, the motor cannot follow the command value with the determined commutation offset. It moves to a close-by rest position or carries out uncontrolled movements. The error message F8010 might occur, but not necessarily!

The "check of the rotational direction" (C3600, configured in P-0-0601) requires a slight motors motion (approx. half an el. pole). A possibly available holding brake is released for this purpose. When an axis is at the mechanical limit stop, an error message is likely to occur!

Drive Control

☞   The "check of the rotational direction" is not suited for non-equilibrated, vertical axes! The axis will drop down when the holding brake is released after C3600 was started!

Effect of an Encoder Gearbox

In two special cases, however, for synchronous motors with encoder gear and a motor that can be evaluated in absolute form (rotary encoders only) the commutation setting is performed only during initial commissioning. Then, when the drive is switched on again, it is immediately ready for operation; automatic commutation setting for initial drive enabling (AF) is not required, so it is not performed in the following cases:

Case 1, Single-turn (or multi-turn) encoder:

- if an n-fold motor revolution (n is an integer) yields exactly one encoder revolution

Case 2, Multi-turn encoder:

- if exactly one motor revolution yields an m-fold encoder revolution (m is an integer)

Storage Procedure of the Optimum Commutation Offset

To achieve the motor's maximum torque/force development when recommissioning the drive, you first must optimize the determined commutation offset during the initial commissioning. For options and methods, see below.

The optimized value of the effective commutation offset (P-0-0521) is stored in different ways, depending on the absolute or relative encoder with active "initial commissioning mode":

- With an absolute motor encoder, directly in P-0-0508 or P-0-3008

- With a relative motor encoder, the optimized value is converted to a reproducible dedicated point fixed with reference to the motor and stored in P-0-0508
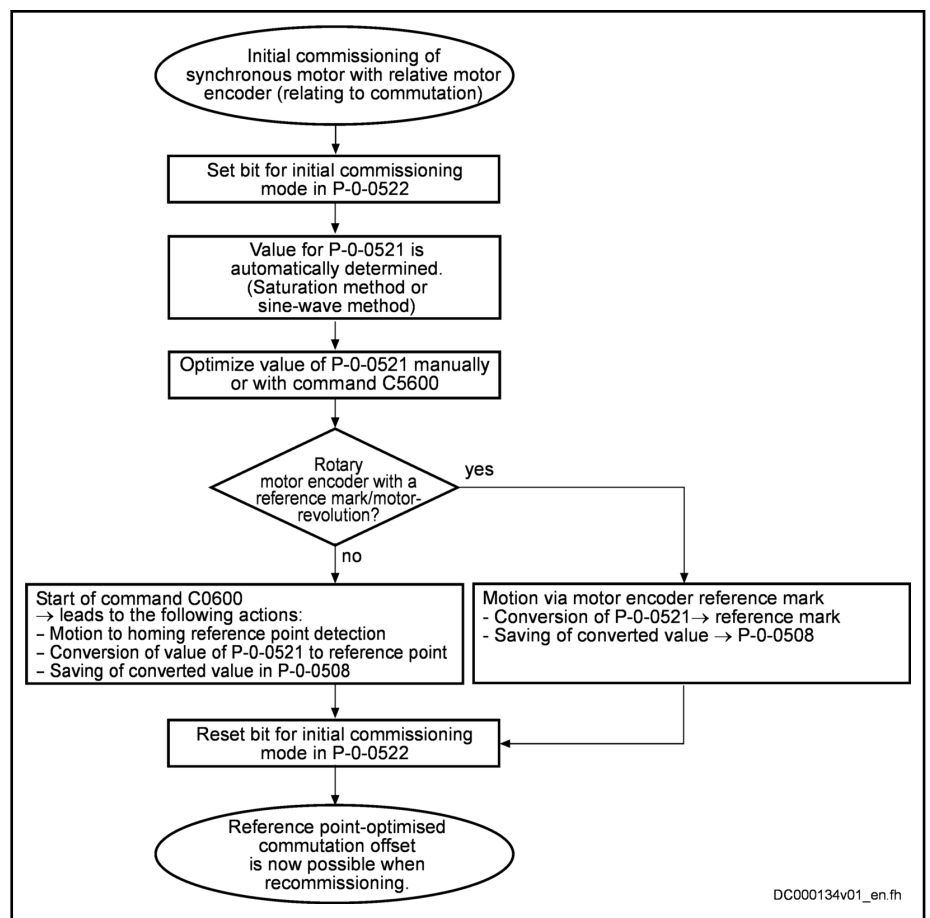
Drive Control

P-0-0521   Effective commutation offset
P-0-0522   Control word for commutation setting
P-0-0508   Commutation offset
C0600   Drive-controlled homing procedure command
C5600   Command subsequent optimization of commutation offset
Fig.6-98:   Storage Procedure of the Optimum Commutation Offset in P-0-0508
                during Initial Commissioning for Subsequently Using the "Optimum
                Commutation Offset with Regard to Reference Point" during Recom-
                missioning

Manually Optimizing the Offset Value

The automatically determined value for the commutation offset is stored in parameter "P-0-0521, Effective commutation offset". When the initial commissioning mode is active (respective bit in P-0-0522), the value of P-0-0521 can be manually optimized. Optimization should be carried out using a force measurement device.

$$(P\text{-}0\text{-}0521)_m = (P\text{-}0\text{-}0521)_a \pm 150$$

m   Manually
a   Automatically determined
Fig.6-99:   Range of Values for Optimizing the Commutation Offset

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

⇒ Before manually optimizing the commutation offset, move the axis to a noncritical position!

Drive Control

Optimizing the Offset Value by Means of Command

The value determined for "P-0-0521, Effective commutation offset" can be checked by the controller and subsequently optimized. For this purpose, use "P-0-0518, C5600 Command subsequent optimization of commutation offset". The drive must be in drive enable ("AF") and in standstill. In addition, the axis must be able to move sufficiently (motion range see table).

Motor design	Motion range	Reference
Rotary	± 10 angular degrees	Motor shaft
Linear	± 0.1 × pole pair distance	Primary part

Fig.6-100:   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.

☞ The execution of "C5600 Command subsequent optimization of commutation offset" is always recommended when there isn't any of the restrictions which are mentioned for the sine-wave method (see above)!

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

⇒ Before automatically optimizing the commutation offset, move the axis to a noncritical position and make sure axis can move!

Storing the "Optimum Commutation Offset with Regard to Reference Point"

For synchronous motors with relative motor encoder, the effective commutation offset (P-0-0521) is determined and, if necessary, optimized in the "initial commissioning mode" (P-0-0522). In order that the same quality of the commutation offset can be reproduced when the motor is recommissioned, the commutation offset is converted to a reproducible dedicated point fixed with reference to the motor and then stored in "P-0-0508, Commutation offset":

- When the drive passes the reference mark with activated "cyclic marker evaluation" (S-0-0277) in the case of motors with one reference mark per motor revolution, the controller, in "P-0-0508, Commutation offset", stores the value of P-0-0521 converted to the mark ("Optimization of the value of P-0-0521..." must have been activated in P-0-0522).

- When the drive passes the dedicated point for homing by executing "S-0-0148, C0600 Drive-controlled homing procedure command" in the case of motors with several reference marks or none per motor revolution or linear motor travel range, the controller, in "P-0-0508, Commutation offset", stores the value of P-0-0521 converted to this dedicated point ("Optimization of the value of P-0-0521..." must have been activated in P-0-0522).

☞ The reproduction of the dedicated point is realized by the reference mark of the motor encoder or the dedicated position for homing the axis. The value converted to this dedicated position is used to determine the correction value; therefore, the method was called "optimum commutation offset with regard to reference point".

Drive Control

Recommissioning a Synchronous Motor

Readiness for operation of a synchronous motor is given after switch-on (re-commissioning after initial commissioning already taken place), when the controller has determined a commutation offset value for this motor or activated a stored value.

Synchronous Motor with Absolute Motor Encoder

With absolute motor encoders and for Rexroth linear motors with relative motor encoder and SHL box, immediate readiness for operation is given. The commutation offset value (P-0-0508, P-0-3008) stored in the controller or in the motor encoder during initial commissioning is activated by applying it to parameter "P-0-0521, Effective commutation offset".

Synchronous Motor with Relative Motor Encoder

For relative motor encoders (exception: Rexroth linear motor with relative motor encoder 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 done by a method with current (for overview of methods see above "Overview of Methods for Determining the Commutation Offset"). The value is contained in parameter P-0-0521 and refers to the position of the axis at switch-on.

Optimum Commutation Offset with Regard to Reference Point

The "optimum commutation offset with regard to reference point" is active, when the optimization of the value of "P-0-0521, Effective commutation offset" was activated in "P-0-0522, Control word for commutation setting". Consequently, the value stored in "P-0-0508, Commutation offset" is compared, when the drive is recommissioned, to the value of the effective commutation offset (P-0-0521) converted to the same dedicated position, when the motor has passed the dedicated position:

- For motors with one reference mark per motor revolution: When the drive has passed the reference mark of the motor encoder ("cyclic marker evaluation" must have been activated in S-0-0277!).

- For motors with several reference marks or none per motor revolution or linear motor travel range: When the dedicated point for homing has been passed after the start of "C0600 Drive-controlled homing procedure command".

If the result of the comparison is verisimilar, the difference of the two values is added as a correction value to the current value of P-0-0521. In this way, the quality of the commutation offset now effective complies with the value stored during initial commissioning.

- For motors with one reference mark per motor revolution, as soon as the drive has passed the reference mark of the motor encoder (i.e. "cyclic marker evaluation" must have been activated in S-0-0277).

- For motors with several reference marks or none per motor revolution or linear motor travel range, as soon as the dedicated point for homing has been passed after the start of "C0600 Drive-controlled homing procedure command".

If the result of the comparison is not verisimilar, the value in parameter P-0-0508 might be wrong (e.g. inverted value). The error message "F2032 Validation error during commutation fine adjustment" is generated and the drive switches off.

☞ If it is not desired to optimize the commutation offset, the optimization can be deactivated via "P-0-0522, Control word for commutation setting". This causes the automatically determined value to remain effective and unmodified!

Drive Control

☞ By using the "optimum commutation offset with regard to refer-
ence point", the effective commutation offset (P-0-0521), after the
motor has been recommissioned, reaches the quality of the value
stored during the initial commissioning of the drive. The resulting
drive behavior is reproducible with regard to the torque/force de-
velopment!
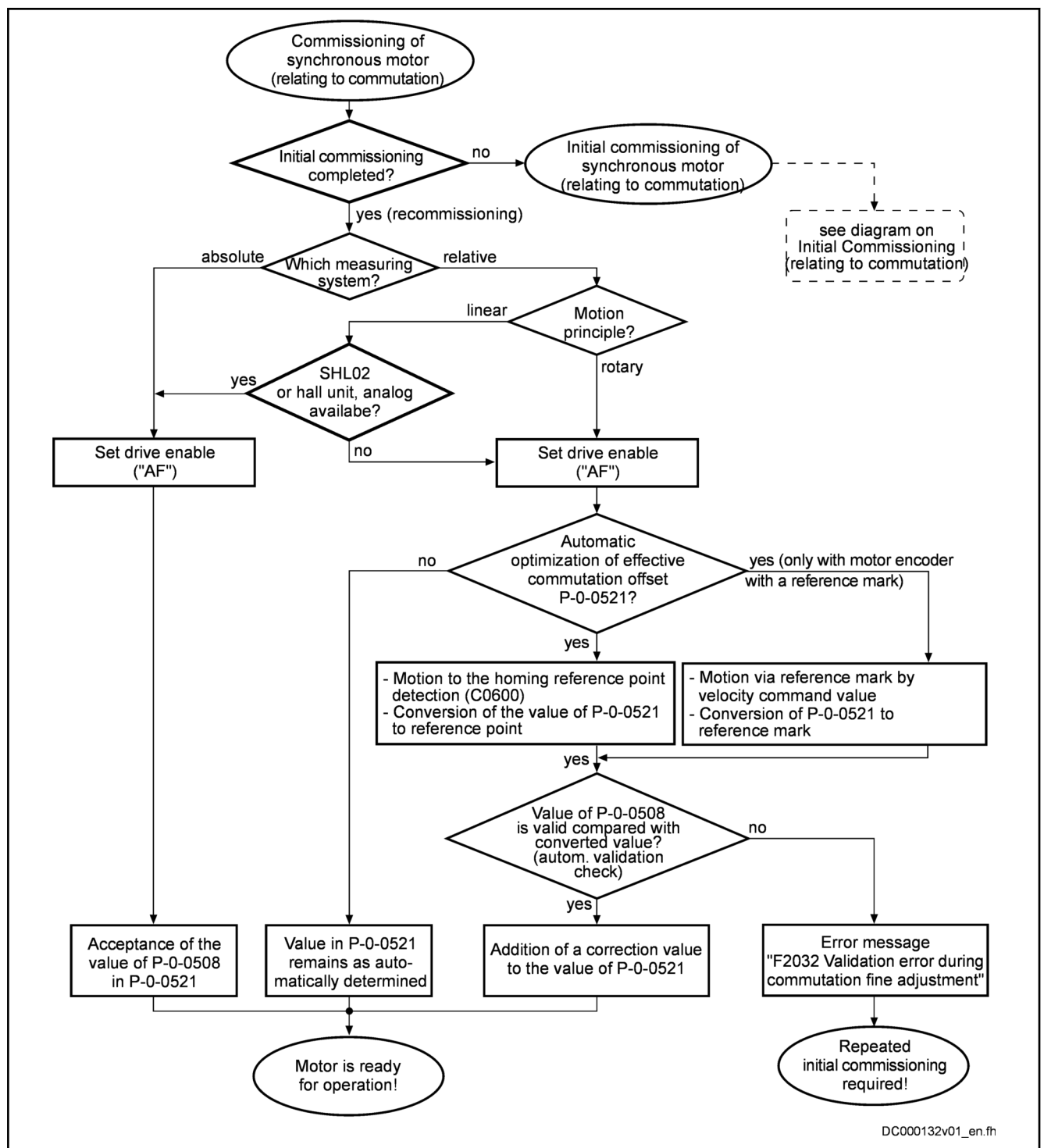
P-0-0521   Effective commutation offset
P-0-0522   Control word for commutation setting
P-0-0508   Commutation offset

Fig.6-101:   Recommissioning Procedure of a Synchronous Motor after Initial
        Commissioning has Taken Place

Drive Control

6.6.2   Commutation Setting for MLF Rexroth Motors

Brief Description

Linear Rexroth kit motors of the MLF and LSF lines are manufactured according to the "synchronous motor" functional principle. 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 SHL02.1 which was developed for linear Rexroth motors.

Hall Sensor Box SHL02.1   The Hall sensor box SHL02.1 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").

DF000221v01_nn.fh
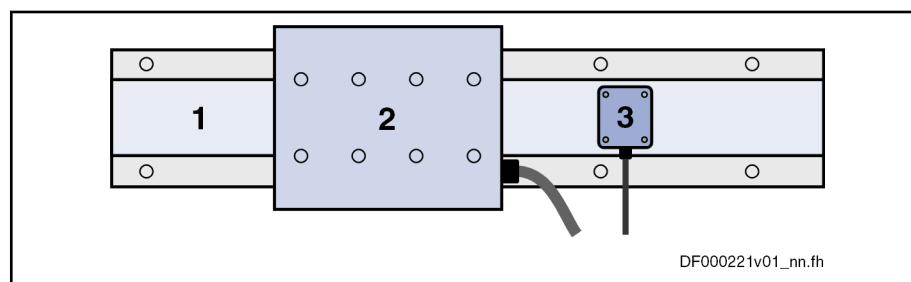
1	Secondary part
2	Primary part
3	Hall sensor box SHL02.1

Fig.6-102:   Linear Rexroth Motor with Hall Sensor Box SHL02.1

For information on mounting and connection, see the documentation on Hall Sensor Box SHL02.1.

Functional Description

Commutation Offset with Relative Motor Encoder and Hall Sensor Box SHL02.1

When using a linear Rexroth motor with relative measuring system as motor encoder and using the Hall sensor box SHL02.1, 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 SHL02.1).

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. EnDat2.1 encoder). The method is currentless, i.e.

Drive Control

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 "P-0-0522, Control word for commutation setting" for initial commissioning:

- Method for determining the commutation offset → "Currentless"
- Initial commissioning mode → "Active"

The drive must be in status "A0013 Ready for power on" ("bb").

Using the Hall Sensor Box SHL02.1

When using the Hall sensor box SHL02.1, carry out the following steps for commissioning:

1. Determine value for "P-0-0508, Commutation offset" according to documentation on hall sensor box SHL02.1 and enter it in "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 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 "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. Activation of the command parameter "P-0-0524, C1200 Commutation offset setting command"

Drive Control

3.   The determined value for the commutation offset is entered by the controller in "P-0-0521, Effective commutation offset" and accepted by "P-0-0508, Commutation offset" and "P-0-3008, Commutation offset, encoder memory".

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 P-0-0522.

6.6.3   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; it is does not require motor motion. 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 section "Basics on Commutation Setting". 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 inaccessi-

bly 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 requires motor-specific values ("P-0-0506, Amplitude for angle acquisition", "P-0-0507, Test frequency for angle acquisition"), the controller determines the commutation offset of the synchronous motor. It is therefore necessary that the generated test current causes magnetic saturation effects in the motor.

The motor-specific setting of voltage and frequency of the test current is carried out automatically when the value "0" has been entered in P-0-0506 at the start of "P-0-0524, C1200 Commutation offset setting command". The detected motor-specific 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 the diagnostic message "C1218 Automatic commutation: Current too low" should be taken!

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. Activation in "P-0-0522, Control word for commutation setting":
    *   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 the value "0" in "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

Drive Control

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. The value in "P-0-0508, Commutation offset" and/or "P-0-3008, Commutation offset, encoder memory" is now read-only.

Each time the drive is switched on again or the measuring system is initialized, the value stored in "P-0-0508, Commutation offset" and/or "P-0-3008, Commutation offset, encoder memory" is applied to "P-0-0521, Effective commutation offset" 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. Activation in "P-0-0522, Control word for commutation setting":
    - 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 the value "0" in "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,

Drive Control

Effective commutation offset". The drive now is operational. In addition, the motor-specific values for P-0-0506 and P-0-0507 were stored.

Recommendation: Optimize the commutation offset! This can be done automatically by activating "C5600 Command subsequent optimization of commutation offset", if the sine-wave method is possible without restrictions for this axis. Otherwise, the commutation offset value should be manually optimized (see section "Basics on Commutation Setting").

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-0-0506, P-0-0507, P-0-0517). Motor is supplied with current and commutation offset determined again.

    Test commutation behavior of drive at several different motor or axis positions. If it is not satisfying (deviations from P-0-0521 greater than +/-30 or "F8078 Speed loop error" at command value input), increase the value of "P-0-0517, Commutation: required harmonics component" until there are only minor deviations from P-0-0521 and the function is reliable!

6. After the force or torque development of the motor required for the axis was confirmed in the test, start "S-0-0148, C0600 Drive-controlled homing procedure command". By this command, due to the active initial commissioning mode, the value of P-0-0521 referring to an arbitrary position is converted to the position of the reference 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 the initial commissioning mode via the 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!

6.6.4   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 section "Basics on Commutation Setting". This section outlines the different methods which can be used for determining the commutation offset.

Drive Control

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 test signal the voltage and frequency of which requires 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 ±45° for rotary motors and ½ pole pair 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 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. Activation in "P-0-0522, Control word for commutation setting":
   - Initial commissioning mode
     - and -
   - Sine-wave method

2. Make presetting for automatic determination of motor-specific parameter values (P-0-0506, P-0-0507) of the test signal required for determining the commutation offset:
   - Enter the value "0" in "P-0-0506, Amplitude for angle acquisition"

3. Switch drive to operating mode ("AB"); 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

Drive Control

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 by means of respective bit. The value in P-0-0508 resp. P-0-3008 is now write-protected.

Each time the drive is switched on again or the measuring system is initialized, the value stored in P-0-0508 and/or P-0-3008 is applied to P-0-0521 and becomes effective as the commutation offset value.

Sine-Wave Method 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" in communication phase "P2" (parameter mode) activate:
   - Initial commissioning mode
     - and -
   - Sine-wave method

2. Make presetting for automatic determination of motor-specific parameter values (P-0-0506, P-0-0507) of the test signal required for determining the commutation offset:
   - Enter the value "0" in "P-0-0506, Amplitude for angle acquisition"

3. Switch drive to operating mode ("AB"); start sine 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 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:

Drive Control

- 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 the active initial commissioning mode, the value of P-0-0521 referring to an arbitrary position is converted to the position of the reference 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! The value in P-0-0508 resp. P-0-3008 is now write-protected.

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!

6.7   Limitations

6.7.1   Overview of Limitations

To protect the mechanical axis system, the controllers and the motors against overload, IndraDrive devices have different possibilities of limitation:

- Torque/Force Limitation
  – Axis-side torque/force limit values, depending on the preceding sign
  – Axis-side torque/force limit values, related to the absolute value (independent of the preceding sign)

- Current Limitation
  – Absolute current limit values, depending on controller or motor
  – Dynamic current limitation, depending on the thermal load of controller or motor

- Velocity limitation
  – Motor-side velocity limit values
  – Axis-side velocity limit values

- Position limitation
  – Evaluation of axis-side travel range limit switches
  – Firmware-side travel range limit values

The existing limiting facilities are active depending on the method of motor control.

Drive Control

Voltage-Controlled Open-Loop Operation (U/f Control)	With voltage-controlled, sensorless open-loop operation, the following limitations are available to protect the device or motor:

- Torque/force limitation via stall protection loop

- Current limitation via current limitation loop

- Position limitation by
    - Travel range limit switches
    - Software limit switches

Closed-Loop Operation of Motors (FXC, FOC, FOCsl)	In closed-loop operation (flux-controlled or current-controlled), there are the following parameterizable limitations to protect the device or motor:

- Torque/Force Limitation

- Current Limitation

- Velocity limitation

- Position limitation by
    - Travel range limit switches
    - Software limit switches

6.7.2   Current and Torque/Force Limitation

Brief Description

Current limitation and torque/force limitation avoid mechanical overload of the axis and thermal overload of motor and controller.

Torque/force limit values due to axis conditions and processing take effect statically as positive and negative limits of the torque/force command value. The thermal overload protection might possibly reduce these limits dynamically, depending on the current thermal load of motor and controller.

Features
- User-side limit values for torque/force (drive-internally converted to current limit values):
    - Bipolar limit values (S-0-0092, P-0-0109)
    - Unipolar limit values (S-0-0082, S-0-0083)

- Display of the current torque/force command value in "P-0-0049, Effective torque/force command value"

- Display of the process torque or process force in "S-0-0084, Torque/force feedback value"

- Drive-side, absolute current limit values in "S-0-0110, Amplifier peak current" and "S-0-0109, Motor peak current"

- Dynamic current limitation depending on work load reduces maximum current to the thermally allowed continuous current on the basis of motor and amplifier temperature model (depending on motor type and possibly selected cooling type, as well as on PWM frequency and amplifier type); currently available maximum current and thermally possible continuous current displayed in the parameters:
    - P-0-4045, Maximum possible continuous current
    - P-0-4046, Effective peak current

- Resulting torque/force limit values from the user-side torque/force limitations and the (dynamic) current limitation depending on work load are displayed in the parameters:
    - P-0-0442, Actual value torque limit positive (stationary)
    - P-0-0443, Actual value torque limit negative (stationary)

Drive Control

- – P-0-0444, Actual value peak torque limit
- Status word for analysis of the currently active torque/current limitation (P-0-0445)
- Display of effective torque-generating current command value ("limited" current command value) in parameter
  - – P-0-0038, Torque-generating current, command value
- Display of actual current values in the parameters
  - – P-0-0440, Actual output current value (absolute value)
  - – P-0-0043, Torque-generating current, actual value
  - – P-0-0044, Flux-generating current, actual value

Pertinent Parameters
- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0109, Motor peak current
- S-0-0110, Amplifier peak current
- S-0-0111, Motor current at standstill
- S-0-0112, Amplifier nominal current
- S-0-0384, Amplifier temperature
- P-0-0001, Switching frequency of the power output stage
- P-0-0038, Torque-generating current, command value
- P-0-0049, Effective torque/force command value
- P-0-0051, Torque/force constant
- P-0-0109, Torque/force peak limit
- P-0-0141, Thermal drive load
- P-0-0440, Actual output current value (absolute value)
- P-0-0441, Drive load warning threshold
- P-0-0442, Actual value torque limit positive (stationary)
- P-0-0443, Actual value torque limit negative (stationary)
- P-0-0444, Actual value peak torque limit
- P-0-0445, Status word torque/current limit
- P-0-0556, Config word of axis controller
- P-0-0640, Cooling type
- P-0-4034, Thermal time constant of winding
- P-0-4035, Thermal time constant of motor
- P-0-4037, Thermal short-time overload of winding
- P-0-4045, Maximum possible continuous current
- P-0-4046, Effective peak current
- P-0-4058, Amplifier type data
- P-0-4059, Electric type data of power section

Pertinent Diagnostic Messages
- E2050 Device overtemp. Prewarning
- E2051 Motor overtemp. prewarning
- E2056 Torque limit = 0

Drive Control

- E2061 Device overload prewarning
- E8055 Motor overload, current limit active
- E8057 Device overload, current limit active
- F2018 Device overtemperature shutdown
- F2019 Motor overtemperature shutdown
- F2021 Motor temperature monitor defective
- F2022 Device temperature monitor defective

Torque/Force Limitation

The torque/force limit can be freely parameterized by the user and provides bipolar and unipolar limits.

Parameters for bipolar limits:

- S-0-0092, Bipolar torque/force limit value
- P-0-0109, Torque/force peak limit

Parameters for unipolar limits:

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative

☞   It is always the lowest value of the torque/force limit values entered in the parameters S-0-0082, S-0-0083, S-0-0092 or P-0-0109 that takes effect!

Depending on the method of motor control, the torque/force limitation influences the control of the motor in different ways.

Motor Control Methods FOC, FOCsl, FXC

In closed-loop motor operation, the unipolar torque limitation takes effect on the torque command value output by the velocity loop. The bipolar torque/force limitation takes effect on the value limited in unipolar form, including possibly added feedforward values.

In addition to the user-side static limit values, the current limitation takes effect dynamically, via "P-0-4046, Effective peak current" on the resulting torque/force limit values (converted via "P-0-0051, Torque/force constant").

Drive Control
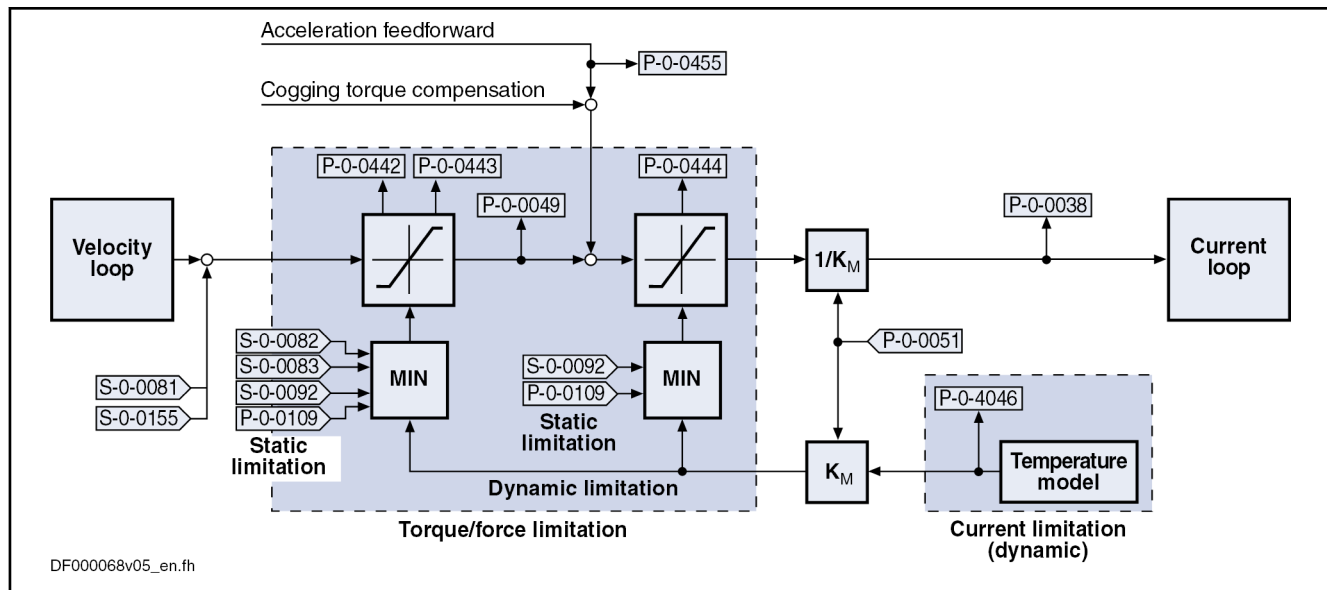
S-0-0081	Additive torque/force command value
S-0-0082	Torque/force limit value positive
S-0-0083	Torque/force limit value negative
S-0-0092	Bipolar torque/force limit value
S-0-0155	Friction compensation
P-0-0038	Torque-generating current, command value
P-0-0049	Effective torque/force command value
P-0-0051	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.6-103:   Torque/Force Limitation with the Motor Control Methods FOC, FOCsl and FXC

U/f Control   In voltage-controlled, sensorless motor operation (U/f), the torque limitation only takes effect on the stall protection loop. The static negative and positive torque limit values are generated from the lowest values of the torque/force limit values entered in S-0-0082, S-0-0083, S-0-0092 or P-0-0109.

In addition to the user-side static limit values, the current limitation takes effect dynamically, via "P-0-4046, Effective peak current" on the resulting torque/force limit values (converted via "P-0-0051, Torque/force constant").

Drive Control
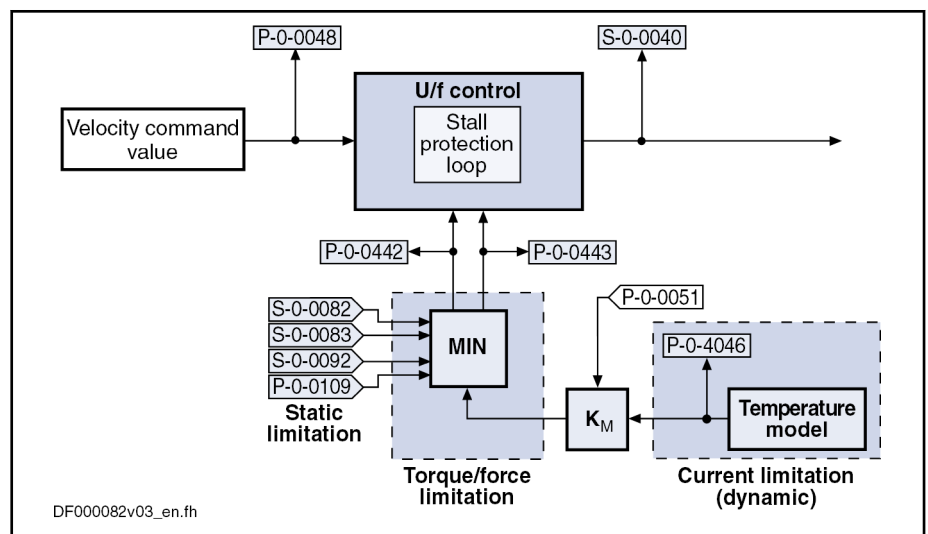
S-0-0040	Velocity feedback value
P-0-0048	Effective velocity command value
P-0-0051	Torque/Force Constant
P-0-0442	Actual value torque limit positive (stationary)
P-0-0443	Actual value torque limit negative (stationary)
P-0-4046	Effective peak current

Fig.6-104:   Torque/Force Limitation in Sensorless U/f Operation of the Motor

Current Limitation

Principles of Current Limitation

☞ The current limitation cannot be parameterized by the user; it takes effect automatically and protects the motor and the amplifier against inadmissible load.

We basically distinguish the following principles of current limitation:

- **Absolute current limitation** (depending on maximum possible currents and continuous currents of motor and drive controller)
- **Dynamic peak current limitation** (depending on work load, realized by motor and amplifier temperature models)

Absolute Current Limitation

The figure below illustrates the generation of the maximum values for continuous current and peak current from the motor- and controller-specific current data (without thermal load of motor and controller).

Drive Control
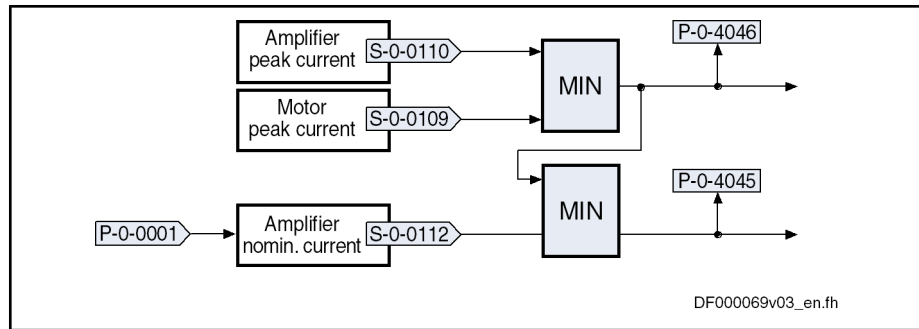
S-0-0110	Amplifier peak current
S-0-0109	Motor peak current
S-0-0112	Amplifier nominal current
P-0-0001	Switching frequency of the power output stage
P-0-4045	Maximum possible continuous current
P-0-4046	Effective peak current

Fig.6-105:   Generating the Maximum Values for Continuous Current and Peak Current

Maximum Possible Continuous Current (P-0-4045)

The maximum possible continuous current (P-0-4045) is the minimum value from the maximum allowed continuous current of the controller (S-0-0112, Amplifier nominal current) and the effective peak current (P-0-4046, Effective peak current).

The nominal current of the amplifier (S-0-0112, Amplifier nominal current) basically depends on the switching frequency of the power section (P-0-0001). With a setting of 12 kHz or 16 kHz in "P-0-0001, Switching frequency of the power output stage", the currently effective switching frequency can be reduced depending on the work load. This increases the allowed continuous current compared to the value at a higher switching frequency (see below "Continuous Current of Controller Depending on Work Load at PWM of 12 kHz or 16 kHz"). However, this increase in the continuous current, just like the reduction of the continuous current at motor standstill, is not displayed in "P-0-4045, Maximum possible continuous current".

Effective Peak Current (P-0-4046)

The output current of the controller is dynamically limited, depending on the thermal load of the motor or controller. The current limit value is displayed in "P-0-4046, Effective peak current". The maximum value results from the minimum of the values of "S-0-0109, Motor peak current" and "S-0-0110, Amplifier peak current".

Dynamic Current Limitation

With dynamic current limitation, the thermal load of controller and motor is determined by means of temperature model calculation, depending on the value in "P-0-0440, Actual output current value (absolute value)" and the duration of effectiveness of this current. Due to the current load, the maximum possible amplifier current or motor current can be limited to the continuously possible current (continuous current):

- **Limitation of amplifier current**

  It is used to protect the drive controller against overload. The firmware-side temperature model calculation takes place on the basis of the amplifier type data determined by the hardware.

  Note: The amplifier type data are determined at the factory and stored in "P-0-4058, Amplifier type data" on the power section.

- **Limitation of motor current**

It is used for overload protection of the motor with peak load and short-time overload operation. The firmware-side temperature model calculation takes place on the basis of motor-specific temperature model data.

Note: In addition, the temperature sensor of the motor might possibly support thermal overload protection (continuous current, rms current).
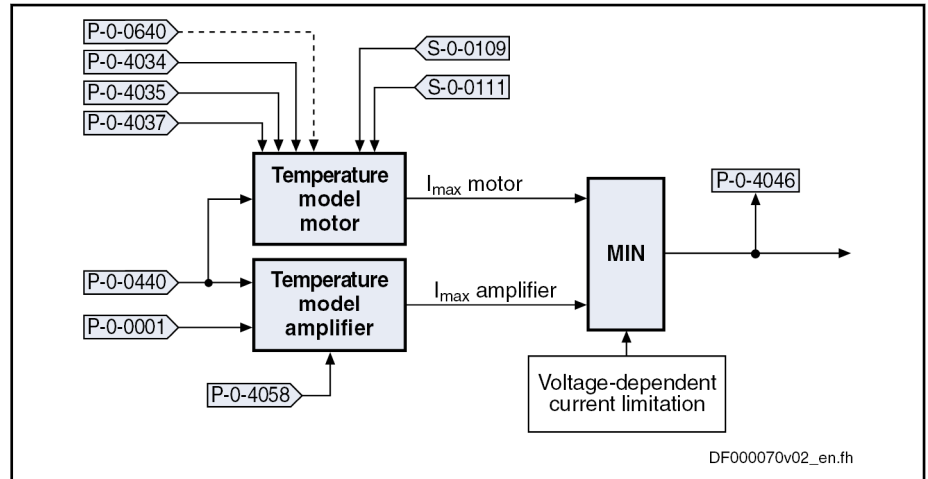
S-0-0109	Motor peak current
S-0-0111	Motor current at standstill
P-0-0001	Switching frequency of the power output stage
P-0-0440	Actual output current value (absolute value)
P-0-0640	Cooling type
P-0-4034	Thermal time constant of winding
P-0-4035	Thermal time constant of motor
P-0-4037	Thermal short-time overload of winding
P-0-4046	Effective peak current
P-0-4058	Amplifier type data

Fig.6-106:   Generating the Dynamic Peak Current Limit Value (Temperature Model)

Properties   Basic properties of dynamic current limitation:

- The value taking effect is always the lowest value resulting from motor current or amplifier current limitation.

- The currently maximum possible continuous current is displayed in P-0-4045, the effective peak current in P-0-4046.

Depending on the method of motor control, the current limitation influences the control of the motor in different ways.

Motor Control Methods FOC, FOCsl, FXC   In closed-loop motor operation, the current limitation, via the value of parameter "P-0-4046, Effective peak current", possibly takes a reducing effect on the user-side, static torque/force limit values. The dynamic torque/force limit value resulting from the value of P-0-4046 is determined via "P-0-0051, Torque/force constant".

The current (limited) torque/force command value is displayed in P-0-0049, the corresponding torque-generating command current in parameter P-0-0038.

U/f Control   In voltage-controlled, sensorless motor operation (U/f), the current limitation takes effect on the current limitation loop and the stall protection loop:

- For the **current limitation loop**, the effective peak current (P-0-4046) is the limit value to which the actual output current value (P-0-0440) is limited by reducing the motor voltage by means of a control process.

Drive Control

- For the **stall protection loop**, the current limitation, in addition to the user-side static limit values, takes effect dynamically via the effective peak current (P-0-4046) on the resulting positive and negative torque/force limit values (P-0-0442, P-0-0443) (converted via "P-0-0051, Torque/force constant").

☞ The static negative and positive torque limit values are generated from the lowest values of the torque/force limit values entered in S-0-0082, S-0-0083, S-0-0092 or P-0-0109.

Motor Temperature Model The value "P-0-4046, Effective peak current" is only generated by the motor temperature model, if the controller has been sufficiently dimensioned compared to the motor. When the motor has not been thermally preloaded, the following curve results at full motor load:
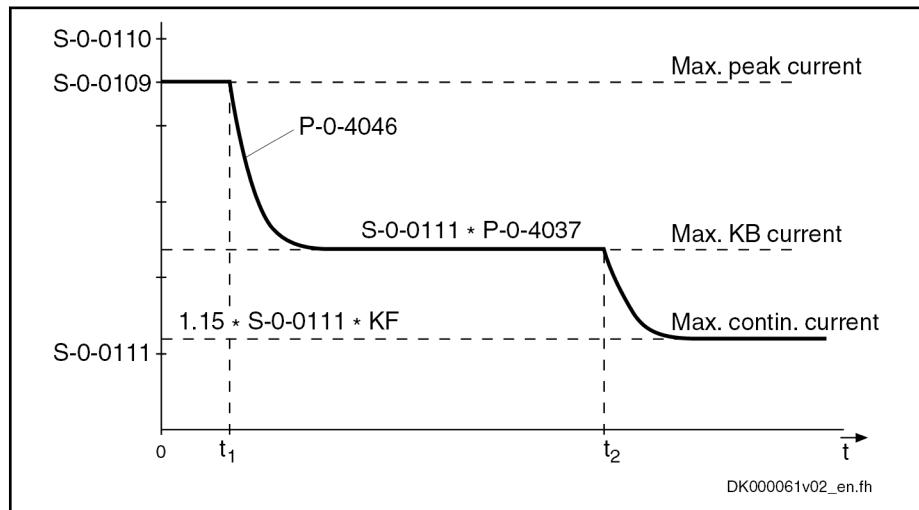
S-0-0109	Motor peak current
S-0-0110	Amplifier peak current
S-0-0111	Motor current at standstill
P-0-4037	Thermal short-time overload of winding
P-0-4046	Effective peak current
t_1	Max. duration after which the motor temperature model reduces to the max. KB current
t_2	Max. duration after which the motor temperature model reduces to the max. continuous current
KB	Short-time operation (KB = "Kurzzeitbetrieb")
KF	Cooling type factor (see note below)

Fig.6-107:   *Curve of Effective Peak Current (P-0-4046) at Motor Load, Generated by Motor Temperature Model*

Depending on the load current of the motor, the times t_1 or t_2 can be determined. They apply to motors which have not been thermally loaded and therefore are theoretical maximum values. In motor operation, t_1 and t_2 depend on the following factors:

- Motor-controller combination
- Thermal preload of drive
- Load cycle

The time t_1 applies to load currents greater than, the time t_2 to load currents smaller than the maximum allowed short-time operation current. The values are determined according to the following formula:

Drive Control

$$t_1 = -\ln\left[1 - \left(\frac{(P\text{-}0\text{-}4037) \times (S\text{-}0\text{-}0111)}{I_{L1}}\right)^2\right] \times (P\text{-}0\text{-}4034)$$

$$t_2 = -\ln\left[1 - \left(\frac{1{,}15 \times KF \times (S\text{-}0\text{-}0111)}{I_{L2}}\right)^2\right] \times \frac{(P\text{-}0\text{-}4035)}{KF}$$

t_1	Max. duration after which the motor temperature model reduces to the max. KB current
t_2	Max. duration after which the motor temperature model reduces to the max. continuous current
I_{L1}	Assumed load current (> max. KB current)
I_{L2}	Assumed load current (max. continuous current < I_L2 < max. KB current)
S-0-0111	Motor current at standstill
P-0-4034	Thermal time constant of winding
P-0-4035	Thermal time constant of motor
P-0-4037	Thermal short-time overload of winding
KF	Cooling type factor (see note below)
Fig.6-108:	*Calculating the Time for the Effective Peak Current (at Starting Condition "Motor has not Been Thermally Loaded")*

☞ The **cooling type factor** depends on the cooling type and the resulting setting of "P-0-0640, Cooling type" (see also Parameter Description):

- 1.0 → For Standard Cooling (MAD, MAF, MBT, MBS, 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)

Amplifier Temperature Model In addition to the motor temperature model, the value of "P-0-4046, Effective peak current" is limited by the amplifier temperature model. The variables of the model calculation are:

- Chronological sequence of "P-0-0440, Actual output current value (absolute value)"

- P-0-4058, Amplifier type data

- P-0-0001, Switching frequency of the power output stage

- Output frequency of the motor voltage

The value of "S-0-0112, Amplifier nominal current" (maximum continuous current of the controller) depends on the setting in "P-0-0001, Switching frequency of the power output stage". At motor standstill (below an output frequency threshold), however, the allowed continuous current value is reduced, compared to the value of S-0-0112, by the temperature model calculation (dynamic reduction of continuous current at motor standstill). At the corresponding motor load, the value of "P-0-4046, Effective peak current" falls below the value of S-0-0112 (unless the motor is the current-limiting component!).

ℹ️ The current data of the amplifiers (power sections of the IndraDrive controllers) for continuous and cyclic load are contained in the separate documentation "Supply Units and Power Sections; Project Planning Manual".

Drive Control

☞ The physical data of motor-controller combinations for servo, main drive and S1 print applications can be retrieved via the selection list program "DriveSelect" (Intranet). "DriveSelect" takes the influence of the motor and amplifier temperature models into account!

Continuous Current of Controller Depending on Work Load at PWM of 12 kHz or 16 kHz

The continuous current of the controller is reduced as the switching frequency of the power output stage (PWM frequency) is increased. When the value in "P-0-0001, Switching frequency of the power output stage" has been set to 12 kHz or 16 kHz, it is possible, however, to reduce the switching frequency depending on the thermal load of the controller. This reduces the thermal load of the power output stage and increases the allowed continuous current of the controller. The respective setting is made in "P-0-0556, Config word of axis controller". This causes the following behavior:

- If the value of "P-0-0141, Thermal drive load" rises to the value set in "P-0-0441, Drive load warning threshold", the switching frequency is internally reduced to 8 kHz. The message "E2061 Device overload prewarning" is generated.

- If the value of "P-0-0141, Thermal drive load" falls below a controller-specific threshold, the value of the switching frequency entered in P-0-0001 takes effect again. The warning "E2061 Device overload prewarning" disappears.

☞ The reduction of the switching frequency depending on the work load only influences the allowed continuous current of the controller. The maximum output current remains at the value belonging to the switching frequency set in P-0-0001! The respective documentations of the power sections contain the current data related to the controller (see "Supply Units and Power Sections; Project Planning Manual").

When the default values for the control loop parameters are loaded ("RL" or command C07_0), the values of the current loop parameters, which have been stored in the encoder data memories of the motors and relate to the PWM frequency of 4 kHz, are converted to the value set in P-0-0001. When the option "reduction of switching frequency depending on work load" has been activated, conversion to the reduced switching frequency takes place!

☞ In the case of manual optimization of the current loop parameters, select the lower switching frequency (PWM). For this purpose enter the value "0" in "P-0-0441, Drive load warning threshold", before optimizing!

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.

☞   "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 Parameter Description P-0-0445). As soon as a limit value has been reached, the respective bit is set. This allows immediately recognizing the limiting value and identifying limits possibly parameterized incorrectly.

To protect the amplifier or drive controller and motor, monitoring functions have been implemented that can activate, in conjunction with the current and torque limitation, the warnings and error messages listed below.

Warnings   General:

- E2056 Torque limit = 0

Device-specific warnings:

- E2050 Device overtemp. Prewarning
- E2061 Device overload prewarning
- E8057 Device overload, current limit active

Motor-specific warnings:

- E2051 Motor overtemp. prewarning
- E8055 Motor overload, current limit active

Error Messages   Device-specific error messages:

- F2018 Device overtemperature shutdown
- F2022 Device temperature monitor defective

Motor-specific error messages:

- F2019 Motor overtemperature shutdown
- F2021 Motor temperature monitor defective

6.7.3   Velocity Limitation

Brief Description

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
- S-0-0113, Maximum motor speed
- P-0-0113, Bipolar velocity limit value of motor

Pertinent Diagnostic Messages
- E2059 Velocity command value limit active

Drive Control

- E2063 Velocity command value > limit value
- F8079 Velocity limit value exceeded

Functional Description

The figure below illustrates the functional principle of velocity limitation:
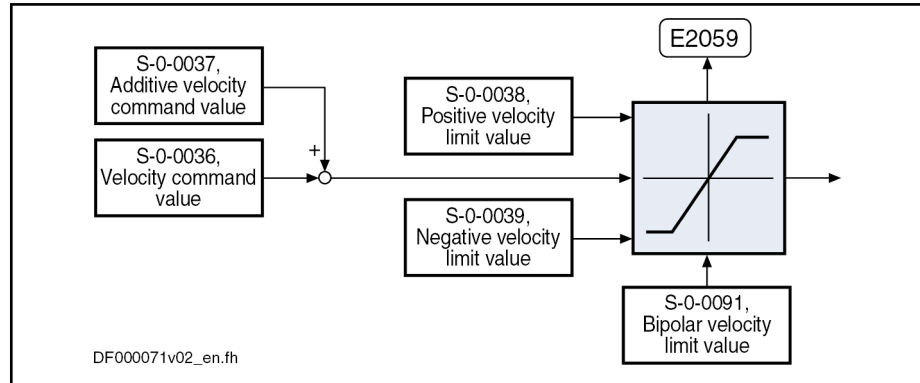
E2059   Velocity command value limit active
Fig.6-109:   Functional Principle of Velocity Limitation

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"
- **In addition, the following motor-related limit values take effect**
  - P-0-0113, Bipolar velocity limit value of motor
  - S-0-0113, Maximum motor speed
-

☞   The limits have to be adjusted to the mechanical properties! When determining the data, you have to take into account that all velocity command values are thereby limited to this value.

This has to be taken into consideration when defining the travel profiles (target position, velocity and acceleration), because an inadmissible lag error can possibly occur due to the limitation that is taking effect.

☞   The default value for S-0-0038 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 "E2059" warning is displayed.
- E2063 Velocity command value > limit value

  "S-0-0036, Velocity command value" is limited to the effective positive

Drive Control

and negative velocity limit, when the value in S-0-0036 is higher than this limit. In this case, the warning "E2063" is generated.

- F8079 Velocity limit value exceeded

  The value of the parameter "S-0-0040, Velocity feedback value" is monitored as soon as it is outside of the standstill window S-0-0124. When it exceeds the 1.125-fold effective positive or negative velocity limit, the error message "F8079" is generated.

6.7.4   Position Limitation/Travel Range Limit Switches

Brief Description

To avoid accidents and damages to the machine, comprehensive preventive safety precautions are provided. Part of these safety precautions is the limitation of the allowed working range (travel range) by the drive. For this purpose, position monitoring functions and position limitations have been implemented in the drive.

⚠ CAUTION	The travel range monitoring function (travel range limit switches or software limit switches) only fulfills the requirements for protecting machinery, but is not sufficient for personal protection!

Realizing Travel Range Monitoring   The drive provides two possibilities of determining and monitoring a limitation of the working range (travel range):

- Monitoring of **position limit values (software limit switches)**

  Monitoring of the motor position for exceeding one of the two position limit values (positive/negative → S-0-0049/S-0-0050) by the homed actual position value (S-0-0403), i.e. value related to the machine zero point

- Monitoring of **travel range limit switches**

  Monitoring for activation of one of the two travel range limit switches (Limit+, Limit-) that are connected to the digital inputs of the drive

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☞   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
- Monitoring of 2 travel range limit switches (Limit+, Limit-) at the drive is possible
- Signal behavior of travel range limit switches can be set (N/C-N/O)
- Activation of travel range limit switches via parameter
- Reaction (error/warning) when exceeding travel range can be set
- Status display of the 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

Drive Control

- Reaction (warning/error) when exceeding can be set
- Activation of position limit values via parameter
- Automatic relation 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-0-0119, Best possible deceleration
- P-0-0222, Travel range limit switch inputs

Pertinent Diagnostic Messages
- E2053 Target position out of travel range
- E8029 Positive position limit exceeded
- E8030 Negative position limit exceeded
- E8042 Both travel range limit switches activated
- E8043 Positive travel range limit switch activated
- E8044 Negative travel range limit switch activated
- F6029 Positive position limit exceeded
- F6030 Negative position limit exceeded
- F6042 Both travel range limit switches activated
- F6043 Positive travel range limit switch activated
- F6044 Negative travel range limit switch activated

Travel Range Limit Switches

At the drive, 2 travel range limit switches (Limit+, Limit-) can be connected and monitored; they can be connected to the digital inputs at the control section.

☞ The travel range limit switch inputs are polled every 2 ms so that the assigned error reaction is started at the earliest approx. 3 ms after the limit switch has been activated.

Activating the Monitoring Function

Monitoring for exceeding the travel range limit switches is only carried out when the monitor was activated via bit 1 of "P-0-0090, Travel range limit parameter".

Reaction when Exceeding the Travel Range

The reaction of the drive when the travel range has been exceeded can be set via bit 2 von "P-0-0090, Travel range limit parameter".

Exceeding Travel Range as an Error

When "0" has been entered in bit 2 of 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.

Drive Control

See also "Velocity Command Value Reset" in section "Error Reactions: Best Possible Deceleration"

Exceeding Travel Range as a Warning

When "1" has been entered in bit 2 of P-0-0090, exceeding the travel range is handled as a warning with the reaction in accordance with the configuration in "P-0-0119, Best possible deceleration".

Drive behavior:

- The drive does not switch off the internal drive enable signal.

- As long as the warning condition is present, i.e. the limit switch is activated, only such command values are accepted that lead back to the allowed range. The command value check depends on the active operation mode (see "Notes on Commissioning" below).

See also "Velocity Command Value Reset" in section "Error Reactions: Best Possible Deceleration"

Position Limit Values (Software Limit Switches)

Parameters for Position Limit Values

The following parameters are available to set the travel range via position limit values:

- S-0-0049, Positive position limit value
- S-0-0050, Negative position limit value

☞ The position limit values are monitored every 2 ms so that the corresponding error reaction is started at the earliest approx. 3 ms after the position limit has been exceeded.

Requirements for Activating the Function

Requirements for using (activating) the position limit value monitoring function:

- The position data reference of the drive must have been established (i.e. the encoder system of the active operation mode must be in reference). The status bit in "S-0-0403, Position feedback value status" then is "1".

- Monitoring of the position limit values has been activated in "S-0-0055, Position polarities" (bit 4 = 1).

Dedicated Point for Monitoring the Position Limit Values

When 2 measuring systems are used, the drive, for position limit value monitoring, automatically refers to the measuring system that has been homed.

☞ When two measuring systems are used and both are in reference, the encoder selected in S-0-0147 (bit 3) is used.

Exceeding the Position Limit Values

Exceeding the position limit values is detected when the actual position value of the active operation mode is outside the travel range defined by the position limit values.

Reaction when Exceeding Position Limit Values

The reaction of the drive when the position limit values have been exceeded can be set via bit 2 von "P-0-0090, Travel range limit parameter".

Exceeding Position Limit Values as an Error

When "0" has been entered in bit 2 of 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"

Drive Control

Exceeding Position Limit Values as a Warning

When "1" has been entered in bit 2 of P-0-0090, exceeding the position limit value is handled as a warning with the reaction in accordance with the configuration in "P-0-0119, Best possible deceleration".

Drive behavior:

- The drive does not switch off the internal drive enable signal.
- As long as the warning condition is present, i.e. the limit switch is activated, only such command values are accepted that lead back to the allowed range. The command value check depends on the active operation mode (see "Notes on Commissioning" below).

See also "Velocity Command Value Reset" in section "Error Reactions: Best Possible Deceleration"

Leaving the Inadmissible Travel Range

After the allowed travel range has been exceeded, the command values are checked for validity and only such command values are accepted that lead back to the allowed travel range.

☞   Moving to the allowed travel range is also possible in the case of error!

Notes on Commissioning

When parameterizing the position limit values, take the positions of the travel range limit switches into account. The working range defined with the two position limit values (S-0-0049, S-0-0050) should be within the working range defined with the travel range limit switches. As long as the position data reference has not been established yet (axis not homed), the function of the software limit switches (position limit values) is not yet guaranteed. Independent thereof is the function of the travel range limit switches that always causes the drive to be switched off when the defined limit is exceeded and therefore avoids collision (machine protection).
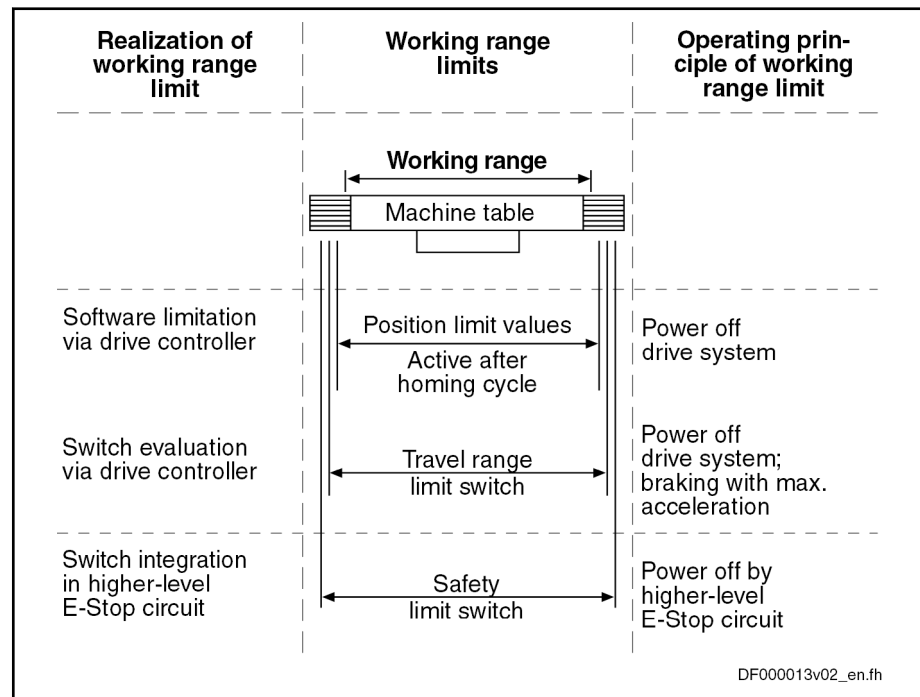
Fig.6-110:   Realizations and Operating Principles of Working Range Limitations

Drive Control

☞ The safety limit switches that can be included in the E-Stop circuit (see separate documentation "Project Planning Manual for Power Sections"), are the last safeguard by the drive. In addition, the control master can monitor the position limit values.

Activating the Position Limit Value Monitor

The monitor of the position limit values is activated by setting bit 4 in "S-0-0055, Position polarities".

☞ Before activating the position limit value monitoring, it is necessary to establish the drive's position data reference, because position limit values are only useful and operational when the axis was homed.

Activating the Travel Range Limit Switches

The travel range limit switches are activated by setting bit 1 in "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-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. the limit switch is still activated or if the position limit values are still exceeded, only such command values are accepted that lead back to the allowed range. The command value check depends on the active operation mode.

The following applies:

Operation mode	Command value check
Torque control	Polarity of the torque/force command value (S-0-0080)
All operation modes with drive-internal velocity control	Polarity of the internal velocity command value
All operation modes with drive-internal position control	Polarity of the velocity resulting from the preset position command value

Fig.6-111:   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!

Drive Control

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	Diagnostic message
As an error (bit 2 = 0)	F6029	F6029 Positive position limit exceeded
	F6030	F6030 Negative position limit exceeded
As a warning (bit 2 = 1)	E8029	E8029 Positive position limit exceeded
	E8030	E8030 Negative position limit exceeded

Fig.6-112:   Diagnostic Messages when Position Limit Values Exceeded

E2053 Target Position out of Travel Range

When "drive-internal interpolation" is used as the active operation mode, the drive checks whether the target position is outside the position limit values (S-0-0049 or S-0-0050). If this is the case, the drive does not move. It generates the warning "E2053 Target position out of travel range" and additionally sets bit 13 in "S-0-0012, Class 2 diagnostics".

Diagnostic Messages when Travel Range Limit Switch Activated

Exceeding the travel range limit switches is detected when they are activated. When this monitor reacts, the corresponding diagnostic message depends on the handling set in "P-0-0090, Travel range limit parameter" (bit 2):

Handling	Display	Diagnostic message
As an error (bit 2 = 0)	F6042	F6042 Both travel range limit switches activated
	F6043	F6043 Positive travel range limit switch activated
	F6044	F6044 Negative travel range limit switch activated
As a warning (bit 2 = 1)	E8042	E8042 Both travel range limit switches activated
	E8043	E8043 Positive travel range limit switch activated
	E8044	E8044 Negative travel range limit switch activated

Fig.6-113:   Diagnostic Messages wen Travel Range Limit Switches Exceeded

States of Travel Range Limit Switches

The states of the connected travel range limit switches are displayed in parameter "P-0-0222, Travel range limit switch inputs":

- Bit 0 → Status of positive limit switch (Limit+)
- Bit 1 → Status of negative limit switch (Limit-)

ℹ️ See also Parameter Description "P-0-0222, Travel range limit switch inputs"

Connecting the Travel Range Limit Switches

See "Digital Inputs/Outputs"

Drive Control

ℹ️ See separate documentation "Control Sections for Drive Controllers; Project Planning Manual"

6.8 Power Supply

6.8.1 Possibilities of Power Supply for IndraDrive

Brief Description

For IndraDrive devices we basically distinguish two series:

- Modular series, consisting of supply unit and modular inverter (IndraDrive M)
- Non-modular series, 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 series, 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, thermal load of Braking resistor
- P-0-0858, Data of external braking resistor
- P-0-0859, Data of internal braking resistor
- P-0-0860, Converter configuration
- P-0-0861, Power supply status word

Pertinent Diagnostic Messages
- E2026 Undervoltage in power section
- E2040 Device overtemperature 2 prewarning
- E2050 Device overtemp. Prewarning
- E2061 Device overload prewarning
- E2086 Prewarning supply module overload
- 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

Drive Control

- E2819 Mains failure
- E2820 Braking resistor overload prewarning
- E2829 Not ready for power on
- E8025 Overvoltage in power section
- E8028 Overcurrent in power section
- E8057 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.: R911309636).

Central Supply   The figures below illustrates the principle of central supply:
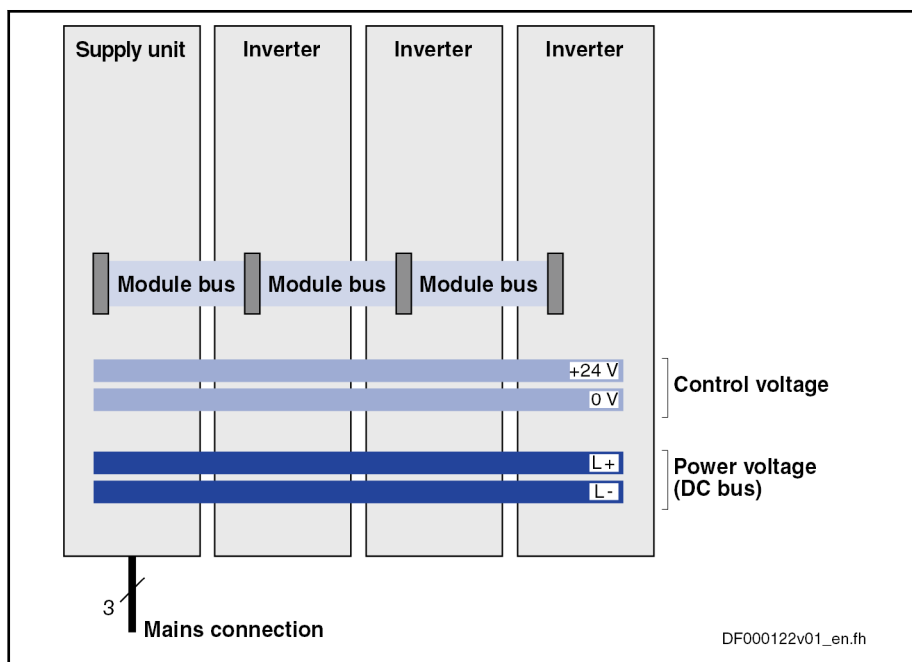
Drive Control

Fig.6-114:   *Mains Supply via Supply Unit*
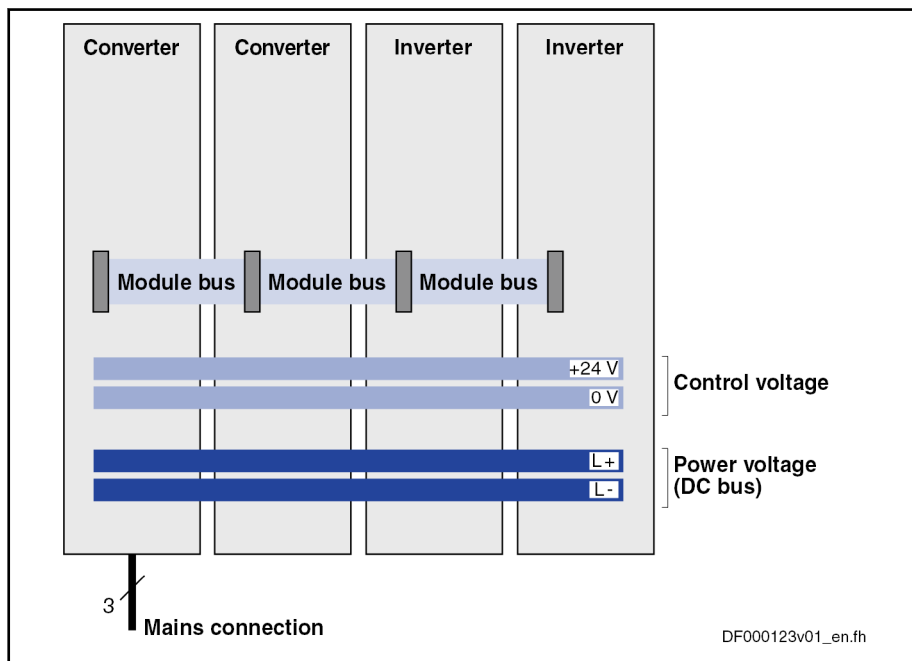
Fig.6-115:   *Mains Supply via Converter*

Group Supply   The figure below illustrates the principle of group supply:

Drive Control
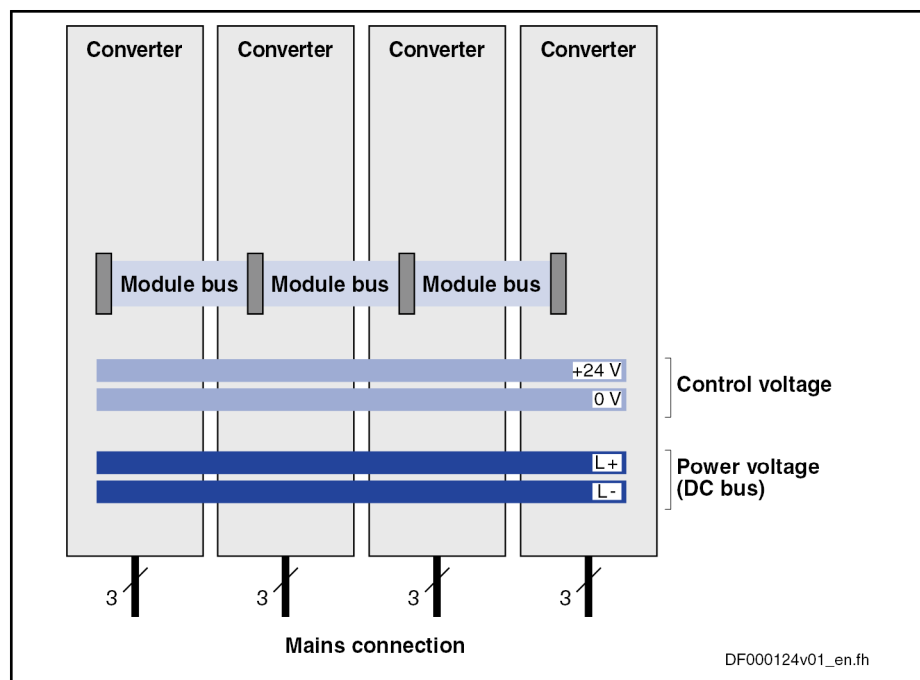
Fig.6-116:   Mains Supply via all Devices

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.: R911309636).

Drive Control

6.8.2 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)	■	■	--	--	↑
"Supply overload" prewarning	■	■	--	■	↑
DC bus ready for power output ("DC bus ok", after switching power voltage on)	■	■	--	--	↑
All module bus nodes error-free	■	■	■	■	↑
					Low

SU   Supply unit
CV   Converters
IV   Inverter
HLB   DC bus 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.6-117:   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

Drive Control

- and -

- Inverter or Converter Connected at Module bus (Collective Error Message "F2086 Error supply module")

Error messages of supply unit cleared via:

- "Esc" button 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" to 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" to 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" to 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 following section "Basics on Power Supply".

Drive Control

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".

ℹ️ 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 purpose, the status information "supply ready for operation" (respective bit in "P-0-0861, Power supply status word") 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!**

Drive Control

☞ 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.: R911309636).

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 ("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 "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.

Drive Control

NOTICE	The status information "supply ready for operation" (respective bit in "P-0-0861, Power supply status word") 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 "Diagnostic and Status Messages" below)
- 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)

NOTICE	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 (for exception, see "Fatal Error... (F8xxx), ..." above)!

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 does not have an integrated mains contactor; the mains voltage is only applied at the mains input terminals of the converter by switching power on.

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 only makes sense 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!

Drive Control

Immediate Measure at Mains Failure

When the failure of mains voltage is detected, the following immediate measures are taken:

- The warning "E2818 Phase failure" resp. "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, mains failure is additionally signaled by opening the relay contact "UD" (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 which must be used to switch the external mains contactor off.
- The error message "E2819 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" resp. "E2819 Mains failure"(for supply units), or "E2819 Mains failure" (for converters) disappears automatically 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 P-0-0118).

There are the following possibilities:

- Error reaction triggered according to setting in "P-0-0119, Best possible deceleration"
- No error reaction (i.e. the message is handled as "non-fatal warning")

Configuring the Power Supply

For each of the drives connected by the module bus it is possible to make basic settings for power supply in "P-0-0118, Power supply, configuration":

- Reaction to drive errors signaled via 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).

Drive Control

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 "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 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 "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 "P-0-0861, Power supply status word". This allows diagnosing the converter in the case of error.

Drive Control

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 "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 "P-0-0858, Data of external braking resistor". If an internal braking resistor is available, its data are contained on the manufacturer side in "P-0-0859, Data of internal braking resistor" and stored in write-protected form in a parameter memory on the power section.

The external braking resistor has to be activated in "P-0-0860, Converter configuration"!

☞　　　When an external braking resistor is connected, the minimum resistance value that can be connected must be taken into consideration (see documentation of the respective device).

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 "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 -

Drive Control

- 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 supply units of the HMV type (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. Dynamic adjustment to the current load always takes place.

- **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 operation modes, dynamic adjustment to the current load takes place.

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 "P-0-0844, thermal load of Braking resistor".

Depending on the load, the switch-on threshold of the braking resistor is increased according to the following characteristic:
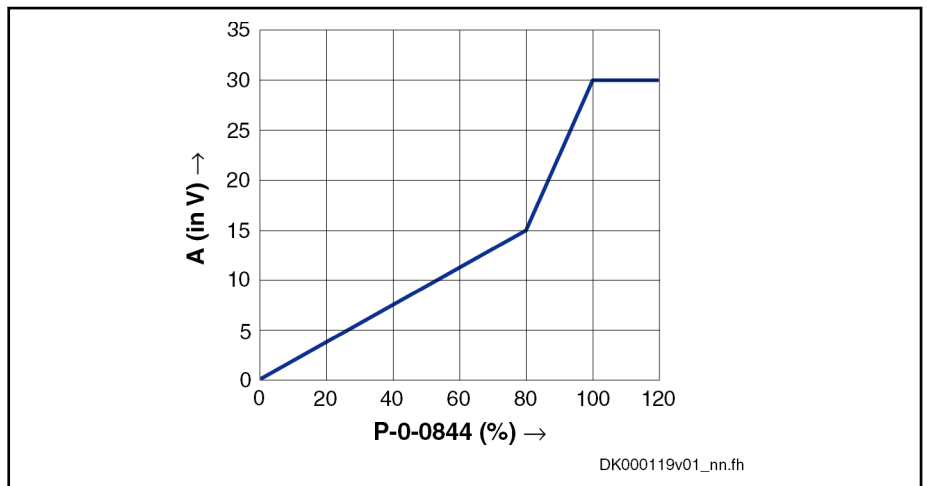
| P-0-0844 | Braking resistor load (in %) |
| A | Adjustment value for reference value (in V) |

Fig.6-118: 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 "P-0-0833, Braking resistor threshold".

Drive Control

> ☞ 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").

6.8.3   Notes on Commissioning

Configuring the 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

- 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:

- 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 the Threshold Value for "Mains Undervoltage" Message

In the case of converters, the threshold value for the "mains undervoltage" message can be set in

- 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

- P-0-0860, Converter configuration.

If an external braking resistor is to be used, the data required for control by the converter have to be entered in

- P-0-0858, Data of external braking resistor.

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 made in

Drive Control

- P-0-0860, Converter configuration.

In accordance with the setting in P-0-0860, the switch-on threshold can be dynamically increased depending on the load. The switch-on threshold currently effective is displayed in

- P-0-0833, Braking resistor threshold.

The current load of the braking resistor is displayed in

- P-0-0844, thermal load of Braking resistor.

⚠ WARNING	Property damage caused by inadmissibly high voltage on the motor terminals!

⇒ For third-party motors, observe the maximum allowed terminal voltage!

6.8.4 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:

- F2814 Undervoltage in mains
- F2818 Phase failure
- F2819 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

Drive Control

- F2833 Ground fault in motor line
- F2836 DC bus balancing monitor error

Braking Resistor   Braking resistor diagnoses:

- P-0-0833, Braking resistor threshold
- P-0-0844, thermal load of Braking resistor

Braking resistor warnings:

- E2802 HW control of braking resistor
- E2820 Braking resistor overload prewarning
- E2829 Not ready for power on

Braking resistor error messages:

- F2820 Braking resistor overload
- F2821 Error in control of braking resistor
- F2825 Switch-on threshold braking resistor too low
- F8838 Overcurrent external braking resistor

Power Section Supply   Power section warnings:

- E8028 Overcurrent in power section
- E8057 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

DOK-INDRV*-MP*-08VRS**-AP01-EN-P   Bosch Rexroth AG   529/1183
Rexroth IndraDrive Firmware for Drive Controllers MPH-, MPB-, MPD-, MPC-08

Operation Modes

7 Operation Modes

7.1 General Information on the Operation Modes

7.1.1 Safety Instructions

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

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

7.1.2 Supported Operation Modes

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

The following overview illustrates by which base packages or functional packages the respective operation mode is supported (if not stated otherwise, this applies to all 3 firmware variants).

Operation 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 operation modes:				
- Torque/force control	CL	–	–	–
- Velocity control	OL/CL	–	–	–
- Position control	CL	–	–	–
- Drive-internal interpolation	CL	–	–	–
- Drive-controlled positioning	CL	–	–	–
- Positioning block mode	CL	–	–	–
Synchronization modes:				
- Velocity synchronization	–	–	OL/CL	–
- Phase synchronization	–	–	CL	–

Operation Modes

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

OL   Open-loop characteristic
CL   Closed-loop characteristic
Fig.7-1:   *Supported Operation Modes*

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

See also "Enabling of Functional Packages"

7.1.3   Operation Mode Handling

Selecting the Operation Mode

It is possible to configure up to 8 different operation modes in the drive (depending on "S-0-0292, List of supported operation modes"). Assignment and configuration are made via the following parameters:

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

☞   If the value "0" was entered in one of these parameters, the error message "F2007 Switching to non-initialized operation mode" is generated when this operation mode is activated.

Activating the Operation Mode   The operation mode is activated and controlled via bits 8, 9 and 11 in "P-0-0116, Device control: control word":

The following applies to P-0-0116:

- Bits 8 and 9 → Selecting primary operation mode and secondary oper. modes 1 to 3
- Bit 11 → Selecting secondary operation modes 4 to 7 (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 S-0-0134 (master control word for SERCOS)!

The figure below illustrates the interrelation of the control word of the respective master communication and the device control word/device status word with regard to the operation mode selection.
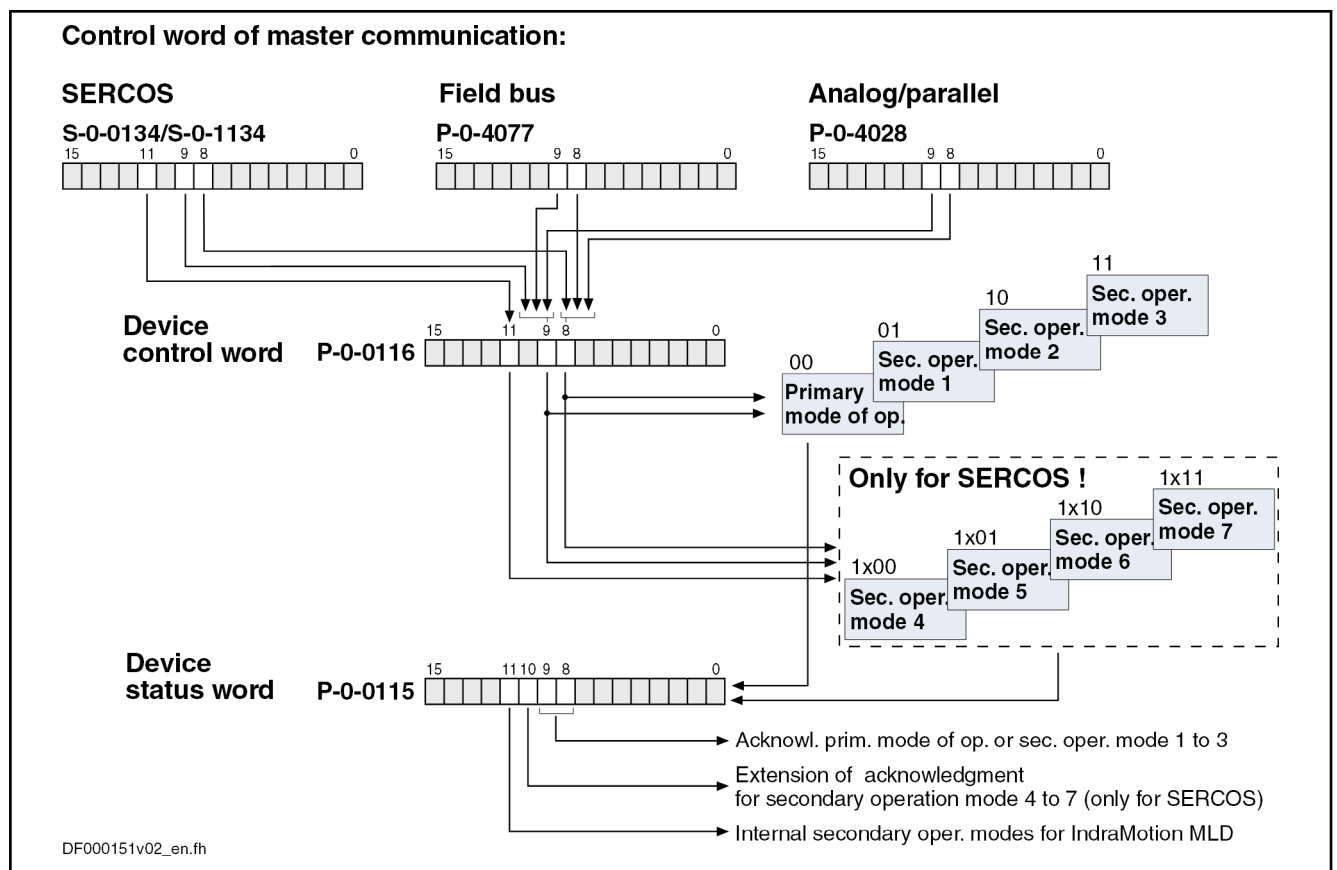
Fig.7-2: Operation Mode Selection via Control Word

☞ The control bits (8 and 9) contained in P-0-0116 are also contained in the control words depending on the master communication (cf. S-0-0134, P-0-4077, P-0-4068 and P-0-4028) and can therefore be written via the control words.

An operation mode defined via the operation mode selection is active when:

- The drive (control section and power section) is ready for operation

- and -

- The drive enable signal sees a positive edge.

Acknowledging the Active Operation Mode

As regards the activation of an operation mode, there are the following kinds of feedback:

- With active operation mode the display of the control panel reads "AF".

- In "S-0-0390, Diagnostic message number" the respective diagnostic message number of the active operation mode is displayed (e.g. "A0101" in "velocity control" mode).

- In "S-0-0095, Diagnostic message", the active operation mode is displayed in text form (e.g. "A0101 Velocity control").

- In "P-0-0115, Device control: status word", bit 3 ("drive follows external command values") is used to acknowledge whether the drive is running in the preset operation mode or not.

- In "P-0-0115, Device control: status word", bits 8, 9 and 10 ("acknowledgment of operation mode") are used to signal the operation mode presently active.

Operation Modes

> ☞ The status bits contained in P-0-0115 (3, 8, 9 and 10) are also contained in the status words depending on the master communication (S-0-0135, P-0-4078) and can therefore be read in the status words. Bit 10, however, is only activated with SERCOS interface!

See also "Device Control and State Machines"

Changing the Operation Mode

When drive enable is activated, the drive, after having gone through the initialization routines, changes to the operation mode that was selected via bits 8 and 9 of the specific control word of the respective master communication (S-0-0134, P-0-4077, P-0-4068 4028 or P-0-0116).

> ☞ The change of operation 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 operation mode become effective, because the initialization of the operation mode is carried out first.

Special Cases   With the following **exceptional circumstances**, the desired operation mode is not carried out in spite of the operation mode having been correctly selected:

- **Drive error** is present

  → The corresponding error reaction is carried out.

- **Fatal warning** was triggered

  → The corresponding reaction is carried out.

- A "**drive command**" (e.g. homing procedure, set absolute position, ...) is executed

  → The command started is carried out.

- **Drive HALT**

  → This drive function is carried out.

See also "Device Control and State Machines"

Drive-Controlled Change of Operation Mode   In order to achieve a quick and smooth change of operation mode in running operation, it is possible to make a "drive-controlled change of operation mode". Drive-internally this procedure ensures that, when the operation mode is changed, the transition is carried out in a synchronized way, even if the command value changes abruptly.

See also "Command Value Adjustment with Position Control"

Command Value Acceptance and Acknowledgment

Immediate Command Value Acceptance   Each preset command value is accepted immediately, when the respective command value parameter (e.g. S-0-0036, S-0-0080, S-0-0258, …) is written in the case of the operation modes:

- Torque/Force Control
- Velocity Control
- Position control with cyclic command value input
- Drive-internal interpolation
- Synchronization modes:
  - Velocity Synchronization with Real/Virtual Master Axis

Operation Modes

–   Phase Synchronization with Real/Virtual Master Axis

–   Electronic cam with real/virtual master axis

–   MotionProfile 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:

- "Drive-controlled positioning" mode

  Acceptance of preset command value (position, velocity) by toggling bit 0 of "S-0-0346, Positioning control word"

  → **Toggle mechanism**

- "Positioning block mode" mode

  Acceptance of the positioning block selected via "p-0-4026, Positioning block selection" by a 0-1 edge of bit 0 of "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:

- "Drive-controlled positioning" mode

  The drive acknowledges the command value acceptance by toggling bit 0 of "S-0-0419, Positioning command acknowledge".

- "Positioning block mode" mode

  The drive acknowledges the command value acceptance by displaying the effective positioning block in "P-0-4051, Positioning block acknowledgment".

☞   In the positioning block mode, too, the acceptance of a new positioning block causes bit 0 of 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

💡   Assignment to functional firmware package, see chapter "Supported Operation Modes".

Operation Modes

In the "torque/force control" mode, a torque/force command value is preset for the drive. If required, this command value can be filtered. When the operation mode has been activated, the diagnostic message is "A0100 Torque control".
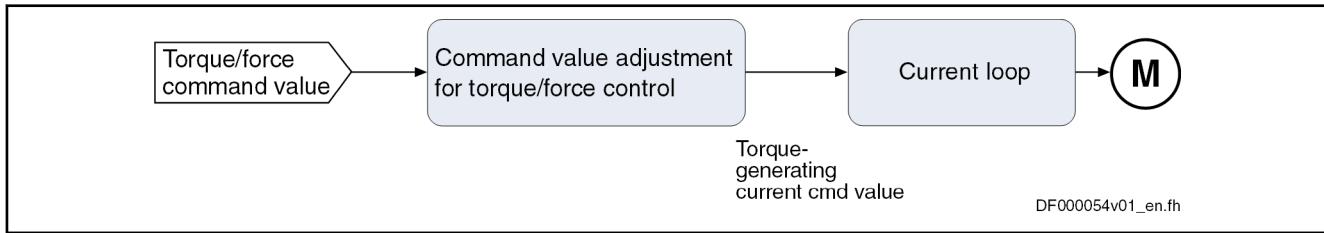
Fig.7-3:   "Torque/Force Control" Block Diagram

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
- Filtering the command value by means of "S-0-0822, Torque/force ramp" and "S-0-0823, Torque/force ramp time"

Pertinent Parameters
- S-0-0080, Torque/force command value
- S-0-0081, Additive torque/force command value
- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0109, Motor peak current
- S-0-0110, Amplifier peak current
- S-0-0111, Motor current at standstill
- S-0-0822, Torque/force ramp
- S-0-0823, Torque/force ramp time
- S-0-0824, Status "Torque/force command value attained"
- P-0-0001, Switching frequency of the power output stage
- P-0-0038, Torque-generating current, command value
- P-0-0049, Effective torque/force command value
- P-0-0051, Torque/force constant
- P-0-0109, Torque/force peak limit
- P-0-4046, Effective peak current

Pertinent Diagnostic Messages
- A0100 Torque control
- E8057 Device overload, current limit active
- E8260 Torque/force command value limit active
- F8079 Velocity limit value exceeded

7.2.2 Command Value Adjustment in Torque/Force Control

Principle of Command Value Adjustment

Filtering the Command Value
The command value preset by "S-0-0080, Torque/force command value" is filtered. The filter effect can be changed by setting of "S-0-0822, Torque/force ramp" and "S-0-0823, Torque/force ramp time".

The message "torque/force command value 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 "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.
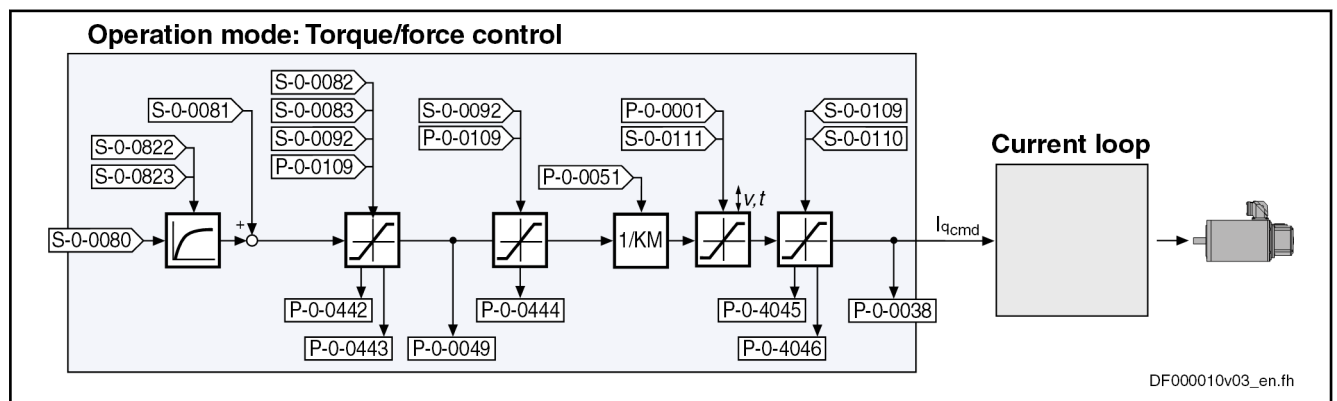
Fig.7-4: Command Value Adjustment in Torque/Force Control

The currently effective actual limit values are displayed (P-0-0442, P-0-0443, P-0-0444; P-0-4045, P-0-4046); so is the output variable of the command value adjustment in torque/force control, the torque-generating component of the current command value (P-0-0038).

Velocity Monitor
In torque/force control, the velocity of the drive is reached depending on the component of the drive torque or the drive force acting on the acceleration. As the velocity of a motor or an axis has to stay within the allowed range in order to avoid damage, the actual velocity value is monitored, as soon as it is outside the standstill window S-0-0124.

If the value of "S-0-0040, Velocity feedback value" exceeds the 1.125-fold value of "S-0-0091, Bipolar velocity limit value", the drive generates the error message "F8079 Velocity limit value exceeded" and switches off with the error reaction that was set.

Notes on Commissioning for Command Value Limitation

On the user side, the following limitations are available:

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- Maximum allowed torque/force (S-0-0092, P-0-0109)
- Motive and regenerative load at stationary velocity (S-0-0082, S-0-0083)

i 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-0-0046, Status word of current controller" results from the current and torque limits.

See also section "Current Loop" below

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 Ds/D/MLD" 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 operation mode:

Operation Modes

Device Overload
- The thermal load of the device depending on the measured current is permanently calculated by a temperature model. When a threshold value is exceeded, the warning "E8057 Device overload, current limit active" is generated (see description of diagnostic messages).

Command Value Limit Active
- If necessary, the drive firmware limits the torque/force command value in dynamic and static form. If such a limitation has been activated, this is signaled by the warning "E8260 Torque/force command value limit active".

Velocity Limit Value Exceeded
- The value of the parameter "S-0-0040, Velocity feedback value" is monitored as soon as it is outside of the standstill window S-0-0124. If it exceeds the 1.125-fold value parameterized in "S-0-0091, Bipolar velocity limit value", the error message "F8079 Velocity limit value exceeded" is generated.

7.3 Velocity Control

7.3.1 Brief Description

> 💡 Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the "velocity control" mode a velocity command value is preset for the drive. The velocity command value is limited by ramps and filters.
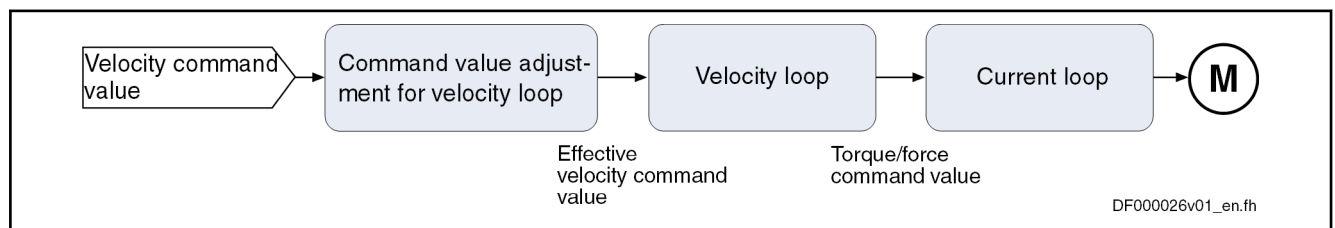
Fig.7-5: *"Velocity Control" Block Diagram*

Features
- Inputting a velocity command value (sum of

  "S-0-0036, Velocity command value" and "S-0-0037, Additive velocity command value") via analog inputs or master communication interface (SERCOS, field bus, ...)

- Selection of predefined and internally stored velocity command values (31 fixed values) is possible via binarily coded digital inputs (e.g., for jogging forward/backward, feeding, setting up, ...) with separately definable acceleration and deceleration ramps (31 different ramps), as well as jerk filter to be set (31 different time constants)

- Use of a drive-internal command value generator for generating command value ramps ("motor potentiometer")

- Inversion of the provided velocity command value before it is processed in the ramp-function generator

- Window comparator for masking critical velocity ranges in the command value channel (e.g. machine resonances) with corresponding acceleration adjustment (see P-0-1209)

- Ramp-function generator with separately adjustable, two-stage acceleration and deceleration limits of the preset velocity command value; switching from ramp 1 to ramp 2 is done with selectable velocity and run-up stop that can be parameterized

- Velocity control via a digital PI loop with extensive filter measures

Operation Modes

- Monitoring the command velocity and actual velocity for exceeding parameter "S-0-0091, Bipolar velocity limit value"
- Additional monitoring with regard to the motor-related limit values "S-0-0113, Maximum motor speed" and "P-0-0113, Bipolar velocity limit value of motor"
- Smoothing of velocity control loop difference via filter that can be parameterized
- Smoothing of preset command value by means of average filter (jerk limitation by means of moving average filter)
- Fine interpolation of the velocity command values; transmission of these command values in the position 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 (P-0-1200 and P-0-1210)

Pertinent Parameters
- S-0-0036, Velocity command value
- S-0-0037, Additive velocity command value
- S-0-0040, Velocity feedback value
- S-0-0091, Bipolar velocity limit value
- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- S-0-0113, Maximum motor speed
- S-0-0156, Velocity feedback value 2
- P-0-0004, Velocity loop smoothing time constant
- P-0-0113, Bipolar velocity limit value of motor
- 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-0-1126, 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

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- P-0-1213, Deceleration ramp 2
- P-0-1214, Control word 2 velocity control
- P-0-1215, Motor potentiometer, acceleration
- P-0-1216, Motor potentiometer, deceleration
- P-0-1217, Motor potentiometer, step size
- P-0-1218, Motor potentiometer, command value
- P-0-1222, Velocity command filter
- P-0-1223, List of acceleration ramps
- P-0-1224, List of deceleration ramps
- P-0-1225, List of smoothing time constants

Pertinent Diagnostic Messages

- A0101 Velocity control
- E2059 Velocity command value limit active
- E2063 Velocity command value > limit value
- F8078 Speed loop error
- F8079 Velocity limit value exceeded

Operation Modes

7.3.2   Command Value Adjustment in Velocity Control

Overview
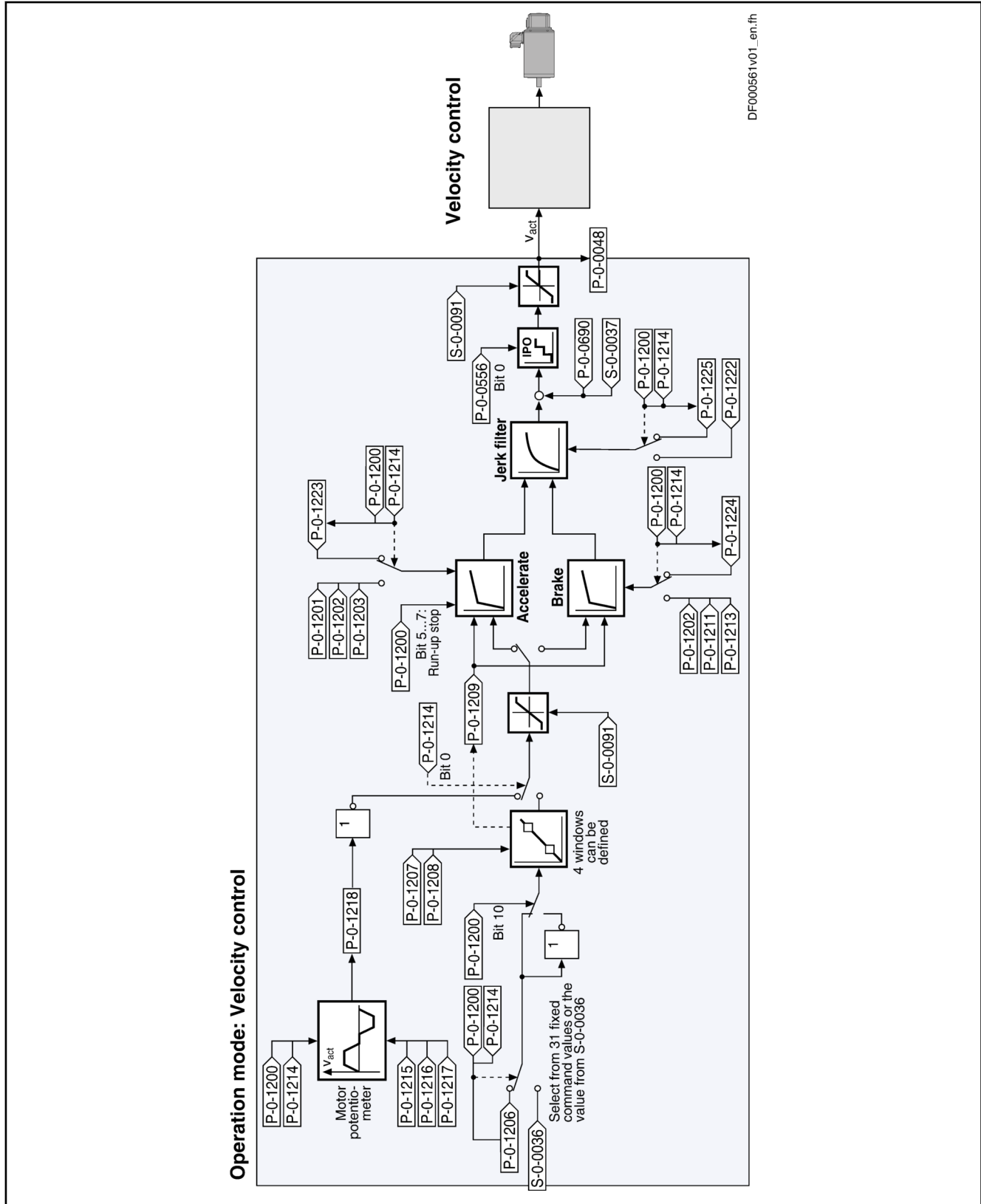
Fig.7-6:   Command Value Adjustment in Velocity Control

> ☞ 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 "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 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 the selection via bits 4…0 of P-0-1200:

- For **direct selection** (P-0-1214, bit 8 = 0)
    - 00000 → Value from S-0-0036 active
    - 00001 → Fixed value 1 from P-0-1206 selected and active
    - 00010 → Fixed value 2 from P-0-1206 selected and active
    - 00100 → Fixed value 3 from P-0-1206 selected and active
    - 01000 → Fixed value 4 from P-0-1206 selected and active
    - 10000 → Fixed value 5 from P-0-1206 selected and active
- For **binary selection** (P-0-1214, bit 8 = 1)
    - 00000 → Value from S-0-0036 active
    - 00001 → Fixed value 1 from P-0-1206 selected and active
    - 00010 → Fixed value 2 from P-0-1206 selected and active

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    –   **00011** → Fixed value 3 from P-0-1206 selected and active

    –   etc.

    –   **11111** → Fixed value 31 from P-0-1206 selected and active

Via the same control bits of parameter P-0-1200, it is in addition possible to select ramp pitches, as well as time constants for the command value smoothing filter (see sections "Ramp-Function Generator" and "Jerk Limitation").

ℹ️   See also Parameter Descriptions "P-0-1200, Control word 1 velocity control" and "P-0-1214, Control word 2 velocity control"

Command Value Generation via Motor Potentiometer

In the operation mode "velocity control", the command value generator (so-called motor potentiometer) provides the possibility of generating a velocity command value characteristic (P-0-1218, Motor potentiometer, command value) via digital input signals ("ramp+" and "ramp–").

The motor potentiometer is activated by setting bit 0 = 1 in "P-0-1214, Control word 2 velocity control".

Inverting the Velocity Command Value

Before it is processed in the ramp-function generator, the provided velocity command value can be inverted. The motor potentiometer is inverted by setting bit 10 = 1 in "P-0-1200, Control word 1 velocity control".

Masking the Command Value

The masking windows (max. 4) that can be defined via "P-0-1207, Lower limit of velocity masking window" and "P-0-1208, Upper limit of velocity masking window" are used to suppress resonance phenomena of a machine or in an installation. The drive should not be permanently moved at velocities within these windows. A velocity command value within the value range of one of the 4 definable windows is either reduced to the lower limit (P-0-1207) or increased to the upper limit (P-0-1208).
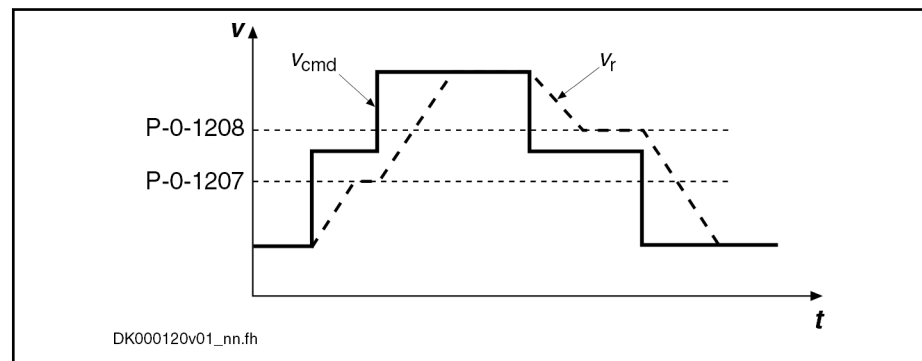
P-0-1207	Lower limit of velocity masking window
P-0-1208	Upper limit of velocity masking window
v_{cmd}	Velocity Command Value
v_r	Velocity ramp
Fig.7-7:	Function "Velocity Masking Window with Hysteresis"

ℹ️   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).
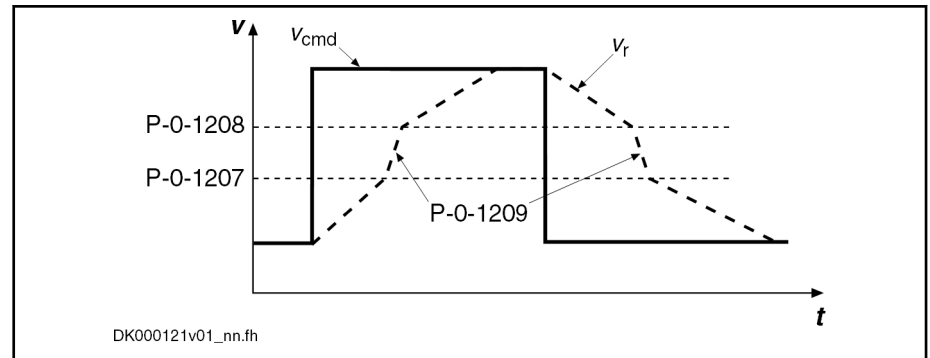
P-0-1207	Lower limit of velocity masking window
P-0-1208	Upper limit of velocity masking window
P-0-1209	Acceleration factors for velocity masking window
v_{cmd}	Velocity Command Value
v_r	Velocity ramp

Fig.7-8:   *Operating Principle of the Acceleration Factors From P-0-1209*

See also Parameter Description "P-0-1209, Acceleration factors for velocity masking window"

Ramp-Function Generator

For the ramp-function generator, we make the following distinction:

- Cyclic command value input via S-0-0036 or motor potentiometer

  → 2 ramps (acceleration and deceleration) and a jerk filter take effect

  Note: For command value input via S-0-0036, also the ramp pitches and the filter time constants can be selected from the list parameters P-0-1223, P-0-1224, P-0-1225 by the control bits in P-0-1200. This option is activated via Bit 9 in "P-0-1214, Control word 2 velocity control".

- Command value input via memory of fixed command values (P-0-1206)

  → 31 sets with individually definable command velocities, jerk limits and acceleration and deceleration ramps can be defined

Command Value Input via S-0-0036 or Motor Potentiometer   The increase (acceleration) and deceleration of the velocity command value input via "S-0-0036, Velocity command value" or a motor potentiometer can be limited in steps via 2 ramps.

- Acceleration process

  → In the first step, the increase of the command value is limited via "P-0-1201, Ramp 1 pitch" (acceleration ramp 1). If the command velocity exceeds the threshold entered in "P-0-1202, Final speed ramp 1" the increase of the command value is limited with the value "P-0-1203, Ramp 2 pitch" (acceleration ramp 2).

- Deceleration or braking process

  → For deceleration "P-0-1211, Deceleration ramp 1" resp. "P-0-1213, Deceleration ramp 2" are used accordingly.

☞   This allows parameterizing different ramps for the acceleration and braking process.

Operation Modes

Command Value Input via Memory of Fixed Command Values

With command value input via the memory of fixed command values (P-0-1206), separate ramp values can be defined for each of the 31 fixed command values via the following list parameters:

- P-0-1223, List of acceleration ramps
- P-0-1224, List of deceleration ramps

These are single-step ramps, i.e. one ramp pitch applies to the entire speed range. Via control bits (bits 0…4) in "P-0-1200, Control word 1 velocity control", the single-step ramps can be selected.

☞   The fixed command values (P-0-1206) and the corresponding time constants of the jerk filter (P-0-1225) are selected via the control bits in P-0-1200!

The assignment of bits 0...4 of parameter P-0-1200 depends on bit 8 of parameter "P-0-1214, Control word 2 velocity control" (see "Activating the Fixed Command Values" in section "Command Value Generation via Memory of Fixed Command Values").

Run-Up Stop

When there is acceleration-dependent torque limitation occurring or due to installation-dependent failures/irregularities, it is necessary to interrupt the acceleration ramp. For this purpose, the "run-up stop" function was implemented; it is controlled via "P-0-1200, Control word 1 velocity control".

Possible settings for activating the "run-up stop" function via the respective bits of P-0-1200:

- Activation of the function without additional condition
- Triggering of torque limitation (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 "run-up stop" function is deactivated.

Jerk Limitation

The velocity command value, the increase and maximum of which are limited, is jerk-limited by means of a 1st order filter.

For jerk limitation, we make the following distinction:

- Cyclic command value input via S-0-0036 or motor potentiometer

   → Jerk limitation takes effect as set in parameter P-0-1222
- Command value input via memory of fixed command values (P-0-1206)

   → Jerk limitation can be separately defined for each of the 31 fixed command values by an individual smoothing time constant (P-0-1225)

Command Value Input via S-0-0036 or Motor Potentiometer

The command value input via "S-0-0036, Velocity command value" or a motor potentiometer is jerk-limited according to the settings in "P-0-1222, Velocity command filter".

Command Value Input via Memory of Fixed Command Values

With command value input via the memory of fixed command values (P-0-1206), an individual filter time constant (P-0-1225, List of smoothing time constants) can be configured for each of the 31 fixed command values; the filter time constant is selected via the control bits (bits 0…4) of parameter "P-0-1200, Control word 1 velocity control".

Operation Modes

☞ The control bits in P-0-1200 are also used to select the fixed command values (P-0-1206) and the corresponding ramp pitches (P-0-1223 and P-0-1224)!

The assignment of bits 0...4 of parameter P-0-1200 depends on bit 8 of parameter "P-0-1214, Control word 2 velocity control" (see "Activating the Fixed Command Values" in section "Command Value Generation via Memory of Fixed Command Values").

Command Value Limitation

The effective velocity command value (sum of values from S-0-0036 and S-0-0037) is limited to the value indicated in parameter "S-0-0091, Bipolar velocity limit value" resp. in the parameters "S-0-0038, Positive velocity limit value" or "S-0-0039, Negative velocity limit value".

See also "Velocity Limitation"

☞ When the limitation takes effect, the drive generates the message "E2059 Velocity command value limit active".

Fine Interpolation

The limited command value available at the output of command value processing can be adjusted, by means of linear fine interpolation, for further processing in the velocity 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; see "P-0-0556, Config word of axis controller").

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"

Operation Modes

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 "P-0-0004, Velocity loop smoothing time constant" the low-pass filter that filters the control difference for the velocity loop can be set.

- To filter the control deviation, it is possible to configure four filters connected in series as low-pass filters or band-stop filters with "P-0-1120, Velocity control loop filter: filter type".

☞   "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/Force Limitation").

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:
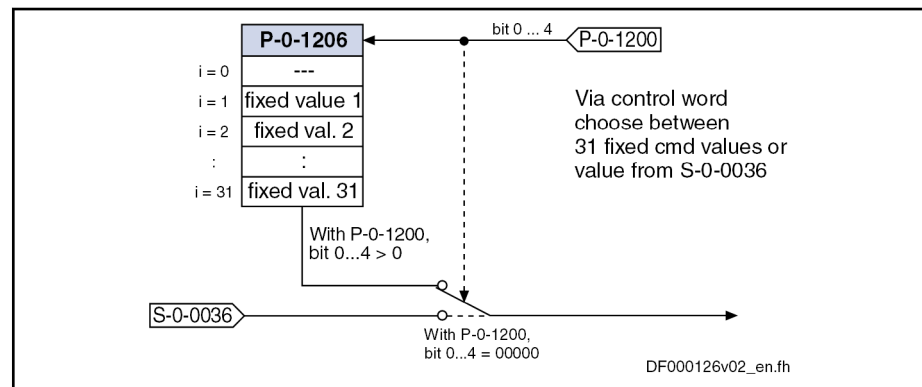
S-0-0036	Velocity command value
P-0-1200	Control word 1 velocity control
P-0-1206	Memory of velocity command values

Fig.7-9:   Selecting the Internally Stored Velocity Command Values

Special Cases   Observe the following special cases for selecting the fixed command values via bit 0…4 of parameter P-0-1200:

- When all 5 bits have been set to "0", the velocity command value (S-0-0036) preset by the master is active.

- If the motor potentiometer was activated via bit 0 of "P-0-1214, Control word 2 velocity control" the selected fixed command values will not take effect.

Operation Modes

Applying the Fixed Command Values
The command values are applied immediately, when the bit pattern is created so that you have to make sure that the bits 0...4 are, as far as possible, simultaneously updated.

If the selection of the fixed command values is switched off via bit 9 of the parameter P-0-1214, the selected fixed command values won't take effect. Instead, the command value of parameter "S-0-0036, Velocity command value".

Motor Potentiometer

Activating the Function
After the motor potentiometer has been activated by setting bit 0 of "P-0-1214, Control word 2 velocity control", the motor potentiometer functionality can be used.

Using and Modifying Command Value Ramps
The command value ramps are used and modified via the two control bits, bit 8 (ramp+) and bit 9 (ramp-) of "P-0-1200, Control word 1 velocity control". These bits can be written in the following ways:

- Via digital inputs

  → See "Digital Inputs/Outputs"

- Via the control panel (comfort or standard control panel)

  → See "Control Panels of the IndraDrive Controllers"

- By simple writing of the parameter via the 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, Control word 2 velocity control" determine the start value after the activation of drive enable (cf. P-0-0115, bit "drive on"); the following settings can be selected:

- **00** → Command value generator starting at command value "0"

- **01** → Command value generator starting with old command value (value is also stored when control voltage switched off!)

- **10** → Command value generator starting with current actual velocity value in S-0-0040

- **11** → Selection not allowed!

Acceleration of the Ramps
Bit 3 of "P-0-1214, Control word 2 velocity control" determines the acceleration behavior; the following cases are to be distinguished:

- **Bit 3 = 0: Constant acceleration**

  → Linear adjustment of command velocity

  The velocity command value is influenced with the duty cycle of "ramp+" or "ramp-" and acceleration remains constant:

  – With the control bit "ramp+", the velocity command value is increased up to the positive limit value (= minimum value of S-0-0091 and S-0-0038), with the acceleration entered in "P-0-1215, Motor potentiometer, acceleration".

  – With the control bit "ramp-", the velocity command value is decreased up to the negative limit value (= minimum value of S-0-0091 and S-0-0038), with the deceleration entered in "P-0-1216, Motor potentiometer, deceleration".

- **Bit 3 = 1: Linearly variable acceleration**

  → Square adjustment of command velocity

  The acceleration is varied in linear form with the duty cycle of "ramp+" or "ramp-":

Operation Modes

–   With the control bit "ramp+", the acceleration value within 2s is increased up to the positive limit value ("P-0-1201, Ramp 1 pitch" or "P-0-1203, Ramp 2 pitch"), with the pitch ("P-0-1215, Motor potentiometer, acceleration").

–   With the control bit "ramp-", the acceleration value within 2 s is decreased 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, Control word 2 velocity control" determines the evaluation mode of the two control inputs "ramp+" and "ramp-"; the following cases are to be distinguished:

●   **Bit 4 = 0: Continuous evaluation**

→ Continuous adjustment of acceleration or velocity via "ramp+" or "ramp-"

–   As long as bit 8 ("ramp+") is set, the command value is increased.

–   As long as bit 9 ("ramp-") is set, the command value is increased.

●   **Bit 4 = 1: Edge-controlled evaluation**

→ Stepwise adjustment of the velocity command value with value of parameter "P-0-1217, Motor potentiometer, step size"

–   With a 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 decreased by the value of parameter P-0-1217.

☞   When a control bit "ramp+" or "ramp-" f 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:
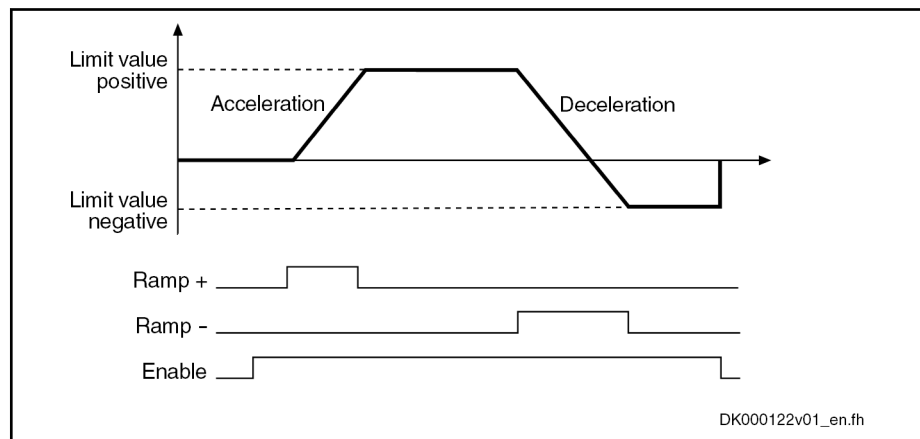
Fig.7-10:   *Linear Adjustment of Command Velocity with Status-Controlled Evaluation of "Ramp+" and "Ramp-"*
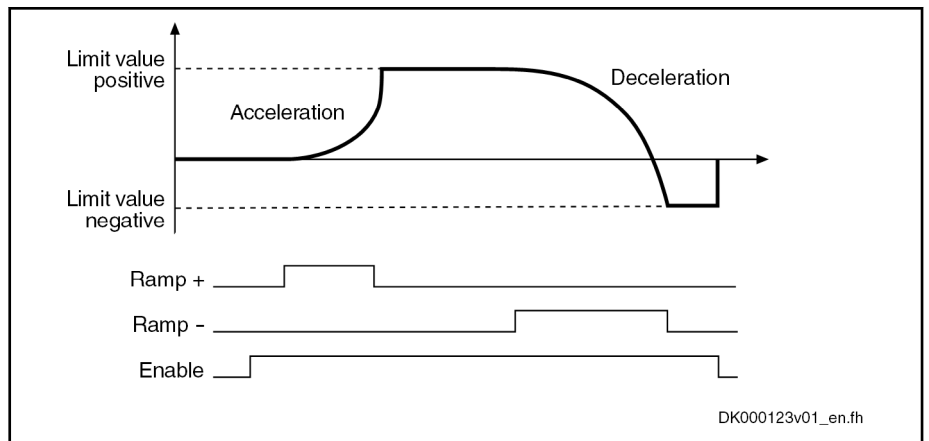
Fig.7-11:   Square Adjustment of Command Velocity with Status-Controlled Evaluation of "Ramp+" and "Ramp-"
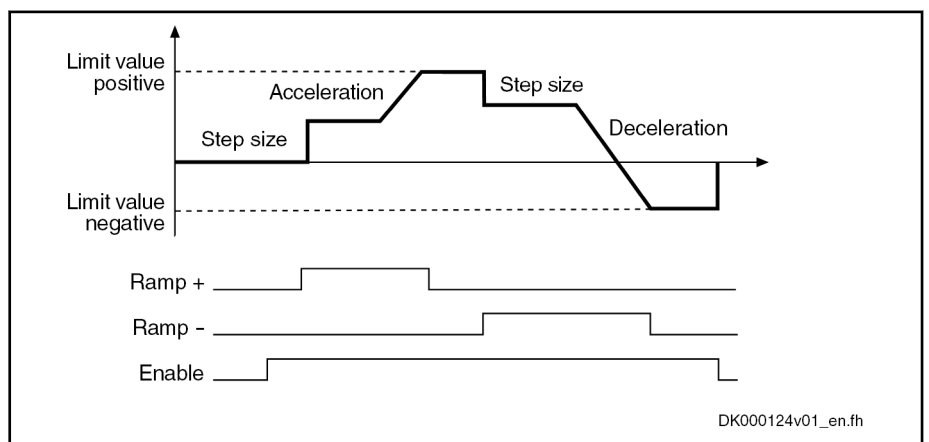
Fig.7-12:   Linear Adjustment of Command Velocity with Edge-Controlled Evaluation of "Ramp+" and "Ramp-"
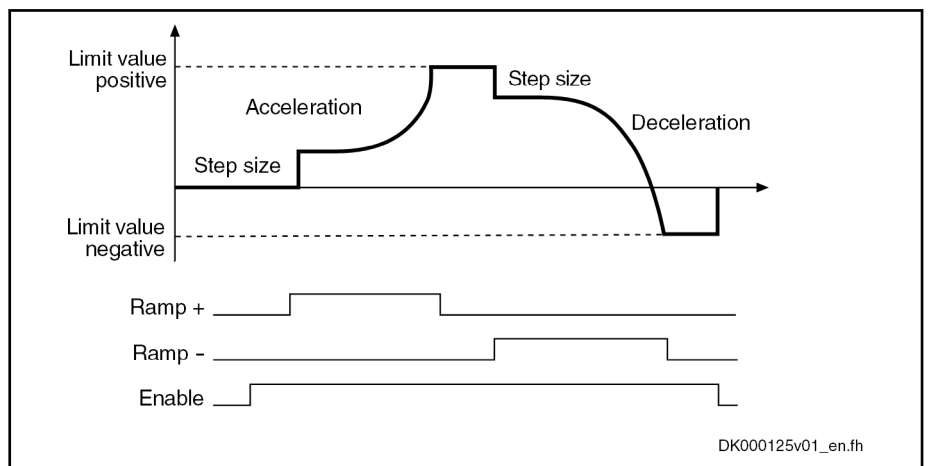
Fig.7-13:   Square Adjustment of Command Velocity with Edge-Controlled Evaluation of "Ramp+" and "Ramp-"

Velocity Mixing

Via "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.

Operation Modes

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 "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 P-0-1207 and P-0-1208 is zero which means that the speed window has not been defined.

7.3.5   Diagnostic Messages and Monitoring Functions

Diagnostic Status Message

Active operation mode   The activated "velocity control" mode is displayed by the following diagnostic message:

- A0101 Velocity control

Status of Ramp-Function Generator

Effective Velocity Command Value   The currently effective velocity command value at the output of command value adjustment, that is preset for the velocity loop via the fine interpolation, is mapped to "P-0-0048, Effective velocity command value".

Status of Ramp-Function Generator (Run-Up Encoder)   "Frequency converter" applications require several status messages that are contained in "P-0-1210, Status word of velocity control mode":

- Bit 0 = 1 → Command value reached

  The output of the ramp-function generator, including the jerk filter, corresponds exactly to the selected command value, i.e. either to the value of S-0-0036 or a selected fixed value from P-0-1205.

- Bit 1 = 1 → Run-up stop active

  The 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.

Operation Modes

- 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".

Monitoring Functions

Monitoring functions specific to the operation mode:

Velocity Command Value Limit Active
- The effective velocity command value (sum from S-0-0036 and S-0-0037) is limited to the value 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
- The value of the parameter "S-0-0036, Velocity command value" is limited to "S-0-0091, Bipolar velocity limit value". f the value in S-0-0036 is higher than the value in S-0-0091, the warning "E2063 Velocity command value > limit value" is generated.

Speed Loop Error
- The drive monitors the correct function of the velocity loop and in the case of fatal errors disables the drive torque with the error message F8078 "F8078 Speed loop error".

Velocity Limit Value Exceeded
- The value of the parameter "S-0-0040, Velocity feedback value" is monitored as soon as it is outside of the standstill window S-0-0124. If it exceeds the 1.125-fold value parameterized in "S-0-0091, Bipolar velocity limit value", the error message "F8079 Velocity limit value exceeded" is generated.

7.4 Position Control with Cyclic Command Value Input

7.4.1 Brief Description

> 💡 Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the "position control" mode, a cyclic position command value is preset for the drive in NC cycle time. This command value is fine interpolated in the drive and jerk-limited via filters, if necessary, before being transmitted to the position loop.

To minimize the lag error, variable acceleration feedforward is available in addition to variable velocity feedforward.

Operation Modes

There are different forms of the "position control" mode which result in the corresponding diagnostic messages when the operation mode was activated (see below "Pertinent Diagnostic Messages").
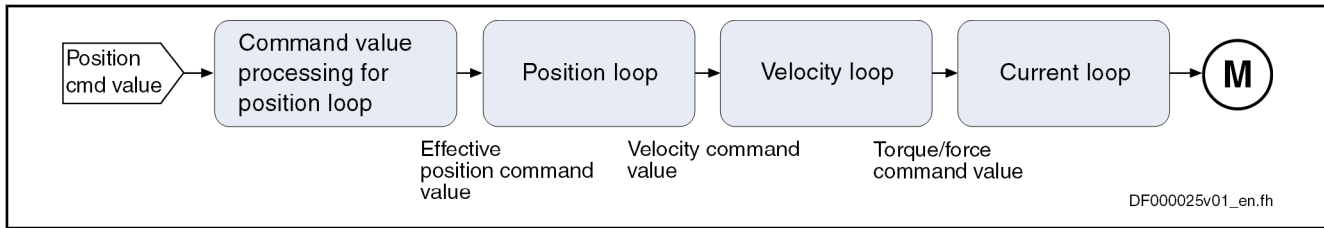
Fig.7-14: "Position Control with Cyclic Command Value Input" Block Diagram

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 operation modes
- Timebase for cyclic command value input defined by "S-0-0001, NC cycle time (TNcyc)"
- Monitoring of the position command value difference for exceeding parameter "S-0-0091, Bipolar velocity limit value"
- Position command values of the control 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"
- Adjustable deceleration of position command value in position clocks (P-0-0456, Position command value delay), maximum 32 clocks.
- Position control with regard to actual position value encoder 1 (motor encoder) or actual position value encoder 2 [external (load-side) encoder], can be dynamically switched
- Velocity feedforward through adjustable factor of 0…150 % (default = 100 %)
- Cyclic acceptance of an additive torque/force command value of the control unit (external acceleration feedforward)

☞   The condition for this operation mode is synchronous communication between the control unit and the drive, as it is the case with SERCOS interface, for example.

Pertinent Parameters

- S-0-0047, Position command value
- S-0-0081, Additive torque/force command value
- S-0-0091, Bipolar velocity limit value
- S-0-0138, Bipolar acceleration limit value
- S-0-0520, Axis control word
- P-0-0010, Excessive position command value
- P-0-0011, Last valid position command value
- P-0-0041, Position command average value filter time constant
- P-0-0042, Current position command average value filter order

- P-0-0047, Position command value control
- P-0-0059, Additive position command value, controller
- P-0-0070, Effective additive torque/force command value
- P-0-0099, Position command smoothing time constant
- P-0-0142, Synchronization acceleration
- P-0-0143, Synchronization velocity
- P-0-0187, Position command processing mode
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0458, Delay of add. command values
- P-0-0556, Config word of axis controller

Pertinent Diagnostic Messages
- A0102 Position mode, encoder 1
- A0103 Position mode, encoder 2
- A0104 Position mode lagless, encoder 1
- A0105 Position mode lagless, encoder 2
- A0154 Position mode drive controlled, encoder 1
- A0155 Position mode drive controlled, encoder 2
- A0156 Position mode lagless, encoder 1 drive controlled
- A0157 Position mode lagless, encoder 2 drive controlled
- F2036 Excessive position feedback difference
- F2037 Excessive position command difference

7.4.2   Command Value Adjustment in Position Control

NC- or Drive-Controlled Position Control

We distinguish the following characteristics of the operation mode "position control with cyclic command value input":

- **NC-controlled position control** (cf. A0102 to A0105)

  The drive generally follows the position command values cyclically input by the master in the NC cycle.

- **Drive-controlled position control** (cf. A0154 to A0157)

  In the case of a change of operation mode to cyclic position control, the drive realizes the corresponding synchronization process, i.e. it generates, internally by means of the internal synchronization parameters (P-0-0142, P-0-0143, P-0-0154, P-0-0151), a smooth transition of the internal position command value from the current actual position to the new command value characteristic input by the NC. After the synchronization process has been completed, the drive follows the position command values input by the master in the NC cycle.

☞   The command value cyclically transmitted by the control unit is displayed in parameter "P-0-0047, Position command value control".

The internal position command value at the position loop is displayed in parameter "P-0-0434, Position command value of controller". If required, it can also be read via parameter "S-0-0047, Position command value".

Operation Modes

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.

ℹ️ 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.

Position Command Value Deceleration

The position command value can be delayed by maximum 32 position clocks after the fine interpolator, before it is fed in the position controller. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position clocks is set with the position command value delay (P-0-0456). The position command value generator without delay (P-0-0457) is entered in a ring buffer and then the position command value with delay is applied in the position command value controller (P-0-0434).

Drive-Controlled Change of Operation Mode

During drive-controlled change of operation mode, the drive makes sure internally that when the operation mode is changed, the transition is carried out in a synchronized way, even if the command value changes abruptly.
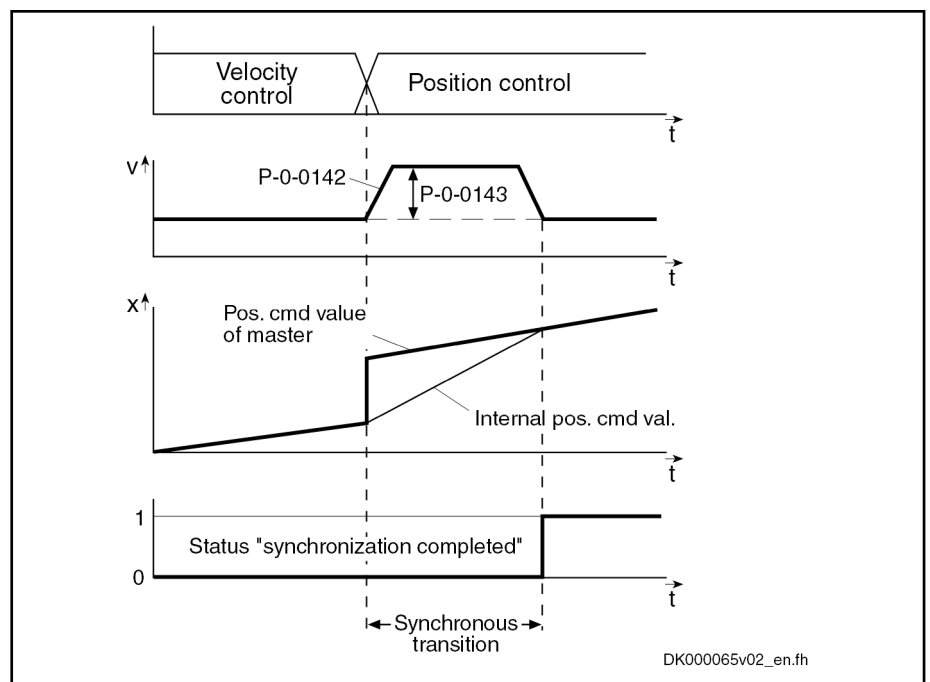
Operation Modes

| P-0-0142 | Synchronization acceleration |
| P-0-0143 | Synchronization velocity |

Fig.7-15:   *Time Diagram "Drive-Controlled Change of Operation Mode"*

See also "Changing the Operation Mode"

External Acceleration Feedforward   The additive torque/force command value (S-0-0081), cyclically transmitted in the NC cycle time by the control unit, can be adjusted in such a way that it takes effect in the controller at the same time as the position command value (S-0-0047). For this purpose, the procedure of the position command value acceptance is emulated for the additive torque/force command value as follows:

- Moving **average filter** in the NC clock with filter order from "P-0-0041, Position command average value filter time constant"

- **Linear fine interpolator** in the position clock to distribute the additive torque/force command value over the position clock

- **Delay element** in the position clock with a delay of a maximum of 64 clocks to be set in "P-0-0458, Delay of add. command values"

The output value of this command value adjustment is added to the output of the velocity loop and is output in the parameter "P-0-0070, Effective additive torque/force command value". With a value greater than zero in "P-0-0458, Delay of add. command values", the function "external acceleration feedforward" is activated.

To make "P-0-0434, Position command value of controller" and P-0-0070 take effect at the same time, parameterize the delay element (P-0-0458) in dependance of "P-0-0187, Position command processing mode":

Operation Modes

P-0-0187	Type of interpolation	P-0-0458
0	Linear interpolation	P-0-0456 + 1
1	Cubic approximation	P-0-0456 + (NC clock / position clock - 1) + 1
2	Cubic fine interpolation	P-0-0456 + (NC clock / position clock) + 1

Fig.7-16:   Calculating the Number of Delay Clocks, External Acceleration Feedforward

If the NC cycle time is identical to the position clock, the term "NC clock / position clock" or "NC clock / position clock - 1" is not required when calculating P-0-0458.

☞   The function is also activated with P-0-0458 = "-1". In this case, the delay element is calculated internally, according to the above formula and depending on P-0-0187.

The PT1 filter that can be parameterized via P-0-0099 is not taken into account by the external acceleration feedforward and therefore should be deactivated when the linear interpolation is used.

Block Diagram   The figure below illustrates command value adjustment in the "position control" mode as a block diagram.
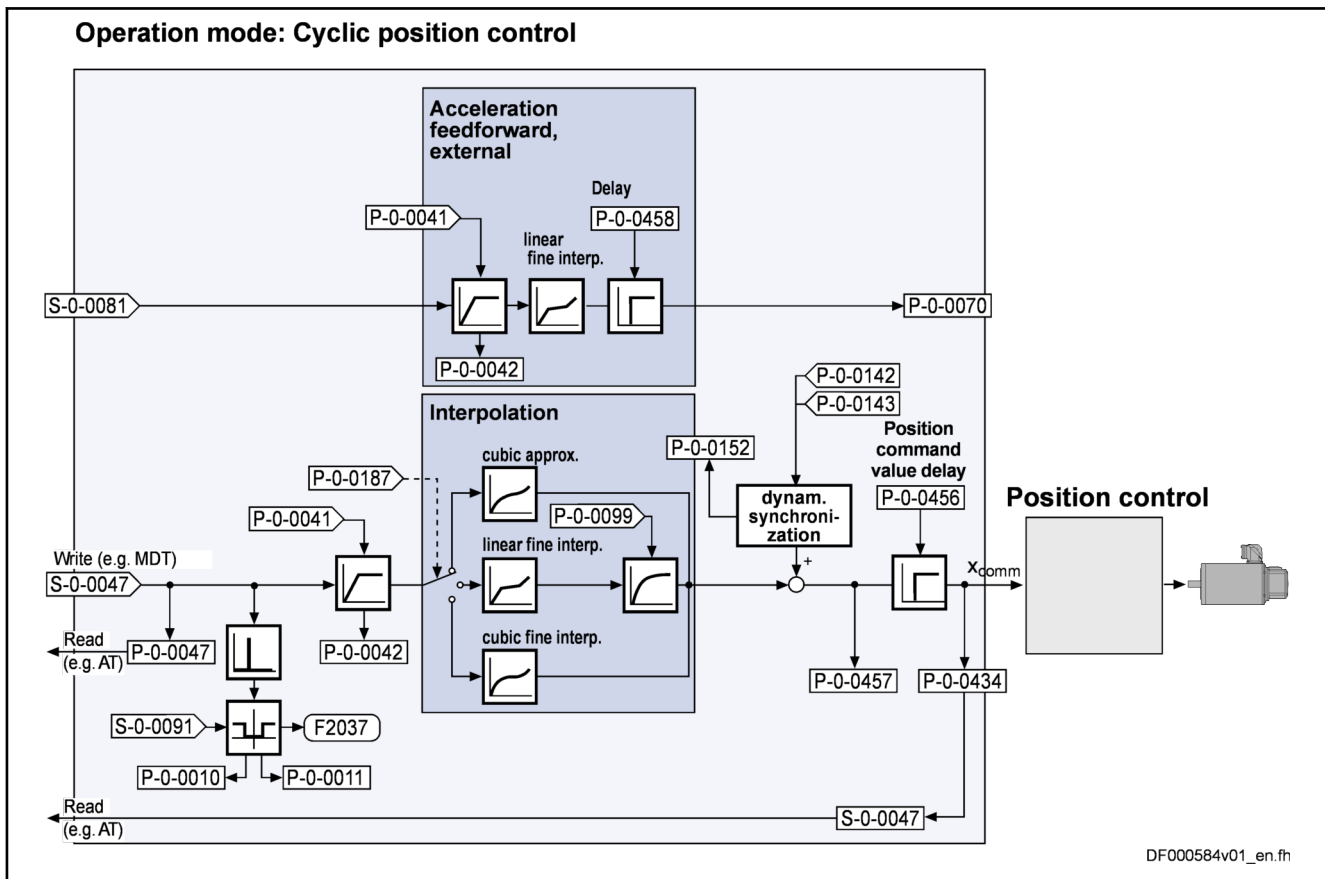
Fig.7-17:   Command Value Adjustment in Position Control

See also "Position Loop" in the same section

See also "Velocity Loop" in the section "Velocity Control"

Operation Modes

See also "Current Loop" in the 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").

Velocity Feedforward

The type of position control with regard to velocity feedforward generally can be set via "S-0-0520, Axis control word", but for operation modes with a definitely assigned encoder (e.g., position control, encoder 1 or ...., encoder 2 etc.) this property is exclusively controlled via a bit of the operation mode parameter.

- Lagless operation (**with** velocity feedforward)
- Operation with lag error (**without** velocity feedforward)

The lag error is the difference between position command value and actual position value. The current value is stored in "S-0-0189, Following distance".

☞ If the mechanical system and the application permit it, lagless operation should always be selected.

The velocity feedforward is variable and can be set via P-0-0040, Velocity feedforward evaluation. This allows setting the lag error to a desired percentage value at constant velocity.

☞ In lagless operation with P-0-0040 = 100%, there is a minimum lag error of "0" at constant velocity.

Acceleration Feedforward

In lagless operation, variable acceleration feedforward can be activated in addition to variable velocity feedforward (P-0-0040, Velocity feedforward evaluation).

To do this, the acceleration-proportional feedforward component (additive torque/force command value) is set via "S-0-0348, Acceleration feedforward gain".

☞ In addition, it is possible to realize feedforward via "P-0-1126, Velocity control loop: acceleration feedforward", but this feedforward is derived from the velocity command value. Therefore, you have to make sure that you 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

Operation Modes

- A0154 Position mode drive controlled, encoder 1
- A0155 Position mode drive controlled, encoder 2
- A0156 Position mode lagless, encoder 1 drive controlled
- A0157 Position mode lagless, encoder 2 drive controlled

Monitoring Functions/Diagnostic Messages Specific to Operation Mode

Monitoring for Single Position Command Value Failure

Position Command Value Extrapolation

In the "position control with cyclic command value input" mode, new position command values are transmitted to the drive in every NC cycle. The difference between the current and the last position command value is determined and a validation check is carried out for this difference.

Reasons why the monitoring function triggers:

- Incorrect command value input by control unit
- Command value transmission error

☞   In the case of single command value failure, the position command value is extrapolated.

Excessive Position Command Difference

When the "position control" mode was activated, the calculated velocity required for reaching the preset position command value (S-0-0047) is compared to "S-0-0091, Bipolar velocity limit value". The NC cycle time (TNcyc in S-0-0001) is used as the time base for converting the position command value differences into a velocity.

If the command velocity corresponding to the preset position command value exceeds the value in S-0-0091, the error message "F2037 Excessive position command difference" is generated. In addition, the two involved command values are written to the following parameters:

- P-0-0010, Excessive position command value
- P-0-0011, Last valid position command value

The velocity resulting from the difference of these two values generated the error message.
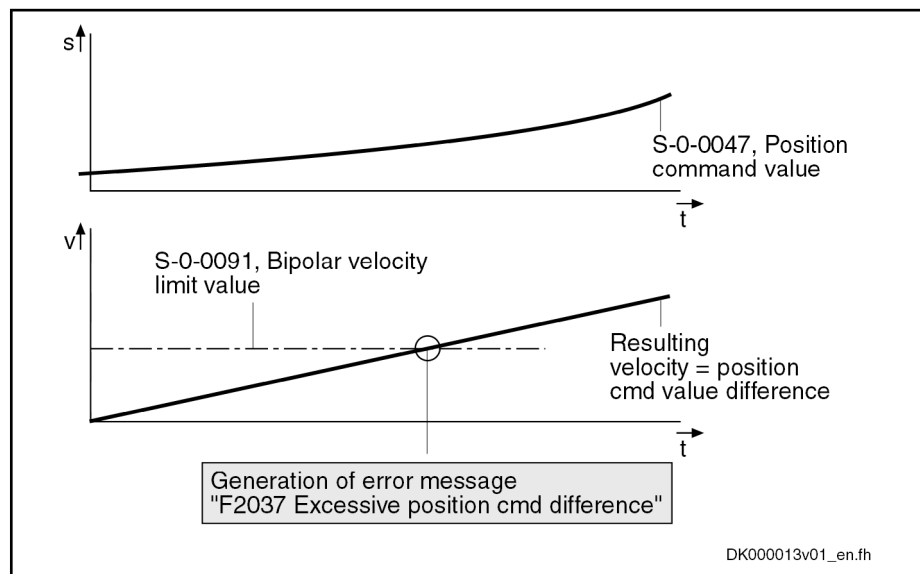
Fig.7-18:   Monitoring for Error "F2037 Excessive Position Command Difference"

☞ 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.

7.5 Drive-Internal Interpolation

7.5.1 Brief Description

💡 Assignment to functional firmware package, see chapter "Supported Operation Modes".

The operation modes "drive-internal interpolation" and "drive-controlled positioning" allow time-optimized positioning of a single axis. The "drive-internal interpolation" mode is the basis for the more comprehensive functionality of the "drive-controlled positioning" mode.

In the "drive-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 operation mode was activated (see below "Pertinent Diagnostic Messages").
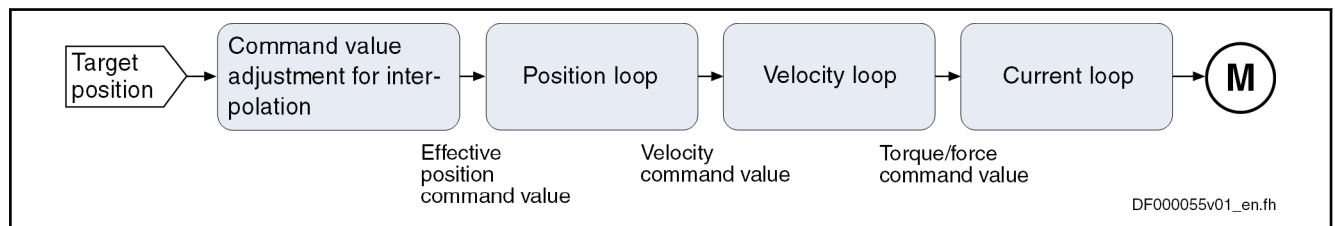
Fig.7-19:   Block Diagram "Drive-Internal Interpolation"

Features
- Drive-internal generation of a position command value profile to travel to a preset target position (S-0-0258) while maintaining the positioning velocity (S-0-0259) and positioning acceleration (S-0-0260) or positioning deceleration (S-0-0359) that can be set; can be set separately
- Jerk limitation of the generated position command value via "S-0-0193, Positioning Jerk"
- Setting of the average value filter (jerk limitation) to fixed filter time by means of interpolation cmd value average value filter time constant (P-0-0641)
- Adjustable deceleration of position command value in position clocks (P-0-0456, Position command value delay), maximum 32 clocks.
- 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)

Operation Modes

- Position control with regard to "S-0-0051, Position feedback value 1" (motor encoder) or "S-0-0053, Position feedback value 2" [external (load-side) encoder]

- Acceleration and deceleration ramps, can be set separately

- No change in direction of motion when "command value mode in modulo format" 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 mode"

☞   In this operation mode, it is possible to separately parameterize the acceleration and deceleration processes. This allows optimum adjustment to the respective application-specific requirements.

Pertinent Parameters
- S-0-0108, Feedrate override
- S-0-0138, Bipolar acceleration limit value
- S-0-0193, Positioning Jerk
- S-0-0258, Target position
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0359, Positioning deceleration
- S-0-0393, Command value mode
- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode
- S-0-0430, Effective target position
- S-0-0437, Positioning status
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant

Pertinent Diagnostic Messages
- A0106 Drive-internal interpolation, encoder 1
- A0107 Drive-internal interpolation, encoder 2
- A0108 Drive controlled interpolation, lagless, encoder 1
- A0109 Drive controlled interpolation, lagless, encoder 2
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2055 Feedrate override S-0-0108 = 0
- F2057 Target position out of travel range

7.5.2   Command Value Adjustment with Drive-Internal Interpolation

The target position can be cyclically preset via "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 "S-0-0430, Effective target position".

The figure below illustrates command value processing in the "drive-internal interpolation" mode as a block diagram.
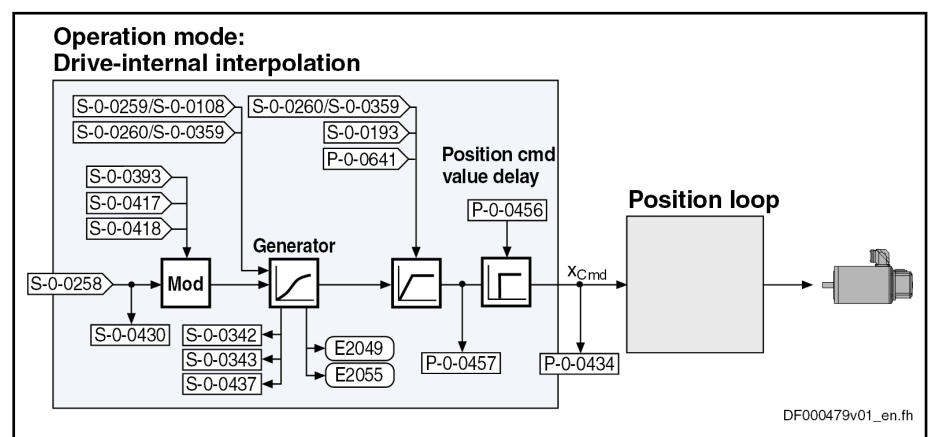
Fig.7-20:   Command Value Adjustment with "Drive-Internal Interpolation"

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 "P-0-0434, Position command value of controller" and can be output at the analog output.

In this operation mode, the same information as relevant in the "position control with cyclic command value input" mode applies to the position control loop.

See also "Control Loop Structure"

See also "Position 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 "S-0-0260, Positioning acceleration".

The maximum velocity during a positioning procedure is the result of:

Operation Modes

$$V_{max} = S\text{-}0\text{-}0259 \times \frac{S\text{-}0\text{-}0108}{100\,\%}$$

S-0-0259	Positioning velocity
S-0-0108	Feedrate override
Fig.7-21:	*Determining the Maximum Velocity during the Positioning Process*

Effective Acceleration and Deceleration

The maximum deceleration is defined in parameter "S-0-0359, Positioning deceleration".

If the value in parameter S-0-0359 equals zero, the drive uses the parameter value of "S-0-0260, Positioning acceleration" for deceleration, too.

If the value in parameter S-0-0260 equals zero, too, the parameter value of "S-0-0138, Bipolar acceleration limit value" is used. If this value has likewise been set to zero, acceleration is not limited. If possible, the drive sets the positioning velocity immediately.

Smoothing Filter (or Jerk Filter)

In the "drive-internal interpolation" mode the position command value can be filtered at the output of the positioning generator. We distinguish between two cases for setting of the filter order.

Case 1: Calculating the filter order from A / R

The filter order of the (moving) average filter available to do this (cf. P-0-0042) is calculated on the basis of the preset positioning acceleration or the positioning jerk.

This means that the parameterized acceleration or deceleration only becomes effective after t = P-0-0042 × $T_{A\_position}$.

☞ 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).

$$P\text{-}0\text{-}0042 = \frac{S\text{-}0\text{-}0260}{S\text{-}0\text{-}0193}[s] * \frac{10^6}{T_{A\_Lage}}$$

$$- \text{or} -$$

$$P\text{-}0\text{-}0042 = \frac{S\text{-}0\text{-}0359}{S\text{-}0\text{-}0193}[s] * \frac{10^6}{T_{A\_Lage}}$$

P-0-0042	Current position command average value filter order
S-0-0260	Positioning acceleration
S-0-0193	Positioning jerk
S-0-0359	Positioning deceleration
Fig.7-22:	*Internally Determining the Value of P-0-0042 for Operation Modes With "Drive-Internal Interpolation"*

☞ The setting S-0-0193 = 0 switches the smoothing filter off; i.e. the desired acceleration or deceleration is immediately reached.

Operation Modes

Case 2: Constant filter order

The filter order can also be set to a constant value. This is made via parameter "P-0-0641, Interpolation cmd value average value filter time constant". The filter order is calculated from the time constant related to the position clock $T_{A\_position}$. In the case of an order > 0 the function "filter order constant" is active and the calculation A/R without effect. In this context, a new filter order may only take effect upon initialization of the operation mode, as well as upon block change. As before, the current filter order is displayed in "P-0-0042, Current position command average value filter order".

Position Command Value Deceleration

The position command value can be delayed by maximum 32 position clocks after the jerk filter, before it is fed in the position controller. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position clocks is set with the position command value delay (P-0-0456). The position command value generator without delay (P-0-0457) is entered in a ring buffer and then the position command value with delay is applied in the position command value controller (P-0-0434).

Modulo Processing

"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, Command value mode":

- Bit 1/0 = 00 → Positive direction of rotation
- Bit 1/0 = 01 → Negative direction of rotation
- Bit 1/0 = 10 → Shortest distance

ℹ️ See also Parameter Description "S-0-0393, Command value mode"

Special Cases   The following special cases apply to the evaluation of the settings for "S-0-0393, Command value mode":

- If the absolute value of the current actual velocity is greater than the velocity threshold for positioning (S-0-0417, Positioning velocity threshold in modulo mode), the drive always moves in the last active direction of rotation.
- If the target position is within the target position window (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

| *NOTICE* | If the velocity threshold for positioning behavior was parameterized with very low values that are within the noise level of the actual velocity value, this can cause unpredictable behavior. |

ℹ️ 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"

Operation Modes

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-internal interpolation, encoder 1
- A0107 Drive-internal interpolation, encoder 2
- A0108 Drive controlled interpolation, lagless, encoder 1
- A0109 Drive controlled interpolation, lagless, encoder 2

Monitoring Functions

Monitoring functions specific to the operation mode:

Target Position out of Travel Range
- If position limit value monitoring is activated (bit 4 of "S-0-0055, Position polarities" has been set) and the measuring system used for the operation mode has been homed, the parameter "S-0-0258, Target position" is monitored for compliance with the position limit values (S-0-0049 or S-0-0050). If these values are exceeded, depending on the definition in "P-0-0090, Travel range limit parameter", either the error message F2057 Target position out of travel range or the warning "E2053 Target position out of travel range" is generated. If the warning has been parameterized, positioning to the limit switches takes place.

  The preset target position will not be accepted.

Positioning Velocity >= Limit Value
- If the preset positioning velocity ("S-0-0259, Positioning velocity") exceeds the maximum allowed limit value ("S-0-0091, Bipolar velocity limit value"), the warning "E2049 Positioning velocity >= limit value" is generated.

  The drive moves to the new target position with the velocity from parameter "S-0-0091, Bipolar velocity limit value".

Feedrate Override (S-0-0108) = 0
- If the positioning velocity factor "S-0-0108, Feedrate override" equals zero, the warning "E2055 Feedrate override S-0-0108 = 0" is generated.

Status Messages

"S-0-0437, Positioning status" contains all important status information for the operation mode "drive-internal interpolation".

ℹ️   See Parameter Description "S-0-0437, Positioning status"

The figures below illustrate the operating principle of the status messages:

Fig.7-23:   *Travel Profile to Explain How the Interpolation Status Messages Work*

In this example, the drive is at the starting position when the new target position is preset.

The result is the following time diagram:
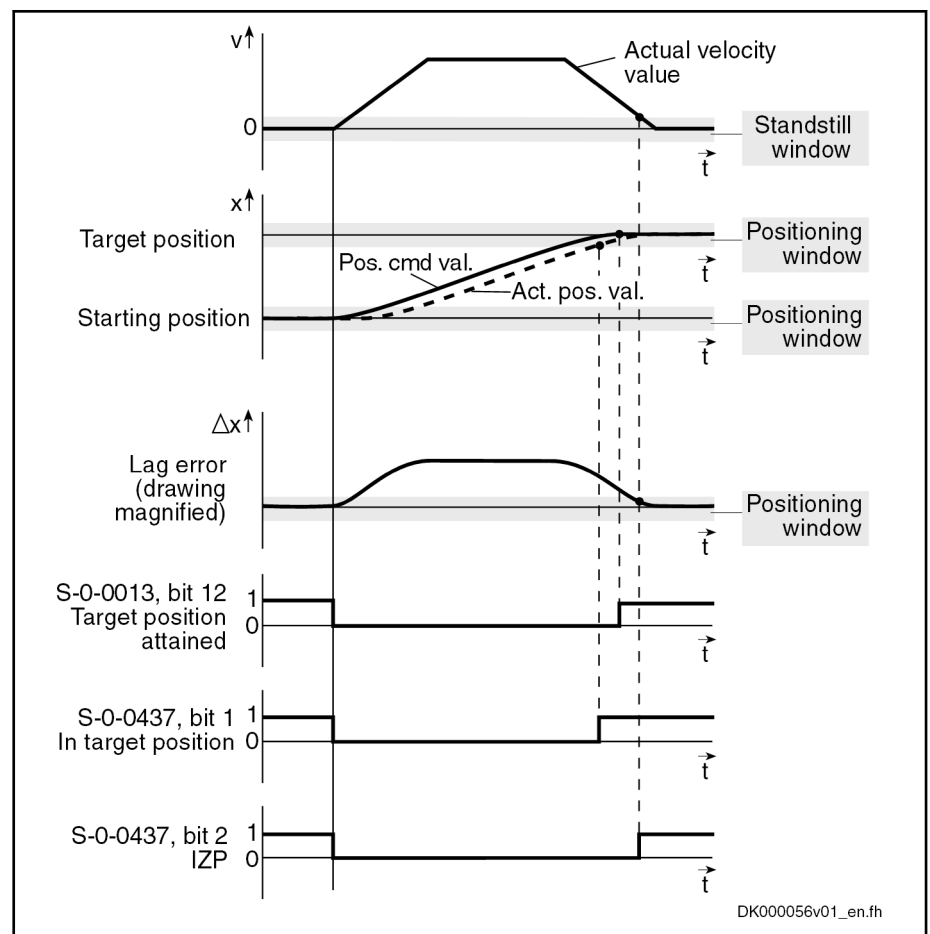
Fig.7-24:   Generating the Status Bits of the Operation Modes With "Drive-Internal Interpolation"

7.6   Drive-Controlled Positioning

7.6.1   Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

The operation modes "drive-internal interpolation" and "drive-controlled positioning" allow time-optimized positioning of a single axis. The "drive-internal interpolation" mode is the basis for the more comprehensive functionality of the "drive-controlled positioning" mode.

In the "drive-controlled positioning" mode, a positioning command value is preset for the drive. The drive can continue processing this value internally in absolute (position target) or relative (travel distance) form. In the internal interpolator, a position command value characteristic is generated as the input value for the position 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 operation mode was activated (see "Pertinent Diagnostic Messages" below).

Operation Modes

| Positioning cmd value | Command value adjustment for positioning | Position loop | Velocity loop | Current loop | M |

Effective position command value — Velocity command value — Torque/force command value

DF000056v01_en.fh
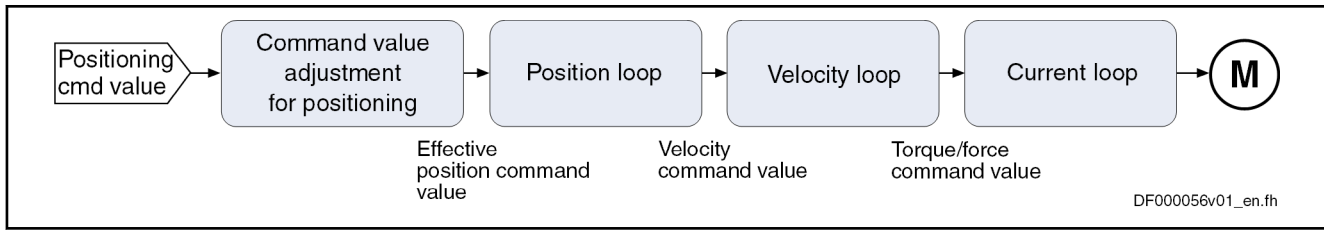
Fig.7-25:   Block Diagram "Drive-Controlled Positioning"

Features

- Processing of an absolute target position or a relative travel distance
- Drive-internal generation of a position command value profile to travel to the positioning command value (S-0-0282) while maintaining the positioning velocity (S-0-0259) and positioning acceleration (S-0-0260) or positioning deceleration (S-0-0359) that can be set; can be set separately
- Acceptance of the positioning command value via toggle bit (S-0-0346, bit 0)
- Jerk limitation of the generated position command value with "S-0-0193, Positioning Jerk"
- Setting of the average value filter (jerk limitation) to fixed filter time by means of interpolation cmd value average value filter time constant (P-0-0641)
- Adjustable position command value delay in position cycle times (P-0-0456), maximally 32 cycles.
- Evaluation of the positioning velocity with "S-0-0108, Feedrate override"
- Monitoring of the positioning velocity for exceeding the value in "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 "S-0-0393, Command value mode" (shortest distance, positive only or negative only direction, no reversal of direction of rotation)
- Position control with regard to "S-0-0051, Position feedback value 1" (motor encoder) or "S-0-0053, Position feedback value 2" [external (load-side) encoder]
- Acceleration and deceleration ramps can be set separately ("S-0-0260, Positioning acceleration" or "S-0-0359, Positioning deceleration")
- Position limit values taken into account when accepting target position, positioning velocity and positioning acceleration
- Jog mode ("infinite travel" positive/negative; S-0-0346, bits 1 and 2)
- Residual path processing can be activated
- "On-the-fly acceptance" of the new target position or intermediate stop

☞   In this operation mode, it is possible to separately parameterize the acceleration and deceleration processes in order to achieve optimum adjustment to the respective application-specific requirements.

Pertinent Parameters

- S-0-0057, Position window
- S-0-0108, Feedrate override

Operation Modes

- S-0-0138, Bipolar acceleration limit value
- S-0-0193, Positioning Jerk
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0282, Positioning command value
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0346, Positioning control word
- S-0-0359, Positioning deceleration
- S-0-0393, Command value mode
- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode
- S-0-0419, Positioning command acknowledge
- S-0-0430, Effective target position
- S-0-0437, Positioning status
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant

Pertinent Diagnostic Messages

- A0150 Drive-controlled positioning, encoder 1
- A0151 Drive-controlled positioning, encoder 1, lagless
- A0152 Drive-controlled positioning, encoder 2
- A0153 Drive-controlled positioning, encoder 2, lagless
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2055 Feedrate override S-0-0108 = 0
- E2064 Target position out of num. range
- F2050 Overflow of target position preset memory
- F2057 Target position out of travel range

7.6.2   Command Value Adjustment with Drive-Controlled Positioning

Overview

The figure below illustrates command value processing in the "drive-control-led positioning" mode as a block diagram.

Operation Modes

Operation mode: Drive-controlled positioning
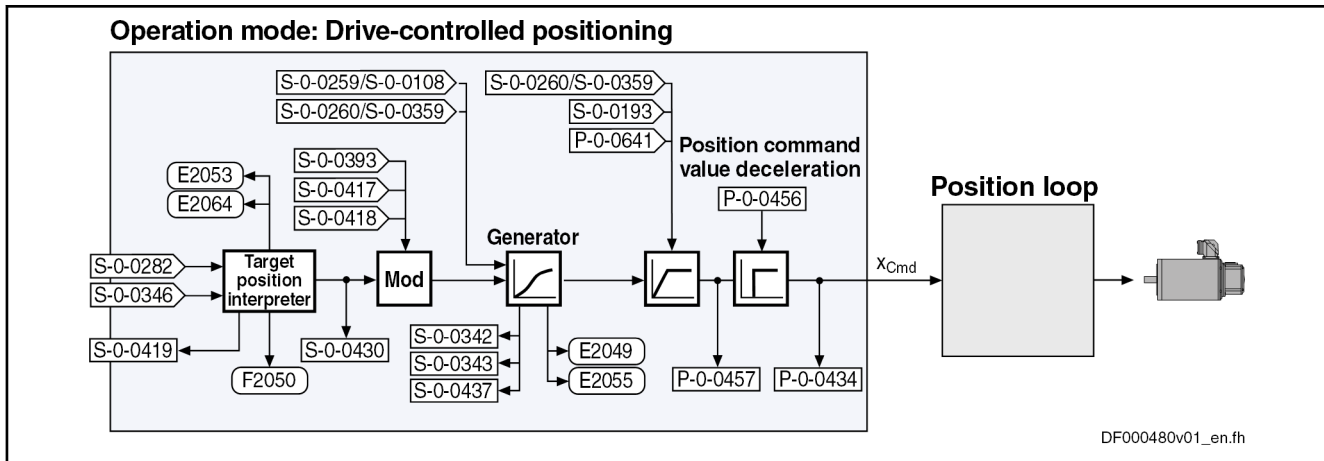
Fig.7-26:   Command Value Adjustment With "Drive-Controlled Positioning"

Position Target Interpreter

Accepting and Acknowledging the Command Value

The acceptance and internal processing of "S-0-0282, Positioning command value" to a value entered in "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 S-0-0430

   (when bit 3 = 0 → absolute **target position**)

- or -

- **added** to the value of 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 "S-0-0430, Effective target position".

Operation Modes
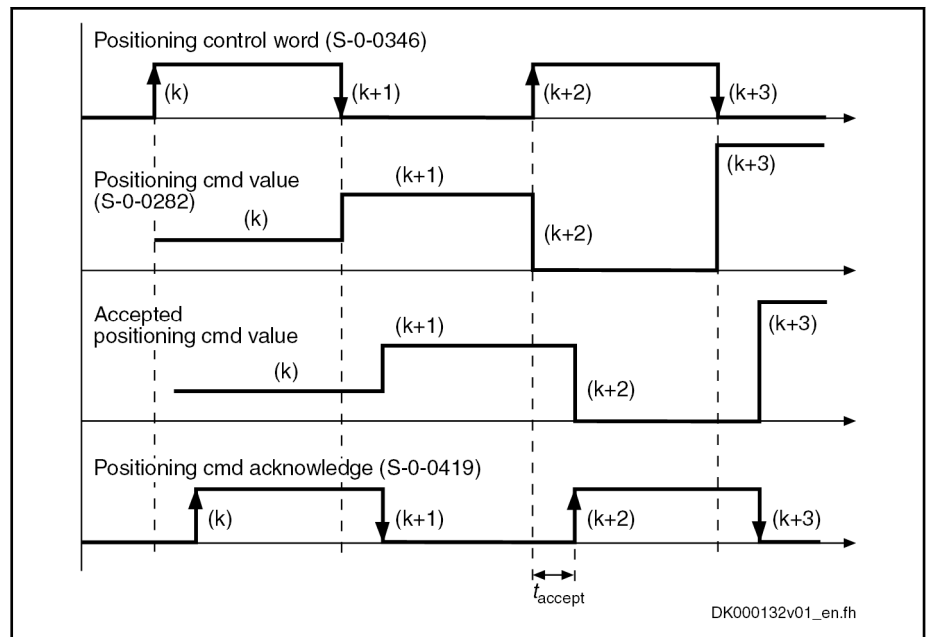
Fig.7-27:   Positioning Command Value Acceptance and Acknowledgment

Time t_{accept} (see illustration above) defines the time that passes between status change of the acceptance bit by the control unit and the reception of acknowledgment in the master. The time is made up of the effective transmission time of the command values and actual values and thus depends on the configuration of the interface to the master (e.g. SERCOS/field bus timing parameter).

☞   If the "drive-controlled positioning" mode is not yet active, the acceptance of the new positioning command value is not acknowledged.

If bit 0 of S-0-0346 is unequal bit 0 of S-0-0419 while the operation mode is active, the positioning command value from S-0-0282 is immediately accepted and the drive immediately moves to this command value.

The acknowledgment of acceptance takes place when the new positioning command value is accepted from the intermediate memory to "S-0-0430, Effective target position" and thus to the position command value generator.

Operation Modes
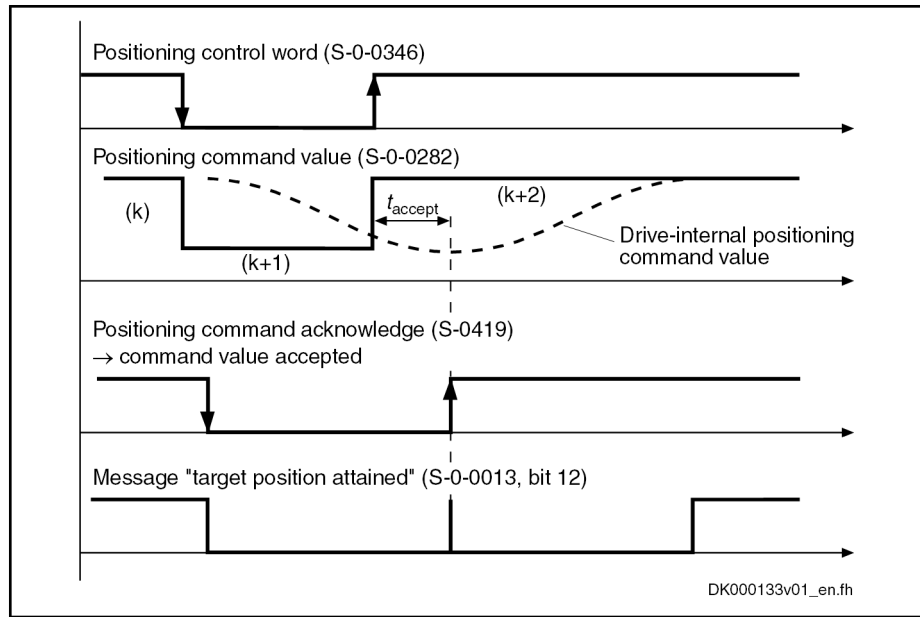
Fig.7-28:   Acknowledgment of Positioning Command Value Acceptance in Mode "Complete Move to Positioning Command Value (k+2)"

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 "S-0-0346, Positioning control word", although the previous positioning command value (k+1) was not accepted [because the drive had not yet moved to the previous positioning command value (k)], the error message "F2050 Overflow of target position preset memory" is generated.
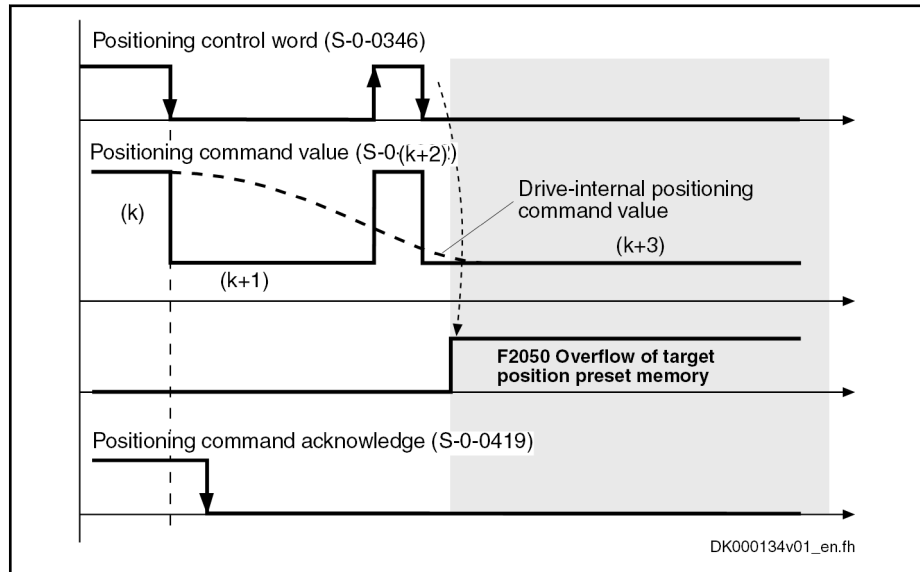
Fig.7-29:   Acknowledgment with Error "Overflow of Target Position Preset Memory"

In addition to bit 0 for mere block acceptance, "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 operation mode was activated, when the position status has been set and bit 2 = 1 in S-0-0393. In this case the residual path, after the operation mode was activated, is traveled without start edge.

Reaction to New Target Position Input

Via bit 5 of S-0-0346, it is possible to determine the time of the reaction to a new target position input:

- **Bit 5= 0** → The drive travels to the last preset target before positioning at the new target. The target is considered to have been reached when the following applies:

  Target position – actual position value < positioning window

- **Bit 5 =1** → The previous target is rejected and the drive immediately travels to the new target.

  → Immediate block change

ℹ️ See also Parameter Description "S-0-0346, Positioning control word"

Processing in Modulo Format

"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

ℹ️ See also Parameter Description "S-0-0393, Command value mode"

Special Cases

The following special cases apply to the evaluation of the settings for "S-0-0393, Command value mode":

- If the absolute value of the current actual velocity is greater than the velocity threshold for positioning (S-0-0417, Positioning velocity threshold in modulo mode), the drive always moves in the last active direction of rotation.

- If the target position is within the target position window (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

Operation Modes

> *NOTICE*   If the velocity threshold for positioning behavior was parameterized with very low values that are within the noise level of the actual velocity value, this can cause an unpredictable behavior.

> **i**   See also Parameter Description "S-0-0417, Positioning velocity threshold in modulo mode" and "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 "P-0-0434, Position command value of controller" and can be output at the analog output.

In this operation mode, the same information as relevant in the "position control with cyclic command value input" mode applies to the position control loop.

See also "Control Loop Structure"

See also "Position Loop" in section "Position Control with Cyclic Command Value Input"

7.6.4   Jog Mode with Drive-Controlled Positioning ("Jogging")

> ☞   The jog mode is part of the positioning mode and not an individual operation mode! This means that there aren't any separate parameters for the jog mode, but you have to use the parameters of the "drive-controlled positioning" mode.

Activating the Jog Mode   To use the jog mode, make the following settings:

- Activate the "drive-controlled positioning" mode

  - and -

- Select the positioning mode "infinite travel" (jog positive or negative → jog mode) via bits 1 and 2 of parameter "S-0-0346, Positioning control word"

Parameterizing the Jog Mode   When jogging, the following parameters are relevant for operation:

- S-0-0108, Feedrate override

  → To achieve online, if necessary, the reduction of the jog velocity by means of a "potentiometer"

- S-0-0193, Positioning Jerk
- S-0-0259, Positioning velocity

  When the jog mode is active, the positioning velocity also takes immediate effect.

- S-0-0260, Positioning acceleration
- S-0-0282, Positioning command value
- S-0-0346, Positioning control word

  → To select the jog direction ("Jog+", "Jog-" and "stopping")

- S-0-0359, Positioning deceleration

The parameters for acceleration, deceleration and jerk are applied at the start and stop of a jog movement.

During the jog mode, changes in the parameters can only take effect when the acceptance bit in the positioning control word (bit 0) is toggled (applies as of MPx-07V10).

☞   Bits 1 and 2 of 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 "S-0-0260, Positioning acceleration".

The maximum velocity during a positioning procedure is the result of:

$$V_{max} = S\text{-}0\text{-}0259 \times \frac{S\text{-}0\text{-}0108}{100\ \%}$$

S-0-0259   Positioning velocity
S-0-0108   Feedrate override
Fig.7-30:   *Determining the Maximum Velocity during the Positioning Process*

Effective Acceleration and Deceleration

The maximum deceleration is defined in "S-0-0259, Positioning velocity".

If the value in parameter S-0-0359 equals zero, the drive uses the parameter value of "S-0-0260, Positioning acceleration" for deceleration, too.

If the value in parameter S-0-0260 equals zero, too, the parameter value of "S-0-0138, Bipolar acceleration limit value" is used. If this value has likewise been set to zero, acceleration is not limited. If possible, the drive sets the positioning velocity immediately.

Smoothing Filter (or Jerk Filter)

In the "drive-controlled interpolation" mode, the position command value can be filtered at the output of the positioning generator. We distinguish between two cases for setting of the filter order.

Case 1: Calculating the filter order from A / R

Operation Modes

The filter order of the (moving) average filter available to do this (cf. P-0-0042) is calculated on the basis of the preset positioning acceleration or the positioning jerk.

Because of the filter the parameterized acceleration or deceleration only becomes effective after $t = \text{P-0-0042} \times T_{A\_position}$.

☞ 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).

$$\text{P-0-0042} = \frac{\text{S-0-0260}}{\text{S-0-0193}}[s] * \frac{10^6}{T_{A\_Lage}}$$

$$- \text{or} -$$

$$\text{P-0-0042} = \frac{\text{S-0-0359}}{\text{S-0-0193}}[s] * \frac{10^6}{T_{A\_Lage}}$$

P-0-0042   Current position command average value filter order
S-0-0260   Positioning acceleration
S-0-0193   Positioning jerk
S-0-0359   Positioning deceleration
Fig.7-31:   Internally Determining the Value of P-0-0042 for Operation Modes with Drive-Internal Interpolation

☞ The setting S-0-0193 = 0 switches the smoothing filter off; i.e. the desired acceleration or deceleration is immediately reached.

Case 2: Constant filter order

The filter order can also be set to a constant value. This is made via parameter "P-0-0641, Interpolation cmd value average value filter time constant". The filter order is calculated from the time constant related to the position clock $T_{A\_position}$. In the case of an order > 0 the function "filter order constant" is active and the calculation A/R without effect. A new filter order can only take effect during initialization of the operation mode and during change of blocks. As before, the current filter order is displayed in "P-0-0042, Current position command average value filter order".

Position Command Value Deceleration

The position command value can be delayed by maximum 32 position clocks after the jerk filter, before it is fed in the position controller. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position clocks is set with the position command value delay (P-0-0456). The position command value generator without delay (P-0-0457) is entered in a ring buffer and then the position command value with delay is applied in the position command value controller (P-0-0434).

Command Value Mode in Modulo Format

Positive/Negative Direction of Motion   If modulo format was selected for displaying position data (infinitely turning axes) and positive or negative direction of motion was set in parameter

Operation Modes

"S-0-0393, Command value mode", the drive moves to the preset target position in the programmed direction.

Via parameter "S-0-0418, Target position window in modulo mode", it is possible to set the distance between actual position value and target position from which on it is the "shortest distance" that is traveled.

"Positive Direction" and Position Target Outside of Target Position Window

The examples below show the behavior of the drive for 3 different start velocities in the "positive direction" mode and target position outside of the target position window (S-0-0418).

- **Case 1:**

  Current velocity positive and braking distance greater than the distance between starting point and next target point

  → Drive moves to next possible target position

- **Case 2:**

  Current velocity positive and braking distance smaller than the distance between starting position and next target position

  → Drive moves to next possible target position

- **Case 3:**

  Current velocity negative (< S-0-0417)

  → Drive brakes to velocity = 0 and positions at next target in positive direction

"Positive Direction" and Position Target Inside of Target Position Window

The examples below show the behavior of the drive for 4 different start velocities in the "positive direction" mode and target position inside of the target position window (S-0-0418).

- **Case 4:**

  Current velocity positive and braking distance greater than the distance between starting point and next target point

  → Drive moves to next possible target position in positive direction

  Braking and moving back would lead to a movement in negative direction greater than the programmed target position window!

  The following applies to the braking procedure:

  Starting position + braking distance – target position **> S-0-0418**

  → Positioning in negative direction not allowed; i.e. drive must move to target in positive direction

- **Case 5:**

  Current velocity = 0

  → Drive moves to target position in negative direction

  The following applies to the braking procedure:

  Starting position + braking distance – target position **< S-0-0418**

  → Positioning in negative direction allowed; i.e. drive must move to target in negative direction

- **Case 6:**

  Current velocity negative and braking distance smaller than the difference between starting position and next target position

  → Drive directly moves to target position in negative direction

  The following applies to the braking procedure:

Operation Modes

Starting position + braking distance (negative) – target position **< S-0-0418**

→ Positioning in negative direction directly at target position

- **Case 7:**

  Current velocity negative (< S-0-0417) and braking distance greater than the difference between starting position and next target position

  → Drive brakes to zero and positions at next target position in positive direction

  The following applies to the braking procedure:

  Starting position + braking distance (negative) – target position **> S-0-0418**

  → Drive brakes to zero and positions positively at next target position

---

☞   As a matter of principle, the braking distance is calculated before starting the positioning movement; the result of the calculation influences the subsequent positioning procedure.

Shortest distance

In the "shortest distance" mode, the drive positions at the effective target position (cf. S-0-0430) over the shortest possible distance.

☞   Depending on "S-0-0417, Positioning velocity threshold in modulo mode", the drive moves with or without change in direction.

"Shortest Distance" with Different Velocities

The following examples show the behavior of the drive in the "shortest distance" mode with different velocities.

- **Case 8:**

  Current velocity positive and **> S-0-0417**; braking distance greater than the distance between starting position and next target position

  → Drive moves to target position that can be reached without reversal of direction, in positive direction

  The following applies to the braking procedure:

  Starting position + braking distance – target position **> S-0-0418**

  → Positioning in negative direction not allowed; i.e. drive must move to target in positive direction

- **Case 9:**

  Current velocity (positive) **< S-0-0417**; braking distance smaller than distance between starting position and next target position

  → Drive moves to next target position

  The following applies to the braking procedure:

  Starting position + braking distance – target position **< S-0-0418**

  → Positioning in negative direction allowed; i.e. drive must move to target in negative direction

- **Case 10:**

  Current velocity (negative) **< S-0-0417**

  Braking distance smaller than distance between starting position and next target position

  → Drive moves to next target position

  The following applies to the braking procedure:

Operation Modes

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, lagless
- A0152 Drive-controlled positioning, encoder 2
- A0153 Drive-controlled positioning, encoder 2, lagless, lagless

Monitoring Functions

Monitoring functions specific to the operation mode:

Target Position out of Travel Range
- If position limit value monitoring is activated (bit 4 of "S-0-0055, Position polarities" has been set) and the measuring system used for the operation mode has been homed, the parameter "S-0-0258, Target position" is monitored for compliance with the position limit values (S-0-0049 or S-0-0050). If these values are exceeded, depending on the definition in "P-0-0090, Travel range limit parameter", either the error message "F2057 Target position out of travel range" or the warning "E2053 Target position out of travel range" is generated. If the warning has been parameterized, positioning to the limit switches takes place.

  The preset target position will not be accepted.

Operation Modes

Positioning Velocity >= Limit Value   •   If the preset positioning velocity (S-0-0259, Positioning velocity) exceeds the maximum allowed limit value (S-0-0091, Bipolar velocity limit value), the warning "E2049 Positioning velocity >= limit value" is generated.

The drive moves to the new target position with the velocity from parameter "S-0-0091, Bipolar velocity limit value".

Feedrate Override (S-0-0108) = 0   •   If the positioning velocity factor "S-0-0108, Feedrate override" equals zero, the warning "E2055 Feedrate override S-0-0108 = 0" is generated.

Status Messages

"S-0-0437, Positioning status" contains all important status information for the operation mode "drive-internal interpolation".

ℹ️ See Parameter Description "S-0-0437, Positioning status"

The figures below illustrate the operating principle of the status messages:

Fig.7-32:   Travel Profile to Explain How the Interpolation Status Messages Work

In this example, the drive is at the starting position when the new target position is preset.

The result is the following time diagram:
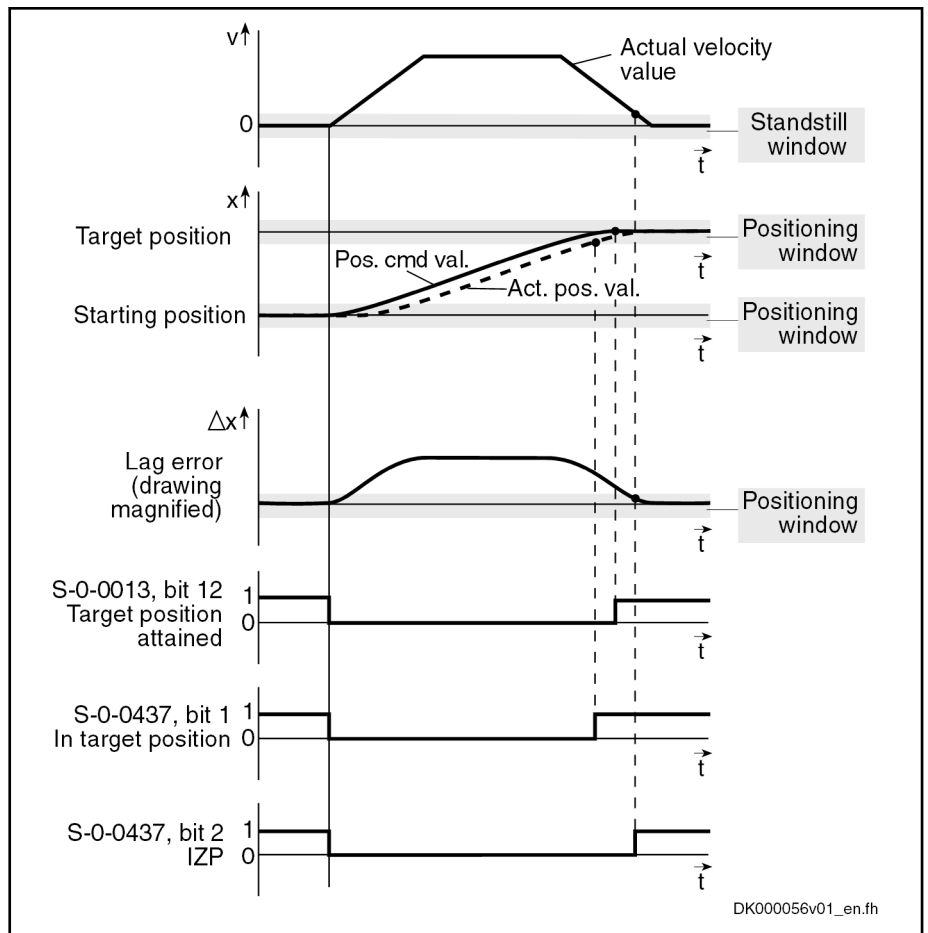
Fig.7-33:   Generating the Status Bits of the Operation Modes with Drive-Internal Interpolation

7.7   Positioning Block Mode

7.7.1   Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

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.
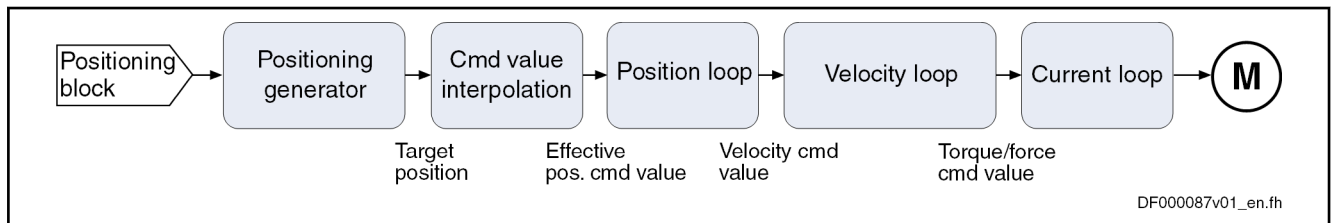
Fig.7-34:   Block Diagram "Positioning Block Mode":

Features   ● Parameterization of up to 64 positioning blocks; each with target position/travel distance, velocity, acceleration, deceleration and jerk

Operation Modes

- Jerk limitation of the generated position command value via "P-0-4009, Positioning block jerk"
- Setting of the average value filter (jerk limitation) to fixed filter time by means of interpolation cmd value average value filter time constant (P-0-0641)
- Adjustable deceleration of position command value in position clocks (P-0-0456, Position command value delay), maximum 32 clocks.
- Defined block acceptance by toggling bit 0 in "S-0-0346, Positioning control word" with reaction time $t_{R\_strobe} = t_{position}$

  Note: With field bus drives, the I/O mode is an exception. In this case, 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

Operation Modes

- S-0-0419, Positioning command acknowledge
- S-0-0430, Effective target position
- S-0-0437, Positioning status
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant
- P-0-4006, Positioning block target position
- P-0-4007, Positioning block velocity
- P-0-4008, Positioning block acceleration
- P-0-4009, Positioning block jerk
- P-0-4018, Positioning block delay time
- P-0-4019, Positioning block mode
- P-0-4026, Positioning block selection
- P-0-4051, Positioning block acknowledgment
- P-0-4052, Positioning block, last accepted
- P-0-4053, Positioning block, last active
- P-0-4057, Positioning block, input linked blocks
- P-0-4060, Positioning block control word
- P-0-4061, Positioning block status word
- P-0-4063, Positioning block deceleration

☞   S-0-0259 is used in positioning block mode to reduce positioning velocity (see also "P-0-4060, Positioning block control word").

Pertinent Diagnostic Messages
- A0162 Positioning block mode
- A0206 Positioning block mode, encoder 1
- A0207 Positioning block mode lagless, encoder 1
- A0210 Positioning block mode, encoder 2
- A0211 Positioning block mode lagless, encoder 2
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2054 Not homed
- E2055 Feedrate override S-0-0108 = 0
- E2058 Selected positioning block has not been programmed
- 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" mode as a block diagram.

Operation Modes
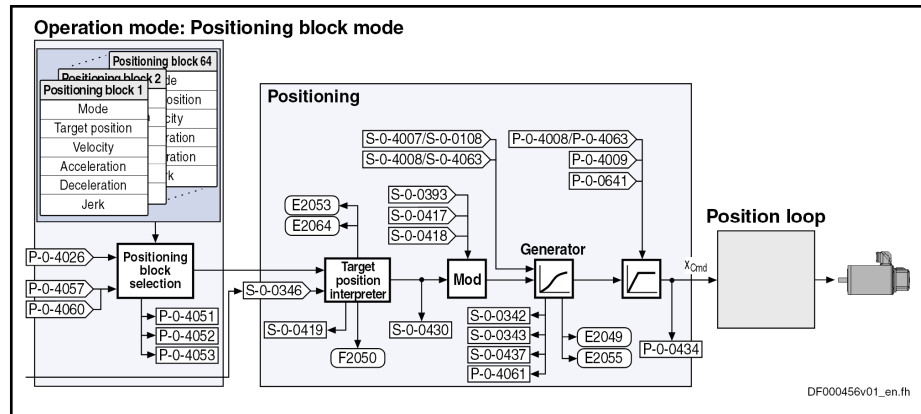
Fig.7-35:   *Command Value Adjustment with Positioning Block Mode*

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 delay time
- P-0-4019, Positioning block mode
- P-0-4063, Positioning block deceleration

☞   Each list parameter contains 64 elements, elements of the same number generate the travel profile of the respective positioning block.

The drive reaches the relevant positioning block velocity after an acceleration phase with the corresponding positioning block acceleration (P-0-4008).

Effective Positioning Velocity   The effective velocity during a positioning process is calculated as follows:

$$v_{max} = P\text{-}0\text{-}4007 \times \frac{S\text{-}0\text{-}0108}{100\ \%}$$

v_{max} Velocity
P-0-4007   Positioning block velocity
S-0-0108   Feedrate override
Fig.7-36:   *Effective Velocity during a Positioning Process*

Effective Acceleration and Decel-   The maximum delay is specified by "P-0-4063, Positioning block
eration   deceleration".

> **NOTICE**   The specified target is never reached or over-run, when the acceleration or deceleration value equals zero, because the drive can no longer brake!

⇒ Set acceleration value > 0 !

☞   Further limitation takes place by the value of "S-0-0138, Bipolar acceleration limit value", because this limit value takes effect in all operation modes with position control.

Jerk Limitation by Jerk Filter   In the "drive-internal interpolation" mode the position command value can be filtered at the output of the positioning generator. We distinguish between two cases for setting of the filter order.

Case 1: Calculating the filter order from A / R

This means that the parameterized acceleration or deceleration only becomes effective after $t = \text{P-0-0042} \times T_{A\_position}$.

☞   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).

$$\text{P-0-0042} = \frac{\text{P-0-4008}}{\text{P-0-4009}}$$

$$- \text{or} -$$

$$\text{P-0-0042} = \frac{\text{P-0-4063}}{\text{P-0-4009}}$$

P-0-0042	Current position command average value filter order
P-0-4008	Positioning block acceleration
P-0-4063	Positioning block deceleration
P-0-4009	Positioning block jerk

Fig.7-37:   *Internally Determining the Value of P-0-0042 for Positioning Block Mode*

☞   The setting P-0-4009 = 0 switches the smoothing filter off; i.e. the desired acceleration or deceleration is immediately reached.

Case 2: Constant filter order

The filter order can also be set to a constant value. This is made via parameter "P-0-0641, Interpolation cmd value average value filter time constant". The filter order is calculated from the time constant related to the position clock $T_{A\_position}$. In the case of an order > 0 the function "filter order constant" is active and the calculation A/R without effect. In this context, a new filter order may only take effect upon initialization of the operation mode, as well as upon block change. As before, the current filter order is displayed in "P-0-0042, Current position command average value filter order".

Position Command Value Deceleration   The position command value can be delayed by maximum 32 position clocks after the jerk filter, before it is fed in the position controller. Thus, synchro-

Operation Modes

nous control of a master axis and the controlled slave axis is made possible. The number of position clocks is set with the position command value delay (P-0-0456). The position command value generator without delay (P-0-0457) is entered in a ring buffer and then the position command value with delay is applied in the position command value controller (P-0-0434).

Positioning Block Control Word

With parameter "P-0-4060, Positioning block control word" (bit 1), the positioning velocity can be limited to the value defined in "S-0-0259, Positioning velocity".

Position Feedback

When a positioning block is completed, bit 4 (end position reached) is set in "P-0-4061, Positioning block status word".

→ |S-0-0430 – S-0-0051/53| < S-0-0057 && no sequential block

Interrupting a Positioning Block

The positioning block mode can be interrupted by:

- Removing drive enable
- Activating "Drive HALT"
- Changing the operation mode
- Jogging
- Positioning stop or operational stop (S-0-0346, bit 1 and bit 2 = 1)
- A drive error occurring

Positioning Block Modes

"P-0-4019, Positioning block mode" determines how the target position is processed in "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

ℹ️ 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)

"S-0-0393, Command value mode" controls the drive behavior in case "modulo format" was set as processing format of the position data.

ℹ️ 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 within the target position window is in the modulo format (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

| *NOTICE* | If the velocity threshold for positioning in modulo format was parameterized with very low values that are within the noise level of the actual velocity value, this can cause unpredictable behavior. |

ℹ️   See Parameter Description "S-0-0417, Positioning velocity threshold in modulo mode"

ℹ️   See 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 operation mode.

☞   This is done by the respective selection of the active operation mode in the status word, by activating drive enable and by setting "Drive Halt" = 1.

Command Value Acceptance   Depending on the master communication, a positioning block is started by:

- Toggling bit 0 in "S-0-0346, Positioning control word"

- or -

- 0-1 edge of bit 0 in "P-0-4060, Positioning block control word", with **field 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 S-0-0346 is toggled internally, too, in the case of a 0-1 edge of bit 0 of P-0-4060.

According to master communication and profile type, the block acceptance requires different configurations in the cyclic command value channel:

- **SERCOS interface**
    - "S-0-0346, Positioning control word" has to be configured in the cyclic data channel (MDT)
- **Field bus interface**
    - In the freely configurable mode (profile type P-0-4084 = 0xFFFE), bit 0 of P-0-4077 is mapped to bit 0 of S-0-0346.
    - In the "I/O mode positioning" (profile type P-0-4084 = 0xFF82), bit 3 of P-0-4068 is mapped to bit 0 of "P-0-4060, Positioning block control word".

        As an alternative, the start in the I/O mode can also take place by setting the start signal (P-0-4068, bit 1).

See also "Command Value Acceptance and Acknowledgment" in section "General Information on the Operation Modes"

Operation Modes

☞   If bit 0 is different in S-0-0346 and in S-0-0419 when the opera-
       tion mode is activated, the selected positioning block is immedi-
       ately accepted and executed.

Block Selection   In the positioning block mode, block selection is always carried out via the
                   content of "P-0-4026, Positioning block selection".

                   Depending on the master communication, P-0-4026 can be written in differ-
                   ent ways:

Configuration of P-0-4026	Master communication		
	SERCOS in terface	Field bus interface	
Via cyclic data channel	■	■	
Via digital inputs	■	■	
Via serial interface	■	■	
Via field bus control word	--	■	

*Fig.7-38:   Possibilities of Writing Parameter P-0-4026 Depending on the Master
             Communication*

☞   The assignment of P-0-4026 to digital inputs requires, among oth-
       er things, "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) posi-
                     tion 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 posi-
                          tioning blocks are only executed, if the target position is within the al-
                          lowed travel range.

                     Example:

                     Absolute positioning with target position = 700 (current position = 200)

Operation Modes

Fig.7-39:   *Absolute Positioning Block*

☞   According to master communication, positioning block accept-
ance 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

Dedicated Position   In the case of relative positioning blocks without residual path storage, the
target position contained in the positioning block is added to the current posi-
tion.

Operation Modes

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)
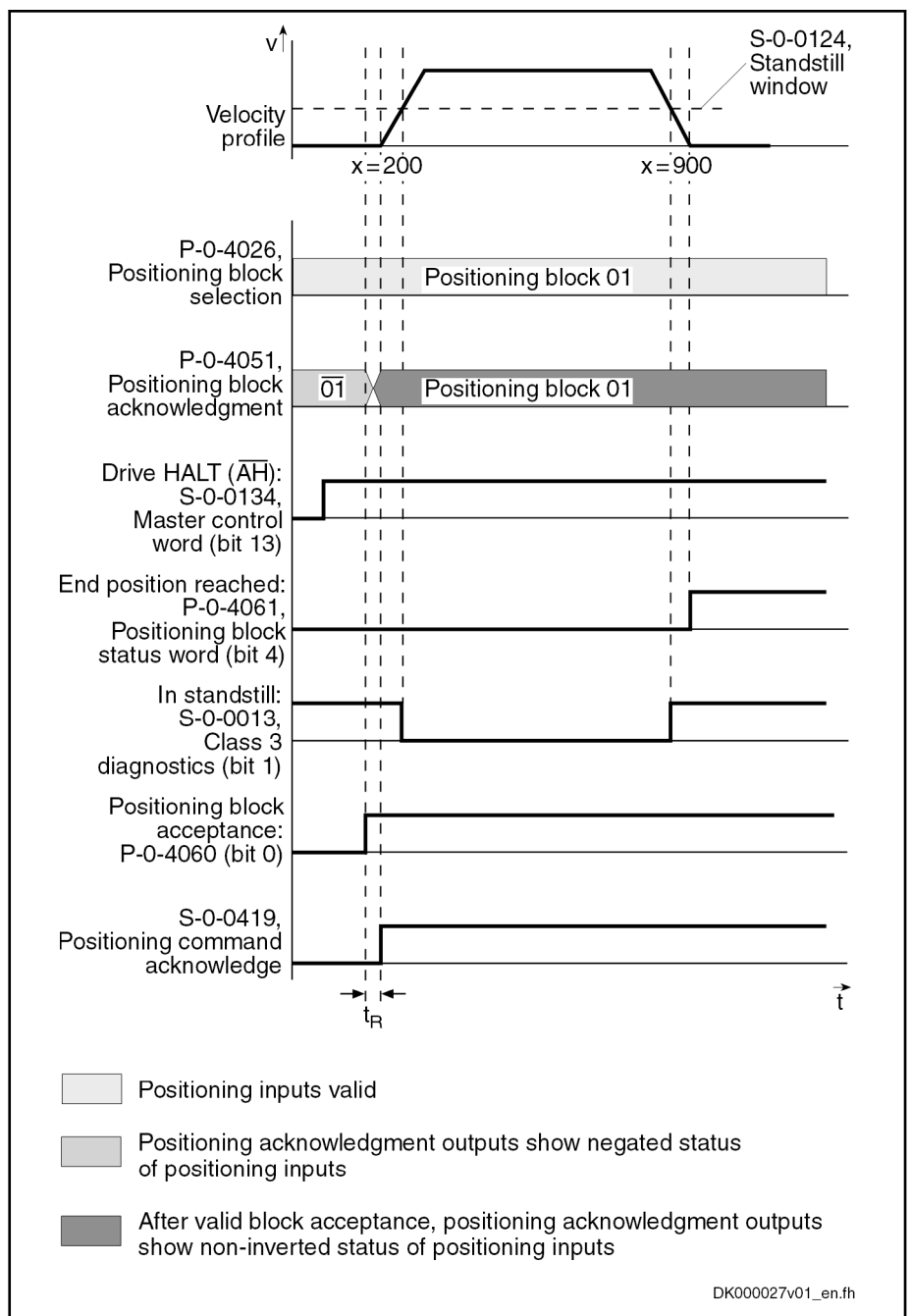
Fig.7-40:   *Relative Positioning Block without Residual Path Storage*

☞   According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 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

Operation Modes
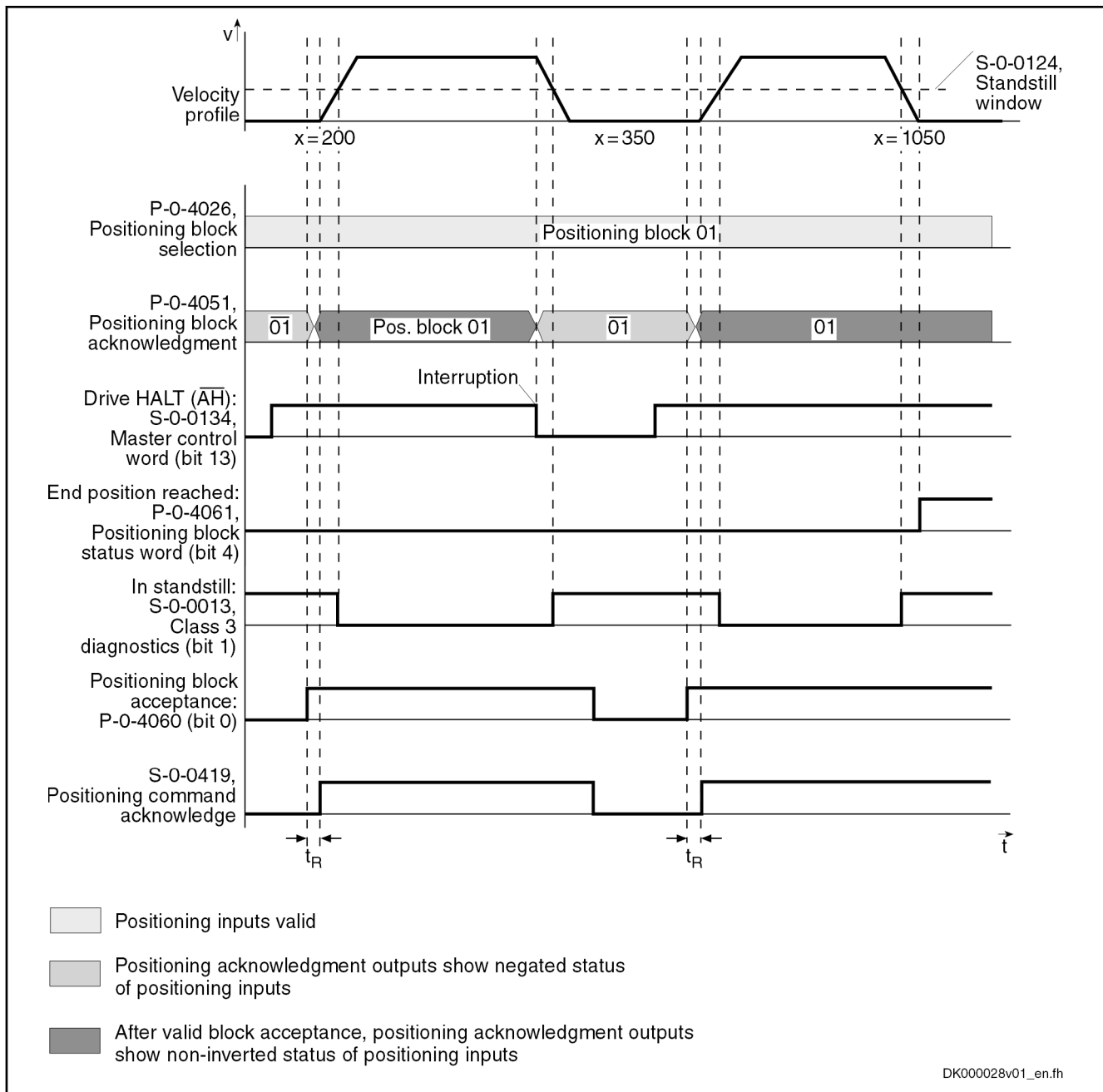
Fig.7-41:   Interrupting a Relative Positioning Bock without Residual Path Storage

☞   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.

Operation Modes

In a relative positioning block with residual path storage, the target position is a relative distance that relates to the target position at which the message "end position reached" was last active.

Relative positioning blocks with residual path storage are also executed, if the drive has not been homed.

Incremental Dimension Reference   By sequencing relative positioning blocks it is possible to position with incremental dimension. If a relative positioning block with residual path storage is interrupted, the incremental dimension reference is retained.

☞   If another positioning block is started while such a positioning block is being executed, the residual path is rejected. If this new block is also a relative positioning block with residual path storage, the target position is related **to the current actual position** as a relative distance.

Example:

- Relative positioning with residual path storage with travel distance = 700 (plus residual path = 20 of positioning block n-1)
- Without interruption
- Current position = 180; new target position = 900

Dedicated Position   The last valid target position is used as dedicated position (in the example, position = 200 of positioning block n-1).

Operation Modes
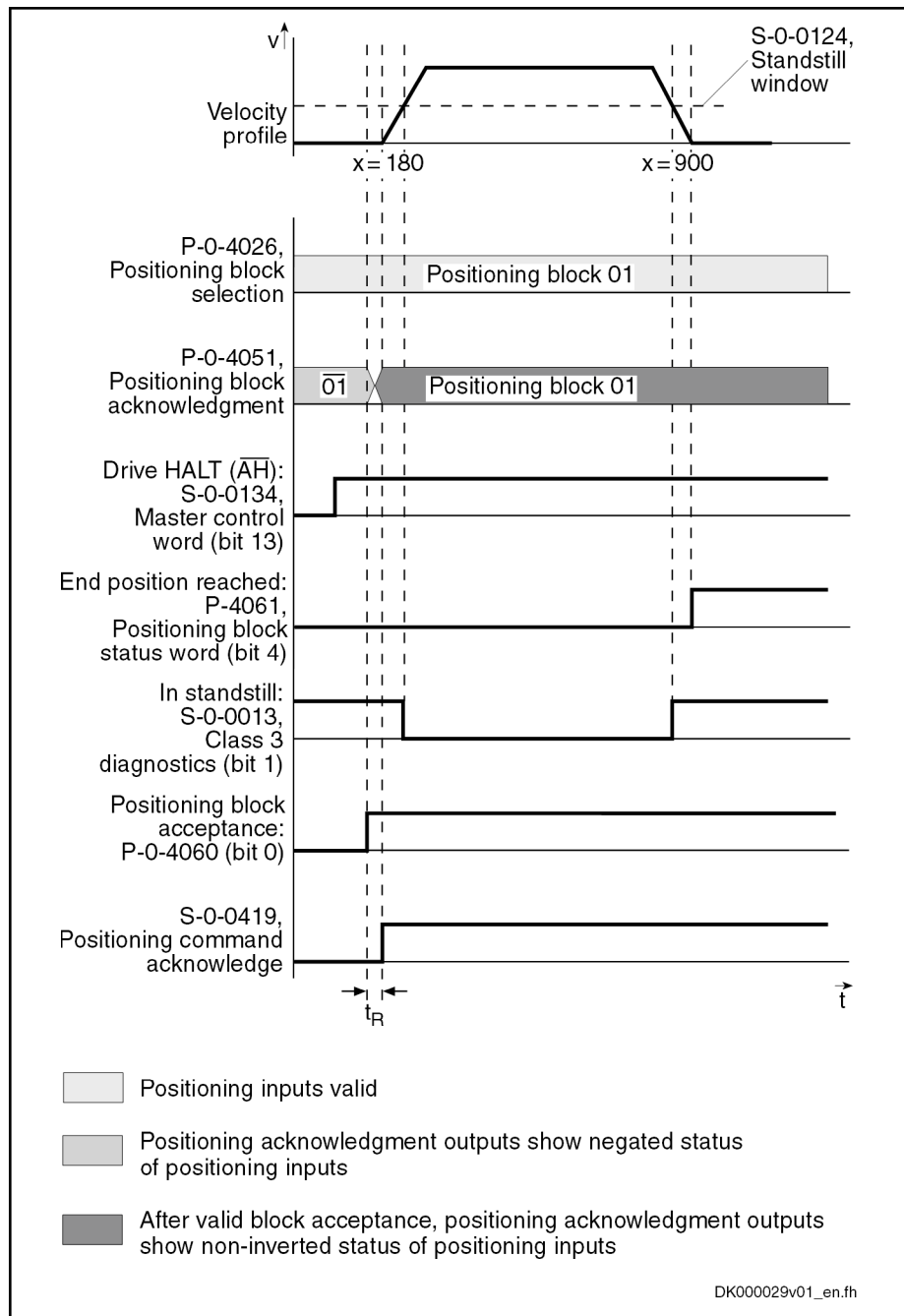
Fig.7-42:   Relative Positioning Block with Residual Path Storage
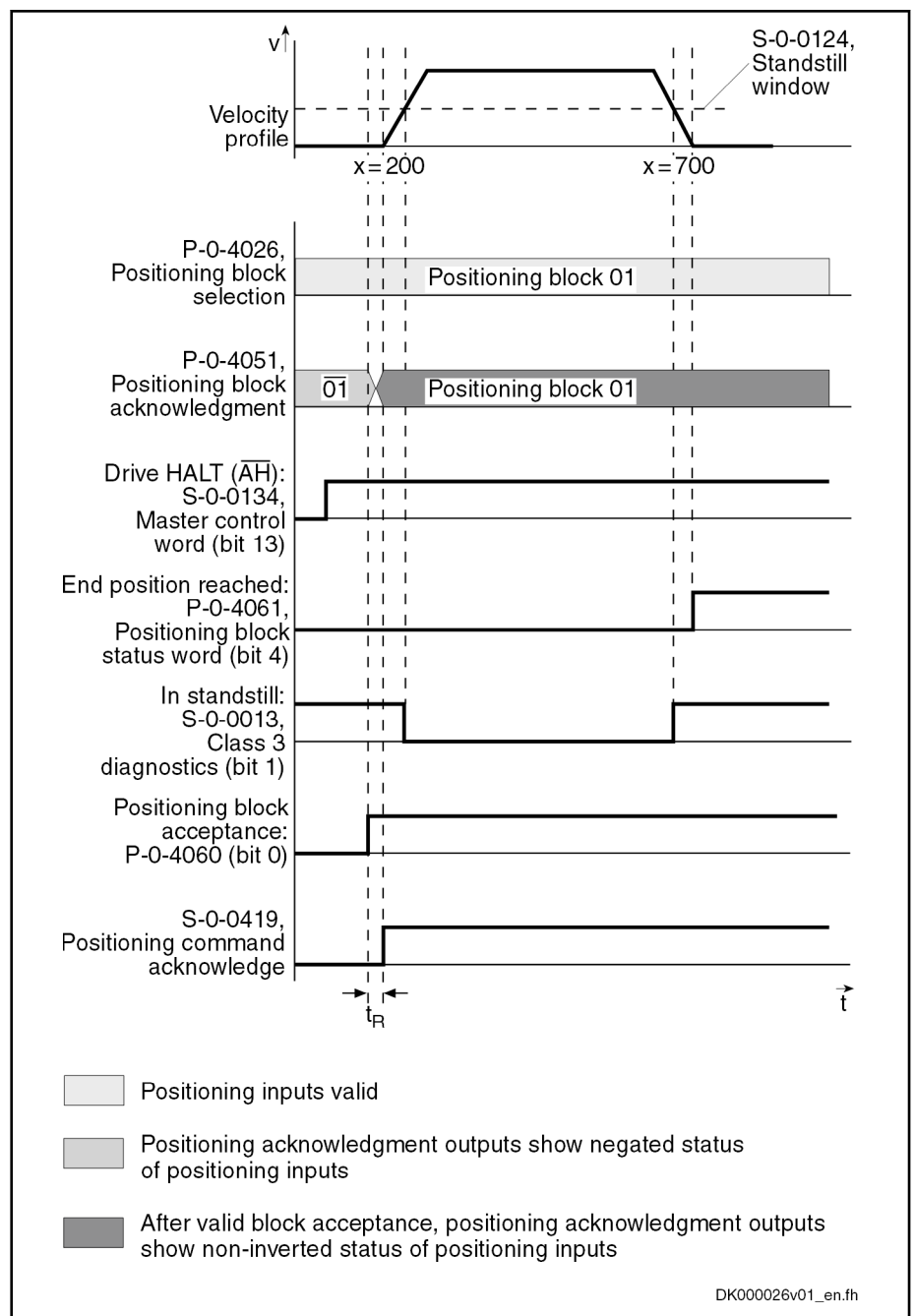
☞   According to master communication, positioning block accept-
ance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of
bit 0 in P-0-4060.

Relative Positioning Block with Residual Path Storage after Activating Drive Enable

Example:

Interrupted relative positioning block with residual path storage after activa-
tion of drive enable with travel distance = 400 (current position = 200; target
position = 800).

Operation Modes

Dedicated 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.
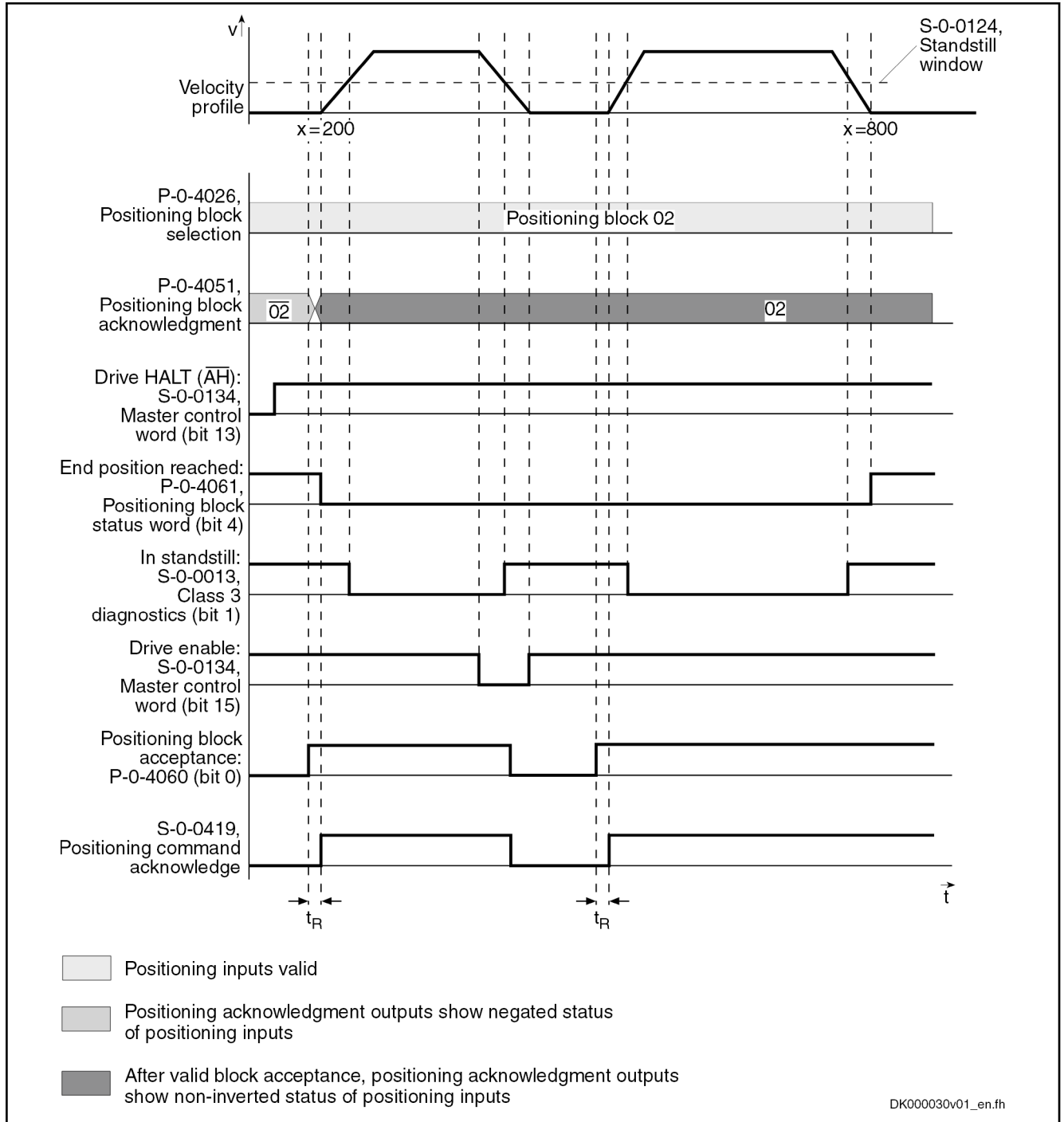
Fig.7-43:   *Relative Positioning Block with Residual Path Storage after Activating Drive Enable*

☞   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.

Operation Modes

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

Dedicated 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.

| NOTICE	When an interruption by means of jogging or positioning stop takes place, the residual path is not traveled when the positioning block is restarted, but the positioning block is restarted (complete relative positioning block). The incremental dimension reference is no longer ensured!
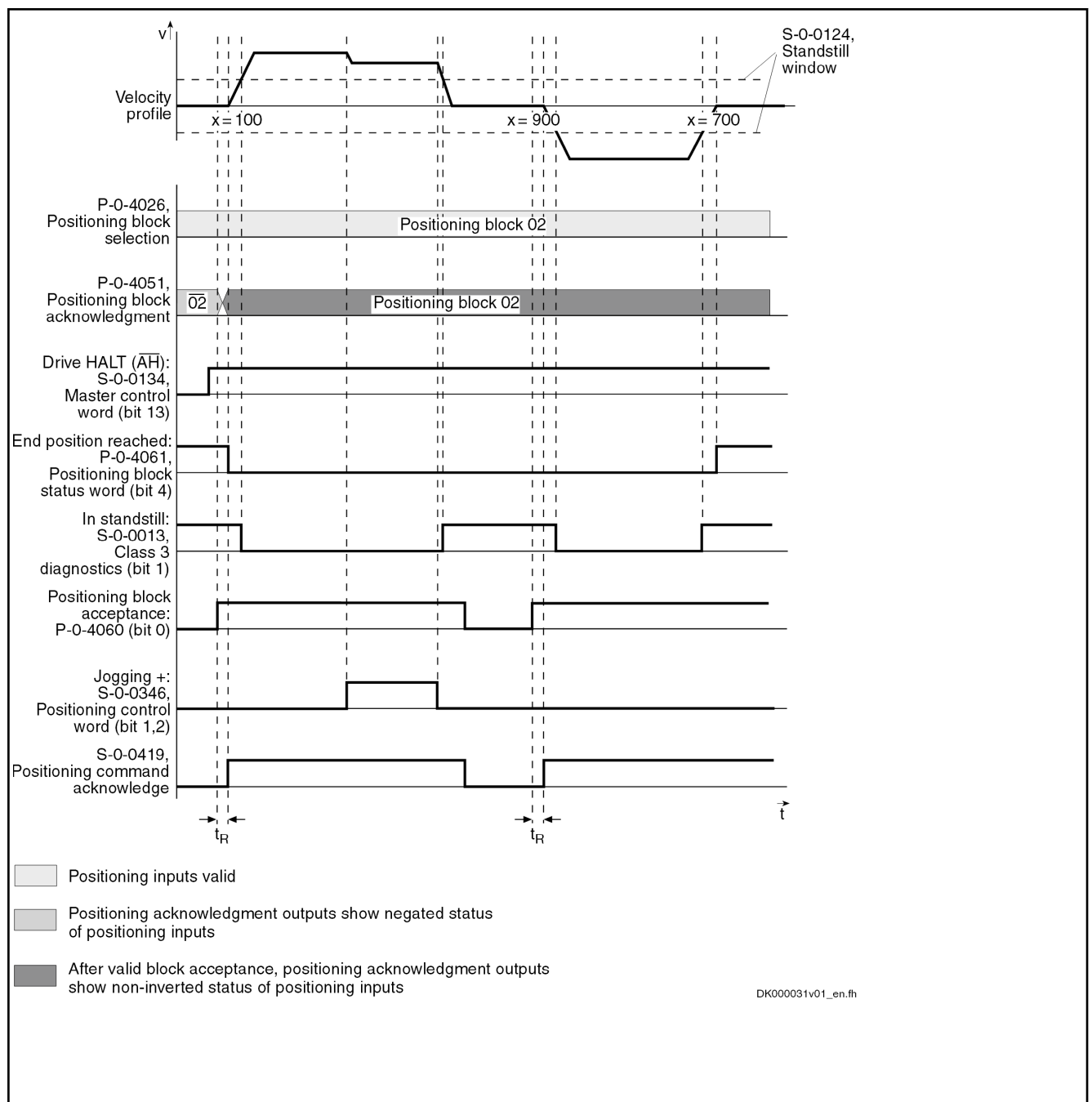
Fig.7-44:   Relative Positioning Block with Residual Path Storage after Jog Mode

☞   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.

Operation Modes

If a single-turn encoder is used, the residual path is rejected and positioning continues at the actual position.

Dedicated Position   The position command value at the last "end position reached" (position = 100) message is used as the 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"Travelling in positive direction" or "Travelling 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
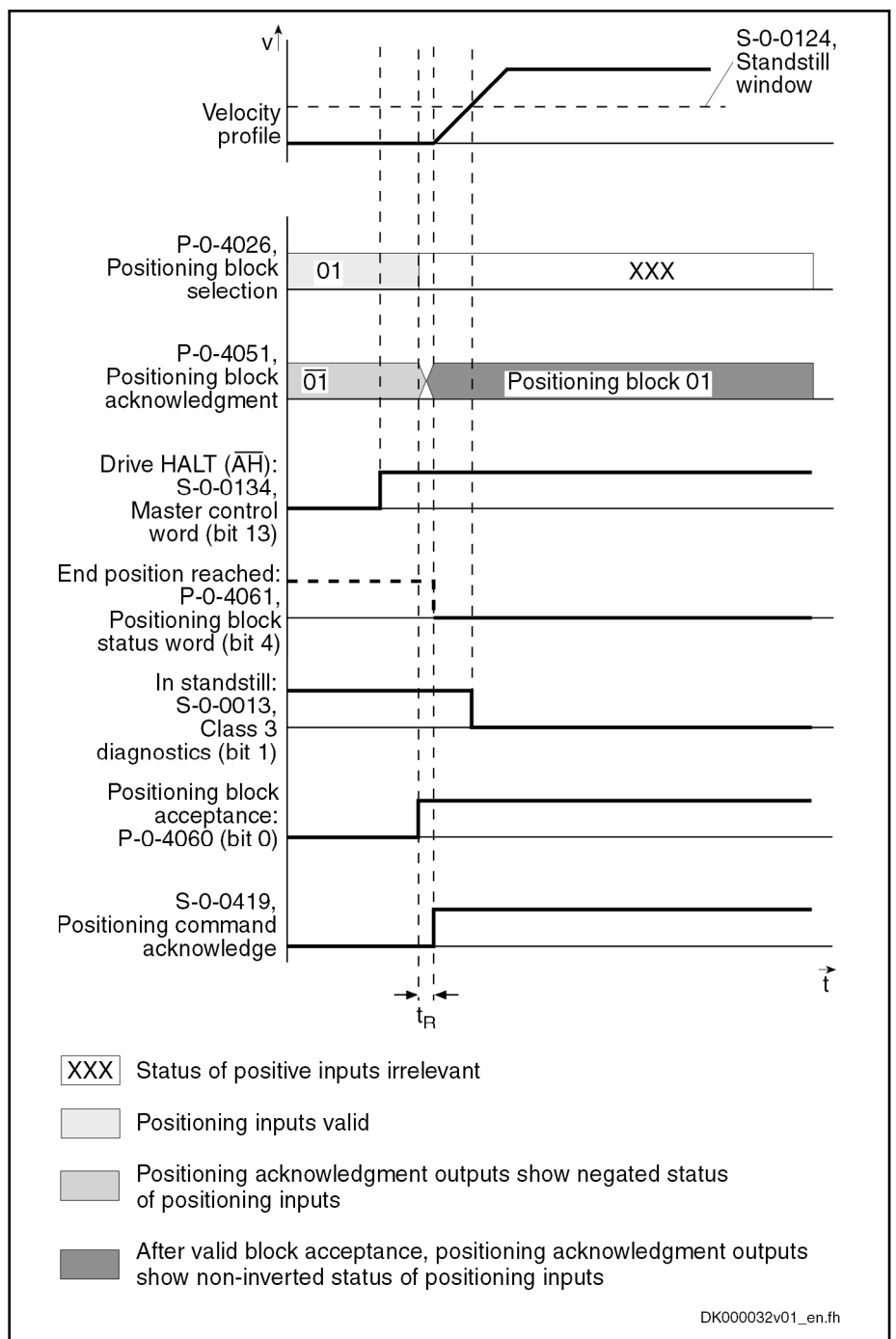
Fig.7-45:   *Example: Infinite travel in positive/negative direction*

☞   According to master communication, positioning block accept-
ance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of
bit 0 in P-0-4060.

Operation Modes

7.7.4   Sequential Block Processing

Basic Function

☞   For sequential block processing, first of all the same basic rules apply as for single-block processing (see description of single-block processing). In addition to mere positioning block functions with defined positioning blocks and block acceptance, there also is a defined block transition to be parameterized.

Selecting and Activating a Sequential Block

A positioning block with sequential block is selected and activated in the usual way, only the first block of the sequential block chain being selected. The sequential block is the block with the next higher block number. A sequential block can also have a sequential block so that after a start block up to 63 sequential blocks can be set.

☞   The potential sequential block of the last valid block is block 0.

Conditions to Advance in Sequential Block Mode

There are two basically different modes for block advance; these modes can be subdivided:

- **Position-Dependent Block Advance**
  - Block transition with old positioning velocity
  - Block transition with new positioning velocity
  - Block transition with intermediate stop and defined delay time (see P-0-4018)
- **Switch-Signal-Dependent Block Advance**

Position-Dependent Block Advance

General Information

With position-dependent block advance, switching to the sequential block is carried out at the target position of the start block.

There are three different types of block transition:

- Block Transition with Old Positioning Velocity (Mode 1)
- Block Transition with New Positioning Velocity (Mode 2)
- Block Transition with Intermediate Stop and Defined Delay Time

Block Transition with Old Positioning Velocity (Mode 1)

Parameter Setting
- "P-0-4019, Positioning block mode" = 0000 0000 0001 000X
  - → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0001 001X
  - → Relative block with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0001 010X
  - → Infinite block in positive direction with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0001 100X
  - → Infinite block in negative direction with sequential block

Function

In this mode, the target position of the start block is run through at the velocity of the start block. Then the positioning velocity is switched to that of the sequential block.

With relative and absolute positioning blocks with block advance, the drive moves in the direction of the target position. As soon as the target position is passed, the drive switches to the next travel block n+1.

With infinite positioning blocks, the drive moves in positive or negative direction. As soon as the target position is passed, the drive switches to next positioning block n+1, the block n representing the positioning block currently in process.

☞ If the target position is not in the selected travel direction, the drive moves in the direction of the target position. Thus the drive always reaches the switching position.
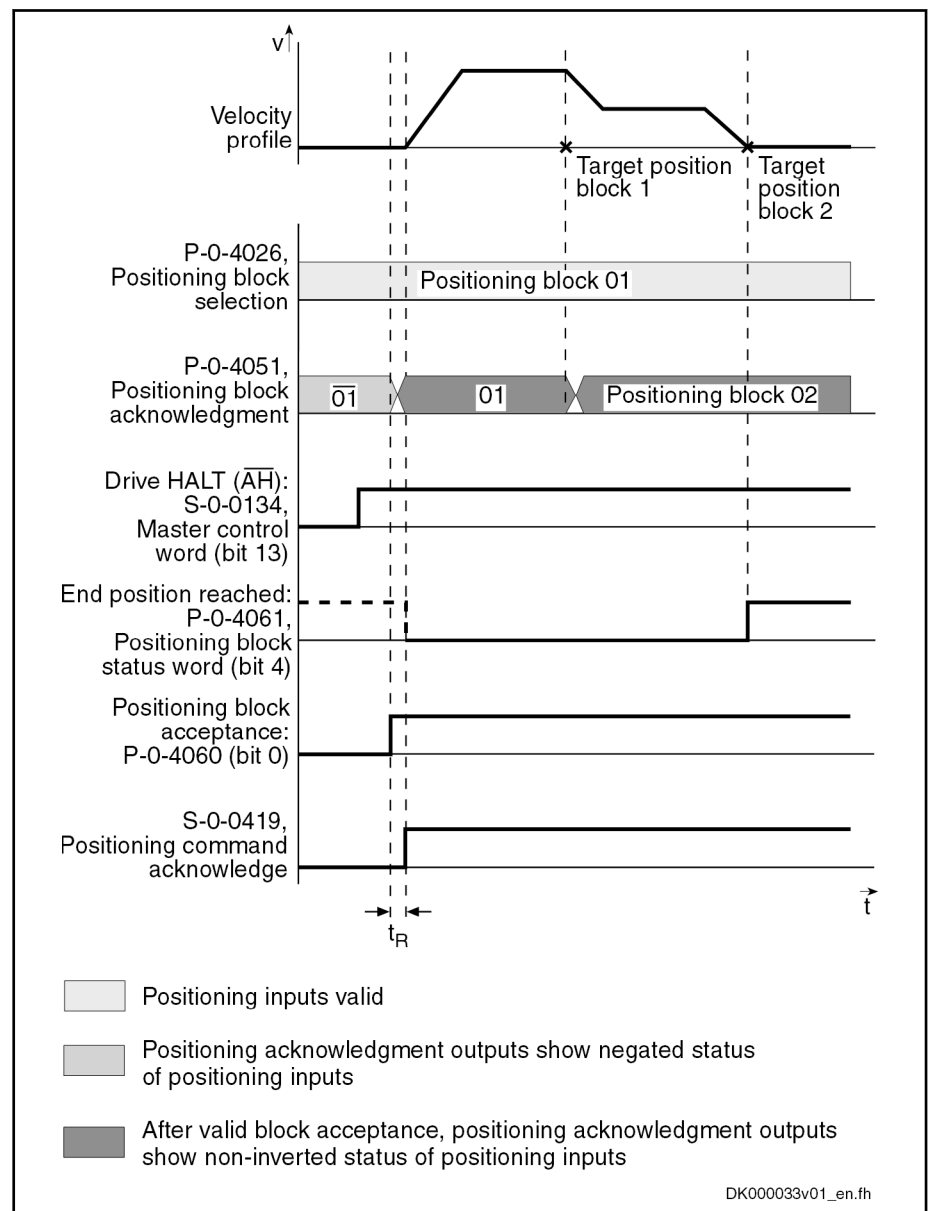
Fig.7-46:   Example: Position-Dependent Block Advance (Mode 1)

☞ 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.

Operation Modes

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. 7-47:   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.

Operation Modes

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.
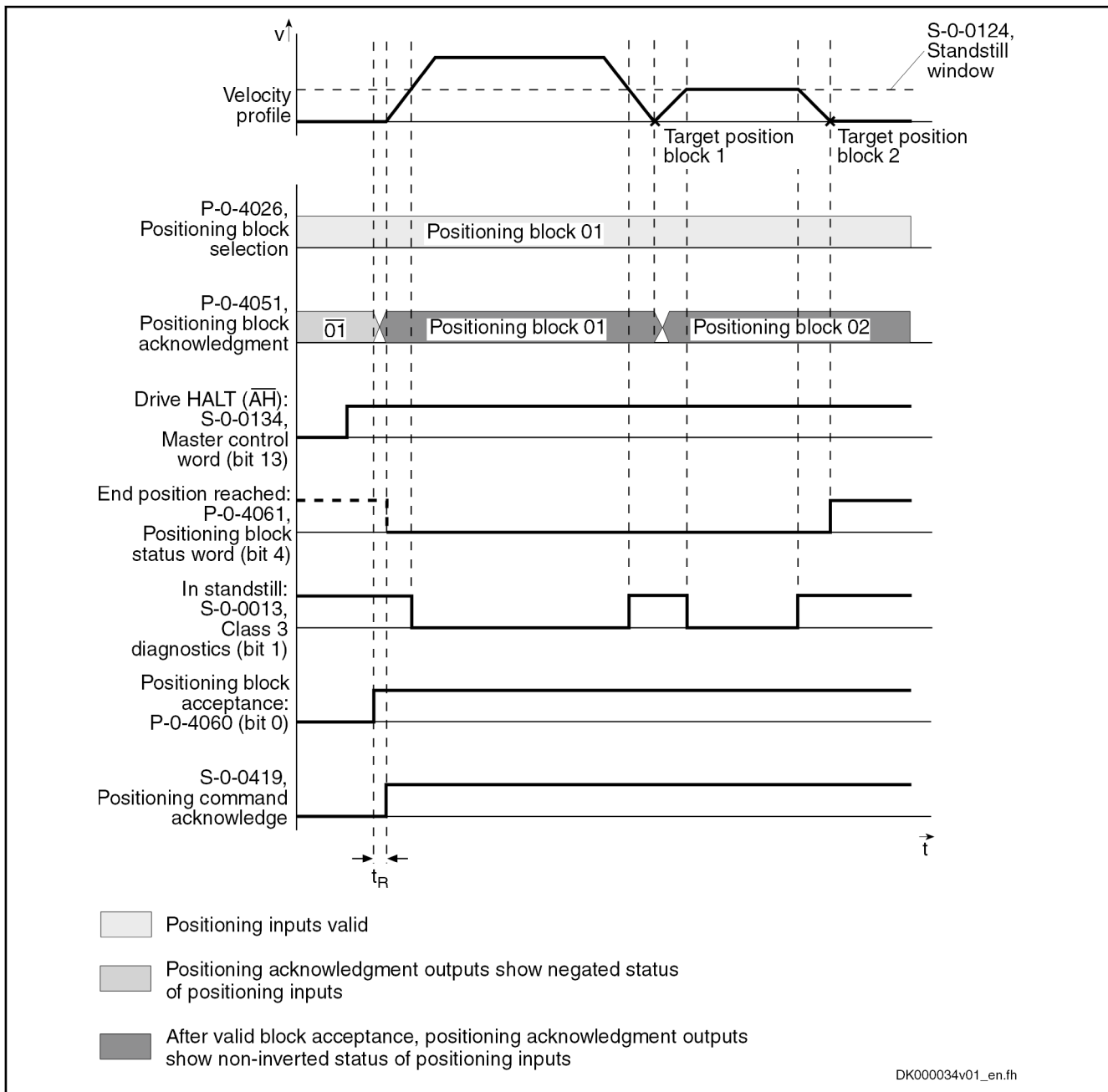
Fig.7-48:   Example: Sequential Block Advance for Target Position with Intermediate Stop

Operation Modes

> ☞ According to master communication, positioning block accept-
> ance 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 position-
ing 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 trig-
> gered 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.

he status of the hardware signals is displayed in "P-0-4057, Positioning
block, input linked blocks".

Function The drive switches to the **next travel block n+1**, as soon as the input for the
sequential block cam 1 changes from "0" to "1". If the target position is not
reached, switching to the new positioning block is carried out while traveling.

The drive switches to the **next travel block n+1**, as soon as the input for the
sequential block cam 2 changes from "0" to "1". If a sequential block cam is
activated during this travel, the drive switches to the positioning block after
the next.

Dedicated Position A following relative positioning block refers to the position at which the se-
quential 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.

Operation Modes

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 "P-0-4026, Positioning block selection"

x   Not relevant

Fig.7-49:   Drive Reaction with Different Switch Signal Sequences

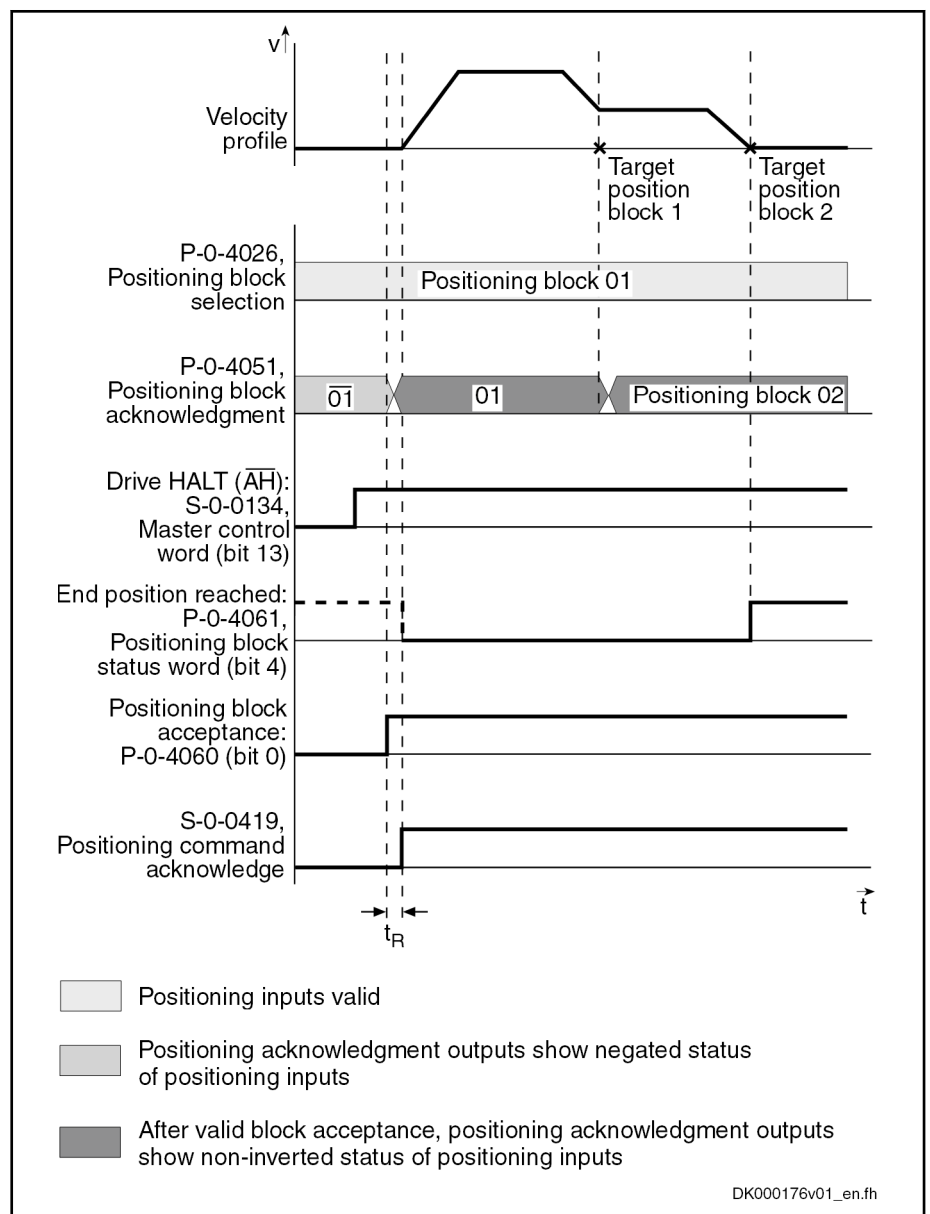|	Velocity profile				S-0-0124, Standstill window
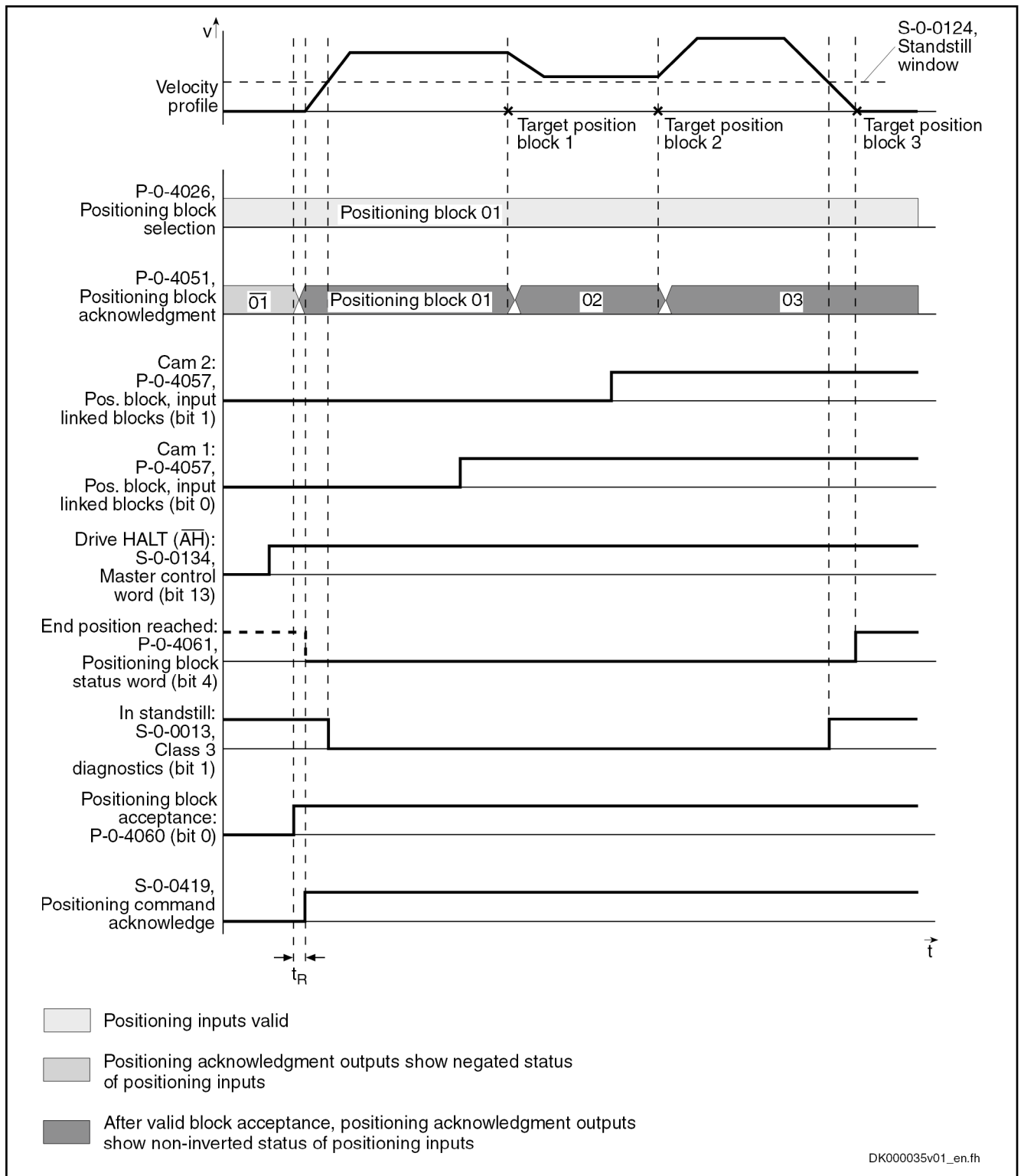
Fig.7-50:   Example: Switch-Signal-Dependent Block Advance

☞ According to master communication, positioning block accept-ance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Operation Modes

Failure of Switch Signal for Block Advance

If the start block of a switch-signal-dependent sequential block is an absolute or relative positioning block, the drive positions at target position, if the switch signal for block advance is not received. The drive thus only generates the message "end position reached" after the sequential block chain is completed. If a switch signal is then applied, the drive will carry out the sequential block.
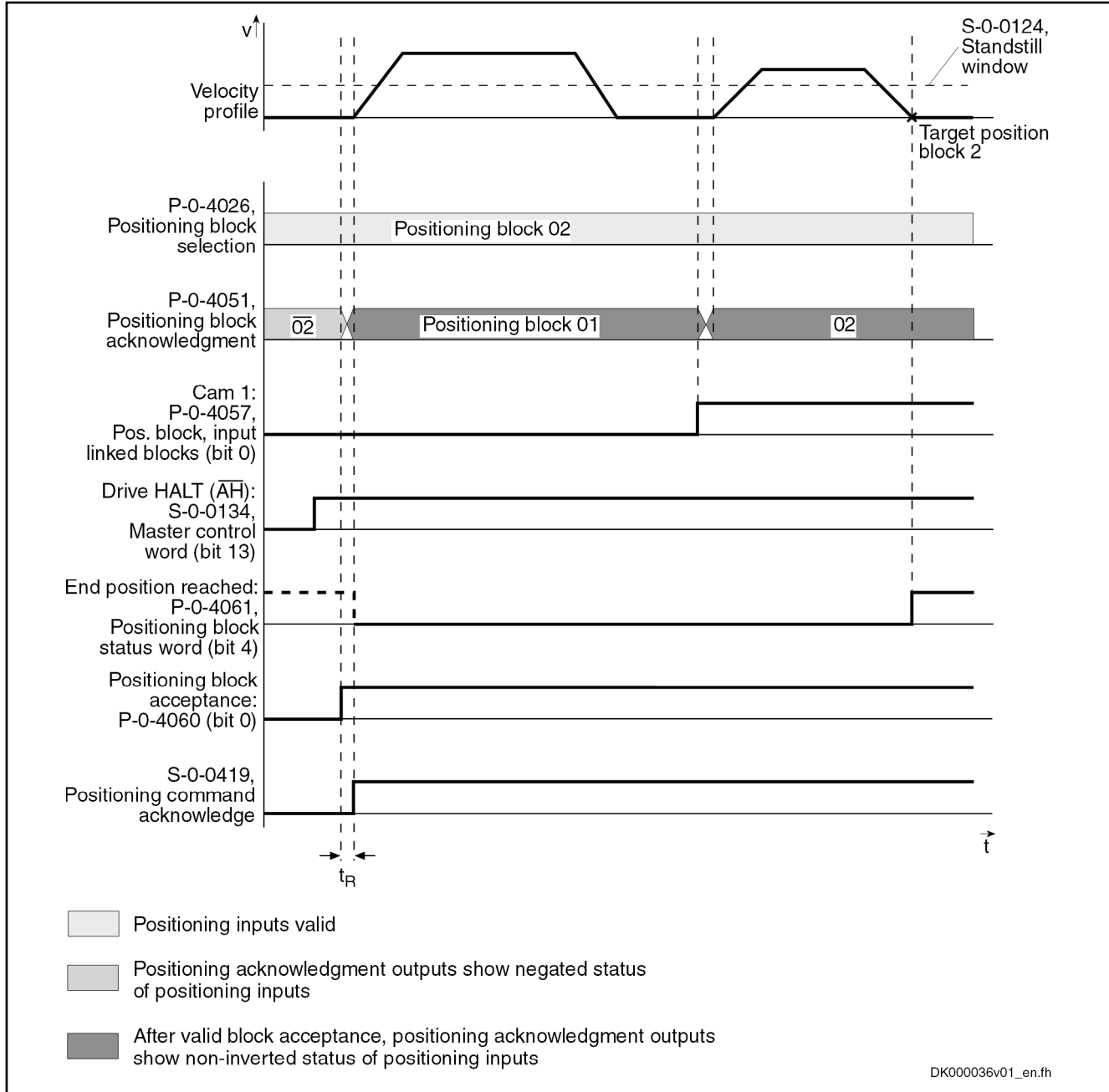
Fig.7-51:   *Example: Switch-Signal-Dependent Block Advance (Behavior with Failure of Switch Signal)*

☞   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.

Operation Modes

☞ | 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 operation mode

Depending on the block type of the sequential block chain that was interrupted and the events occurring during this interruption, the sequential block chain is processed differently after a restart.

☞ | In sequential block mode, relative positioning blocks **without residual path storage** are **not allowed**, as otherwise the incremental dimension reference would get lost in the case of interruption.

Given an interruption, a restart will end the sequential block chain.

Dedicated Position

The dedicated position is the original start position of the sequential block chain.

☞ | The incremental dimension reference is retained, as only absolute and relative positioning blocks with residual path storage are used in sequential block mode!

Operation Modes
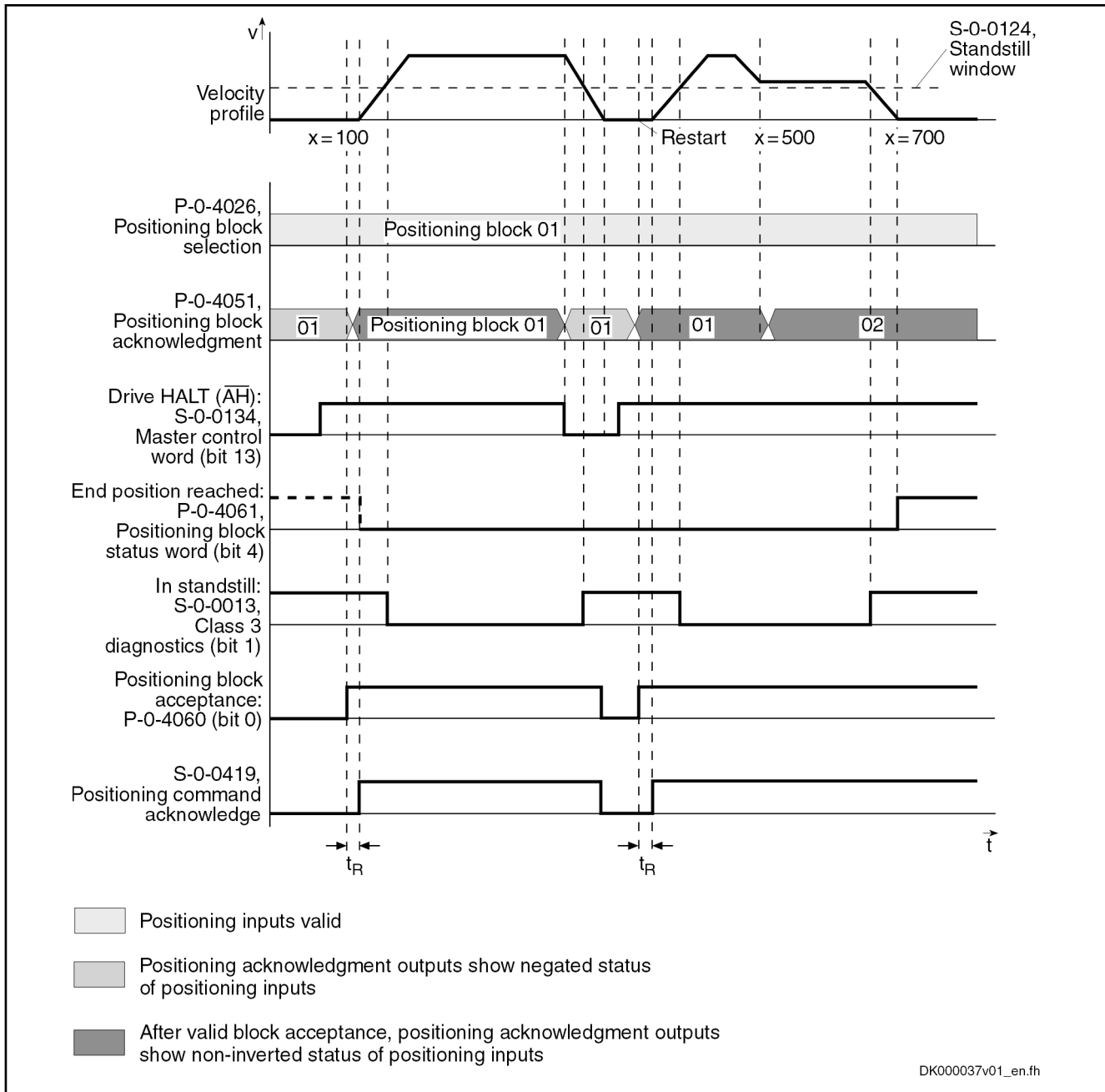
Fig.7-52:   Example: Sequential Block Interruption with Same Block Selected

☞   According to master communication, positioning block accept-
           ance 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 Operation   When changing the operation mode during an interruption, the sequential
Mode   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 over-
           run 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.

Operation Modes

Interrupting a Sequential Block Chain with Selection of New Positioning Block

If a new positioning block is selected during an interruption (e.g. with "Drive HALT"), the previously interrupted sequential block chain is not completed after a restart, but the currently selected block is executed.

Dedicated Position

The dedicated position is the current actual position value.

NOTICE	In case the sequential block is interrupted, the incremental dimension reference gets lost; therefore, the residual path is not traveled when the positioning block is restarted, but the positioning block is restarted (complete relative positioning block). The incremental dimension reference is no longer ensured!

The conditions for the interruption of sequential blocks also apply after the control voltage is switched off, if an absolute encoder is used.

Interrupting a Sequential Block Chain with Absolute Sequential Blocks

An interruption with absolute positioning blocks does not represent any problem, as the position data reference is always guaranteed.

When a **new block number** is selected in the case of an interruption, the sequential block interrupted before is not completed when toggling bit 0 in "S-0-0346, Positioning control word" or with a 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.7-53:	*Minimum Acceleration Value with Sequential Block Mode (Linear)*

Operation Modes

☞ 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 there is a change of sign of the velocity at target position n. If the acceleration parameterized in block n is too low to decelerate within the path difference x_n-x_{n-1} from velocity v_{n-1} to the value "0" the parameterized target position x_n will be overrun.

This may cause software or hardware limit switches to trigger.
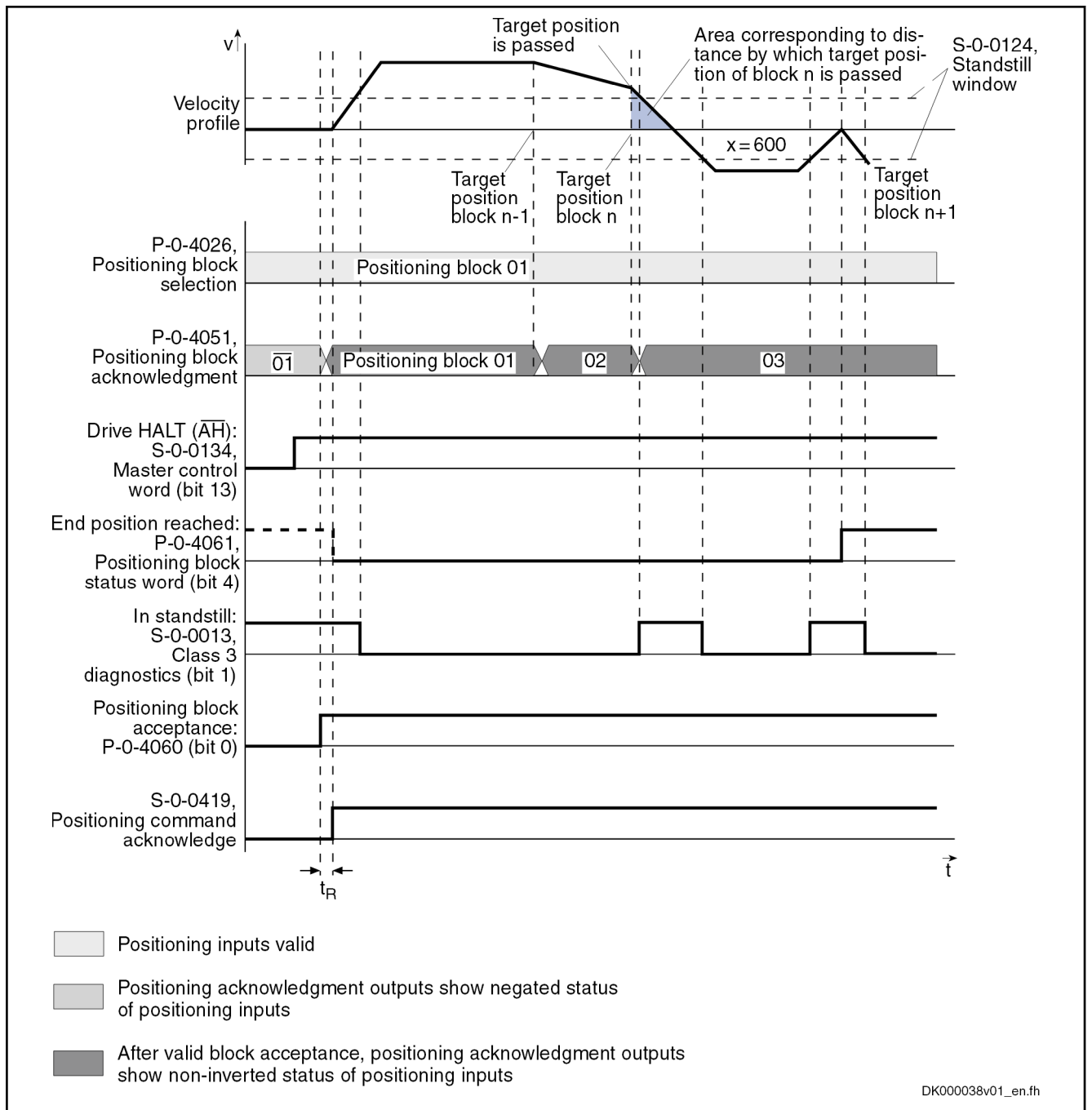
Fig.7-54:   *Parameterizing a Sequential Block with Directional Change*

☞ 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!

Operation Modes

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 Operation Mode

After the positioning block mode has been activated, the complement of the block number of the selected positioning block is acknowledged, until a start signal (toggling of bit 0 in "S-0-0346, Positioning control word" or 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.

Acknowledge With "Drive HALT"

If "Drive HALT" is active, the complement of the block number of the selected positioning block is output in "P-0-4051, Positioning block acknowledgment".

Acknowledgment with Secondary Operation Modes

The acknowledgment is not affected by secondary operation modes, error reaction and command inputs, i.e. "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.
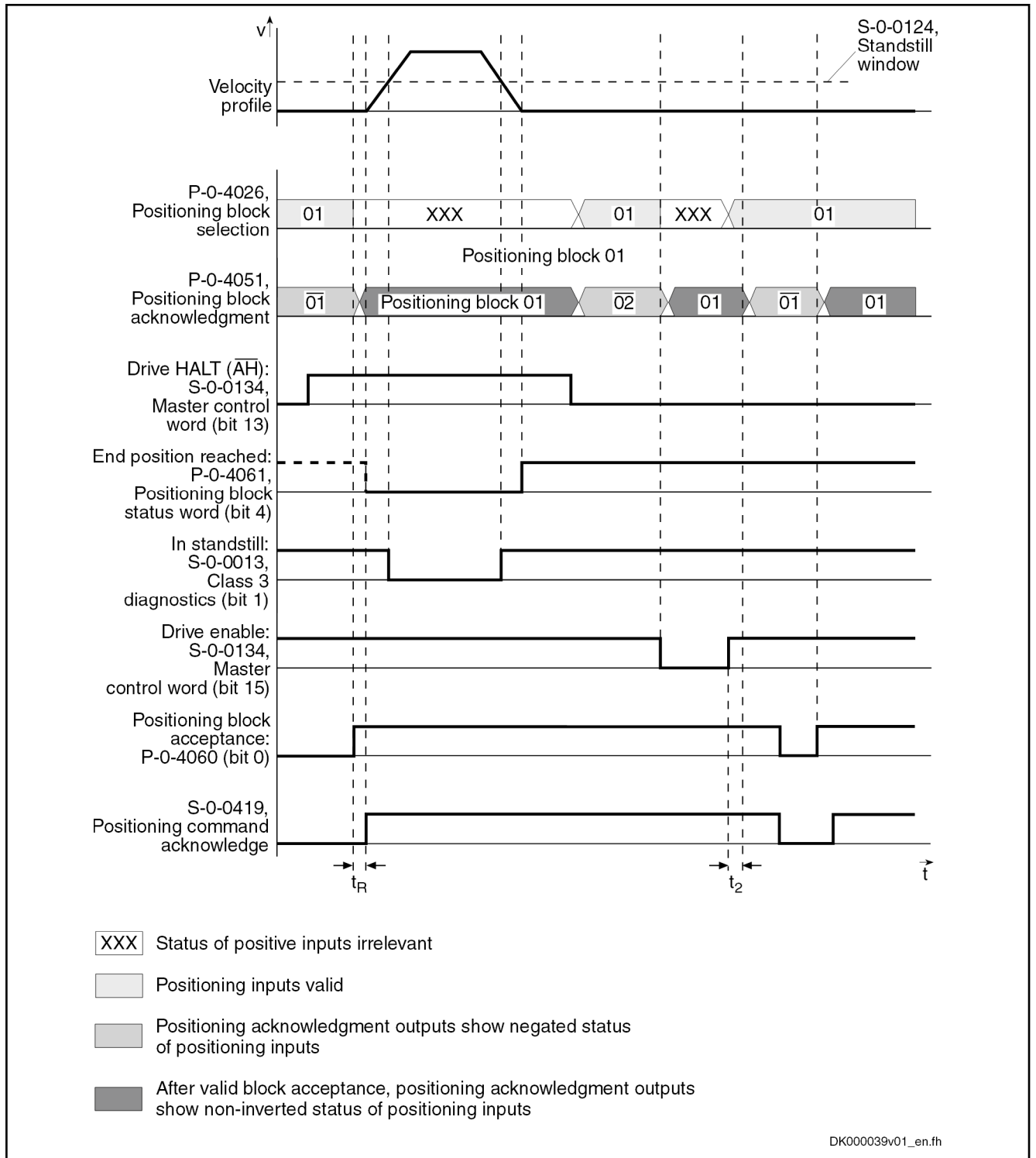
Fig.7-55:   Acknowledgment and Message "End Position Reached" after Drive
              Enable Switched Off

☞   According to master communication, positioning block accept-
      ance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of
      bit 0 in P-0-4060.

Operation Modes

Acknowledgment with Control Voltage Interrupted	If the control voltage is switched off, the last accepted positioning block is stored in "P-0-4052, Positioning block, last accepted" so that after switching control voltage on, it is always the last accepted positioning block that is output.
With Absolute Value Encoder	If an **absolute value encoder** is used, it is possible to decide, after the control voltage is switched off and on, whether the drive still is at the target position of the last accepted positioning block (end position reached).
	The "end position reached" message is generated as soon as the drive is ready for operation again (bb contact closed).
With Single-Turn Encoder	If a **single-turn encoder** is used, the "end position reached" message is not clearly defined after a voltage interrupt until the first target position has been run to or homed.

> 🖝 The "end position reached" message is only retained if the axis has not been moved during the interruption. If the axis is moved into the positioning window during the interruption, the "end position reached" message will also be generated! After activating drive enable, positioning block acknowledge changes as described under "Acknowledgment with Drive Enable Switched Off".

Status Messages

Status Bits
In addition to the status messages during the "drive-internal interpolation" mode, the "end position reached" status message is generated in the "positioning block mode" (bit 4 = 1 in "P-0-4061, Positioning block status word"), if the following applies:

- |S-0-0430 – S-0-0051/S-0-0053| < S-0-0057 (In Position)

  - and -

- No sequential block has been selected.

See also section "Status Messages" of the operation mode "Drive-Internal Interpolation"

ℹ️ 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" he 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. or single blocks (no sequential block processing), the contents of P-0-4052 and P-0-4053 are always equal!

- P-0-4057, Positioning block, input linked blocks

    → Contains an image of the digital sequential block inputs (switch cam inputs)

Diagnostic Messages

Diagnostic status messages:
- A0162 Positioning block mode
- A0206 Positioning block mode, encoder 1
- A0207 Positioning block mode lagless, encoder 1
- A0210 Positioning block mode, encoder 2
- A0211 Positioning block mode lagless, encoder 2

Warnings:
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2054 Not homed
- E2055 Feedrate override S-0-0108 = 0
- E2058 Selected positioning block has not been programmed
- 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 the Synchronization Modes

The synchronization modes allow the drive to run synchronously with regard to a real or virtual master axis. The synchronization modes are basically divided into the following groups:

- **Velocity synchronization**
- **Position synchronization with the operation modes**
    - Phase synchronization
    - Electronic cam
    - MotionProfile

The figure below illustrates how the synchronization modes are integrated in the control loop structure.

Operation Modes

DF000577v01_en.fh11
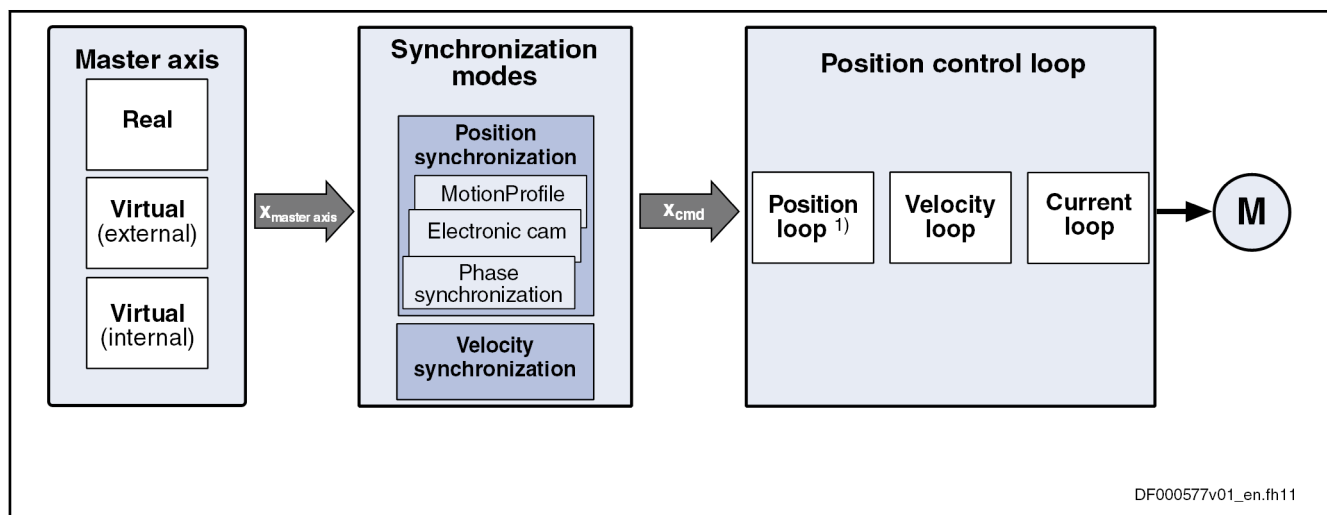
1)   Position loop not with "velocity synchronization" mode

Fig.7-56:   *General Block Diagram of the Synchronization Modes*

All synchronization modes have the following identical or similar basic functions which are comprehensively described in this section:

- Adjustment of master axis, consisting of
    - Generation of master axis
    - Master axis offset and modulo limitation
    - Electronic gear with fine adjustment
- Drive-controlled dynamic synchronization

☞   The individual synchronization modes basically differ in the following function blocks:

          - Command value processing specific to operation mode

          - Command value addition for slave axis

          These function blocks are described specific to operation mode in the individual sections on the respective synchronization modes.

The figure below illustrates the interaction of the individual basic functions (function blocks) of the synchronization modes.
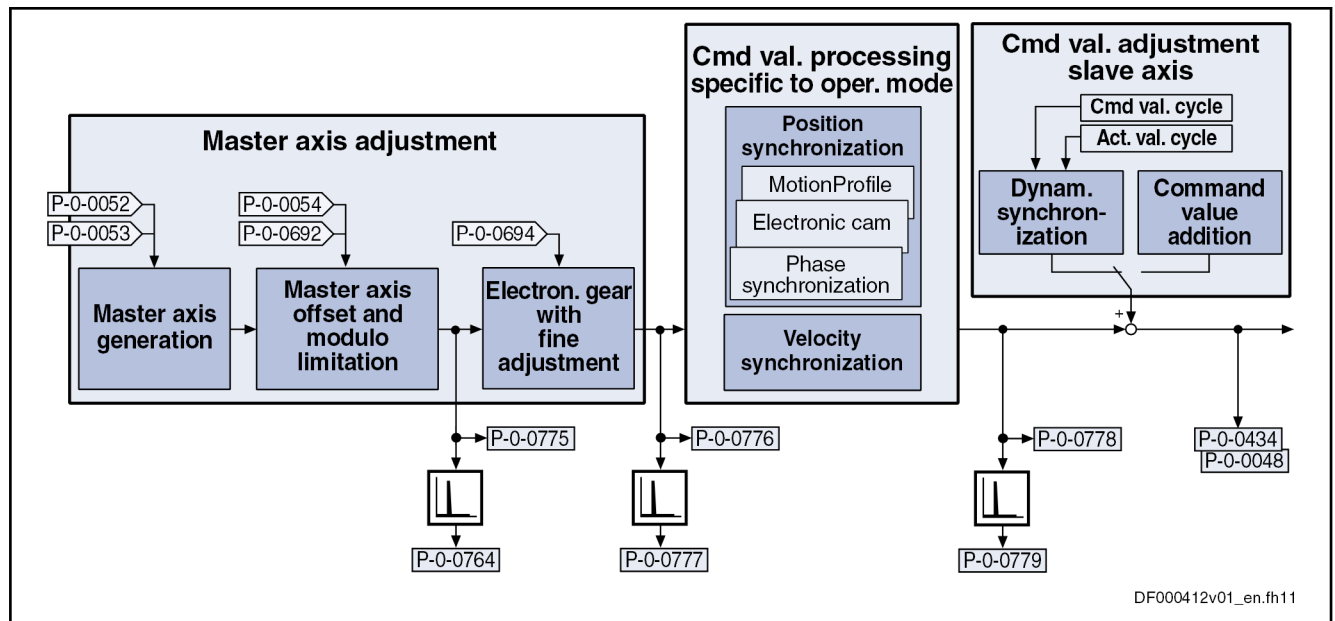
P-0-0048	Effective velocity command value
P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0054	Additive master axis position
P-0-0434	Position command value of controller
P-0-0692	Additive position command value, process loop
P-0-0694	Gear ratio fine adjustment, process loop
P-0-0761	Master axis position for slave 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
P-0-0787	Group axis position

Fig.7-57:   Function Blocks of the Synchronization Modes

Explanation of Terms

Master axis:

The virtual or real axis which makes available the master axis position for generating the synchronous position command value for the slave axis is called master axis.

Master axis cycle

The master axis cycle specifies the range of the master axis values. It corresponds to a master axis revolution or a multiple thereof. In order to allow for the correct processing of the master axis positions (e.g. in case of modulo overflows), the drive must now the value of the master axis cycle. By configuring parameter **"P-0-0750, Master axis revolutions per master axis cycle"**, the control unit informs the drive of the value of the master axis cycle.

Slave axis:

The drive following the command values derived from the master axis is referred to as slave axis.

Command value cycle:

In processes with different machining cycles, the slave axis must be able to synchronize over several master axis revolutions or divisions of a master axis

Operation Modes

revolution. This possibility is given via the so-called command value cycle. The modulo value of the command value cycle is internally calculated depending on the electronic gear (P-0-0156, Master drive gear input revolutions; P-0-0157, Master drive gear output revolutions) and the values "P-0-0750, Master axis revolutions per master axis cycle" and "S-0-0103, Modulo value".

See Parameter Description "P-0-0754, Command value cycle"

Actual value cycle (position actual value in actual value cycle):

The modulo range within which the actual position values of the slave axis are to be found in case of active position synchronization mode (P-0-0753, Position actual value in actual value cycle) is called actual value cycle ("P-0-0786, Modulo value actual value cycle"). The user can define the modulo value of the actual value cycle.

☞   **The position synchronization modes (phase synchronization, cam and MotionProfile) use the "position actual value in actual value cycle" (P-0-0753) in order to close their position control loop.**

By means of the "position actual value in actual value cycle" and the synchronization range that has been set (see Parameter Description for "P-0-0155, Synchronization mode"), the travel distance for synchronization is determined when one of the position synchronization modes is activated. In this connection, the travel distance is limited to the synchronization range, i.e. the command value cycle, division of the command value cycle or modulo range (S-0-0103, Probe value 1 positive edge).

See Parameter Description "P-0-0753, Position actual value in actual value cycle"

See Parameter Description "P-0-0786, Modulo value actual value cycle"

The modulo value of the actual value cycle must be set such that it corresponds to an integral multiple of the command value cycle or of the modulo range (S-0-0103, Probe value 1 positive edge).

Configuring and Controlling the Synchronization Modes

The synchronization modes velocity synchronization and position synchronization are configured and controlled by means of the following synchronization parameters.

Pertinent Parameters (Synchronization Parameters)
- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes

By means of parameter P-0-0520, it is possible to make the following settings for the position-controlled operation modes:
- Position control with lag error or lagless
- Use of encoder 1 or encoder 2

See also "Operation Mode Handling"

Command Value Addition

This section contains an overview of the basic possibilities of adding command values. The characteristics and details specific to operation mode are described in the section of the respective synchronization mode.

Operation Modes

Pertinent Parameters	•	S-0-0037, Additive velocity command value
	•	S-0-0048, Additive position command value
	•	P-0-0048, Effective velocity command value
	•	P-0-0054, Additive master axis position
	•	P-0-0060, Filter time constant additive position cmd value
	•	P-0-0434, Position command value of controller
	•	P-0-0686, Additive position command value, positioning velocity
	•	P-0-0687, Additive position command value, positioning acceleration
	•	P-0-0688, Additive master axis position, positioning velocity
	•	P-0-0689, Additive master axis position, positioning acceleration
	•	P-0-0690, Additive velocity command value, process loop
	•	P-0-0691, Additive position command value, process loop
	•	P-0-0692, 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.
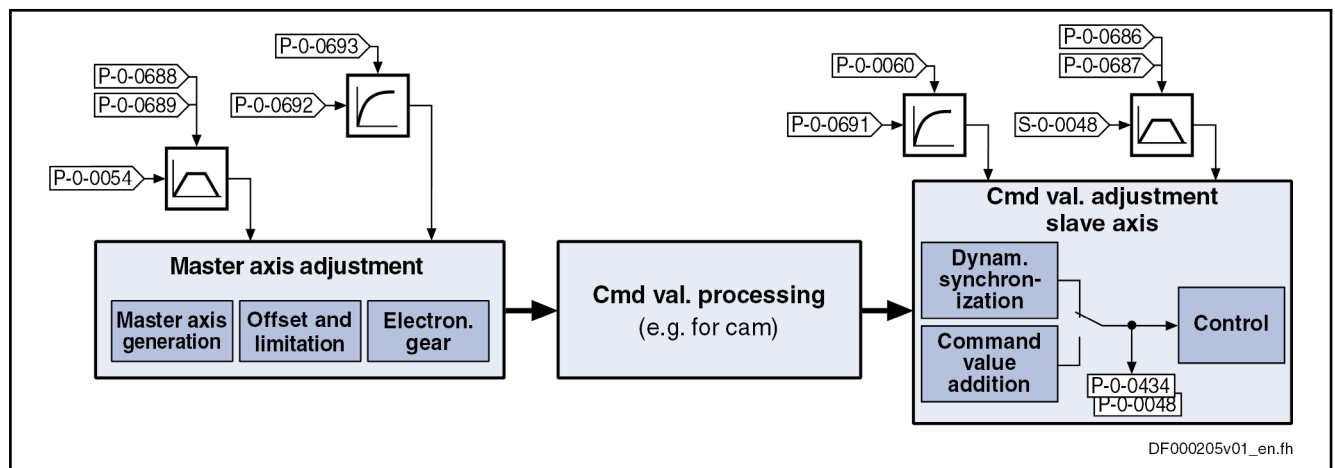
Fig.7-58:   *Possibilities of Command Value Addition for Master and Slave Axis*

Master Axis Adjustment

Brief Description

Master Axis Generation
The following are possible as signal sources for the resulting master axis position (**P-0-0775**):

- **Real master axis** (P-0-0052, Actual position value of measuring encoder)
- **Virtual master axis, external** (P-0-0053, Master axis position)
- **Virtual master axis, internal** (P-0-0761, Master axis position for slave axis)
- **Virtual master axis 2, external / group master axis** (P-0-0787, Group axis 1 position)

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"

Operation Modes

> – 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 operation mode as compared to the master axis position preset by master axis evaluation.

Pertinent Parameters   The following parameters are used in conjunction with master axis adjustment:

- P-0-0052, Actual position value of measuring encoder
- P-0-0053, Master axis position
- P-0-0054, Additive master axis position
- P-0-0084, Number of bits per master axis revolution
- P-0-0688, Additive master axis position, positioning velocity
- P-0-0689, Additive master axis position, positioning acceleration
- P-0-0692, 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
- P-0-0787, Group axis 1 position

The following parameters are used in conjunction with the electronic gear with fine adjustment:

- P-0-0083, Gear ratio fine adjustment
- P-0-0108, Master drive polarity
- P-0-0156, Master drive gear input revolutions
- P-0-0157, Master drive gear output revolutions
- P-0-0694, Gear ratio fine adjustment, process loop
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity

Master Axis Generation

The synchronization modes allow the drive to run synchronously with regard to a real or virtual master axis. Command value input in the synchronization modes takes place depending on the 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".

☞ The scaling of the position data generated with a measuring encoder is rotary and axis- or shaft-related. Due to the infinite motion range of the measuring encoder and the limited value range of the position data, modulo scaling is set automatically. The modulo range can be selected as an integral multiple of an axis- or shaft-side revolution. The parameter "P-0-0765, Modulo factor measuring encoder" is used to set the modulo range of the measuring encoder. This parameter must be set to the same value as "P-0-0750, Master axis revolutions per master axis cycle".

See also "Measuring Encoder"

- **Virtual master axis, external**

  For external virtual master axes, the master (e.g. MLD) cyclically inputs command values in the NC clock via the master communication in parameter "P-0-0053, Master axis position".

- **Virtual master axis, internal**

  For internal virtual master axes, the master axis position is generated by the master axis generator contained in the drive and is input in the position loop clock via "P-0-0761, Master axis position for slave axis".

  See also "Virtual Master Axis Generator"

- **Virtual master axis 2, external / group axis 1 position**

  For the external virtual master axis 2, the master (e.g. MLD) cyclically inputs command values in the NC clock via the master communication in parameter "P-0-0787, Group axis 1 position". The parameter "P-0-0788, Group axis 1 position, fine-interpolated" contains the group axis 1 position (P-0-0787) fine interpolated in linear form with regard to the position loop clock.

☞ The selection which master axis is used by the position synchronization modes (phase synchronization, cam or MotionProfile) or the velocity synchronization mode is made via bits 6 and 7 of parameter "P-0-0088, Control word synchronization modes".
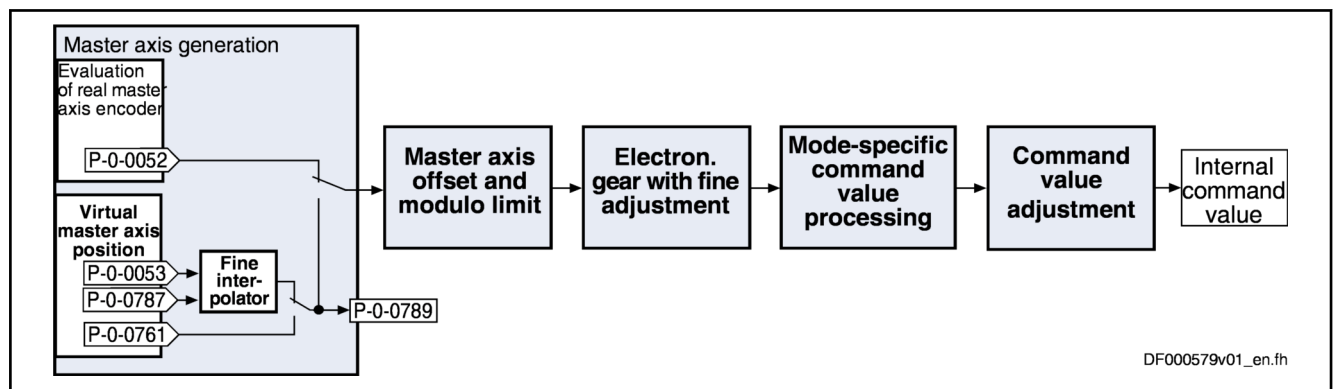
P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0787	Group axis 1 position
P-0-0761	Master axis position for slave axis
P-0-0789	Master axis position, fine-interpolated

Fig.7-59:   *Function Block "Master Axis Generation" for Real/Virtual Master Axis*

For the generation of the master axis (real or virtual), the following requirements must be taken into consideration (with N = value from "P-0-0084, Number of bits per master axis revolution"):

Operation Modes

- The master axis position can only be processed in a binary format (1 master axis revolution = 2^N increments).
- The minimum/maximum value of "P-0-0054, Additive master axis position" at maximum corresponds to the master axis cycle (P-0-0750 × 2^N).

  Note: When "P-0-0750, Master axis revolutions per master axis cycle" equals zero, the resulting maximum value for parameter P-0-0054 is ($2^{31} - 1$) increments and the minimum value is -2^{31} increments.

Master Axis Offset and Modulo Limitation

In conjunction with master axis adjustment, it is possible to add an offset and limit the preset master axis values.
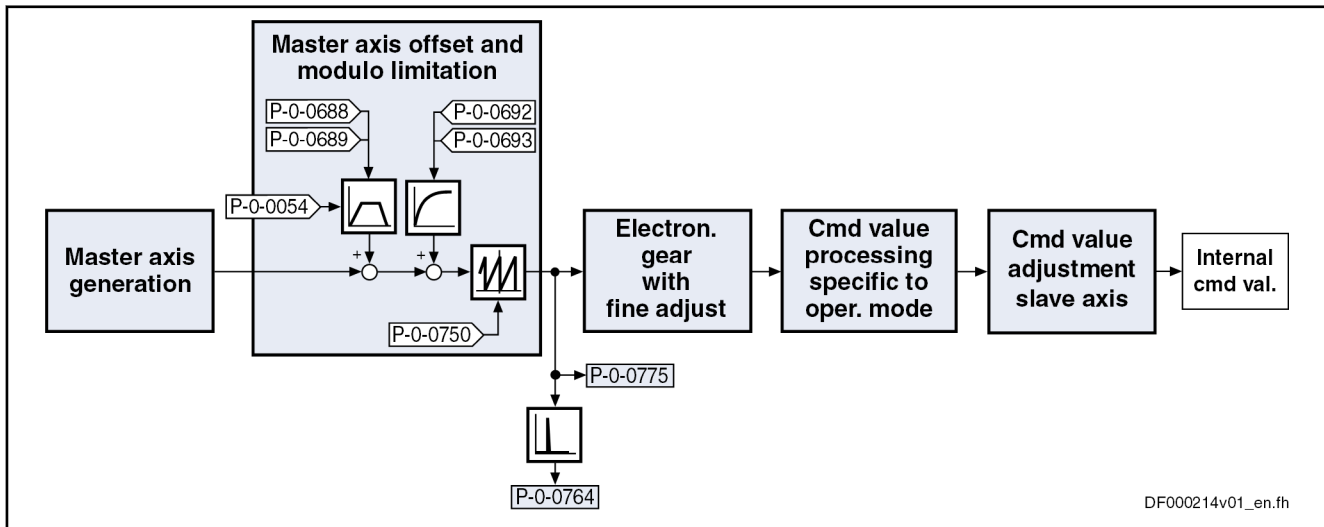
Fig.7-60:   *Function Block "Master Axis Offset and Modulo Limitation" for Real/Virtual Master Axis*

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.

Generating the Resulting Master Axis Position   The "P-0-0775, Resulting master axis position" is the master axis position which takes effect at the input of the electronic gear in the synchronous operation modes. Depending on the parameterization, the resulting master axis position consists of several different master axis positions and is generated in the drive in the position loop clock.

See chapter 5.1.2.1, description of parameter "P-0-0755, Resulting master axis position"

Limiting the Master Axis Position

The resulting master axis position is limited to the master axis cycle ("P-0-0750, Master axis revolutions per master axis cycle").

With N = value from "P-0-0084, Number of bits per master axis revolution" the following applies:

→ Modulo value master axis cycle = P-0-0750 × 2^N

Observe the following aspects:

- The master axis cycle is set by means of the parameter

  "P-0-0750, Master axis revolutions per master axis cycle" as integer multiple of a master axis revolution (= 2^N increments).

- The total of the master axis values (master axis generation including additive master axis positions) for generating the resulting master axis position (see Parameter Description "P-0-0775, Resulting master axis position") must not exceed twice the master axis range (P-0-0750 × 2^N)!

☞ When a real master axis is used, the parameter "P-0-0765, Modulo factor measuring encoder" must be set to the same value as the parameter "P-0-0750, Master axis revolutions per master axis cycle".

Master Axis Speed

The master axis speed is generated by differentiating the resulting master axis position (P-0-0775) and displayed in parameter "P-0-0764, Master axis speed".

Electronic Gear Function with Fine Adjustment

The input value for the electronic gear is the resulting master axis position (P-0-0775).
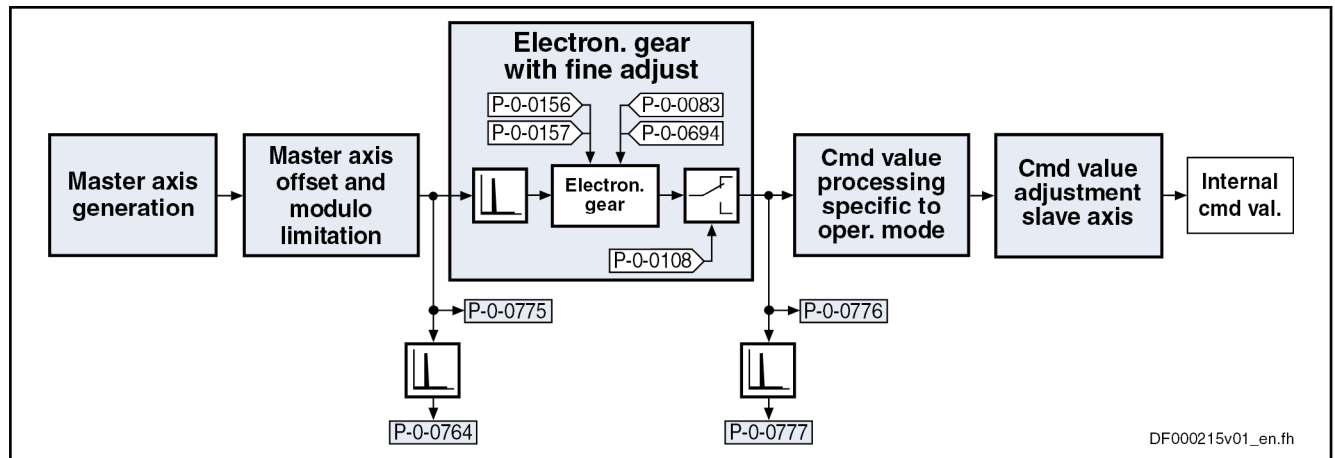
Fig.7-61:   Function Block "Electronic Gear with Fine Adjustment"

Functional Principle

The function block "electronic gear with fine adjustment" is divided into the following subfunctions:

- Electronic master axis gear with fine adjustment

- Polarity reversal of master axis position

The input value for the function block "electronic gear with fine adjustment" is either

- "P-0-0775, Resulting master axis position" in the position synchronization mode

or

- "P-0-0764, Master axis speed" in the velocity synchronization mode.

Operation Modes

The input values are processed in the position loop clock, see also "Performance Data"

The output value(s) for the function block "electronic gear with fine adjustment" are:

- "P-0-0776, Effective master axis position" only in the position synchronization mode

- "P-0-0777, Effective master axis velocity"

☞ The effective master axis position is **only** generated if one of the position synchronization modes is active. With modulo scaling, the effective master axis position is limited to $2^{P-0-0084}$ increments (one master axis revolution).

Calculating the Output Values

Calculating the factor of the electronic master axis gear with fine adjustment

$$f_{Gear} = \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times (1 + \frac{P\text{-}0\text{-}0083}{100\%}) \times (1 + \frac{P\text{-}0\text{-}0694}{100\%}) \times f_{pol}$$

P-0-0156	Master drive gear input revolutions
P-0-0157	Master drive gear output revolutions
P-0-0083	Gear ratio fine adjustment
P-0-0694	Gear ratio fine adjustment, process loop
f_{pol}, P-0-0108	Master drive polarity

Fig. 7-62:   Factor of the electronic master axis gear with fine adjustment

Calculating the effective master axis position when activating the "position synchronization" mode

$$P\text{-}0\text{-}0776 = (P\text{-}0\text{-}0775 \times f_{Gear})\%2^{P\text{-}0\text{-}0084}$$

P-0-0776	Effective master axis position
P-0-0775	Resulting master axis position
f_{Gear}	Factor of the electronic master axis gear with fine adjustment
%	Modulo operand
P-0-0084	Number of bits per master axis revolution

Fig. 7-63:   Effective Master Axis Position when Activating the "Position Synchronization" Mode

☞ When the "position synchronization" mode is activated, the absolute value of the result not yet limited to $2^{P-0-0084}$ increments mustn't exceed the value $2^{31}-1$ increments. Otherwise, "P-0-0776, Effective master axis position" is incorrectly initialized.

Calculating the effective master axis position with active "position synchronization" mode

After the effective master axis position was initialized in absolute form upon activation of the operation mode, the subsequent processing will only be differential.

$$P\text{-}0\text{-}0776 = (P\text{-}0\text{-}0776 + \Delta P\text{-}0\text{-}0775 \times f_{Gear})\%2^{P\text{-}0\text{-}0084}$$

P-0-0776	Effective master axis position
ΔP-0-0775	Difference of the resulting master axis position per position loop clock
f_{Gear}	Factor of the electronic master axis gear with fine adjustment
%	Modulo operand
P-0-0084	Number of bits per master axis revolution
Fig.7-64:	Effective Master Axis Position with Active "Position Synchronization" Mode

Calculating the effective master axis position with active "position synchronization" and "velocity synchronization" modes

$$P\text{-}0\text{-}0776 = (P\text{-}0\text{-}0775 \times f_{Gear})\%2^{P\text{-}0\text{-}0084}$$

P-0-0777	Effective master axis velocity
P-0-0764	Master Axis Speed
f_{Gear}	Factor of the electronic master axis gear with fine adjustment
Fig.7-65:	Effective Master Axis Position with Active "Position Synchronization" and "Velocity Synchronization" Modes

☞ "P-0-0777, Effective master axis velocity" mustn't fall below the following values:

- Advanced performance: 240000 rpm
- Standard performance: 120000 rpm
- Economy performance: 60000 rpm

Command Value Processing for Slave Axis Depending on Operation Mode

When the output value of the electronic 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 operation mode" is described in the sections on the respective operation mode:

- See "Velocity Synchronization"
- See "Position Synchronization: Phase Synchronization"
- See "Position Synchronization: Electronic Cam"
- See "Position Synchronization: MotionProfile"

Master Axis Cycle, Command Value Cycle, Actual Value Cycle and Synchronization Ranges

Applications

The extended functions of synchronization (master axis cycle, command value and actual value cycle) are required in conjunction with the following applications:

- Change of format, i.e. variable master axis gear settings in operation
- Necessity of mechanical relation of slave axis to master axis

☞ Command value and actual value cycle are only relevant for the position synchronization modes ("phase synchronization", "cam" and "MotionProfile").

Operation Modes

The figure below illustrates the interaction of the pertinent parameters for the command value cycle and the actual value cycle:
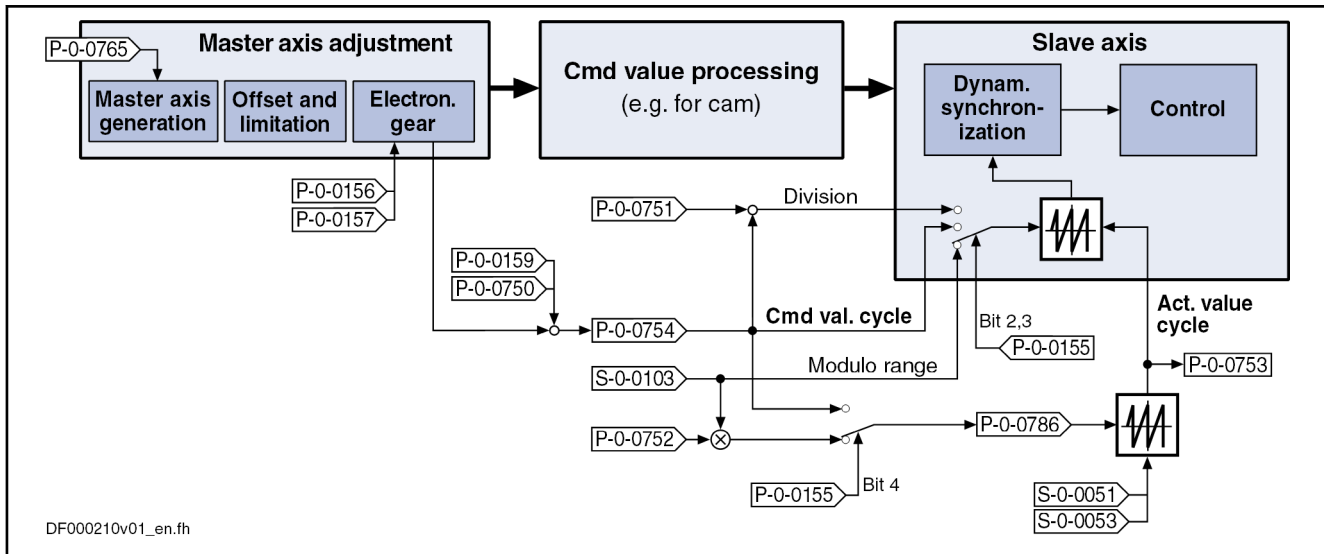
Fig.7-66:   *Generation and Operating Principle of the Command Value and Actual Value Cycle*

Master Axis Cycle   The master axis cycle specifies the range of the master axis values. It corresponds to a master axis revolution or a multiple thereof. The drive must be notified the master axis cycle by the control in order to allow for the correct processing of the master axis positions (e.g. modulo overflows).

The master axis cycle is configured via parameter **"P-0-0750, Master axis revolutions per master axis cycle"**. See Parameter Description "P-0-0750, Master axis revolutions per master axis cycle"

In printing machines, for example, the master axis cycle specifies how many master axis revolutions are required for producing a (partial) product. After each master axis cycle, the mechanical alignment of all slave axes to each other corresponds to the initial position in the machining process.

In more complex systems, the duration of the partial processes required for producing a product is different. The end product consists of several partial products running through different processing cycles.

In the following example, brochures consisting of two double pages A, B are produced. Within one revolution of the impression cylinder, the two double pages A, B are printed onto one path. A cross cutter divides the imprinted path into the partial formats A and B. The partial products A, B are taken over by a collective cylinder. One part B is in each case put onto one part A. After 2 revolutions of the collective cylinder, 6 subsequent partial products A, B are processed. In order to allow for a clear alignment of all drives also after one master axis revolution, the multi-turn capability of the master axis (P-0-0750) is used. In the drives, different synchronization ranges for the individual partial processes are set.
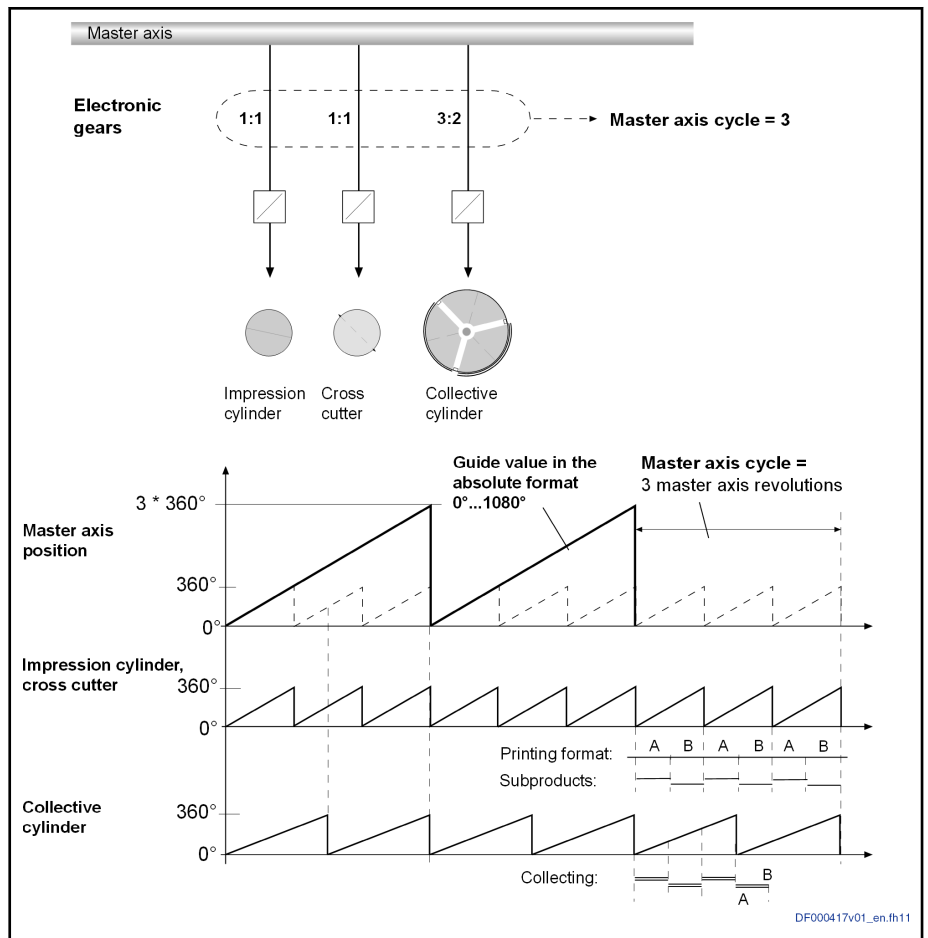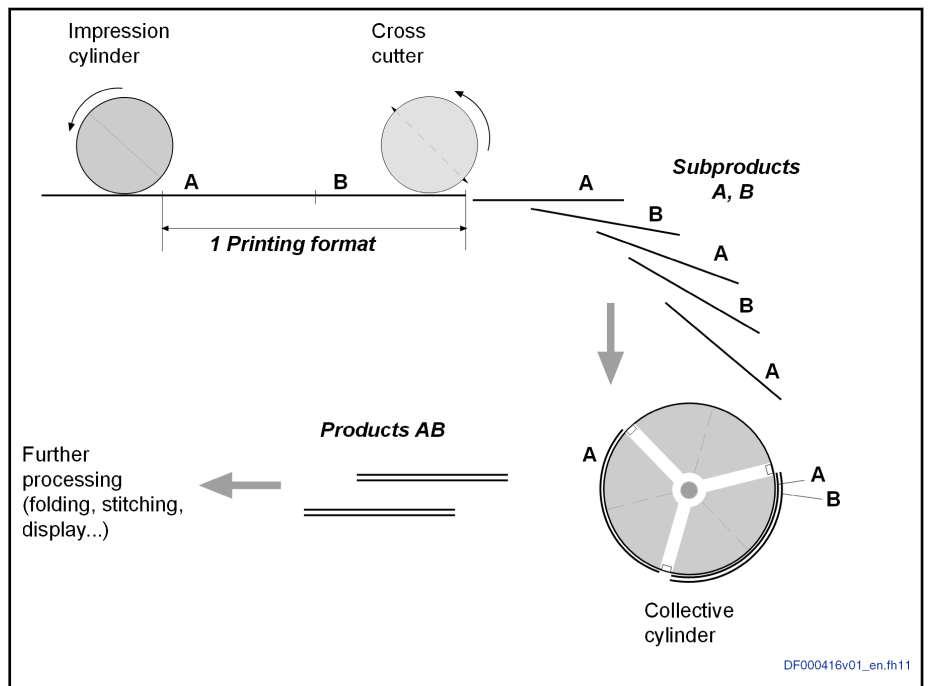
Fig.7-67:

Fig.7-68:

During commissioning, the master axis cycle is once set according to the following rule:

Operation Modes

$$\text{Master axis cycle} = \text{LCM of the P-0-0156}$$

LCM: Least common multiple
P-0-0156:   Master drive gear input revolutions
Fig.7-69:   Master Axis Cycle

In format-variable processes, the electronic gears of individual slave axes are changed in case of a product change: The partial processes may vary, depending on the product. In these applications, all admissible gear settings must be considered when determining the master axis cycle.

Command Value Cycle   In processes with different machining cycles, the slave axis must be able to synchronize either over several master axis revolutions or divisions of a master axis revolution. This property is defined via the so-called command value cycle.

See Parameter Description "P-0-0754, Command value cycle"

The command value cycle results from the settings for the master axis cycle, the electronic gear and the modulo range. It specifies the range in which its master-axis-synchronous position command values are to be found. This absolute position range is the command value cycle; i.e. the position range of the slave axis within a master axis cycle.

☞   The command value cycle is calculated internally by the drive and displayed in parameter "P-0-0754, Command value cycle". The command value cycle for synchronization is only required in the case of modulo scaling of the slave axis.

The range for the command value cycle at the slave axis is defined by the master axis cycle and the electronic gear.

With "Phase synchronization",

with "Cam without gear reduction" and (P-0-0755 = 0) and

with "MotionProfile without gear reduction" (P-0-0755 = 0):

$$\text{Command value cycle} = \text{P-0-0750} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times \text{S-0-0103}$$

With "Cam with gear reduction" (P-0-0755 ≠ 0) and

with "MotionProfile with gear reduction" (P-0-0755 ≠ 0):

$$\text{Command value cycle} = \text{P-0-0750} \times \frac{\text{P-0-0157} \times \text{S-0-0103}}{\text{P-0-0156} \times \text{P-0-0755}}$$

Fig.7-70:   Command Value Cycle with Modulo Scaling

☞   The master-axis-synchronous position command values are an absolute position range related to the master axis cycle; they are not the range of the effective position command values of the axis generated in dependance of the operation mode.

Operation Modes

Actual Value Cycle / Position Actual Value in the Actual Value Cycle

The modulo range, within which the actual position values (P-0-0753, Position actual value in actual value cycle) of the slave axis are to be found in case of active position synchronization mode, is called actual value cycle.

☞ The position synchronization modes (phase synchronization, cam and MotionProfile) use the "position actual value in actual value cycle" (P-0-0753) in order to close their position control loop.

By means of the "position actual value in actual value cycle" and the synchronization range that has been set (see Parameter Description for "P-0-0155, Synchronization mode"), the travel distance for synchronization is determined when one of the position synchronization modes is activated. In this connection, the travel distance is limited to the synchronization range (command value cycle, division of the command value cycle or modulo range, "S-0-0103, Modulo value").

See Parameter Description "P-0-0753, Position actual value in actual value cycle"

See Parameter Description "P-0-0786, Modulo value actual value cycle".

The modulo value of the actual value cycle must be set in such a way that it corresponds to an integer multiple of the command value cycle or the modulo range (S-0-0103, Modulo value).

☞ The parameter "P-0-0786, Modulo value actual value cycle" displays the value range of the actual value cycle.

For the setting of bit 4 in parameter "P-0-0155, Synchronization mode", we distinguish the following cases:

- Bit 4 = 1

  → The actual value cycle (P-0-0786) equals the command value cycle (P-0-0754).

- Bit 4 = 0

  → The actual value cycle is determined by the parameters "P-0-0752, Load revolutions per actual value cycle slave axis" and "S-0-0103, Modulo value".

$$P\text{-}0\text{-}0786 = S\text{-}0\text{-}0103 \times P\text{-}0\text{-}0752$$

Fig.7-71:   Internal Calculation Formula of the Value for P-0-0786

The actual value cycle (P-0-0786) is calculated

- automatically when progressing from parameter mode to operating mode

- or -

- manually by starting the command "P-0-0071, C3100 Command Recalculate actual value cycle" for recalculating the actual value cycle in the operating mode when a parameter, that is used for calculating the actual value cycle, was changed in the operating mode.

☞ At the start of command C3100, the status bits in "S-0-0403, Position feedback value status" and the status bit in "P-0-0089, Status word synchronization modes" (bit 4) are cleared. After the position data reference has been successfully established, the bits are set again.

Operation Modes

Synchronization Range   In the case of modulo scaling, the range for synchronization can be set in parameter "P-0-0155, Synchronization mode", i.e. the distance to be traveled is limited to this range:

- Modulo value (S-0-0103)
- Command value cycle (P-0-0754)
- Division of the command value cycle

☞   The actual position value used for calculating the distance must be unequivocal in the range in which synchronization is to take place. The actual value cycle must therefore be determined in such a way that is a multiple of the synchronization range, i.e. a multiple of the command value cycle (P-0-0754) or the modulo value (S-0-0103).

Synchronization in the Command Value Cycle   The distance traveled during synchronization is the result of the difference between synchronous position command value (+ "S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and the position actual value in actual value cycle (P-0-0-0753). The synchronization distance is limited to the modulo command value cycle.

$$\text{Distance} = \% \text{ cmd value cycle} \left[x_{sync} + (S\text{-}0\text{-}0048) + (P\text{-}0\text{-}0691) - \text{actual position value} \right]$$

Fig.7-72:   Synchronization Distance During Synchronization in Command Value Cycle

Within the actual value cycle, there may be several synchronization ranges with the value of a command value cycle.

Example of the calculation of the synchronization distance with standing master axis:

Fig.7-73:

- Phase synchronization mode
- Modulo value (S-0-0103) = 360°
- Master axis cycle (P-0-0750) = 3

Operation Modes

- Master drive gear input revolutions (P-0-0156) = 3
- Master drive gear output revolutions (P-0-0157) = 2
- Command value cycle (P-0-0754) = 720°
- Actual value cycle (P-0-0786) = 720°
- Additive command values (S-0-0048 / P-0-0691) = 0°
- Number of bits per master axis revolution (P-0-0084) = 20 bits
- Resulting master axis position (P-0-0775) = 2228224 Incr
- Current position actual value in actual value cycle (P-0-0753) = 210°
- Master axis has stopped

When the operation mode is activated, the following synchronous position command value results:

X_{SYNC} = %P-0-0786 [P-0-0775 * P-0-0157 * S-0-0103 / ($2^{P-0-0084}$* P-0-0156)] = 510°.

According to the preceding formula, the following synchronization distance results:

Distance = %720° [510°- 210°] = 300°

Depending of the configuration of the parameter "P-0-0154, Synchronization direction", the slave axis travels the following distance in order to reach the synchronous position.

- Shortest distance: Synchronization distance = +300° da 300° < (P-0-0754 / 2)
- Positive direction: Synchronization distance = + 300°
- Negative direction: Synchronization position = 300° - P-0-0754 = - 420°

☞   If, however, the shortest distance to the absolute synchronization is smaller than "P-0-0151, Synchronization window for modulo format", the shortest distance will be traveled and the specified synchronization direction will be ignored.

Synchronization in a Division of the Command Value Cycle

The number of divisions per command value cycle and thus the division itself are determined via parameter "P-0-0751, Synchronization divisions per command cycle slave axis". This value must be integer.

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ "S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and the position actual value in actual value cycle. The synchronization distance is limited to a division of the modulo command value cycle.

$$\text{Distance} = \% \text{ division of cmd value cycle} \left[x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - \text{actual position value} \right]$$

Fig.7-74:   Synchronization Distance for Synchronization in a Division of the Command Value Cycle

Example 1

- A collective cylinder is to only synchronize within one of several collection areas.
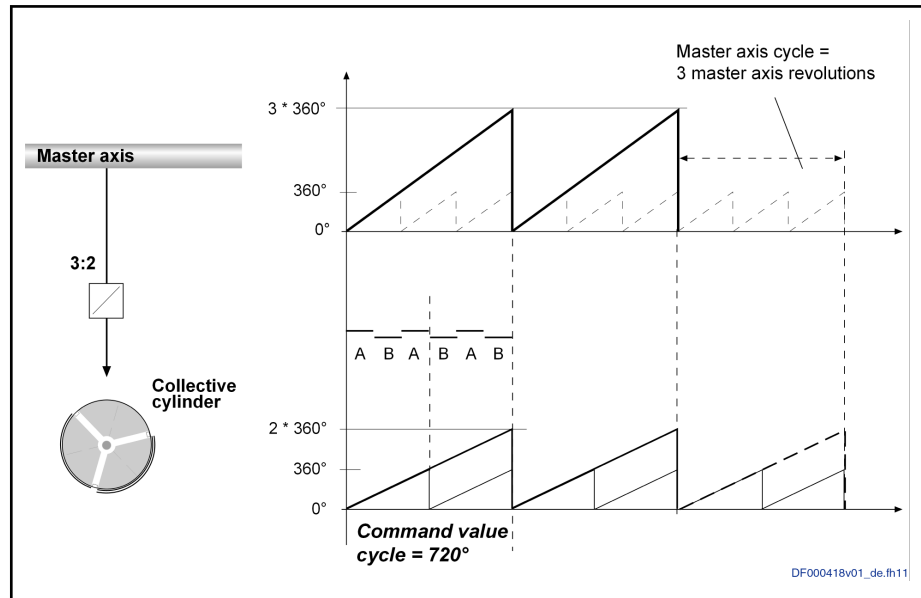
Operation Modes
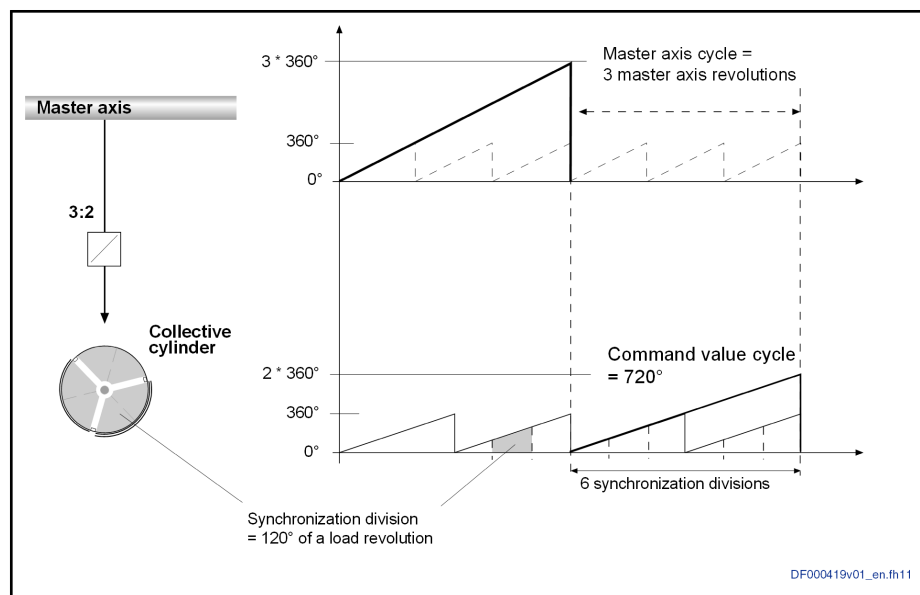
Fig.7-75:

- Phase synchronization mode
- Modulo value (S-0-0103) = 360°
- Master axis cycle (P-0-0750) = 3
- Master drive gear input revolutions (P-0-0156) = 3
- Master drive gear output revolutions (P-0-0157) = 2
- Command value cycle (P-0-0754) = 720°
- Synchronization divisions (P-0-0751) = 6
- Actual value cycle (P-0-0786) = 720°
- Additive command values (S-0-0048 / P-0-0691) = 0°
- Number of bits per master axis revolution (P-0-0084) = 20 bits
- Resulting master axis position (P-0-0775) = 2228224 Incr
- Current position actual value in actual value cycle (P-0-0753) = 210°
- Master axis has stopped

When the operation mode is activated, the following synchronous position command value results:

X_{SYNC} = %P-0-0786 [P-0-0775 * P-0-0157 * S-0-0103 / ($2^{P-0-0084}$* P-0-0156)] = 510°.

According to the preceding formula, the following synchronization distance results:

Distance = %(P-0-0754 / P-0-0751) [510°- 210°] = 60°

Depending of the configuration of the parameter "P-0-0154, Synchronization direction", the slave axis travels the following distance in order to reach the synchronous position.

- Shortest distance: Synchronization distance = +60° da 60° == (P-0-0754 / (P-0-0751 * 2))

  Synchronization position = P-0-0753° + 60° = 270°
- Positive direction: Synchronization distance = +60°

  Synchronization position = P-0-0753° + 60° = 270°

- Negative direction: Synchronization distance = 60° - (P-0-0754/ P-0-0751) = - 60°

  Synchronization position = P-0-0753° - 60° = 150°

☞ If, however, the shortest distance to the absolute synchronization is smaller than "P-0-0151, Synchronization window for modulo format", the shortest distance will be traveled and the specified synchronization direction will be ignored.

Example 2
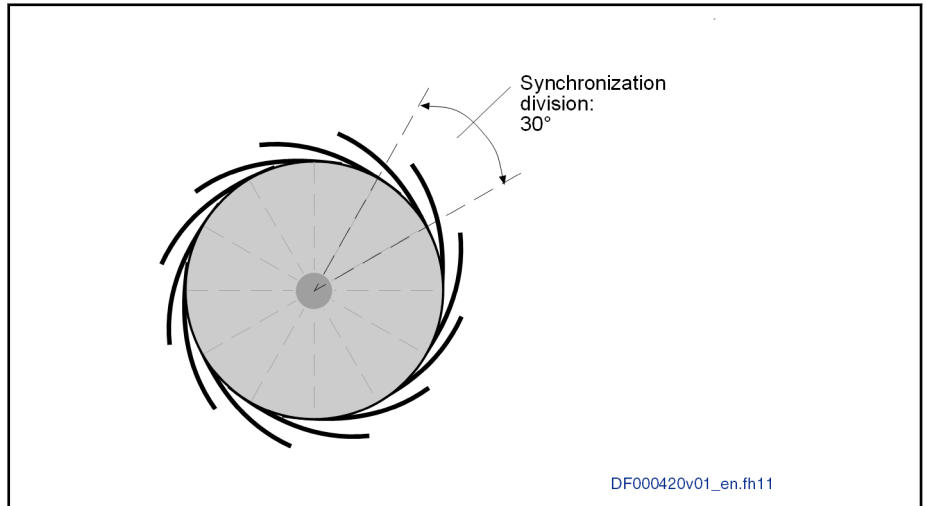
Fig.7-76:

In the ongoing process, each paddle takes up a product; e.g. a printed magazine. Upon switch-on, the paddle wheel only synchronizes in the area of one paddle in order to ensure that collected copies do not fall out.

Synchronization in the Modulo Range

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ "S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and the position actual value in actual value cycle. The synchronization distance is limited to the modulo value (S-0-0103).

$$\text{Distance} = \% \text{ modulo value} \left[x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - \text{actual position value} \right]$$

Fig.7-77:   Synchronization Distance for Synchronization in Modulo Range

Notes on Usage and Parameterization

Selecting the Actual Value Cycle and Master Axis Cycle

When using the command value cycle or actual value cycle, observe the following aspects:

- Master axis cycle:

  P-0-0750 = LCM of "P-0-0156, Master drive gear input revolutions" when using several electronic gear ratios.

  The least common multiple (LCM) of all P-0-0156 must be preset, of the axes in the system which have to synchronize unequivocally in the master axis cycle.

  This ensures that one position before the electric gear can be unequivocally assigned to each position after the electric gear.

- Actual value cycle:

Operation Modes

The setting of the actual value cycle depends on the following questions:

–   In which range(s) is synchronization to take place later on?

–   Are several electronic gear ratios to be set at the axis?

When these two questions have been clarified, you can proceed according to the following decision matrix to set the actual value cycle:
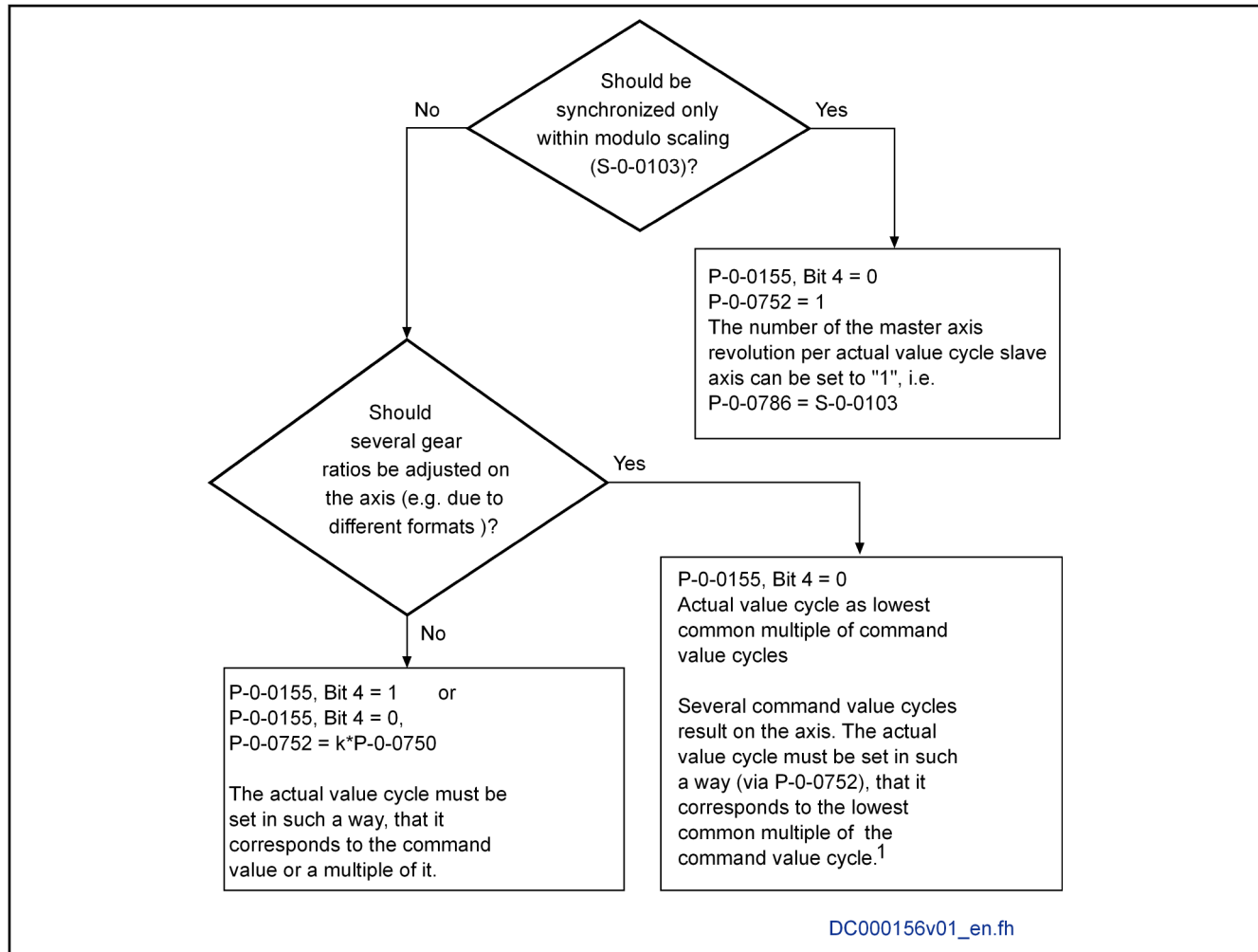
1)   If the requirement cannot be fulfilled by parameterizing the actual value cycle, it is possible to have the range of the actual value cycle calculated by the drive by analogy to the command value cycle by setting bit 4 = "1" in parameter "P-0-0155, Synchronization mode".

Fig.7-78:   Commissioning

Calculating the Actual Value Cycle (P-0-0786)   The actual value cycle (P-0-0786) is calculated

●   automatically when progressing from parameter mode to operating mode

- or -

●   manually by starting the command "P-0-0071, C3100 Command Recalculate actual value cycle" for recalculating the actual value cycle in the operating mode when a parameter, that is used for calculating the actual value cycle, was changed in the operating mode.

Operation Modes

☞   At the start of command C3100, the status bits in "S-0-0403, Position feedback value status" and the status bit in "P-0-0089, Status word synchronization modes" (bit 4) are cleared. After the position data reference has been successfully established, the bits are set again.

The actual value cycle is calculated in dependence of bit 4 of parameter "P-0-0155, Synchronization mode".

- With **bit 4 = 0** in P-0-0155, the actual value cycle is determined in dependence of "P-0-0752, Load revolutions per actual value cycle slave axis":

$$P\text{-}0\text{-}0786 = S\text{-}0\text{-}0103 \times P\text{-}0\text{-}0752$$

Fig.7-79:   "Modulo Value Actual Value Cycle" (P-0-0786) with Rotary and Linear Modulo Scaling and P-0-0155, Bit 4 = 0

- With **bit 4 = 1** in P-0-0155 (actual value cycle = command value cycle), the actual value cycle is determined according to the formulas below:

With "Phase synchronization",

with "Cam without gear reduction" (P-0-0755 = 0) and

with "MotionProfile without gear reduction" (P-0-0755 = 0):

$$\text{Actual value cycle (P-0-0786)} = P\text{-}0\text{-}0750 \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times S\text{-}0\text{-}0103$$

With "Cam with gear reduction" (P-0-0755 $\neq$ 0) and

with "MotionProfile with gear reduction" (P-0-0755 $\neq$ 0):

$$\text{Actual value cycle (P-0-0786)} = P\text{-}0\text{-}0750 \times \frac{P\text{-}0\text{-}0157 \times S\text{-}0\text{-}0103}{P\text{-}0\text{-}0156 \times P\text{-}0\text{-}0755}$$

Fig.7-80:   "Modulo Value Actual Value Cycle" with Modulo Scaling and P-0-0155, Bit 4 = 1

Establishing the Position Data Reference

"P-0-0753, Position actual value in actual value cycle" is set by

- The "set absolute position procedure" command
- "Drive-controlled homing procedure"

For the actual position value that is selected by means of parameter "S-0-0520, Axis control word", in the parameter mode (PM)

If, for example, encoder 1 is selected in parameter mode (PM) in parameter S-0-0520, the actual position value in actual value cycle (P-0-0753) will change by analogy with the actual position value 1 (S-0-0051).

☞   In contrast to the actual position value in actual value cycle (P-0-0753), the actual position value 1 (S-0-0051) is limited to the modulo value (S-0-0103)!

Homing of the actual position value 1 then causes the actual position value in actual value cycle (P-0-0753) to be set to the same value as actual position value 1.

Operation Modes

☞ The position status of the position actual value in actual value cycle is displayed in bit 4 of parameter "P-0-0089, Status word synchronization modes".

Synchronization Direction

In the case of absolute position scaling, the calculated synchronization distance is always traveled. The settings in parameters "P-0-0154, Synchronization direction" and "P-0-0151, Synchronization window for modulo format" are **not** taken into account.

For modulo axes, the distance is limited to +/-0.5 × synchronization range. In addition, the settings in parameters "P-0-0154, Synchronization direction" and "P-0-0151, Synchronization window for modulo format" are taken into account.

☞ The setting in parameter "P-0-0154, Synchronization direction" will only take effect, if the shortest distance (absolute value ≤ 0.5 × synchronization range) is greater than the synchronization window. In this case, the synchronization direction according to parameter P-0-0154 is used (positive or negative or shortest distance). If the shortest distance is smaller than the synchronization window, the shortest distance will always be traveled.

Synchronization with Absolute Scaling

The position command value is generated in absolute form. There is no command value cycle and no actual value cycle calculated.

Synchronization may take place up to $\pm\ 2^{31\ -\ P\text{-}0\text{-}0084}$ revolutions absolute as the max. master axis encoder range ranges from -2^{31} to $2^{31}-1$ increments.

☞ Make sure that the motion of the slave axis does not exceed the range defined in parameter "S-0-0278, Maximum travel range".

In order to be able to travel in absolutely synchronous form within the max. travel range (S-0-0278), the parameter "P-0-0750, Master axis revolutions per master axis cycle" has to be initialized with zero.

☞ Incorrect parameterization can cause unwanted jumps in position.

Recommendation: Activate position limit value monitor!

See "Position Limitation/Travel Range Limit Switches"

The synchronization distance is calculated according to the following formula:

$$\text{Distance}\ =\ x_{sync}\ +\ (\text{S-0-0048})\ +\ (\text{P-0-0691})\ -\ \text{actual position value}$$

Fig.7-81:   Synchronization Distance with Absolute Scaling

☞ The synchronization range corresponds to the maximum travel range.

Dynamic Synchronization of the Slave Axis

Brief Description

The synchronization process is a drive-controlled motion with the objective of achieving absolute or relative synchronization between master axis and slave axis. Depending on the synchronization mode, we distinguish the following characteristics of dynamic synchronization:

Operation Modes

Synchronization with Velocity Synchronization

Features of synchronization in the "velocity synchronization" mode:

- Synchronization takes place as velocity adjustment
- Option: Synchronization only in case of activation of the operation mode or always
- Generation of status message "synchronization completed" (P-0-0152; bit 0)
- Generation of status message "synchronous mode in synchronization" (P-0-0089, bit 8)

Synchronization with the Position Synchronization Modes

Features of the synchronization with the position synchronization modes:

- Selection sequence of synchronization is **single-step, double-step or double-step optimized**
- Synchronization **absolute** (position and velocity adjustment) or **relative** (only velocity adjustment)
- **Modulo ranges** to be set for synchronization:
  - Modulo value (S-0-0103)
  - Command value cycle slave axis (P-0-0754)
  - Division for command value cycle (setting in P-0-0751)
- Possibility of repeated synchronization with active operation mode (P-0-0088, bit8)
- Direction for synchronization to be set for position adjustment of modulo axes, shortest distance, positive or negative direction in parameter "P-0-0154, Synchronization direction"; setting the tolerance window with only positive or negative direction via "P-0-0151, Synchronization window for modulo format"
- Display of the difference between position actual value in actual value cycle and the synchronous position command value generated from the master axis position in parameter "P-0-0034, Position command additional actual value"
- Generation of status message "synchronization completed" (P-0-0152; bit 0)
- Command value addition for slave axis possible
- Generation of status message "synchronous mode in synchronization" ("P-0-0089, Status word synchronization modes", bit 8)

ℹ️ 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:

Operation Modes
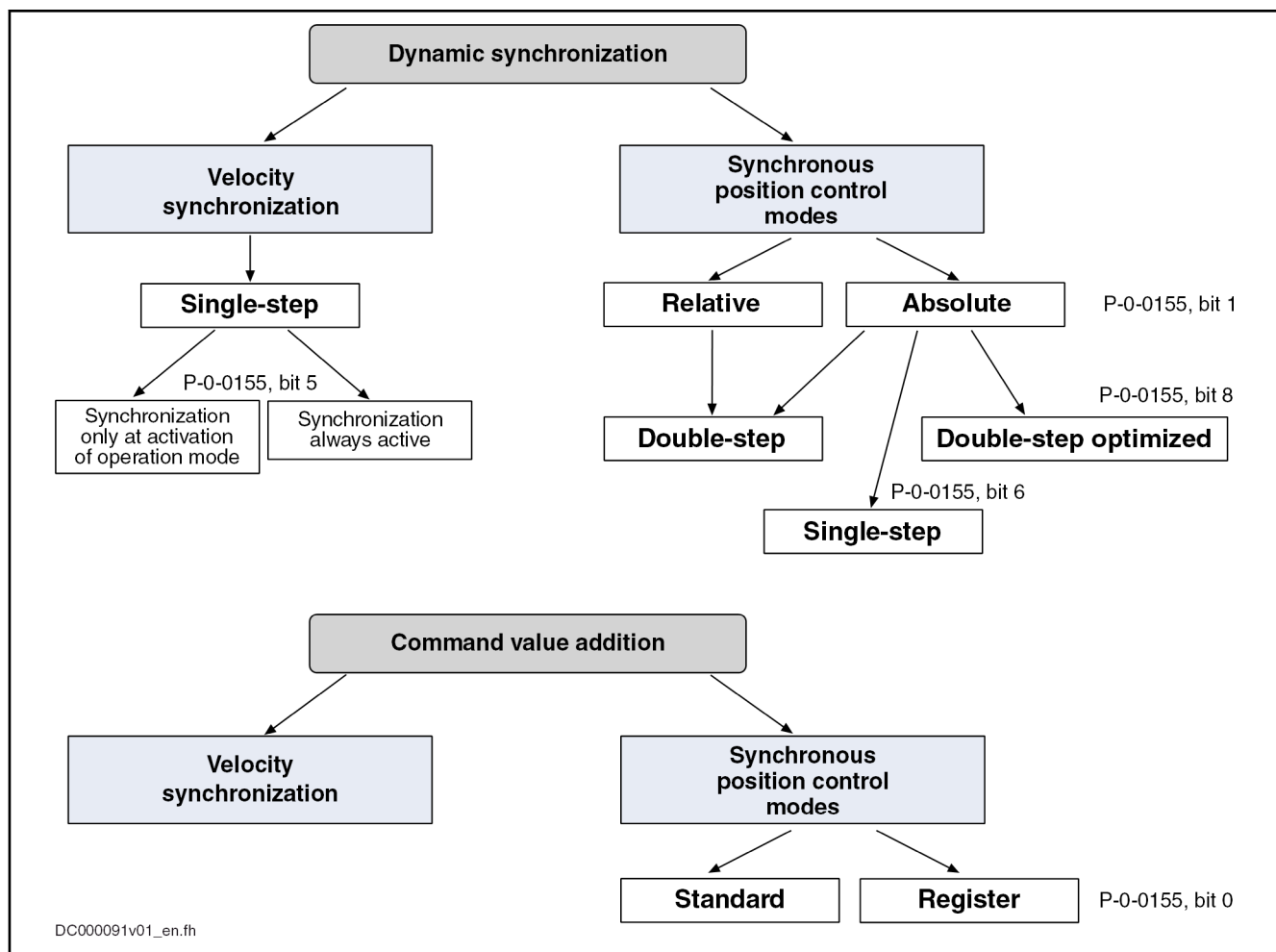
Fig.7-82:   Overview of Methods to be Selected for Synchronization and for Command Value Addition

☞   In the default setting of parameter P-0-0155 all bits are at value "0"!

Pertinent Parameters   The following parameters are used in conjunction with dynamic synchronization:

- S-0-0048, Additive position command value
- S-0-0183, Velocity synchronization window
- S-0-0228, Position synchronization window
- P-0-0034, Position command additional actual value
- P-0-0060, Filter time constant additive position cmd value
- P-0-0071, C3100 Command Recalculate actual value cycle
- P-0-0142, Synchronization acceleration
- P-0-0143, Synchronization velocity
- P-0-0151, Synchronization window for modulo format
- P-0-0152, Synchronization completed
- P-0-0154, Synchronization direction
- P-0-0155, Synchronization mode

- P-0-0686, Additive position command value, positioning velocity
- P-0-0687, Additive position command value, positioning acceleration
- P-0-0691, Additive position command value, process loop
- P-0-0697, Synchronization, master axis synchronous position
- P-0-0698, Synchronization, master axis synchronization range
- P-0-0751, Synchronization divisions per command cycle slave axis
- P-0-0752, Load revolutions per actual value cycle slave axis
- P-0-0753, Position actual value in actual value cycle
- P-0-0754, Command value cycle
- P-0-0786, Modulo value actual value cycle

Synchronization with the Velocity Synchronization Mode

Drive-controlled dynamic synchronization in the "velocity synchronization" mode is carried out depending on bit 5 of parameter "P-0-0155, Synchronization mode".

- Bit 5 = 0 → Synchronization only when operation mode is activated

  After the first synchronization and with the operation mode active, the changes of velocity are made at maximum acceleration (S-0-0138, Bipolar acceleration limit value)

- Bit 5 = 1 → Synchronization is always active

By generating velocity command values, the drive accelerates or decelerates during synchronization until the synchronous velocity has been reached. The velocity command values are generated taking the preset synchronization acceleration (P-0-0142) into account.
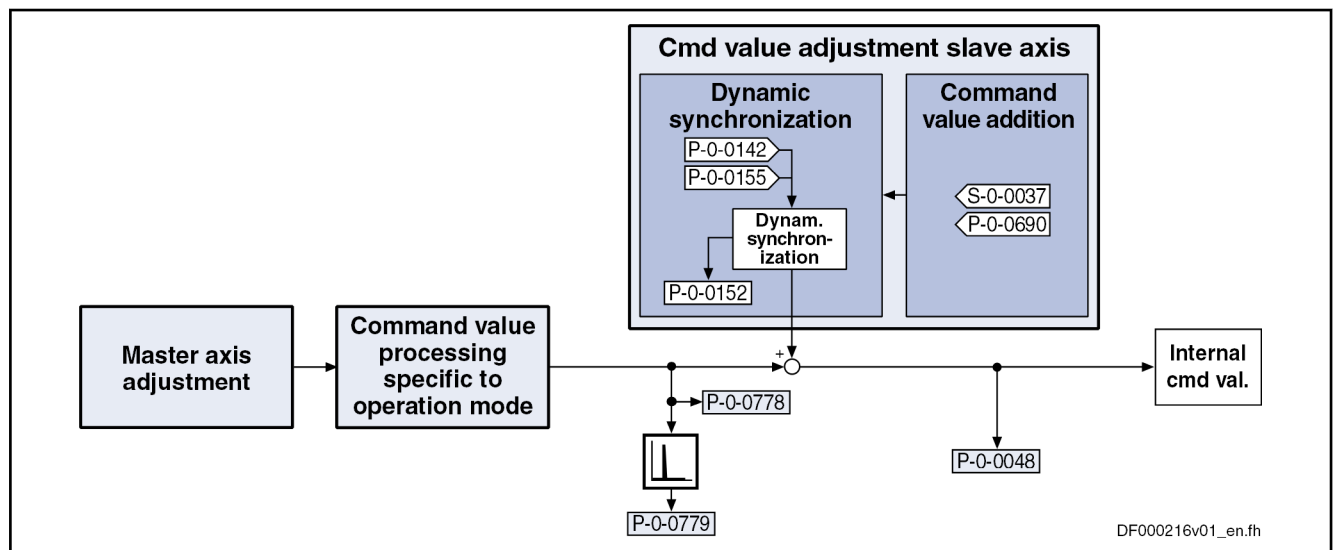
Fig.7-83:   Function Block "Dynamic Synchronization" with Velocity Synchronization

Synchronization with the Position Synchronization Modes

In the position synchronization modes, you can select between single-step, double-step, optimized double-step, and relative synchronization.

☞   All settings relevant for synchronization have to be made in parameter "P-0-0155, Synchronization mode".

Operation Modes

The figure below contains an overview of the parameters used for synchroni-zation.

☞   Not all listed parameters are required for each synchronization process!
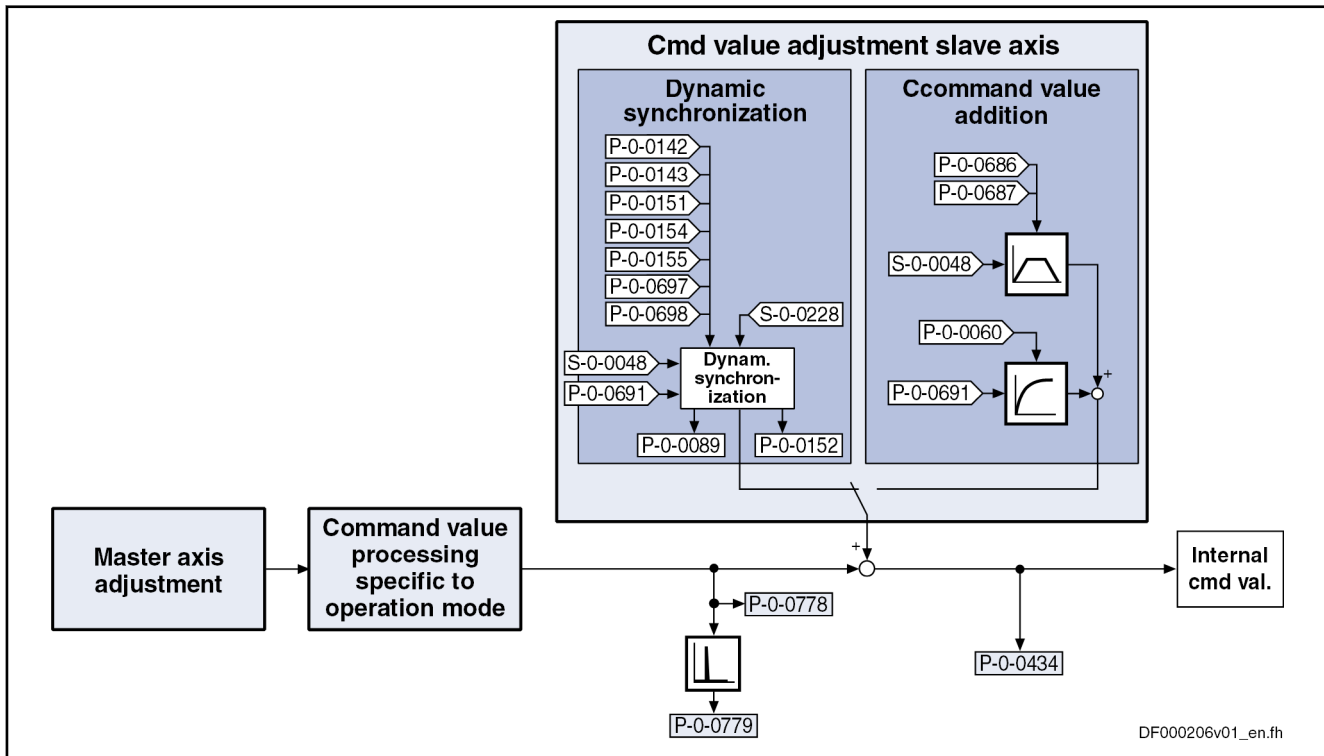
Fig.7-84:   Function Block "Dynamic Synchronization" with Synchronous Position Control Modes

Single-Step Synchronization   Single-step synchronization is a master-axis-synchronous synchronization that is added to the synchronous movement. The processing of the slave axis synchronization distance is carried out while the master axis is going through the master axis synchronization range.

As a slave axis synchronization distance can only be calculated with absolute synchronization (bit 1 = 0 in parameter "P-0-0155, Synchronization mode", single-step synchronization is only possible with absolute synchronization.

Selection takes place via bit 6 of the parameter P-0-0155.

In this case, the corresponding parameters take effect:

* P-0-0697, Synchronization, master axis synchronous position
* P-0-0698, Synchronization, master axis synchronization range

☞   The parameters P-0-0697 and P-0-0698 refer to the output of the electronic gear.

By means of bit 7 = 1 in parameter P-0-0155 a relative master-axis-synchro-nous synchronization is set. As a consequence, synchronizing is immediately started at activation of the synchronization mode. The parameter for the mas-ter axis synchronous position (P-0-0697) does not take effect. Starting the synchronizing process for inactive master axis, this will produce a velocity command value of zero. This effect must be prevented for active slave axis.

Operation Modes

With bit 7 = 0, you can set that the master-axis-synchronous synchronization motion only starts when the master axis start position is passed (absolutely master-axis-synchronous). This position results from subtraction of master axis synchronous position and master axis synchronization range. Until the master axis start position is passed, the axis decelerates or accelerates, based on the current actual velocity, with the parameterized synchronization acceleration (P-0-0142) in the direction of the synchronous velocity.

Single-Step Synchronization with Modulo Position Scaling

For modulo axes, the slave axis synchronization distance is not unequivocal. It can be increased or reduced by one or several synchronization ranges. By setting bit 9 in the parameter "P-0-0155, Synchronization mode", you can select the optimization of the slave axis synchronization distance by the drive. As an alternative, the slave axis synchronization distance can be influenced by the parameters "P-0-0154, Synchronization direction" and "P-0-0151, Synchronization window for modulo format".

- **Distance optimization** (P-0-0155, bit 9 = 1): An ideal value for the slave axis synchronization distance is firstly calculated from the values available for master axis velocity, master axis synchronization distance and slave axis velocity, and the ideal value of the standardized velocity (2.08333) for the motion profile "velocity in rest" which is used. The required slave axis synchronization distance (difference between synchronous position command value and actual position value of the slave axis) is then approximated as near as possible to the ideal value by adding or subtracting synchronization ranges. The optimization aims at not having any reversal point in the position curve in the added synchronization profile. In this case, there won't be any maximum in the velocity curve (overshooting) and no change of the acceleration sign. When the user significantly increases the master axis synchronization distance, this also increases the slave axis synchronization distance. The occurring acceleration values can thus be reduced.

- **No distance optimization** (P-0-0155, bit 9 = 0): The polarity of the added slave axis synchronization distance ist set in the parameter "P-0-0154, Synchronization direction". However, this only applies if the absolute value of the shortest synchronization distance is greater than the value of "P-0-0151, Synchronization window for modulo format". The maximum value (absolute value) of the added synchronization distance corresponds to one synchronization range.

For single-step synchronization, observe the following notes on utilization:

- Single-step synchronization is only active when the operation mode is activated. This means that, after the synchronous operation mode was activated, synchronization starts the next time the master axis start position is passed.

  The master axis position used for the comparison with the master axis start position is defined:

  – **In phase synchronization** by parameter "P-0-0776, Effective master axis position"

  – **In cam and MotionProfile mode** by parameter "P-0-0227, Cam table, access angle"

- The profile for synchronization is determined by a 5th order polynomial.

- The synchronous position command values, generated from the master axis positions, take immediate effect when the master axis start position is passed or at the beginning of the master axis synchronization range.

- The velocity of the master axis should be constant when passing through the master axis synchronization range.

Operation Modes

- The values set in the parameters "P-0-0142, Synchronization acceleration" and "P-0-0143, Synchronization velocity" are not taken into account for the synchronization process.

- Apart from by the other conditions of the synchronization mode, the resulting characteristics of velocity and acceleration can only be influenced by the master axis synchronization range.

- For modulo axes, the polarity of the slave axis synchronization distance can be set by parameter "P-0-0154, Synchronization direction". However, this only applies if the absolute value of the shortest synchronization distance is greater than the value of parameter "P-0-0151, Synchronization window for modulo format".

- Synchronization is completed when the master axis position has gone through the master axis synchronization range. Bit 0 of "P-0-0155, Synchronization mode" then defines how subsequent changes of "S-0-0048, Additive position command value" are processed (see section "Command Value Addition for Slave Axis" below).

To be noticed for single-step synchronization

With single-step synchronization, a profile "velocity in rest" (standard profile "G-R" according to VDI 2143) is added to the synchronous position command values:

- The distance traveled with the added profile is determined by the difference of synchronous position command value (+ "S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and actual position value at the starting point of time.

- When modulo scaling has been set, the distance is limited to the synchronization range set in parameter "P-0-0155, Synchronization mode".

- The parameter "P-0-0154, Synchronization direction" is not evaluated with modulo scaling. The preferred direction set is taken into account, if the determined synchronization distance is greater than the "P-0-0151, Synchronization window for modulo format".

- The initial velocity of the profile is determined by the difference of actual velocity and synchronous velocity at the starting point of time.

- We assume that the acceleration of the slave axis at the starting point of time equals zero.

☞   More details regarding the "velocity in rest" profile used are described in section "MotionProfile"!

Double-Step Synchronization   The double-step synchronization process consists of velocity adjustment and subsequent position adjustment.

Step 1 – Velocity adjustment:

- The drive either accelerates or decelerates from the current actual velocity at the time of activation to the synchronous velocity.

- The synchronous velocity is generated by differentiating the synchronous position command value. The synchronous position command value x_{sync} is determined from the master axis position ("P-0-0052, Actual position value of measuring encoder" or "P-0-0053, Master axis position") according to the operation mode.

- Velocity adjustment already takes place in position control. When accelerating or decelerating, the drive takes the value in parameter "P-0-0142, Synchronization acceleration" into account.

Operation Modes

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.7-85:   *Difference with Absolute Synchronization (Travel Distance)*

In the second step of synchronization, the difference generated during velocity adjustment is compensated by a travel motion taking"P-0-0142, Synchronization acceleration" and "P-0-0143, Synchronization velocity" into account. This position adjustment is added to the synchronous movement.

The figure below illustrates the absolute synchronization to a virtual master axis, the master axis being in standstill when the operation mode is activated.

Operation Modes

Fig.7-86: *Example: Absolute Synchronization out of Standstill*

Explanation of the example

- When the operation mode is activated, the synchronous velocity = 0. The current master axis position differs from the synchronous position.

- The synchronization status signals "synchronization running" (P-0-0152, bit 0 = 0).

- The absolute angle reference between slave axis and master axis position is established. The slave axis is turning with the parameterized synchronization velocity (P-0-0143). During acceleration and deceleration, the synchronization acceleration (P-0-0142) is effective.

- As soon as the position difference between master axis and slave axis is smaller than the "position synchronization window" (S-0-0228), the status bit "slave axis has been synchronized" (P-0-0089, bit 8 = 1) is output.

  Bit 0 is set in parameter P-0-0152 when synchronization has been completed.

The figure below illustrates the absolute synchronization to a virtual master axis, the master axis having a velocity ≠ 0 when the operation mode is activated.

| Step 1 | Velocity adjustment |
| Step 2 | Position adjustment |

Fig.7-87: *Example: Absolute Synchronization in Running Operation*

Explanation of the example

- When the operation mode is activated, the master axis moves at constant velocity.

- The synchronization status signals "synchronization running" (P-0-0152, bit 0 = 0).

- Based on its current position, the slave axis accelerates to the synchronous velocity. While this is done, the synchronization acceleration (P-0-0142) is effective.

- After velocity adjustment, the absolute position reference is established. Position adjustment takes place with parameterized synchronization acceleration (P-0-0142) and synchronization velocity (P-0-0143).

- As soon as the position difference between master axis and slave axis is smaller than the "position synchronization window" (S-0-0228), the status bit "slave axis has been synchronized" (P-0-0089, bit 8 = 1) is output.

  Bit 0 is set in parameter P-0-0152 when synchronization has been completed.

Optimized Double-Step Synchronization

The third synchronization method available for selection is a mixture between one-step and double-step synchronization. This method has the following characteristics:

- not master-axis-synchronous
- Immediate start upon activation of the synchronous operation mode
- No separation between velocity and position adjustment

Operation Modes

- Superimposed synchronization motion with 2nd order interpolator
- Limitation of synchronization motion by "P-0-0142, Synchronization acceleration" and "P-0-0143, Synchronization velocity"
- Reduce braking acceleration (deceleration) during positioning in order to reduce the number of acceleration jumps

Specific features with modulo position scaling

We distinguish two cases depending on whether upon start of the synchronization process, the braking distance is smaller or larger than a synchronization range.

In the 1st case, the initial velocity of the synchronization motion (difference between synchronous velocity and current actual velocity) is so small that positioning can take place immediately. When determining the synchronization distance, you than analyze parameter "P-0-0154, Synchronization direction", in connection with "P-0-0151, Synchronization window for modulo format".

In the 2nd case, you firstly reduce the velocity of the synchronization motion until the braking distance is smaller than one synchronization range. In this case, a parameterized synchronization direction is ignored, so that the velocity of the synchronization motion has no change of sign.

Relative Synchronization   If no absolute position reference between master axis and slave axis is necessary, relative synchronization is used. With relative synchronization, the slave axis velocity is only adjusted to the synchronous velocity derived form the master axis positions. After synchronization, the slave axis is moved synchronously to the master axis.
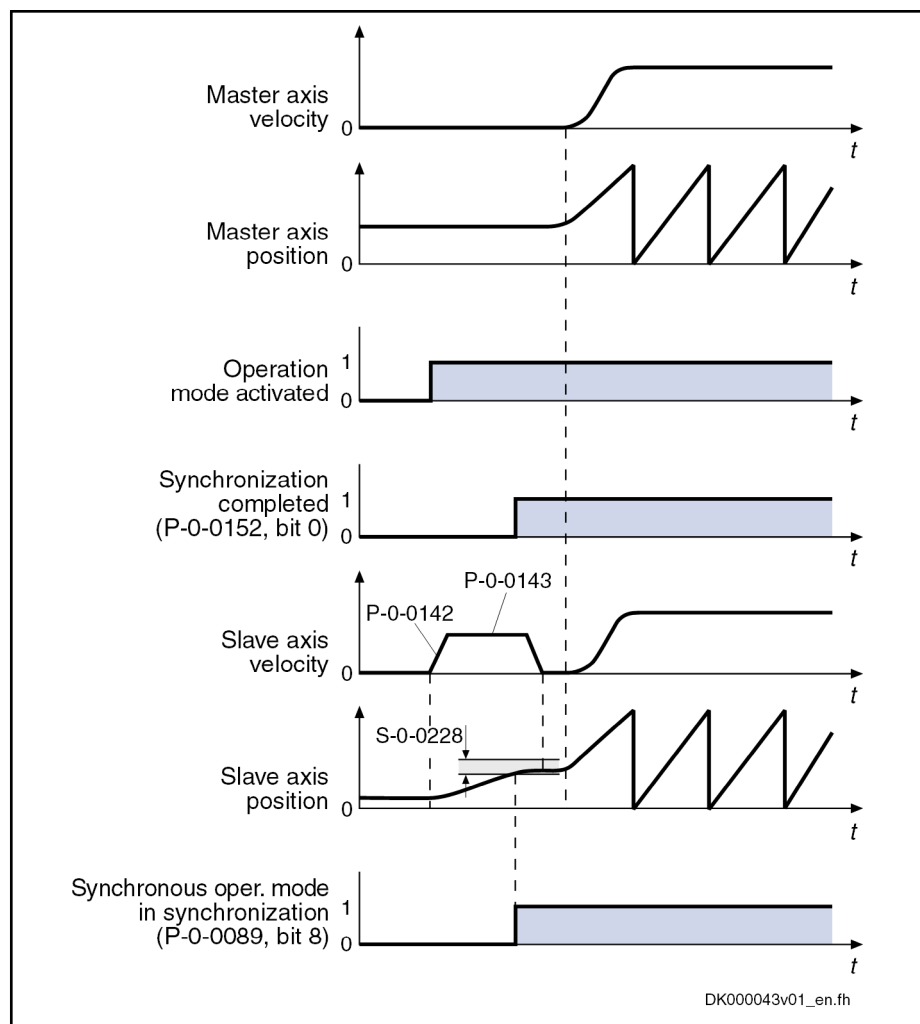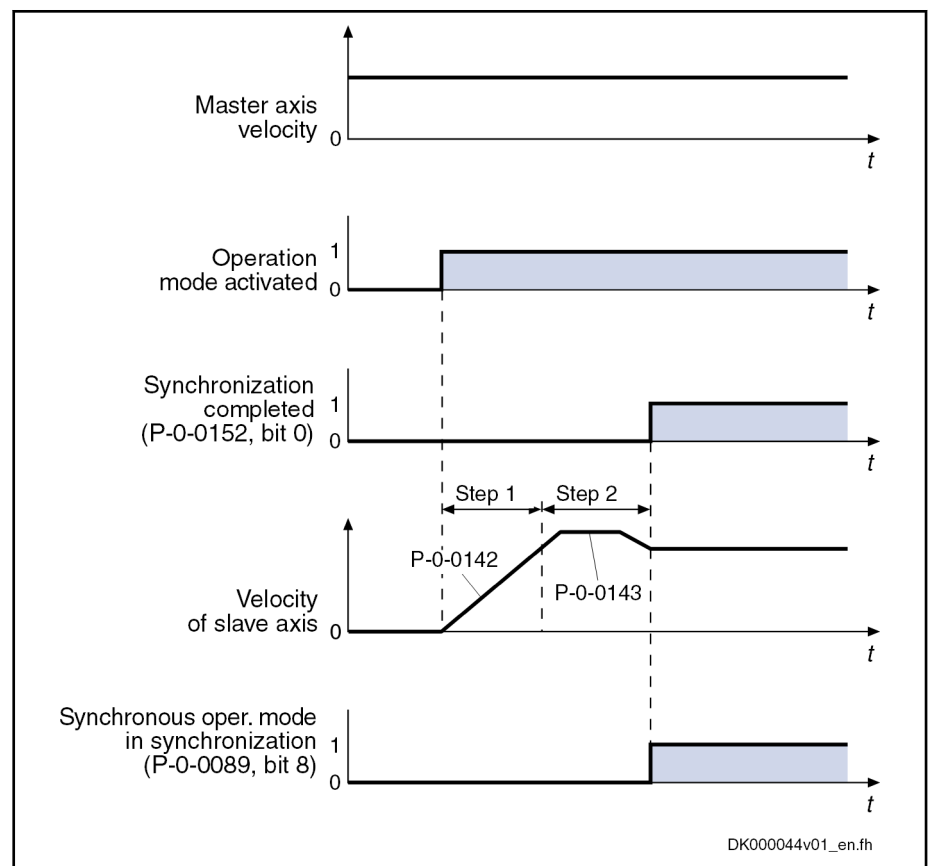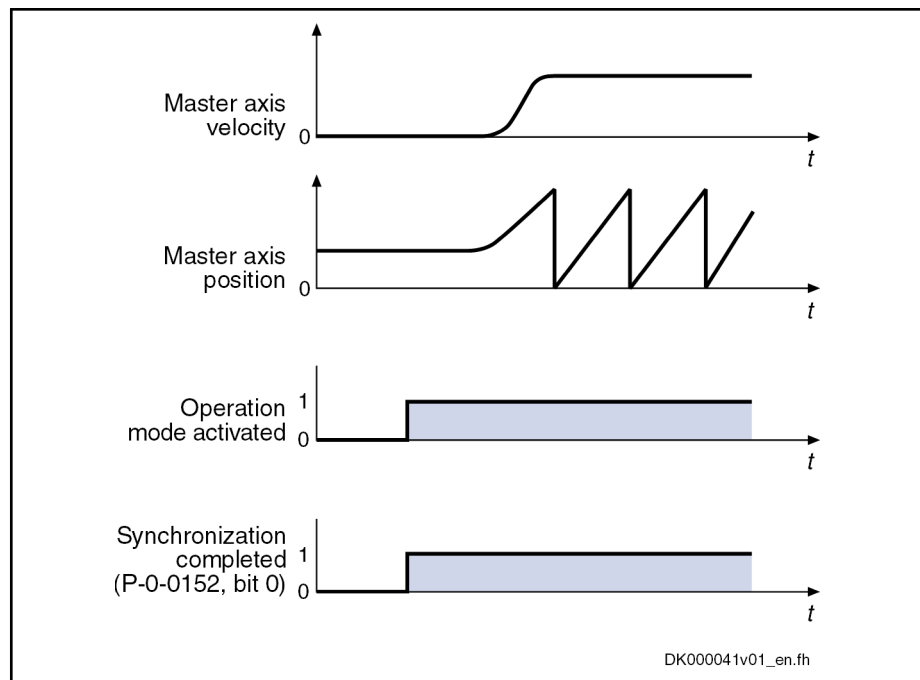

Fig.7-88:   Example: Relative Synchronization out of Standstill

Explanation of the example

- When the operation mode is activated, the synchronous velocity = 0.
- When the operation mode is activated, the bits for "synchronization completed" (P-0-0152; bit 0 = 1) and "slave axis has been synchronized" (P-0-0089, bit 8 = 1) are output.
- When the machine starts, the axis, based on its current position, follows the master axis position with relatively synchronous position.

Operation Modes

The figure below illustrates the relative synchronization to a virtual master axis, the master axis having a velocity ≠ 0 when the operation mode is activated.
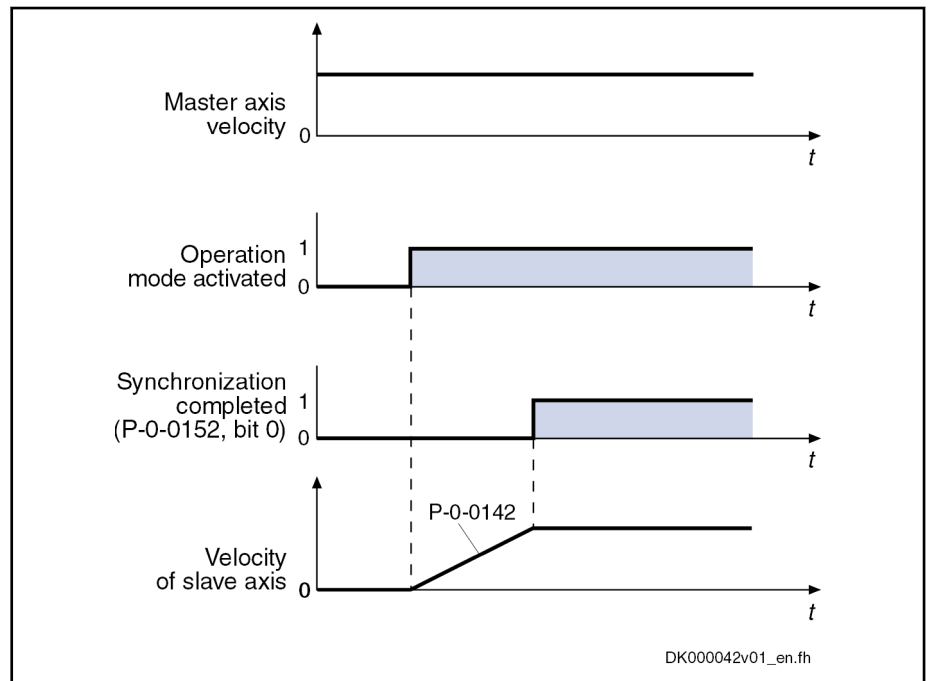
Fig.7-89:   *Example: Relative Synchronization in Running Operation*

Explanation of the example

- When the operation mode is activated, the master axis moves at constant velocity.

- Based on its current position, the slave axis accelerates to the synchronous velocity. While this is done, the synchronization acceleration (P-0-0142) is effective.

- Upon reaching the synchronous velocity, the bits for "synchronization completed" (P-0-0152, Bit 0 = 1) and "slave axis has been synchronized" (P-0-0089, bit 8 = 1) are output.

Absolutely Synchronized Slave Axis

The drive is absolutely synchronous to the master axis when the following condition has been fulfilled:

$$S\text{-}0\text{-}0228 \geq \left| \%modulo\left[(P\text{-}0\text{-}0753) - \langle\langle S\text{-}0\text{-}0048) + (P\text{-}0\text{-}0691) + P\text{-}0\text{-}0778)\rangle\right] \right|$$

S-0-0228	Position synchronization window
P-0-0753	Position actual value in actual value cycle
S-0-0048	Additive position command value
P-0-0691	Additive position command value, process loop
P-0-0778	Synchronous position command value

Fig.7-90:   *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)

Operation Modes

☞   In the case of absolute scaling, there is no modulo limitation!

Command Value Addition for Slave Axis

Brief Description

In the "velocity synchronization" mode, the addition of command values for the slave axis is directly associated with the synchronization process.

In synchronous position control modes, the addition of command values for the slave axis is an independent functional sequence for which you can choose between the following modes as regards command value addition:

- **"Standard" mode**

  → Changes are processed with the values from the parameters P-0-0686 and P-0-0687

- **"Register controller" mode**

  → Changes are smoothed by a 1st order filter (time constant in parameter P-0-0060)

The mode is selected via bit 0 of parameter "P-0-0155, Synchronization mode". As default setting, the "standard" mode is active.

"Standard" Mode

In the "standard" mode, all further changes in the value of parameter "S-0-0048, Additive position command value" are - after synchronization of the operation mode is completed - processed with the values set in the following parameters:

- P-0-0686, Additive position command value, positioning velocity
- P-0-0687, Additive position command value, positioning acceleration
- P-0-0151, Synchronization window for modulo format
- P-0-0154, Synchronization direction

The changes made in parameter "P-0-0691, Additive position command value, process loop" are smoothed via a 1st order filter. The time constant of the filter is set in parameter "P-0-0060, Filter time constant additive position cmd value".

☞   The status bit "synchronization completed" is only set when the condition $P\text{-}0\text{-}0434 = S\text{-}0\text{-}0048 + x_{sync}$ has been fulfilled.
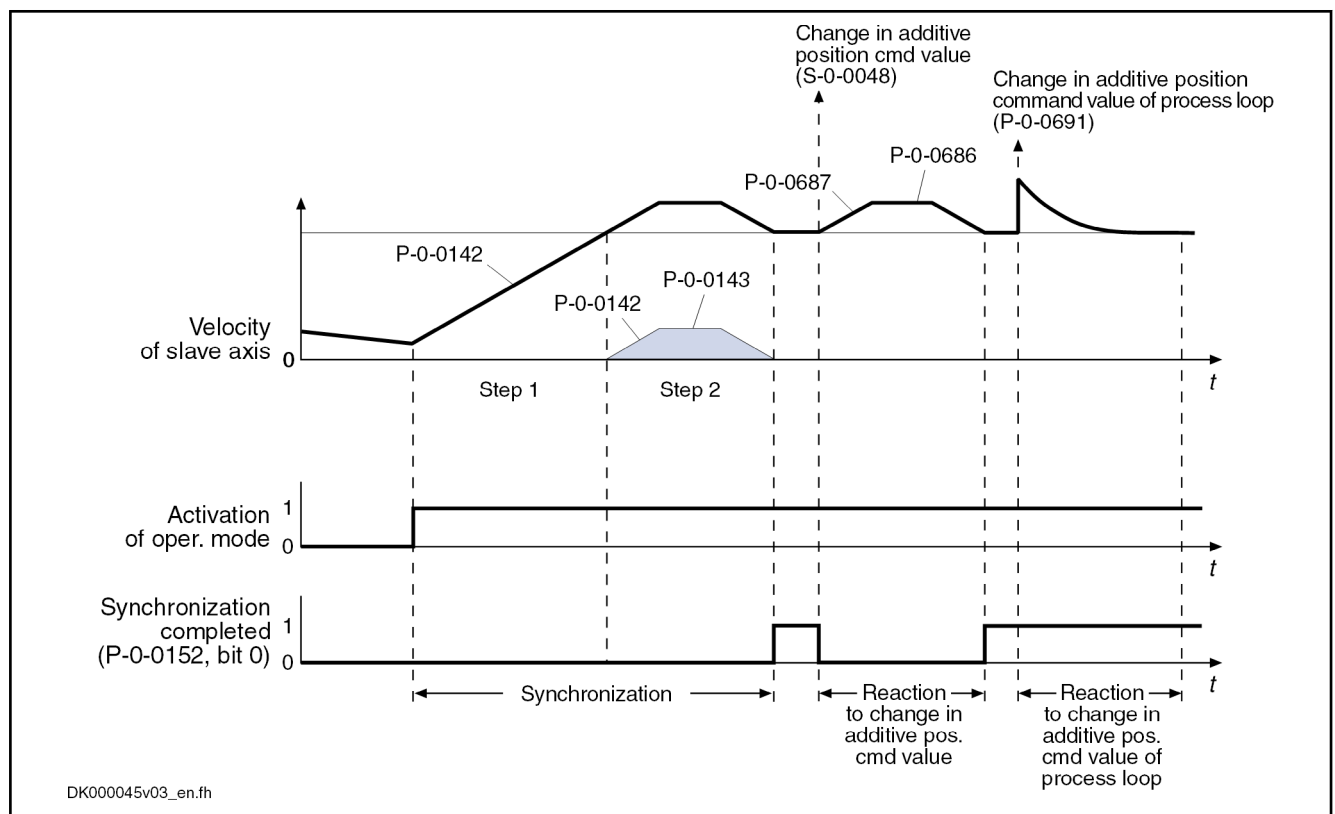
Fig.7-91:   *"Standard" mode*

☞   In the "standard" mode, the command values are limited with re-
gard to "S-0-0091, Bipolar velocity limit value" and "S-0-0138,
Bipolar acceleration limit value".

Register Controller "Mode"

In the "register controller" mode, all further changes in the parameter
"S-0-0048, Additive position command value" are, after synchronization,
smoothed by a 1st order filter. The time constant of the filter is set in parame-
ter "P-0-0060, Filter time constant additive position cmd value". The value of
"P-0-0691, Additive position command value, process loop" is processed in
differential form and the difference between old and new value of P-0-0691 is
added to the position command value.

☞   The status bit "synchronization completed" is set when the abso-
lute synchronization has been reached and will not be cleared,
even with further changes in "S-0-0048, Additive position
command value" and "P-0-0691, Additive position command
value, process loop".

Operation Modes
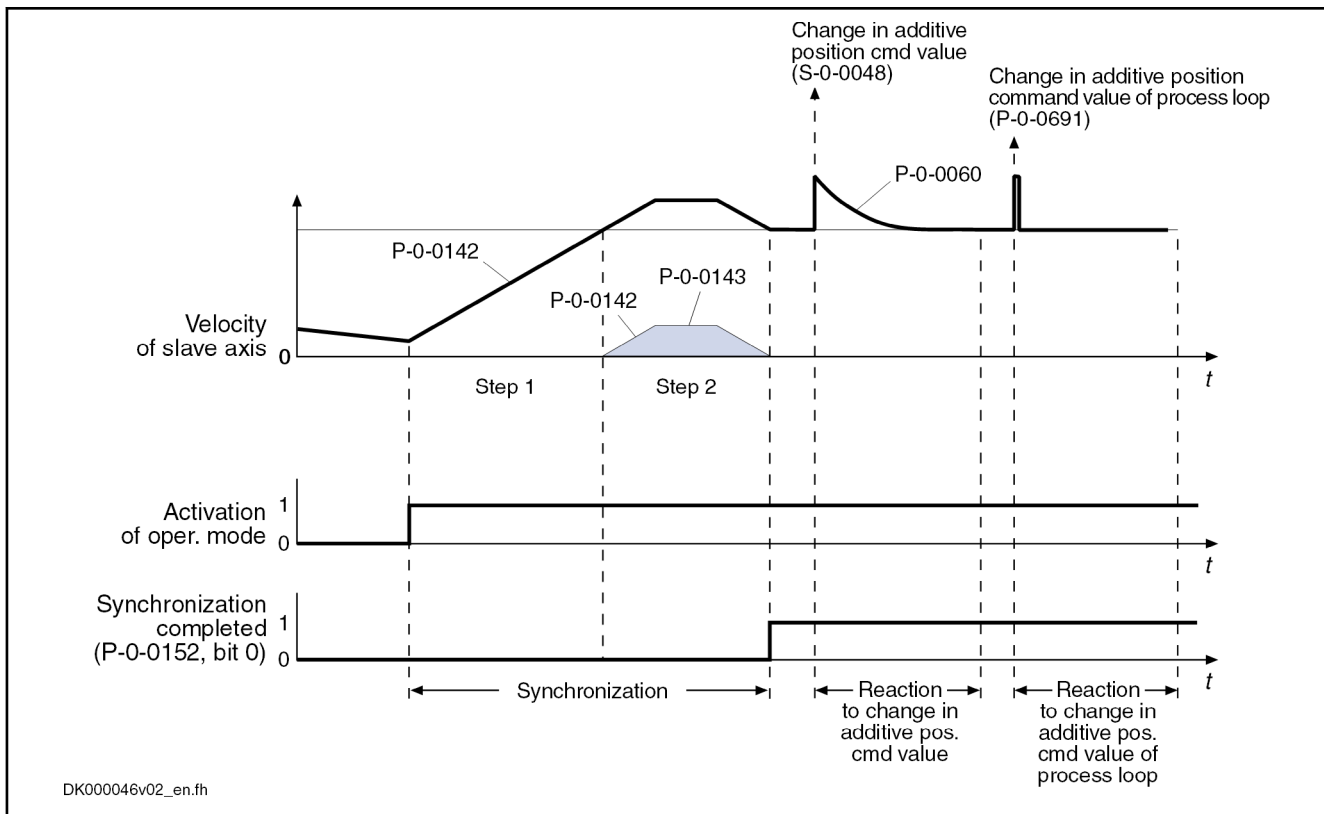
Fig.7-92:   *"Register Controller" Mode*

> ☞   In the "register controller" mode, the command values are moni-
> tored with regard to "S-0-0091, Bipolar velocity limit value" and
> "S-0-0138, Bipolar acceleration limit value".

If the command value exceeds the limit values, the error message "F2037
Excessive position command difference" is generated.

Possible countermeasures:

- Increasing the filter time constant
- Reducing the changes in the additive position command value
- Increasing the limit values for velocity and acceleration

Diagnostic and Status Messages

Status Messages

In addition to some status and display parameters that are valid for all opera-
tion modes, the parameters "P-0-0089, Status word synchronization modes"
and "P-0-0152, Synchronization completed" are available for diagnosing the
synchronization modes.

Synchronous Mode in Synchroni-
zation   The feedback signaling that the slave axis has been synchronized takes
place in bit 8 of parameter "P-0-0089, Status word synchronization modes".

- Bit 8 = 0 → Slave axis has not been synchronized
- Bit 8 = 1 → Slave axis has been synchronized

Depending on the synchronization mode, the drive sets bit 8 in parameter
P-0-0089.

In the case of velocity synchronization:

Operation Modes

$$\left| dx_{sync} + (S\text{-}0\text{-}0037) + (P\text{-}0\text{-}0690) - (S\text{-}0\text{-}0040) \right| < S\text{-}0\text{-}0183$$

Fig.7-93:   Condition for "Slave Axis has Been Synchronized" in the Case of Velocity Synchronization

In the case of synchronous position control modes:

$$\left| x_{sync} + (S\text{-}0\text{-}0048) + (P\text{-}0\text{-}0691) - (P\text{-}0\text{-}0753) \right| < S\text{-}0\text{-}0228$$

Fig.7-94:   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 operation modes "phase synchronization" and "electronic cam":

- First synchronization process

  → Bit 0 is set when the distance up to the absolute or relative position has been traveled.

- Cyclic normal operation

  → When bit 0 has been set, the fact of whether bit 0 is cleared for the duration of the following travel reaction when the additive position command value (S-0-0048) is changed, depends on the setting of bit 0 in parameter "P-0-0155, Synchronization mode". If bit 0 = 1 in parameter P-0-0155 ("register controller" mode), bit 0 remains set in parameter P-0-0152.

Diagnostic Messages

In conjunction with the synchronization modes, there is a number of diagnostic messages specific to operation mode.

Diagnostic command messages:

- C0244 Act. modulo value cycle greater than max. travel range
- C3100 Recalculate actual value cycle
- C3101 Act. modulo value cycle greater than max. travel range
- C3102 Drive is still in drive enable

Warnings:

- E2049 Positioning velocity >= limit value
- E2063 Velocity command value > limit value

Diagnostic error messages:

- F2002 Assignment of encoder for synchronization is not allowed
- F2003 Motion step skipped
- F2004 Error in MotionProfile
- F2005 Cam table invalid
- F2037 Excessive position command difference

Operation Modes

7.8.2 Velocity Synchronization with Real/Virtual Master Axis

Brief Description

> 💡 Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the operation mode "velocity synchronization with real/virtual master axis", the drive follows a preset master axis velocity 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:
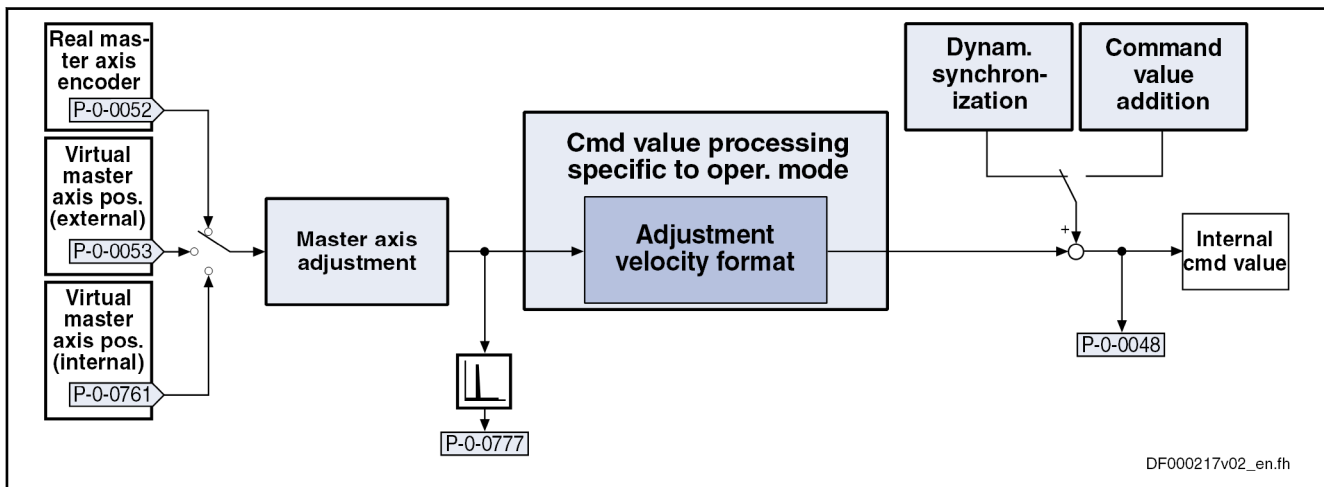
P-0-0048	Effective velocity command value
P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0761	Master axis position for slave axis
P-0-0777	Effective master axis velocity

Fig. 7-95:   *Function Blocks of the Operation Mode "Velocity Synchronization with Real/Virtual Master Axis"*

Variants of the Operation Mode   There are the following variants of the operation mode to be selected:
- Velocity synchronization with real master axis
- Velocity synchronization with virtual master axis

Application of the Operation Mode   Velocity synchronization is used, for example, for simple transport rolls of printing machines. The drive runs with a velocity synchronous to the master

axis. The track speed at the circumference of the transport roll or the winder is preset by the electric gear. A defined tension can be set by the fine adjustment of the gear.

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in velocity synchronization:

- S-0-0103, Modulo value
- S-0-0183, Velocity synchronization window
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization 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 Operation Mode
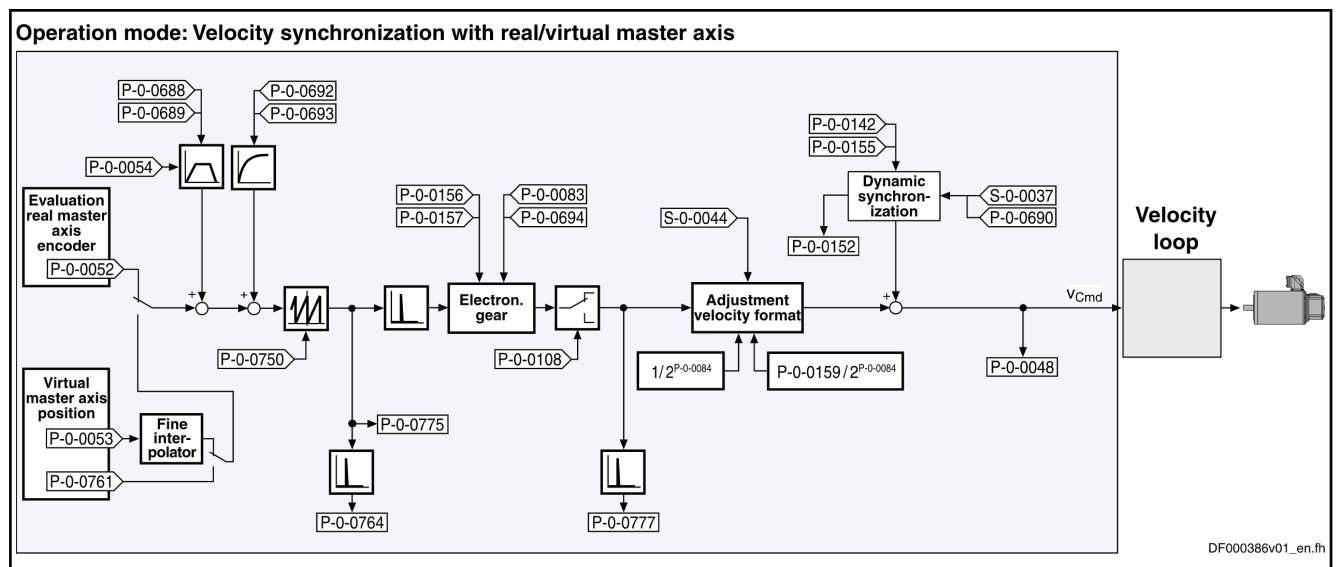
Fig.7-96:   Block Diagram: Velocity Synchronization with Real/Virtual Master Axis

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 adjustment

See "Basic Functions of the Synchronization Modes"

Operation Modes

Command Value Adjustment

Overview Command value adjustment in the "velocity synchronization" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operation mode
- Command value adjustment slave axis, consisting of
  – Dynamic synchronization
  – Command value addition

☞ Only the function block "command value processing" specific to velocity synchronization is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

See "Basic Functions of the Synchronization Modes"
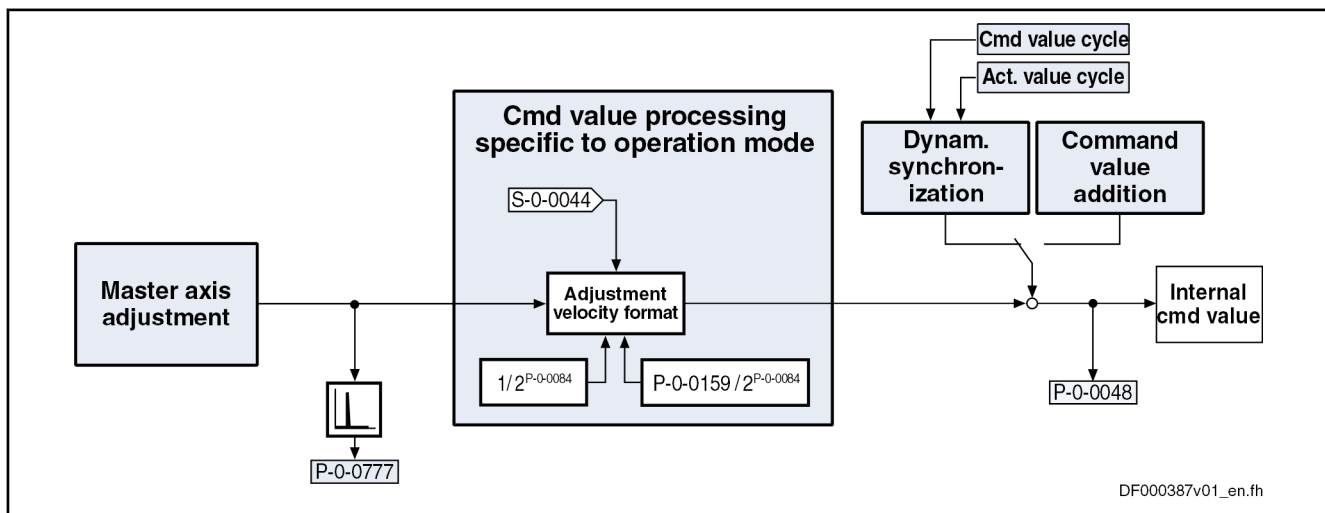
Fig.7-97: Command Value Processing Specific to Operation Mode for Velocity Synchronization

Generating the Synchronous Velocity Command Value

The synchronous velocity command value (dx_{sync}) is generated in terms of the selected master axis polarity (P-0-0108) and the scaling type (S-0-0044) that was set, using one of the following equations:

$$dx_{sync} = \pm\Delta \left[(P\text{-}0\text{-}0053) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)\right] \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times \left[1 + (P\text{-}0\text{-}0083)\right] \times \left[1 + (P\text{-}0\text{-}0694)\right] \times \frac{1}{2^{P\text{-}0\text{-}0084}}$$

dx_{sync} Synchronous velocity command value
Fig.7-98: Generating the Synchronous Velocity Command Value with Rotary Scaling

$$dx_{sync} = \pm\Delta \left[(P\text{-}0\text{-}0053) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)\right] \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times \left[1 + (P\text{-}0\text{-}0083)\right] \times \left[1 + (P\text{-}0\text{-}0694)\right] \times \frac{P\text{-}0\text{-}0159}{2^{P\text{-}0\text{-}0084}}$$

dx_{sync} Synchronous velocity command value
Fig.7-99: Generating the Synchronous Velocity Command Value with Linear Scaling

☞ One master axis revolution is standardized to 2^N increments (with N = value from "P-0-0084, Number of bits per master axis revolution"). This means that the LSB of the master axis position corresponds to 2^{-N} master axis revolutions.

Synchronization with Velocity Synchronization

The synchronization process is a drive-controlled motion with the aim of synchronizing the axis to the master axis velocity. The slave axis is velocity-synchronous when the following condition has been fulfilled:

$$dx_{sync} + (S\text{-}0\text{-}0037) + (P\text{-}0\text{-}0690) = S\text{-}0\text{-}0040$$

dx_{sync}	Synchronous velocity command value
S-0-0040	Velocity feedback value

Fig.7-100:   Condition for Velocity Synchronism of the Slave Axis

Synchronization Process   Upon activation of the operation 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:

$$\Delta \left[(P\text{-}0\text{-}0053) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)\right]$$

-or-

$$\Delta \left[(P\text{-}0\text{-}0052) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)\right]$$

Fig.7-101:   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"

ℹ See also Parameter Description "P-0-0155, Synchronization mode"

Notes on Commissioning and Parameterization

General Parameterization   For general parameterization, it is necessary to make machine-specific pre-settings:

- 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

Operation Modes

See "Scaling of Physical Data"

- For linear scaling with rotary motor, parameterizing the feed constant per slave axis revolution (S-0-0123)

- Parameterizing the load gear of the slave axis (S-0-0121 and S-0-0122)

Parameterizing the Operation Mode

Sequence of parameterization specific to operation mode:

1. Depending on "P-0-0750, Master axis revolutions per master axis cycle" the range of values for the master axis can be between 0 and $2047 \times 2^{P-0-0084}$ 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 "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 adjustment
   - 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 operation mode (drive enabled, "AF"):

- A0110 Velocity synchronization, virtual master axis
- A0111 Velocity synchronization, real master axis
- A0164 Velocity synchronization

Error Messages and Warnings

Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operation mode:

- E2063 Velocity command value > limit value

There are also several status messages specific to operation mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word synchronization modes" and "P-0-0152, Synchronization completed").

7.8.3   Phase Synchronization with Real/Virtual Master Axis

Brief Description

💡 Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the operation mode "phase synchronization with real/virtual master axis", the drive follows a preset master axis position in an absolute or relative phase synchronous way.

The real master axis velocity is generated by a measuring encoder, 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 adjustment, 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:
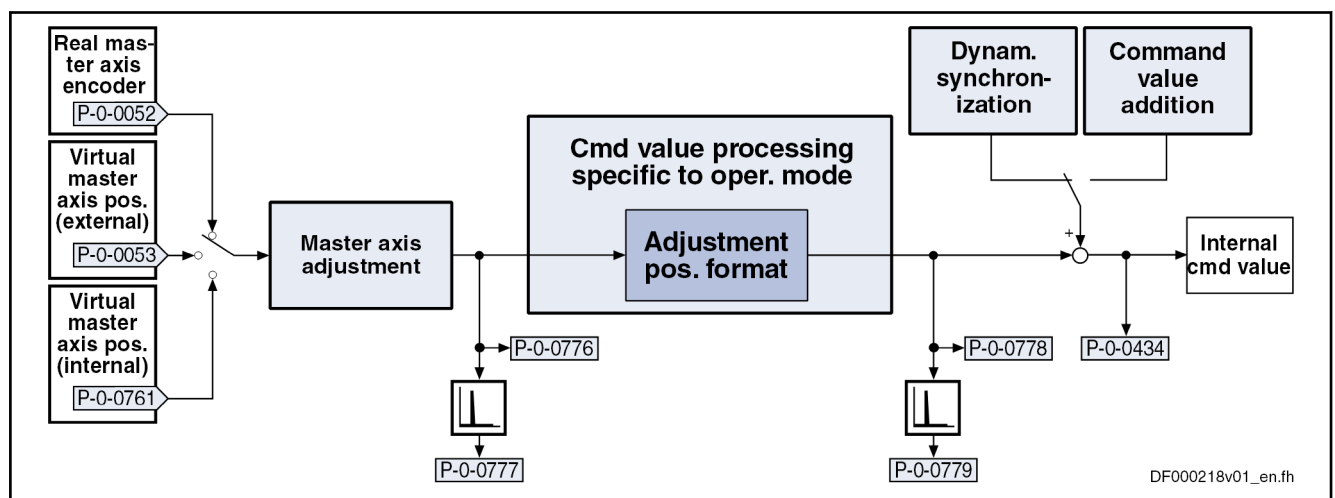
P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0434	Position command value of controller
P-0-0761	Master axis position for slave axis
P-0-0776	Effective master axis position
P-0-0777	Effective master axis velocity
P-0-0778	Synchronous position command value
P-0-0779	Synchronous velocity

Fig.7-102: Function Blocks of the Operation Mode "Phase Synchronization with Real/Virtual Master Axis"

Variants of the Operation Mode   There are the following variants of the operation 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 operation mode variant "position synchronization", select phase synchronization and the master axis in "P-0-0088, Control word synchronization modes". The encoder selection and lagless position control are set in "S-0-0520, Axis control word".

Operation Modes

Application "Absolute Phase Synchronization"	In machining processes that require absolute phase synchronization, e.g. printing, punching or perforating in printing machines, the absolute position reference to the master axis is established in the "phase synchronization" mode. The drive synchronizes with a position command value that is generated from master axis position and additive position command value.
Application "Relative Phase Synchronization"	For machining processes that only require relative phase synchronization, e.g. synchronization of belts or feed rollers without defined starting point, a relative position reference to the master axis is established. During the first synchronization, there is only an adjustment to the synchronous velocity but no position adjustment carried out.
Pertinent Parameters	In addition to the general parameters of all synchronization modes, there are other parameters involved in phase synchronization:

- S-0-0103, Modulo value
- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes
- P-0-0159, Slave drive feed travel
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity
- P-0-0778, Synchronous position command value
- P-0-0779, Synchronous velocity

See also "Pertinent Parameters" in the subsections of "Basic Functions of the Synchronization Modes"

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"

Overview of the Operation Mode
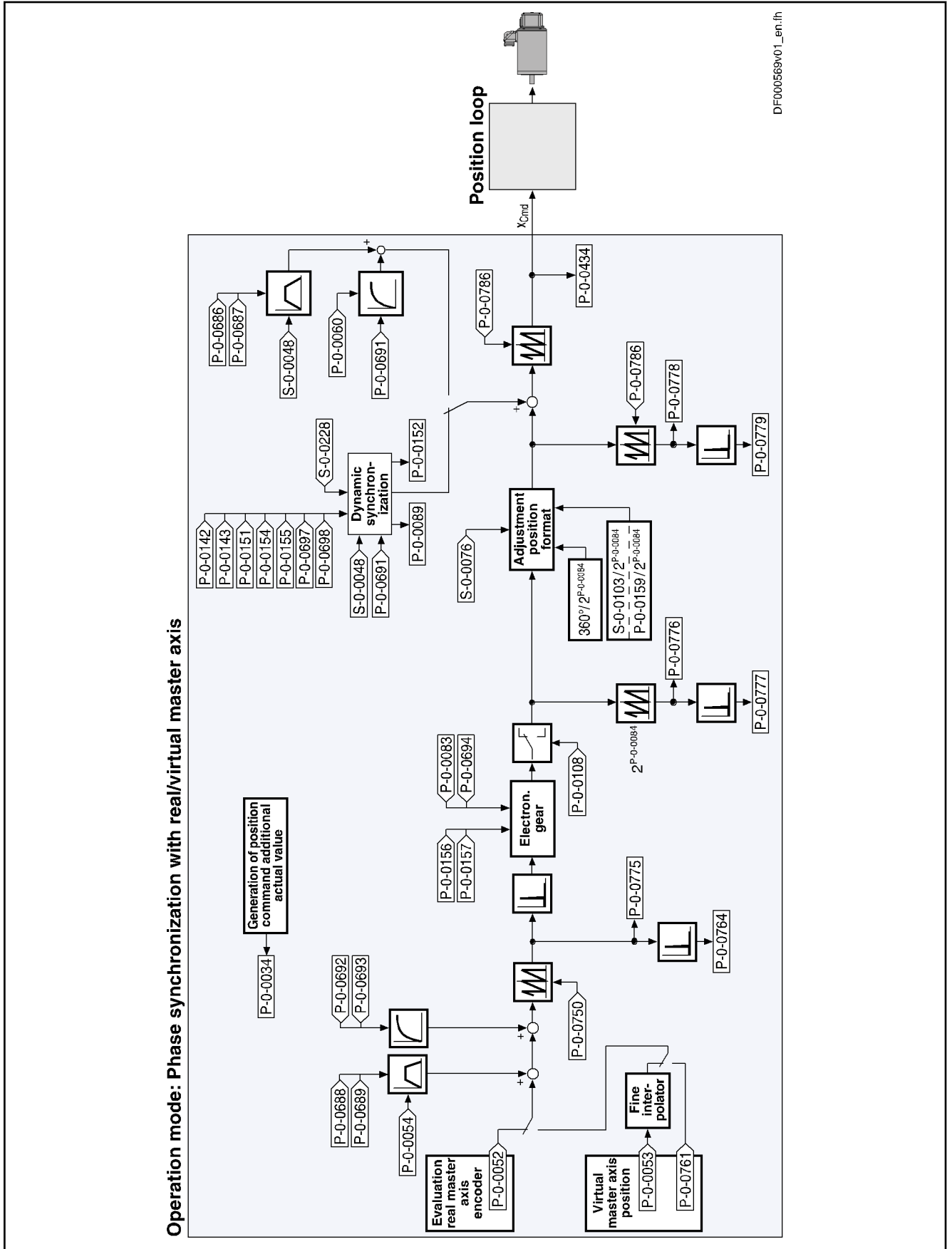
Fig.7-103:   Block Diagram: Phase Synchronization with Real/Virtual Master Axis

Operation Modes

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 adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "phase synchronization" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operation mode
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

☞   Only the function block "command value processing" specific to phase synchronization is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

See "Basic Functions of the Synchronization Modes"
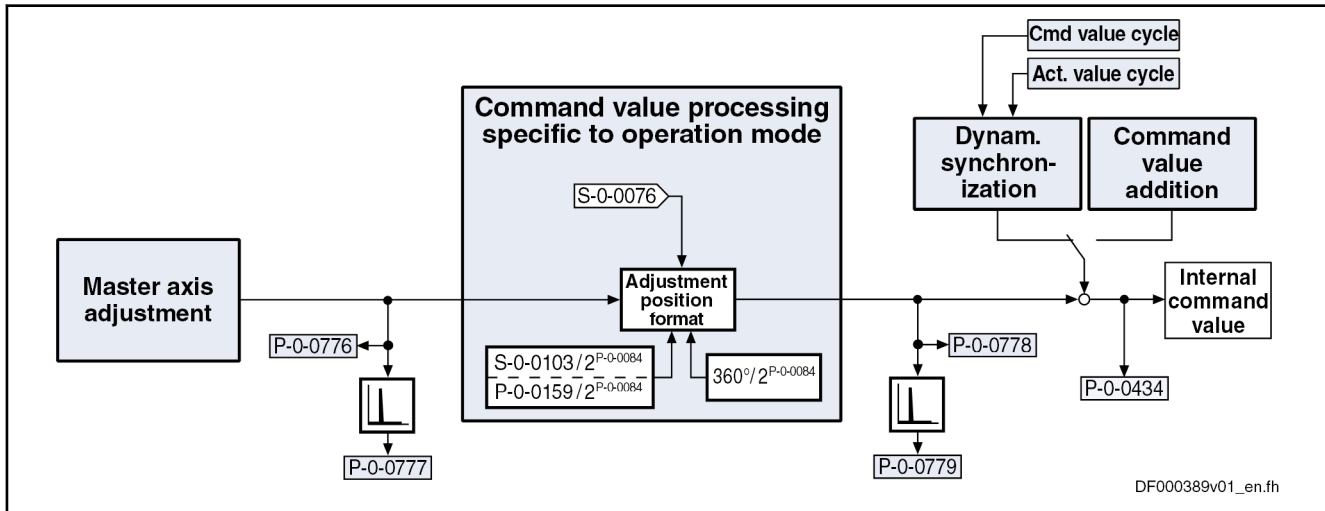
Fig.7-104:   *Command Value Processing Specific to Operation Mode for Phase Synchronization*

Generating the Internal Position Command Value

In the operation mode "phase synchronization with real/virtual master axis", the internal position command value (P-0-0434) is generated by addition of the synchronous position command value (x_{sync}) with the components of the additive position command value (S-0-0048) and the additive position command value of process 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:

$$x_{sync} = \left\langle P\text{-}0\text{-}0775 \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times \left[1 + (P\text{-}0\text{-}0083)\right] \times \left[1 + (P\text{-}0\text{-}0694)\right] \times \frac{S\text{-}0\text{-}0103}{2^{P\text{-}0\text{-}0084}} \right\rangle \% P\text{-}0\text{-}0786$$

Fig.7-107:   Generating the Synchronous Position Command Value with Modulo Scaling

$$x_{sync} = \left\langle P\text{-}0\text{-}0775 \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times \left[1 + (P\text{-}0\text{-}0083)\right] \times \left[1 + (P\text{-}0\text{-}0694)\right] \times \frac{360°}{2^{P\text{-}0\text{-}0084}} \right\rangle \% P\text{-}0\text{-}0786$$

Fig.7-108:   Generating the Synchronous Position Command Value with Rotary Absolute Scaling

$$x_{sync} = \left\langle P\text{-}0\text{-}0775 \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times \left[1 + (P\text{-}0\text{-}0083)\right] \times \left[1 + (P\text{-}0\text{-}0694)\right] \times \frac{P\text{-}0\text{-}0159}{2^{P\text{-}0\text{-}0084}} \right\rangle \% P\text{-}0\text{-}0786$$

Fig.7-109:   Generating the Synchronous Position Command Value with Linear Absolute Scaling

☞   One master axis revolution is standardized to 2^N increments (with N = value from "P-0-0084, Number of bits per master axis revolution"). This means that the LSB of the master axis position corresponds to 2^{-N} master axis revolutions.

Synchronization

See "Basic Functions of the Synchronization Modes"

Notes on Commissioning and Parameterization

General Parameterization

For general parameterization, it is necessary to make machine-specific presettings:

Scaling of Data   • Scaling of parameter data (linear or rotary)

Operation Modes

> – 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 "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 "P-0-0750, Master axis revolutions per master axis cycle" the range of values for the master axis can be between 0 and $2047 \times 2^{P\text{-}0\text{-}0084}$ increments. In the special case P-0-0750 = 0, the master axis range is from $-(2^{31})$ to (2^{31})-1. This case is utilized 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 "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 adjustment

    - P-0-0694, Gear ratio fine adjustment, process loop

    - P-0-0108, Master drive polarity

    - P-0-0156, Master drive gear input revolutions

    - P-0-0157, Master drive gear output revolutions

6. "Modulo" Synchronization

    The following settings have to be made for synchronization:

    - Mode for reaction to changes in 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)

Operation Modes

- 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 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 "P-0-0750, Master axis revolutions per master axis cycle" the range of values for the master axis can be between 0 and $2047 \times 2^{P-0-0084}$ increments. In the special case P-0-0750 = 0, the master axis range is from $-(2^{31})$ to $(2^{31})-1$. This case is utilized 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 "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 Switches")!

4. Slave Drive Feed Travel

   The distance that the slave axis covers per master axis revolution is determined in "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 adjustment
   - P-0-0694, Gear ratio fine adjustment, process loop
   - P-0-0108, Master drive polarity
   - P-0-0156, Master drive gear input revolutions
   - P-0-0157, Master drive gear output revolutions

6. "Absolute" Synchronization

   The following settings have to be made for synchronization:
   - Mode for reaction to changes in 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)

Operation Modes

Commissioning Summary

The figure below illustrates the basic sequence of commissioning.
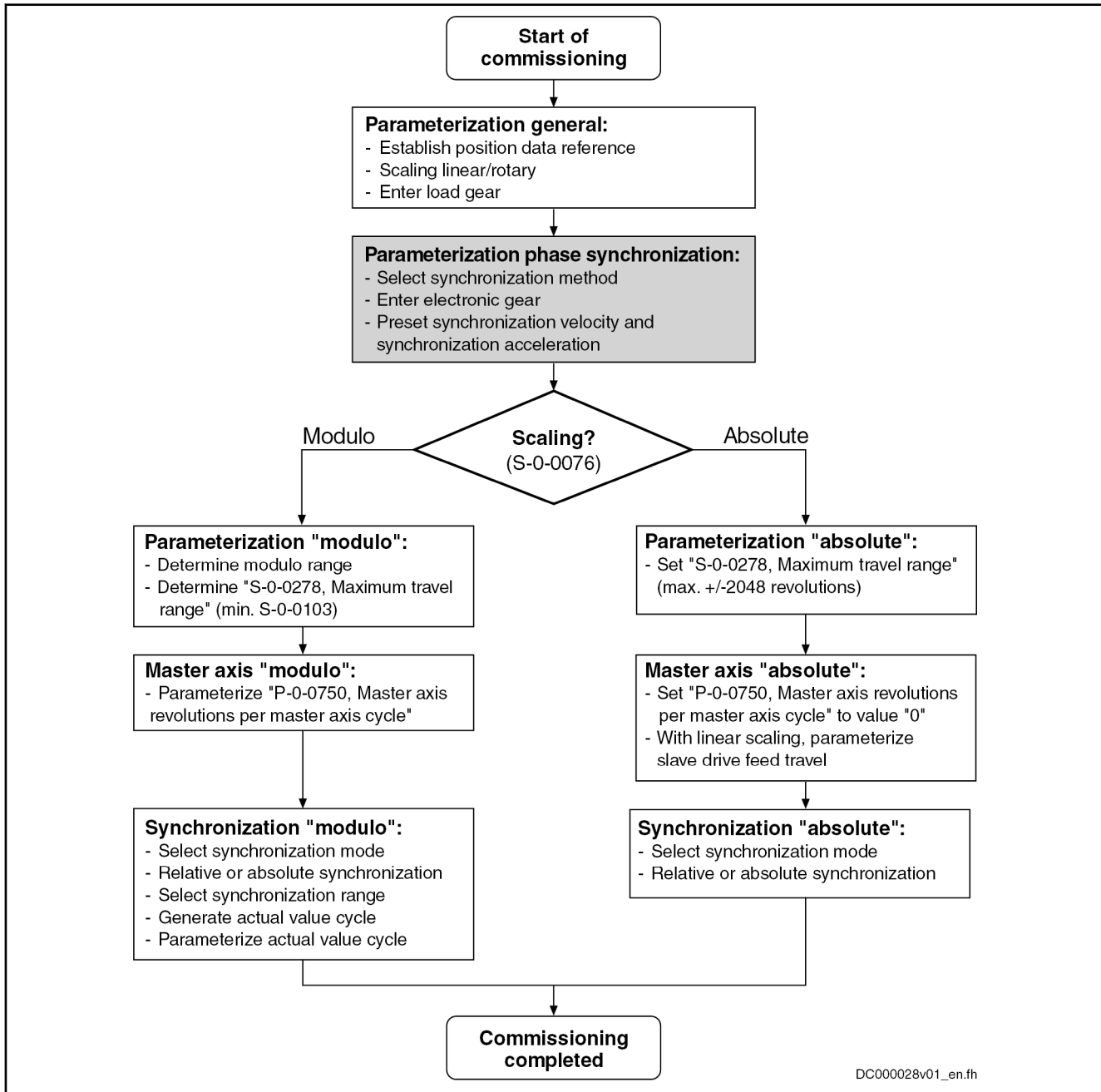
Fig.7-110:   Overview of Commissioning Steps for Phase Synchronization

Diagnostic and Status Messages

Diagnostic Status Messages   The following diagnostic status messages are displayed in normal operation of the operation mode (drive enabled, "AF"):

- A0112 Phase synchronization, encoder 1, virtual master axis
- A0113 Phase synchronization, encoder 2, virtual master axis
- A0114 Phase synchronization, encoder 1, real master axis
- A0115 Phase synchronization, encoder 2, real master axis

Operation Modes

- A0116 Phase synchr. lagless, encoder 1, virtual master axis
- A0117 Phase synchr. lagless, encoder 2, virtual master axis
- A0118 Phase synchr. lagless, encoder 1, real master axis
- A0119 Phase synchr. lagless, encoder 2, real master axis
- A0163 Position synchronization

Error Messages and Warnings   Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operation mode:

- 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 operation mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word for synchronous operation 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 "S-0-0521, Axis status word".

7.8.4   Electronic Cam With Real/Virtual Master Axis

Brief Description

💡 Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the operation mode "electronic cam with real/virtual master axis", there is a fixed relationship between the master axis position and the slave axis.

The real master axis velocity is generated by a measuring encoder, 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 tables with a max. of 1024 data points (P-0-0072, P-0-0092, P-0-0780, P-0-0781)
- 4 cam tables with a max. of 128 data points (P-0-0783, P-0-0784, P-0-0785, P-0-0786)
- Cubic spline interpolation of the cam data points
- Dynamic angle offset and angle offset at begin of table
- Freely definable switch angle for cam and cam 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"

Operation Modes

- Cross cutter function
- Clocked Pull Roll

The figure below illustrates the interaction of the individual subfunctions (function blocks) of the "electronic cam" mode:
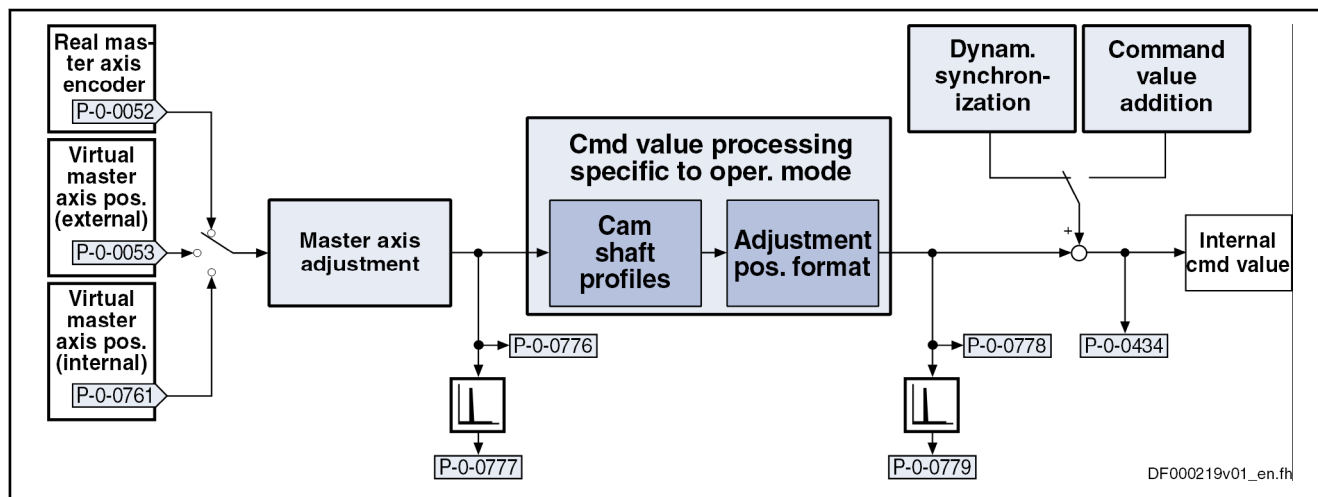
P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0434	Position command value of controller
P-0-0761	Master axis position for slave axis
P-0-0776	Effective master axis position
P-0-0777	Effective master axis velocity
P-0-0778	Synchronous position command value
P-0-0779	Synchronous velocity

Fig.7-111:   Function Blocks of the "Electronic Cam" Mode

Variants of the Operation Mode   There are the following variants of the operation mode to be selected:

- Position synchronization
- Cam with real master axis, encoder 1
- Cam with real master axis, encoder 2
- Cam with real master axis, encoder 1, lagless
- Cam with real master axis, encoder 2, lagless
- Cam with virtual master axis, encoder 1
- Cam with virtual master axis, encoder 2
- Cam with virtual master axis, encoder 1, lagless
- Cam with virtual master axis, encoder 2, lagless

☞   In the operation mode variant "position synchronization", select electronic cam shaft and the master axis in "P-0-0088, Control word synchronization modes". The encoder selection and lagless position control are set in "S-0-0520, Axis control word".

Pertinent Parameters   In addition to the general parameters of all synchronization modes, there are other parameters involved in this operation mode:

- S-0-0103, Modulo value
- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0061, Angle offset begin of table

Operation Modes

- P-0-0072, Cam table 1
- P-0-0073, Cam distance 2
- P-0-0085, Dynamic angle offset
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes
- P-0-0092, Cam table 2
- P-0-0093, Cam distance
- P-0-0094, Cam switch angle
- P-0-0144, Cam distance switch angle
- P-0-0158, Angle offset change rate
- P-0-0159, Slave drive feed travel
- P-0-0227, Cam table, access angle
- P-0-0695, Angle offset begin of 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 table 3
- P-0-0781, Cam table 4
- P-0-0782, Cam table 5
- P-0-0783, Cam table 6
- P-0-0784, Cam table 7
- P-0-0785, Cam table 8

See also "Pertinent Parameters" in the subsections of "Basic Functions of the Synchronization Modes"

Pertinent Diagnostic Messages   In addition to the general diagnostic messages of all synchronization modes, there are other diagnostic messages involved in this operation mode:

- A0128 cam shaft, Cam, encoder 1, virtual master axis
- A0129 Cam, encoder 2, virtual master axis
- A0130 Cam, encoder 1, real master axis
- A0131 Cam, encoder 2, real master axis
- A0132 Cam, lagless, encoder 1, virt. master axis
- A0133 Cam, lagless, encoder 2, virt. master axis
- A0134 Cam, lagless, encoder 1, real master axis
- A0135 Cam, lagless, encoder 2, real master axis
- A0163 Position synchronization
- F2005 Cam table invalid

See also "Pertinent Diagnostic Messages" in the subsections of "Basic Functions of the Synchronization Modes"

Operation Modes

Overview of the Operation Mode
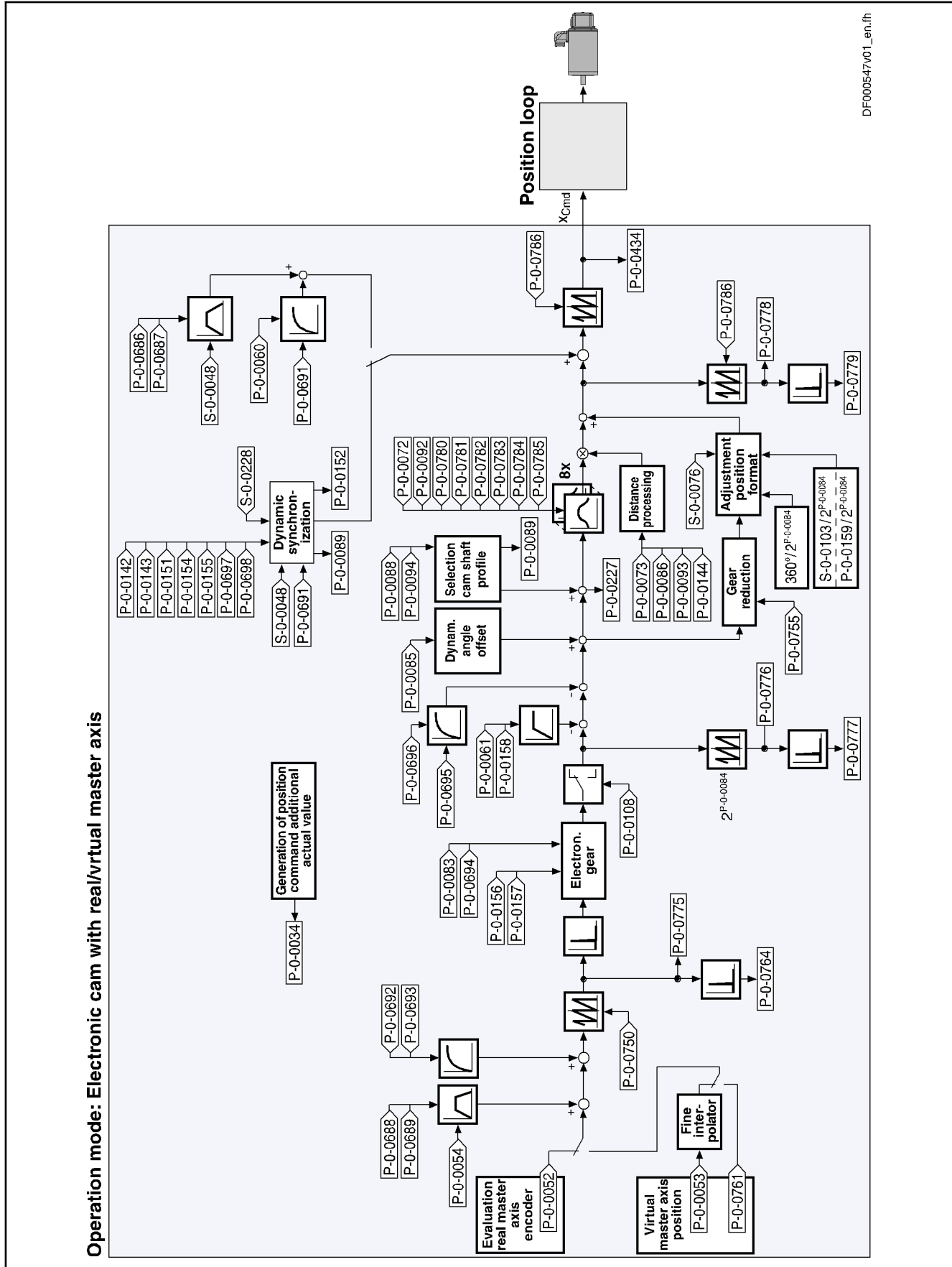
Fig.7-112:   Block Diagram: Electronic Cam with Real/Virtual Master Axis

Operation Modes

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 adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "electronic cam" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operation mode, consisting of
  - Cam tables (incl. access)
  - Adjustment of position format
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

☞ Only the function block "command value processing" specific to the cam 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"
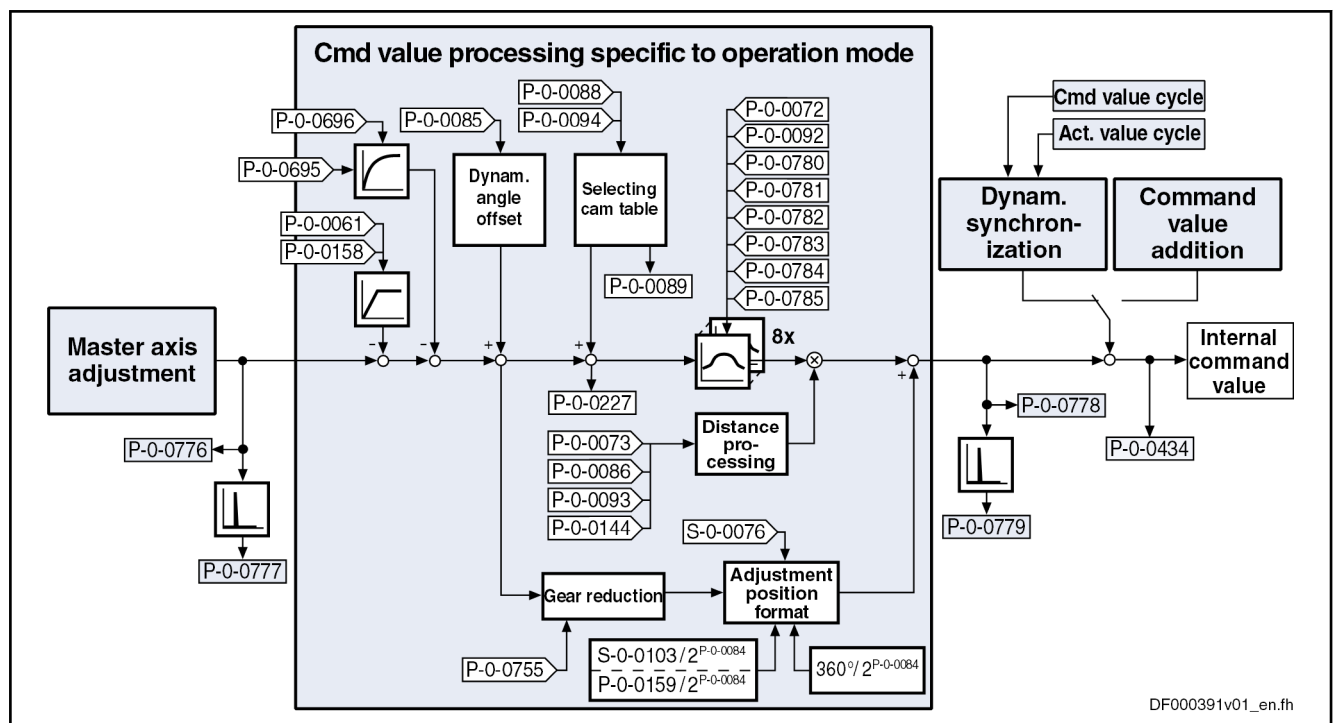
Fig.7-113:   Command Value Processing Specific to Operation Mode for Cam Mode

Generating the Internal Position Command Value

In the operation mode "electronic cam with real/virtual master axis", the internal position command value (P-0-0434) is generated by addition of the syn-

Operation Modes

chronous 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.7-114:   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.7-115:   Generating the Internal Position Command Value in the Synchronized Status

In the function block "command value processing specific to operation mode" the calculations specific to the cam mode are carried out for generating the synchronous position command value.

Depending on "P-0-0061, Angle offset begin of table" and "P-0-0695, Angle offset begin of profile, process loop" , an interpolated table value is taken from the cam tables in every control cycle and the difference to the last interpolated table value is multiplied by the cam 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 operation 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 table limit is exceeded in positive direction, the table continues with its first value, the same happens if the limit is exceeded in negative direction.

Calculating the Internal Position Command Value (Initialization)   Upon activation of the operation mode "electronic cam with real/virtual master axis", the position command value of the drive is first initialized in terms of the following relation:

$$x_{F(\varphi L)} = \left[h \times tab(\varphi_{ZGW}) + \frac{\varphi_{ZGW}}{U} + x_V + x_{VPR} \right] \% IWZ$$

x_F	Position command value of slave drive (P-0-0434)
φL	Resulting master axis position (P-0-0775)
h	Cam distance (P-0-0093 or P-0-0073)
$tab(\varphi)$	Cam tables (P-0-0072, P-0-0092, P-0-0780, P-0-0781)
φ_{ZGW}	Table 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.7-116:   *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}	Table access angle
+/-	Master drive polarity (P-0-0108)
φ_L	Resulting master axis position (P-0-0775)
G_a	Master drive gear output revolutions (P-0-0157)
G_e	Master drive gear input revolutions (P-0-0156)
F	Gear ratio fine adjustment (P-0-0083)
F_{PR}	Gear ratio fine adjustment, process loop (P-0-0694)
φ_V	Angle offset begin of table (P-0-0061)
φ_{VPR}	Angle offset begin of table, process loop (P-0-0695)

Fig.7-117:   *Determining the Table Access Angle*

NOTICE   With the operation mode activated, differences, that later on will be added again, are processed in the electronic gear and the cam tables. Therefore, changes in the electronic gear and the cam distance do not cause position command value jumps. Velocity jumps, however, can occur and the absolute position reference, established when activating the operation mode, is lost.

Accessing the Cam Table   In every position loop cycle (Advanced: T = 250 µs, Basic: T = 500 µs), an interpolated table value is taken from the activated cam table, the difference to the last interpolated table value is generated and a multiplication with the cam distance is carried out. The result is added to the position command value.

Cubic spline interpolation takes place between the table values.

☞   With an infinite cam, the difference between initial value and final value of the cam table is 100%.

Calculating the Internal Position Command Value (in Cyclic Operation)   The position command value is generated as per the following relation:

Operation Modes

$$x_{F(n)(\varphi L)} = \left\langle x_{F(n-1)(\varphi L)} + \left[h \times \Delta tab(\pm \varphi_L) \times \frac{G_a}{G_e} - \varphi_V + \varphi_d \right] \pm \Delta \varphi_L \times \left[\frac{G_a}{G_e} \times (1 + F) - \frac{\varphi_V}{U} + x_V \right] \right\rangle \% IWZ$$

x_F	Position command value of slave drive (P-0-0434)
φ_L	Resulting master axis position (P-0-0775)
h	Cam distance (P-0-0093 or P-0-0073)
$tab(\varphi)$	Cam tables (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 table (P-0-0061+ P-0-0695)
φ_d	Dynamic angle offset (P-0-0085)
F	Fine adjustment (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.7-118:   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 pre-settings:

Scaling of Data
- Scaling of parameter data (linear or rotary)
    - S-0-0076, S-0-0077, S-0-0078 and S-0-0079 for position data
    - S-0-0044, S-0-0045 and S-0-0046 for velocity data
    - S-0-0160, S-0-0161 and S-0-0162 for acceleration data

  See "Scaling of Physical Data"

- For linear scaling with rotary motor, parameterizing the feed constant per slave axis revolution (S-0-0123)

- Parameterizing the load gear of the slave axis (S-0-0121 and S-0-0122); if available

- Determining the synchronization velocity (P-0-0143) and the synchronization acceleration (P-0-0142)

Selecting and Acknowledging the Active Cam

Select and acknowledge the active cam table:
- The active cam table (P-0-0072, P-0-0092, P-0-0780 to P-0-0785) is selected with parameters"P-0-0088, Control word synchronization modes" and "P-0-0094, Cam switch angle".

- The active cam is included in "P-0-0089, Status word synchronization modes". Switching of the cam is started by changing the control word. It is carried out by the drive and acknowledged in the status word, when the master axis position exceeds the angle set in "P-0-0094, Cam switch angle".

Operation Modes

☞ For constantly fault-free processing of the position data with infinitely turning axes, the values resulting from gear reduction (P-0-0086, bit 4 = 1) must be used for forward motion. A finite cam table can be superimposed. When using an infinite cam table (difference between first and last table value > 50%), a small error can occur with each table sequence. Exception: Cam distance corresponds to modulo value (S-0-0103).

☞ When cams are used with a difference between the table values of two cam elements > 50%, the "linear cam interpolation" must be activated (P-0-0086, bit 7 = 1). An exception is a difference of > 50% between the first and the last table value of one cam.

Parameterizing the Cam Distance

Parameterize the cam distance:

- "P-0-0144, Cam distance switch angle" defines at which table access angle and thus table element a change in value becomes effective for "P-0-0093, Cam distance". If the table values in the switch range = 0, an absolute position reference is maintained in the case of a change.

- In "P-0-0086, Configuration word synchronous operation modes", select with bits 0 and 1 whether new values for cam distance (P-0-0093) and for the electronic gear (P-0-0156/P-0-0157) take effect immediately or only when the cam distance switch angle is passed or when the cam table is switched.

  In bit 3, you can determine which reference is to be valid for delayed acceptance of changes (cam distance switch angle or cam table switching).

ℹ See also Parameter Description "P-0-0086, Configuration word synchronous operation modes"

Parameterizing Angle Offset

To avoid great position jumps when changing the table access angle, a new value for "P-0-0061, Angle offset begin of table" does not immediately become effective. Starting with the current value, a ramp-like approximation to the new value is carried out. The approximation is carried out over the shortest possible distance. The gradient of the ramp is set in "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 "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 "P-0-0696, Filter time constant, angle offset profile, process loop".

Dynamic Angle Offset

"P-0-0085, Dynamic angle offset" can be used for compensating a lag error in operation with lag distance, if the mechanical system does not allow lagless operation.

With dynamic angle offset, the table access angle is offset depending on the velocity so that the internal master axis position can be calculated according to the formula below:

Operation Modes

$$\varphi_{\text{effective internal master axis pos.}} = \varphi_{\text{internal master axis pos.}} + \frac{v_{\text{internal master axis velocity}}}{\text{Kv-factor}} \times \text{dynam. angle offset}$$

Internal   After electronic gear (P-0-0156/P-0-0157) and fine adjustment (P-0-0083)

Fig.7-119:   *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 $T_A = N \times T_{\text{position}}$.

Clocked Pull Roll   For the special case "clocked pull roll", it is possible, with bit 2 = 1 of parameter "P-0-0086, Configuration word synchronous operation modes", to change between "P-0-0093, Cam distance" and "P-0-0073, Cam distance 2", depending on the gradient of the cam.

Positive gradient means that "P-0-0093, Cam distance" is active, negative gradient means that "P-0-0073, Cam distance 2" is active.

Cross Cutter Function   By means of the command values of "P-0-0755, Gear reduction", a cross cutter axis can be operated. A cross cutter (rotating knife) is used to cut a defined piece (format) off some material that is transported at constant velocity. The format is set by the electronic 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 to the constant speed of the axis that is caused by the linear component of the gear reduction. With constant cam table, it is then possible to define, by means of the 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 "P-0-0755, Gear reduction". Per cam table sequence, the cutting cylinder will move by the distance of two knives at the circumference.

- To change the format "on the fly", it is necessary to simultaneously change electronic gear and cam distance in the cutting range. This function is switched on by setting bit 1 in "P-0-0086, Configuration word synchronous operation modes". A change in the electronic gear will only take effect, when the new value, after having changed the cam distance, is accepted when passing the angle of "P-0-0144, Cam distance switch angle".

"Modulo" Parameterization

For "modulo" parameterization, make the following settings:

1. Modulo Range

   In "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 "P-0-0750, Master axis revolutions per master axis cycle" the range of values for the master axis can be between 0 and $2047 \times 2^{P-0-0084}$ increments. In the special case P-0-0750 = 0, the master axis range is from $-(2^{31})$ to $(2^{31})-1$.

4. "Modulo" Master Axis

    The "modulo" master axis is a master axis the master axis positions of which are within the master axis cycle determined by "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 adjustment
    - P-0-0694, Gear ratio fine adjustment, process loop
    - P-0-0108, Master drive polarity
    - P-0-0156, Master drive gear input revolutions
    - P-0-0157, Master drive gear output revolutions

6. "Modulo" Synchronization

    The following settings have to be made for synchronization:

    - Mode for reaction to changes in 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 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 "P-0-0750, Master axis revolutions per master axis cycle" the range of values for the master axis can be between 0 and $2047 \times 2^{P-0-0084}$ increments. In the special case P-0-0750 = 0, the master axis range is from $-(2^{31})$ to $(2^{31})-1$.

3. "Absolute" or "Modulo" Master Axis

    The "absolute" master axis is a master axis the master axis positions of which are within the master axis cycle determined by "P-0-0750, Master axis revolutions per master axis cycle". The master axis positions in this case do neither overflow nor underflow.

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This possibility is not used for practical application. Theoretically, the absolute master axis could be used for infinite cams (e.g., linear cams) and/or when a gear reduction (P-0-0755) unequal zero is selected.

NOTICE	When a gear reduction (bit 4, P-0-0086 = 1) has been parameterized, the modulo overflow of the master axis mustn't take place with absolute position scaling! Otherwise, this would cause unwanted jumps in position.

The "modulo" master axis is a master axis the master axis positions of which are within the master axis cycle determined by "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.

NOTICE	Incorrect parameterization can cause unwanted jumps in position.

It is recommended that you activate the position limit value monitor (see "Position Limitation/Travel Range Limit Switches")!

4. Slave Drive Feed Travel

    The distance that the slave axis covers per master axis revolution is determined in "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 adjustment
    -   P-0-0694, Gear ratio fine adjustment, process loop
    -   P-0-0108, Master drive polarity
    -   P-0-0156, Master drive gear input revolutions
    -   P-0-0157, Master drive gear output revolutions

6. "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.
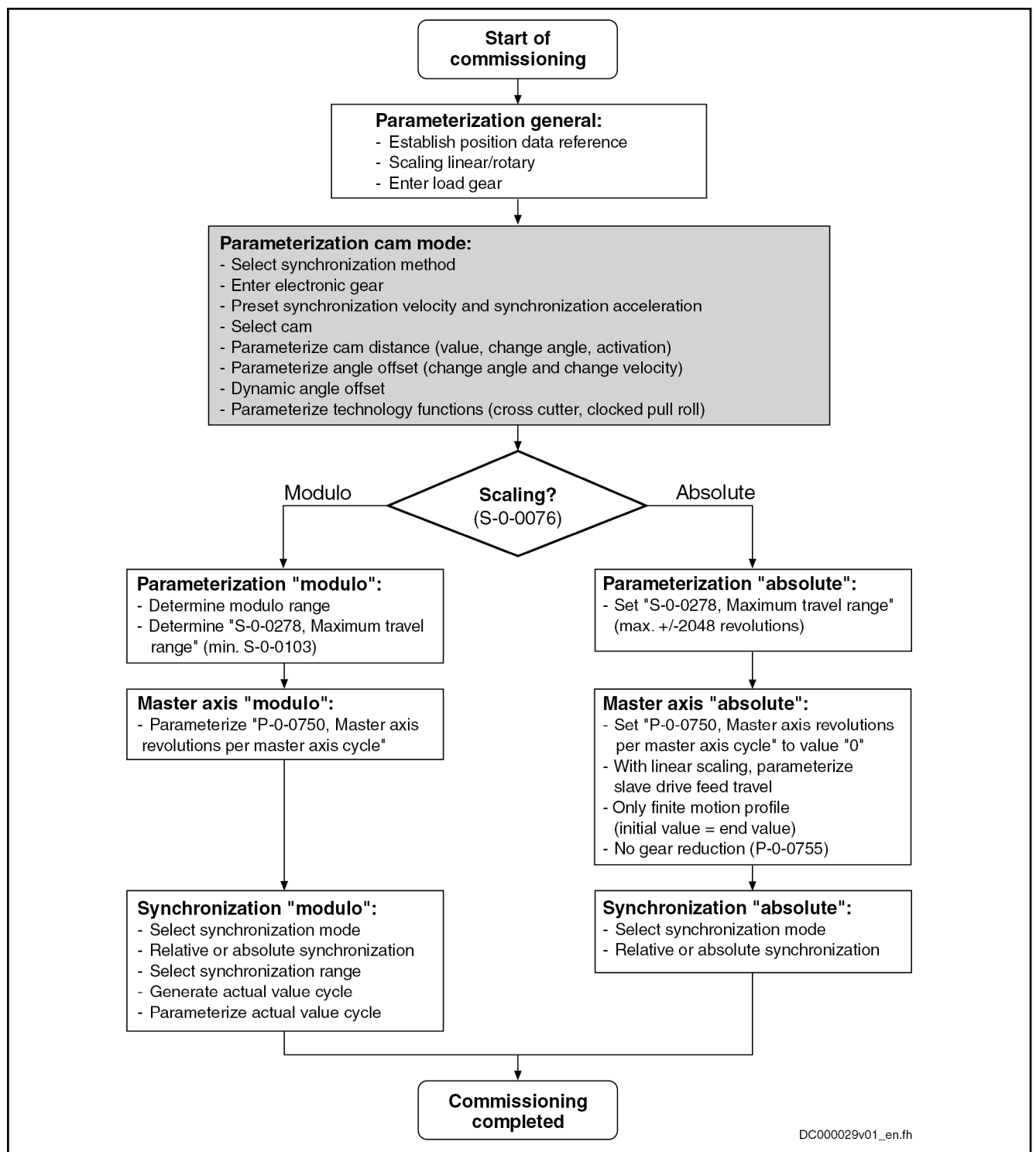
Operation Modes

Fig.7-120:   Overview of Commissioning Steps for Cam Mode

Diagnostic and Status Messages

Diagnostic Status Messages   The following diagnostic status messages are displayed in normal operation of the operation mode (drive enabled, "AF"):

- A0128 Cam, encoder 1, virtual master axis
- A0129 Cam, encoder 2, virtual master axis

Operation Modes

- A0130 Cam, encoder 1, real master axis
- A0131 Cam, encoder 2, real master axis
- A0132 Cam, lagless, encoder 1, virt. master axis
- A0133 Cam, lagless, encoder 2, virt. master axis
- A0134 Cam, lagless, encoder 1, real master axis
- A0135 Cam, lagless, encoder 2, real master axis
- A0163 Position synchronization

Error Messages and Warnings Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operation mode:

- F2005 Cam table invalid

  → This message is generated when, with the drive having been enabled, a cam table (P-0-0072, P-0-0092, P-0-0780, P-0-0781) is accessed that has not been written with 8, 16, 32, 64, 128, 512 or 1024 valid values.

Status Bits There are also several status messages specific to operation mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word synchronization modes").

Position Loop Status The status display via the control encoder for lagless operation or operation with lag error takes place in "S-0-0521, Axis status word".

7.8.5   MotionProfile with Real/Virtual Master Axis

Brief Description

💡 Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the operation mode "MotionProfile with real/virtual master axis", there is a fixed relationship between the master axis position and the slave axis.

The real master axis velocity is generated by a measuring encoder, 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 table
- Motion laws can be selected (rest in rest, rest in velocity, velocity in rest, velocity in velocity, constant velocity)
- Motion laws realized by 5th order polynomial or, in the case of rest in rest, alternatively by inclined sine curve
- Individual distance for each motion step
- Dynamic angle offset and angle offset at begin of table
- Absolute synchronization can be switched off
- Synchronization mode to be selected
- Absolute or relative processing of the motion steps to be selected
- Synchronization range to be selected
- Cross cutter function

The figure below illustrates the interaction of the individual subfunctions (function blocks) of the "MotionProfile" mode:
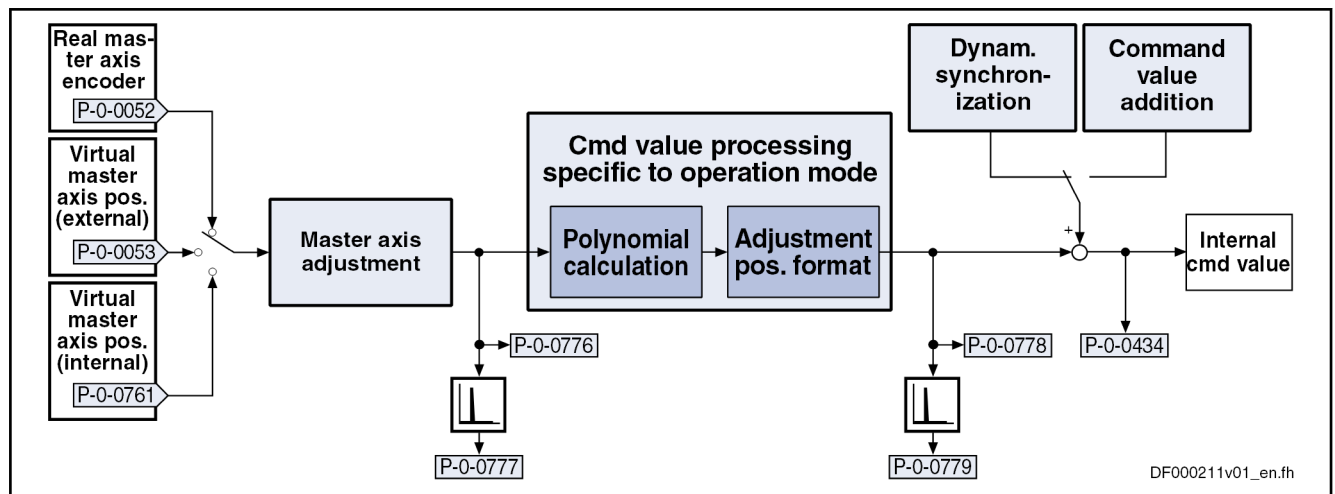
P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0434	Position command value of controller
P-0-0761	Master axis position for slave axis
P-0-0776	Effective master axis position
P-0-0777	Effective master axis velocity
P-0-0778	Synchronous position command value
P-0-0779	Synchronous velocity

Fig.7-121:   *Function Blocks of the "MotionProfile" Mode*

Variants of the Operation Mode   There are the following variants of the operation mode to be selected:

- Position synchronization
- Motion Profile with real master axis, encoder 1
- Motion Profile with real master axis, encoder 2
- MotionProfile with real master axis, encoder 1, lagless
- MotionProfile with real master axis, encoder 2, lagless
- MotionProfile with virtual master axis, encoder 1
- MotionProfile with virtual master axis, encoder 2
- MotionProfile with virtual master axis, encoder 1, lagless
- MotionProfile with virtual master axis, encoder 2, lagless

☞   In the operation mode variant "position synchronization", select the MotionProfile and the master axis in "P-0-0088, Control word synchronization modes". The encoder selection and lagless position control are set in "S-0-0520, Axis control word".

Pertinent Parameters   In addition to the general parameters of all synchronization modes, there are other parameters involved in this operation mode:

- S-0-0103, Modulo value
- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0061, Angle offset begin of table
- P-0-0085, Dynamic angle offset
- P-0-0086, Configuration word synchronous operation modes

Operation Modes

- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes
- P-0-0158, Angle offset change rate
- P-0-0159, Slave drive feed travel
- P-0-0227, Cam table, access angle
- P-0-0695, Angle offset begin of profile, process loop
- P-0-0696, Filter time constant, angle offset profile, process loop
- P-0-0700, MotionProfile, master axis switching position
- P-0-0701, Motion step 1, slave axis initial position
- P-0-0702, MotionProfile, diagnosis, set 0
- P-0-0703, 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 laws, set 0
- P-0-0707, List of distances, set 0
- P-0-0708, List of slave axis velocities, set 0
- P-0-0709, MotionProfile, diagnosis, set 1
- P-0-0710, 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 laws, set 1
- P-0-0714, List of distances, set 1
- P-0-0715, List of slave axis velocities, set 1
- P-0-0755, Gear reduction
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity
- P-0-0778, Synchronous position command value
- P-0-0779, Synchronous velocity

See also "Pertinent Parameters" in the subsections of "Basic Functions of the Synchronization Modes"

Pertinent Diagnostic Messages   In addition to the general diagnostic messages of all synchronization modes, there are other diagnostic messages involved in this operation mode:

- A0136 MotionProfile, encoder 1, virtual master axis
- A0137 MotionProfile, encoder 2, virtual master axis
- A0138 MotionProfile, encoder 2, real master axis
- A0139 MotionProfile, encoder 1, real master axis
- A0140 MotionProfile lagless, encoder 1, virtual master axis
- A0141 MotionProfile lagless, encoder 2, virtual master axis
- A0142 MotionProfile lagless, encoder 1, real master axis
- A0143 MotionProfile lagless, encoder 2, real master axis
- A0163 Position synchronization
- F2003 Motion step skipped
- F2004 Error in MotionProfile

See also "Pertinent Diagnostic Messages" in the subsections of "Basic Functions of the Synchronization Modes"

Operation Modes

Overview of the Operation Mode
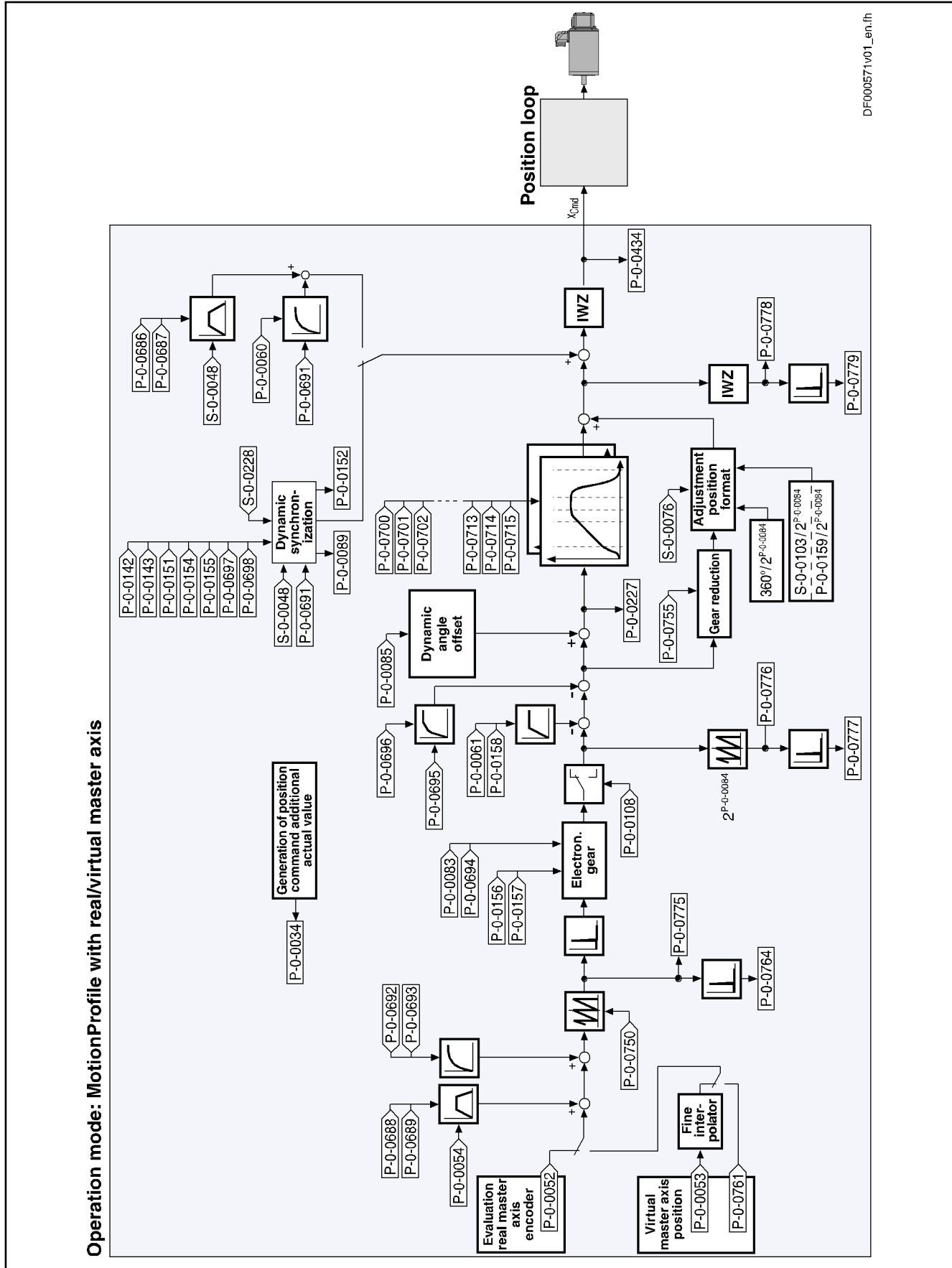
Fig.7-122:   Block Diagram: MotionProfile with Real/Virtual Master Axis

Operation Modes

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 adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "MotionProfile" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operation mode, consisting of
  - Cam tables (incl. access)
  - Adjustment of position format
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

☞ In the following only the function block "command value processing" specific to operation mode for the MotionProfile will be described in detail. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

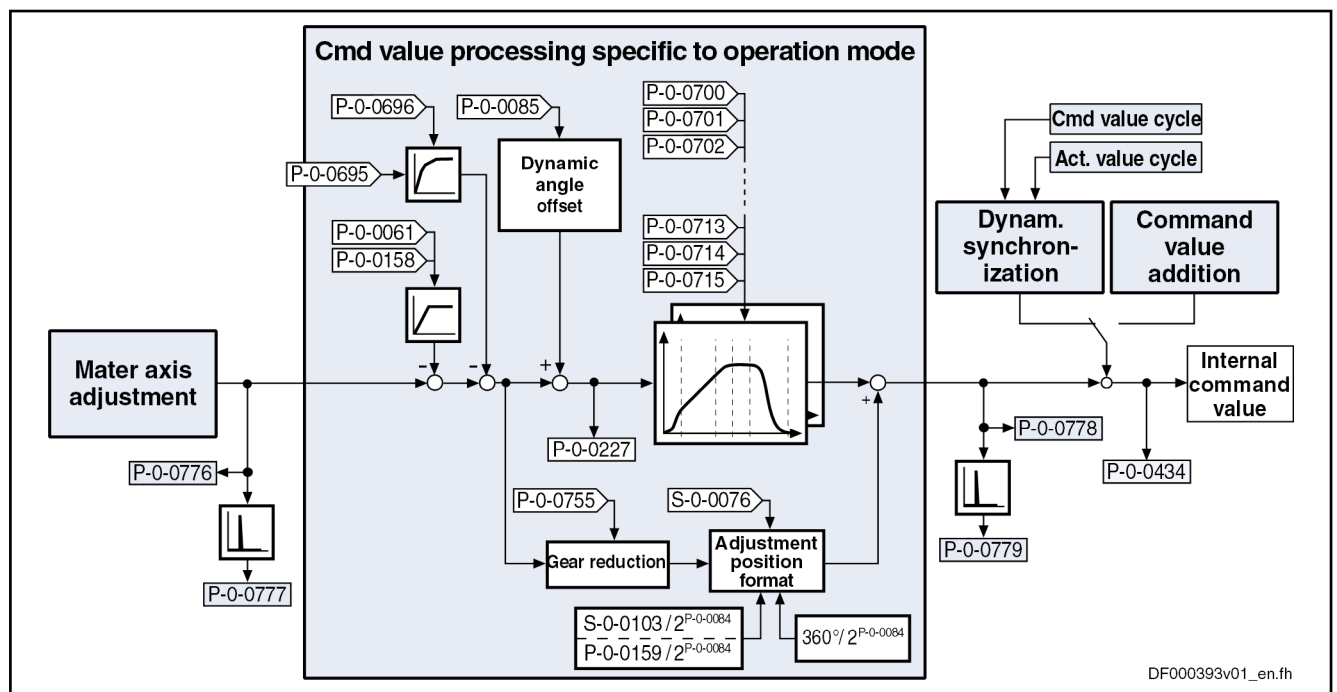See "Basic Functions of the Synchronization Modes"

Fig.7-123:   Command Value Processing Specific to Operation Mode with Motion-Profile

Generating the Internal Position Command Value

In the operation mode "MotionProfile with real/virtual master axis", the internal position command value (P-0-0434) is generated by addition of the syn-

Operation Modes

chronous 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.7-124:   Generating the Internal Position Command Value

Note: In the synchronized state (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.7-125:   Generating the Internal Position Command Value in the Synchronized State

In the function block "command value processing specific to operation mode", the calculations specific to the MotionProfile are carried out for generating the synchronous position command value.

"P-0-0227, Cam table, access angle" is generated first. The current motion step is determined from this value and the master axis initial positions of the individual motion steps. Depending on the motion law of this motion step, the decision is taken as to whether the current step is determined by a cam table or a standard table. With the table access angle, table access or a polynomial calculation takes place accordingly to calculate the standardization value (factor) for the distance of this step. The standardization value for a cam table is between +799,999999 % and -799,999999 %, for a standard table it is between 0 and 1. The multiplication of standardization value and distance of the current step results in a position command value which is added to the final position value of the previous motion step. Depending on the setting in the motion law of this step, the sum is processed in absolute or relative form.

If the phase-synchronous path has been activated by bit 4 of "P-0-0086, Configuration word synchronous operation 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 operation mode "MotionProfile with real/virtual master axis", the position command value of the drive is first initialized in terms of the following relation:

$$x_{F(\varphi L)} = \left[x_{start\_n} + H_n \times f_n(\varphi_{ZGW}) + \left(\frac{\varphi_{ZGW}}{U}\right) \times \left(\frac{MW}{2^{20}}\right) + x_V + x_{VPR} \right] \% IWZ$$

x_F	Position command value of slave drive (P-0-0434)
x_{start_n}	Slave axis initial position of the current motion step
H_n	Distance of the current motion step
$f_{n\ (\varphi ZGW)}$	Standardized function value of the current motion step from table access or polynomial calculation
φ_{ZGW}	Table access angle
U	Gear reduction (P-0-0755)
MW	Modulo value
x_V	Additive position command value (S-0-0048)
x_{VPR}	Additive position command value, process loop (P-0-0691)
IWZ	Modulo actual value cycle

Fig.7-126:   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}	Table access angle
+/-	Master drive polarity (P-0-0108)
φ_L	Resulting master axis position (P-0-0775)
G_a	Master drive gear output revolutions (P-0-0157)
G_e	Master drive gear input revolutions (P-0-0156)
F	Gear ratio fine adjustment (P-0-0083)
F_{PR}	Gear ratio fine adjustment, process loop (P-0-0694)
φ_V	Angle offset begin of table (P-0-0061)
φ_{VPR}	Angle offset begin of table, process loop (P-0-0695)

Fig.7-127:   Determining the Table Access Angle

The slave axis initial position of the current motion step is supposed to be zero, when relative processing of the position data (bit 10 = 1) has been set in the control word for 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.

NOTICE	With the operation 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 operation mode, is lost.

Synchronization

See "Basic Functions of the Synchronization Modes"

Operation Modes

Notes on Commissioning and Parameterization

General Parameterization

Parameterizing Angle Offset

"P-0-0061, Angle offset begin of table" allows shifting the table access angle. To avoid great position jumps when changing the table access angle, a new value for 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 "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

"P-0-0085, Dynamic angle offset" can be used for compensating a lag error in operation with lag distance, if the mechanical system does not allow lagless operation.

With dynamic angle offset, the table access angle is offset depending on the velocity so that the internal master axis position can be calculated according to the formula below:

$$\varphi_{\text{effective internal master axis pos.}} = \varphi_{\text{internal master axis pos.}} + \frac{v_{\text{internal master axis velocity}}}{\text{Kv-factor}} \times \text{dynam. angle offset}$$

Internal   After electronic gear (P-0-0156/P-0-0157) and fine adjustment (P-0-0083)

Fig.7-128:   *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 $T_A = N \times T_{\text{position}}$.

Switching the Electronic Gear

When bit 1 (gear switching) has been set in "P-0-0086, Configuration word synchronous operation modes", any change, with active operation 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 MotionProfile

Number of Motion Steps

In "P-0-0703, Number of motion steps, set 0" and "P-0-0710, Number of motion steps, set 1" first 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.

Master Axis Velocity

Via "P-0-0704, Master axis velocity, set 0" or "P-0-0711, Master axis velocity, set 1" set the master axis velocity required for calculating specific motion steps.

Operation Modes

☞   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 laws, set 0
- P-0-0707, List of distances, set 0
- P-0-0708, List of slave axis velocities, set 0
- P-0-0712, List of master axis initial positions, set 1
- P-0-0713, List of motion laws, set 1
- P-0-0714, List of distances, set 1
- P-0-0715, List of slave axis velocities, set 1

A motion step is limited by a master axis initial position and a master axis end position. The master axis end position is determined by the master axis initial position of the following motion step or by 360 degrees.

The slave axis velocity can be preset in the case of certain standard profiles or is preset by the distance and the profile.

☞   The positions of the data in the lists define to which step the values belong. For example, the data at the second position of the lists for master axis initial position, mode, distance and slave axis velocity define the second motion step.

           This means that the number of elements defined in the lists as must be at least the number of motion steps.

Standard Profiles

Different standard profiles or a cam table can be defined as the motion law of a step.

The following motion laws are available:

- Rest in rest (R-R)
- Rest in velocity (R-V)
- Velocity in rest (V-R)
- Constant velocity (V)
- Velocity in velocity (V-V)
- Cam table

Rest in Rest

For the profile "rest in rest", there are three profiles available. These profiles are characterized by the fact that velocity and acceleration are zero at the start and at the end of the motion. You can choose between the standardized motion laws "5th order polynomial" and "inclined sine curve". The third profile "rest in rest with limited velocity" is realized in a 5th order polynomial. For this profile, it is necessary to indicate a maximum velocity of the slave axis.

In addition, these profiles are defined by the distance and the master axis range.

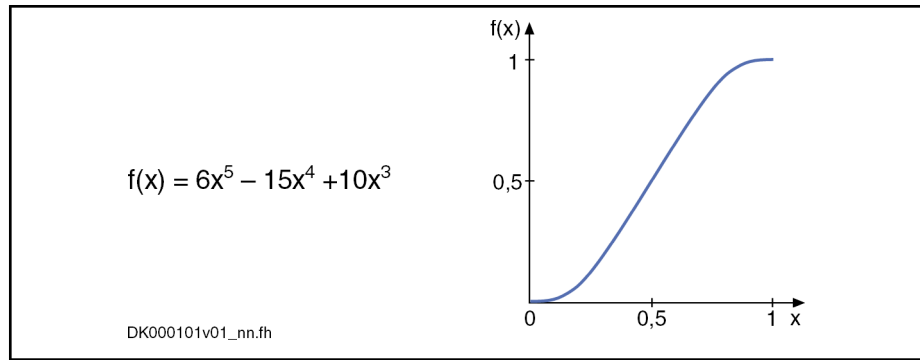The following relation applies to the profile "5th order polynomial":

Operation Modes

DK000101v01_nn.fh

$$f(x) = 6x^5 - 15x^4 + 10x^3$$

Fig.7-129:   *"5th Order Polynomial" Profile*

The following relation applies to the "inclined sine curve" profile:

DK000102v01_nn.fh

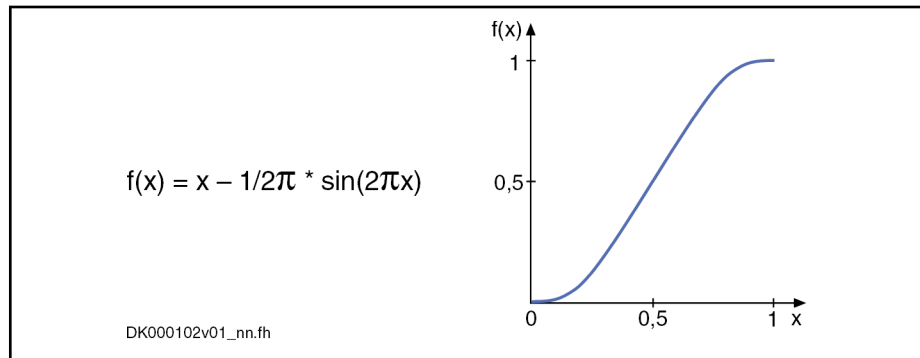$$f(x) = x - 1/2\pi * \sin(2\pi x)$$

Fig.7-130:   *"Inclined Sine Curve" Profile*

☞   You should prefer the profile with inclined sine curve for mechanical systems susceptible to oscillation, as the jerk curve is better. The occurring maximum values for velocity and acceleration, however, are higher.

For the profile "rest in rest with limited velocity", the maximum occurring slave axis velocity is calculated from the indicated values of master axis velocity, master axis distance and master axis range. If this velocity is lower than the indicated maximum slave axis velocity, the above-mentioned 5th order polynomial is used. The maximum velocity is parameterized in the list of the slave axis velocities. If the maximum slave axis velocity would be exceeded, this step is divided into three individual steps "rest in velocity", "constant velocity" and "velocity in rest". In the middle part, the axis moves with the maximum slave axis velocity.

The following figure illustrates the velocity curves of a simple 5th order polynomial (black) and of the profile "rest in rest with limited velocity" (blue) for identical values of axis distance, master axis range and master axis velocity.
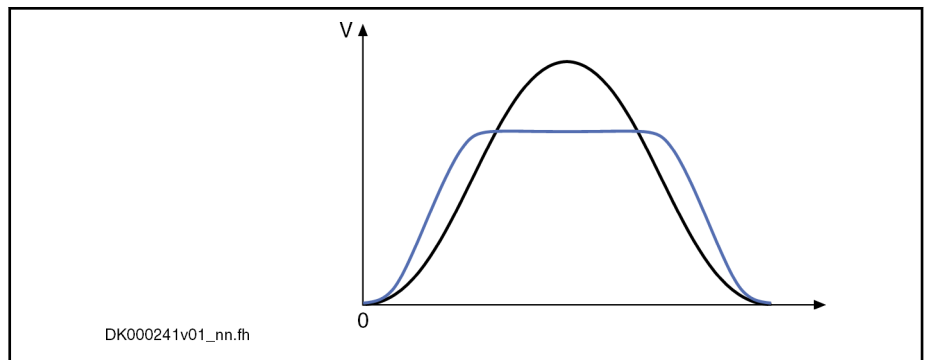
Operation Modes

Fig.7-131:   Profile "Rest in Rest with Limited Velocity" → Curve of the Slave Axis
Velocity

In case it is not possible to divide this step into three individual steps, maybe due to the distance being to large, on examination of this profile, the respective error number (81 … 88, for significance, please see description of diagnostic message F2004) is indicated in the diagnosis parameter of the Motion-Profile set in question.

If the profile "rest in rest" is divided into the three steps "rest in velocity", "constant velocity" and "velocity in rest", acceleration values will occur in the first and the last partial range which are significantly higher than for the profile with the simple 5th order polynomial. The acceleration values are not monitored!

Rest in Velocity   The profile "rest in velocity" is used for transition from standstill to a certain velocity. The velocity and the acceleration at the beginning of the profile are zero. At the end of the profile, the slave axis velocity preset by the corresponding parameter has been reached. The acceleration at the end of the profile is zero.

The drive calculates the coefficients of this polynomial from the following values preset for this motion step:

- Master axis range

- Distance

- Slave axis velocity

- Master axis velocity

The profile is calculated with a 5th order polynomial:

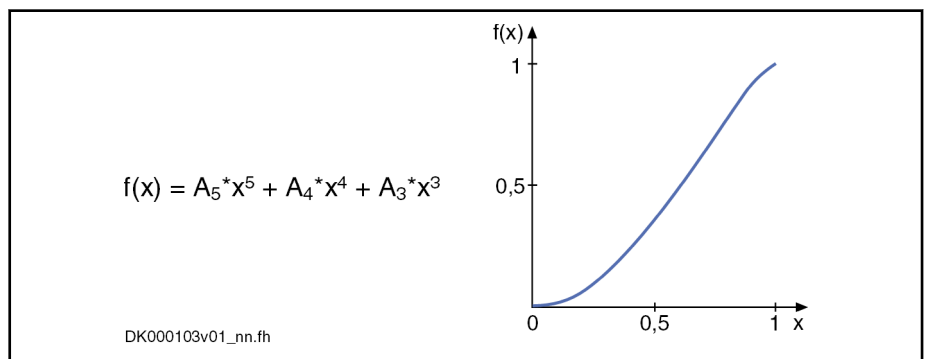$$f(x) = A_5 {}^*x^5 + A_4 {}^*x^4 + A_3 {}^*x^3$$

Fig.7-132:   "Rest in Velocity" Profile

☞   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:

Operation Modes

$$v_{standard} = \frac{v_{slave\ axis} \times master\ axis\ range}{v_{master\ axis} \times distance}$$

Fig.7-133:   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:

$$f(x) = A_5{}^*x^5 + A_4{}^*x^4 + A_3{}^*x^3 + A_1{}^*x$$

DK000104v01_nn.fh
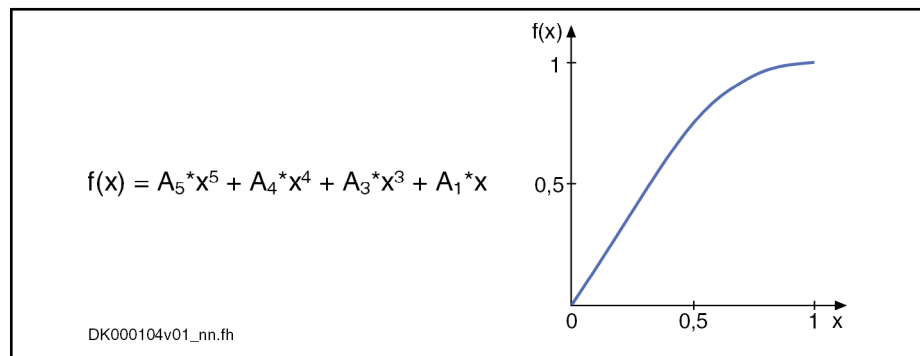
Fig.7-134:   "Velocity in Rest" Profile

☞   The function curve contains a reversal point, when the standardized velocity $v_{standard}$ is not between the values 1.66 and 2.5.

The standardized velocity can be calculated with the following formula, the master axis range being the difference of two master axis initial positions:

$$v_{standard} = \frac{v_{slave\ axis} \times master\ axis\ range}{v_{master\ axis} \times distance}$$

Fig.7-135:   Calculating the Standardized Velocity

☞   The distance belonging to this motion step mustn't be zero!

Operation Modes

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):

$$f(x) = x$$

DK000105v01_nn.fh
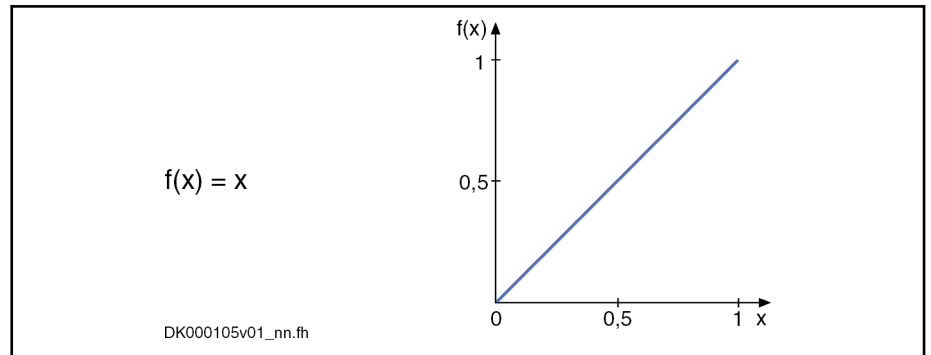
Fig.7-136:   "Constant Velocity" Profile

The slave axis velocity is determined from the following values preset for this motion step:

- Master axis range
- Distance
- Master axis velocity

$$v_{slave\ axis} = \frac{distance \times v_{master\ axis}}{master\ axis\ range}$$

Fig.7-137:   Calculating the Slave Axis Velocity

It is not necessary to enter a value for the slave axis velocity. For the validation check, a value is calculated in the drive according to the above formula. The calculated value can be read from the list parameter for the slave axis velocities.

Velocity in Velocity (2 Velocities)

The profile "velocity in velocity" is used for transition from one slave axis velocity to a different slave axis velocity. The velocity at the beginning of the profile must correspond to the indicated slave axis velocity. The velocity at the end of the profile is determined by the velocity parameter of the subsequent motion step. The acceleration at the beginning and at the end of the profile is zero.

The profile is calculated with a 5th order polynomial:

$$f(x) = A_5{}^*x^5 + A_4{}^*x^4 + A_3{}^*x^3 + A_1{}^*x$$

DK000106v01_nn.fh
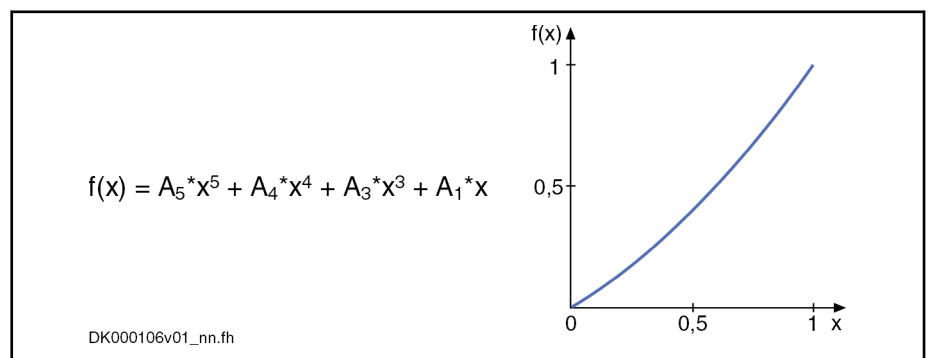
Fig.7-138:   "Velocity in Velocity" Profile

Operation Modes

The drive calculates the coefficients of this polynomial from the following values preset for this motion step:

- Master axis range
- Distance
- Master axis velocity
- 2 slave axis velocities

☞ The function curve contains a reversal point, when the pair of values $v_{standard0}$ and $v_{standard1}$ is not in the range that is defined by the functions $f1(x) = (5 - 2x)/3$ and $f2(x) = (5 - 3x)/2$. The range is marked in the figure below.

DK000209v01_en.fh
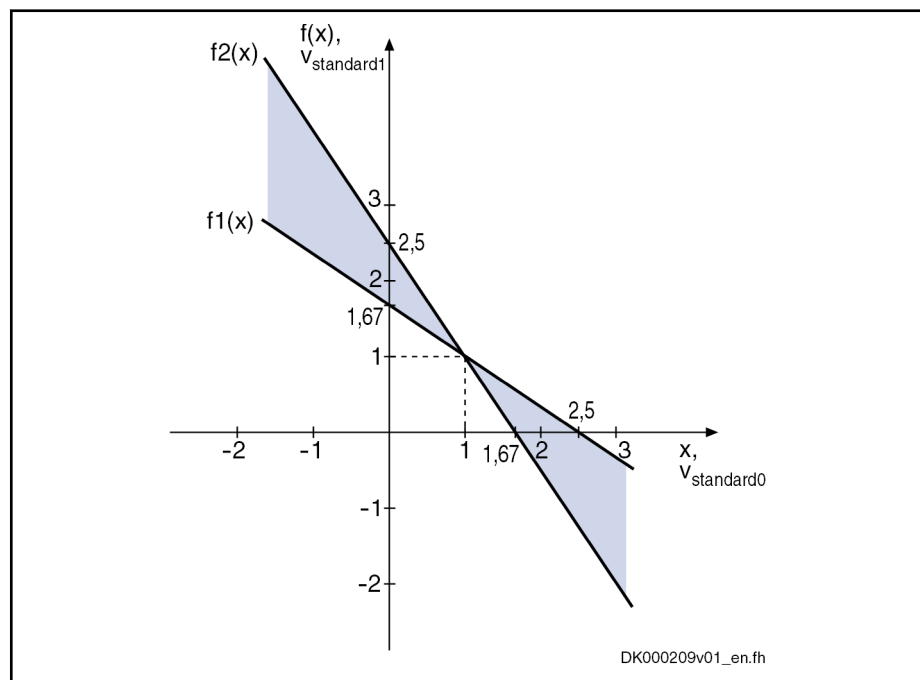
Fig.7-139:   *Advantageous Range for the Pair of Values v_standard0 and v_standard1*

$$v_{standard0} = \frac{v_{BS0} \times master\ axis\ range}{v_{master\ axis} \times distance}$$

$$v_{standard1} = \frac{v_{BS1} \times master\ axis\ range}{v_{master\ axis} \times distance}$$

v_{BS0}	Slave axis velocity i
v_{BS1}	Slave axis velocity i+1
Master axis range	Difference of two master axis initial positions

Fig.7-140:   *Calculating the Standardized Velocities v_standard0 and v_standard1*

☞   The distance belonging to this motion step mustn't be zero!

<div style="text-align:right">Cam Table</div>

When you select a cam table via "P-0-0706, List of motion laws, set 0" or "P-0-0713, List of motion laws, set 1", the selected cam table is used instead of a motion profile.

The value selected from "P-0-0705, List of master axis initial positions, set 0" or "P-0-0712, List of master axis initial positions, set 1" determines as of which master axis position a table is processed. This master axis initial position determines the position of the 1st table element, the master axis end position determines the position of the last table element. The master axis end position is determined by the master axis initial position of the following motion step or by 360 degrees for the last motion step.

The number of data points of a table is variable. The table length results from the parameterized actual length.

The data point distance is calculated according to the formula below:

$$\text{Data point distance} = (\text{master axis end position} \ - \ \text{master axis initial position}) \times 2^{\,P\text{-}0\text{-}0084} \ / \ 360 \ / \ (n\text{-}1)$$

P-0-0084   Number of bits per master axis revolution
n   Number of table elements
Fig.7-141:   *Calculating the Data Point Distance (in Increments)*

The table values can be between –799.999999 % and +799.999999 %.

The first table value has to be zero. The value of the last table element is arbitrary.

For one table sequence the traveled path results from the product of the distance and the last table element.

Cubic spline interpolation is carried out between the data points.

☞   The format of the cam table in the MotionProfile must be the "new" cam table format for which the last table value corresponds to the value at 360 degrees (corresponding bit in P-0-0086, bit 8...15 = 1).

See also operation mode "Electronic Cam with Real/Virtual Master Axis"

<div style="text-align:right">Changing the MotionProfile</div>

A change in the data of a motion step normally requires changes in other motion steps. An individual change therefore mustn't be immediately applied. When the operation mode is active, position command value jumps might occur.

When the master axis velocity is changed, it is also necessary, for motion steps with contained velocity, to recalculate the polynomial coefficients.

To allow changes while the operation mode is active, there are two sets with a maximum of 8 motion steps. The use of the second data set is selected by bit 9 of "P-0-0088, Control word synchronization modes".

In the control word, make the setting to determine which one of the two sets is to be active. For switching, you have to change bit 9; switching takes place when the position set in parameter "P-0-0700, MotionProfile, master axis switching position" is passed.

The active set is displayed in bit 3 of "P-0-0089, Status word synchronization modes".

☞   In case a profile is processed in relative form, the switch angle must comply with the master axis initial position of a motion step.

Operation Modes

MotionProfile Check

To check a MotionProfile you can query information on both sets from the status word (P-0-0089). After a set has been changed, the complete set is checked. The check was carried out when the 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 operation mode, the message "F2004 Error in MotionProfile" (class 1 diagnostics error) is generated. This error message is also generated when the active set, with active operation mode, is changed in such a way that the profile check is unsuccessful.

There are the following validation checks for the sequence of motion:

- The master axis initial positions of the motion steps used must increase and be smaller than 360 degrees.

- "Constant velocity" motion law

  → The motion profile is defined by master axis range and distance. The velocity is calculated and possibly compared to preset velocities of previous and following step.

- "Rest in velocity" motion law

  → The following step mustn't start with a rest position. If the following motion step is "velocity in rest", "constant velocity" or "velocity in velocity", the velocity values have to match. The distance must not be zero.

- "Velocity in rest" motion law

  → The previous step mustn't end with a rest position. If the previous motion step is "rest in velocity" or "constant velocity", the velocity values have to match. The distance must not be zero.

- "Velocity in velocity" motion law

  → The previous step mustn't end with a rest position. If the previous motion step is "rest in velocity" or "constant velocity", the velocity values have to match. The distance must not be zero.

- The first value of a cam table must be zero.

- In the case of absolute position scaling and absolute MotionProfile, the sum of travel distances must be zero. The travel distances are to be taken from the distance values or, for a motion step with table, from the product of final table value and distance.

- In the case of modulo position scaling and absolute MotionProfile, the sum of travel distances must be zero or a multiple of the modulo value (S-0-0103). The travel distances of the individual steps are determined like in the case of absolute position scaling.

The profile is checked after every change. When the 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.
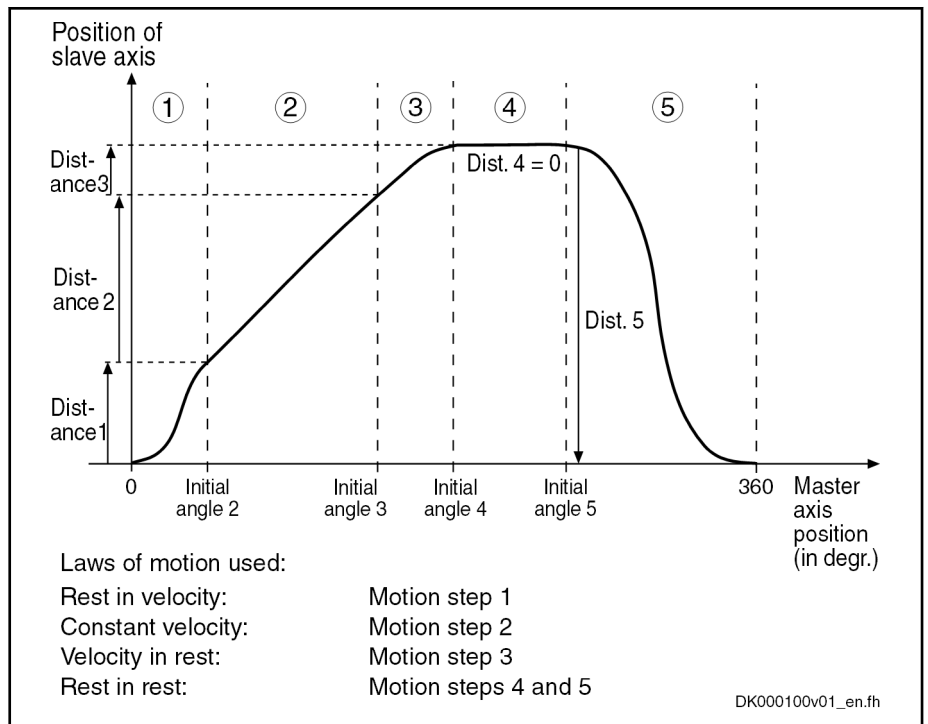
Fig.7-142:   Example of a MotionProfile with 5 Motion Steps

Commissioning Summary

The figure below illustrates the basic sequence of commissioning.
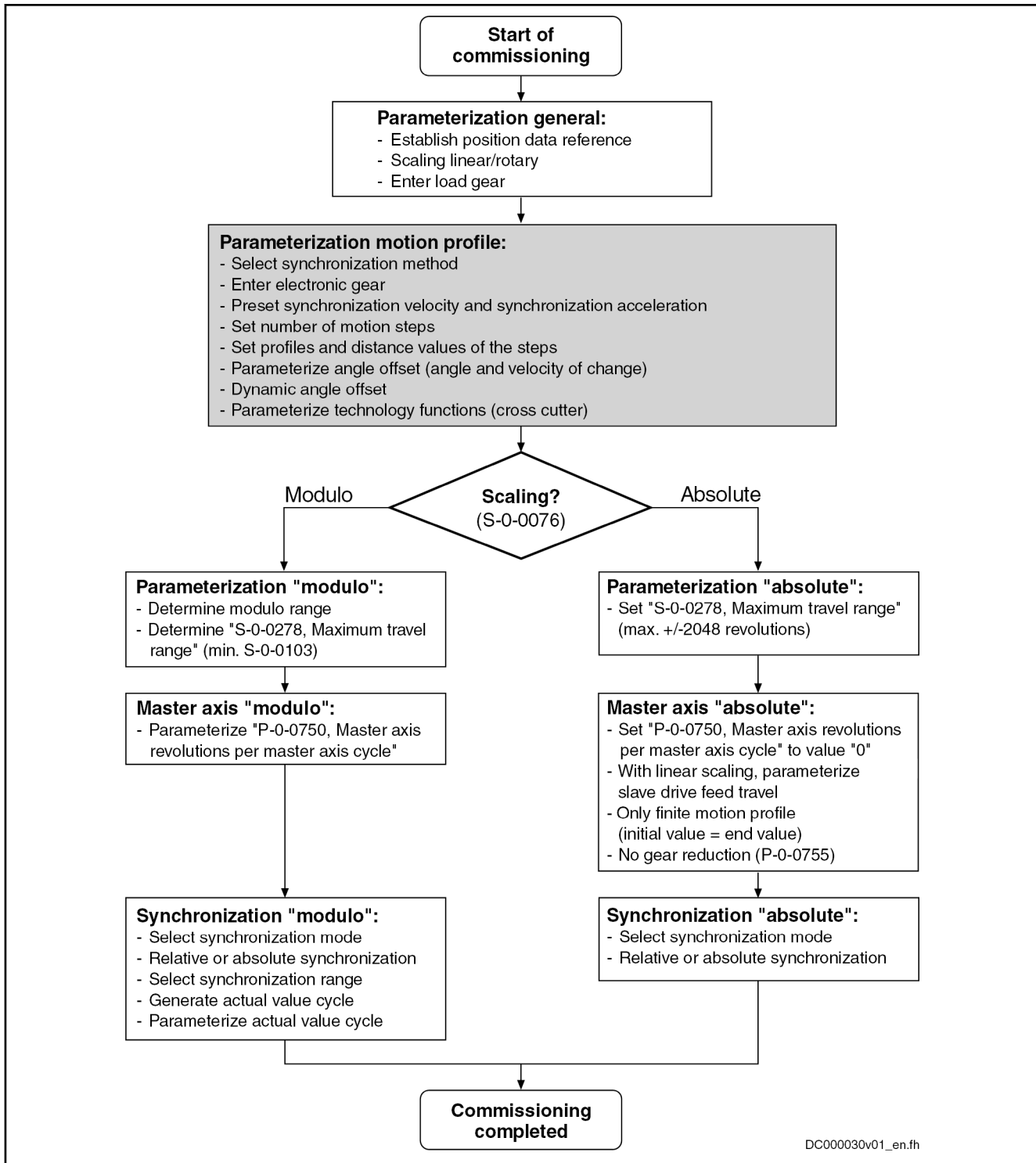
Operation Modes

Fig.7-143:   *Overview of Commissioning Steps for Motion Profile*

Diagnostic and Status Messages

Diagnostic Status Messages   The following diagnostic status messages are displayed in normal operation of the operation mode (drive enabled, "AF"):

- A0136 MotionProfile, encoder 1, virtual master axis
- A0137 MotionProfile, encoder 2, virtual master axis

Operation Modes

- A0138 MotionProfile, encoder 2, real master axis
- A0139 MotionProfile, encoder 1, real master axis
- A0140 MotionProfile lagless, encoder 1, virtual master axis
- A0141 MotionProfile lagless, encoder 2, virtual master axis
- A0142 MotionProfile lagless, encoder 1, real master axis
- A0143 MotionProfile lagless, encoder 2, real master axis
- A0163 Position synchronization

Error Messages and Warnings Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operation mode:

- F2003 Motion step skipped

  → This error message is displayed when the master axis velocity is that high that a motion step is skipped during the processing of the profile. This is the case when the product from master axis velocity and position loop cycle time (see Parameter Description "P-0-0556, Config word of axis controller") becomes greater than the master axis range of a step.

- F2004 Error in MotionProfile

  → This message is generated, if a profile that has not passed the validation checks is activated with the drive having been enabled.

If a discrepancy is detected during the validation check, its possible cause is encoded by means of an error number (for its significance, see description of diagnostic message F2004) in one of the following diagnosis parameters:

- P-0-0702, MotionProfile, diagnosis, set 0
- P-0-0709, MotionProfile, diagnosis, set 1

Status Bits There are also several status messages specific to operation mode generated in the drive that are mapped to specific status bits (see also "P-0-0089, Status word synchronization modes").

Position Loop Status The status display via the control encoder for lagless operation or operation with lag error takes place in "S-0-0521, Axis status word".

8 Extended Axis Functions

8.1 Safety Instructions

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

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

8.2 Availability of the Extended Axis Functions

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

Extended axis function	In base package (characteristic)	In functional package … (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 halt")	OL/CL	–	–	–
v_{cmd} reset while maintaining a_{max}	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[2]	–	–	–
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	–	–

Extended Axis Functions

Extended axis function	In base package (characteristic)	In functional package … (on the basis of a base package with the following characteristics)		
		Servo function	Synchronization	Main spindle
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	–	CL[2][3]	OL/CL[2][3]	OL/CL[2]
Drive-controlled oscillation	–	–	–	OL/CL[2]
Parking axis	OL/CL	–	–	–
Integrated safety technology	only available via the corresponding hardware configuration			

OL   Open-loop characteristic
CL   Closed-loop characteristic
1)   Not with firmware version MPB
2)   Not with firmware version MPD
3)   For parameter group control loop and application only
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 "P-0-2004, Active functional packages".

See also "Enabling of Functional Packages"

8.3   Drive Halt

8.3.1   Brief Description

> Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The "Drive halt" function is used to shut down an axis with defined acceleration and defined jerk.

In the default case, Drive Halt is performed as a quick stop in position control or velocity control. The control mode position is activated if one of the operation modes (S-0-0032 ...) is defined with position control (incl. internal PLC operation modes). Otherwise velocity control mode is active.

With the configuration Drive Halt (P-0-0558, bit 1, 2), the control mode can also be selected freely.

*   Bit 1,2 = 1,1 position control
*   Bit 1,2 = 1,0 velocity control

With the "Drive Halt" configuration (P-0-0558, bit 0 = 1), it is possible to switch to "operational stop" function. In this case, the operation modes "Velocity control", "Drive-internal interpolation", "Drive-controlled positioning" and "Positioning block" are internally stopped with V-cmd = 0. After "Drive Halt" has been removed, the motion is re-activated.

Extended Axis Functions

The adjustable position command value delay in position cycle times (P-0-0456) is a maximum of 32 cycles.

☞ In addition to the "Drive Halt" function, there is an operational stop for the operation modes "Drive-controlled positioning" and "Drive-internal interpolation". However, this function has its own control signal.

Features

- Activated via the "halt bit" of master communication (see "Device Control and State Machines")

- Active operation mode interrupted; drive remains in control (after setting the "halt bit" the interrupted operation mode is continued)

- **Quick stop in position control**

  → Shutdown with acceleration (S-0-0372) and jerk limit values (S-0-0349) in position control.

- **Quick stop in velocity control**

  → Shutdown with acceleration (S-0-0372) and jerk limit values (S-0-0349) in velocity control.

- If the Drive Halt delay (S-0-0372) is set to "0", "S-0-0138, Bipolar acceleration limit value" takes effect during shutdown.

- Acknowledgement of "Drive Halt" in P-0-0115

Pertinent parameters

- S-0-0124, Standstill window

- S-0-0349, Bipolar jerk limit

- S-0-0372, Drive Halt acceleration bipolar

- S-0-0138, Bipolar acceleration limit value

- P-0-0115, Device control: status word

- P-0-0434, Position command value of controller

- P-0-0456, Position command value delay

- P-0-0457, Position command value generator

- P-0-0558, Drive Halt configuration

8.3.2   Functional Description

Quick stop

When the "Drive halt" function is activated, the drive no longer follows the command values of the active operation mode, but automatically shuts down while maintaining a parameterized acceleration.

Activating the "Drive halt" function

The "Drive halt" function is activated by:

- Removing the Drive halt bit in the control word of the 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")

Return to the previously active operating mode

The operation mode active before and still selected becomes active again, when the Drive Halt bit is set again in the control word of the master communication.

The kind of shutdown with "Drive halt" depends on the initialization of the operation modes, but can also be determined via the Drive halt configuration.

Extended Axis Functions

Quick stop in position control

With position control, shutdown is carried out using the the delay in "S-0-0372, Drive Halt acceleration bipolar" and the jerk in "S-0-0349, Bipolar jerk limit"

☞   If the content of "S-0-0372, Drive Halt acceleration bipolar" equals "0", deceleration is carried out by means of the value in "S-0-0138, Bipolar acceleration limit value".

When Drive halt is started from an operation mode with position command value delay, the delay is activated for Drive halt, too.

The position command value can be delayed by a maximum of 32 position clocks after the fine interpolator, before it is fed into the position loop. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position clocks is set with the position command value delay (P-0-0456). The position command value generator without delay (P-0-0457) is entered in a ring buffer and then the position command value with delay is applied in the position command value controller (P-0-0434).

Position-controlled shutdown is carried out with position control with lag error, if an operation mode that also contained position control with lag error was active before. If not, the function is carried out with lagless position control.

Quick stop in velocity control

If control mode velocity is set, the shutdown in velocity control is made using the value in parameter "S-0-0372, Drive Halt acceleration bipolar" and the jerk in "S-0-0349, Bipolar jerk limit"

☞   If the content of "S-0-0372, Drive Halt acceleration bipolar" equals "0", deceleration is carried out by means of the value in "S-0-0138, Bipolar acceleration limit value".

Extended Axis Functions
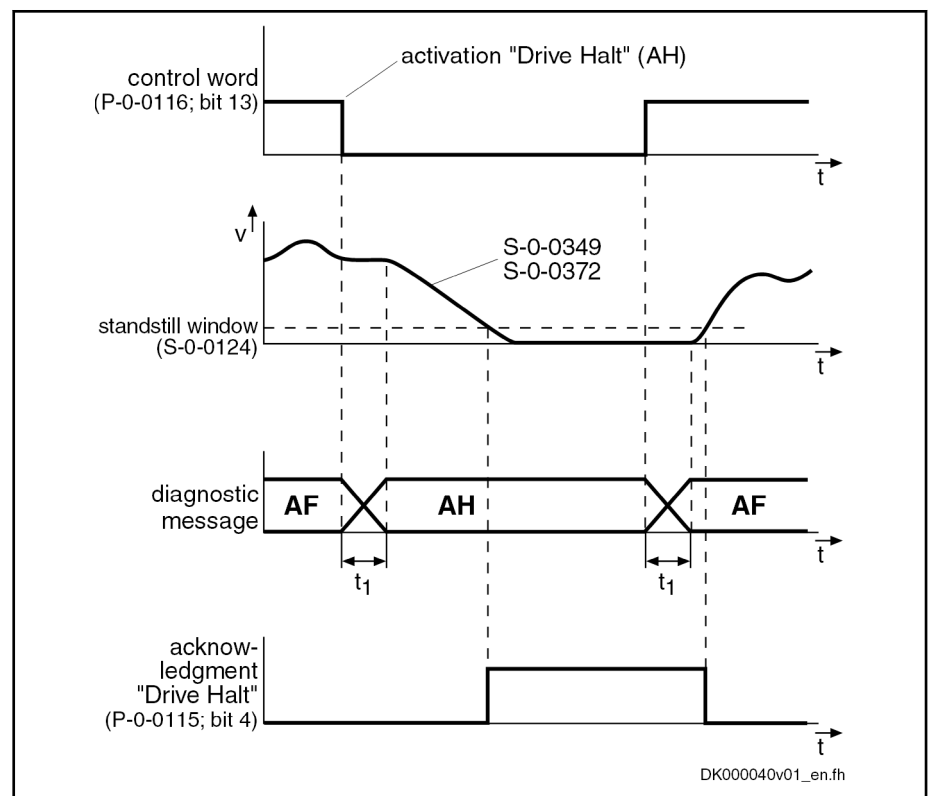
S-0-0349   Jerk limit bipolar
S-0-0372   Quick-stop delay
Fig.8-2:   *"Drive halt" principle with quick stop*

Operational stop   The "Drive halt" function as operational stop is activated by removing the Drive halt bit in the control word of the master communication (e.g. with sercos, bit 13 in "S-0-0134, Master control word").

If in the Drive Halt configuration, the operational stop is selected "P-0-0558, bit 0 = 1 ", the active operation mode is maintained. It is shut down with command velocity = 0. For shutdown, the parameters of the active operation mode are used. After Drive halt has been removed, the operation mode and the axis motion, if applicable, continue.

This only applies to the operation modes "Velocity control", "Drive-internal interpolation", "Drive-controlled positioning" and "Positioning block mode".

8.3.3   Notes on Commissioning

Diagnostic and status messages   The activated "Drive Halt" function is displayed as described below:

- "AH" appears on the control panel display at the front of the device
- "A0010" is entered in parameter "S-0-0390, Diagnostic message number"
- "A0010 Drive HALT" is entered in parameter "S-0-0095, Diagnostic message"
- In the bit "Status of command value processing" in the status word of the master communication (e.g. for sercos: Bit 3 = 0 in "S-0-0135, Drive status word")

Acknowledgment of "Drive halt"   An acknowledgment is carried out when the actual velocity falls below the threshold defined in "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".

Extended Axis Functions

8.4   Error Reactions

8.4.1   Overview of Error Reactions

Depending on the operation mode that is used and certain 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 into 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 that occurred and
*   The setting of the following parameters:
    *   P-0-0117, Activation of control unit reaction on error
    *   P-0-0118, Power supply, configuration
    *   P-0-0119, Best possible deceleration

☞   At the end of each error reaction, the drive switches torque-free. Power off depends on the setting in P-0-0118!

Error classes   There are 7 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 unit reaction on error"
F3xxx	Non-fatal safety technology error	According to setting in "P-0-0119, Best possible deceleration" and "P-0-0117, Activation of control unit reaction on error"
F4xxx	Interface error	According to setting in "P-0-0119, Best possible deceleration"
F6xxx	Travel range error	According to setting in "P-0-0119, Best possible deceleration"

Extended Axis Functions

Diagnostic message number	Error class	Error reaction
F7xxx	Safety technology error	According to setting in bit 9 of parameter "P-0-3210, Safety technology configuration"
F8xxx	Fatal error	Immediate torque disable, if this is the error reaction for non-fatal errors, otherwise general deceleration of the motor via short circuit of motor windings
F9xxx	Fatal system error	Immediate torque disable

Fig.8-3:   *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.

8.4.2   Best Possible Deceleration

Brief Description

The error reaction "Best possible deceleration" (to be set in "P-0-0119, Best possible deceleration") is carried out automatically with the following states:

- Non-fatal errors (F2xxx)
- Non-fatal safety technology errors (F3xxx)
- Interface errors (F4xxx)
- Travel range errors (F6xxx)
- Safety technology error (F7xxx) (however depending on bit 9 of "P-0-3210, Safety technology configuration")
- Drive enable is removed (see S-0-0134 resp. P-0-4077 or P-0-0115, bit 15)

☞   With fatal system errors (F9xxx/E-0800) the setting in P-0-0119 is ignored, the drive is shut down with immediate torque disable.

One of the following reactions for "Best possible deceleration" can be set in P-0-0119:

- Velocity command value reset (Emergency halt)
- Velocity command value reset with ramp and filter ("Emergency halt")
- Velocity command value reset with ramp and filter ("quick stop")
- Return motion (only with extension package "servo function")
- Torque disable
- Braking by short circuit of motor windings

Extended Axis Functions

	NOTICE	If the "Torque disable" error reaction has been set in P-0-0119, the drive also reacts with torque disable with F8 errors; otherwise, the motor is braked - with the majority of F8 errors - by shorting the motor windings!

Due to the system, braking by shorting the motor windings is not possible with:

- F8000 Fatal hardware error
- F8060 Overcurrent in power section

Intended Use and Parameterization Options

Parameterization options and intended use of best possible deceleration.

Type of shutdown	Intended use	Parameterizable deceleration as a reaction to	
		- Travel range errors **F6xx** - Safety technology errors **F7xx**	- Non-fatal errors **F2xx** - Non-fatal safety technology errors **F3xx** - Interface errors **F4xx** - Drive enable removed - Drive-contr. transition to special mode standstill SS1ES / SS1
Emergency halt Velocity command value reset	Fastest possible deceleration	P-0-0119, bit 7..0.4 = 0	P-0-0119, bit 3...0 = 0
Emergency halt Velocity command value reset with ramp and filter	Decel. preventing mech. system from damage while maintaining emergency halt properties	P-0-0119, bit 7..0.4 = 0100	P-0-0119, bit 3...0 = 0100
Torque disable	For slave axes when they have been bonded to the master axis	P-0-0119, bit 7..0.4 = 0001	P-0-0119, bit 3...0 = 0001
Quick stop Velocity command value reset with ramp and filter	Decel. preventing mech. system from damage while maintaining quick stop properties	Not possible	P-0-0119, bit 3...0 = 0010
Return motion	For specific return motion in **case of error** only in conjunction with functional expansion package "SRV"	Not possible	P-0-0119, bit 3...0 = 0011

P-0-0119   Torque/force peak limit
Fig.8-4:   Parameterization options of best possible deceleration

Extended Axis Functions

☞ Best possible deceleration **cannot** be parameterized for fatal warnings.

In the case of the fatal warnings **E8029, E8030, E8034, E8042, E8043** and **E8044**, the drive is decelerated by means of velocity command value reset with the ramp from "S-0-0138, Bipolar acceleration limit value". The available torque is limited by the parameter "P-0-0109, Torque/force peak limit".

Effective Limitation Parameters

Depending on the configured best possible deceleration, different limitation parameters take effect in the case of error.

Type of deceleration	Torque/force limit	Acceleration limit values				Jerk limit values		Filter time constant calculated from
	P-0-0109	S-0-0138	S-0-0429	S-0-0372	P-0-0057	S-0-0349	P-0-0058	
Emergency halt Velocity command value reset	■ [1]	■				No jerk limitation active		No filter active
Emergency halt Velocity command value reset with ramp and filter	■ [1]	■	■			■		S-0-0349 & S-0-0429
Torque disable	**With servo brake**: Friction torque of holding brake **With main spindle brake**: Not defined **Without motor brake**: Not defined					No jerk limitation active		No filter active

Extended Axis Functions

Type of deceleration	Torque/force limit	Acceleration limit values				Jerk limit values		Filter time constant calculated from
	P-0-0109	S-0-0138	S-0-0429	S-0-0372	P-0-0057	S-0-0349	P-0-0058	
Quick stop Velocity command value reset with ramp and filter	■[1]	■		■		■		S-0-0349 & S-0-0372
Return motion	■[1]				■		■	P-0-0057 & P-0-0058

[1]   For reasons of compatibility, the parameterized limitation can be changed to the smallest value from S-0-0082, S-0-0083, S-0-0092 and P-0-0109 by means of parameter P-0-0119, bit#9.

S-0-0138   Bipolar acceleration limit value
S-0-0349   Jerk limit bipolar
S-0-0372   Drive halt acceleration bipolar
S-0-0429   Emergency halt deceleration
P-0-0109   Torque/force peak limit

Fig.8-5:   Effective limitation parameters

Time Flow of the Error Reaction

Time flow with available motor hold brake

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 also "Motor Holding Brake"

Deceleration in U/f operation

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 (see "P-0-0045, Control word of current controller"). The maximum deceleration of the shutdown is preset by the value entered in "P-0-0569, Maximum stator frequency slope".

Velocity Command Value Reset ("Emergency Halt")

Intended use

Velocity command value reset ("emergency halt") is used, when the fastest possible deceleration in the case of error is desired.

P-0-0119, Bit 0...3 = 0;
P-0-0119, Bit 4...7 = 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 from parameter P-0-0109. The acceleration limit value is the parameter "S-0-0138, Bipolar acceleration limit value". (See also "Limitations: Current and Torque/Force Limitation")..

In open-loop U/f control, deceleration by means of

P-0-0109, Torque/force peak limit only takes place, when the stall protection loop has been activated, see "P-0-0045, Control word of current controller".

☞   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!

When the drive has been equipped with a holding brake and this brake has been configured as a servo brake (P-0-0525, Holding brake control word), it is activated after "S-0-0273, Maximum drive off delay time" is over and drive enable is internally switched off after the time from "S-0-0207, Drive off delay time" has elapsed.

When the brake is used as a main spindle brake, drive enable is internally switched off after "S-0-0273, Maximum drive off delay time" is over and the brake is applied at a velocity smaller than 10 rpm.
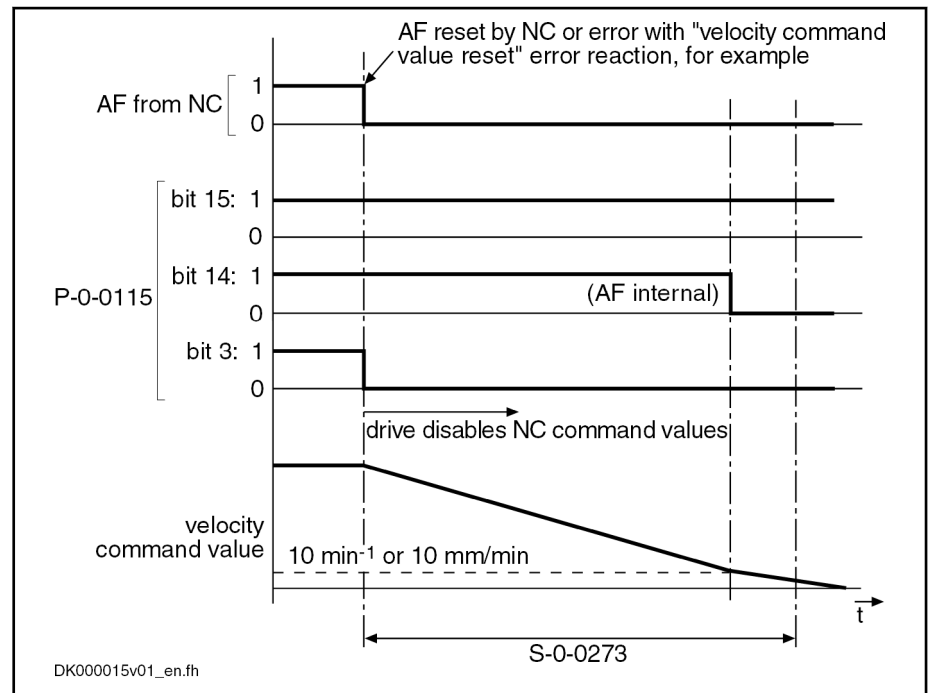
S-0-0273	Maximum drive off delay time
P-0-0115	Device control: Status word
Fig.8-6:	Time flow of velocity command value reset

| NOTICE | If the value entered for S-0-0273 is too small, the error reaction is sometimes aborted without axis standstill! |

Pertinent parameters
- S-0-0138, Bipolar acceleration limit value
- S-0-0273, Maximum drive off delay time
- P-0-0045, Control word of current controller
- P-0-0109, Torque/force peak limit
- P-0-0569, Maximum stator frequency slope

Velocity Command Value Reset with Ramp and Filter ("Emergency Halt")

Intended use

Velocity command value reset with ramp and filter ("emergency halt") is used, when it is desired to have deceleration preventing the mechanical system from damage while maintaining the emergency halt properties.

P-0-0119, bit 0...3 = 4;
P-0-0119, bit 4...7 = 4

In the case of error
- the closed-loop-controlled servo drive in velocity control

- or -

Extended Axis Functions

> • the open-loop-controlled drive in U/f operation

is shut down with a command value ramp, determined by S-0-0429, Emergency halt deceleration and the jerk-limiting value (S-0-0349).

If the value in S-0-0429="0", "S-0-0138, Bipolar acceleration limit value" takes effect.

The torque/force limitation is derived from the parameter P-0-0109.

☞   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-0-0138, Bipolar acceleration limit value
- S-0-0349, Bipolar jerk limit
- S-0-0429, Emergency halt deceleration
- P-0-0109, Torque/force peak limit
- P-0-0569, Maximum stator frequency slope

Velocity Command Value Reset with Filter and Ramp ("Quick Stop")

Intended use   Velocity command value reset with filter and ramp ("quick stop") is used, when it is desired to have deceleration preventing the mechanical system from damage while maintaining the quick stop properties.

P-0-0119, Bit 0…3 = 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 shut down with a command value ramp, determined by S-0-0372, Drive Halt acceleration bipolar and the jerk limit value

S-0-0349, Bipolar jerk limit. When the value S-0-0327 = "0", the value in

S-0-0138, Bipolar acceleration limit value takes effect. The torque/force limitation is derived from the parameter P-0-0109.

☞   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-0-0138, Bipolar acceleration limit value
- S-0-0349, Bipolar jerk limit
- S-0-0372, Drive Halt acceleration bipolar
- P-0-0569, Maximum stator frequency slope
- P-0-0109, Torque/force peak limit

The parameters take effect as described in the "Drive Halt" function.

Torque Disable

Intended use   Torque disable is used for a slave axis when the axis has been bonded to the master axis.

P-0-0119, Bit 0…3 = 1;
P-0-0119, Bit 4…7 = 1   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.

When the drive has been equipped with a holding brake and this brake has been configured as a servo brake (P-0-0525, Holding brake control word), it is immediately activated. When the brake is used as a main spindle brake, it is only applied at a velocity smaller than 10 rpm.

NOTICE	Drive continues to move unbraked in the case of error!
	Danger to life from parts in motion when the safety door at the machining cell is opened!

⇒ Check drive for motion (e.g. using "S-0-0040, Velocity feedback value", if possible) and wait for standstill!

Return Motion

> Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Intended use   Return motion is used, when the systematic return of the axis from the machining area is required in the case of error.

P-0-0119, Bit 0...3 = 3   If "return motion" was set 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 und
- 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, Current position command average value filter order) being calculated from "P-0-0057, Return acceleration" and "P-0-0058, Return jerk".

$$P\text{-}0\text{-}0042 = \frac{P\text{-}0\text{-}0057}{P\text{-}0\text{-}0058}$$

Fig.8-7:   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:

Extended Axis Functions

- Target position = active position command value

  → i.e. "S-0-0013, Class 3 diagnostics" , bit 12="1"

- and -

- $v_{act} = 0$

  → i.e. "S-0-0013, Class 3 diagnostics", bit 1="1" (actual velocity smaller than "S-0-0124, Standstill window")
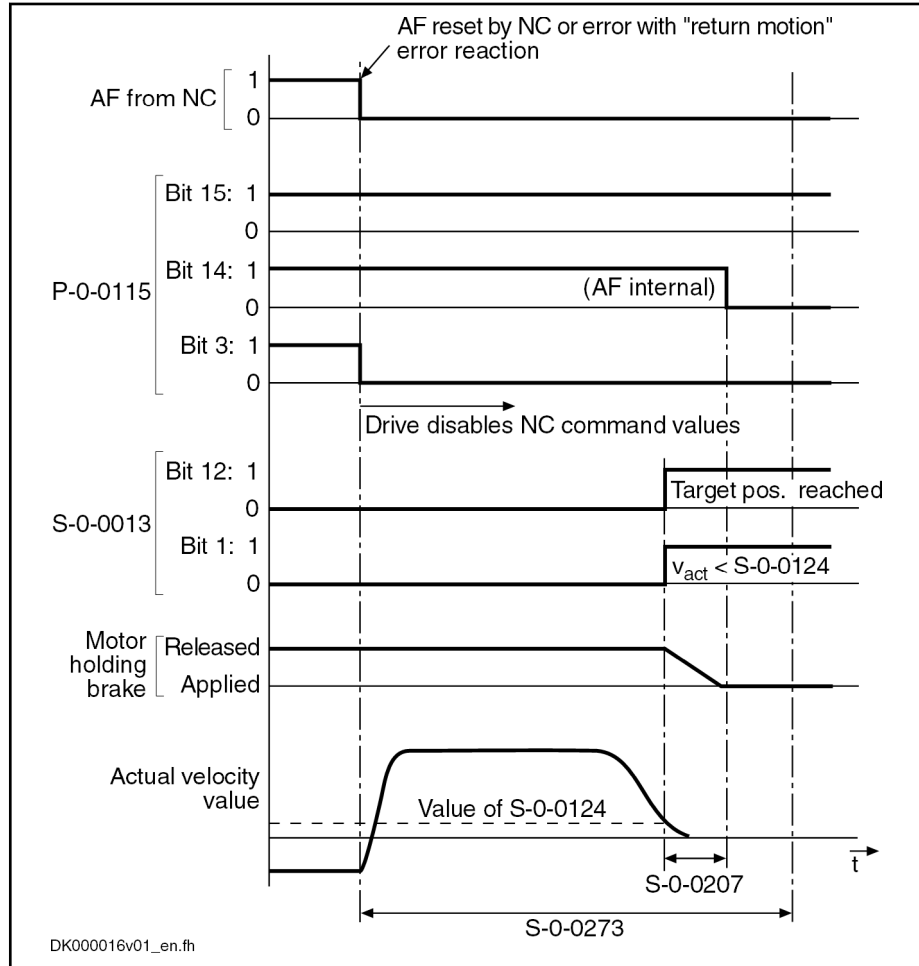
S-0-0013	Class 3 diagnostics
S-0-0207	Drive off delay time
S-0-0124	Standstill window
S-0-0273	Maximum drive off delay time
P-0-0115	Device control: Status word

Fig.8-8:   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") are activated, i.e. when

- in "S-0-0055, Position polarities", bit 4 for "activation of position limit values" is set to "1"

  - 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 "return motion" error reaction.

☞ 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).

Deceleration via Short Circuit of Motor Windings

P-0-0119, Bit 8 = 1   If P-0-0119, Bit 8=1, with F8 errors, the motor decelerates via a controller-internal short circuit of the motor windings. In an F8 error occurs, a holding brake controlled by the controller behaves according to the functional principle set in "P-0-0525, Holding brake control word":

- Brake immediately applied if "servo brake" is set

- Brake only applied below 10 rpm if "main drive brake" is set

☞ Due to the system, deceleration via short circuit of motor windings is not possible for:

- F8000 Fatal hardware error

- F8060 Overcurrent in power section

- F8067 Synchronization PWM-Timer wrong

- F8133 Error when checking interrupting circuits

8.4.3   Package Reaction on Error

Brief Description

💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

"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 enables the package reaction only to be activated with 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 damage can be minimized:

Extended Axis Functions

- Machine damage
- Tool/workpiece/material damage

⚠ WARNING	The package reaction is not suitable to avoid 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 error 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 error 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 error to supply	Power off only with F8 error, otherwise via NC master with DC bus short circuit

Fig.8-9:   *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

Extended Axis Functions

- Handling of "undervoltage" message for inverters (type HMS or HMD) and converters (type HCS)
- Automatic clearing of error "F2026 Undervoltage in power section" by switching drive enable off
- Signaling of own, fatal drive errors (F8xxx) to the supply via module bus

8.4.4 Control Reaction on Error

NC Reaction on Error

Brief Description

> 💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

To avoid damage to the machine, some applications require that the master (e.g. NC) retains control of the travel profile of the axes 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 P-0-0117.

The master is informed of an error in the drive controller via the drive status word (see S-0-0135) so that the master can shut down the machine axes in a coordinated way and therefore avoid possible damage.

> ☞ NC reaction on error is only possible with non-fatal errors (diagnostic message F2xxx), otherwise the drive always reacts with an immediate drive-side error reaction.

Pertinent parameters
- S-0-0135, Drive status word
- P-0-0117, Activation of control unit reaction on error
- P-0-0119, Best possible deceleration

Functional Description

In the case of NC reaction on error, the axis 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 "P-0-0117, Activation of control unit reaction on error".

P-0-0117, bit 0:

- Bit 0 = 0 → The drive carries out its error reaction **without delay** 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 P-0-0119 **only 30 s after recognizing the error**. The drive, for the duration of 30 s after detection of the error, continues following the command values of the master and therefore allows an **NC error reaction**.

  Note: If the error message is deleted within this waiting period after detection of the error, **no** drive reaction set in P-0-0119 is executed.

Extended Axis Functions

☞   The activation of "NC reaction on error" (P-0-0117, bit 0 = 1) only
           makes sense for masters that have the respective procedure for
           the case of error.

MLD Reaction on Error

Brief Description

💡   Assignment to functional firmware package, see chapter "Availa-
           bility of the Extended Axis Functions".

As an alternative to the NC reaction, IndraMotion MLD can also perform a re-
action in the event of error for the (local) axis. In this, the MLD reaction differs
functionally from the NC reaction insofar as by means of IndraMotion MLD,
even for an interface error (F4xxx), an error reaction to be defined by the user
can be executed for the (local) axis.

☞   Prerequisite for utilization of the MLD error reaction is the ena-
           bling of the PLC function in the drive (see "Enabling of Functional
           Packages").

Pertinent parameters
- S-0-0135, Drive status word
- P-0-0117, Activation of control unit reaction on error
- P-0-0119, Best possible deceleration
- P-0-2003, Selection of functional packages

Functional Description

With an MLD reaction on error, the (local) axis is also commanded by the
IndraMotion MLD for another 30 seconds in the case of an error. The MLD
retains control over the axis if it had control before the error occurred, or
takes over control of the axis, which results in control by an external control
unit being interrupted.

Activating the NC reaction   The MLD reaction on error is activated in "P-0-0117, Activation of control unit
reaction on error".

P-0-0117, bit 1 (bit 0 must be Zero):

- Bit 1 = 0 → The drive carries out its error reaction **without delay** accord-
  ing to the setting in "P-0-0119, Best possible deceleration", after recog-
  nizing the error.

- Bit 1 = 1 → The drive carries out its error reaction according to the set-
  ting in P-0-0119 **only 30 seconds after recognizing the error**. For a peri-
  od of 30 seconds from the time of error recognition, the IndraMotion
  MLD receives control over the axis and can therefore perform an **MLD
  error reaction**.

  Note: If the error message is deleted within this waiting period after de-
  tection of the error, **no** drive reaction set in P-0-0119 is executed.

Notes on utilization   Observe the following aspects when using the function:
- 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.

- An MLD reaction on error is only possible with non-fatal errors (F2xxx) and with interface errors (F4xxx), otherwise the drive always reacts with an immediate drive-side error reaction.

- The MLD reaction on error facilitates a very fast and - above all - flexible reaction to the occurrence of an error.

8.5 E-Stop Function

8.5.1 Brief Description

💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The E-Stop function is used to shut down the drive with selectable drive reaction (see Parameter Description "P-0-0008, Activation E-Stop function") via a digital input of the drive controller.

There are the following options when using the E-Stop function:

- E-Stop with reaction to interface error (F4034 Emergency-Stop activated)

  → **Reaction:** Best possible deceleration (as set in P-0-0119)

- E-Stop with reaction to travel range error (F6034 Emergency-Stop activated)

  → **Reaction:** Velocity command value reset

- E-Stop as fatal warning "E8034 Emergency-Stop activated"

  → **Reaction:** Best possible deceleration (as set in P-0-0119)

☞ If "E-Stop" was parameterized as a warning, it is not 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 activated
- F4034 Emergency-Stop activated
- F6034 Emergency-Stop activated

8.5.2 Functional Description

By activating the E-Stop input (P-0-0008, bit 0 = 1) and assigning bit 0 of P-0-0223 to a digital input, the drive is caused to carry out, with 0 V at the E-Stop input, the reaction defined via P-0-0008 for shutting the drive down.

E-stop reaction according to P-0-0008, bit 2

The reaction first of all depends on the setting of bit 2 in P-0-0008.

If the interpretation "fatal warning" was parameterized in P-0-0008 (bit 2 = 1), the drive reacts, as in the case when the external drive enable is switched off, with the reaction set in "P-0-0119, Best possible deceleration".

- The warning "E8034 Emergency-Stop activated" appears. In "S-0-0012, Class 2 diagnostics" bit 15 is set (manufacturer-specific warning).

- Simultaneously, the bit "change bit class 2 diagnostics" is set in the drive status word.

Extended Axis Functions

> ☞   This change bit is cleared by reading "S-0-0012, Class 2 diagnostics". Using "S-0-0097, Mask class 2 diagnostics", warnings can be adjusted in terms of their effect on the change bit.

> ☞   To reactivate the drive, the E-Stop input must be deactivated and **another 0-1 edge must be applied to the external drive enable**.

If the interpretation was set as an error in P-0-0008 (bit 2 = 0), the reaction selected in bit 1 is carried out:

- The error diagnosis "F4034 Emergency-Stop activated" (or "F6034 Emergency-Stop activated") appears
- Bit 15 is set in parameter "S-0-0011, Class 1 diagnostics".
- Bit 13 (drive 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, if the E-Stop is no longer active.

> ☞   The error reaction is carried out without delay, independent of "P-0-0117, Activation of control unit reaction on error".

E-stop reaction according to P-0-0008, bit 1

If bit 1 = 0 was set in parameter P-0-0008, the drive is shut down according to the error reaction parameterized via "P-0-0119, Best possible deceleration".

The diagnostic message upon activating the E-Stop input then is "F4034 Emergency-Stop activated".

If bit 1 = 1 was set in parameter P-0-0008, the drive, when the E-Stop triggers, is braked with maximum torque to speed = 0, independent of the error reaction set in P-0-0119. This setting corresponds to the best possible deceleration "velocity command value reset".

The diagnostic message upon activating the E-Stop input then is "F6034 Emergency-Stop activated".

8.5.3   Notes on Commissioning

Activation and Polarity of the E-Stop Input

Assigning digital input

Prerequisite for using the function is the assignment of bit 0 of parameter P-0-0223 to a digital input (see "Digital Inputs/Outputs"). A voltage level at the digital input therefore also affects bit 0 of P-0-0223.

> **NOTICE**   Without this assignment to the digital input, the E-Stop reaction fails to occur in spite of the input having been activated!

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 "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

Extended Axis Functions

Selecting the Drive Reaction

Determining the reaction

It is possible to determine whether an error message or a warning is generated when 0 V is generated 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

ℹ See documentation "Control Sections for Drive Controllers; Project Planning Manual"

☞ The polarity of the input cannot be selected. It is always active when the signal = 0 V; this means that 0 V at the digital input causes the E-Stop to trigger.

8.5.4 Diagnostic and Status Messages

Diagnostic Warning and Error Messages

There are the following diagnostic messages for the E-Stop function:

- Warning "E8034 Emergency-Stop activated"

  → E-Stop with best possible deceleration

- Error "F4034 Emergency-Stop activated"

  → E-Stop with best possible deceleration

- Error "F6034 Emergency-Stop activated"

  → E-Stop with velocity command value reset

Status messages

The status of the E-Stop input can be read via "P-0-0223, E-Stop input":

- Bit 0 = 0: 0 V at input

  → E-Stop triggers

- Bit 0 = 1: 24 V at input

  → E-Stop does not trigger

8.6 Compensation Functions / Corrections

8.6.1 Friction Torque Compensation

Brief Description

💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Extended Axis Functions

The behavior of a machine axis is negatively affected by static friction when starting or when reversing the direction. The drive-internal friction torque compensation allows the static friction to be compensated by adding a torque/force command value, depending on the direction of movement.
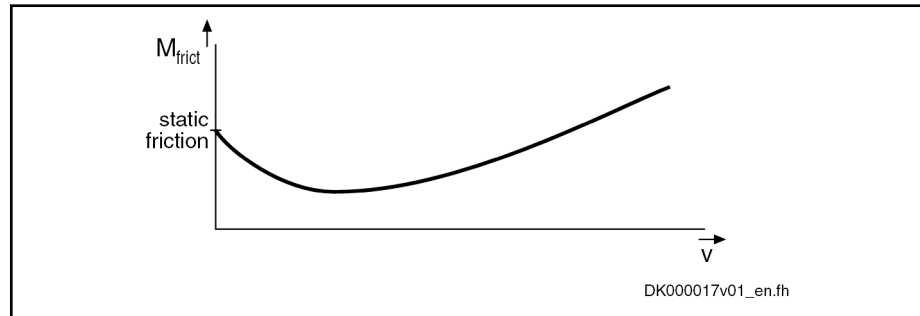

*Fig.8-10:*   *Friction torque curve with static friction*

☞   Friction torque compensation is mainly intended to be used in precision machine tools and to reduce the path errors caused by static friction. This applies particularly to circular errors at the quadrant transitions.

Pertinent parameters   • S-0-0092, Bipolar torque/force limit value

• S-0-0124, Standstill window

• S-0-0155, Friction compensation

Functional Principle

The principle of friction torque compensation is that the known friction component is pre-controlled (compensated) via an added torque/force command value and does not have to be compensated by the controller. This allows the control behavior to be improved (little lag error) especially when reversing the direction of movement. Precision of drive control is thereby increased.
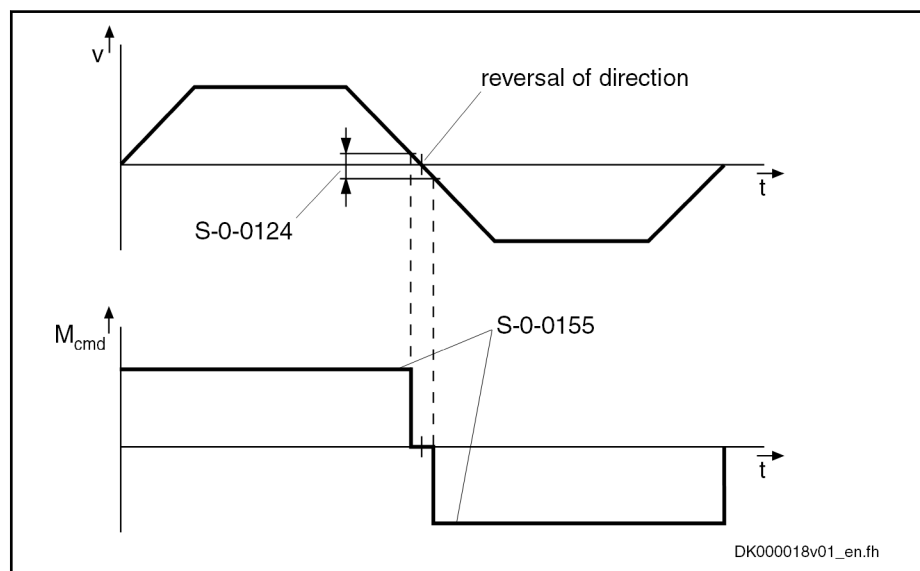
S-0-0124   Standstill window
S-0-0155   Friction compensation
Fig.8-11:   *Functional principle of friction compensation*

Extended Axis Functions

☞   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 operation mode

- Connect the master; it must allow moving the drive (e.g. jog function).

- Set and activate the travel range limits of the axis (cf. P-0-0090, S-0-0049, S-0-0050).

- If the friction characteristic of the axis is highly temperature-dependent, bring the drive to operating temperature before determining the compensation value.

- Set the torque limit to minimum value so that the drive cannot surmount the static friction and does not move in spite of command value input.

☞   If the drive can only be moved in position control, the lag error monitor has to be switched off, as otherwise the error "F2028 Excessive deviation" can occur during determination of the compensation value!

Determining the compensation value   Determine the compensation value (S-0-0155) in the following steps:

1. Preset a positive command value for the axis and increase "S-0-0092, Bipolar torque/force limit value" until the axis moves. The value then contained in S-0-0092 corresponds to the static friction component for positive direction (friction value_positive).

   Repeat this procedure in the other direction of 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 "S-0-0155, Friction compensation".

$$S\text{-}0\text{-}0155 = \frac{|\text{friction value\_positive}| + |\text{friction value\_negative}|}{2}$$

Fig.8-12:   Generating the average value for the entry into parameter S-0-0155

Extended Axis Functions

8.6.2   Axis Error Correction

Brief Description

The actual position value provided by the measuring system can differ from the real actual position value at the axis, e.g. at the point of chip removal in the case of metal-cutting machining, due to

- Inaccuracy of the measuring system,
- Transmission inaccuracy in mechanical transmission elements such as gear, clutch, feed spindle etc.,
- Thermal expansion of machine parts of the drive system.

IndraDrive controllers provide the following correction functions to compensate the mechanically determined position error sources:

- 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!

Extended Axis Functions

> ☞ All position-dependent correction functions only take effect after the position data reference was established for the respective encoder (see "Establishing the Position Data Reference").
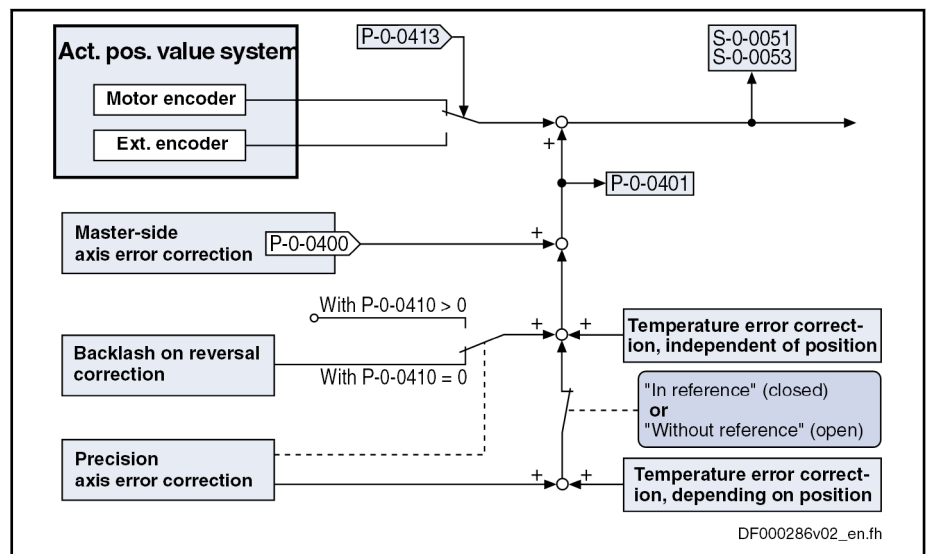
Active correction value

The sum of active correction values is displayed in "P-0-0401, Axis correction active correction value". The value refers to the encoder selected in P-0-0413.

Usability of the functions of axis error correction

It is possible to use several axis error corrections at the same time. The availability of the individual correction functions, however, depends on the functional package which has been activated.

The figure below illustrates the interaction of the subfunctions for axis error correction.

S-0-0051	Position feedback 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.8-13:   *Overview of the usability of the functions of axis error correction*

Backlash on Reversal Correction

> 💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

By means of the backlash on reversal correction, it is easily possible to correct backlash in the mechanical axis system.
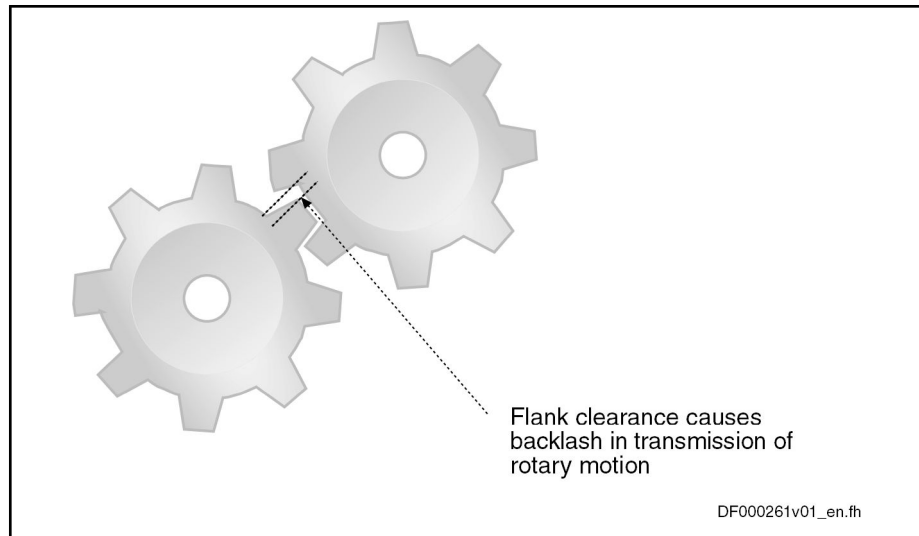
Extended Axis Functions

Fig.8-14:   Illustration of backlash with toothed wheels

The function is activated by inputting the backlash in parameter "S-0-0058, Reversal clearance". The actual position values of the encoder selected via P-0-0413 are corrected with the value from S-0-0058 (taking the direction of motion into account).

With position control   In position control, the direction of motion is recognized by the sign of the value of "P-0-0434, Position command value of controller", derived with respect to time.
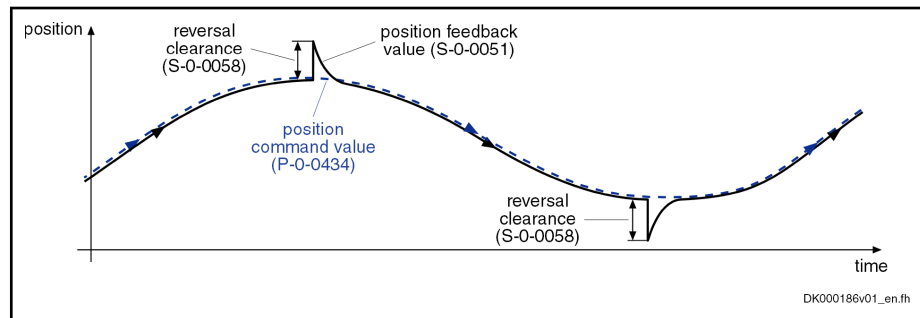
Fig.8-15:   Operating principle of backlash on reversal correction in position control (reversal clearance added in the case of negative sign of the value of P-0-0434)

With velocity control   In velocity control, reversal of the direction of motion is recognized when the velocity command value (S-0-0036) has exceeded the absolute value of the standstill window (S-0-0124) in positive or negative direction. The standstill window acts as hysteresis!
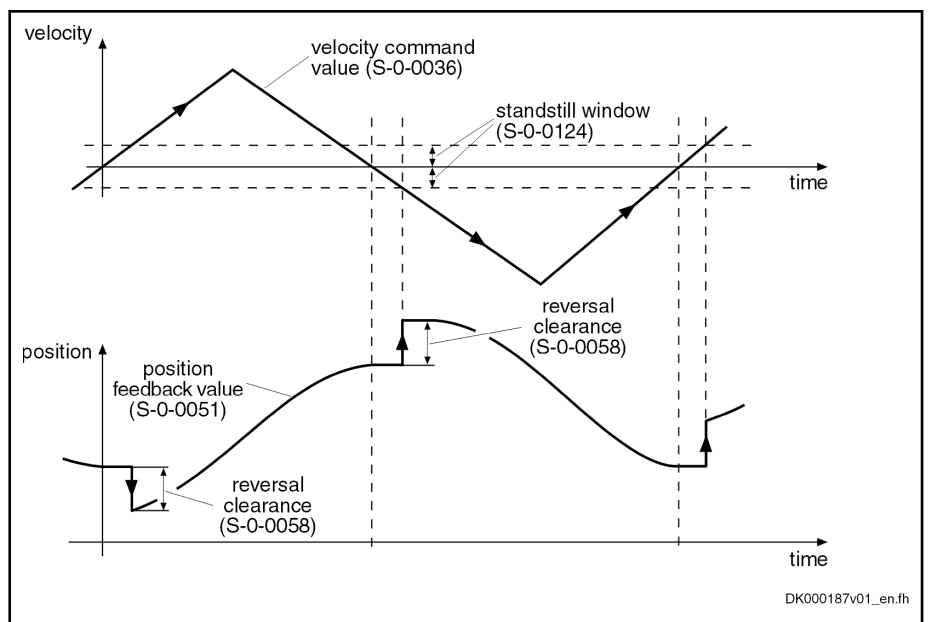
Fig.8-16:   Operating principle of backlash on reversal correction in velocity control (reversal clearance added when velocity command value leaves standstill window with negative velocity)

$$x_{act\_corr} = x_{act}$$

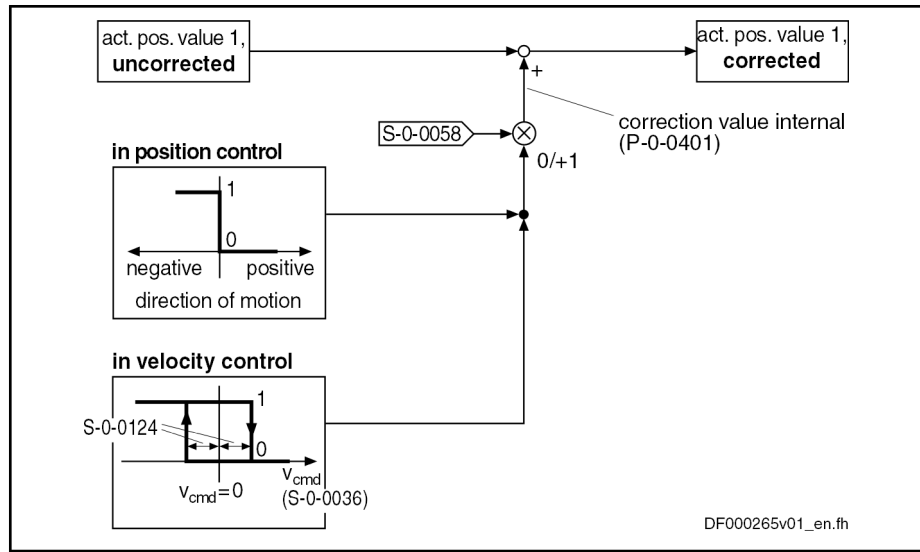| x_{act_corr} | Corrected actual position value 1 |
| x_{act} | Uncorrected actual position value 1 |

Fig.8-17:   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.8-18:   Corrected actual position value for negative direction

Extended Axis Functions

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.8-19:	*Block diagram of backlash on reversal correction*

Determining the reversal clearance

The following procedure is recommended for determining the value for "S-0-0058, Reversal clearance":

- By means of jog mode, move axis in positive direction

- Place dial gauge at appropriate spot of mechanical axis system and set it to zero

- Jog axis in negative direction, until change in pointer deflection of dial gauge is visible

The reversal clearance then is determined according to the following calculation:

$$\text{Reversal clearance} = \Delta x_{\text{control}} - \Delta x_{\text{dial gauge}}$$

$\Delta x_{\text{control}}$	Distance traveled from zero position of dial gauge according to control display
$\Delta x_{\text{dial gauge}}$	Distance traveled according to dial gauge referring to its zero position
Fig.8-20:	*Determining the input value for S-0-0058*

Precision Axis Error Correction

> Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The precision axis error correction is used for correcting non-linear encoder errors and non-linear errors of the mechanical system. The correction acts on the encoder selected by means of P-0-0413.

Pertinent parameters

- P-0-0401, Axis correction active correction value

- P-0-0408, Axis correction start position

- P-0-0409, Axis correction end position

- P-0-0410, Axis correction support point distance

Extended Axis Functions

- P-0-0411, Axis correction, correction table positive
- P-0-0412, Axis correction, correction table negative

Correction values

By means of the tables "P-0-0411, Axis correction, correction table positive" and "P-0-0412, Axis correction, correction table negative" it is possible to enter position- and direction-dependent correction values, so-called correction support points, within the correction range.

Correction range

The correction range lies within the value range that is limited by the parameters "P-0-0408, Axis correction start position" and "P-0-0409, Axis correction end position" The start position (P-0-0408) is preset by the user, the end position (P-0-0409) is determined on the drive side from the maximum value of the correction table support points used (from P-0-0411 and P-0-0412) and the support point distance (P-0-0410).

Correction support points

The positions for which correction support points are entered, are determined via the parameters "P-0-0410, Axis correction support point distance" and "P-0-0408, Axis correction start position" Between the correction support points, the correction values are calculated by cubic spline interpolation.

The actual position values of the encoder selected via P-0-0413 are corrected with the interpolated values of "correction table positive" (P-0-0411) or "correction table negative" (P-0-0412), taking the direction of motion into account.

Depending on the operation mode, the direction of motion is recognized in different ways:

- **In position control**, by the sign of the value of "P-0-0434, Position command value of controller", derived with respect to time
- **In velocity control**, when the velocity command value (S-0-0036) exceeds the absolute value of the standstill window (S-0-0124) in positive/ negative direction

  → The standstill window acts as hysteresis!

Activating precision axis error correction

The precision axis error correction is active, when a value greater than zero was entered in "P-0-0410, Axis correction support point distance" and the position data reference was established for the encoder the actual position value of which is to be corrected.
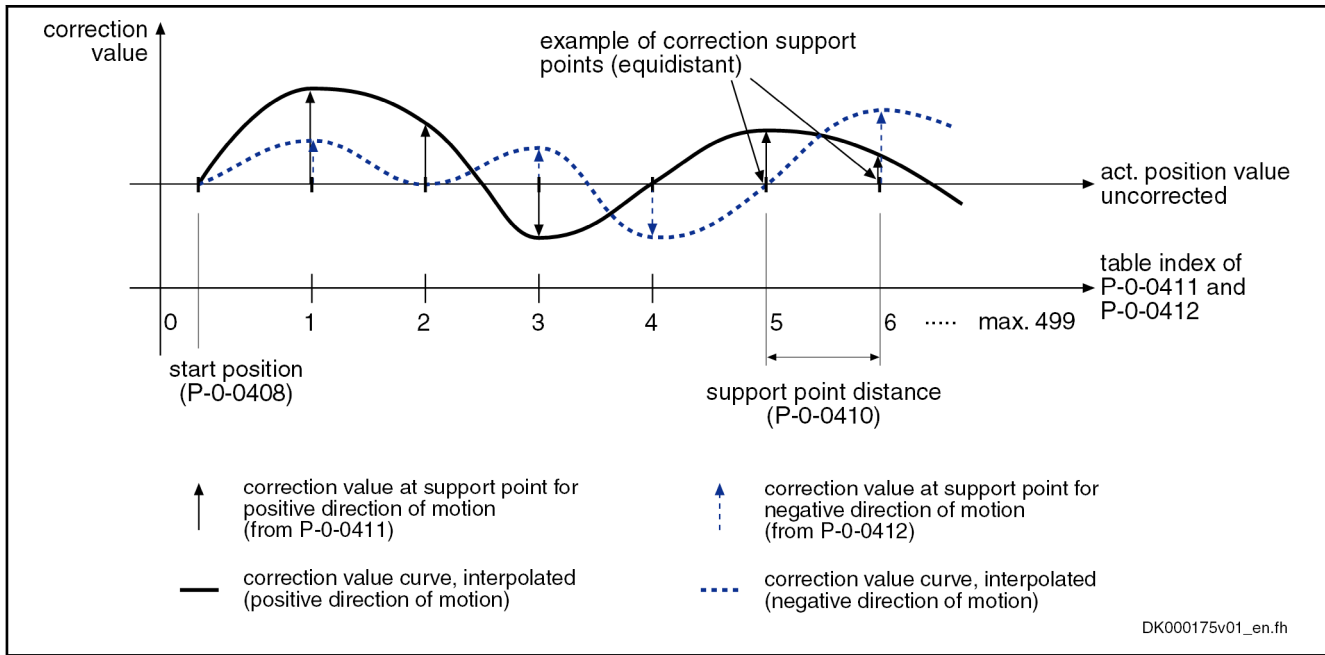
Extended Axis Functions

Fig.8-21:   *Illustration of correction value generation from the entered correction support points*

| Table in-dex	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.8-22:   *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:

Extended Axis Functions
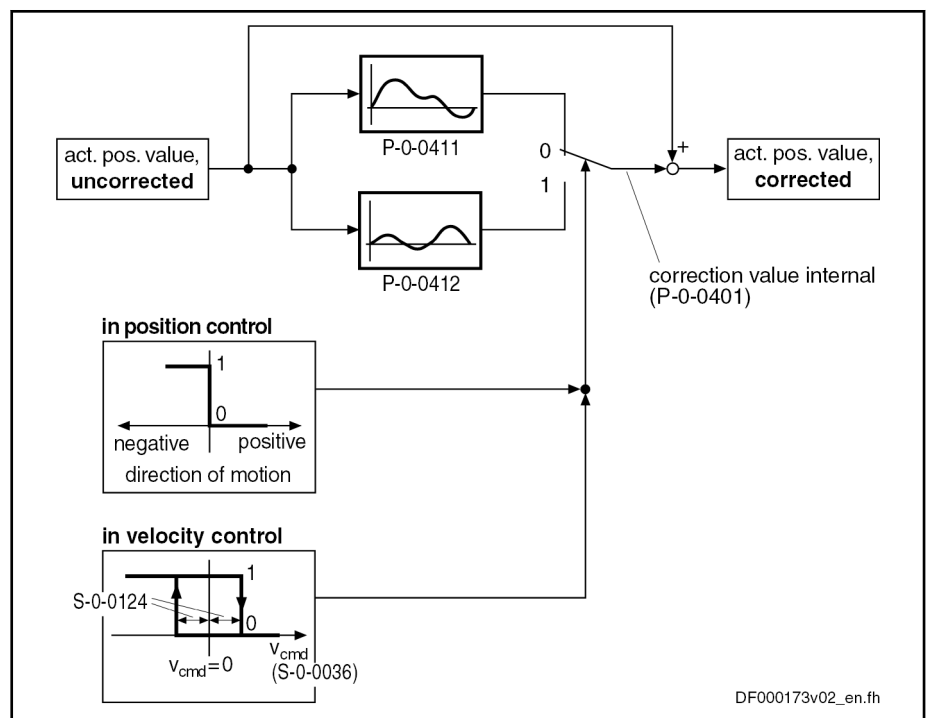
S-0-0036   Velocity command value
S-0-0124   Standstill window
P-0-0401   Axis correction active correction value
P-0-0411   Axis correction correction table positive
P-0-0412   Axis correction correction table negative
Fig.8-23:   *Block diagram of precision axis error correction*

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.8-24:   *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!

Extended Axis Functions

$$P\text{-}0\text{-}0410 = \frac{\text{length of correction range}}{\text{max. number of support points (P-0-0411;P-0-0412)}}$$

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.8-25:   *Determining the support point distance*

☞ When the value in parameter P-0-0410 equals zero, the precision axis error correction is deactivated!

Determining the start position   The start position for precision axis error correction defines the position of the first correction support point, the end position is determined by the controller and displayed in "P-0-0409, Axis correction end position".

Control-Side Axis Error Correction

💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

IndraDrive controllers provide the possibility of cyclically transmitting control-side correction values for the actual position value to the drive and using them for calculating the actual position value in the position control clock.

The control-side axis error correction is activated when "P-0-0400, Axis correction external correction value" has been included in the master data telegram. The correction values act on the encoder selected in "P-0-0413, Axis correction control word" .

☞ For control-side axis error correction, it is not necessary to establish the position data reference drive-internally for the respective encoder!
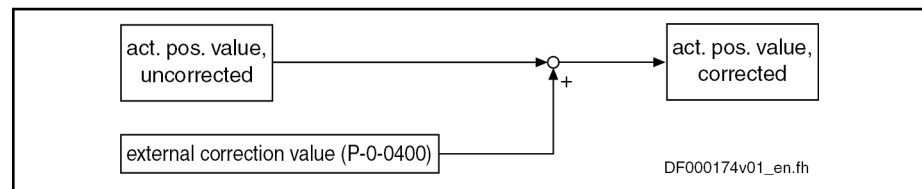

Fig.8-26:   *Control-side axis error correction*

Temperature Error Correction

General Information

💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The temperature error correction is used to correct actual position value errors that can occur due to temperature-dependent linear expansion at servo axes.

Dependencies of the actual position value errors of thermal cause   According to the mechanical configuration of the axis and the arrangement of the workpiece or tool, the actual position value errors caused by the influence of temperature can

- only depend on temperature

Extended Axis Functions

- or -

- depend on the temperature and on the axis position.

IndraDrive controllers therefore provide two possibilities of temperature error correction:

- Independent of position
- Depending on position

Measured temperature value

The measured temperature value has to be made cyclically available by the control master via the master communication. Separate measured temperature values are used for position-dependent and position-independent temperature error correction!

Reference temperature

The temperature-dependent correction functions are working relatively to a reference temperature at which there isn't any temperature-dependent actual position value error present. The reference temperature value has to be entered in "P-0-0402, Axis correction reference temperature".

☞ When actual position reference values are measured, all machine parts must have reference temperature!

Scaling

All temperature data is 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).
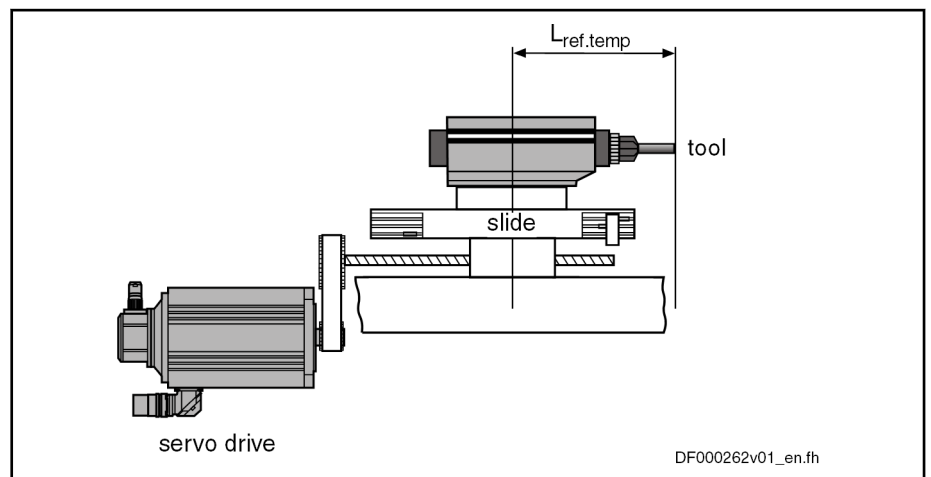
Position-Independent Temperature Error Correction

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.8-27:   *Applicational example for position-independent temperature error correction*

Extended Axis Functions

> ☞   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:
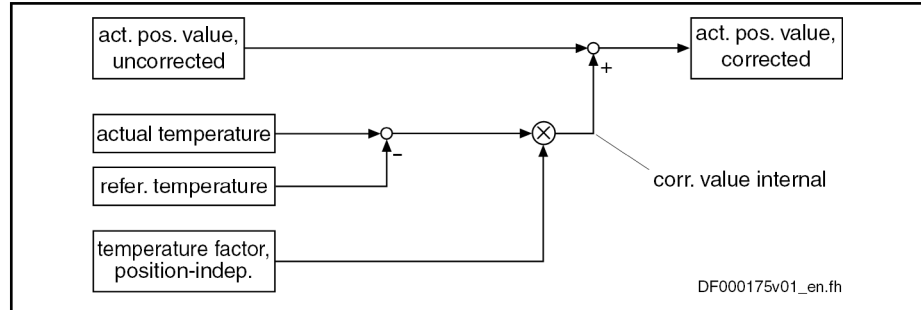

Fig.8-28:   *Position-independent temperature error correction*

Drive-internal determination of the correction value:

$$x_{korr} = P\text{-}0\text{-}0407 \times \left[(P\text{-}0\text{-}0405) - (P\text{-}0\text{-}0402)\right]$$

x_{corr}	Correction value, temperature-dependent
P-0-0407	Axis correction temperature factor pos.-independent
P-0-0405	Axis correction actual temperature pos.-independent
P-0-0402	Axis correction reference temperature

Fig.8-29:   *Determining the correction value*

Position-independent temperature factor   The value for "P-0-0407, Axis correction temperature factor pos.-independent" can be determined by means of calculation or measurement.

Calculating the value   If all data for the formula below can be unequivocally assigned due to the assembly of the mechanical system, the correction factor can be calculated.

$$P\text{-}0\text{-}0407 = \alpha \times L_{ref.\ temp.}$$

P-0-0407	Axis correction temperature factor pos.-independent
a	Linear expansion coefficient of the material
$L_{ref.temp.}$	Material length the temperature expansion of which has to be compensated (at reference temperature)

Fig.8-30:   *Calculating the value for P-0-0407*

$$P\text{-}0\text{-}0407 = \alpha \times L_{ref.\ temp.}$$
$$= 0{,}000018\ 1/K \times 100\ mm$$
$$= 0{,}00018\,mm/0{,}1K$$

P-0-0407	Axis correction temperature factor pos.-independent
a	For example, 0.000018 1/K, if temperature scaling °C (default scaling)
$L_{ref.temp.}$	For example, 100 mm (preferred scaling)

Fig.8-31:   *Example for calculating the value for P-0-0407*

Measuring the value   If it is impossible to calculate the value for P-0-0407 (e.g. if the object of correction consists of different materials), it has to be measured. A series of measurements determines the actual position value error of the object of cor-

rection at different temperatures. Depending on the temperature difference, a straight line can be approximated by means of the measuring points.
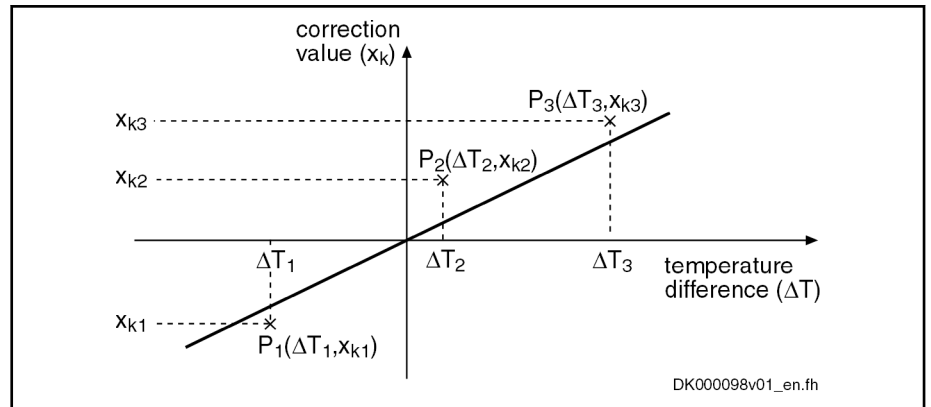
x_{kn}	Correction value (measured position value – actual position value (S-0-0051/S-0-0053))
ΔT_n	Temperature difference (measured temperature – reference temperature (P-0-0402))

Fig.8-32:   Approximated straight correction line on the basis of measured correction values at different ΔT

Calculation by means of the measured values

The gradient of the approximated straight line is the value of the position-independent temperature factor. By means of the value from the series of measurements, it is possible to calculate the position-independent temperature factor:

$$P\text{-}0\text{-}0407 = \frac{n \times \sum(\Delta T_n \times x_{kn}) - \sum\Delta T_n \times \sum x_{kn}}{n \times \sum \Delta T_n^{\,2} - \left(\sum \Delta T_n\right)^2}$$

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.8-33:   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"

☞   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 dedicated position for the position-dependent temperature error correction.

Extended Axis Functions

Pertinent parameters
- P-0-0402, Axis correction reference temperature
- P-0-0403, Axis correction reference position for temp. corr.
- P-0-0404, Axis correction actual temperature pos.-dependent
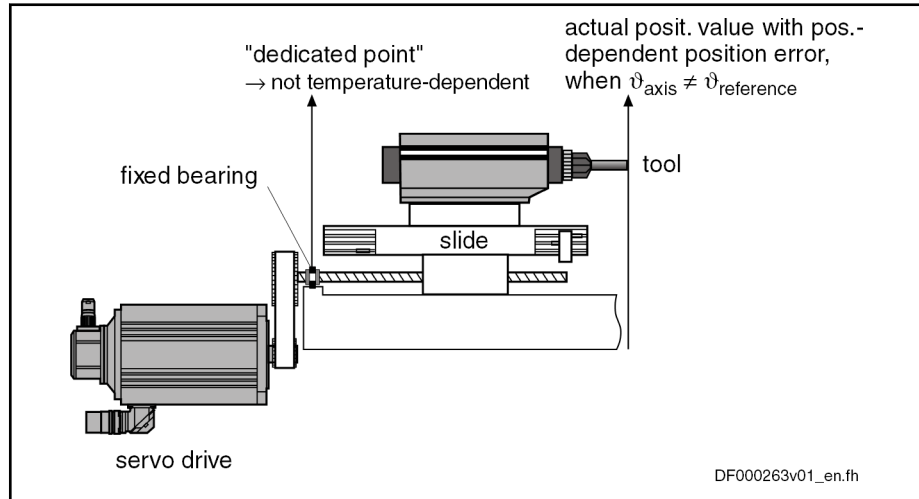- P-0-0406, Axis correction temperature factor pos.-dependent

Fig.8-34:   Applicational example of 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:
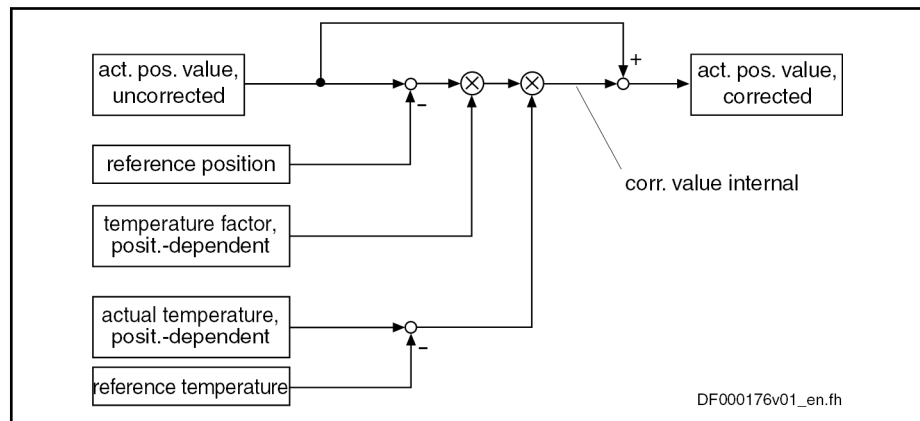
Fig.8-35:   Position-dependent temperature error correction

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:

Extended Axis Functions

$$x_{korr} = \left[(S\text{-}0\text{-}0051) - (P\text{-}0\text{-}0403) \right] \times \left[(S\text{-}0\text{-}0404) - (P\text{-}0\text{-}0402) \right] \times P\text{-}0\text{-}0406$$

X_{corr}	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 dedicated position for temp. corr.
P-0-0404	Axis correction actual temperature pos.-dependent
P-0-0402	Axis correction reference temperature
P-0-0406	Axis correction temperature factor pos.-dependent

Fig.8-36:   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 dedicated position for position-dependent temperature error correction and is entered in "P-0-0403, Axis correction reference position for temp. corr.".

Determine the dedicated position by:

- Direct measurement, if the arrangement of the mechanical transmission elements allows unequivocally recognizing the dedicated position

- or -

- A series of measurements with which the actual position value error is measured at axis positions clearly different from the dedicated position (at constant temperature that is clearly different from the reference temperature (P-0-0402))

Dedicated position by means of series of measurements

As in the majority of cases it is impossible to determine the dedicated point by direct measurement, determining the dedicated point by means of a series of measurements is of great importance.
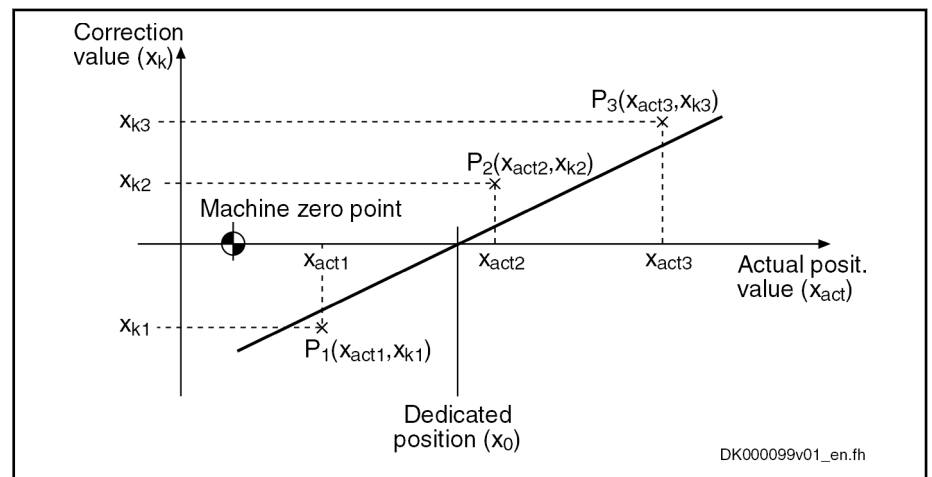

Fig.8-37:   Illustration of the reference position

By means of the measuring points (P_1, P_2, P_3), it is possible to determine the dedicated position by the equation of an approximated straight line:

$$x_0 = \frac{-b}{a}$$

x_0	Reference position
b	Intersection point of straight line and correction value axis (x_k)
a	Gradient of the straight line

Fig.8-38:   Determining the reference position

Extended Axis Functions

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.8-39:   *Auxiliary equation 1 for determining the reference 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.8-40:   *Auxiliary equation 2 for determining the reference 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.8-41:   *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:

Extended Axis Functions

$$\sum x_{kn} = (-0{,}03 + 0{,}01 + 0{,}025)\ \text{mm} = +0{,}005\ \text{mm}$$

$$\sum x_{act\_n} = (10{,}0 + 70{,}0 + 105)\ \text{mm} = 185{,}0\ \text{mm}$$

$$\sum \left(x_{act\_n} \right)^2 = (10^2 + 70^2 + 105^2)\ \text{mm}^2 = 16025\ \text{mm}^2$$

$$\sum x_{act\_n} \times x_{kn} = (-0{,}3 + 0{,}7 + 2{,}625)\ \text{mm}^2 = +3{,}025\ \text{mm}^2$$

Fig.8-42:   *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.8-43:   *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.8-44:   *Example: Auxiliary equation 2*

$$x_0 = \frac{-(-0{,}034621)}{0{,}00058845} = 58{,}83\ \text{mm}$$

x_0 Reference position

Fig.8-45:   *Example: Determining the reference position*

In order to be able to determine the dedicated position as exactly as possible, several series of measurements are to be recorded at different temperatures for position-dependent temperature error correction.

The resulting dedicated position is determined by the arithmetic mean of the calculated dedicated positions.

Position-dependent temperature factor

The value for "P-0-0406, Axis correction temperature factor pos.-dependent" is determined

- by means of the data of the mechanical transmission elements

- or -

- by means of series of measurements for actual position value error at different temperatures at an identical axis position.

Temperature factor by means of series of measurements

To determine the position-dependent temperature factor, it is necessary to record a series of measurements of correction values at different temperatures, at least at one position that clearly differs from the dedicated position.

Depending on the temperature difference, a straight line can be approximated through the measuring points.

Extended Axis Functions
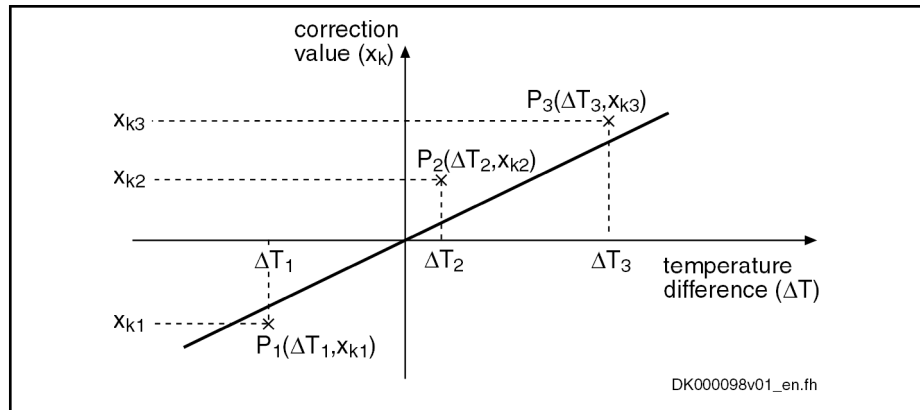
x_{kn}	Correction value (measured position value – actual position value (S-0-0051/S-0-0053))
ΔT_n	Temperature difference (measured temperature – reference temperature (P-0-0402))

Fig.8-46: Approximated straight correction line on the basis of measured correction values at different ΔT with identical actual position

The gradient of the approximated straight line is the value of the position-dependent temperature factor. By means of the value from the series of measurements, it is possible to calculate the position-dependent temperature factor:

$$P\text{-}0\text{-}0406 = \frac{n \times \sum (\Delta T_n \times x_{kn}) - \sum \Delta T_n \times \sum x_{kn}}{n \times \sum \Delta T_n^2 - \left(\sum \Delta T_n\right)^2}$$

P-0-0406	Axis correction temperature factor pos.-dependent
n	Number of measured values
ΔT_n	Temperature difference at which the correction value x_kn was determined
x_{kn}	Correction value at the temperature difference ΔT_n

Fig.8-47: 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-independent temperature error correction is activated, when the value of "P-0-0406, Axis correction temperature factor pos.-dependent"

☞ When the value in parameter P-0-0406 equals zero, the function of position-dependent temperature error correction is deactivated. This correction function requires position data reference for the measuring system to the corrected!

8.6.3 Quadrant Error Correction

Brief Description

💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

With 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, Velocity time range for quadrant error correction
- P-0-0439, Table of velocity pulse for quadrant error correction

Functional Description

With quadrant error correction, static friction possibly occurring at the reversal points of the direction of motion is compensated by adding an additional, pulse-shaped command value to the velocity command value at the output of the position 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.
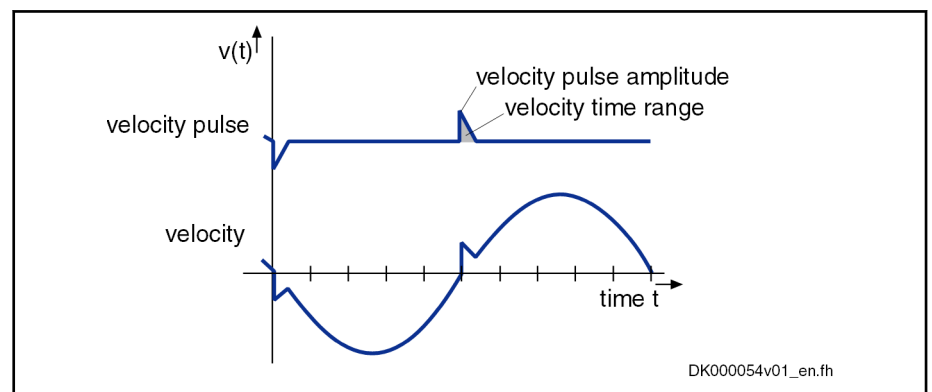

Fig.8-48:   Schematic curves of velocity pulse and velocity command value with quadrant error correction

The controller detects changes in the direction of motion by the time flow of the cyclic position command values.

Reference circle, reference radius

The settings for quadrant error correction are made when a reference circle is processed (radius of reference circle in "P-0-0436, Reference radius for quadrant error correction"), e.g. the circle that is demanded for the reference piece.

Extended Axis Functions

The amplitude of the velocity pulse of quadrant error correction is preset depending on the circular velocity. The pulse is added abruptly and decreases in a ramp-like way.

The higher the path velocity, the higher the pulse and the steeper it approaches zero, because the velocity time range of the pulse is independent of the velocity. It corresponds to the value entered in "P-0-0437, Velocity time range for quadrant error correction".

Estimation for the velocity time range

For the dimensioning of P-0-0437, it is recommended to estimate the required pulse amplitude and the duration of the pulse. This is to be done with regard to the path velocity and the duration for processing the reference circle (P-0-0436):

$$P\text{-}0\text{-}0437 = \frac{1}{2} \times \frac{a}{100\%} \times v_{path} \times \frac{b}{100\%} \times T_{circle}$$

P-0-0437	Velocity time range for quadrant error correction
a	Percentage of path velocity
v_{path}	Path velocity
b	Percentage of duration for processing of circle contour
T_{circle}	Duration for processing of circle contour

Fig.8-49:   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, Velocity time range for quadrant error correction

- P-0-0439, Table of velocity pulse for quadrant error correction

It is possible to store 20 pairs of values for velocity and pulse amplitude in the mentioned parameters, the velocities have to be entered in ascending order.

Determining the velocity pulse amplitude

The velocity pulse amplitude to be assigned to a current circular velocity is determined by means of the list parameter values:

- Between 2 pairs of values the pulse amplitude is interpolated in linear form, depending on the current path velocity.

- Below the lowest path velocity the pulse amplitude is set to zero.

- Above the highest path velocity the pulse amplitude assigned to the highest path velocity continues to take effect.

Determining the current circular velocity

The controller calculates the current circular velocity by means of the current acceleration command value of the drive calculated from the position command values. The reference radius (P-0-0436) is the basis for calculating the path velocity.

If the drive-internal resolution of the calculated acceleration command value is low, quadrant error correction sometimes is without effect. For this case, it is recommended to integrate the extended position command value ("P-0-0100, Position command value extension") in the cyclic master communication. This extends the decimal places of the position command value.

☞   Experience has shown that it is absolutely necessary to integrate the extended position command value (P-0-0100) in the cyclic master communication on the control side!

Activating the quadrant error correction

The quadrant error correction is activated by the control master by setting the respective bit of "P-0-0435, Control word of position controller". It is only advantageous to use the function when a circular form is to be machined in the part program.

The correction is to be activated at the earliest one clock after the start of circular interpolation so that the velocity pulse won't be added when the drive is starting. Otherwise high velocity pulses damaging the contour could be added, due to the mostly high starting accelerations, when the drive is starting.

For machining other contours, the quadrant error correction is to be deactivated. To do this, the respective bit of P-0-0435 is to be contained in the cyclic master communication and activated depending on the kind of machining.

☞   The quadrant error correction remains without effect when the value "0" is contained in "P-0-0437, Velocity time range for quadrant error correction".

Notes on Commissioning

For commissioning it is necessary to move the drive by the control master in cyclic circular interpolation. The quality of the circular form has to be determined, in the ideal case with measuring equipment for circular form testing.

Recommended commissioning steps

The quadrant error correction is to be commissioned in the following steps:

1. Make the following presettings:

   - Enter value for "P-0-0436, Reference radius for quadrant error correction"

   - Set quadrant error correction inactive in "P-0-0435, Control word of position controller"

   - Set "P-0-0437, Velocity time range for quadrant error correction" to "0"

   - Write for example 50% and 70% (list lines 1 and 2) of the maximum circular velocity to "P-0-0438, Velocity time range for quadrant error correction"

   - In "P-0-0439, Table of velocity pulse for quadrant error correction", write the value "0" to first two list lines

2. Move drive on control side in circular interpolation with 50% of maximum circular velocity and check quality of circular form with measuring equipment for circular form testing.

3. Set quadrant error correction active in "P-0-0435, Control word of position controller"

4. Write approx. 1% of current path velocity to list line 2 of "P-0-0439, Table of velocity pulse for quadrant error correction".

5. Increase value in "P-0-0437, Velocity time range for quadrant error correction" starting with low values, observe quality of circular form with measuring equipment; increase values until maximum quality of circular form has been reached.

   If quality of circular form does not improve, write lower or higher value to list line 2 of P-0-0439, depending on tendency of improvement of circular form quality.

6. After optimum value was written to P-0-0437, operate drive with other, different circular velocities in order to determine optimum values for P-0-0439.

☞   Observe interpolation data (see above) for the velocity pulse amplitude depending on the current path velocities (P-0-0438 and P-0-0439)!

Extended Axis Functions

8.6.4   Cogging Torque Compensation

Brief Description

> 💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Motors for which the magnetic excitation is realized with permanent magnets (e.g. synchronous motors) in many cases show cogging torques or cogging forces. Cogging torques/cogging forces already act on the moving component of the motor in the de-energized state and aim at moving it to a stable position.

When the motor is put into motion by control, the cogging torques/cogging forces act on the motor in a decelerating or accelerating way, according to the position. For applications in which minimum lag error or very constant velocity is important, the position-dependent cogging torques/cogging forces can have a negative effect.

To improve the synchronous operation and lag error behavior of synchronous motors, IndraDrive controllers provide cogging torque and cogging force compensation for drives with high demands on lag error and synchronous operation quality. For this purpose, additive torque command values take effect in drive control in a position-dependent way; these values require an unequivocal position reference between motor measuring system and motor. .

The position reference for incremental encoders is automatically established by searching for the reference marks. If this is impossible, switch to the function "position reference by means of homing" (P-0-1131, Control word of cogging torque compensation). In this case, the position reference is only established by the "homing" command which allows using encoders without a mark or with several marks.

Hardware requirements
The motor must have been equipped with a motor encoder. Cogging torque compensation is impossible with sensorless motor operation!

Pertinent parameters
- P-0-0162, C1800 Command Drive optimization / command value box
- P-0-0165, Drive optimization, control word
- P-0-0170, Drive optimization, acceleration
- P-0-0171, Drive optimization, velocity
- P-0-1129, Cogging torque compensation value
- P-0-1130, Table of cogging torque compensation values pos. Direction
- P-0-1131, Control word of cogging torque compensation
- P-0-1132, Table of cogging torque compensation values neg. direction
- P-0-1133, 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
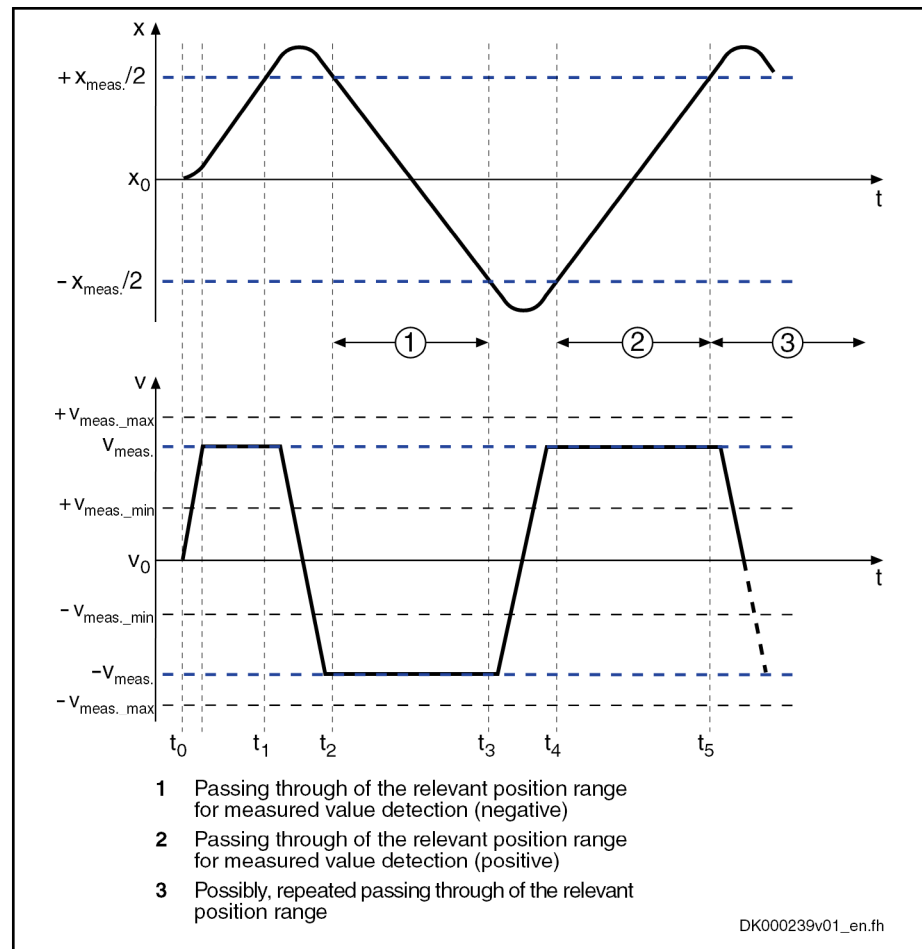
Pertinent diagnostic messages
- C1808 Drive not homed
- C4800 Command Determine cogging torque compensation table

Extended Axis Functions

- 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

Functional Description

Recording the cogging behavior

The cogging behavior of a motor is recorded once at constant velocity during initial commissioning. The torque/force command values currently generated by the velocity loop are recorded in a position-dependent way within a measured value detection range.

Before the measured values are recorded, the position reference must have been established between motor encoder and motor.

Determining the measured values by internal command value input

The tables of values for cogging torque compensation can be recorded by activating "P-0-0162, C1800 Command Drive optimization / command value box". In this case, the command value for the motion for measured value detection is generated internally.

Determining the measured values by control-master-side, external command value input

For mechanically connected axes (e.g. Gantry axes), however, the required velocity command value can also be set by the control master.

The command value must meet the following requirements:

- Rotary motor → Motion over minimum one motor revolution is required
- Linear motor → Motion over minimum one pole pair distance is required
- The measured value detection is only possible at constant velocity; the measuring velocity must be selected within the permitted value range, depending on the performance that has been set (see below).
- If the drive must move in both positive and negative direction, it is necessary to record measured values for positive and negative direction of motion. Otherwise, only command values for the intended direction of motion are required.
- The controller divides the range of measured value detection (motor revolution or pole pair distance) into a position raster with 1024 sections. For every section of the raster, a compensation value is stored that has been determined via 40 measured values. Depending on the selected measuring velocity, the detection range must be passed a maximum of 40 times and at least once in every required direction of motion.

Command value curve for bidirectional measured value detection

The figure below illustrates the position command value curve, to be preset by the control master, for measured value recording for cogging torque compensation in the event that the drive has to move in both directions.

Extended Axis Functions

x₀ — Position at starting point of time for the execution of the command

x_0 Position at starting point of time for the execution of the command
x_{meas} Measuring distance
v_{meas} Velocity during measuring value detection

Fig.8-50:   *Position command value curve for bidirectional recording of the measured values for cogging torque compensation*

☞   The position at the time of command start (x_0) is automatically set to the middle of the position range for recording of the measured value! When command "C4800 Command Determine cogging torque compensation table" is activated, the axis must be located at a sufficient distance to the limits of the travel range!

☞   Measured value recording must be carried out in both directions under the following conditions:

- Axis has **no** modulo scaling

- or -

- Axis with "modulo" scaling and "shortest distance" command value mode (see "Notes on Commissioning" below)

Command value curve for unidirectional recording of the measured values

The figure below illustrates the position command value curve, to be preset by the control master, for measured value recording for cogging torque compensation in the event that the drive is to move in one direction only.
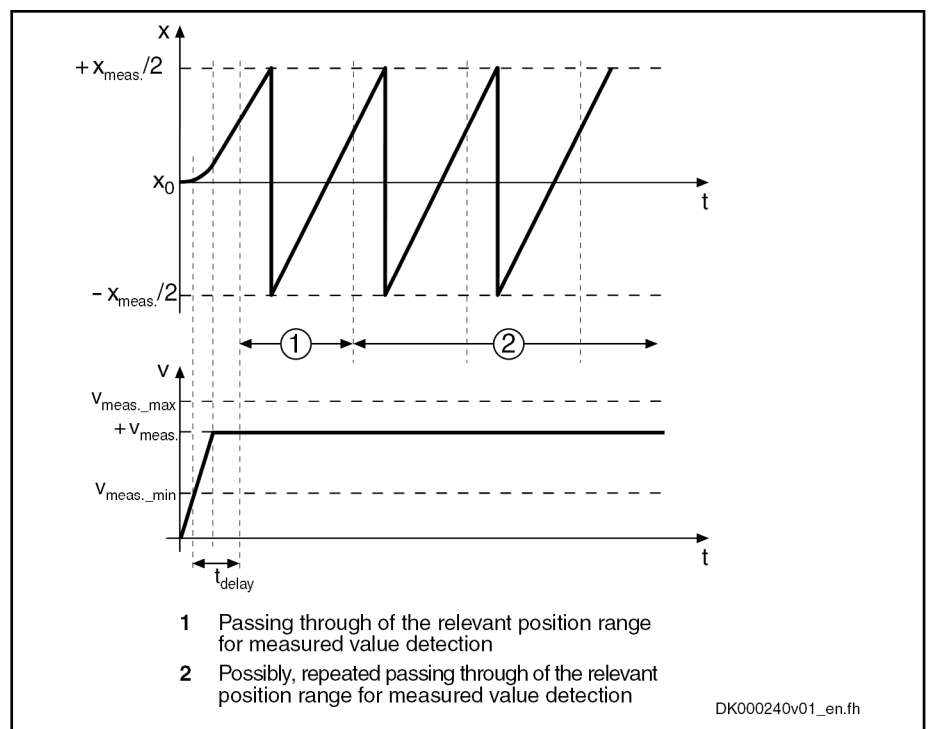
Extended Axis Functions

x_0	Position at starting point of time for the execution of the command
x_{meas}	Measuring distance
v_{meas}	Velocity during measuring value detection
t_{delay}	Delay period of 0.5 s before detection of the measured values
Fig.8-51:	*Position command value curve for unidirectional recording of the measured values for cogging torque compensation*

The unidirectional detection of the measured values for the table for cogging torque compensation is carried out in that direction which corresponds to the preceding sign of the command value, which has been recognized for the first time after activation of the command "C4800 Command Determine cogging torque compensation table".

Under the following conditions, measured value detection can only be carried out in one direction:

- Axis with "modulo" and command value mode "positive direction" or "negative direction"

Range of values for measuring velocity

The measuring velocity refers to the motor output shaft or the slide of the linear motor. For load reference the command value input is to be selected such that the motor-side velocity lies in the permitted value range! The value range depends on the selected control performance.

Extended Axis Functions

	Minimum measuring velocity v_{meas_min}		Maximum measuring velocity v_{meas_max}	
Performance	Rotary (in 1/min)	Linear [1] (in mm/min)	Rotary (in 1/min)	Linear [1] (in mm/min)
Economy	0,47	35,16	58,6	4394,5
Basic	0,94	70,31	117,2	8789,1
Advanced	1,88	140,63	234,4	17578,1

1)   Velocity for linear motors with a pole pair distance of 75 mm

Fig.8-52:   *Value range for the measuring velocity depending on the performance set*

$$V_{Meas\ limit(PWT)} = V_{Meas\_limit\ (75mm)} * \frac{PWT}{75mm}$$

PWT   Pole pair distance of linear motor

$V_{meas\_limit(PWT)}$ Limit value of measuring velocity depending on the pole pair distance of a linear motor

$V_{meas\_limit(75\ mm)}$ Limit value of measuring velocity for linear motor with PWT = 75 mm according to top table

Fig.8-53:   *Conversion of measuring velocity limit values for linear motors*

☞   When the maximum measuring velocity is used, the range for the measuring value detection must be passed at least 40 times, for minimum measuring velocity at least once.

Recording of correction values

Ideally, the cogging torque correction values of a motor is to be determined when the machine has not yet been connected.

After recording the 40 required measured values within each position raster section, a torque/force correction value for each of these position sections is determined and stored in the cogging torque compensation tables. Every table has 1024 values and is stored in the parameters below:

* P-0-1130, Table of cogging torque compensation values pos. Direction
* P-0-1132, Table of cogging torque compensation values neg. direction

☞   "P-0-1133, Status word of cogging torque compensation" displays whether the required number of measurements per position raster has been reached.

Recording with motor axis group

If, for example, the cogging torques for a rotary synchronous kit motor are to be compensated, the recording of the values for the tables for cogging torque compensation is only possible in the motor-axis group as the motor is only operational after it has been installed in the machine or the axis.

If a kit motor moves a shaft, which is not rotationally symmetrical (unbalanced), and its cogging torques are to be compensated, the influence of the rotor-position-dependent inertia can be drive-internally eliminated from the measured compensation tables by means of calculation. The settings required for this must be executed in "P-0-1131, Control word of cogging torque compensation".

☞ The influence of an unbalanced mass can only be eliminated when the unbalance occurs periodically with reference to a rotor revolution!

For linear synchronous motors (kit motors) too, recording of the cogging torque compensation tablevalues is only possible in the motor-axis group, however eliminating axis-side influences only makes sense when they equally affect the entire travel range (e.g. weight of a vertical axis, friction etc,).

Activating cogging torque compensation

The cogging torque compensation must be activated via the respective bit of "P-0-1131, Control word of cogging torque compensation".

Effect of cogging torque compensation

Position-dependent adding of torque/force correction values, as is required for cogging torque compensation, is carried out below the adjustable velocity threshold "P-0-1134, Velocity threshold for attenuation of cogging torque compens") with the percentage of the correction values entered in "P-0-1139, Cogging torque compensation adaption factor" (default:100%).

Above the switch-off velocity threshold in ("P-0-1135 Velocity threshold for switching off cogging torque compens."), which can be set, compensation is totally ineffective (0%), because delays due to calculating time might possibly worsen the motor's cogging torque. Between the lower and the upper velocity threshold, the effectiveness of the correction values is linearly reduced from the current value of P-0-1139 to 0%, depending on the actual velocity value.

With low speeds, intermediate values interpolated with regard to the actual position value are generated from neighboring correction values of the position raster and take effect depending on the position cycle time, in order to keep the changes of the additive torque/force command values (compensation values) as continuous as possible.

The effect of the compensation values can be intensified or attenuated stationarily or on the side of the control master (process-dependent) with "P-0-1139, Cogging torque compensation adaption factor", the reference values (100%) are the table values, see Parameter Description. The currently effective position-dependent compensation command value is displayed in parameter "P-0-1129, Cogging torque compensation value".

☞ Parameter "P-0-1129, Cogging torque compensation value" is set to "0", when the (drive-internal) cogging torque compensation is deactivated.

Torque/force limitation and cogging torque compensation

The following limitations affect the total torque/force command value, including the current compensation value:

- S-0-0092, Bipolar torque/force limit value
- P-0-0109, Torque/force peak limit

The following limitations do not affect the (additive) compensation value, merely the output of the velocity loop:

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative

External cogging torque compensation

If the drive-internal cogging torque compensation is not activated, compensation values from outside can affect the motor control via parameter "P-0-1129, Cogging torque compensation value". A control master (e.g. via MLD etc.) can describe cyclically that processing in the controller is being performed in the velocity loop clock. The value is inputted unchanged into the motor control as an additive torque/force command value.

Extended Axis Functions

☞ Functionalities of drive-internal cogging torque compensation, like velocity-dependent attenuation (P-0-1134, P-0-1135) or adaption by adaption factor (P-0-1139) are not available with external cogging torque compensation.

If drive-internal cogging torque compensation is activated, values written externally to P-0-1129 are ignored.

☞ Drive-internal cogging torque compensation is only available in functional packages "Servo" and "Sync"! Cogging torque compensation values can be specified externally in the base package via P-0-1129!

Notes on Commissioning

Procedure

The compensation of cogging torque/cogging force through the IndraDrive firmware is carried out in two steps during **initial commissioning**:

1. Recording and storing of the position-dependent cogging behavior over one motor revolution or one pole pair distance and generating position-dependent torque and force correction values for the compensation of the cogging behavior.

☞ In most cases, the travel range of linear motors covers several pole pair distances. It is assumed that the position-dependent cogging force curve is the same over all pole pair distances of the travel range!

2. Activation of the cogging torque compensation within a velocity range of the drive

The cogging torque compensation activated in the drive parameter set only takes effect **when the drive is operated** and after it has been switched on again, after the position reference has been established:

- With absolute measuring systems, the position reference is always available, i.e. compensation takes immediate effect.

- With relative measuring systems, the position reference must first be established. This takes place automatically when the motor is moved during operation or by homing the drive with a command.

Initial Commissioning

General mechanical conditions

The values for the cogging torque compensation table are determined during the initial commissioning of the motor. If possible, the motor is not yet to be connected to the machine for this!

If the motor, as is obligatory for kit motors, has already been mounted at or in the axis, it is preferably to be able to move in a load-free way!

Notes on commutation setting

The commutation offset (for synchronous motors) must have been optimized and, for relative motor encoders, stored with relation to the reference point! The cogging torque compensation only leads to an improvement of the motor characteristics if the commutation offset is the same so that it can be reproduced (Use "Optimum commutation setting with regard to reference point" for relative motor encoder!).

Extended Axis Functions

Notes on velocity and position loop setting	In addition, the parameters of the velocity loop must have been optimized for the axis, in order for the correction values for the cogging torque compensation tables are determined with the appropriate or required velocity control loop settings or filter settings.

When the axis is moved in position control, lagless command value input is highly recommended to ensure that the velocity command value generated for the measured value recording is as constant as possible. Keep the proportional gain of the position control loop (Kv) as low as possible.

Establishing the position reference

First, establish the position reference between motor and motor encoder:

- Absolute motor encoder (single-turn or multi-turn motor encoder): Execute command "P-0-0012, C0300 Set absolute position procedure command".

- Relative motor encoder with reference mark: Move the motor over the reference mark of the encoder. For motor encoders with distance-coded reference marks, two neighboring marks must be passed.

- Relative motor encoder without reference mark or several per motor revolution: Execute the command "S-0-0148, C0600 Drive-controlled homing procedure command". In "P-0-1131 Control word of cogging torque compensation" "Position reference by means of homing" has to be set.

☞ For absolute motor encoders, no motion of the axis is required before measured value detection!

Internal recording of correction values for cogging torque compensation

Through activation of "P-0-0162, C1800 Command Drive optimization / command value box" and with appropriate setting in "P-0-0165, Drive optimization, control word", the controller itself generates the curve of the velocity command value for the determination of the correction values.

Make the required settings in the corresponding IndraWorks dialog:
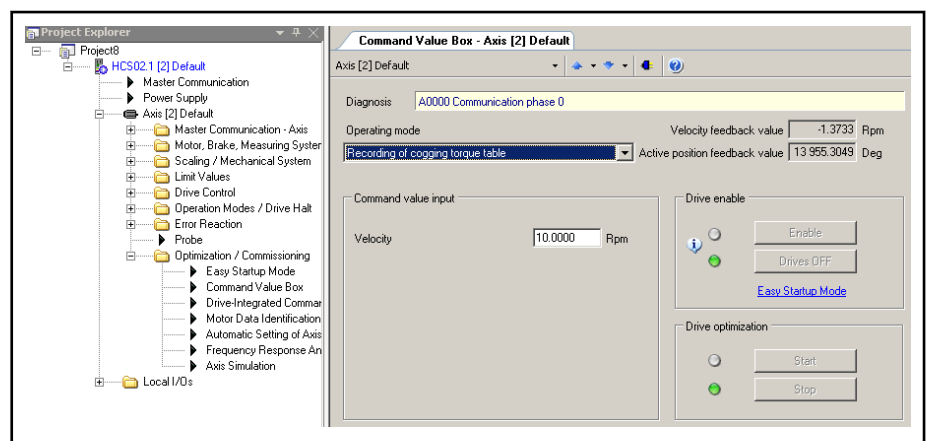
Fig.8-54:   IndraWorks dialog to select the drive-internal recording of the cogging torque table and input the velocity

Depending on the motor design (rotary or linear), the controller generates a velocity command value curve that cause a movement with constant velocity via 1.5 motor revolutions (rotary) or via 1.5 pole pair distancen (linear). The travel velocity is preset by the user via "P-0-0171, Drive optimization, velocity" and is to be defined according to the permitted value range (see further above). The duration of the motion at constant velocity is given by the preset velocity value. The maximum acceleration occurring in the command value range is preset via "P-0-0170, Drive optimization, acceleration" and can be limited by the user to a value permitted for the mechanical axis system.

Extended Axis Functions

☞   The total motion range extends with bidirectional measured value recording to 1.5 motor revolutions with rotary motors and 1.5 pole pair distances with linear motors (synchronous operation, v = constant) and the respective revolutions or distances required for reversal of motion (reversal).

A quasi-endless travel range is required with unidirectional measured value recording, only possible with rotary axes!
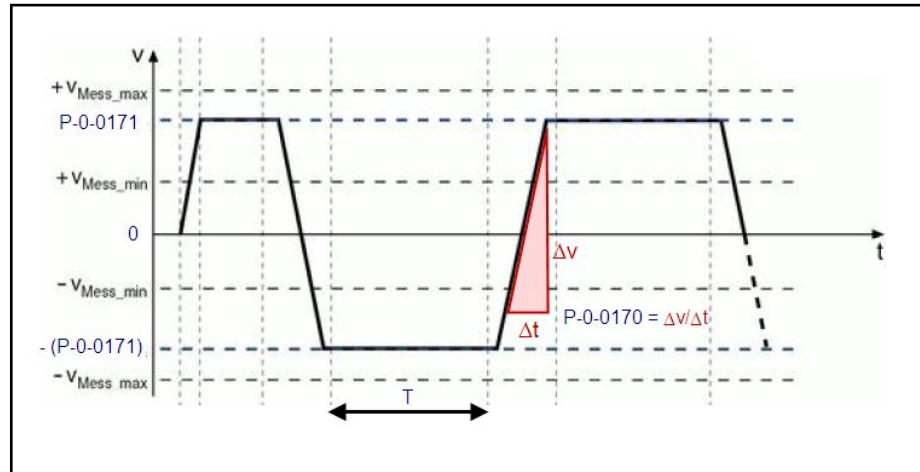
P-0-0170	Drive optimization, acceleration
P-0-0171	Drive optimization, velocity
T	Duration of motion at constant velocity for measured value detection for a complete motor revolution or pole pair distance

Fig.8-55:   Velocity command value curve for bidirectional recording of the measured values for cogging torque compensation

NOTICE   **The axis performs independent movements → Property damage might occur on inobservance of the general conditions when starting the command C1800!**

- Ensure that the axis does not travel into the collision area by the drive-internal command value by setting an appropriate initial position!

- Select as high an acceleration value as possible, in order to reach a constant velocity command value over the shortest possible distance! This minimizes the travel distance if the motion is carried out in both directions.

- Select as low a position control loop amplification as possible S-0-0104 (Kv) to improve smoothness of running at constant velocity!

- Ensure with the presetting of unidirectional command values (modulo scaling and unidirectional command value mode) that the motor shaft can rotate infinitely!

External command value input for determining correction values

☞   Master-side command value input is only required, when the drive-internal command value input cannot be used, e.g. for mechanically connected axes which can only be moved together via the control master.

To record the cogging torque compensation tables via command values externally set, the control master must make available a routine, which provides the required velocity command value for the axes to be moved.

Extended Axis Functions

External command value input: determining velocity for measuring value recording

The velocity for measuring value detection is to be determined according to the requirements of the above table ("Value Range for the Measuring Velocity"). With maximum velocity, passing the measuring value range up to 40 times may become necessary!

The minimum travel range of the motor is to be evaluated and a master-side command value profile is to be defined (programmed) such that the motor passes through the measuring value detection range an adequate number of times. The following applies to the direction of movement:

- Bidirectional for motion of the axis both positive and negative direction (starting position is the centre of the measuring value detection range)

- Unidirectional in the direction of axis movement with movement of the axis in only one direction

External command value input: Preset command value profile

For recording the values for the cogging torque compensation tables, "P-0-1138, C4800 Command Determine cogging torque compensation table" must be activated and the required command value profile must be set.

☞ For recording the values for the cogging torque compensation table for axes with position scaling "modulo" (setting in S-0-0076) the following conditions must be taken into consideration:

- If in the parameter "S-0-0393, Command value mode" the option "shortest distance" has been set, the controller expects command values for both motion directions of the motor ("bidirectional").

- If in "S-0-0393, Command value mode" the option "positive direction" or "negative direction" has been set, the controller expects that the axis has only one permitted motion direction and therefore command values are only preset for one motion direction ("unidirectional").

During the motion according to the command value input, measuring values are recorded, from which the values for the correction tables are determined. In "P-0-1133, Status word of cogging torque compensation" it is displayed when enough measuring values have been recorded in order to complete the command value input.

After completion of the measuring value recording, the correction values for the cogging torque compensation table are automatically determined and appropriately stored in the position raster. Now the execution of the command C4800 can be terminated.

☞ During the recording of measured values, "C48" flashes on the display. As soon as the measuring value recording is completed, the flashing is also stopped and "C48" is displayed continuously!

☞ After the replacement of the motor or motor encoder, the values for the cogging torque compensation table must be determined again!

Activating the function

Cogging torque compensation is activated by setting the corresponding bit in "P-0-1131, Control word of cogging torque compensation"!

Checking effectiveness

The effectiveness of the cogging torque compensation can be evaluated with the comparison of various status variables of the drive between active and non-active function. With low travel velocities, the effect of the compensation can be recognized most clearly.

Extended Axis Functions

The values of the status variables relevant for the comparison are contained in the following parameters:

- S-0-0040, Velocity feedback value
- S-0-0189, Following distance
- P-0-0049, Effective torque/force command value

With "P-0-1139, Cogging torque compensation adaption factor" the effect of the stored compensation values can be attenuated or intensified and the compensation values can be attenuated depending on the velocity until the system switches off.

The corresponding velocity thresholds can be set in the following parameters:

- P-0-1134, Velocity threshold for attenuation of cogging torque compens
- P-0-1135, Velocity threshold for switching off cogging torque compens.

For this purpose, the axis must be controlled with command value characteristics which result in constant axis velocities of different levels. The amplitude of the above stated state variables must be evaluated without and with active cogging torque compensation. The values for P-0-1134 and P-0-1135 are to be determined such that the amplitudes have minimum values **with active compensation**.

Appropriate command value characteristics can be generated by:

- Internal command value box: Reversing between two axis positions or stepwise operation in velocity or position control, see IndraWorks dialog
- External command value input by control master, using the same command value profile as for the recording of the cogging torque compensation tables

☞   The velocity range in which it is advantageous to use cogging torque compensation can be increased by adjusting the value "P-0-1136, Lead time cogging torque compensation", if necessary!

Possible problems with measured value recording

In case the command value does not comply with the requirements (see above), measured value recording is stopped and the execution of the command is aborted with the corresponding error message:

- C4801 Cogging torque compensation: Measuring vel. too high
- C4802 Cogging torque compensation: Measuring vel. too low
- C4803 Cogging torque compensation: Inadmissible acceleration

If an error occurs when cogging torque compensation table is stored, the following message is generated:

- C4804 Cogging torque comp.: Err. when storing corr. val table

If, with a relative motor encoder, the drive has not read the reference marker(s) on activation of the command C4800, the following message is generated:

- C1808 Drive not homed

Operating the drive

Establishing the position reference

☞   For the operation of the drive with active cogging torque compensation, the respective bit must be set in "P-0-1131, Control word of cogging torque compensation".

The cogging torque compensation activated in the drive parameter set only takes effect when the position reference between motor encoder and motor has been established. The position reference is generally automatically established, when the controller has read the reference mark of a relative motor encoder or two neighboring reference marks of a relative, distance-coded motor encoder. With absolute motor encoders, compensation takes immediate effect without the motor having to move.

If a relative motor encoder has no reference marks or has several per motor revolution, the drive must be homed to establish the position reference between the motor encoder and the motor.

☞ If the position reference can only be established by homing, this must be correspondingly configured in the control word (P-0-1131).

The cogging torque compensation activated in the drive parameter set takes immediate effect after the position reference has been established!

8.6.5   Correction of the Torque/Force Constant

Brief Description

Fields of application

💡 **Base package** of all firmware versions in **closed-loop** characteristic

Displaying the motor load, load limit values

With IndraDrive devices, the current motor load is determined on the drive side and displayed. The load can be limited via the controller.

You can select the unit of the load display and of the limit value input:

- Percentage-based, related to the continuous or nominal motor current
- Physical, values in "Nm" (rotary) or "N" (linear)

The load of the motor is determined by means of the measured motor current; with physical scaling, the controller determines the motor torque or force by using the currently flowing current for calculating the motor-type-specific torque or force constant.

If torque/force precision up to approx. +/- 5% is required (e.g., for load limitation) due to the mechanical axis system or process technology, the controller provides the "correction of torque/force constant". In this case, the motor-type-specific value is corrected depending on the current motor current, the motor temperature and the average speed.

☞ Due to the downward compatibility of the firmware and possibly unavailable parameter values (e.g., for third-party motors), this correction must be separately activated!

Pertinent Parameters

- P-0-0448, Temperature-dependent torque/force coefficient
- P-0-0449, Speed-dependent torque/force coefficient
- P-0-0450, Current torque/force constant
- P-0-0556, Config word of axis controller
- P-0-3055, Maximum motor torque/force, encoder memory
- P-0-3056, Nominal motor torque/force, encoder memory

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- P-0-3057, Speed-dependent torque/force coefficient, encoder memory
- P-0-3058, Temperature-dependent torque/force coefficient, enc. memory
- S-0-0533, Nominal torque/force of motor
- S-0-0534, Maximum torque/force of motor

Pertinent Diagnostic Messages

- None -

Functional Description

Determining the torque/force

The torque or force generated by a motor is determined on the drive side by means of the measured motor current and a so-called "torque/force constant":

$$\text{Rotary motor: } M_i = K_M * I_q; \qquad K_M = f_{(I_q, J)}$$
$$\text{Linear motor: } \quad F_i = K_F * I_q; \qquad K_F = f_{(I_q, J)}$$

M_i	Inner torque of the rotary motor
K_M	Torque constant, current- and temperature-dependent
I_q	Motor current, torque-/force-generating component
F_i	Inner force of the linear motor
K_F	Force constant, current- and temperature-dependent
θ	Motor temperature

Fig.8-56:   *Current dependence and temperature dependence of the motor torque or force*

Physically, the so-called "torque or force constant" is, however, not a static value, it depends on:

- Value of the currently flowing motor current: Reduction in currents greater than $I_{nominal}$

- Temperature of motor winding and rotor: Reduced when temperature rises

Percentage-based scaling

For reasons of compatibility with the existing firmware, the percentage-based scaling of torque/force data is the default setting. The percentage of the drive load and percentage limit values are current-related and refer to "S-0-0111, Motor current at standstill".

☞   With percentage-based scaling of the torque/force data, there is generally reference to the current in the default status, the reference value is "S-0-0111, Motor current at standstill" * "P-0-0051, Torque/force constant".
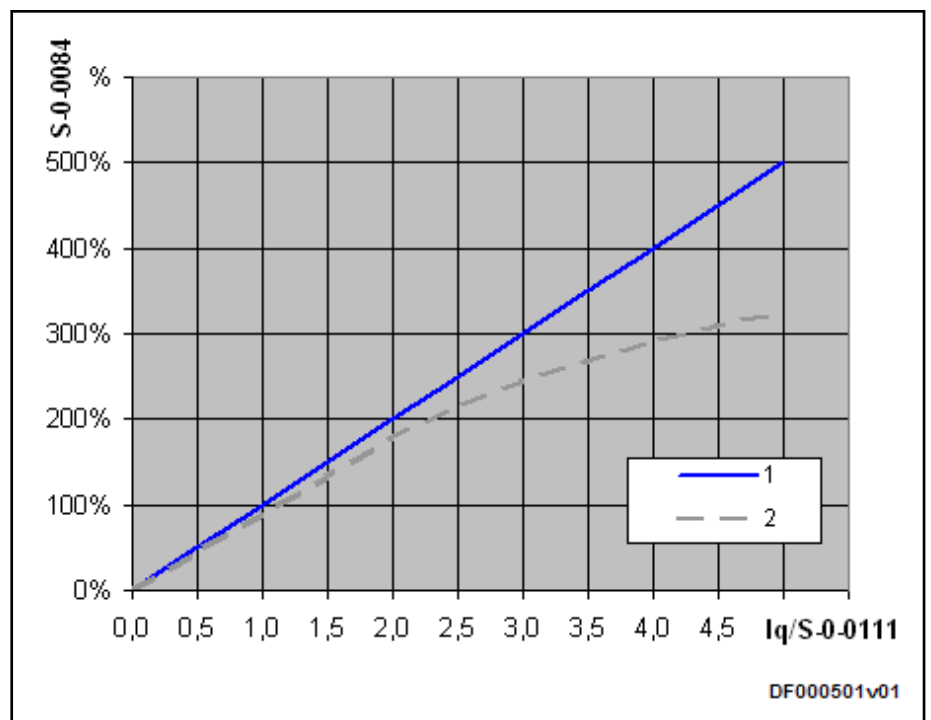
| Graph 1 | Current-dependent load determined on the drive side (default, without K_M correction) |
Graph 2	Effective, current-dependent load at the motor (basic curve)
Iq	Motor current, torque-generating component
S-0-0111	Motor current at standstill
S-0-0084	Torque/force feedback value in percent
Fig.8-57:	*Comparison of torque/force curves, on drive side and motor side, percentage-based scaling, 100% value = P-0-0051*S-0-0111*

Physical scaling

If, for example, due to the setting of load limit values, physical scaling (rotary: Nm; linear: N) is selected, note that the drive-internal load determination, in the default status, takes place with:

$$\text{Actual value:} \quad M_i \text{ or, } F_i = P\text{-}0\text{-}0051 \cdot P\text{-}0\text{-}0043$$

$$\text{Command value:} \quad M_i \text{ or, } F_i = P\text{-}0\text{-}0051 \cdot P\text{-}0\text{-}0038$$

M_i, F_i	Inner torque or force of the motor
P-0-0051	Nominal value of the torque/force constant, static value, specific to motor type
P-0-0043	Torque-generating current, actual value
P-0-0038	Torque-generating current, command value
Fig.8-58:	*Drive-internal calculation of motor torque or force (default)*

This drive-internal calculation leads to deviations from the torque or force action at the motor. This has a particularly negative effect when torque/force limit values are entered because the value which the limit value causes at the motor can strongly deviate, possibly worsening the drive performance considerably:

Extended Axis Functions
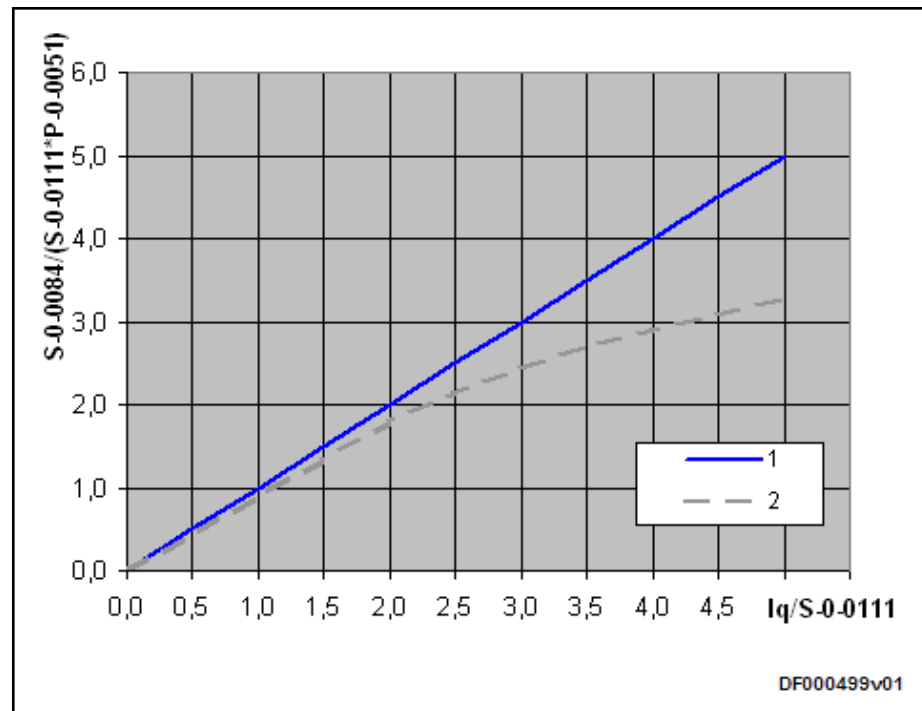
Graph 1	Current-dependent load determined on the drive side (default, without K_M correction)
Graph 2	Effective load at the motor (basic curve)
Iq	Motor current, torque-generating component
S-0-0111	Motor current at standstill
S-0-0084	Torque/force feedback value in Nm or N
P-0-0051	Torque/force constant
Fig.8-59:	*Comparison of torque/force curves, physical scaling*

Correction function

The "correction of the torque/force constants" can be activated to improve torque/force precision. The following influences on the torque/force constant are taken into account:

- Magnetic field weakening by magnetic saturation due to increased motor current compared with nominal current
- Magnetic field weakening by increased motor winding temperature
- Magnetic field weakening by increased rotor temperature depending on the average speed
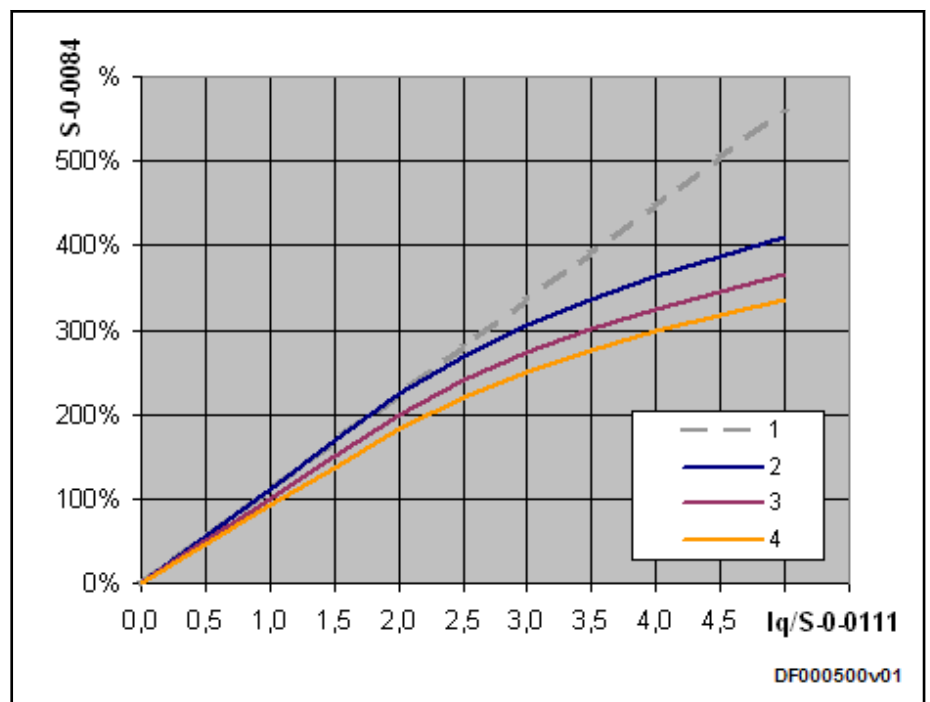
Graph 1	Load curve without K_M correction (linear current-dependent with P-0-0051)
Graph 2	Load curve with K_M correction (magnetic saturation taken into account)
Graph 3	As graph 2, additional consideration of the measured winding temperature (here nominal overtemperature with "S-0-0111, Motor current at standstill")
Graph 4	As graph 3, additional consideration of the speed-dependent motor temperature rise
S-0-0084	Torque/force feedback value in percent
Iq	Motor current, torque-generating component
S-0-0111	Motor current at standstill
Fig.8-60:	*Torque/force curves with K_M correction, percentage-based scaling, 100% value = S-0-0533, nominal torque/force of motor*

☞ With percentage-based scaling and active "correction of the torque/force constants", the displayed percentage or the percentage limitation set refers to "S-0-0533, Nominal torque/force of motor"

Magnetic saturation is taken in account by entering the maximum torque caused by "S-0-0109, Motor peak current" in "S-0-0534, Maximum torque/force of motor".

The change in the torque/force constant caused by the temperature rise is corrected by:

- Measured winding temperature ("S-0-0383, Motor temperature") and motor-type-dependent value of "P-0-0448, Temperature-dependent torque/force coefficient"

- Dynamically averaged speed (average absolute value) and motor-type-dependent value of "P-0-0449, Speed-dependent torque/force coefficient"

☞ The correction of the torque/force constant only works correctly, when the value of "P-0-0051, Torque/force constant" relates to the ambient temperature 20°C.

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The value of the current effective torque/force constant is displayed in

- P-0-0450, Current torque/force constant

Rexroth motors   For Rexroth MSK synchronous motors, the parameter values for the correction are determined by the manufacturer and in future will be provided in the motor encoder memory. With older motor versions, the values for manual input can be obtained via the manufacturer-side "DriveBase" database.

Third-party motors

The torque/force constant can also be corrected for third-party motors. It is not obligatory to correct all the aforementioned influences. However, it is recommended the magnetic saturation is corrected as, in most cases, it considerably improves torque precision. For this purpose, enter the following parameters correctly:

Maximum data:

- "S-0-0109, Motor peak current" and
- "S-0-0534, Maximum torque/force of motor"

Nominal data:

- "S-0-0111, Motor current at standstill" and
- "S-0-0533, Nominal torque/force of motor"

It only makes sense to use temperature-dependent and speed-dependent correction, when correct values are available or were determined for the required coefficients:

- P-0-0448, Temperature-dependent torque/force coefficient
- P-0-0449, Speed-dependent torque/force coefficient

☞ Depending on the respective precision requirements, it can be necessary to perform complex series of measurements on the respective motor while checking the torque at the motor shaft!

Notes on Commissioning

Activation   You can access the dialogs to activate correction of the torque/force constant via the "Project Explorer" of "IndraWorks Ds/D/MLD":

Extended Axis Functions
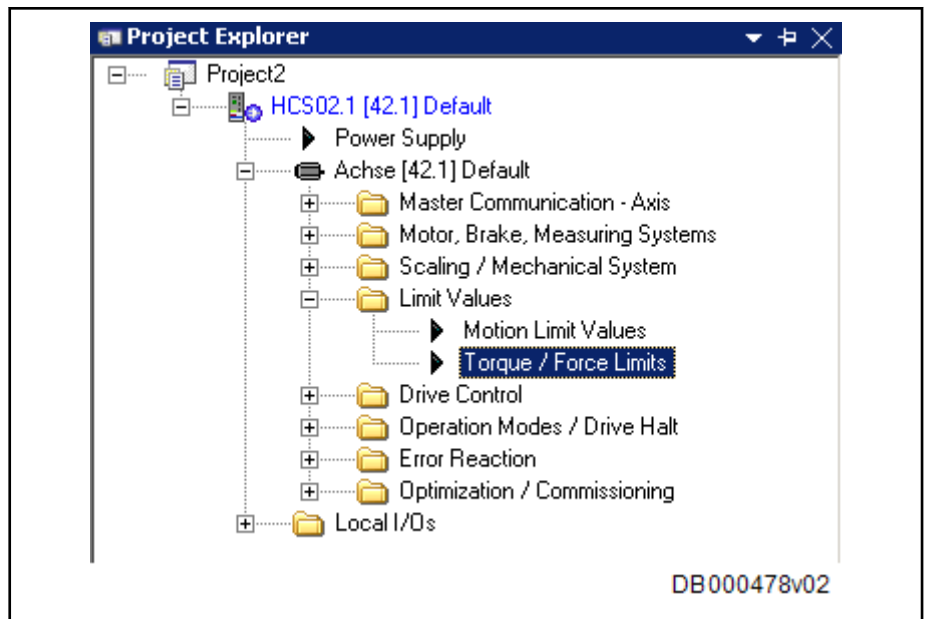
Fig.8-61:   Accessing the "Torque/force limits" dialog in which "correction of the torque/force constant" can be activated
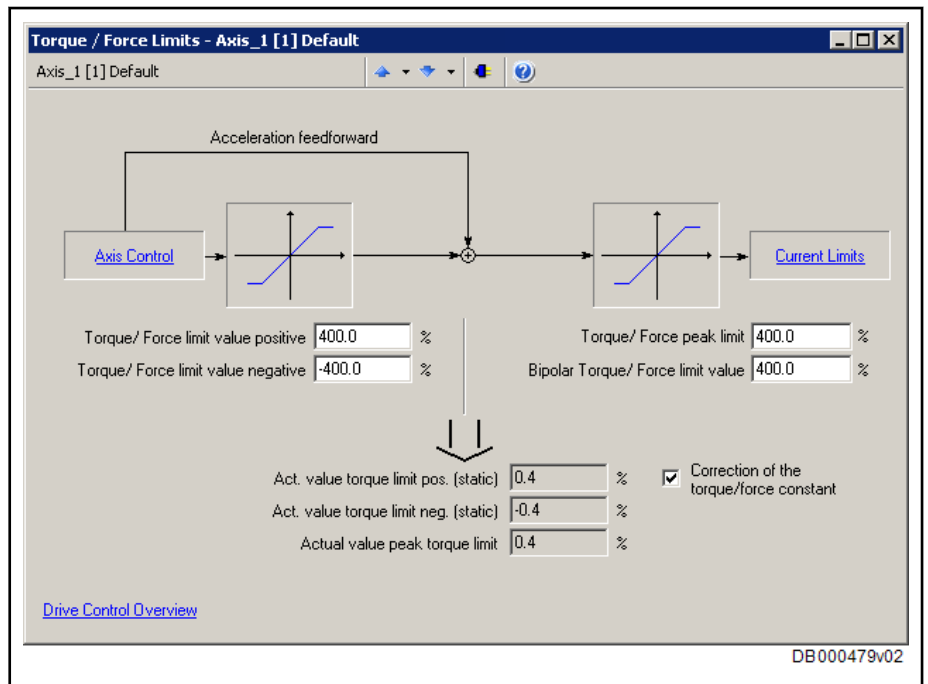
Fig.8-62:   Activating "Correction of the torque/force constant" in the dialog for torque/force limits by highlighting (ticking the checkbox sets the corresponding bit of "P-0-0556, Config word of axis controller")

Parameter display or parameter input   The corresponding parameters are motor type-related values. They are displayed in the "Motor" dialog or entered for third-party motors, if necessary:

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Fig.8-63:   *Display or input of motor type-specific parameters, such as parameters for correcting the torque/force constants "S-0-0533, Nominal torque/force of motor", "S-0-0534, Maximum torque/force of motor", "P-0-0448, Temperature-dependent torque/force coefficient" and "P-0-0449, Speed-dependent torque/force coefficient"*

Diagnostics, status messages   With active correction, the torque/force constant is adjusted to meet current influences and displayed:
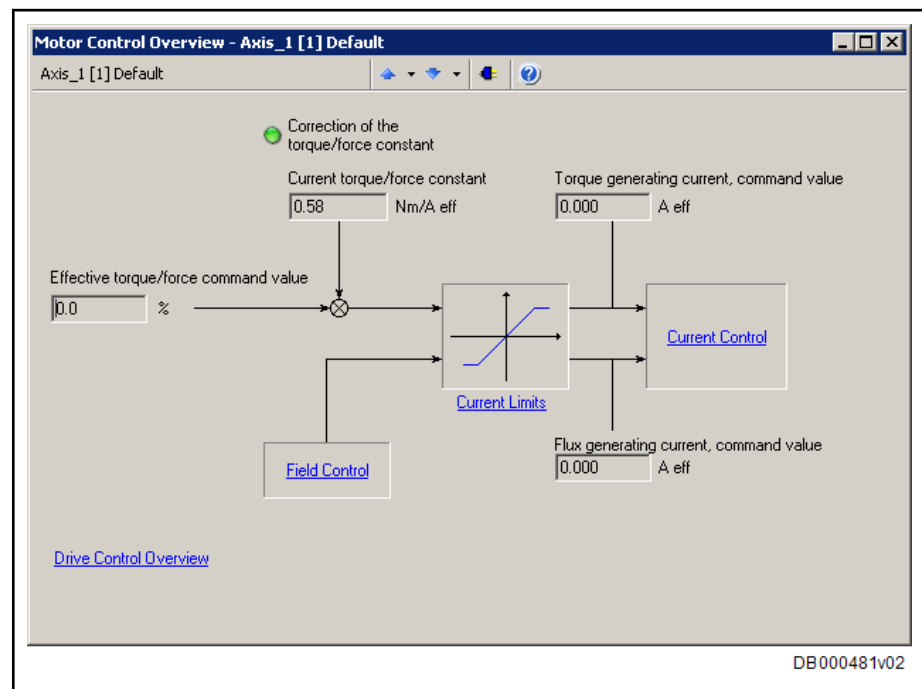
Fig.8-64:   *Display of the activated correction of the torque/force constant by the green highlight, as well as display of the value of the current torque/force constant (P-0-0450, Current torque/force constant)*

8.7   Measuring Wheel Mode

8.7.1   Brief Description

💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Measuring wheel mode is used for material feed axes, for example in sheet metal machining. A rotary encoder that detects the infeed length is driven by a measuring wheel with frictionally engaged contact to the material surface for direct measurement of the infeed of moved material.

The position control loop is closed by the motor encoder and measuring wheel encoder and any possible slip between the motor and material does not cause incorrect measured values of the material length.

☞ Measuring wheel mode may only be activated when contact has been established between the measuring wheel and material surface.

DF000264v01_en.fh
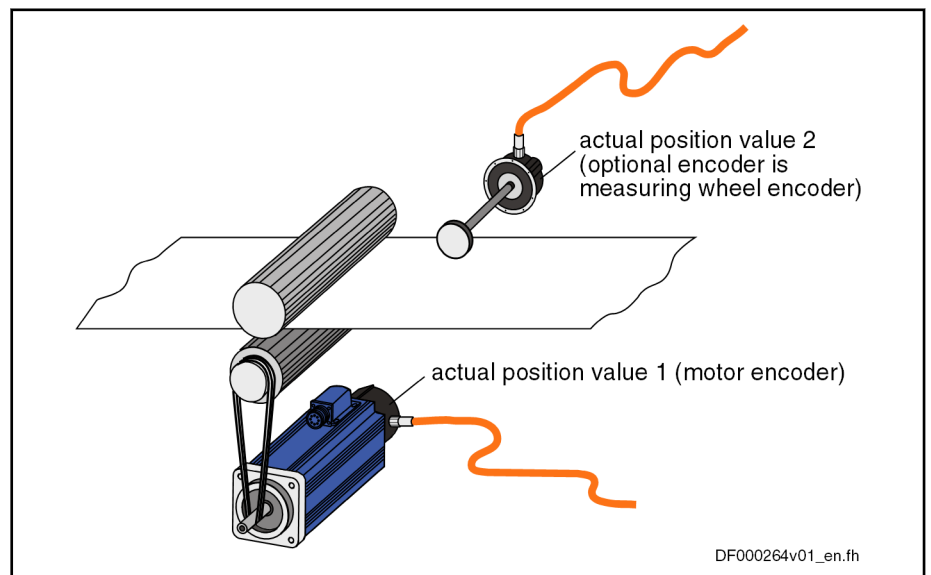
Fig.8-65:   Typical arrangement of a drive for material infeed with measuring wheel encoder

Hardware requirements   The measuring wheel encoder is an optional (external) encoder that is connected as per the connection diagram contained in the separate documentation "Control Sections for Drive Controllers; Project Planning Manual".

See also Measuring Systems

Pertinent parameters   The following parameters are used to parameterize this function:

- S-0-0520, Axis control word
- S-0-0521, Axis status word
- P-0-0241, Actual pos. smoothing time constant for hybrid pos. control
- P-0-0242, Current actual slip value in %
- P-0-0243, Maximum occurred actual slip value in %
- P-0-0244, Monitoring window of slip in %

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The following parameters are used to parameterize the measuring wheel encoder:

- S-0-0115, Position feedback 2 type
- S-0-0117, Resolution of feedback 2
- P-0-0123, Feed constant 2 (optional encoder)
- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)
- P-0-0185, Control word of encoder 2 (optional encoder)

Pertinent diagnostic messages - F2036 Excessive position feedback difference

8.7.2   Functional Description

Measuring wheel mode can only be used in operation modes in which the drive is in position control. The actual position value detected by the measuring wheel encoder is added to the actual position value of the motor encoder and is used as the "hybrid actual position value" for position control. The difference between both actual position values (by mechanical slip, elasticity, …) is smoothed by a settable filter and compensated by addition to the actual position value of the motor encoder.
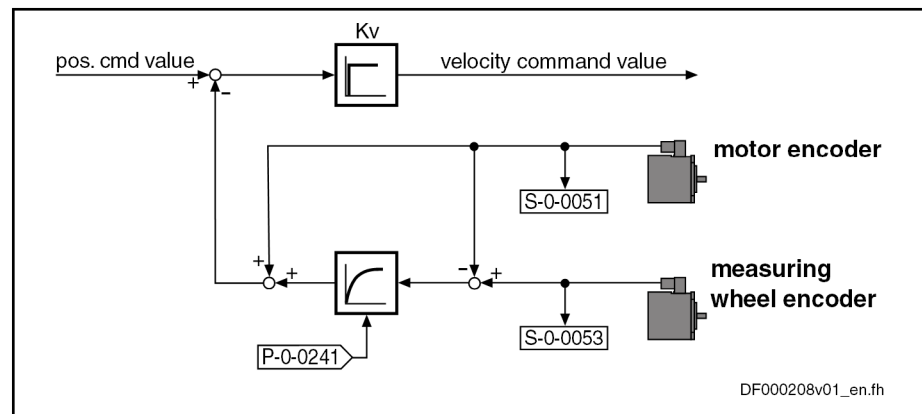
S-0-0051   Position feedback 1 value
S-0-0053   Position feedback 2 value
P-0-0241   Actual pos. smoothing time constant for hybrid pos. control
*Fig.8-66:*   *Generating the "hybrid actual position value" in measuring wheel mode*

For measuring wheel mode, activate the optional encoder in "P-0-0185, Control word of encoder 2 (optional encoder)" as the measuring wheel encoder (presetting). The measuring wheel mode itself is switched on by activating the "hybrid actual position value" in "S-0-0520, Axis control word".

☞   Due to the "0" in "P-0-0241, Actual pos. smoothing time constant for hybrid pos. control", the actual position value of the motor encoder is ignored and only the actual position value of the measuring wheel encode is used for position control.

The mechanical layout of the measuring wheel encoder in the mechanical drive system is illustrated in the figure below:
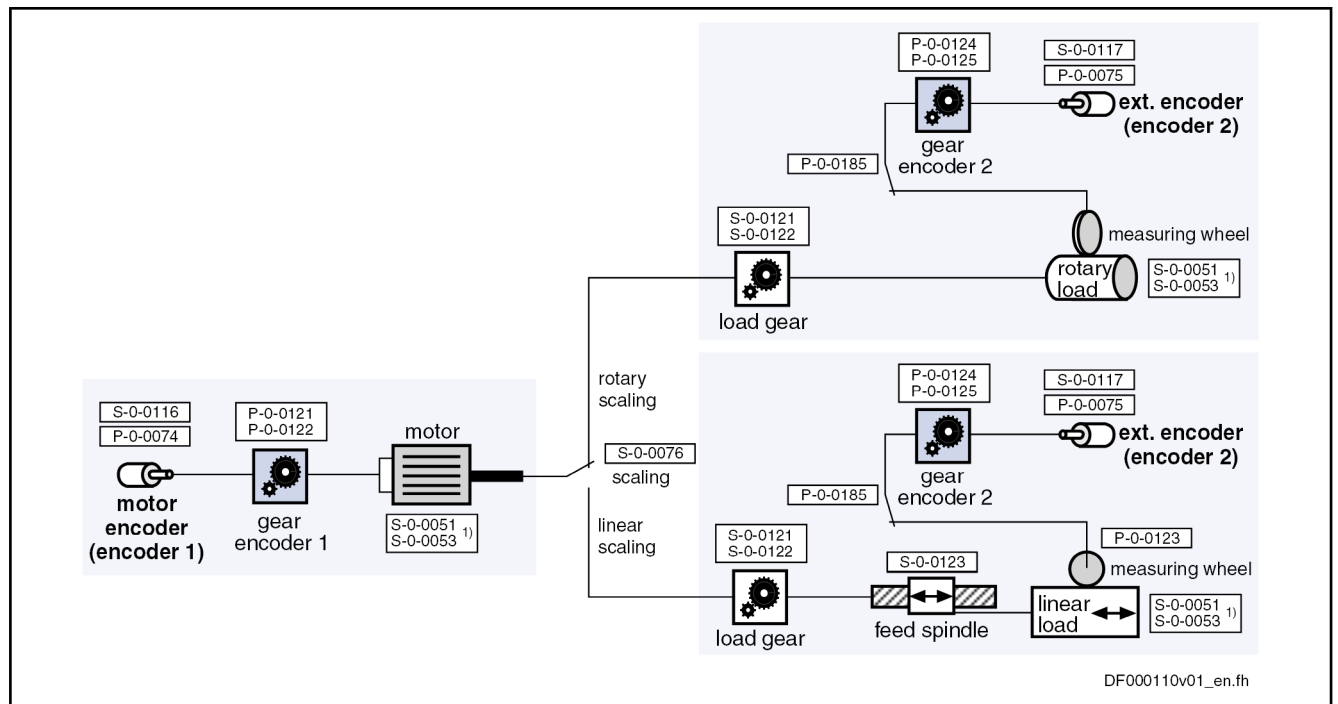
1)	S-0-0051/S-0-0053, depending on scaling (S-0-0076)
S-0-0051	Position feedback 1 value
S-0-0053	Position feedback 2 value
S-0-0076	Position data scaling type
S-0-0116	Feedback 1 resolution
S-0-0117	Feedback 2 resolution
S-0-0121	Input revolutions of load gear
S-0-0122	Output revolutions of load gear
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.8-67:   *Arrangement of the measuring wheel encoder in the mechanical drive system*

Operation modes and measuring wheel mode

Measuring wheel mode can only be used in position-controlled operation modes.

Position data reference

Activating measuring wheel mode clears any possible position data reference to the axis for both encoders. In measuring wheel mode, the axis can only be moved relatively, the control master itself must establish the position data reference to the material to be fed!

After measuring wheel mode has been deactivated, the position data reference to the axis has to be established again for relative and absolute encoders, if necessary.

It is also possible to maintain an existing position data reference of the encoders. To do so, the relevant bit must be set in "P-0-0185, Control word of encoder 2 (optional encoder)". The option to maintain the position data reference when activating/deactivating the measuring wheel mode can only be used if it is ensured that the mechanical reference of the actual position value

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from the measuring wheel encoder to the motor encoder or the material to be measured is not shifted.

NOTICE	Risk of machine damage or rejection if the material position is not indicated correctly due to slip effects between the material and motor encoder!

⇒ Only activate measuring wheel mode, if the measuring wheel is moved by the material in a frictionally engaged way!

As with position-controlled measuring wheel mode, the actual position value of the additional measuring wheel encoder becomes active for control, it is necessary to initialize this actual position value with an appropriate value. The initialization method can be set in "P-0-0185, Control word of encoder 2 (optional encoder)".

- Operating mode-dependent encoder initialization
- Encoder initialization by the last encoder active in position control

Operating mode-dependent encoder initialization

Depending on the relevant bit of P-0-0185, in position-controlled operation modes the actual position value of the motor encoder is carried over to the actual position value of the measuring wheel encoder when measuring wheel mode is activated ("S-0-0051, Position feedback value 1" → "S-0-0053, Position feedback value 2").

When switching to a non-position-controlled operation mode while the measuring wheel mode is active, the actual position value of the measuring wheel encoder is carried over to the actual position value of the motor encoder ("S-0-0053, Position feedback value 2" → "S-0-0051, Position feedback value 1").

In non-position-controlled operation modes control, as a basic principle, takes place with regard to the motor encoder. If measuring wheel mode is activated first and only then the drive is switched to a position-controlled operation mode, the actual position value of the motor encoder is carried over to the actual position value of the measuring wheel encoder ("S-0-0051, Position feedback value 1" → "S-0-0053, Position feedback value 2") **when the drive is switched to position-controlled operation mode**.

In non-position-controlled operating modes, it is possible to lift the feed rolls off the material (discharge the feed rolls) when measuring wheel mode is active.

Encoder initialization by the last encoder active in position control

Depending on the relevant bit of P-0-0185 the actual position values of the motor encoder and measuring wheel encoder are initialized with the actual position value of the last encoder active in position control, if the position control between the motor encoder and the hybrid actual position value of the two encoders is switched (Switching in S-0-0520, Bit 0). If the hybrid actual position value is not switched to the actual position value of the motor encoder the original initialization of the measuring wheel encoder is maintained.

Monitoring the slip

By means of measuring wheel mode, any slip that can occur between the material and drive motor is compensated by position control. But slip also implies wear in the mechanical drive system and on the material. The controller assists the reduction of wear and tear by allowing the monitoring of the slip that occurs to be set to a maximum permissible value.

The current actual slip value is displayed in "P-0-0242, Current actual slip value in %". It refers to

- One measuring wheel revolution, if the "feed constant 2" is active in P-0-0185 (typical case: measuring wheel measures linear infeed)

- or -

- One revolution of the external encoder, if "feed constant 2" is not active in P-0-0185 (encoder measures rotary infeed).

If the calculated slip exceeds the value in "P-0-0244, Monitoring window of slip in %" (value not equal to

"0"), the slip monitoring function triggers with the error message "F2036 Excessive position feedback difference" and the drive reacts with the error reaction that has been set.

To determine the monitoring window, the maximum occurring slip, e.g. during a machining cycle, is stored in "P-0-0243, Maximum occurred actual slip value in %".

☞ The slip monitor is deactivated with the value "0" in parameter P-0-0244!

8.7.3 Notes on Commissioning

Presettings First set the parameter values relevant to the mechanical arrangement of the motor, motor encoder, axis and measuring wheel (see fig. "Arrangement of the measuring wheel encoder in the mechanical drive system"). In addition, configure "P-0-0185, Control word of encoder 2 (optional encoder)" in such a way that the external (optional) encoder is used as the "measuring wheel encoder".

Activating measuring wheel mode

NOTICE	Property damage caused by uncontrolled movements of the if the measuring wheel encoder or feed motor do not have contact to the material being fed!

⇒ Only activate measuring wheel mode, if the measuring wheel is moved by the material in a frictionally engaged way!

Measuring wheel mode is switched on by activating the "hybrid actual position value" in "S-0-0520, Axis control word". As a prerequisite, the drive has to be in a position-controlled operation mode.

As any possible data reference of both encoders to the axis can be lost, the control master can only move the drive with a 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 the motor encoder or measuring wheel encoder transmitted by the drive and an installation-side signal!

Deactivating measuring wheel mode The measuring wheel mode can be deactivated by

- Deactivating the "hybrid actual position value" in "S-0-0520, Axis control word"
- Switching to communication phase P2 (or parameter mode),
- Switching the drive off.

If the position data reference of the encoders to the axis is required, it must be reestablished after measuring wheel mode has been deactivated!

Setting jerk attenuation Jerky slip phenomena can be attenuated by entering a value greater than zero in "P-0-0241, Actual pos. smoothing time constant for hybrid pos. control".

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> ☞ The value "0" in P-0-0241 switches off the attenuation and causes only the actual position value of the optional measuring wheel encoder to be effective.

Procedure:

1. Enter value "0" in P-0-0241 and move axis at a 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 in measuring wheel mode   Slip monitoring when measuring wheel mode is active is activated by entering a value greater than zero into "P-0-0244, Monitoring window of slip in %".

> ☞ The value "0" in parameter P-0-0244 causes slip monitoring to be switched off! The value in "P-0-0242, Current actual slip value in %" is then is no longer reset after each revolution of the measuring wheel or external encoder, but the total slip since deactivation of slip monitoring is displayed (possibly continuously increasing value).

Procedure:

1. First enter a high value into "P-0-0244, Monitoring window of slip in %" so that slip monitoring cannot be triggered.

2. Enter "0" into "P-0-0243, Maximum occurred actual slip value in %" and run a complete positioning cycle of the axis with maximum infeed velocity several times, if necessary.

3. After having cyclically moved the axis, read parameter P-0-0243 and enter a value, multiplied by a safety factor (e.g. "2"), into "P-0-0244, Monitoring window of slip in %".

If the value in "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.

8.8   Positive Stop Drive Procedure

8.8.1   Brief Description

> 💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

In special applications, it is necessary to move machine axes operated in position or velocity control up to a limit stop to generate forces of pressure.

In default cases, when an axis travels to a limit stop, the drive signals a drive error by the monitoring facilities of the position or velocity control loop and reacts by shutting down.

But if the drive detects the special operating case "positive stop drive procedure", it can ignore the messages from the position and motion monitors and generate the required force of pressure, if necessary.

The control master signals this special case to the controller of IndraDrive drives via a command. Upon this command, the drive switches off the re-

spective 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

8.8.2   Functional Description

Moving a machine axis to a limit stop in a position-controlled way, e.g. for generating a force of pressure, is a process specifically provoked on the master side. To do this, the master inputs a command value for the drive that the axis cannot reach because the mechanical limit stop is situated before it.

In order to avoid error messages and reactions with the drive having been blocked, the execution of "C1300 Positive stop drive procedure command" (S-0-0149) is started before the limit stop is reached. This switches off the following monitors that would cause class 1 diagnostic errors:

- "Drive does not follow command value" monitor
  - → 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 "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.

Resetting command C1300 switches on monitoring again!

NOTICE	**Property damage can be caused by moving to positive stop too rapidly!**

⇒ Reduce travel velocity and torque/force limit value (S-0-0092) to values that do not cause damage to the mechanical system!

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☞   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!

8.8.3   Notes on Commissioning

To acknowledge 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 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

☞   Parameters S-0-0124, S-0-0082, S-0-0083 and S-0-0092 are also used for other functions. Changes of values entered for the function "positive stop drive procedure" specifically have to be reset!

Before positive stop is reached, start:

- S-0-0149, C1300 Positive stop drive procedure command

After drive has moved away from positive stop, reset the command, if necessary!

Diagnostic message   The command has been executed when the "commands change bit" is set in "S-0-0135, Drive status word" and no command error is pending.

If a class 1 diagnostics error is pending at the start of command C1300 (e.g. because the axis has already reached positive stop), the command is not executed. The following message is displayed:

- C1301 Class 1 diagnostics error at command start

8.9   Redundant Motor Encoder

8.9.1   Brief Description

💡   Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Motor control of synchronous motors requires a position measuring system that measures the position of the moving part of the motor as opposed to the static part. In the event of a 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 to detect the position at the load with the required precision.

With axis control, the entire mechanical drive system between the motor encoder and load position of the external encoder is mapped via parameters. This allows the position of the motor encoder to be calculated from the position of the external encoder or the load position to be determined from the motor encoder position, if the mechanical drive system is slip-free.

If there is a defect in the motor encoder, the motor position can be determined via the position of the external encoder and the synchronous motor can be decelerated in a controlled way when an external encoder is used.

With 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. However, if the asynchronous motor is operated without encoder, controlled deceleration via an external encoder in the event of an error is not possible depending on the drive task!

☞ You can only use measuring systems with U_{pp} = 1 V or resolvers as redundant motor encoders!

Pertinent parameters	• P-0-0185, Control word of encoder 2 (optional encoder)

Pertinent diagnostic messages
- F2031 Encoder 1 error: Signal amplitude incorrect
- F2042 Encoder 2: Encoder signals incorrect
- F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)
- F8042 Encoder 2 error: Signal amplitude incorrect

8.9.2 Functional Description

Relevance of the function

The function "redundant motor encoder" is used to shut down the axis with the error reaction set, even if the motor encoder is defective. For this purpose, the position data of the motor encoder required for motor control is replaced by the position data of the external (optional) measuring system derived from the motor shaft position or primary part position.

Requirements

To use the "redundant motor encoder" function, the axis must be equipped with an external (optional) measuring system (U_{pp} = 1 V or resolver) and the mechanical connection between the measuring systems must be slip-free. In addition, the optional encoder must be activated as a redundant motor encoder in parameter "P-0-0185, Control word of encoder 2 (optional encoder)".

☞ The "redundant motor encoder" function can also be used for axes with a linear motor, if an external measuring system is available.

Operating principle

When the redundant motor encoder is activated, the error message "F2031 Encoder 1 error: Signal amplitude incorrect" is triggered and any possible position data reference is cleared, if the motor encoder is defective. The controller switches the internal signal paths of the encoder evaluation so that both parameter "S-0-0051, Position feedback value 1" and parameter "S-0-0053, Position feedback value 2" receive the signals from the external encoder (activated as a redundant motor encoder). The signal path for the commutation of the motor is also switched.
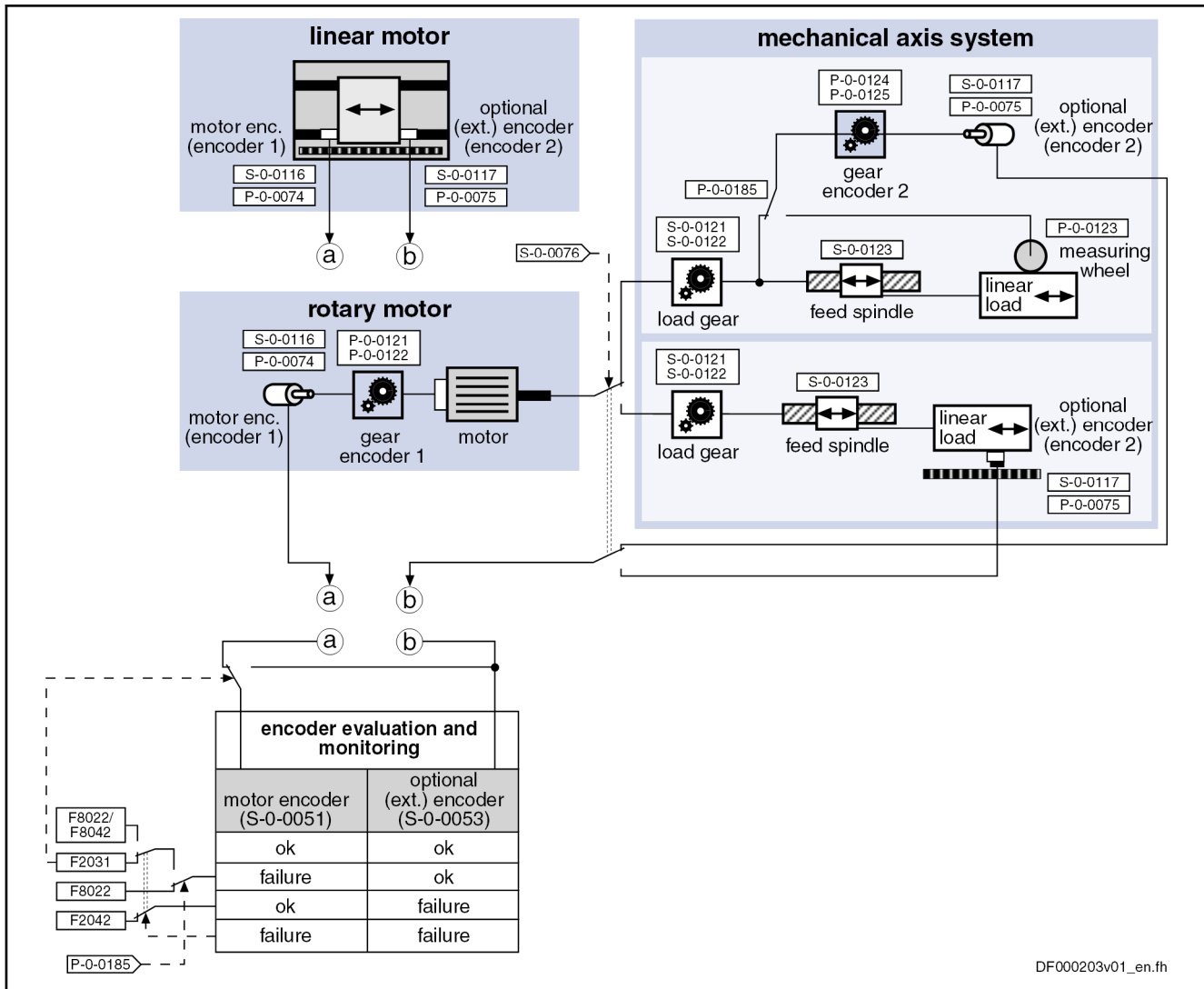
Extended Axis Functions

Fig.8-68:   Redundant encoder evaluation with axes with rotary motors and linear motors

Reactions if motor encoder defective

If a defect occurs with the motor encoder when the external encoder (redundant motor encoder) is intact, this triggers error message "F2031 Encoder 1 error: Signal amplitude incorrect". Due to the intact position data of the external encoder derived from the motor position, it is possible to carry out master-controlled deceleration (P-0-0117, Activation of control unit reaction on error) or the error reaction of the axis set in parameter "P-0-0119, Best possible deceleration".

Without a redundant motor encoder it would only have been possible to disable the motor torque!

Reactions if external encoder defective

If a defect occurs in the redundant motor encoder with the motor encoder intact, the error message "F2042 Encoder 2: Encoder signals incorrect" is triggered and the axis is shut down with a master-side NC reaction or in lin with the error reaction set.

Reactions if both encoders defective

If a defect occurs simultaneously in the motor encoder and in the redundant encoder, the message of a fatal F8xxx error is triggered:

- "F8042 Encoder 2 error: Signal amplitude incorrect" if motor encoder was defective first,

- "F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)" if redundant motor encoder was defective first.

The drive torque is disabled and the drive coasts to stop.

Resetting motor encoder and external encoder F2 errors   The message of a motor encoder defect (F2031) or a defect of the external encoder (F2042) cannot be cleared in communication phase 4 and it is necessary to switch to communication phase 2 or to "Parameter" mode. If it is necessary to replace the motor encoder or dismantle and refit it again to eliminate the cause of the error, 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 dismantled and refitted, the position data reference has to be established again, if necessary.

8.9.3 Notes on Commissioning

Presettings   First enter the basic settings:

- Set parameter values for mechanical axis system (see "Mechanical Axis System and Arrangement of Measuring Systems")

- Only set parameter values for motor encoder and external encoder (see Measuring Systems) and, with the external (optional) encoder, select the usage as "Redundant motor encoder" "P-0-0185, Control word of encoder 2 (optional encoder)"
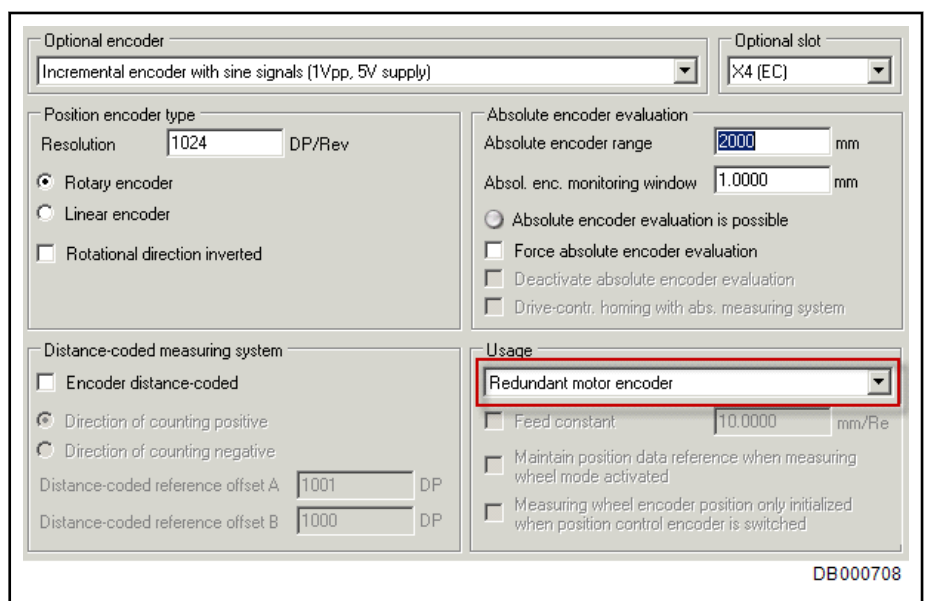
Fig.8-69:   IndraWorks dialog for the use of the external (optional) encoder as a "redundant motor encoder"

- Determine behavior of the drive in the event of an error (see "Error Reactions")

Extended Axis Functions

Fig.8-70:   IndraWorks dialog for setting 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 velocity and position control loop parameters with an 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)")

* Test velocity and position control loop settings at P-0-1119 = 0% at P-0-1119 = 100%

  → Velocity and position control loops are only closed via a redundant motor encoder (see "Closed-Loop Axis Control (Closed-Loop Operation)")

Enter the setting for velocity and position control loop such that the axis shows steady behavior in operation both with a motor encoder and with a redundant motor encoder.

8.10   Spindle Positioning

8.10.1   Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

With "spindle positioning" drive function, the drive aligns the spindle independently with regard to the spindle zero position, at a command from the master. The command position is transmitted to the drive controller via parameters and can be preset as a absolute or relative position.

By means of the "spindle positioning" command, the spindle can be positioned in a position-controlled way (e.g. within "velocity control" mode) without having to switch operation mode from velocity to position control.

Use of the "spindle positioning" drive function:

* For **milling and drilling spindles**
  – To prepare tool change → Spindle remains at a defined position to allow the tool to be changed

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- With **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
- With **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 reference switch may be required.

See "Establishing Position Data Reference for Relative Measuring Systems"

Pertinent parameters
- S-0-0152, C0900 Position spindle procedure command
- S-0-0153, Spindle angle position
- S-0-0154, Spindle positioning parameter
- S-0-0180, Spindle relative offset
- S-0-0222, Spindle positioning speed
- S-0-0372, Drive Halt acceleration bipolar
- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode
- S-0-0437, Positioning status
- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- P-0-1201, Ramp 1 pitch
- P-0-1202, Final speed ramp 1
- P-0-1203, Ramp 2 pitch
- P-0-1211, Deceleration ramp 1
- P-0-1213, Deceleration ramp 2

Pertinent diagnostic messages
- C0900 Position spindle command
- C0902 Spindle positioning requires drive enable
- C0903 Error during initialization
- C0906 Error during search for zero pulse

8.10.2   Functional Description

Basic Sequence of the Function

Spindle positioning is started via "S-0-0152, C0900 Position spindle procedure command". During the execution of the command, the controller ignores the current command value of the active operation mode.

The presetting for the kind of positioning and motion of the spindle towards the target position is made in "S-0-0152, C0900 Position spindle procedure command".

Sequence of spindle positioning   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 parameters

Extended Axis Functions

"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 parameters "S-0-0042, Homing acceleration" and "S-0-0041, Homing velocity", before the drive moves to the target position according to step 2.

Type of positioning
The spindle can be positioned at

*   absolute target position

- or -

*   relative target position.

When "absolute target position" is 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" is 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".

Motion direction during positioning
With 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 permitted 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.

☞   With a mechanical system with slip (e.g. V-belt) between the 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, Signal status word".

Spindle positioning with non-homed control encoder
If the encoder selected for spindle positioning does not yet have the position data reference to the spindle (see "S-0-0403, Position feedback value status"), the position data reference is automatically established during the execution of spindle positioning!

See also "Establishing the Position Data Reference"

The figure below illustrates the basic sequence of the drive function "spindle positioning".
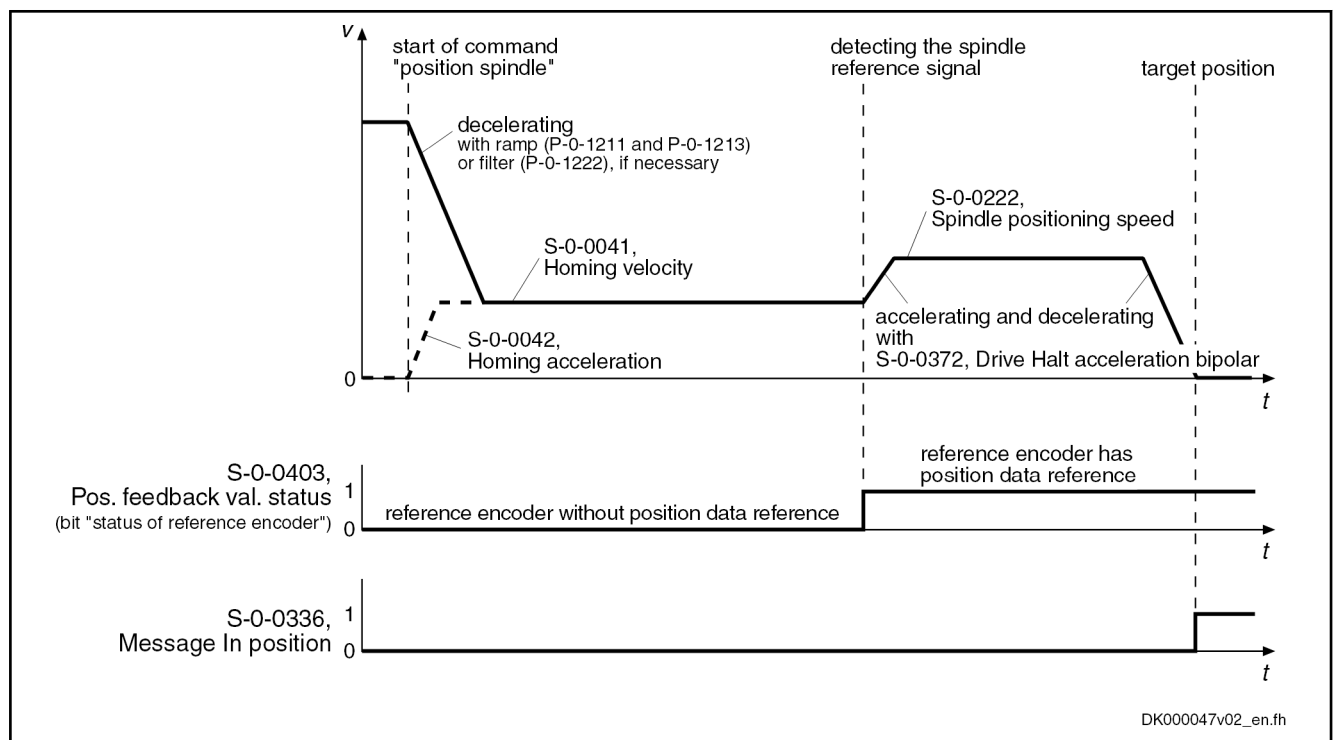
Extended Axis Functions

Fig.8-71:   Basic sequence of spindle positioning (including establishing position data reference)

"Target position reached" message

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 less than the threshold value in parameter "S-0-0124, Standstill window"

  - and -

- the distance to target position is less than the value in parameter "S-0-0057, Position window".

[i] See also Parameter Description "S-0-0013, Class 3 diagnostics"

Specific Features With "Modulo" Position Data Format

Infinitely turning axis

Spindles for tool machines or rotary axes mostly are generally infinitely rotating axes, their positioning requirement lying within one revolution (0…360 degrees). With these axes it is recommended that "modulo" position data format is used because it allows the actual position values to be displayed with reference to one axis revolution only.

Ambiguity of the 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 a different length. In addition, one or several additional revolutions can be required until the target position has been reached!

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Spindle positioning from standstill

From standstill, the spindle or rotary axis positions are determined in "S-0-0154, Spindle positioning parameter":

- With the selected direction of motion ("clockwise" or "counter-clockwise")

- or -

- with the direction of motion in which the target position can be reached over the shortest possible distance ("shortest distance")

Spindle positioning from 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 the current axis position to the target position

at the start of spindle positioning.

The actual sequence of the positioning process of a turning axis can differ in spite of the determined direction of positioning motion.

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

Current direction of rotation at start of spindle positioning	Start position of spindle positioning …	
	… within the target position window (S-0-0418)	… outside of the target position window (S-0-0418)
as defined direction of positioning motion ("clockwise" or "counter-clockwise")	Positioning takes place over the shortest distance, if values do not leave target position window during deceleration. If values leave the target position window during deceleration, the drive is positioned, according to the selected direction of positioning motion, at the next target position to be reached.	Positioning takes place at the next target position that can be reached, while maintaining the direction of velocity. If the "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.
Contrary to defined direction of positioning motion ("clockwise" or "counter-clockwise")	If the "braking distance **<** distance start position-target position", the drive moves to the target position over the shortest distance. If the "braking distance **>** distance start position-target position", positioning takes place after deceleration of the motor, with reversal of the direction of velocity, at the next target position to be reached.	The motor is decelerated to a standstill. The positioning process then takes place at next target position to be reached, according to the determined direction of positioning motion.

Fig.8-72:   Dependence of the positioning process on the start position with the defined direction of positioning motion "clockwise" or "counter-clockwise"

Current velocity at the start of spindle positioning …	
… greater than the value of S-0-0417 (velocity threshold)	… less than the value of S-0-0417 (velocity threshold)
Positioning takes place at the next target position to be reached, while maintaining the direction of velocity. If the "braking distance > distance of 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 the "braking distance < distance of start position-target position", positioning takes place at next target position to be reached, while maintaining the direction of velocity. If the "braking distance > distance of start position-target position", positioning takes place after deceleration of the motor, with reversal of the direction of velocity at the next target position to be reached.

Fig.8-73:   Dependence of the positioning process on the velocity at the start of spindle positioning with defined direction of positioning motion "shortest distance"

8.10.3   Notes on Commissioning

Presettings   Determining kind of positioning and direction of positioning motion:

- S-0-0154, Spindle positioning parameter

Determining maximum velocity for spindle positioning:

- S-0-0222, Spindle positioning speed

Determining threshold values for "in position" message:

- S-0-0057, Position window
- S-0-0124, Standstill window

ℹ️ See also Parameter Description "S-0-0013, Class 3 diagnostics"

If the position data is scaled in modulo format, it is possible to specify limiting conditions that improve the reproducibility of the positioning process:

- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode

Presetting taget position   The target position of the spindle is preset via

- S-0-0153, Spindle angle position (absolute positioning)

- or -

- S-0-0180, Spindle relative offset (relative positioning).

Starting spindle positioning   Spindle positioning is started by starting the command

- S-0-0152, C0900 Position spindle procedure command

Diagnosing spindle positioning   The target position effective for the positioning process is displayed in

- S-0-0430, Effective target position.

Ending spindle positioning   When the target position has been reached, this is displayed in

- S-0-0336, Status "In position"

    - and -

- S-0-0013, Class 3 diagnostics.

The respective message bit changes from "0" to "1" when the conditions for the message have been fulfilled. The execution of the "position spindle" command is thereby acknowledged as having been "completed without error".

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8.10.4   Diagnostic Messages

The execution of spindle positioning requires drive enable (AF). Diagnostic message in the case of error:

- C0902 Spindle positioning requires drive enable

If an absolute encoder is used as a control encoder, the position data reference of the encoder must have been established before the initial 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 initial spindle positioning (unless already done). If the drive does not detect the home switch signal, the following diagnostic message is generated:

- C0903 Error during initialization

If a relative encoder is used as a control encoder, the position data reference is established with the initial spindle positioning (unless already done). If the drive does not detect any reference mark signal, the following diagnostic message is generated:

- C0906 Error during search for zero pulse

8.11   Parameter Set Switching

8.11.1   Brief Description

> 💡 Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

IndraDrive devices have been equipped with 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 ut the command of the control master.

Applicational information By switching parameter sets during operation, the values of certain parameters can be adapted to the different operation phases and machining processes. This assists workflows in flexible manufacturing plants.

Uses of this include:

- Changing from C-axis to roughing or finishing operation with spindles
- Positioning mode for tool change with different gear ratios
- Changing of 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, only in alternative functional package main spindle function

Extended Axis Functions

- Winding parameters, only in alternative functional package main spindle function
- Motor control and motor encoder parameters, only in alternative functional package main spindle function

Pertinent parameters
- S-0-0216, C4100 Switch parameter set command
- S-0-0217, Preselect parameter set command
- S-0-0219, IDN-list of parameter set

  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
- C0273 Modulo value for motor encoder cannot be displayed
- C0278 Modulo value for optional encoder cannot be displayed
- C0280 Maximum travel range cannot be displayed internally
- C4100 Switch parameter set command
- C4101 Switching only possible without AF
- C4103 Preselect parameter set forbidden value
- C4104 Error during parameter set switching (->S-0-0423)

8.11.2 Functional Description

General Information

Parameter set switching is activated

- By triggering command "C4100 Switch parameter set command" (S-0-0216) via control master

- or -

- "Drive-controlled" by changing "S-0-0217, Preselect parameter set command"

The triggering of parameter set switching is set in "P-0-2216, Parameter set switching, configuration".

The drive firmware then activates the parameter set determined by the value of "S-0-0217, Preselect parameter set command". The active value is displayed in "S-0-0254, Current parameter set". After switching on it is always set 0 that is active.

To minimize the times required for switching and storing or loading the parameter sets of a drive, the switchable parameters are permanently assigned to the following groups:

- **Application** (e.g. parameters for limit values for torque/force, position, velocity, etc.)
- **Control loop** (e.g. parameters for gain factors of position and velocity loop, etc.)
- **Load gear** (parameters for load gear input and load gear output revolutions, load inertia, etc.), only in alternative functional package main spindle function

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- **Winding** (current loop parameters for winding switching, start-delta switching, etc.), only in alternative functional package main spindle function

- **Motor control and motor encoder parameters** (changes in the control process, motor switching, etc.), only in alternative functional package main spindle function

"P-0-2216, Parameter set switching, configuration" determines which of the mentioned parameter groups are to be switchable. In addition, "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 parameters P-0-2216 and P-0-2217.

☞   Parameters of non-configured sets or groups:

- are not listed in "S-0-0192, IDN-list of all backup operation data".
- are write-protected in the operation mode.

Parameters are addressed via their identification numbers (IDN). With switchable parameters, the number for the respective parameter set has to be taken into account.

Defining Parameter Groups

Applicational parameters   The following switchable parameters are permanently assigned to the "application" group (only in the alternative functional packages servo function, main spindle function, synchronization):

- S-0-0038, Positive velocity limit value
- S-0-0039, Negative velocity limit value
- S-0-0057, Position window
- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0091, Bipolar velocity limit value
- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0125, Velocity threshold nx
- S-0-0126, Torque threshold Tx
- S-0-0138, Bipolar acceleration limit value
- S-0-0157, Velocity window
- S-0-0158, Power threshold Px
- S-0-0193, Positioning Jerk
- S-0-0222, Spindle positioning speed
- S-0-0261, Coarse position window
- S-0-0349, Bipolar jerk limit
- S-0-0372, Drive Halt acceleration bipolar
- S-0-0822, Torque/force ramp
- S-0-0823, Torque/force ramp time
- P-0-0041, Position command average value filter time constant

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- 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-0-0237, 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-0-0641, Interpolation cmd value average value filter time constant
- P-0-1201, Ramp 1 pitch
- P-0-1202, Final speed ramp 1
- P-0-1203, Ramp 2 pitch
- P-0-1211, Deceleration ramp 1
- P-0-1213, Deceleration ramp 2
- P-0-1222, Velocity command filter
- P-0-4010, Load inertia

Control loop parameters   The following switchable parameters are permanently assigned to the "control loop" group (only in the alternative functional packages servo function, main spindle function, synchronization):

- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- S-0-0104, Position loop Kv-factor
- S-0-0348, Acceleration feedforward gain
- S-0-0826, Torque/force window
- P-0-0004, Velocity loop smoothing time constant
- P-0-0040, Velocity feedforward evaluation
- P-0-0180, Acceleration feedforward smoothing time constant
- P-0-1119, Velocity mix factor feedback 1 & 2
- P-0-1120, Velocity control loop filter: filter type
- P-0-1121, Velocity control loop filter: limit frequency of low pass
- P-0-1122, Velocity control loop filter: bandwidth of band-stop filter
- P-0-1123, Vel. cont. loop filter: center frequency of band-stop filter
- P-0-1126, Velocity control loop: acceleration feedforward

Load gear parameters   The following switchable parameters are permanently assigned to the "load gear" group (only in alternative functional package main spindle function):

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- S-0-0052, Reference distance 1
- S-0-0121, Input revolutions of load gear
- S-0-0122, Output revolutions of load gear
- S-0-0150, Reference offset 1
- S-0-0299, Home switch offset
- P-0-0109, Torque/force peak limit

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☞   If load-related position, velocity or acceleration parameters exist, switching of the parameters of the "load gears" group is not allowed while the safety technology is active with the configuration "scaling of safety parameters according to setting of scaling system" (P-0-3210, bit14 = "0") and "gear independence with safety technology encoder mounted on the load side not active" (P-0-3210, bit 15 = "0"),

☞   Gear switching combined with an absolute measuring system as a motor encoder and load-side data reference can lead to wrong reference data. The encoder reference is shown as being available,in certain circumstances, although the load-side reference is not available. In the event of this configuration, homing must always be re-done after gear switching.

Winding parameters   The following switchable parameters are permanently assigned to the "Winding" group (only in the alternative main spindle function functional package):

- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- S-0-0109, Motor peak current
- S-0-0111, Motor current at standstill
- S-0-0113, Maximum motor speed
- S-0-0141, Motor type
- S-0-0201, Motor warning temperature
- S-0-0204, Motor shutdown temperature
- S-0-0533, Nominal torque/force of motor
- S-0-0534, Maximum torque/force of motor
- P-0-0051, Torque/force constant
- 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-0-0568, Voltage boost
- P-0-0569, Maximum stator frequency slope
- P-0-0570, Stall protection loop proportional gain
- P-0-0571, Stall protection loop integral action time
- P-0-0572, Slip compensation factor
- P-0-0573, IxR boost factor
- P-0-0574, Oscillation damping factor
- P-0-0577, Square characteristic: lowering factor
- P-0-0578, Current for deceleration, absolute value

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- P-0-0579, Current for deceleration, time period
- P-0-0590, Motor model frequency loop proportional gain
- P-0-0591, Motor model frequency loop integral action time
- P-0-0592, Motor model adjustment factor
- P-0-0593, FXC: Total flux loop proportional gain
- P-0-0594, FXC: Total flux loop integral action time
- P-0-0595, FXC: Frequency loop proportional gain
- P-0-0596, FXC: Frequency loop scaling factor of inertia
- P-0-0597, FXC: Current loop proportional gain
- P-0-0598, FXC: Current loop integral action time
- P-0-0599, FXC: Slip frequency filter time constant
- P-0-0600, FXC: Rated slip frequency
- P-0-0602, FXC: Minimum no-load current
- P-0-4002, Charact. of quadrature-axis induct. of motor, inductances
- P-0-4003, Charact. of quadrature-axis inductance of motor, currents
- P-0-4004, Magnetizing current
- P-0-4005, Flux-generating current, limit value
- P-0-4013, Current limit value of demagnetization
- P-0-4016, Direct-axis inductance of motor
- P-0-4017, Quadrature-axis inductance of motor
- P-0-4032, Motor type plate data
- P-0-4036, Rated motor speed
- P-0-4039, Stator leakage inductance
- P-0-4040, Rotor leakage inductance
- P-0-4041, Motor magnetizing inductance
- P-0-4042, Characteristic of motor magnetizing inductance
- P-0-4043, Rotor time constant
- P-0-4048, Stator resistance

Motor control and motor encoder parameters

The following switchable parameters are permanently assigned to the "motor control and motor encoder parameters" group (only in alternative functional package main spindle function):

- S-0-0116, Resolution of feedback 1
- S-0-0206, Drive on delay time
- S-0-0207, Drive off delay time
- S-0-0277, Position feedback 1 type
- P-0-0001, Switching frequency of the power output stage
- P-0-0018, Number of pole pairs/pole pair distance
- P-0-0045, Control word of current controller
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0077, Assignment motor encoder->optional slot
- P-0-0121, Gear 1 motor-side (motor encoder)
- P-0-0122, Gear 1 encoder-side (motor encoder)
- P-0-0124, Gear 2 load-side (optional encoder)

Extended Axis Functions

- P-0-0125, Gear 2 encoder-side (optional encoder)
- 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-0-0540, Torque of holding brake
- P-0-0575, Search mode: search current factor
- P-0-0576, Search mode: finding point slip factor
- P-0-0601, Configuration motor data identification
- P-0-0640, Cooling type
- P-0-4014, Type of construction of motor
- P-0-4034, Thermal time constant of winding
- P-0-4035, Thermal time constant of motor
- P-0-4037, Thermal short-time overload of winding

Conditions and Timing for Parameter Set Switching

"Application", "Control loop" and "Load gear" parameter groups

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:
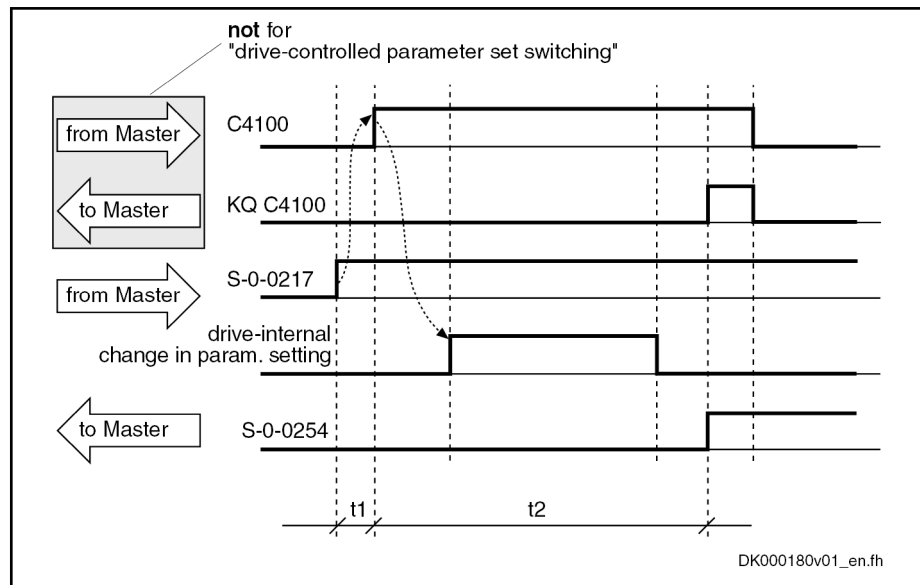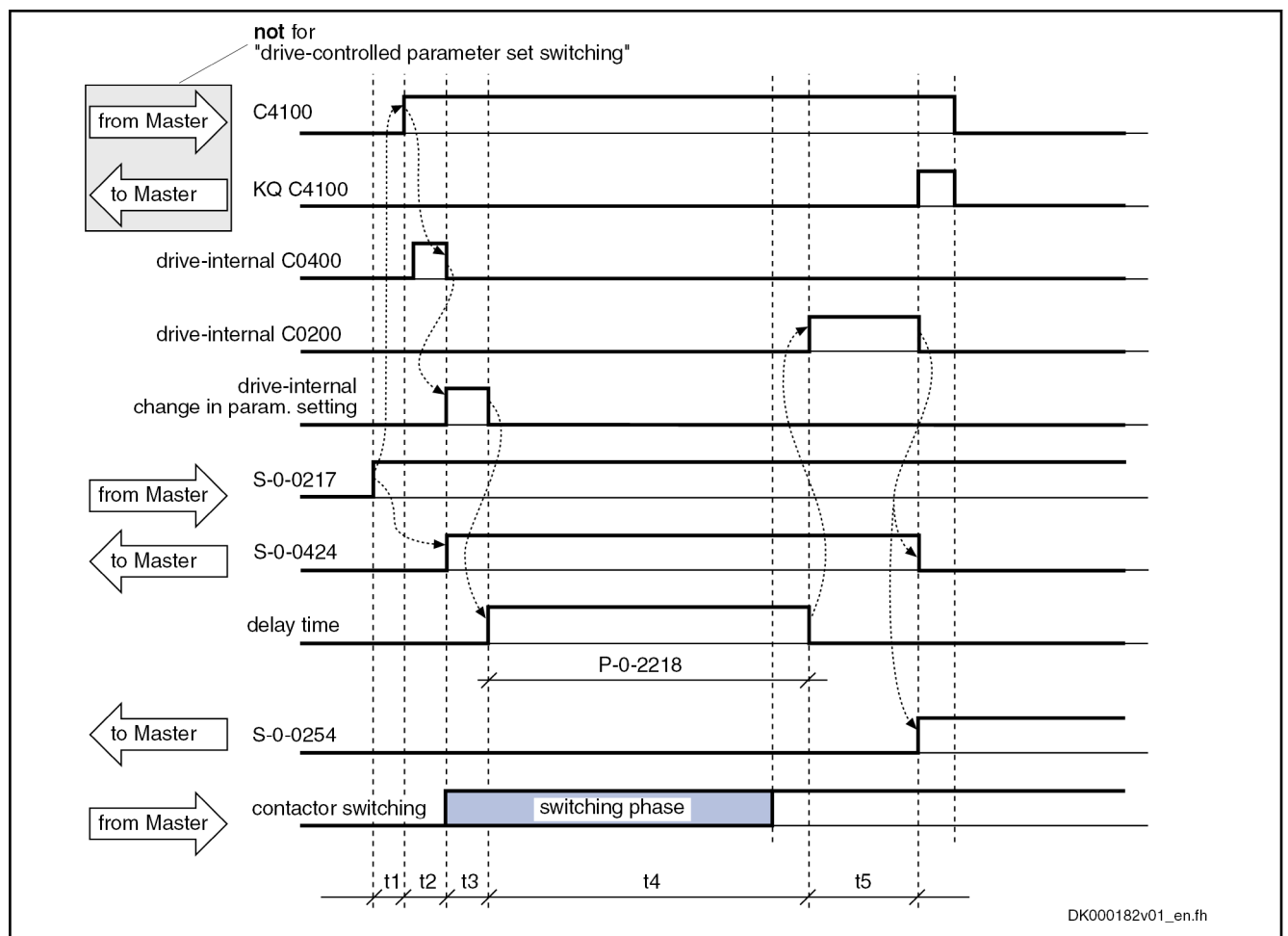

C4100	Switch parameter set command
KQ C4100	Switch parameter set command acknowledgment
S-0-0217	Preselect parameter set command
S-0-0254	Current parameter set
t1	Approx. 6 ms (drive-controlled parameter set switching)
t2	Approx. 5…30 ms

Fig.8-74: Sequence diagram for switching Application, Control loop and Load gear parameters

"Load gear" parameter group and safety technology

If, with load-related position, velocity- and/or acceleration data the "Load gears" parameter group is included in the switching, f"fixed format related to the motor" or "gear independence with safety technology encoder mounted on the load-side " has to be set for the scaling of the SI parameters (P-0-3210, Safety technology configuration), otherwise the transition command error "C0256 Safety technology configuration error" is generated when changing from parameter mode to operating mode with safety technology activated.

If the gear ratio of the load gear is changed by parameter set switching, the position data reference is maintained ("homed" in "S-0-0403, Position feedback value status"), if the position data directly refers to an encoder:

- Data reference to load with position control on an external encoder
- Data reference to motor shaft with position control on the motor encoder

Otherwise, the reference of the position data is lost through the changes in the gear ratio of the load gear and the position data reference has to be established again.

The following command errors might occur:

- C0273 Modulo value for motor encoder cannot be displayed
- C0278 Modulo value for optional encoder cannot be displayed
- C0280 Maximum travel range cannot be displayed internally

For troubleshooting in case of an error, see description of diagnostic messages for the respective error message!

NOTICE	By parameter set switching with "AF", the command values can change internally. This can cause accidental axis motion!

⇒ Via the control master, make sure that the changes in the controlled system really took place (query the feedbacks)!

"Winding" parameter group

The parameter group "winding" can also 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 "chapter "Conditions and Timing for Parameter Set Switching" on page 784").

Winding switching thereby takes place in the shortest possible time. By the appropriate setting in P-0-2218, there is sufficient delay until switching times of contactors, relays etc. are over.

Extended Axis Functions

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.8-75:   Sequence diagram for switching the winding parameters

"Motor control and motor encoder parameters" parameter group

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"!

In connection with the switching of the encoder parameters, via "P-0-2218, Parameter set switching, delay time", return into the operating mode can be

to delay the return to operating mode via "C0200 Exit parameterization level procedure command" to have sufficient delay until switching times of contactors, relays etc. are over.

C4100	Switch parameter set command
KQ C4100	Switch parameter set command acknowledgment
C0400	Activate parameterization level 1 procedure command
C0200	Exit parameterization level procedure command
S-0-0217	Preselect parameter set command
S-0-0254	Current parameter set
S-0-0424	Status parameterization level
P-0-2218	Parameter set switching, delay time
t1	Approx. 6 ms (drive-controlled parameter set switching)
t2	Approx. 50 ms, for resolver measuring system approx. 250 ms
t3	Approx. 6 ms
t4	According to the value of P-0-2218
t5	Approx. 1...15 s

Fig.8-76:   Sequence diagram for switching motor control and motor encoder parameters

☞ During the execution of "C4100 Switch parameter set command", command error messages C02xx might possibly occur, if inadmissible states (e.g. switching times) are still present before switching back to operating mode takes place!

8.11.3   Notes on Commissioning

Presettings   Preselect parameter groups to be switched in:

- P-0-2216, Parameter set switching, configuration

Determine number of switchable parameter sets in:

Extended Axis Functions

- P-0-2217, Parameter set switching, preselection range

If desired, activate "drive-controlled parameter set switching" in 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-0-xxxx to P-0-xxxx) but are not listed in in S-x-0219:

- are not listed in "S-0-0192, IDN-list of all backup operation data".
- are write-protected in the operation mode.

Initial state

After switching on, it is always "parameter set 0" that is active first. "S-0-0254, Current parameter set" displays "0".

Carrying out parameter set switching

Before the function is activated, the number of the parameter set to which switching is to take place must be entered in parameter "S-0-0217, Preselect parameter set command".

Sequence of the function:

- Command "C4100 Switch parameter set command" (S-0-0216) is started via control master
- Successful parameter set switching is checked in parameter "S-0-0254, Current parameter set" (new parameter set number must have been acknowledged in this parameter)
- Command C4100 is cleared by control master

Diagnostic messages

During execution of the command, the message "C41" appears on the display of the controller.

Possible failures are displayed by the following diagnostic messages:

- C4101 Switching only possible without AF
- C4103 Preselect parameter set forbidden value
- C4104 Error during parameter set switching (->S-0-0423)

In conjunction with gear switching, the following diagnostic messages are possible:

- C0273 Modulo value for motor encoder cannot be displayed
- C0278 Modulo value for optional encoder cannot be displayed
- C0280 Maximum travel range cannot be displayed internally

8.12   Star-Delta Switching

8.12.1   Brief Description

Fields of application

By using star(Y)-delta(D) switching, the torque-power characteristics of a spindle can be adapted to different machining requirements for short-time operation without mechanical transmission elements:

- Material removal (roughing): high torque, low speed
- Fine-machining (finishing): high speed, low torque

DK000314v01_en.fh
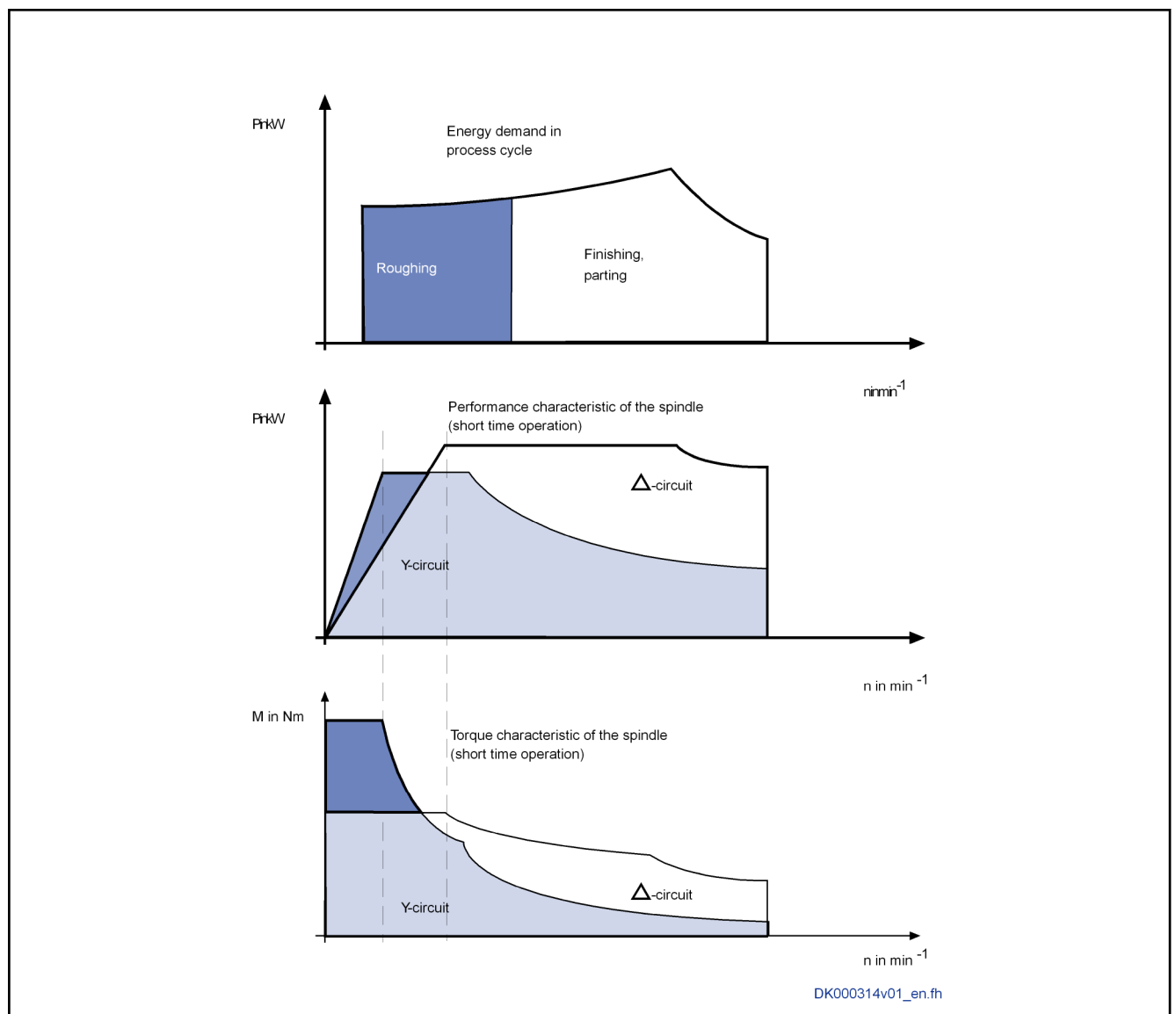
| Y | Star configuration |
| D | Delta configuration |

Fig.8-77:   *Schematic operating characteristics of a spindle drive with star-delta switchable motor*

The spindle drive performance with star configuration is only approximately 2/3 of the drive performance with delta configuration, i.e. star-delta switching is not a complete replacement for gear switching, as the same drive performance is available at each gear stage! The increased torque in short-term operation with the star configuration compared with delta configuration is not accompanied by an increase in the permanent torque of the spindle!

☞   The increase of the short-time operating torque can also be achieved by increased type current from the controller with a fixed wired motor, instead of using star-delta switching. This makes the contactor switch redundant, which is not maintenance-free in the long term, which also entails additional wiring and braking problems in the event of mains power failure.

Extended Axis Functions

Star-delta switching is generally unsuitable for milling spindles, due to the long run-up times with the star configuration!

Features

Motor design

Star-delta switching can only be used with Rexroth motors or with external motors specifically designed for this purpose. With these motors, all six winding ends of the three-phase AC motor are routed into the motor's terminal box. Standard motors have fixed internal wiring and only three power connections are accessible!

Procedure with star-delta switching

IndraDrive controllers assist the star-delta switching of synchronous and asynchronous AC motors in the following way:

- Thanks to switchable parameters, one parameter set with all relevant motor parameters is assigned to each switching mode of the motor in the controller. The "Main spindle" functional package is needed for this, which offers "parameters set switching".

- Star-delta switching can be performed during operation, i.e. when the drive is active. The controller converts the motor start-up voltage to the new switching mode and, in doing, so, achieves the imperceptible transition of the switching modes. However, the contactors for switching the motor windings are not activated by the controller and must be activated externally by the control master.

- Each switching mode has to be commissioned per se and is stand-alone effective and functional. There is no conversion of winding-specific parameter values according to the respective switching mode.

Activating star-delta switching

The change to the other switching mode is triggered by switching parameters ("Parameter set switching").

Pertinent parameters

- P-0-2216, Parameter set switching, configuration
- S-0-0217, Preselect parameter set command
- S-0-0216, C4100 Switch parameter set command
- S-0-0219, IDN-list of parameter set

Pertinent diagnostic messages

- C4100 Switch parameter set command

8.12.2   Functional Description

Features of Asynchronous Motors

Rexroth asynchronous motors with a winding configuration for star-delta switching (prefix"Y" in the first position of the winding characteristic number of the motor type key) are delivered in principle without motor parameters in the encoder memory, even if a memory is available (motor encoder option "S2" or "M2").

The motor parameter set for the star and delta switching of Rexroth asynchronous motors is provide by the "IndraWorks" tool. If must be uploaded into the controller during commissioning.

Refer to "Notes on Commissioning" for further information.

Features of Synchronous Motors

Synchronous motors with motor encoder are only operational if they are operated with the correct commutation offset in addition to the motor type-specific parameters. Therefore a commutation offset must be identified for each

switching mode and stored in the controller for star-delta- witchable motors so that it can be reactivated during the respective winding switching operation.

Absolute motor encoder

The use of absolute motor encoders that can be evaluated is recommended in principle for synchronous motors. This is advantageous, as the motor is immediately operational following initial commissioning after switching on again (see chapter "Commutation Setting"). The majority of absolute motor encoders that can be evaluated also offer an encoder memory, and the commutation offset can also be stored here so that the motor is immediately operational even with different controllers.

However, two type-specific motor parameters sets, including different commutation offset values, have to be stored for star-delta switchable synchronous motors. This is not possible in the encoder data memory, therefore this data is only stored in the drive controller. When the drive is switched on, normally the commutation offset at "PM" -> "OM" is automatically read from the encoder memory (P-0-3008), and the value is thereby written in the drive (P-x-0508, PUD). This would be unusable for star-delta switching and must therefore be deactivated in "P-0-0522, Control word for commutation setting"!

☞ Rexroth synchronous housing motors are designed as standard with absolute motor encoders and encoder memories, thereby ensuring that the correct motor parameters, including the commutation offset value, are available when commissioning the drive. These motors are not star-delta-switchable!

☞ Please refer to the corresponding chapter in the document when parameterizing and commissioning external synchronous motors and when adjusting the commutation offset with absolute motor encoders!

Relative motor encoder

The use of relative motor encoders is also possible with synchronous motors. This has the disadvantage that the commutation offset for operation of the motor has to be determined each time the motor is switched on. This is done automatically when the drive is enabled ("AF") for the first time after switching on, but can result in values with different qualities, which could lead to lower motor torque/force development than expected. This potential shortcoming can be eliminated by "reference point-optimum commutation setting" (see chapter "Commutation Setting").

The motor type-specific parameters for the star and delta switching of a synchronous motor are stored in the controller in a parameter set with switchable parameters. Nevertheless, the respective value of "P-0-0521, Effective commutation offset" is still to be optimized before it is saved in the drive (P-x-0508), in order to be able to use the benefits of "reference point-optimum commutation setting" (see chapter "Commutation Setting").

☞ The use of "reference point-optimum commutation setting" is strongly recommended when using relative motor encoders, as this results in reproducible torque/force development of the motor!

☞ Please refer to the corresponding chapters in the document when parameterizing and commissioning external synchronous motors and when adjusting the commutation offset with relative motor encoders!

Extended Axis Functions

Timing with Star-delta Switching

Star-delta switching is triggered by parameter set switching, providing the parameter group "Winding" ("P-0-2216, Parameter set switching, configuration") has been included in the switching.

☞ The timing of the parameter set switching for the "Winding" parameter group is described in detail in the chapter "Conditions and Timing for Parameter Set Switching".

The control master causes the contactors to be activated for star-delta switching. The time required for the contactor switching determines the value of "P-0-2218, Parameter set switching, delay time", by means of which the control master can adjust the star-delta switching time to the hardware-side conditions. If star-delta switching does not take place with each parameter set switch when using more than two switchable parameters sets, the control master can correspondingly reduce the current value of P-0-2218 prior to the switch.

8.12.3   Notes on Commissioning

Generating Parameter Sets for Star-Delta Switching of Rexroth Asynchronous Motors

☞ Only Rexroth asynchronous motors are available for star-delta switching!

Each motor switching mode corresponds to a set of switchable parameters. The sets of switchable parameters first need to be generated. Recommended procedure:

- First parameterize the motor for a switching mode! This is supported by IndraWorks by the "Motor" dialog. Select the relevant motor in the Configurator in the dialog. The database values are listed, with identification numbers of parameter sets "0" (star configuration) and "1" (delta configuration) appearing for star-delta switchable motors:

Extended Axis Functions
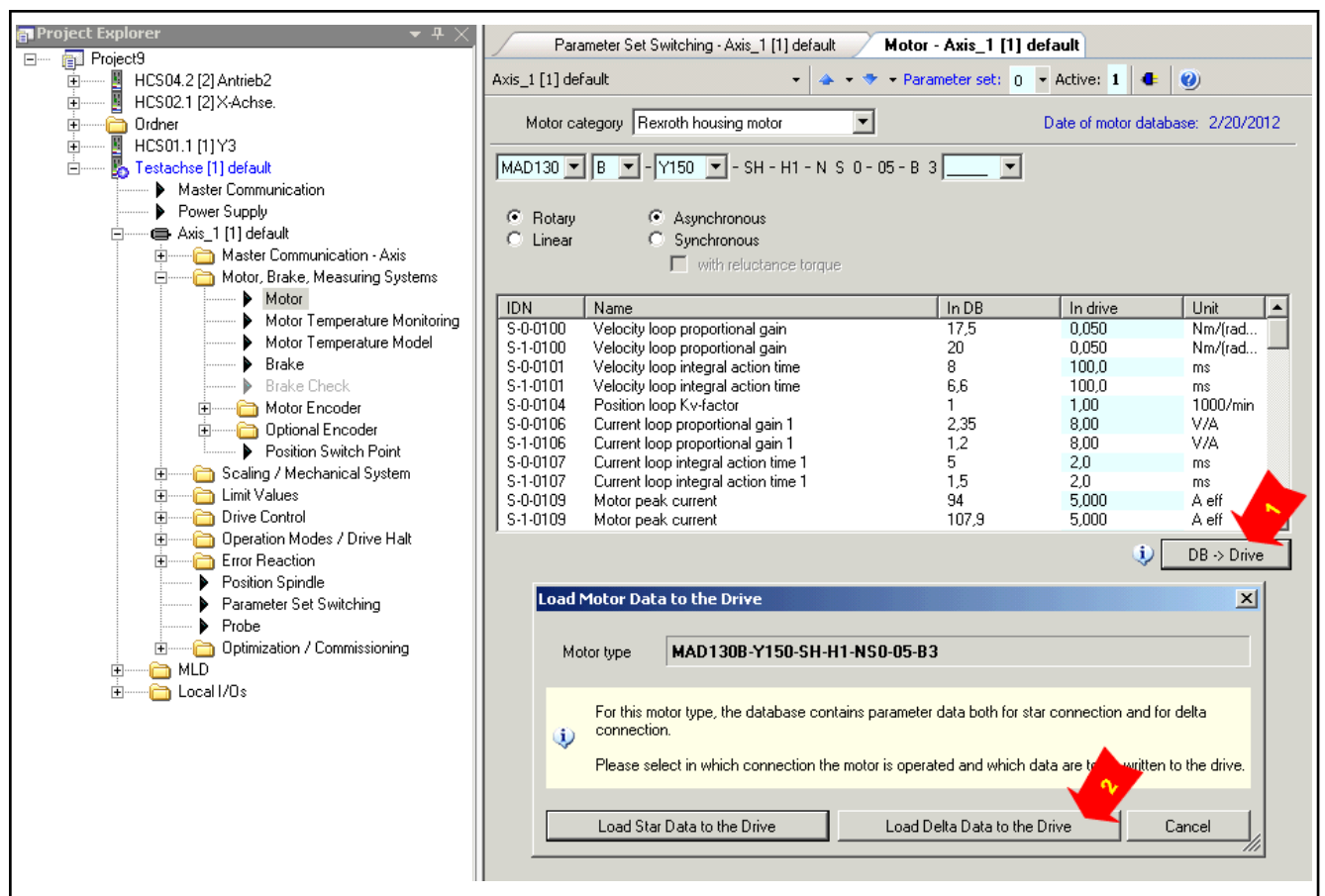
Fig.8-78:   IWD dialog for uploading motor parameters into the active switchable parameter sets with a star-delta switchable MAD motor

After "Upload database value" ("DB→drive") has been requested, a further dialog appears with a selection as to whether the parameters for star or delta switching are to be uploaded. The database values are always uploaded to the parameter set "0".

☞   For reasons of clarity, parameter set "0" is assigned to the star configuration and "1" to delta configuration. Other assignments are also possible!
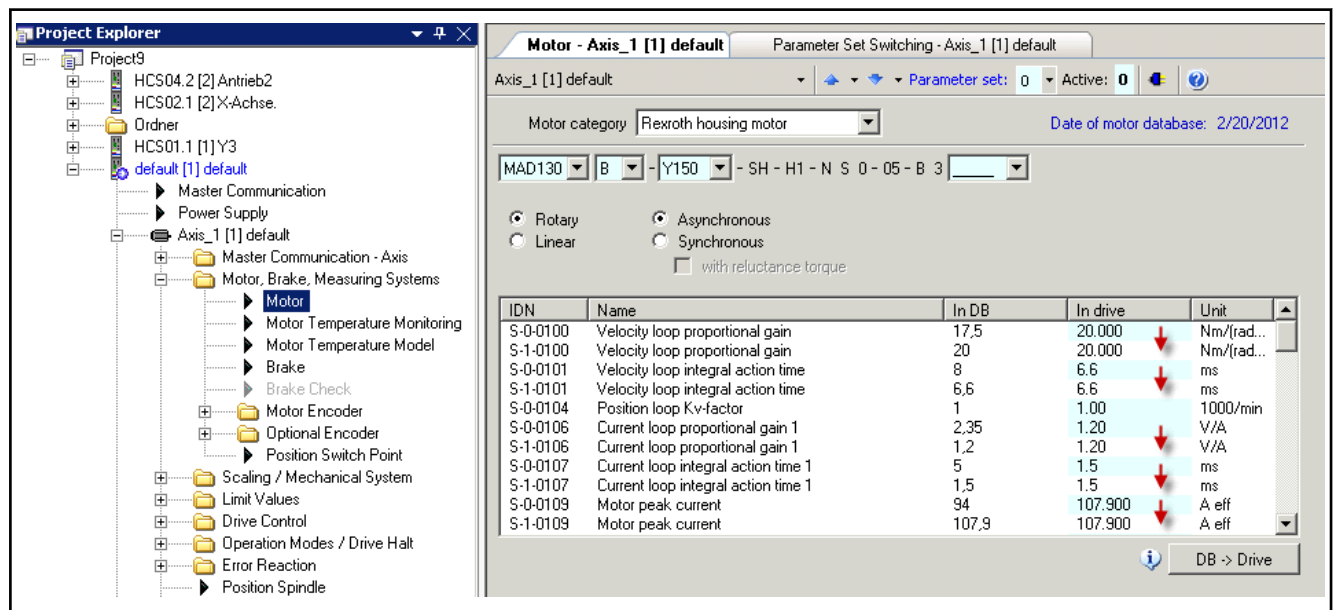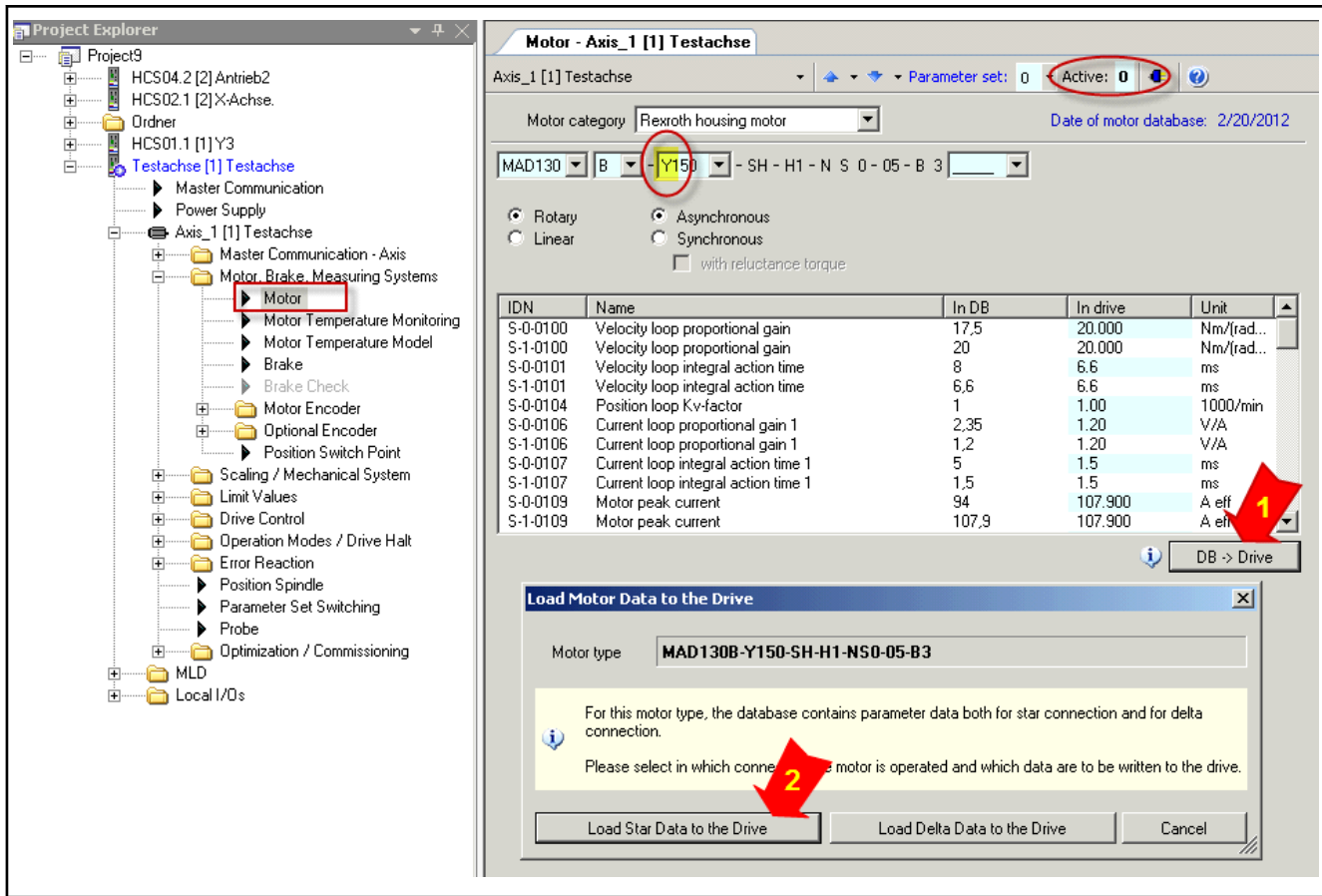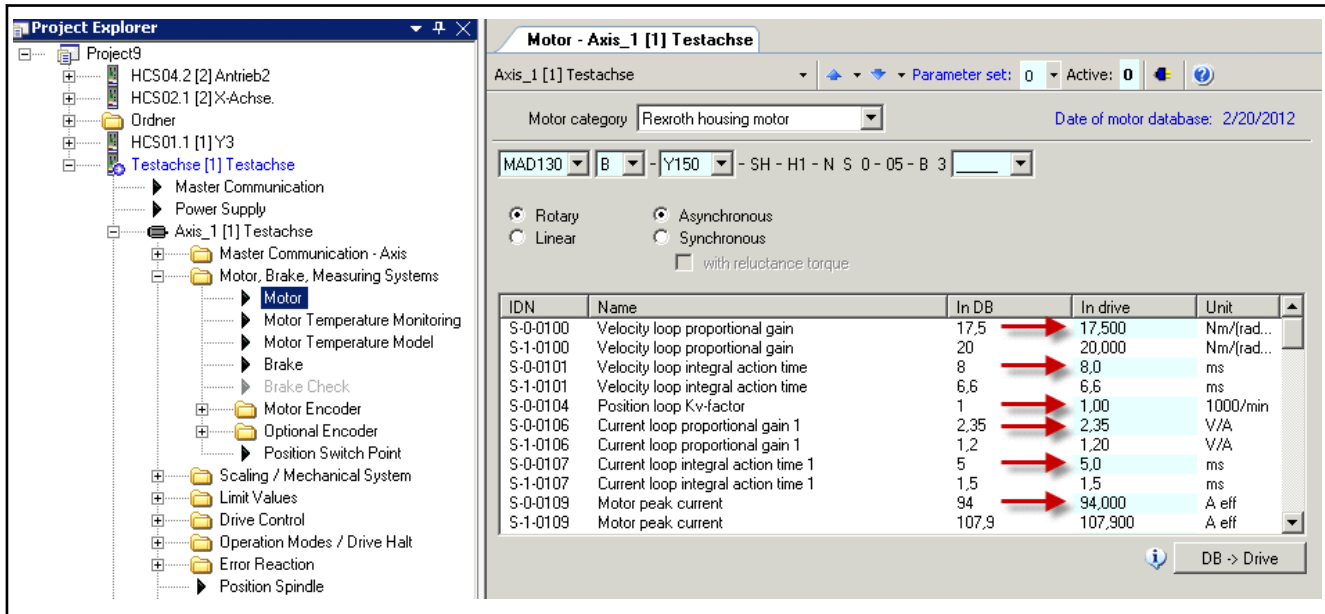
Extended Axis Functions

Fig.8-79:   Completed uploading of delta motor parameters into the parameter set "0" of the switchable parameter sets with a star-delta switchable MAD motor

- Defining parameter groups to be switched: The respective parameter groups must be selected, which contain parameters, which require different values depending on their switching mode ("P-0-2216, Parameter set switching, configuration", see also "Parameter set switching, defining parameter groups").

    – Compulsory: Winding parameter group

    – Optional: "Control loop parameters", "Application parameters" and "Load gear parameters" groups (required if one or more parameters are contained in these groups, for which different parameter values are possible depending on the motor switching)

    – Not recommended: Motor control and motor encoder parameter group, as switching is only possible in "Bb" or "Ab" and not "on the fly" (with "AF").

- Copy parameter set "0" after activating all requisite parameter groups in parameter set "1" relevant for switching. The values of parameter set "0" are therefore also in parameter set "1" (duplication).
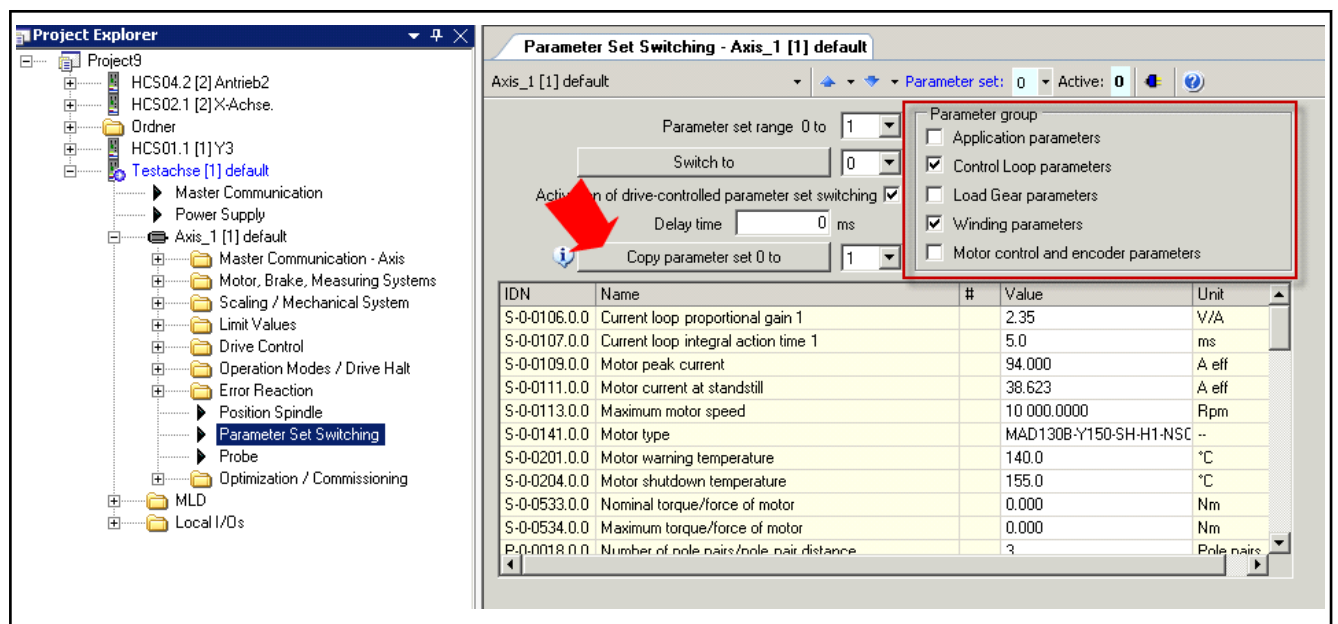
Fig.8-80: *IWD dialog for selecting parameter groups, which are included in parameter set switching, only the "Winding parameters" here, copying parameter set "0" to "1"*

Fig.8-81: *Completed copying of motor parameters into parameter set "1" of the switchable parameter sets with a star-delta switchable MAD motor*

- Now upload the parameter values for the star switching into the drive. The data are always uploaded into parameter set "0" of the switchable parameter sets.

Extended Axis Functions

Y150   "Yxxx": code for Y-D switchable MAD motor
*Fig.8-82:   IWD dialog for uploading motor parameters into the active switchable
                  parameter sets with a star-delta switchable MAD motor*

*Fig.8-83:   Completed uploading of star motor parameters into active parameter
                  set "0" of the switchable parameter sets with a star-delta switchable
                  MAD motor*

Generating Parameter Sets for Star-Delta Switching of Third-party Motors

First parameterize and start up the motor for each switching mode: See chapter "Motor, Mechanical Axis System, Measuring Systems, Third-party Motors"

As switchable winding parameters are needed for star-delta switching, it is sensible to prepare for parameter switching via the relevant IWD dialog:
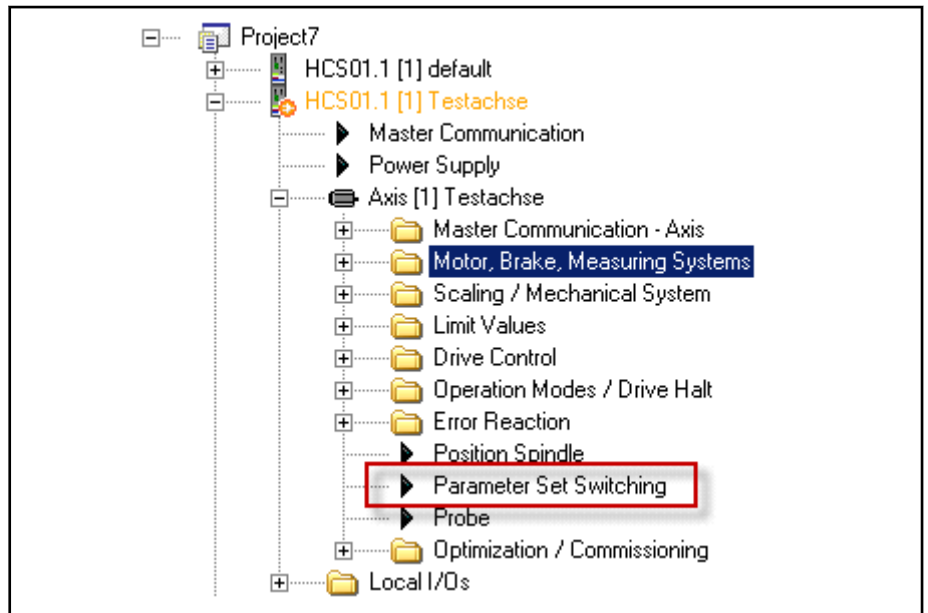
Fig.8-84:   Layout of the dialog for parameter set switching in the IWD Explorer
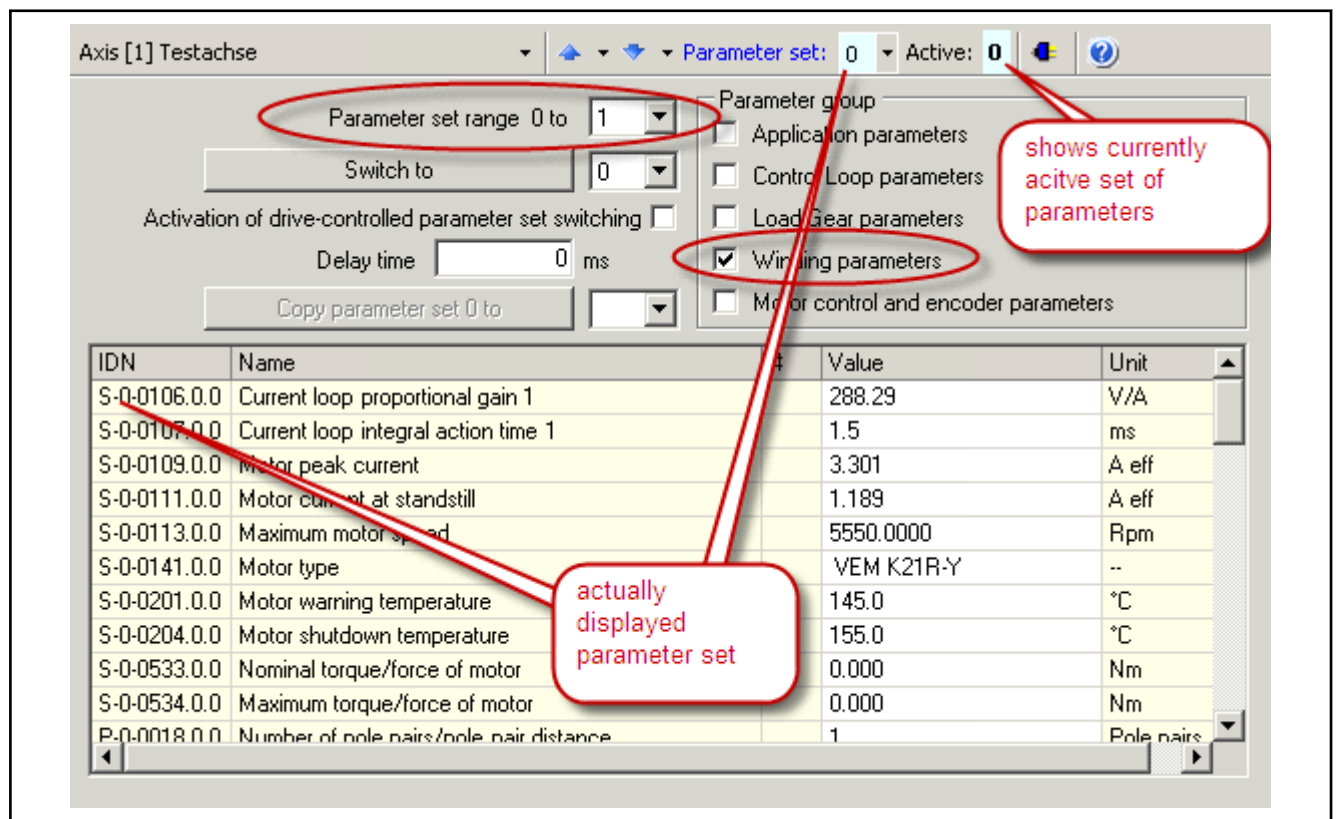
Fig.8-85:   Defining of switchable parameters: Parameter set range (0...max.7), parameter groups of switchable parameters, start of switching

Extended Axis Functions

Select a minimum of "0" and "1" for the parameter set range and a maximum of "0" to "7" is possible. Select at least the winding parameters with the parameter group or select further groups, if the Y-D parameters relevant for the switch are in another parameter group.

Asynchronous third-party motors

Third-party asynchronous motors are advantageously parameterized by inputting the data from the motor's type plate. Y/D data is generally given there.

☞   See chapter "Motor, Mechanical Axis System, Measuring Systems, Third-party Motors, Information of Asynchronous Motors"

The input of the type plate data is supported by the IWD motor dialog. Note here that data is inputted in the parameter set "displayed", although the specific motor parameters are only calculated in the "active" parameter set!

Fig.8-86:   Dialog box for input of the type plate data of third-party asynchronous motors using switchable parameter sets

Synchronous third-party motors

Third-party synchronous motors are parameterized by inputting motor data. The motor data must be available for star and delta switching of the motor windings or be given on the manufacturer's side.

☞   See chapter "Motor, Mechanical Axis System, Measuring Systems, Third-party Motors, Information of Asynchronous Motors"

The input of motor data for third-party motors is supported by the IWD motor dialog. Note here that data is inputted in the "displayed" parameter set, although the specific motor control parameters are only calculated in the "active" parameter set!
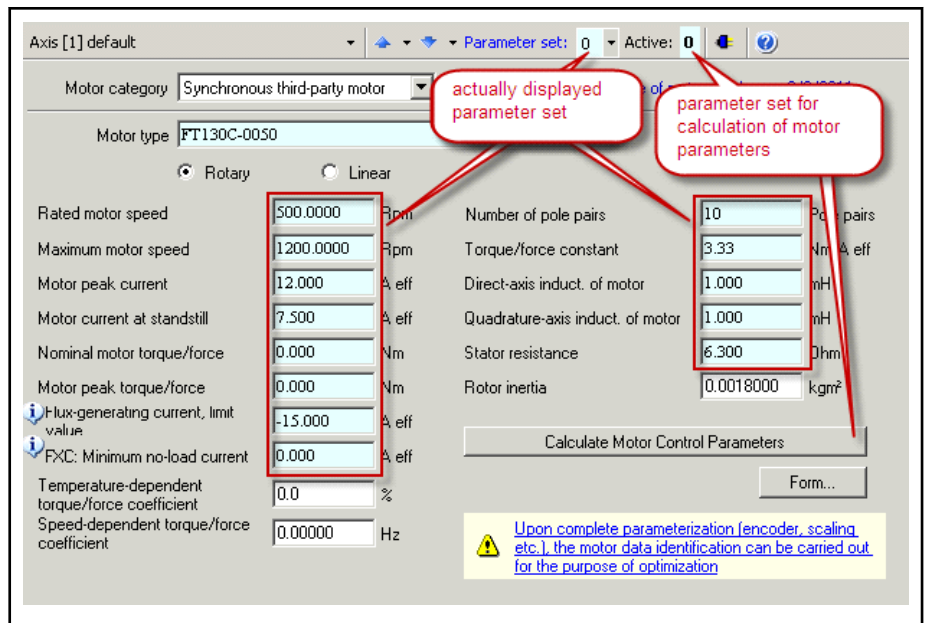
Extended Axis Functions

Fig.8-87:   *Dialog box for input of the type plate data of third-party synchronous motors using switchable parameter sets*

Commissioning of the Motor in Star and in Delta Switching

Rexroth asynchronous motors   Rexroth asynchronous motors are operational when the switching mode and assigned motor parameters are correctly assigned. Only the velocity control loop still has to be adjusted to the mechanical conditions of the axis.

Third-party motors   With third-party motors, with the initial commissioning in each switching mode of the motor windings, "motor parameter identification" is to be performed, ideally "with motion", providing this is possible on the axis. To do so, first switch to the respective assigned set of switchable parameters.
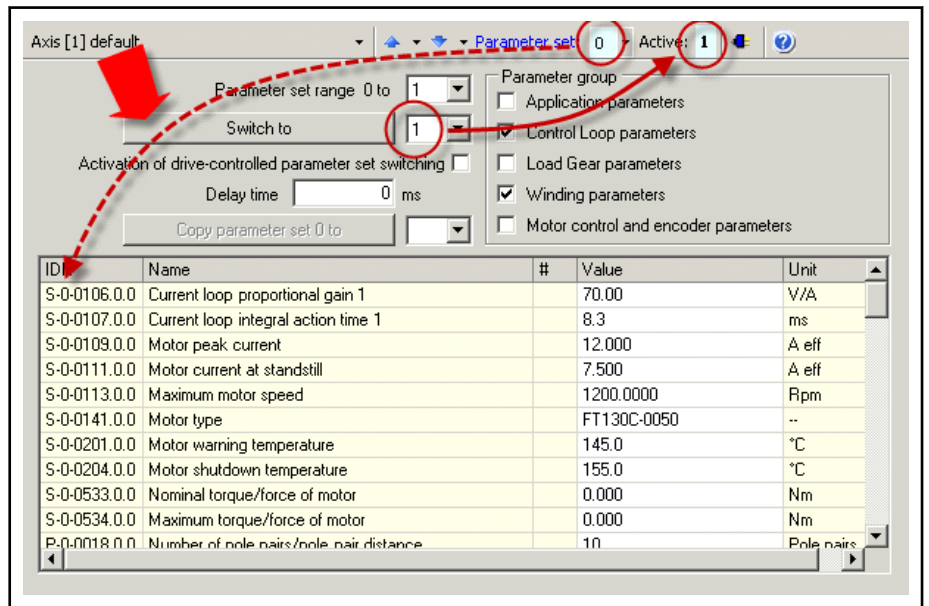
Fig.8-88:   *IWD dialog for switching parameters, showing here: Active: Parameter set 1, Display: Parameter set 0*

Also check the validity of the motor and motor encoder. This is done with "P-0-0565, C3600 Command Motor data identification", and with "P-0-0601, Configuration motor data identification" the different actions are configured.
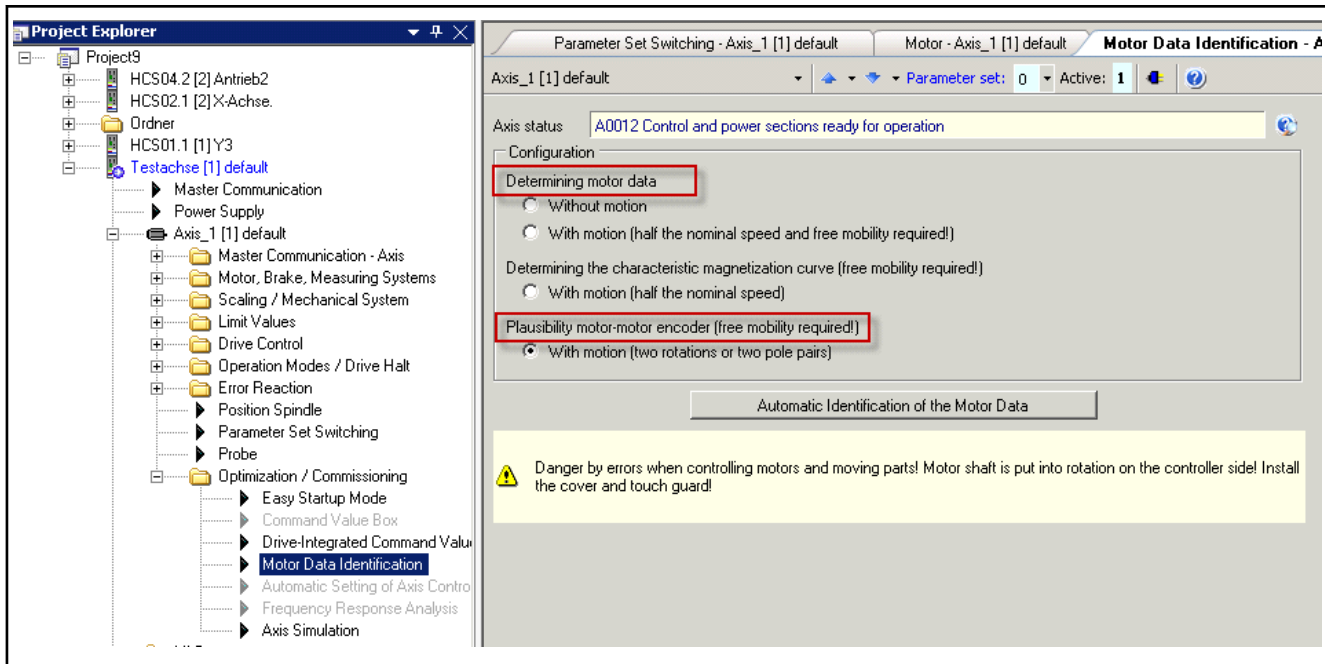
Extended Axis Functions

Fig.8-89:   IWD dialog for the configuration and start of "C3600, Command motor data identification"

☞   See also "Third-Party Motors on IndraDrive Controllers" chapter

Asynchronous third-party motors When the motor parameters have been determined and the validity of motor encoder and motor has been ascertained, the drive enable ("AF") can be set. The motor must now follow the command value. If this is not the case, the velocity control loop still has to be adapted to the mechanical conditions of the axis. This is needed in principle.

☞   See also "Third-Party Motors on IndraDrive Controllers" chapter

Synchronous third-party motors When the motor parameters have been determined and the validity of the motor encoder and motor has been determined, the commutation setting must still be entered with synchronous motors. This is done depending on the configuration of the motor encoder and the arrangement of its reference marks, as explained in the chapter "Commutation Setting".

☞   See also "Notes on Commissioning" in the chapter "Basics on Commutation Setting" and the respective process (with current) for commutation setting!

When the commutation offset is set, the drive enable ("AF") can be set. The motor must now follow the command value. If this is not the case, the velocity control loop still has to be adapted to the mechanical conditions of the axis. This is needed in principle.

☞   The use of "reference point-optimum commutation setting" is strongly recommended when using relative motor encoders, as this results in reproducible torque/force development of the motor!

Activating Star-delta Switching

The star-delta switching is triggered by switching into another parameter set, which is assigned to the other switching mode. The control master causes

the contactors in the motor supply line to be switched. The switching time is adjusted to the hardware-side conditions via "P-0-2218, Parameter set switching, delay time".
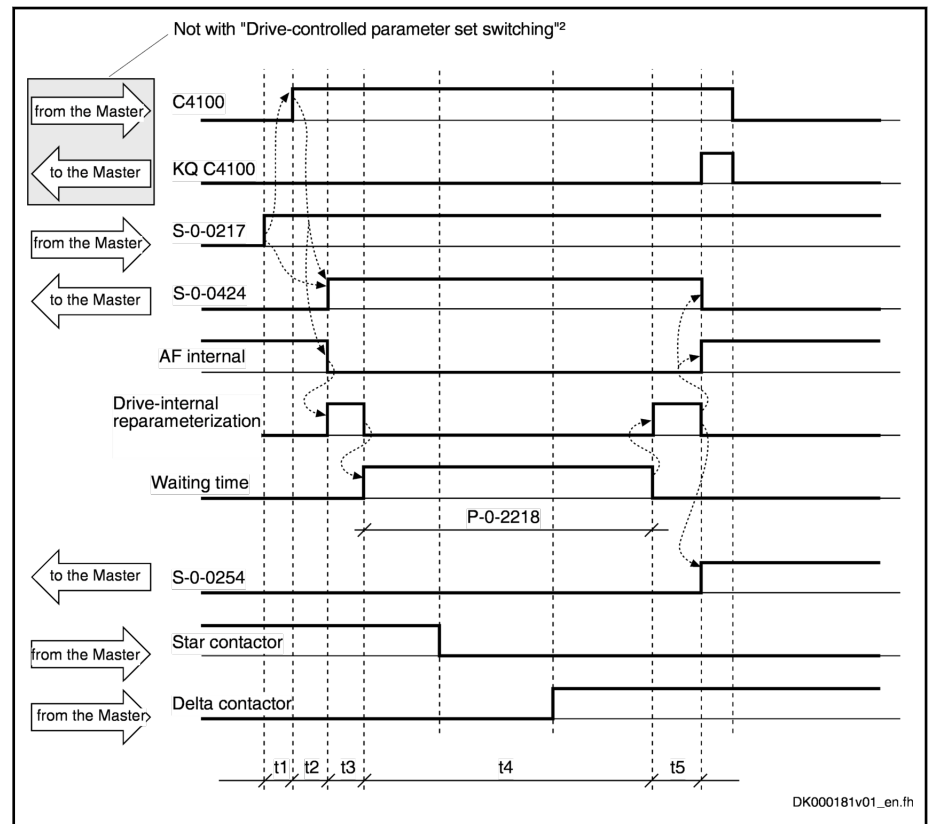

Fig.8-90:   Sequence diagram for switching the winding parameters

8.13 Drive-Controlled Oscillation

8.13.1 Brief Description

> Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Upon a command of the control master, the drive ignores the cyclic command value input and independently turns alternately in a positive and negative direction (speed oscillation). The cyclic speed characteristic can be set via parameters and can be realized symmetrically or asymmetrically.

Applicational information   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

Extended Axis Functions

- C4201 Oscillation requires drive enable
- C4202 Oscillation command speed cannot be reached

8.13.2 Functional Description

Drive-controlled oscillation is adjusted to the individual requirements of the meshing/engaging procedure via parameters. Oscillation cycle time, oscillation speed and oscillation offset speed can be set.

By means of the oscillation offset speed, oscillation can be asymmetrically configured in order to overcome tooth-to-tooth positions during the meshing procedure.
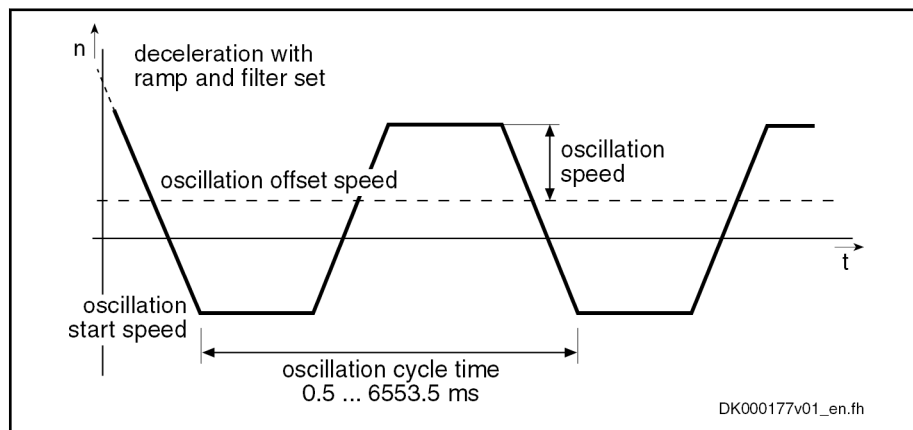
Fig.8-91:   Speed characteristic with drive-controlled oscillation

Start of "drive-controlled oscilla- Triggering of command "C4200 Drive-controlled oscillation command" causes
tion" 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 less 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.

Generating command values 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 are not active.

The parameter values for drive-controlled oscillation can be changed during the oscillation process. At the latest after the oscillation cycle time is over, the drive reacts to the new values.

After execution of command C4200 has been completed, the drive follows the currently present command value.

8.13.3 Notes on Commissioning

Presettings/checks Before activating the function "drive-controlled oscillation" the following presettings or checks have to be made:

- Value in parameter ""S-0-0215, Oscillation cycle time"" has to be not equal to 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 (increments of 0.5 ms)!

Activating oscillation   The function is activated by starting command "C4200 Drive-controlled oscillation command" (S-0-0190) via the control master.

Ending 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

8.14 Parking Axis

8.14.1 Brief Description

> Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

If individual axes within a master communication group (e.g. sercos ring, PROFIBUS) are to be temporarily deactivated, without taking them out of the axis group on the hardware and communication side, the 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 procedure command

Pertinent diagnostic messages   •   C1600 Parking axis command

8.14.2 Functional Description

Parameter "S-0-0139, C1600 Parking axis procedure command" can only be activated in parameter mode (communication phase "P2" or "P3"). Executing the command causes the following actions:

- Monitoring functions of measuring systems are deactivated
- Motor temperature monitoring is deactivated
- Reference bits in "position feedback value status" are disabled
- If "S-0-0128, C5200 Communication phase 4 transition check" is executed, there is no initialization of drives
- "PA" is displayed on the control panel and in the diagnostic system
- Master-side drive enable is ignored

Extended Axis Functions

> ☞ The execution of command C1600 is not acknowledged as com‐
> pleted 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 the measuring systems are activated
- Motor temperature monitoring is activated
- Standard diagnostic messages appear again on the display and in the
  diagnostic system
- Drive enable is possible again in communication phase "P4"

> ☞ As the position data reference of relative measuring systems is
> 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"; switch to the parameter
> mode from the operating states "bb" or "Ab" via "S-0-0420, C0400
> Activate parameterization level procedure command". By activat‐
> ing "S-0-0422, C0200 Exit parameterization level procedure
> command", the drive returns to the operating mode.

8.15   Integrated Safety Technology

8.15.1   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 exam‐
> ples of application are described in the separate documentation
> "Rexroth IndraDrive: Integrated Safety Technology According to
> IEC61508"   (DOK-INDRV*-SI2-**VRS**-FK**-EN-P;   part   no.
> R911327664).

8.15.2   Product Presentation

What is "Integrated Safety Technology"?

The control sections of the IndraDrive range can be equipped with one of the
following optional modules:

- One optional module "Safe Torque Off" ("L2") or
- One optional module "Safe Motion" ("S2")

By the mentioned optional modules, IndraDrive is equipped with integrated
safety technology which provides the user with an electronic starting lockout,
as well as with universally programmable safe motion and standstill monitor‐
ing.

Definition   "Safe Motion" means application-related safety functions which are applica‐
ble   for   personal   protection   at   machines   according   to
EN ISO 13849-1 Category 3 PL d and IEC EN 62061 SIL 2.

Extended Axis Functions

"Safe Torque Off" means application-related safety functions which are applicable for personal protection at machines according to EN ISO 13849-1 Category 3 PL e and IEC EN 62061 SIL 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 safe channel in PROFIBUS (PROFIsafe)

Certification

The safety technology was certified by TÜV Rheinland®; the NRTL listing by TÜV Rheinland of North America is in preparation.

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 an 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 according to EN ISO 13849-1 Category 3 PL d and IEC EN 62061 SIL 2 (when using "Safe Motion") or EN ISO 13849-1 Category 3 PL d/PL e and IEC EN 62061 SIL 2/SIL 3 (when using "Safe Torque Off"), as required in EN 1010-1 (printing and paper converting machines), EN 12415 (turning machines) and EN 12417 (machining centres).

- Control functions in the case of error according to EN 60204-1 (see "Using diversity" in EN 60204-1).

Integrated Safety Technology as IndraDrive Platform Solution

The different characteristics (e.g. PROFIsafe) require different hardware:

Control section type	Description	Characteristics of integrated safety technology		
		Safe Torque Off (optional module "L2")	Safe Motion (optional module "S2")	
			Digital I/Os	PROFIsafe
CSH01.1C	ADVANCED	X	X	X
CSH01.3C	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			
CSB01.1N-AN	BASIC ANALOG	X		
CSB01.1N-SE	BASIC SERCOS	X		
CSB01.1N-PB	BASIC PROFIBUS	X		

Fig.8-92:   Overview of the Hardware Requirements for the Integrated Safety Technology

Extended Axis Functions

> ☞ For using the integrated safety technology "Safe Motion" or "Safe Torque Off" according to IEC EN 61508 or EN ISO 13849-1, at least the firmware version MP*07VRS or higher must be used in the drive.
>
> In addition to the optional module "S2", using PROFIsafe requires the master communication module "PROFIBUS" (PB) together with the respective firmware version (as of MP*07VRS)!

Characteristics and Classification of Safety Technology

Functionality Levels   The available integrated safety functions can be divided into 2 levels:

- Level 1: Purely hardware-based safety technology, "Safe torque off" is part of it (optional safety technology module "L2" required)
- Level 2: Extensive integrated safety technology including all other safety functions, such as "Safely-limited speed", "Safely-monitored position",... (optional safety technology module "S2" required)

Characteristics Regarding the Interfaces   Apart from the classification of the safety functions, we distinguish the kinds of control (e.g. digital I/Os or PROFIBUS). The following characteristics are supported:

- Digital I/Os
- PROFIsafe

8.15.3   Safe Torque Off (STO)

Brief Description

> ☞ Using the function "Safe torque off" requires the optional safety technology module "L2".

The energy supply to the drive is safely interrupted with the safety function "Safe torque off". The drive cannot generate any torque/force and, as a consequence, it cannot generate any dangerous motions, either.

> ☞ Before activating the safety function "Safe torque off", 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 "Safe torque off", 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 a weight compensation; for such axes, Bosch Rexroth recommends that you use the safe braking and holding system.

Features   The safety function "Safe torque off" has the following features:

- Corresponds to stop category 0 according to EN 60204-1
- Is suited for safety-relevant applications up to Category 1 PL c and Category 3 PL d/PL e according to EN ISO 13849-1 or up to SIL 1/SIL 2/SIL 3 according to IEC EN 62061.
- The energy supply to the motor is safely interrupted via two channels.

- The **selection** is made via two channels using either an N/C-N/O or an N/C-N/C combination.

  To attain SIL 3/PL e, selection must take place via a higher-level safety master which also attains SIL 3/PL e.

- The safe state is **acknowledged** by an N/C-N/O contact; to attain SIL 2/PL d and SIL 3/PL e, the acknowledgment must always be evaluated.

- For **dynamization of the safety function selection**, the function must be activated at least every 168 hours (SIL 2/PL d) or 24 hours (SIL 3/PL e). For this reason, the operating hours of the power section at which the safety function "Safe torque off" was selected the last time are stored in the parameter "P-0-0102, Oper. hours power section at last activation of STO".

  To attain SIL 1/PL c, the dynamization of the safety function selection is not required.

- Monitoring the validity of the selection: 100 ms after selection was changed.

- The time intervals for activating the safety function "Safe torque off" 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 the parameter "P-0-0104, Change history time interval of forced dynamization".

- The status of the safety function "Safe torque off" is displayed via the parameter "P-0-0106, Operating status of STO".

Pertinent Parameters   The following parameters are used in conjunction with the safety function "Safe torque off":

- P-0-0101, Configuration for STO selector
- P-0-0102, Oper. hours power section at last activation of STO
- P-0-0103, Time interval of forced dynamization
- P-0-0104, Change history time interval of forced dynamization
- P-0-0106, Operating status of STO

Pertinent Diagnostic Messages   The following diagnostic messages can be generated in conjunction with the safety function "Safe torque off":

- F8027 Safe torque off 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 Safe torque off while drive enabled
- With the safety function "Safe torque off" activated, the display of the IndraDrive control panel shows "STO".

8.15.4   Integrated safety technology

Features   - Dual-channel selection on safety functions via digital inputs/outputs (24 V) or digital inputs/outputs (24 V) and master communication or a safe process data channel for PROFIBUS-DP (PROFIsafe)

- **Integrated functionality for detecting "sleeping" errors:**
  - Dual-channel data processing with structure by diversity

Extended Axis Functions

- – Cross comparison of safety-relevant data
- – Dynamization of static states
- Password protection for all safety technology parameters
- Safety functions in normal operation and special mode

  → "Safe maximum speed", "Safe direction", "Safely-limited position"
- Safety functions of safety technology function category "Safe standstill"

  → "Safe stop 1 (Emergency stop)", "Safe stop 1", "Safe stop 2", "Safe braking and holding system"
- Safety functions of safety technology function category "Safe motion"

  → "Safely-limited speed", "Safe direction", "Safely-limited increment", "Safely-monitored position"
- Auxiliary functions

  → "Safely-monitored stopping process", "Safe homing procedure", "Safe brake check", "Safe parking axis"
- Safety functions for "Safe feedback"

  → "Safe diagnostic outputs", "Safe door locking device", "Safe inputs/outputs" [only available via master communication "PROFIBUS" (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 separate documents "Integrated Safety Technology; Functional and Application Description" and "Parameter Description".

Pertinent diagnostic messages   For the pertinent diagnostic messages in conjunction with integrated safety technology, see separate document "Integrated Safety Technology According to IEC61508; Functional Description" under the corresponding safety function.

8.15.5   Functions of the Integrated Safety Technology

Overview

A differentiaton is made between the following operating states of integrated safety technology:
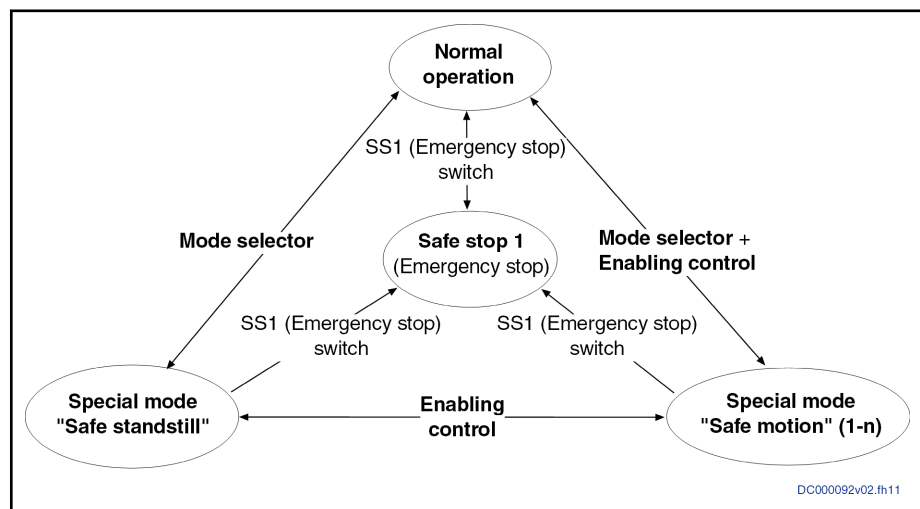

Fig.8-93:   Operating states of integrated safety technology

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 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 static error states, so-called sleeping errors, are realized in the system:

- **Dual-channel data processing** with structure by diversity

- **Cross comparison** of the safety-relevant data

- **Dynamization** of static states

These measures guarantee that a single error cannot cause the loss of the safety functions.

The installation or machine manufacturer has to determine in how far this is sufficient for an existing installation or machine by a risk analysis according to annex I of Directive 98/37/EEC.

☞   After 2009-12-31, the new Machinery Directive 2006/42/EG must be applied.

States of Integrated Safety Technology

Normal and special mode
The following safety functions are supported in the "normal mode/special mode state:"

- **Safety-limited maximum velocity**

  → → Defines a safe maximum speed in normal mode/special mode

- **Safety-limited position**

  → → Defines a positive and a negative safe position in normal/special mode

  Note: The safely-limited position requires establishing the safe reference!

- **Safe direction of motion**

  → 2-channel monitoring for permitted direction of motion

Safe standstill
The "Safe standstill" status supports the following safety functions :

- **Safe stop 1**

  → Corresponds to Stop category 1 according to EN 60204-1; with drive-controlled best possible deceleration and time monitoring

- As an alternative -

- **Safe stop 2**

  → 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 -

- **Safe stop 1 (Emergency stop)**

  → Like "Safe stop 1", but with no switching to "Safe motion" by actuating the enabling control device

☞   Selection of "safe stop 1"/"safe stop 2" is made via the safety switches S1/S2; selection of "safe stop 1 (Emergency stop)" is made via dedicated switches

Extended Axis Functions

- **Safe braking and holding system**

  → It is safely prevented that gravity-loaded axes move down accidentally

Safe motion   In the status "safe motion", the following safety functions are supported by "Safety on Board":

- **Safely limited velocity**

  → 2-channel monitoring for exceeding a speed threshold

- **Safe direction of motion**

  → 2-channel monitoring for permitted direction of motion

- **Safely-limited increment**

  → 2-channel monitoring for allowed travel distance

- **Safely-monitored position**

  → 2-channel monitoring for monitored position

  Note: The safely-monitored position requires establishing the safe reference!

Auxiliary functions   The following auxiliary functions are provided:

- **Safely-monitored stopping process**

  → 2-channel monitoring of transition to safe standstill or safe motion

- **Safe homing procedure**

  → To establish the reference for channel 1 and channel 2

  Note: The safe reference is a prerequisite for the "Safely limited position" and the "Safely-monitored position"!

- **Safe brake check**

  → Cyclic test for both holding brakes (is required for the safe braking and holding system)

- **Safe parking axis**

  → Safe parking of the axis by safe locking of the output stage and acknowledgment of safety, although no encoder is available

"Safe feedback" safety functions   The following safety functions are provided for "safe feedback":

- **Safe diagnostic outputs**

  → To transmit the "safe state" to additional system components

- **Safe door locking device** (not with PROFIsafe)

  → A drive that acts as the diagnostic master can summarize the safe state of several axes within a protective zone and control a safety door.

- **Safety-related inputs/outputs (for PROFIsafe)**

  → Safe inputs/outputs of the drive are used for connecting sensors and actuators which the higher-level master controls via PROFIsafe.

8.15.6   Notes on Commissioning

Safe Torque Off

Using the optional safety technology module "Safe Torque Off" (L2) does not require any special kind of commissioning; the corresponding wiring is sufficient.

[i] For detailed descriptions and information, see separate documentation "Rexroth IndraDrive: Integrated Safety Technology According to IEC 61508"

Safe Motion

Commissioning of the optional safety technology module "Safe Motion" (S2) is made through menu prompts via the commissioning tool "IndraWorks Ds/D/MLD".

ℹ️ For detailed descriptions and information, see separate documentation "Rexroth IndraDrive: Integrated Safety Technology According to IEC 61508"

9 Optional Device Functions

9.1 Safety Instructions

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

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

9.2 Availability of the Optional Device Functions

The following overview illustrates by which base packages or functional packages the respective optional device function is supported (if not stated otherwise, this applies to all 4 firmware variants, MPB, MPD, MPH and MPC).

Optional device function	In base package (characteristic)	in the functional package … (on the basis of a base package with the following characteristics)		
		Servo function	Synchronization	Main spindle
Cross communication (CCD)	Only available via 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	–	–	–
Command value box	OL/CL	–	–	–
Encoder emulation	CL	–	–	–
Dynam. Position switch	–	CL	CL	–
Probe	CL	–	OL/CL	–
Measuring encoder	–	OL/CL	OL/CL	–

OL   Open-loop characteristic
CL   Closed-loop characteristic
1)   Depending on hardware configuration
Fig.9-1:   *Availability of the optional device functions*

Optional Device Functions

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

See also "Enabling of Functional Packages"

9.3 Cross Communication (CCD)

9.3.1 Brief Description

Overview   The IndraDrive "Cross Communication" device function (**C**ross **C**ommunication **D**rives → CCD) permits the electronic (digital) coupling of axes and the connection of I/O modules for IndraMotion MLD.
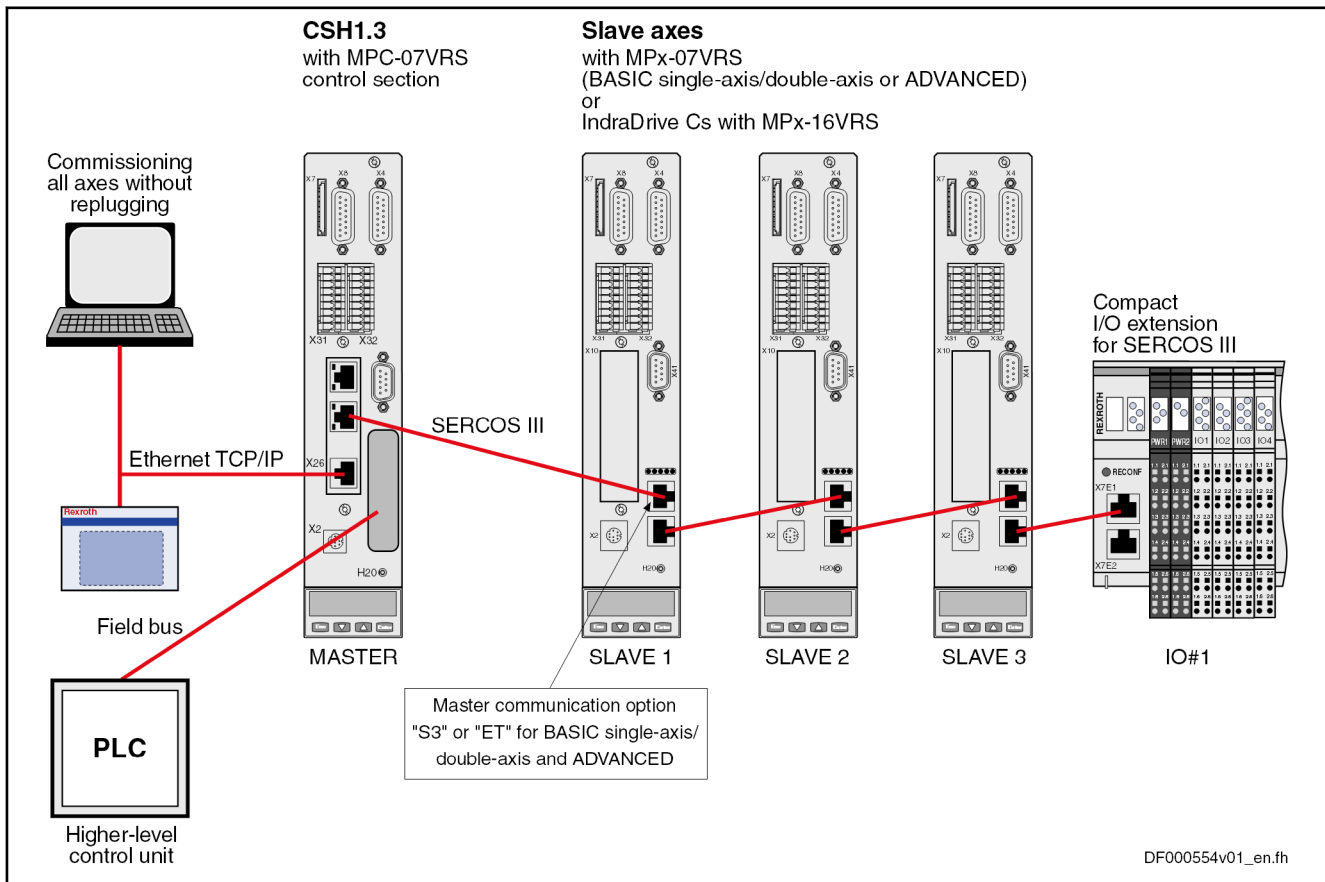
Fig.9-2:   Hardware topology of the Cross Communication Drive (CCD)

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 requires a master communication interface (e.g. PROFIBUS®) in addition to the CCD optional module ("sercos III master connection").

CCD modes (kinds of coupling)   When Cross Communication (CCD) is used between the drives, we differentiate between the following versions (CCD modes):

- **CCD system mode**

  CCD slaves have a direct logic connection to the field bus master and command triggering and input of process data takes place via an external control unit.

- **CCD basic mode**

Optional Device Functions

The same functions are available as for CCD system mode although the user must parameterize them himself. It is not possible to use MLD-M functionality in the master axis.

- **MLD-M system mode**

  The CCD slaves do not have 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 takes place by the MLD-M in the CCD master.

Features The "Cross Communication (CCD)" device function is characterized by the following features:

- Synchronization of CCD slaves to the CCD master
- Transmission of freely configurable external **process data** (command values and actual values of the external control unit)
- Command value linking by transmission of freely configurable process data from the CCD axes (e.g. master/slave, Gantry axis)
- Connection of I/O extensions for sercos III via CCD (a maximum of 4 modules per CCD master)
- Parameterizable CCD (sercos III) cycle time (0.25 ms to 4 ms; depending on the CCD mode, 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 in the CCD group via the CCD master interfaces (RS232, Engineering port, field bus, …)
- Command triggering of the CCD slaves depending on the selected CCD mode via external control unit or internally via MLD in the CCD master
- Max. number of CCD slaves: 7 or 9 respectively (depending on the CCD mode; see below "Performance Features")

Fields of application Typical applications for Cross Communication:

- Control tasks for multi-axis applications
  – Anti-backlash
  – Synchronous operation control
  – Load control of several axes
- Simple command value linking
  – Position command value linking (gantry axes)
  – Torque/force linking
- Simple motion controls with decentralized command value adjustment for single-axis positioning and master axis linking
- I/O extension by connection of I/O modules for sercos III via CCD

Restrictions When using Cross Communication, observe the following restrictions:

- "Coordinated Motion" is not possible with the Cross Communication function!
- The multiplex channel for external controls in the CCD master is not available in MLD-M system mode

Hardware requirements Using the "Cross Communication" drive function requires the following control section designs:

Optional Device Functions

- **CCD master**

  Control section/device in ADVANCED version with CCD option

  → CSH-01.3C-xx-xxx-xxx-CCD-xx-x-..

- **CCD slaves**

  Control section with master communication interface "sercos III" (S3) , or "MultiEthernet" (ET); possible with the following versions:

  – BASIC UNIVERSAL single-axis → CSB-01.xC-S3-xxx-xx-x, CSB-01.xC-ET-xxx-xx-x

  – BASIC UNIVERSAL double-axis → CDB-01.xC-S3-xxx-xx-x, CDB-01.xC-ET-xxx-xx-x

  – ADVANCED single-axis → CSH-01.xC-S3-xxx-xx-x, CSH-01.xC-ET-xxx-xx-x

  – IndraDrive Cs single-axis → HCS01.1E-W00xx-A-0x-x-xx-xx-xx-xx-xx-FW

  ℹ️ See documentation "Control Sections for Drive Controllers; Project Planning Manual"

Firmware requirements   Observe the following aspects in relation to the firmware when using the "Cross Communication" drive function:

- This drive function is supported from firmware version MPx04 onwards.

- With firmware versions MPx04 and MPx05, all drives of a CCD group (CCD master and CCD slaves) must be operated with the same firmware version (e.g. all MPx05VRS).

- The CCD master must be operated with MPC07VRS or MPC08VRS (CSH1.3). CCD slaves with MPx04 or MPx05 cannot be operated in this case.

- As with integrated safety technology, this firmware function does not require separate enabling of functional packages; the function of Cross Communication Drive is also available with the corresponding hardware design.

Pertinent parameters   The parameters listed below are only available for the CCD master:

- P-0-0197, System time

- 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 addresses

- P-0-1604, CCD: addresses of projected I/Os

- 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-0-1610, CCD: cycle time

- P-0-1610.0.3, CCD: Actual topology

- P-0-1610.0.21, CCD: Slave addresses at end of line

- P-0-1610.0.30, CCD: Diagnostic message text

- 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 cmd 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-0-1619, CCD: Slave information at the topology location
- P-0-1620.0.3, CCD: Command topology
- P-0-1620.0.4, CCD: Slave identification
- P-0-1620.0.5, C7400 CCD: Switching to phase 2
- P-0-1620.0.6, C7500 CCD: Switching to phase 4
- P-0-1620.0.21, C7100 CCD: Command Close ring
- P-0-1620.0.30, CCD: I/O selection for commando C72
- P-0-1620.0.31, C7200 CCD: Commando Apply I/O configuration
- P-0-1621, CCD: configuration list master communication cmd values
- P-0-1621.x.1, CCD: Slave address in high level network
- P-0-1621.x.9, CCD: Master comm. C0100 Comm. phase 3 transition check
- P-0-1621.x.10, CCD: Master comm. C5200 Comm. phase 4 transition check
- P-0-1621.x.24, CCD: Master comm. gateway parameter pool 1
- P-0-1621.x.25, CCD: Master comm. gateway parameter pool 2
- P-0-1621.x.35, C5300 CCD: SIII SYNC delay measuring procedure command
- 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-0-1627, CCD: configuration list master cmd values I/Os
- P-0-1628, CCD: configuration list act. master values I/Os
- P-0-1629, CCD: configuration compact I/Os
- P-0-1630, CCD: diagnosis
- P-0-1630.x.1, CCD: Slave IP address
- P-0-1630.x.2, CCD: Device Status (S-Dev)
- P-0-1630.x.3, CCD: Connection-Control #0 (C-Con)
- P-0-1630.x.20, CCD: Resource-Status (S-Res)
- P-0-1631, CCD: AT error counter
- P-0-1632, CCD: system data 2 bytes
- P-0-1633, CCD: system data 4 bytes
- P-0-1634.x.1, CCD: Module type codes of the modular I/Os
- P-0-1635, C7000 CCD: command adjust slave addresses

Optional Device Functions

- P-0-1636, CCD: Command topology addresses
- P-0-1637, CCD: error counter Port-1
- P-0-1638, CCD: error counter Port-2
- P-0-1639, CCD: allowed telegram failures
- 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-0-1645.x.1, CCD connection: Configuration
- P-0-1645.x.2, CCD connection: Connection number
- P-0-1645.x.3, CCD connection: Telegram assignment
- P-0-1645.x.4, CCD connection: Max. length of connection
- P-0-1645.x.5, CCD connection: Current connection length
- P-0-1645.x.6, CCD connection: Configuration list
- P-0-1645.x.8, CCD connection: Connection control (C-Con)
- P-0-1645.x.10, CCD connection: Producer cycle time
- P-0-1645.x.11, CCD connection: Allowed losses of producer data
- P-0-1645.x.12, CCD connection: Error counter data losses
- P-0-1645.x.20, CCD connection: IDN allocation of real-time bits
- P-0-1645.x.21, CCD connection: Bit number allocation of real-time bits
- P-0-1651, CCD: master control word, slave 1
  (up to P-0-1659)
- P-0-1660.x.2, CCD: Device Control (C-Res)
- P-0-1660.x.3, CCD: Connection-Control #1 (C-Con)
- P-0-1660.x.20, CDD: Resource-Control (C-Res)
- P-0-1661, CCD: drive status word, slave 1
  (up to P-0-1669)
- P-0-1670, CCD: active actual position value, master
- P-0-1671, CCD: active actual position value, slave 1
  (up to P-0-1679)
- P-0-1680, CCD: actual velocity value, master
- P-0-1681, CCD: actual velocity value, slave 1
  (up to P-0-1689)
- P-0-1690, CCD: actual torque/force value, master
- P-0-1691, CCD: actual torque/force value, slave 1
  (up to P-0-1699)
- P-0-1701, CCD: Diagnostic message number, slave 1
  (up to P-0-1709)
- P-0-1710, CCD: signal status word, master
- P-0-1711, CCD: signal status word, slave 1
  (up to P-0-1719)

Optional Device Functions

- P-0-1720, CCD: signal control word, master
- P-0-1721, CCD: signal control word, slave 1
  (up to P-0-1729)
- P-0-1730, CCD: Command value data container 1, Master 4Byte
- P-0-1731, CCD: Command value data container 1, Slave 1 4Byte
  (up to P-0-1739)
- P-0-1740, CCD: Command value data container 2, Master 4Byte
- P-0-1741, CCD: Command value data container 2, Slave 1 4Byte
  (up to P-0-1749)
- P-0-1750, CCD: Command value data container 3, Master 4Byte
- P-0-1751, CCD: Command value data container 3, Slave 1 4Byte
  (up to P-0-1759)
- P-0-1760, CCD: Command value data container 4, Master 4Byte
- P-0-1761, CCD: Command value data container 4, Slave 1 4Byte
  (up to P-0-1769)
- P-0-1770, CCD: Actual value data container 1, Master 4Byte
- P-0-1771, CCD: Actual value data container 1, Slave 1 4Byte
  (up to P-0-1779)
- P-0-1780, CCD: Actual value data container 2, Master 4Byte
- P-0-1781, CCD: Actual value data container 2, Slave 1 4Byte
  (up to P-0-1789)
- P-0-1790, CCD: Actual value data container 3, Master 4Byte
- P-0-1791, CCD: Actual value data container 3, Slave 1 4Byte
  (up to P-0-1799)
- P-0-1800, CCD: Actual value data container 4, Master 4Byte
- P-0-1801, CCD: Actual value data container 4, Slave 1 4Byte
  (up to P-0-1809)
- P-0-1810, CCD: Status word synchronous operation modes, master
- P-0-1811, CCD: Status word synchronous operation modes, slave 1
  (up to P-0-1819)
- P-0-1820, CCD: Command value data container 1, Master 2Byte
- P-0-1821, CCD: Command value data container 1, Slave 1 2Byte
  (up to P-0-1829)
- P-0-1830, CCD: Command value data container 2, Master 2Byte
- P-0-1831, CCD: Command value data container 2, Slave 1 2Byte
  (up to P-0-1839)
- P-0-1840, CCD: Command value data container 3, Master 2Byte
- P-0-1841, CCD: Command value data container 3, Slave 1 2Byte
  (up to P-0-1849)
- P-0-1850, CCD: Command value data container 4, Master 2Byte
- P-0-1851, CCD: Command value data container 4, Slave 1 2Byte
  (up to P-0-1859)

Optional Device Functions

- P-0-1860, CCD: Actual value data container 1, Master 2Byte
- P-0-1861, CCD: Actual value data container 1, Slave 1 2Byte (up to P-0-1869)
- P-0-1870, CCD: Actual value data container 2, Master 2Byte
- P-0-1871, CCD: Actual value data container 2, Slave 1 2Byte (up to P-0-1879)
- P-0-1880, CCD: Actual value data container 3, Master 2Byte
- P-0-1881, CCD: Actual value data container 3, Slave 1 2Byte (up to P-0-1889)
- P-0-1890, CCD: Actual value data container 3, Master 2Byte
- P-0-1891, CCD: Actual value data container 3, Slave 1 2Byte (up to P-0-1899)

☞ The standard sercos III parameters are used for configuring sercos III communication in the slaves, (see "S-0-1001, SERCOS III: NC cycle time (TNcyc)" 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
- C7000 CCD: Command Close ring
- C7001 CCD: Impossible to close ring
- C7100 CCD: Command Close ring
- C7101 CCD: Impossible to close ring
- C7200 CCD: Command Apply I/O configuration
- C7201 CCD: Impossible to apply I/O configuration
- C7400 CCD: Switching to phase 2
- C7401 CCD: Impossible to switch to phase 2
- C7500 CCD: Switching to phase 4
- C7501 CCD: Impossible to switch to phase 4
- E4012 Maximum number of CCD slaves exceeded
- E4013 Incorrect CCD addressing
- E4014 Incorrect phase switch of CCD slaves
- E4016 CCD: Topology error
- E4017 CCD: Unknown I/O configuration
- F2140 CCD slave error
- F4012 Incorrect I/O length
- F4140 CCD communication error
- F6140 CCD slave error (emergency halt)
- F8140 Fatal CCD error

9.3.2   Functional Description of CCD Modes

Comparison of CCD Modes

With IndraDrive, Cross Communication is available in different variants (CCD modes) which are distinguished by the performance features contained in the following table:

Feature	CCD system mode	CCD basic mode	MLD-M system mode
Acyclic communication between CCD master-side field bus interface and CCD slaves[1]	Yes	No	No
Process data gateway and profile interpreter from the external master (e.g. field bus interfaced PLC) to CCD slaves[4]	Yes	No	No
Synchronization of CCD slaves to the CCD master	Yes	Yes	Yes
Cross Communication for command value linking in the CCD group	Yes	Yes	Yes
Command triggering via external control unit, i.e. slaves receive elementary information on device control (e.g. drive enable, operation mode input) for slaves from the external master (e.g. field bus-interfaced PLC)	Yes	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, operation mode input) from MLD in the CCD master	No	restricted [2]	Yes
Use of up to four I/O extensions as CCD slaves	Yes	Yes	Yes

1)	Acyclic communication not available with CANopen interface
2)	Command triggering is possible, if control words are configured and operated correspondingly (e.g. P-0-1651)
3)	Command triggering is possible, if MLD registers (e.g. P-0-1370 et seq.) are configured and operated correspondingly and interpreted in the MLD-M of the CCD master
4)	Process data gateway not available with CANopen interface

Fig.9-3:   *Comparison of CCD Modes*

Performance Features

The table below contains the main features and important data on the CCD modes:

Optional Device Functions

	Command triggering (Motion Control)		Possible master communications						Max. number of axes
							sercos		
	CCD master	CCD Slave	PROFIBUS® PROFINET® EtherNet/IP™ DeviceNet™	CANopen	Parallel, Analog, et al.	Ether-CAT®	II	III	
CCD system mode	Remote	Remote	Profiles 0xFFFE, 0xFFFD for all CCD nodes	-	-	Yes			9+1
CCD basic mode	Local	Local	All profiles (only for CCD master)	Yes		Yes			9+1
MLD-M system mode	Local	Remote MLD-M	All profiles (only for CCD master)	Yes		Yes, without profile			9+1

Remote   Control by external master
Remote MLD-   Control by MLD-M in the CCD master
M
Local   Control by local MLD-S of the respective axis
Fig.9-4:   Performance features of CCD Modes

Maximum number of axes and CCD cycle time   The maximum number of possible drives in the group (CCD slaves) depends on:

- Selected CCD mode
- CCD cycle time set
- Volume of cyclic data (MDT, AT) per CCD slave

CCD cycle time	CCD system mode	MLD-M system mode[1]	CCD basic mode
250 µs [2] / 500 µs	1 slave + 1 master (2 slaves + +1 master)	--	1 slave + 1 master (2 slaves + +1 master)
1000 µs	6 slaves + 1 master	6 slaves[4] + 1 master	6 slaves + 1 master
2000 µs / 4000 µs	9 slaves + 1 master 7 slaves + 1 master[3]	9 slaves + 1 master	9 slaves + 1 master
	The values in brackets are only valid for 24 bytes or less of MDT/AT data per slave.		

1)   MLD-M system mode can only be selected in Basic performance of the CCD master.
2)   250 µs cycle time is only possible if all drives in the CCD group are operated in Advanced control (CSH01.x control sections required).
3)   A maximum of 7 CCD slaves is possible for sercos II; independently of the MDT-/AT data
4)   Economy performance is not possible in the CCD slaves
Fig.9-5:   Maximum number of drives depending on CCD cycle time

☞   sercos III I/O slaves are not included in the above overview and are to be added to the maximum possible number of axes specified. Therefore, 4 sercos III I/O slaves are always possible in addition to the specifications above.

Cyclic data   It is possible to transmit up to 16 IDNs, with a total data volume of 48 bytes, in each direction (command values and actual values).

In **CCD system mode** (not applicable with sercos II, sercos III and EtherCAT), only the freely configurable profile (0xFFFE and 0xFFFD) is supported in the

Optional Device Functions

CCD master (applicable only with PROFIBUS®, PROFINET®, EtherNet/IP^{TM}, DeviceNet^{TM})!

The resulting connection length between the CCD master and CCD slaves in **CCD system mode** results from the cyclic command and actual values exchanged between the master communication master (control) and the CCD slaves (P-0-1621, P-0-1622) and the data from the parameters (P-0-1623, P-0-1624, P-0-1625 and P-0-1626), which is needed for cyclic communication between the CCD master and CCD slaves.

In CCD system mode, for example, with 9 CCD slaves, a maximum of 24 bytes of AT data and 24 bytes of MDT data is permitted, i.e. the sum of P-0-1621 and P-0-1625 may only be a maximum of 24 bytes per slave.

The maximum data volume that can be transmitted from the master communication master (external control) to the CCD master depends on the master communication of the CCD master and consists of the data from parameters P-0-1621, P-0-1622, P-0-4080 and P-0-4081:

- PROFIBUS®: 208 bytes (of both command and actual values)
- PROFINET®/EtherNet/IP^{TM}: 480 bytes (of both command and actual values)
- DeviceNet^{TM}: 384 bytes (of both command and actual values)
- sercos II: 384 bytes (of both command and actual values)

CCD System Mode

In CCD system mode, the higher-level (external) master has control over the CCD slaves. Command triggering and input of process data takes place via the external master (e.g. field bus interfaced PLC).

System structure (not with sercos II and EtherCAT®)

The figure below illustrates the system structure of the CCD system mode with field bus master communication (as regards command triggering and process data communication for collective bus connection). The figure only contains the command triggering and the process data of the external control unit and does not show the data between the CCD master and CCD slaves.

Optional Device Functions
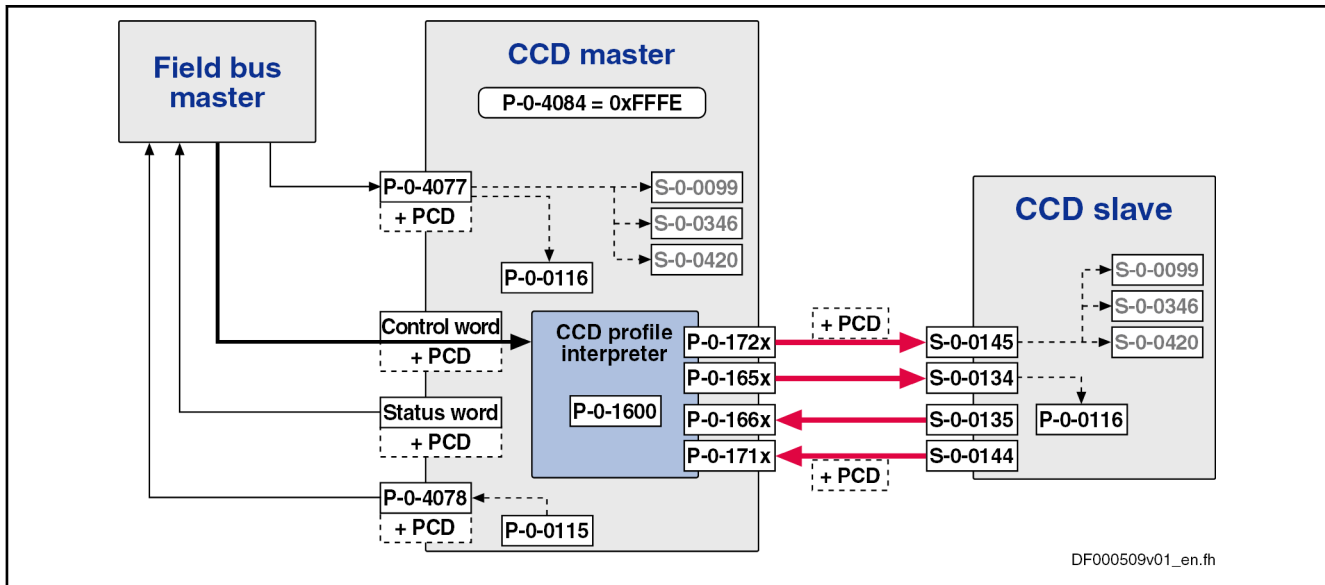
PCD	Process data (cyclic command values and actual values)
S-0-0099	C0500 Reset class 1 diagnostics
S-0-0144	Signal status word
S-0-0145	Signal control word
S-0-0346	Positioning control word
S-0-0420	C0400 Activate parameterization level 1 procedure command
S-0-0134	sercos III: Master control word
S-0-0135	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 of CCD system mode with field bus interface*

Configuration with sercos II+III and EtherCAT

The subcarrier sercos III slaves are parameterized in the higher-order controller by default based on the master-side master communication i.e. for example with EtherCAT the cyclic data is configured using parameter "S-0-0016, Configuration list of AT" and "S-0-0024, Configuration list of MDT" for the CCD master as well as for the CCD slaves in the control configuration.
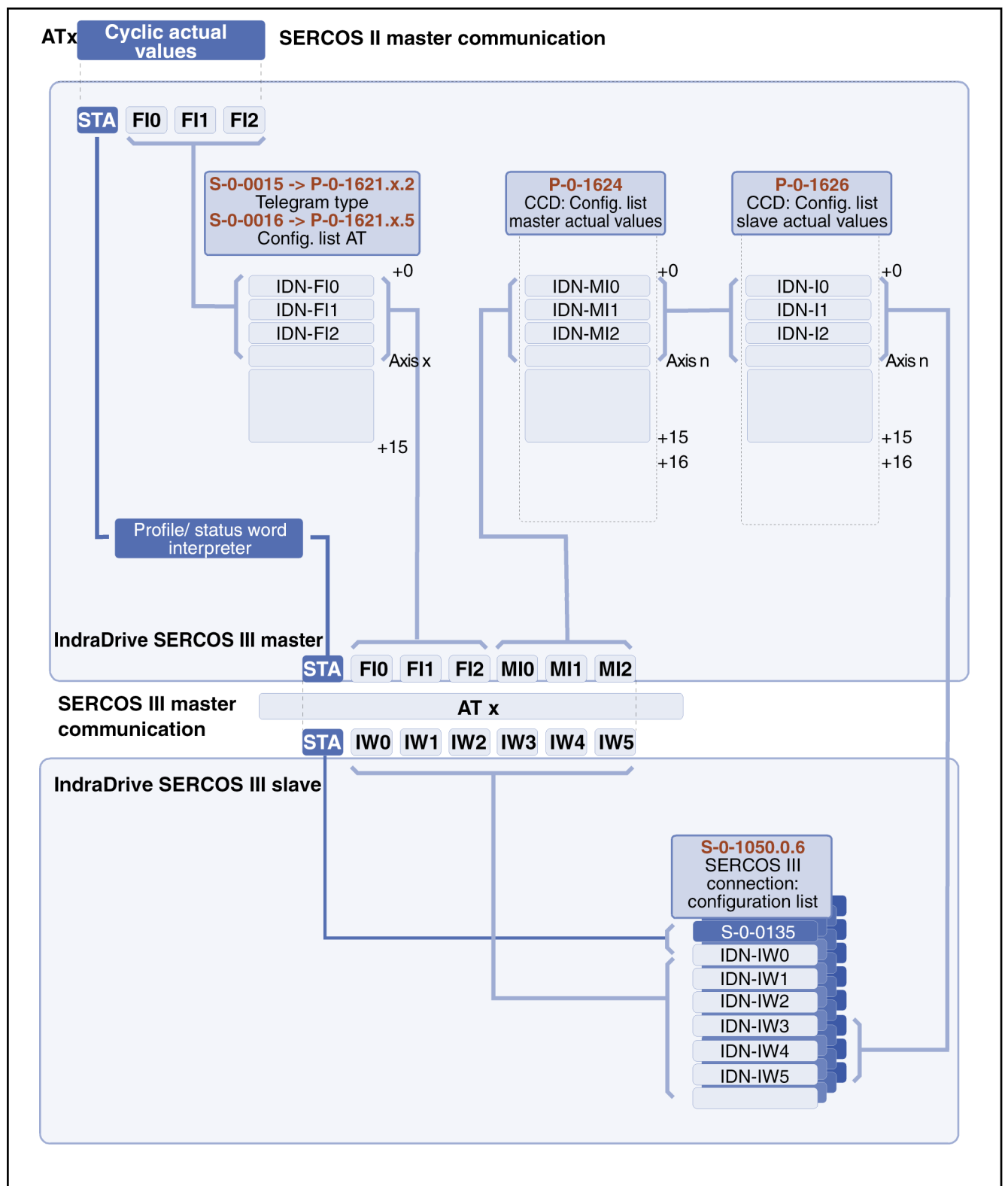
Fig.9-7: *Data flow and parameterization of cyclic actual values*

Features The following applies to CCD system mode (not with sercos II+III):

- For each logic field bus slave (CCD slave), the field bus/drive control word is segmented and converted by the CCD master to a master con-

Optional Device Functions

trol word (S-0-0134) 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, operation mode selection).

- For each logic field bus slave (CCD slave), the field bus/drive status word is generated by means of the drive status word (S-0-1135) 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, parameters "P-0-1623, CCD: configuration list master cmd values" to "P-0-1626, CCD: configuration list actual slave values" 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, 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.

☞ Exception: The bits of the signal control and status words are not required with sercos II+III and EtherCAT and all 15 bits can be used freely. The signal control word and the status word must be taken into account for every slave in the respective MDT (S-0-1050.1.6) and AT(S-0-1050.0.6) data (see following section).

- The cyclic process data (command values and actual values) of master communication (P-0-1621 and P-0-1622 in the CCD master) is directly mapped to the CCD bus in the AT and MDT (and vice versa). The external field bus master can access the parameters of the CCD slaves using these parameters.

☞ Exception: Parameters P-0-1621 and P-0-1622 are not taken into account with sercos II and EtherCAT. The cyclic data from the control to the CCD slaves is configured individually for each axis (CCD master and slave) via the configuration lists for drive (S-0-0016) and master data (S-0-0024) telegram.

Notes on utilization   Observe the following aspects when using CCD system mode:

- Free process data can be used in CCD system mode for pure master/slave cross communication in addition to the process data of master communication. The contents of the configuration lists in parameters P-0-1623 to P-0-1626 must be manually extended for this!

- The freely configurable profile type (P-0-4084 = 0xFFFE and 0xFFFD) is supported with field bus master communication.

- To guarantee data consistency between the CCD master and CCD slaves (container consistency) (in relation to data from external controllers to drives) when using EtherNet/IP™ and DeviceNet™ in CCD system mode, the "virtual slave" function (see "Dead Time Compensation") must be used for CCD master data.

Optional Device Functions

- In sercos II+III CCD system mode, the timing in the CCD group is set in such a way that the cyclic data from the higher-oder controller (--> sercos II/III master) in the CCD master (--> sercos II/III slave) and CCD slave is effective simultaneously. This does not cause any delay in the processing of cyclic data in the drives. Dead time compensation, for example, extrapolation, is therefore not necessary.

- When using the (unassigned) bits of the signal control word and the signal status word (S-0-0145, S-0-0144), take the following aspects into account:

  – The MDT for the slaves must at least contain the signal control word and the AT must at least contain the signal status word (to be configured in P-0-1621 and P-0-1622, with sercos II+III and EtherCAT in S-0-1050.0.6 and S-0-1050.1.6, see also above).

  – Only bits 12 to 15 of the signal status word (S-0-0144) and of the signal control word (S-0-0145) can be used.

☞ Exception: All bits can be used with sercos II+III and EtherCAT.

  – Bits 0 to 11 in the signal status word of the CCD slaves are always zero for the control unit (this does not apply to sercos II+III and EtherCAT master communication).

  – The signal control word of the slaves is parameterized by the master using parameters P-0-1612 and P-0-1614, with sercos II+III and EtherCAT, as usual, in each axis using the usual standard parameters (S-0-0027 and S-0-0329)

  – The signal status word of the slaves is parameterized by the master using parameters P-0-1611 and P-0-1613, with sercos II+III and EtherCAT in each axis using the standard parameters (S-0-0026 and S-0-0328).

Control word in CCD system mode   The table below shows the conversion of the bits in the control word of the "emulated field bus slave" of the CCD master to the actual parameters of the CCD slave. The external master thereby has control over the CCD slaves. This control word for the slave emulated in the CCD master corresponds to the structure of the field bus control word (P-0-4077) and has to be taken into account accordingly in the cyclic output data of the external control unit.

☞ This does not apply to sercos II+III and EtherCAT. The master control word (S-0-0134) has to be used here. This data is copied to the corresponding bits of the sercos III parameter (S-0-0134) of the respective CCD slaves in the CCD master.

Bit in P-0-4077	Meaning in the field bus profile	Target parameter in the slave	Access to slave via ...
0	Command value acceptance	S-0-0346, Positioning control word; bit 0	S-0-0145: Bit 0
1	Operation mode setting	S-0-0420, C0400 Activate parameterization level procedure command S-0-0422, C0200 Exit parameterization level procedure command	S-0-0145: Bit 7 S-0-0145: Bit 8

Optional Device Functions

Bit in P-0-4077	Meaning in the field bus profile	Target parameter in the slave	Access to slave via ...
2	Going to zero	S-0-0148, C0600 Drive-controlled homing procedure command	S-0-0145: Bit 1
3	Absolute / relative	S-0-0346: Bit 3	S-0-0145: Bit 2
4	Immediate block change	S-0-0346: Bit 5	S-0-0145: Bit 3
5	Clear error	S-0-0099: Command clear error (S-0-0099, C0500 Reset class 1 diagnostics)	S-0-0145: Bit 4
6,7	Positioning / jogging	S-0-0346: Bit 1, 2	S-0-0145: Bit 5, 6
8,9	Command operation mode	S-0-0134, Master control word; bit 8, 9	Direct access to S-0-0134
10,11	--	--	--
12	IPOSYNC	S-0-0134, Master control word; bit 10	Direct access to S-0-0134
13	Drive Halt	S-0-0134, Master control word; bit 13	Direct access to S-0-0134
14	Drive enable	S-0-0134, Master control word; bit 14 (is only automatically set with active field bus communication)	Direct access to S-0-0134
15	Drive ON	S-0-0134, Master control word; bit 15	Direct access to S-0-0134

Fig.9-8:   *Conversion of field bus control word (P-0-4077) to CCD slave parameters with field bus profile type 0xFFFE*

☞   (Not applicable with sercos II+III and EtherCAT master communication)

As "S-0-0145, Signal control word" is used for mapping the control bits not contained in "S-0-1134, Master control word", in CCD system mode by default it has been configured in the cyclic master data telegram (MDT → S-0-1050.1.6) of the corresponding CCD slave! In addition, other bits have been permanently configured so that the user can only define 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 the master communication (does not apply to sercos II+III, EtherCAT® master communication)

The cyclic command values for a CCD slave consist of at least 2 bytes control word (same structure as field bus control word; see P-0-4077) and the data from "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 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 P-0-1621.

☞   The 2-byte status word P-0-4077 is converted to 4-byte master status word + 2-byte signal status word!

☞   With profile type P-0-4084 = 0xFFFD, bits 0, 2, 3, 4, 6 and 7 are not evaluated in the control word!
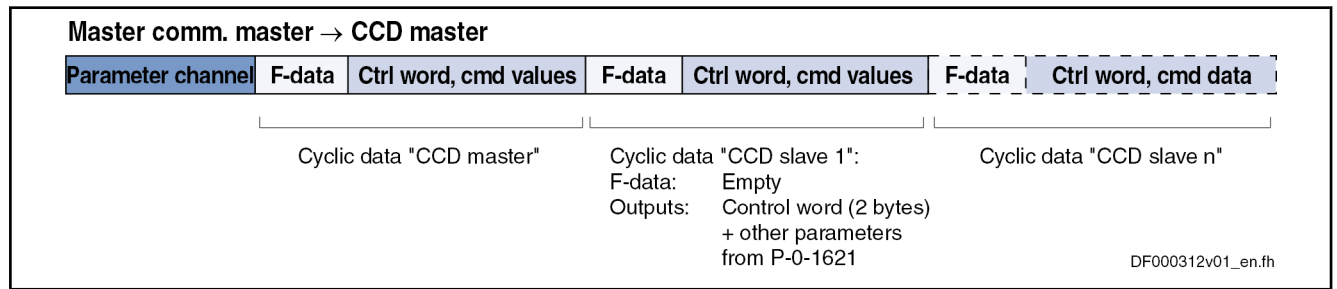
Optional Device Functions

PROFIBUS® and PROFINET

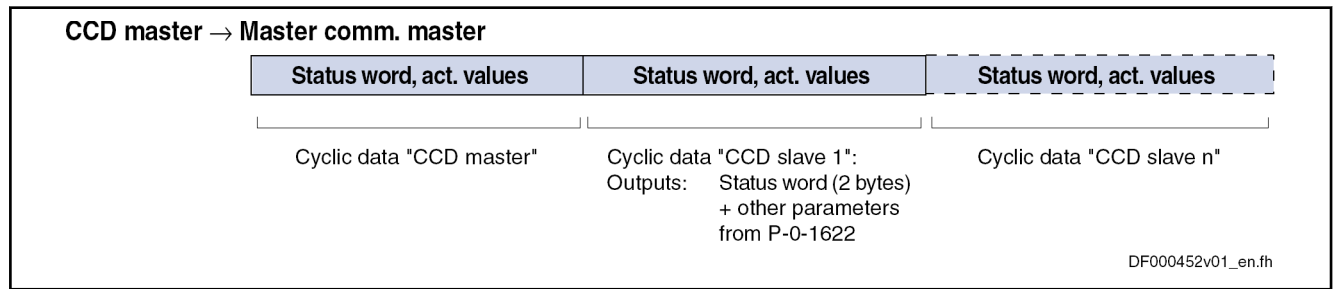P-0-1621   Configuration list of master communication command values for CCD
Fig.9-9:   Command value channel from master communication master to CCD group with PROFIBUS® and PROFINET

EtherNet/IP(TM):
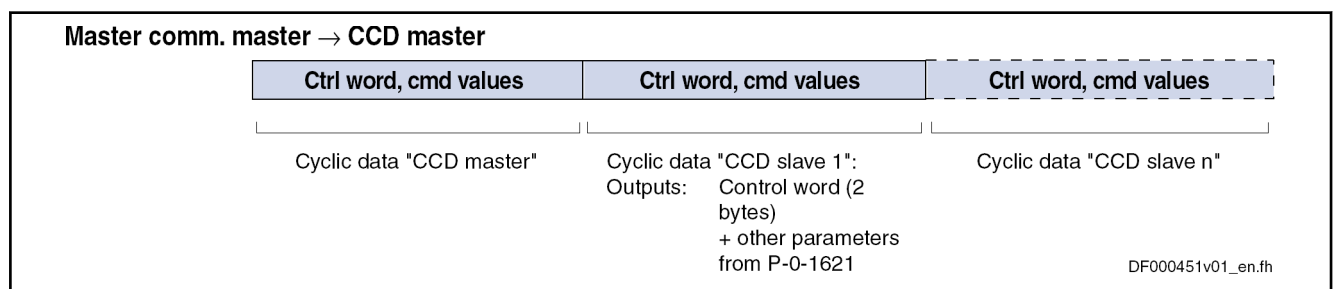
P-0-1621   Configuration list of master communication command values for CCD
Fig.9-10:   Structure of an assembly/cyclic data container with EtherNet/IP(TM)

Status word in CCD system mode

The table below shows the assignment of the bits in the status word of the "emulated field bus slave" of the CCD master to the actual parameters of the CCD slave. The external master thereby gets the information via the CCD slaves. This status word for the slave emulated in the CCD master corresponds to the structure of the field bus status word (P-0-4078) and has to be taken into account accordingly in the cyclic input data of the external control unit.

☞   This does not apply to sercos II+III and EtherCAT. Here the bits of the drive status word (S-0-0135 with sercos III) of the CCD slaves in the CCD master are copied to the sercos II, sercos III or EtherCAT status word (S-0-0135) of the respective slave.

Bit in P-0-4078	Meaning in the field bus profile	Source parameter in slave	Access to slave via ...
0	--	--	--
1	Operation mode acknowledgment	S-0-0424, Status parameterization level	S-0-0144: Bit 0
2	In_Reference	S-0-0403, Position feedback value status	S-0-0144: Bit 1
3	In_Standstill	S-0-0331, Status "n_feedback = 0"	S-0-0144: Bit 2
4	Command value reached	P-0-0115, Device control: status word; bit 12	S-0-0144: Bit 3
5	Command change bit	S-0-0135, Drive status word; bit 5	Direct access to S-0-0135
6	--	--	--

Optional Device Functions

Bit in P-0-4078	Meaning in the field bus profile	Source parameter in slave	Access to slave via ...
7	Status of command value processing	S-0-0135, Drive status word; bit 3	Direct access to S-0-0135
8,9	Actual operation mode	S-0-0135, Drive status word; bit 8.9	Direct access to S-0-0135
10	Command value acknowledgment	S-0-0419: Bit 0	S-0-0144: Bit 4
11	Class 3 diagnostics message	S-0-0135, Drive status word; bit 11	Direct access to S-0-0135
12	Class 2 diagnostics warning	S-0-0135, Drive status word; bit 12	Direct access to S-0-0135
13	Class 1 diagnostics drive error	S-0-0135, Drive status word; bit 13	Direct access to S-0-0135
14/15	Readiness for operation	S-0-0135, Drive status word; bit 14,15	Direct access to S-0-0135

Fig.9-11:   *Conversion of field bus status word (P-0-4078) to CCD slave parameters with profile 0xFFFE*

☞   (Not applicable with sercos II, sercos III or EtherCAT master communication)

As "S-0-0144, Signal status word" is used for mapping the status bits not contained in "S-0-1135, Drive status word", it is configured by default in the cyclic drive telegram (AT → S-0-1050.0.6)! In addition, other bits have been permanently configured so that the user can only define 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 the master communication (not applicable with sercos II+III, EtherCAT® master communication)

The cyclic actual values of a CCD slave consist of at least a 2-byte status word (same structure as field bus status word; see P-0-4078) and the data from "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 P-0-1622.

☞   The 2-byte status word P-0-4078 is composed of a 4-byte drive status word + a 2-byte signal status word!

PROFIBUS® and PROFINET
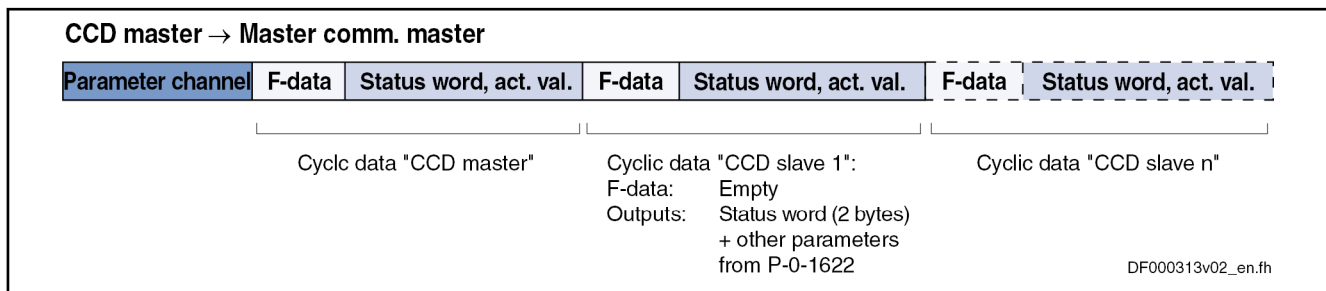
P-0-1622   Configuration list of master communication actual values for CCD
Fig.9-12:   *Actual value channel of the CCD group to the master communication master with PROFIBUS® and PROFINET*

Optional Device Functions

EtherNet/IP(TM):

| | P-0-1622 | Configuration list of master communication actual values for CCD |
| | Fig.9-13: | *Structure of an assembly/cyclic data container with EtherNet/IP(TM)* |

Cyclic command values with sercos II

Control-side configuration of the master data telegram is made as usual, via the standard parameters "S-0-0009, Position of data record in MDT" and "S-0-0024, Configuration list of MDT". This information is interpreted in the CCD master and then copied to P-0-1621.x.3 or P-0-1621.x.6. When configuring the connections for the CCD slaves, the CCD master must observe the contents from parameter P-0-1621.x.3 or P-0-1621.x.6 for the command values and copy them accordingly to the parameters, such as to S-0-1050.1.6

Cyclic actual values with sercos II

Control-side configuration of the master data telegram is made as usual, via the standard parameters "S-0-0006, AT Transmission starting time (T1)" and "S-0-0016, Configuration list of AT". This information is interpreted in the CCD master and then copied to P-0-1621.x.3 or P-0-1621.x.6. When configuring the connections for the CCD slaves, the CCD master must observe the contents from parameter P-0-1621.x.2 or P-0-1621.x.56 for the actual values and copy them accordingly to the parameters, such as to S-0-1050.1.5

☞ Class 3 diagnostics bit (S-0-0135, bit 11) does not exist with sercos III CCD slaves. This information is therefore not supplied. The bit is always "0".

CCD Basic Mode

With CCD basic mode, there is no automatic interpretation of control information by the CCD master. The CCD master cannot automatically route cyclic data of the master communication to the CCD slaves. 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 CCD basic mode with field bus master communication, sercos interface and parallel/analog interface:

Optional Device Functions

DF000508v02_en.fh
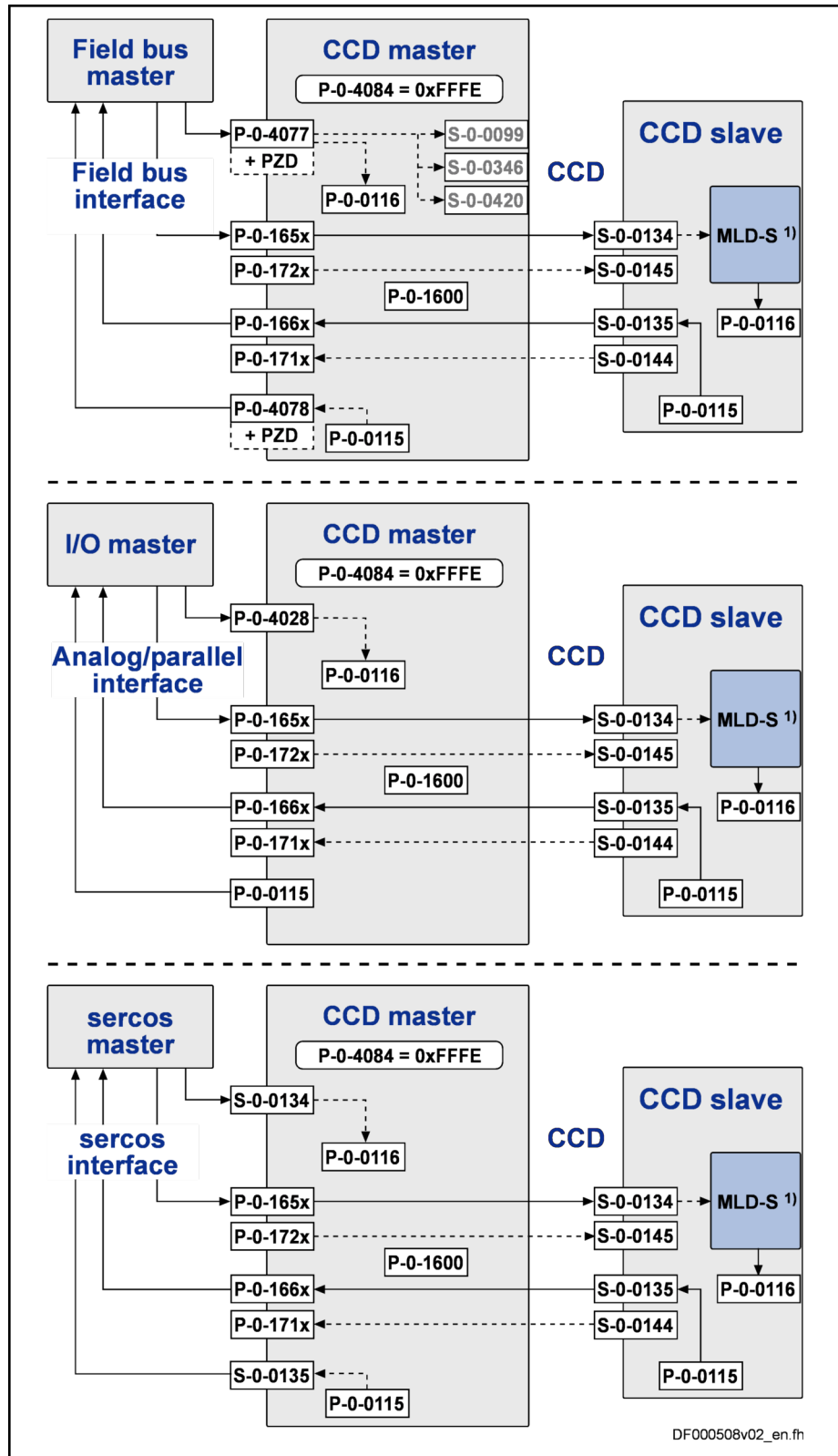
Optional Device Functions

Field bus interface	PROFIBUS®, PROFINET®, CANopen, EtherNet/IP™, DeviceNet™
sercos interface	sercos I+II, EtherCAT®
PCD	Process data (cyclic command values and actual values)
1)	With permanent control
Fig.9-14:	Overview of CCD basic mode for different master communication interfaces

Features

In CCD basic mode, the external master (field bus, sercos interface, analog/parallel interface) has **restricted access** to the CCD slaves. The following applies:

- CCD basic mode is used when only process data is to be exchanged between the CCD master and the CCD slaves. Parameters P-0-1623 to P-0-1626 are relevant for parameterizing the data exchange. Only the data listed in these parameters is exchanged between the master and slave.

- The profile interpreter is not active even with an active field bus card in the CCD master. Parameters P-0-1611 to P-0-1614 are not effective. 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. Parameters P-0-172x and P-0-171x therefore have to be written or read in the CCD master.

- As the drive status word of the slaves in the AT is always transmitted with 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 with 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 CCD basic mode, this permits the control of basic input, such as enable, operation mode selection etc., for the slaves using 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. 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:

Optional Device Functions
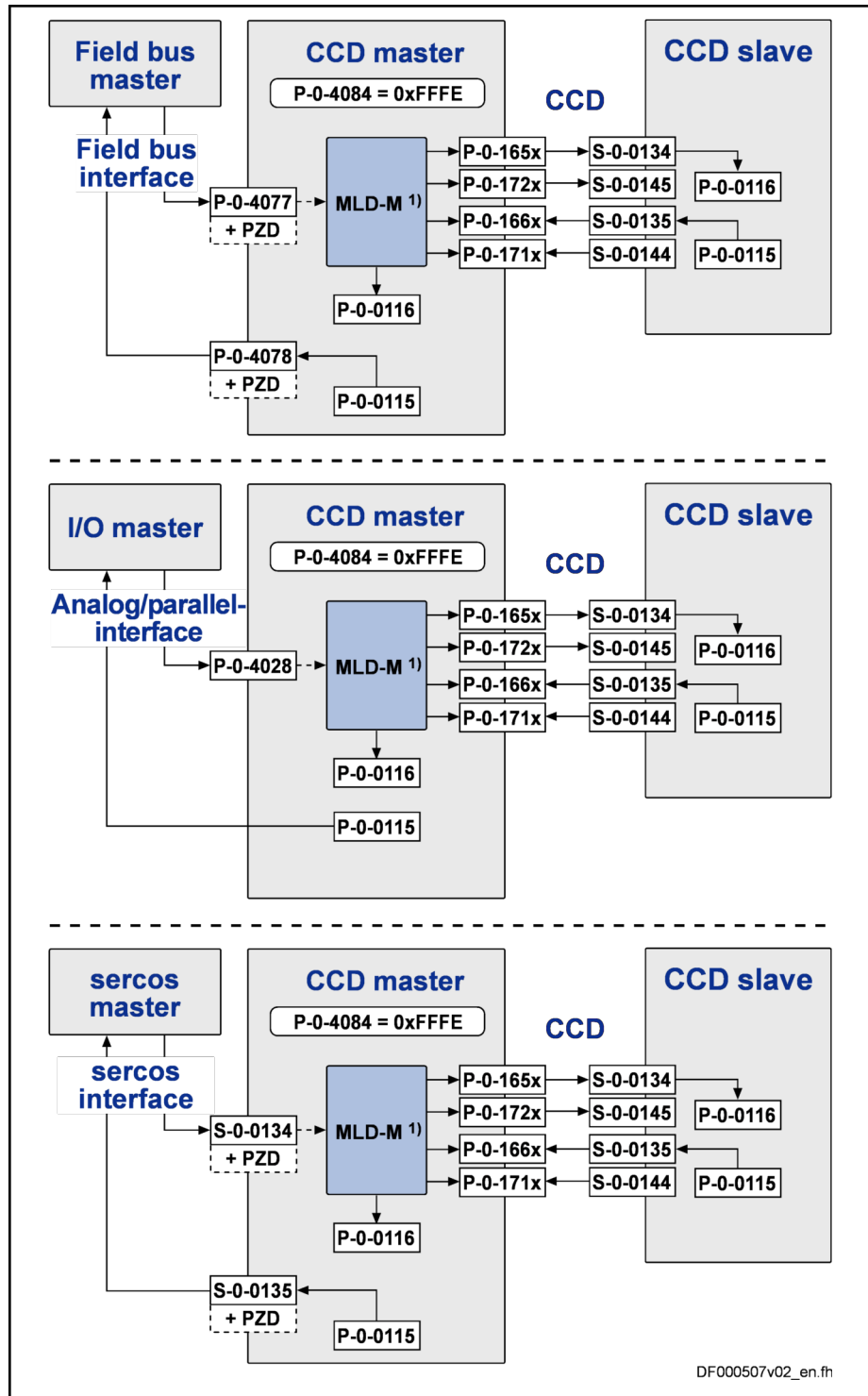
Field bus interface	PROFIBUS®, PROFINET®, CANopen, EtherNet/IP™, DeviceNet™
sercos interface	sercos I+II, EtherCAT®
PCD	Process data (cyclic command values and actual values)
1)	With permanent control

Fig.9-15:   *Overview of MLD-M system mode for different master communication interfaces*

Optional Device Functions

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 is generated by the CCD master and vice versa (master/slave cross communication). Part of it 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.

- The multiplex channel for external controls in the CCD master is not available in MLD-M system mode

The signal control word and 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 to access them from the PLC program (so-called "Axis-Data 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.

ℹ️ See also separate documentation "Rexroth IndraMotion MLD".

State Machine and Phase Input

General information

From MPC-08VRS onwards, P-0-1600, bit 5 can be used to configure the behavior or the coupling of the state machine/phase progression of the CCD slaves. It is possible, when doing so, to decouple phase input for the CCD slaves from the state machine of the CCD master (from MPC-08VRS onwards, P-0-1600, Bit 5 = 0 applies for the default setting), see "Decoupled CCD phase progression".

The behavior to date of the firmware versions up to MPC-07VRS, i.e. the fixed coupling of the CCD master's state machine and phase input of the CCD slaves can also be set: P-0-1600, bit 5 = 1; see "Coupled CCD phase progression".

Diagnostic options of the state machine and phase input in the CCD group

- The following parameters are involved in the switching of the CCD phase:

- The input value of the state machine is the value of parameter "P-0-1605, CCD: command communication phase".

- The present communication phase of the CCD bus is displayed in parameter "P-0-1606, CCD: actual communication phase".

Optional Device Functions

- In parameter "P-0-1609, CCD: status word", there is information on the phase state machine, such as "target phase", "actual phase", "phase switch active", "phase switch aborted with error" etc.

Decoupled CCD phase progression

sercos phase input for CCD/slaves

Decoupling "Parameter" mode (PM) <--> "Operation" mode (OM), switching the CCD Master (subdevice state machine) and sercos phase switching of the CCD slave results in the CCD group's sercos communication generally being in phase 4 when the devices are switched on and remains, as far as possible, in phase 4, independently of the PM/OM state of the CCD master. Access to sercos III I/Os is therefore possible independently of the CCD master's subdevice state machine (PM/OM).

The time at which the CCD master is at phase 4 after switching on the target phase for the CCD group depends on the master communication of the CCD master:

- With sercos II, sercos III, EtherCAT® in transition command "C5200 Communication phase 4 transition check" (S-0-0128, C5200 Communication phase 4 transition check)

- With other master communication in transition command "C0200 Exit parameterization level procedure command" (S-0-0422, C0200 Exit parameterization level procedure command)

☞　　sercos (II+III) CCD system mode presents an exception to this: here the sercos phase input for the CCD group is coupled directly to the sercos phase transition of the CCD master (PM<-->OM switching is unaffected by this). If the CCD master is switched by the controller to phase 2/4, then (in CCD system mode) the CCD slaves are also automatically switched to phase 2/4 (see below: "Communication state machine with sercos II+III CCD system mode")

To avoid an error with the PM->OM switching of a CCD slave (drive-only) preventing phase progression to phase 4, the subdevice state machine is decoupled from the phase progression in the CCD slaves. This is done for the projected drives and is set by the CCD master once it has reached phase 2 by setting bit 0 = "1" in parameter "P-0-4088, Master communication: Drive configuration" of the CCD slaves.

Automatic PM/OM switching of the CCS slaves

The subdevice state machine of the CCD master is coupled to the subdevice state machine of the CCD slaves in the CCD group. That way not every CCD slave in the CCD group has to be individually switched to OM or PM. If PM is switched to OM in the CCD master (automatically during run-up or later, depending on P-0-4-88, bit 0 in the CCD master), then the CCD master only performs the PM->OM switch even with the CCD slaves (drives-only) as soon as the CCD group is in phase 4. An OM->PM switch in the CCD master does not influence the sercos phase but also switches the CCD slaves (drives only) to PM.

Properties:

- An OM-->PM switch in the CCD master does not lead to the CCD slaves leaving sercos phase 4. (Up to now this has caused the target phase of the CCD group (P-0-1605, CCD: command communication phase) and thus the CCD slaves to be set to phase 2)

- The CCD slaves are switched to PM/OM in the same way as the CCD master

- An error in the transition command of a CCD slave does not lead to the termination of phase progression to phase 4
- If CCD communication is not in phase 4, the cyclic data is exchanged (as it has been to date) via the service channel
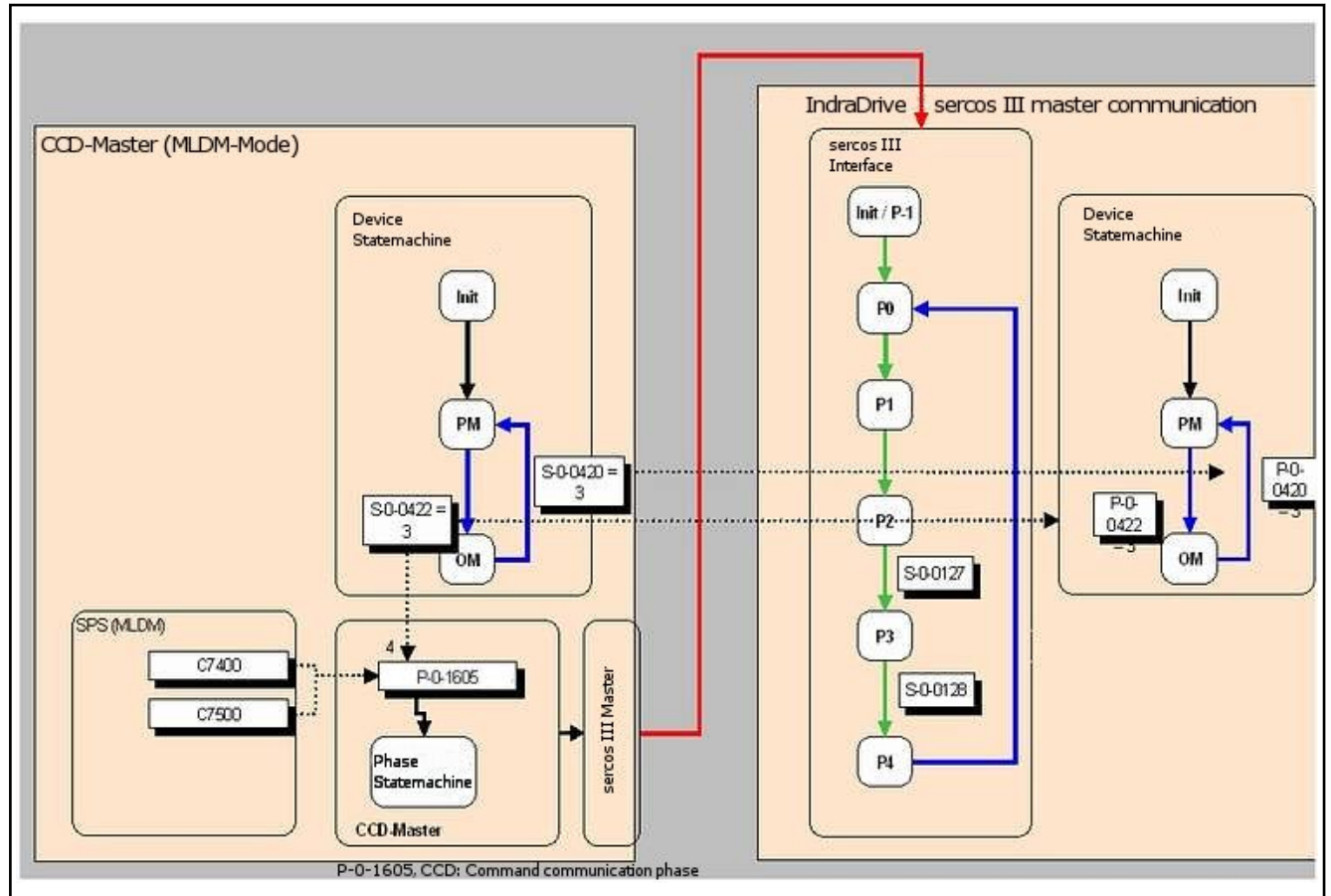

Fig.9-16: CCD master subdevice state machine decoupled from sercos phase input of the CCD slaves

The CCD slaves do not reach sercos phase 4 or leave it in the following exceptional cases:

1. Error during communication:
   - Actual topology and command topology are different
   - Telegram failures > than parameterized in P-0-1639
2. Changed configuration of CCD communication:
   - Changing telegram times
   - Changing telegram content
3. During phase progression an error occurs in command S-0-0127 (C0100) or S-0-0128 (C5200) by incorrect parameterization of the telegram timing or telegram content.

(Manual) input of the CCD communication phase

The sercos phases of the CCD group can also be manually inputted. This is necessary, for example for changes of the telegram content or timing. The CCD master offers two new commands for this:

- P-0-1620.0.5, C7400 CCD: Switching to phase 2

Optional Device Functions

- P-0-1620.0.6, C7500 CCD: Switching to phase 4

☞ The command

P-0-1620.0.5, C7400 CCD: Switching to phase 2 can only be executed if the CCD master is in "Parameter" mode (PM).

Coupled CCD phase progression

For reasons of compatibility, the behavior up to now can be set (as in firmware versions up to and including MPC07VRS), that is a fixed coupling of the state machine in the CCD master and phase input for the CCD slaves: P-0-1600, bit 5 = "1". To generate unequivocal phase input (communication phase) for the CCD slaves with multi-axis field bus connection (in the system mode), this input is realized in the CCD master by a CCD phase state machine.

Data is primarily provided to the phase state machine of the CCD bus, and thus the CCD slaves, from the device state machine of the CCD master. If the CCD master is switched in the operation mode (OM), the command communication phase of the CCD group is phase 4 (P-0-1605 = "4"). If, in contrast, the CCD master is in "Parameter" mode (PM), the command communication phase of the CCD group is phase 2 (P-0-1605 = "2").

☞ sercos II+III- and EtherCAT CCD system mode is the exception: The sercos phase input for the CCD group is coupled directly to the sercos phase transition of the CCD master. If the CCD master is switched by the controller in phase 2/4, then (in CCD system mode) the CCD slaves are also automatically switched in phase 2/4. The CCD slaves are switched in phase 2/4 by PM/OM switching in the CCD master. (see also below: "Communication state machine with sercos II+III CCD system mode")

The device is switched from Parameter mode to Operation mode (and vice versa) in the CCD master by the following commands:

- S-0-0422, C0200 Exit parameterization level procedure command

  → By activating command C0200, all functions are switched to "active" status again (Operation mode → P-0-1605 = 4).

- S-0-0420, C0400 Activate parameterization level procedure command

  → By activating the command C0400, all functions are switched to the status "inactive" again (parameter mode → P-0-1605 = 2).
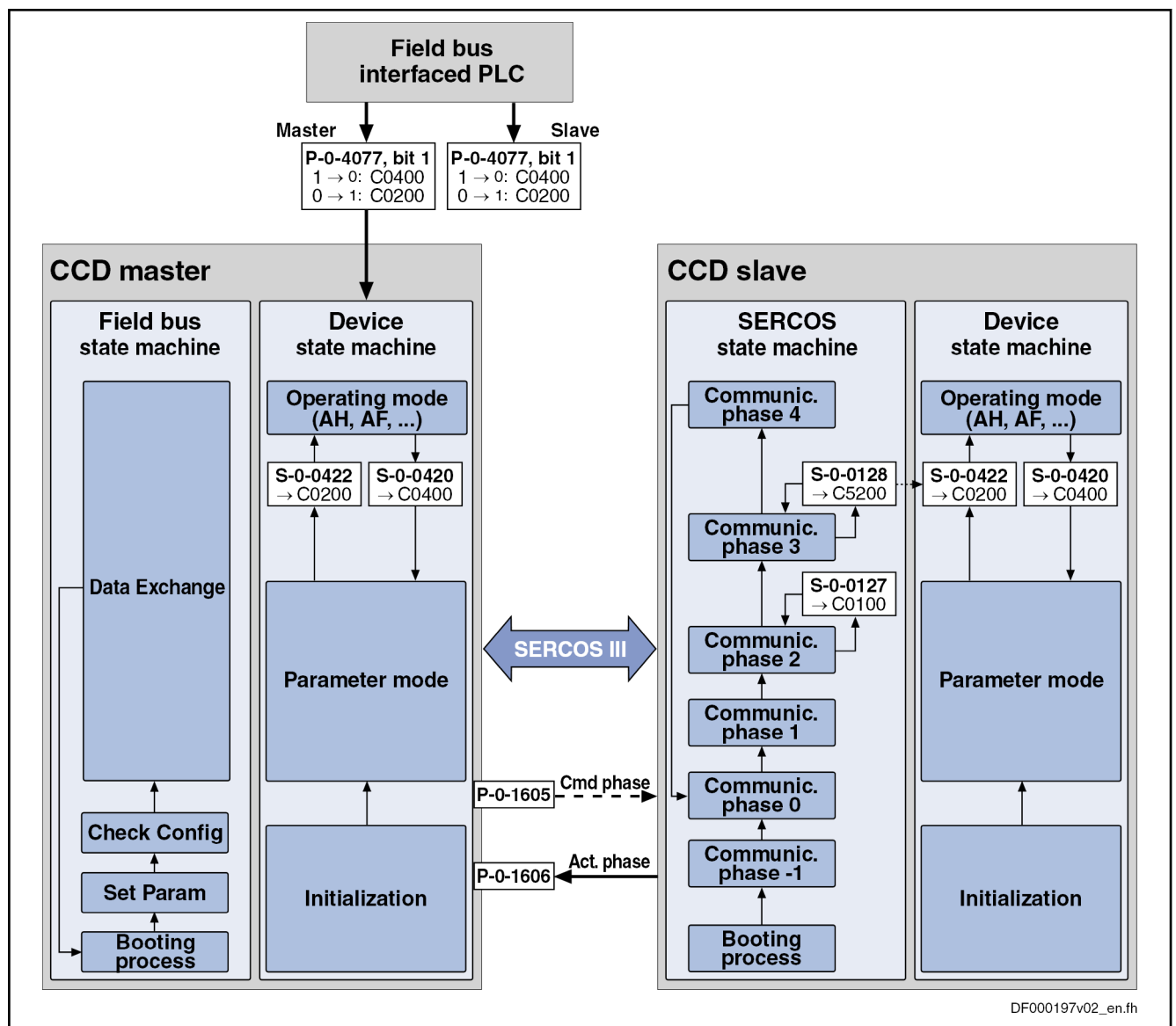
Fig.9-17:   Cross Communication state machine

Communication state machine with sercos II+III and EtherCAT-CCD system mode

The basic phase input with sercos II + III and EtherCAT state machine switching in CCD system mode is independent of the setting in P-0-1600, bit 5:

Once switched on, the CCD master initializes sercos III communication and tries to switch the projected CCD slaves to phase 2.

In phase 1, the sercos master communication of the CCD master already takes into account all addresses in the CCD group available in the sercos ring (addresses of local slave (CCD master) + projected CCD slaves), even if the CCD group is not in phase 2.

In phase 2, the controller can talk to all slaves in the CCD group via the service channel. The CCD group must also be in phase 2 for this, otherwise an SVC error occurs (SVC not open). The command "S-0-0127, C0100 Communication phase 3 transition check" from the control to the CCD slaves is detected by the CCD master, not transmitted and acknowledged with or without error, depending on the parameterization of the sercos communication. Phase switch of the CCD slaves only takes place in the transition com-

Optional Device Functions

mand "S-0-0128, C5200 Communication phase 4 transition check" of the master.

If the sercos communication between the control and CCD master is in phase 3, the sercos III communication between the CCD master and CCD slaves is still in phase 2. Starting command S-0-0128 causes phase progression for the CCD slaves from phase 2 to phase 4 in the CCD master. At the end of command S-0-0128 in the CCD master, the S3 communication between the CCD master and the CCD slaves is in phase 4. The command S-0-0128 from the control to the CCD slaves is detected by the CCD master, not transmitted and always acknowledged without error.

In phase 4, cyclic and acyclic communication with the CCD slaves is possible without restrictions and behaves as if the CCD slaves were directly in the sercos ring.

If the device state of the CCD master is changed by the command S-0-0420 or S-0-0422 (PM/OM switch), the behavior of the CCD slaves depends on the setting in P-0-1600, bit 5:

P-0-1600, bit 5 = "0" (Decoupled CCD phase progression): the device state machine (PM/OM switch) in the CCD slave is directly coupled to the device state machine of the CCD master. If the command S-0-0422 (-->OM)/ S-0-0420 (-->PM) is started in the CCD master, the CCD slaves are also switched to OM/PM. Command S-0-0420 in the CCD master does NOT change the sercos III phase of the CCD group.
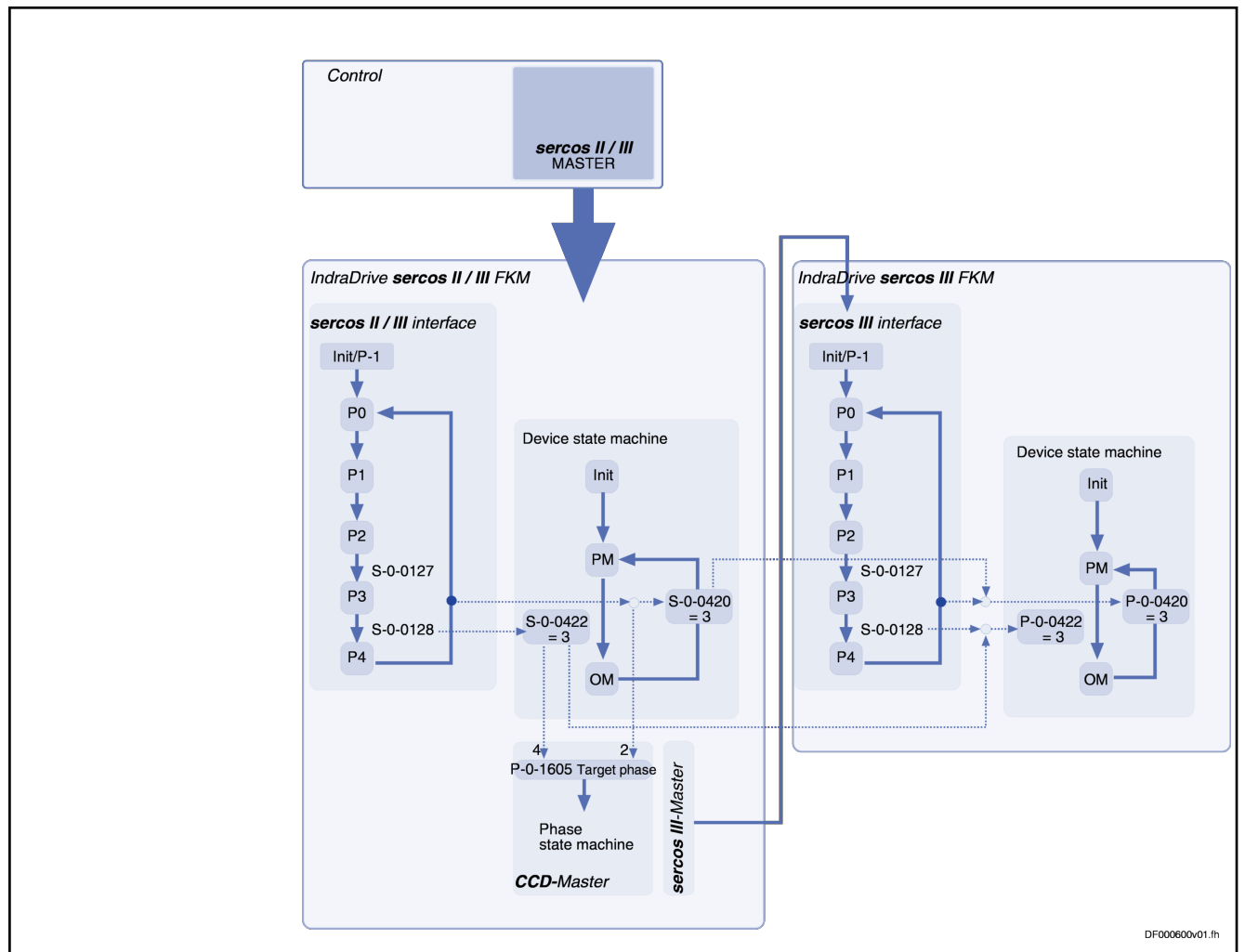
Fig.9-18:   sercos phase progression in CCD system mode for sercos II+III and EtherCAT with P-0-1600, bit 5 = "0"

With P-0-1600, bit 5 = "1" (Coupled CCD phase progression): If the command S-0-0422 (-->OM) is started in th CCD master, the sercos III phase of the CCD group is switched to phase 4. Command S-0-0420 in the CCD master switches the sercos III phase of the CCD group to phase 2. The PM/OM switch in the CCD slave is not directly coupled to the device state machine of the CCD master.

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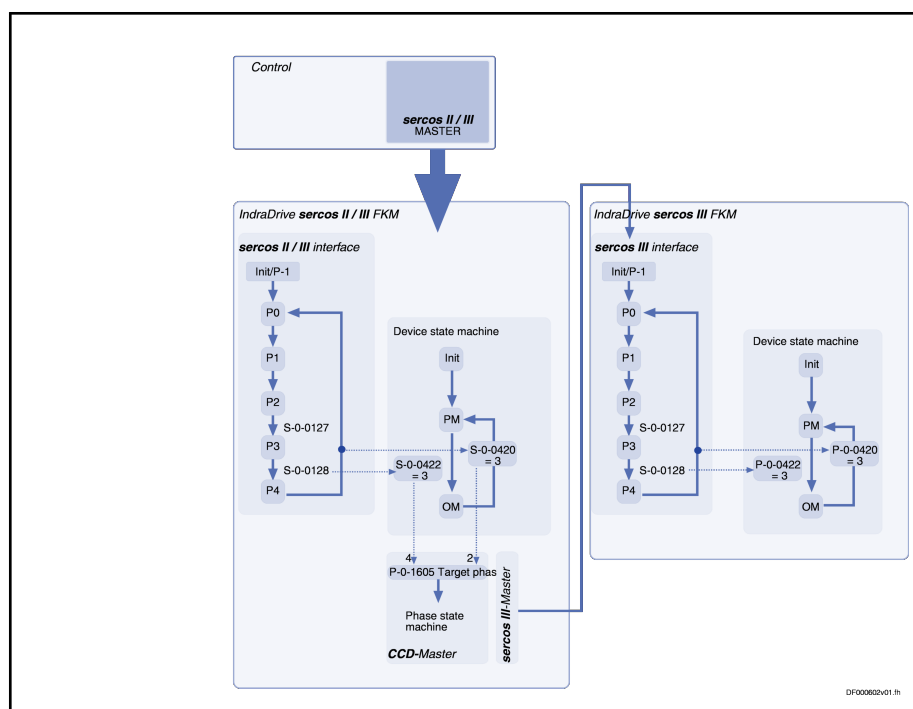
Fig.9-19:   *sercos phase progression in CCD system mode for sercos II+III and EtherCAT with P-0-1600, bit 5 = "1"*

CCD - Diagnostic System

Display and evaluation of the diagnostic numbers in the CCD group

The following parameters are available in the CCD master for displaying the statuses 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, it is possible with this parameter, in the event of an error, to obtain detailed information on the causes of the error and trouble shooting.

- "P-0-1701, CCD: Diagnostic message number, slave 1" to "P-0-1709, CCD: Diagnostic message number, slave 9"

These parameters are used for displaying and evaluating the diagnostic message number for each slave (see Parameter Description "S-0-0390, Diagnostic message number"). By configuring P-0-170x in "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.

Identification of the CCD slave type

If the CCD group is in phase 2, it is possible to identify which slave type is at which position in the CCD group. This enables, for instance, the topology and wiring sequence to be checked to ensure correct remote address assignment.

Parameter P-0-1619.SI.SE (EIDN) provides various information on the identified slaves at their topology positions. The SI relates to the topology position

Optional Device Functions

(physical position in the wiring sequence, cf. P-0-1603, CCD: Actual topology addresses). Different information on the respective sercos III slave at the corresponding topology position is displayed as SE (see Overview below). The parameter is fulfilled by the CCD master when phase 2 is reached. If the corresponding parameter is not available with a slave, then the field remains empty.

☞   Phase 2 is also reached by the CCD master if the slave addresses are not unequivocal or addresses other than the projected slave addresses are found. The user has no access to the CCD slaves in this case and must first resolve the addressing problem. Information from parameter P-0-1619.SI.SE can be used, for example, to start the correct remote address assignment for unequivocal addressing.

Parameter P-0-1619.SI.SE has the following structure (SI corresponding to the topology position of the slave):

Offset byte	Content	Assignment	Offset byte	Content	Assignment of offset byte
0x0	3812	Const. real length			
0x2	3812	Const. max. length			
0x4	13	Number of slaves (number of SI)			
0x8	0x00018653	P-0-1619.0.1 CCD: Vendor code #0	0x778	0x00058653	P-0-1619.0.4 CCD: Serial number #0
0xC	Attr.	Attribute	0x77C	Attr.	Attribute
0x10	Date	Date S-0-1300.0.3 slave 1	0x780	Actual length	Date S-0-1300.0.12 slave 1
...	...		0x782	Max. length	
0x40	Date	Date S-0-1300.0.3 slave 13	0x784	Date	
0x44	0x00028653	P-0-1619.0.2 CCD: Device name #0	...	...	
0x48	Attr.	Attribute	0xAB0	Actual length	Date S-0-1300.0.12 slave 1
0x4C	Actual length	Date S-0-1300.0.4 slave 1	0xAB2	Max. length	
0x4E	Max. length		0xAB4	Date	
0x50	Date		...	...	

Optional Device Functions

Offset byte	Content	Assignment	Offset byte	Content	Assignment of offset byte
...	...		0xAF4	0x00068653	P-0-1619.0.4 CCD: FSP type #0
0x37C	Actual length	Date S-0-1300.0.4 slave 13	0xAF8	Attr.	Attribute
0x37E	Max. length		0xAFC	Date	Date S-0-1302.0.1 slave 1
0x380	Date		...	...	
...	...		0xB2C	Date	Date S-0-1302.0.1 slave 13
0x3C0	0x00038653	P-0-1619.0.3 CCD: Device ID #0	0xB30	0x00078653	P-0-1619.0.4 CCD: Application type #
0x3C4	Attr.	Attribute	0xB34	Attr.	Attribute
0x3C8	Actual length	Date S-0-1300.0.5 slave 1	0xB38	Actual length	Date S-0-1302.0.2 slave 1
0x3CA	Max. length		0xB3A	Max. length	
0x3CC	Date		0xB3C	Date	
...	...			...	
0x6F8	Actual length	Date S-0-1300.0.5 slave 13	0xE68	Actual length	Date S-0-1302.0.2 slave 13
0x6FA	Max. length		0xE6A	Max. length	
0x6FC	Date		0xE6C	Date	
...	...		...	...	
0x73C	0x00048653	P-0-1619.0.4 CCD: Connected to sub-device #0	0xEAC	0x00088653	P-0-1619.0.8 CCD: Addressing version
0x740	Attr.	Attribute	0xEB0	Dez. o. Vz	Attribute
0x744	Date	Date S-0-1300.0.6 slave 1	0xEB4	Date	Date of addressing version slave 1
...	...		...	...	
0x774	Date	Date S-0-1300.0.6 slave 13	0xEE4	Date	Date of addressing version slave 13

Fig.9-20:

Optional Device Functions

Targeted "radioing" of a CCD slave

The diagnostic LED of a sercos III slave in the CCD group can be activated in a targeted manner in order to identify its actual/physical installation location. It is therefore possible to determine which sercosIII slave belongs to which topology position (-->CCD slave) in the CCD group. Parameter "P-0-1620.0.4, CCD: Slave identification" can be used to activate the diagnostic LED from the CCD master with a sercos III slave in phase 2 by inputting a topology position (cf. P-0-1603). It is therefore possible to identify a specific sercos III slave at a topology position by "radioing" (activating the diagnostic LED). The value "0" switches off the function.

Example:

- P-0-1620.0.4 = 0 -> Function inactive

- P-0-1620.0.4 = 1 -> "Radio" slave at topology position 1

- P-0-1620.0.4 = 2 -> "Radio" slave at topology position 2

- …

- P-0-1620.0.4 = 1 -> "Radio" slave at topology position n

Synchronization of system time

The system time of the CCD slave is automatically set to that of the CCD master

In every CCD mode, the CCD master automatically/always sets P-0-0197 in the CCD slave to the value of P-0-0197 in the CCD master in phase progression (directly after CCD phase 2 has been reached, and also briefly before switching to phase 4). The system time in the CCD slaves (P-0-0197) is also set to the value of P-0-0197 in the CCD master if P-0-0197 is written in the CCD master. Counting then continues from the new value. This enables (almost) synchronous error diagnosis of the CCD group. The delay when setting/transmitting the system time in the CCD slaves is taken into account and compensated for by the CCD master.

☞   Bit 6 in P-0-1600 can be used to deactivate this function of the automatic writing of the system time (P-0-0197) by the CCD master in the CCD slaves.

Properties of system time

In the CCD master, the system time is stored in P-0-0197 and is retained even after the drive has been switched off. If another value is written in parameter P-0-0197, counting continues from this time on from this value (see also parameter description P-0-0197). If no value is entered in P-0-0197, counting automatically continues from 01.01.2000 in the CCD master. P-0-0197 is not contained in P-0-0192 and is also not overwritten when "loading basic parameters".

Diagnostic Parameters of sercos Communication

There are different parameters which allow users to obtain information on causes of errors or identify conditions for an error reaction when there are problems with sercos III communication.

- Parameter "P-0-1631, CCD: AT error counter" contains the number of the AT telegrams which failed. The error counter rises at most once per communication cycle. It rises if the corresponding AT telegram fails both on Port 1 and on Port 2.

Optional Device Functions

- Parameters "P-0-1637, CCD: error counter Port-1" and "P-0-1638, CCD: error counter Port-2" are used to read the error counters of the sercos FPGA according to sercos III specification (see Parameter Description).

In parameter "P-0-1639, CCD: allowed telegram failures", it is possible to set the number of permitted telegram failures (recorded in parameter P-0-1631) which can occur directly one after the other before the error message "F4140 CCD communication error" is triggered.

Error Reaction of the CCD Group

The CCD error reaction is selected and activated via bits 7 and 8 of parameter "P-0-1600, CCD: configuration".

Basic setting:

- In 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 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 entered 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. bits 7, 8 and 10 in parameter P-0-1600 have not been set!

Features of sercos II+ III and EtherCAT CCD system mode

In addition to the options described above regarding error reactions, the following aspects are to be observed when using sercos II CCD system mode:

- A communication error in the sercos II + III ring or EtherCAT network results in the CCD slaves automatically being switched via phase 0 to phase 2 by the CCD master.

- A communication error of a CCD slave always results in "F4140 CCD communication error" in the master. Thus all axes are decelerated in the same way, independently of the error reaction parameterized via "P-0-1600, CCD: configuration".

Cyclic Process Data

For 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 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 parameterized at the CCD master via parameters P-0-1621 to P-0-1626. During phase progression, the master automatically assumes parameterization of the slaves via S-0-1050.0.6, S-0-1050.1.6, ...

The figure below illustrates the parameterization of the process data channel and the effect of parameters P-0-1621 to P-0-1626 for the following cases (not applicable with sercos II + III and EtherCAT master communication in the CCD master):

1. Configuration of MDT data (cyclic command values)

2. Configuration of AT data (cyclic actual values)
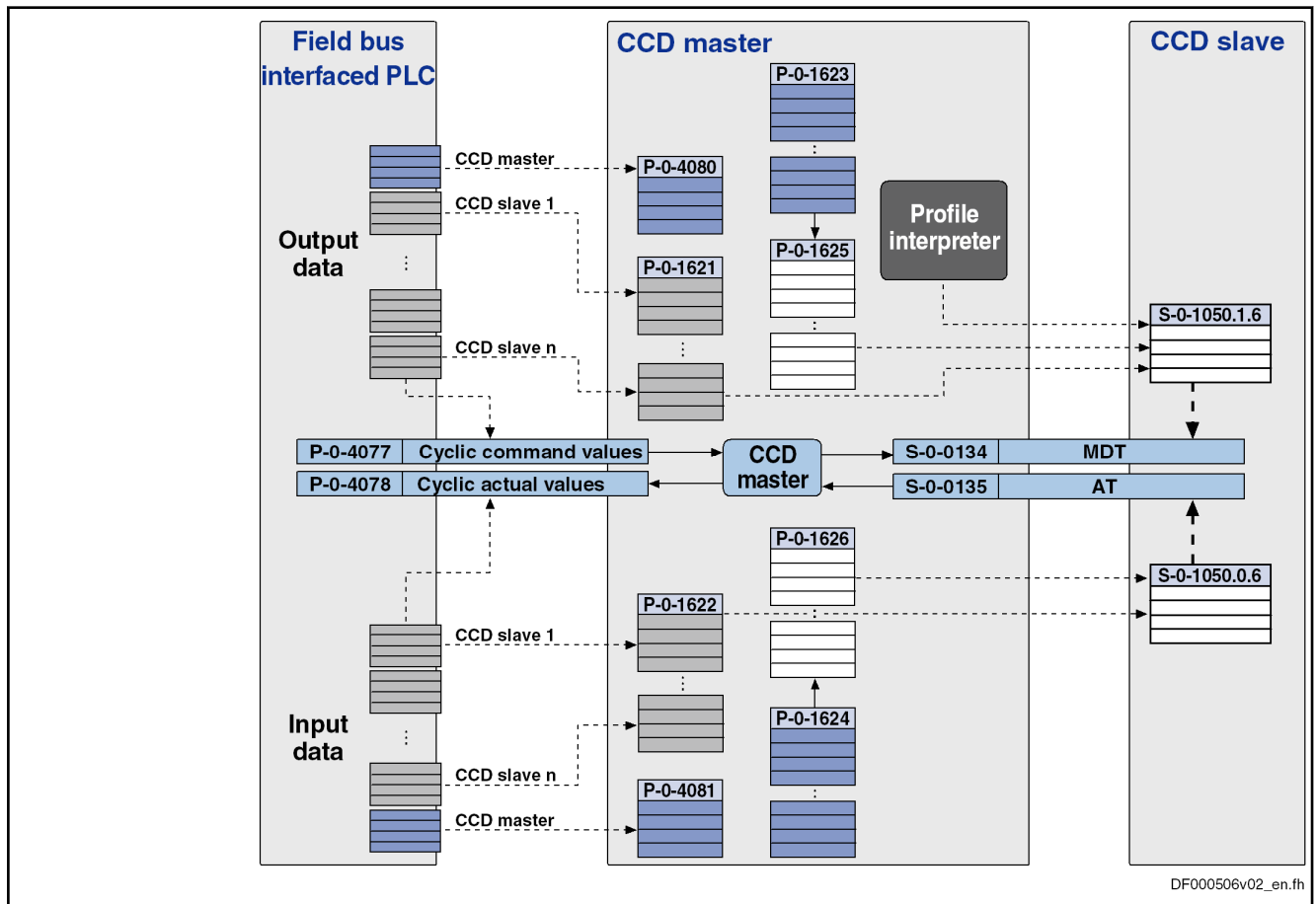
Fig.9-21:   Configuring cyclic process data

Configuration is done as follows:

- In the CCD master, the required cyclic process data between the external PLC and the CCD slave is configured in parameters P-0-1621 (MDT) or P-0-1622 (AT). The cyclic data of the controller at the CCD slaves is not configured with sercos II + III and EtherCAT using the aforementioned parameters P-0-1621 and P-0-1622, but directly from the controller using the usual parameters. With

    – sercos II and EtherCAT, these are parameters "S-0-0016, Configuration list of AT"

    and "S-0-0024, Configuration list of AT"

    – sercos III "S-0-1050.x.1 SIII-Connection: Connection setup" and "S-0-1050.x.6 SIII-Connection: Configuration list"

- The command values (MDT) to be transmitted from the CCD master to the CCD slave are configured in the relationship P-0-1623 ↔ P-0-1625. The list parameter P-0-1623 contains the parameters which the master enters into the MDT for the slave. The list parameter P-0-1625 contains the information about which parameters in the slave the data from the master is intended (S-0-1050.1.6).

- The actual values (AT) to be transmitted from the CCD slave to the CCD master are configured in the relationship P-0-1624 ↔ P-0-1626. The list parameter P-0-1624 contains the information about which parameters in the master the data from the slave is intended. The list parameter

Optional Device Functions

P-0-1626 contains the information about which parameters the slave enters into the AT for the master (S-0-1050.0.6).

I/O extensions for sercos III

I/O extensions for sercos III are only used in the CCD group with MLD-M or MLD-S. There is no connection to the master communication in the CCD master. Configuration and assignment to the CCD master and the slaves takes place via IndraWorks.

I/O extensions are included/projected like a drive as CCD slaves in the CCD group. With MLD, it is possible to access these extension modules (see separate documentation "Rexroth IndraMotion MLD").

The following I/O extensions for sercos III are supported by the CCD master and can be connected and evaluated at the CCD master:

- Rexroth inline digital block I/O
- Rexroth inline analog block I/O
- Rexroth inline modular I/O (field bus coupler (R-IL S3 BK DI8 DO4-PAC); analog input/output modules (R-IB IL AI xx ; R-IB IL AO xx); digital input/output modules (R-IB IL 24 DI xx ; R-IB IL 24 DO xx))

Parameterization of the Rexroth inline block I/O

The following settings are to be entered to configure the Rexroth inline digital/analog block I/O extensions (cyclic data):

- The command values (MDT) to be transmitted from the CCD master to the inline digital/analog block I/O extension are configured in parameter "P-0-1627, CCD: configuration list master cmd values I/Os". This list parameter contains the parameters, which the master enters into the MDT for the I/O block; for example, the bits of the PLC register in parameter P-0-1410 in the CCD master (written by MLD-M) are outputted at the outputs of the inline I/O block extension.

- The actual values (AT) to be transmitted from the inline block I/O extension to the CCD master are configured in parameter "P-0-1628, CCD: configuration list act. master values I/Os". This list parameter contains information about for which parameters in the master the data from the slave is intended; for example, the inputs of the inline block I/O extension are to be read to parameter P-0-1390 of the CCD master (in MLD-M).

Parameterization of the Rexroth inline modular I/O

A maximum of 4 sercos III modular I/O field bus couplers, each with a maximum of 16 disks, can be operated on a drive controller. All of the disks are supported, which can be operated as simple digital or analog I/Os.

The different configuration options of the individual disks can be read in the respective documentation and are only partially accessible via the dialog. The settings must be entered by accessing the parameters, directly via the IndraWorks interface or using the function blocks from the "RIL_sercosIII.lib" library. List parameters P-0-1470.0.x and P-0-1471.0.x in the CCD master (x corresponding to the I/O number according to the sequences of the I/Os configured in P-0-1604; x = 1...4) are available to map the I/Os (nodes) in the CCD master. Each list parameter (P-0-1470.0.1, P-0-1470.0.2, P-0-1470.0.3, P-0-1470.0.4, P-0-1471.0.1, P-0-1471.0.2, P-0-1471.0.3, P-0-1471.0.4) covers a complete Inline Modular I/O with all its possible disks (analog and digital) with its 200 bytes.

Usage:

- The content of the list parameter "P-0-1471.0.x: PLC outputs range AT %QB1000 - %QB1199" is assigned directly to the output data of the I/O. The individual disks of the I/O are assigned continuously allocated in turn to specific bytes in the list parameter (with different numbers of

bytes according to the type of disk). The assignment is based on the number of bytes per disk and cannot be changed.

- In list parameter "P-0-1470.0.x: PLC inputs range Bereich AT %IB1000 - %IB1199" the input data pending at I/O x is copied. The individual disks are assigned continuously in turn to specific bytes in the list parameter (with different numbers of bytes according to the type of disk). The assignment is based on the number of bytes per disk and cannot be changed.

☞ The analog I/Os are configured (scaled etc.) in the modular I/O via access to the parameters (please refer to the appropriate description for the configuration of the analog disks (nodes).

Addressing

A differentiation is made between the following schemes of addressing:

- Logic individual axis addressing → for CCD communication setting of the master communication address at each axis (e.g. 09, 02, 03, 05)
- Device address with automatic subindex → for PROFIBUS® (e.g. 9.02)
- Subindex address is used via PLC → 1st slave axis has address 1

☞ Any individual setting of the serial addressing via parameter "P-0-4022, Drive address of serial interface" does not take effect via the CCD group. The remote axes can only be addressed via their master communication address in the CCD master, not however via the (changed) serial address of P-0-4022.

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 have to be entered in parameter "P-0-1601, CCD: addresses of projected drives". In "P-0-1604, CCD: addresses of projected I/Os", enter the addresses of the compact I/O extension connected to the CCD master. The slave number and address is assigned via the order of the list elements, so that CCD slave 1 is the drive with the address entered in list element 0 (etc.).

- The slave addresses found by the CCD master in phase 0 of the CCD axis group are entered in the list parameter "P-0-1603, CCD: Actual topology addresses" in ascending order according to their actual line topology order (i.e. as they have been connected to the CCD master one after the other). Up to phase 2, this parameter can contain double addresses.

- In parameter "P-0-1636, CCD: Command topology addresses", all addresses of the CCD slave (drives and I/O extensions) connected to the CCD master have to be indicated in ascending order according to their (desired) topology order. Only the slaves contained in this list can be addressed as of CCD phase 2. Also those addresses of the sercos III slaves must be listed which are only connected to the CCD master, but have not been projected.

- If the command topology (P1636) contains addresses that were not listed/found in the actual topology, the warning "E4013 Incorrect CCD addressing" is generated in CCD phase 2. Continued switching to CCD phase 3 or 4 is impossible.

Optional Device Functions

- From phase 2 onwards, all addresses contained in the actual topology (P1603) must also be contained in the command topology (P-0-1636). The order for monitoring is irrelevant here. It is only important that all the respective addresses are contained, and no further/other addresses are only contained in P-0-1603 or only in P-0-1636. Either the addresses of the command topology (P-0-1636) must be adjusted to those of the actual topology (P-0-1603) or the addresses of the CCD slaves must be set to those of the command topology via command "C7000 CCD: Command adjust slave addresses" (P-0-1635). Only in this way is it possible, for example, to assign an unequivocal address to the compact I/O extensions!

- The slaves found in the actual or command topology and projected in parameter P-0-1601 or P-0-1604 are entered in the list parameter "P-0-4031, Overview of device addresses" during the transition to phase 1:

  – List element 0: Address of CCD master
  – List element 1: Address of CCD slave (drive) from P-0-1601 [0]
  – List element 2: Address of CCD slave (drive) from P-0-1601 [1]
  – List element n: Address of CCD slave (drive) from P-0-1601 [n]
  – List element n+1: Address of compact I/O from P-0-1604 [0]
  – List element n+m: Address of compact I/O from P-0-1604 [m]

☞ The slave addresses contained in the parameters P-0-1601 and P-0-1604 have to be found in the list parameter P-0-1603 or P-0-1636, otherwise the message "E4013 Incorrect CCD addressing" or "C0265 Incorrect CCD address configuration" is generated during phase progression of the master.

Specific features with sercos II+III   The CCD system mode for sercos (II+III) consists of 2 networks: the high-level network for control (sercos II master communication) and the low-level network between CCD master and CCD slaves on the basis of the sercos III communication. In both networks the individual nodes (slaves) are addressed via the sercos address. The CCD master must be able to unequivocally establish the connection between slave address in the high-level network (sercos II) and slave address in the low-level network (sercos III). Thus, any address within the allowed address frame can be assigned in both networks. Therefore, with sercos II CCD system mode, the addressing of the nodes (including the CCD slaves to be addressed) within the sercos II ring is independent of the addressing of the CCD slaves in the sercos III network of the CCD communication

To enable the CCD master to establish the connection of the addresses in the sercos II ring to the addresses of the CCD slaves in the sercos III network, the parameters " P-0-1621.x.1 CCD: Slave address in high level network" are available in the CCD master. Which x, i.e. which parameter refers to which CCD slave, depends on the order parameterized in "P-0-1601, CCD: addresses of projected drives". Addresses must be assigned for every CCD slave in the CCD master in parameters P-0-1621.x.1. The CCD slaves in the sercos II ring are detected and addressed via the same addresses.

Example: In this case, the address set in P-0-1621.0.1 corresponds to the address via which the first (->actual drive address P-0-1601, Element 0) CCD slave is reached from the sercos II control. With the address set in P-0-1621.1.1 the second slave (P-0-1601, element 1) is reached from the sercos II ring etc. It is therefore possible to address the CCD slave with the

drive address (address in display) 3 from the sercos II control with address 55.

Deactivating CCD slaves

All physically existing/connected CCD slaves (drives and I/Os) must be contained in "P-0-1601, CCD: addresses of projected drives" and "P-0-1604, CCD: addresses of projected I/Os". To deactivate physically existing CCD slaves, it is possible to leave out/remove addresses (drives, I/Os). The concerned slaves in this case are no longer taken into account by the CCD master and signal "E4010 Slave not scanned or address 0".

⚠ **WARNING**	When addresses are left out/removed, possible gaps in P-0-1601 and P-0-1604 are automatically filled so that changes in the logic order (Axis2, Axis3, ...) can occur. This has a direct effect on the MLD program and the CCD process data! To avoid the (undesired) effects of gaps being filled up, use the function "parking axis" in the axis to be deactivated (and do not remove the corresponding address). See also function "parking axis".

To deactivate physically **inexistent** slaves, use the corresponding firmware functionality as of MPH-05 (deactivate addresses in P-0-1601/P-0-1604, set bit 15 in the respective list element) (supported by IndraWorks). The deactivated slaves in this case are not taken into account by the CCD master, but the logic order is not changed so that the rest of the CCD configuration can be maintained.

☞ When all CCD slaves have been deactivated, X24 has to be connected to X25 with a sercos cable.

Acyclic Communication (Parameterization Gateway)

To allow the individual parameters of the slaves to be accessed 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 Cross Communication.

For this purpose, the following interfaces with the following possibilities are supported:

● Serial interface with binary SIS protocol (see also "Serial Communication"

☞ 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!

● sercos service channel "sercos Communication"

● Field bus interface with the available parameterization options (DPV1, …)

☞ The parameterization gateway is not supported with EtherNet/IP™.

Optional Device Functions

- EtherNet interface with TCP/IP

☞   For this application, the unassigned EtherNet connection (so-called "Engineering Port") at the CCD master can be used for parameterization.

When accessing the CCD slave via SIS protocol the following must be observed during implementation:

The address of the CCD master must be entered as receiver address in the general SIS telegram header. The receiver address to be entered in the service-dependent section for parameter services 0x80, 0x10, etc. is the address of the slave. The master accepts the telegram and routes the request to the slave via CCD.
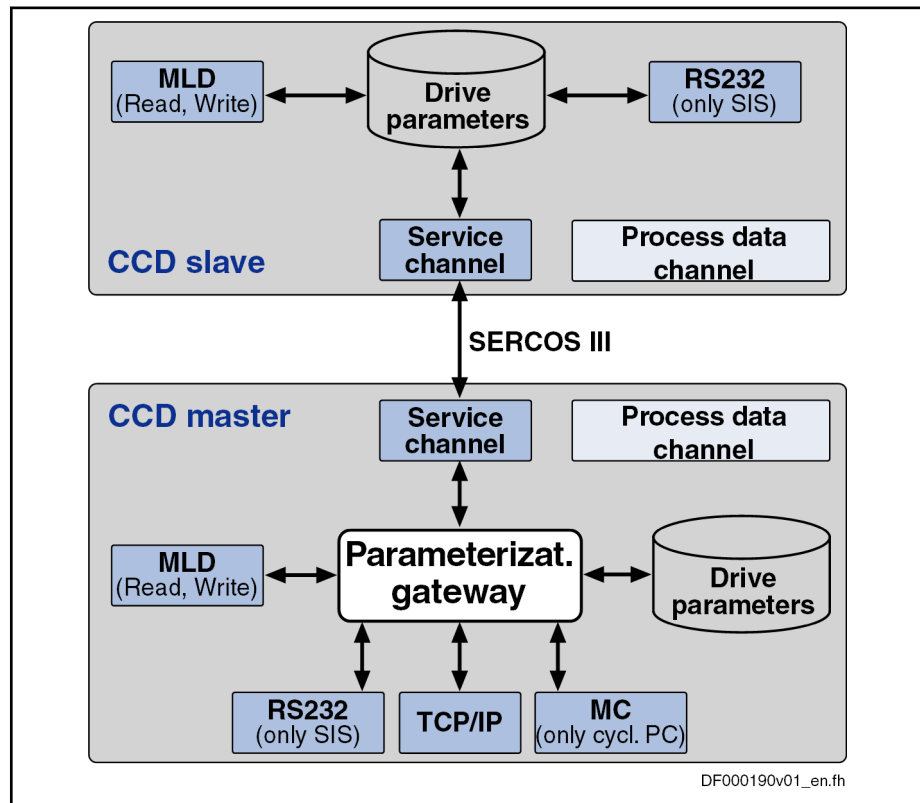
MC   Master communication
Fig.9-22:   Functional diagram of the parameterization gateway

Cycle Time

Configuration of CCD cycle time   The CCD cycle time is set in the master via parameter "S-0-0001, NC cycle time (TNcyc)" or "P-0-1610, CCD: cycle time". The CCD master then presets this time for the slaves in parameter "S-0-1050.x.10, SIII-Connection: Producer cycle time".

The resulting cycle time which is preset for the CCD slaves in parameter S-0-1050.x.10 (→ actual CCD cycle time) corresponds to the smaller value from the parameters S-0-0001 and P-0-1610 of the master (if P-0-1610 is not equal to zero).

The CCD master automatically determines the sercos cycle time of the CCD slaves in parameter "S-0-1002, SERCOS III: Communication Cycle time (tScyc)" and sets it to the smallest connection cycle time.

Optional Device Functions

The timing settings made by the master can be seen in parameter "P-0-1602, CCD: timing settings"

The number of CCD slaves limits the possible CCD cycle time (see "Performance Features").

Special case of sercos II+III CCD system mode
In sercos II+III CCD system mode, S-0-1002 is set in the CCD slaves to a fixed value, depending on the NC cycle time (S1) of the sercos II/III communication of the CCD master:

S1, (sercos II/III) NC cycle time in the CCD master	500 µs	1000 µs	2000 µs-4000 µsand high-performance in all CCD axes	2000 µs-4000 µsand standard performance in at least one CCD axis	2000 µs-4000 µsand economy performance in at least one CCD axis
S1002 in the CCD Slave	250 µs	500 µs		1000 µs	2000 µs

Fig.9-23:   Set by CCD master in the CCD slave

This results in a dead time compensation and it is possible in sercos II/III CCD system mode that the cyclic data of the CCD master (--> sercos II/III slave) and CCD slave take effect simultaneously.

☞ The sercos III cycle time set in S-0-1--2 of the CCD slaves by the CCD master must be supported by every CCD slave. The sercos II/III cycle time of the sercos II/III communication may have to be increased (cf. table above).

Ring Recovery and Redundancy

Redundancy in the master means that, in the event of a ring interruption, the CC data that was previously exchanged directly between the slaves is copied from one line to the other by the CCD master. This causes a sercos cycle offset with the CC data. This does not affect MS data.

Optional Device Functions
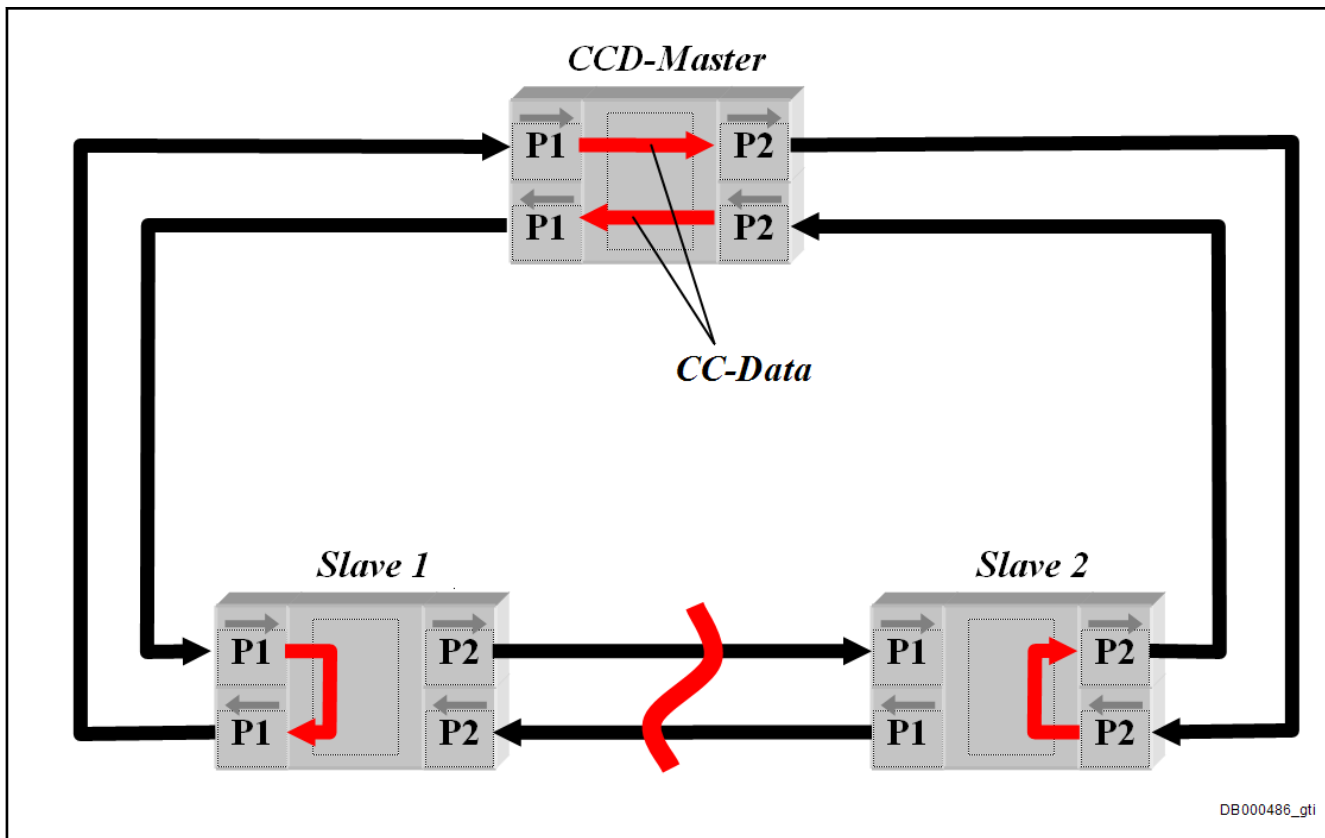
Fig.9-24:   Redundancy in the master

With ring interruption, the double ring is split into 2 lines, while with ring recovery the topology is changed vice versa. To ensure that this functions without errors, bus master and bus slave must be able to handle both, the respective topology states and the transitions. The values in parameter "S-0-1003, SERCOS III: Allowed MST losses in CP3/CP4" must not be exceeded, even during the transitions.

The CCD master has the following functions for display of the ring interruption and for ring recovery:

- Parameterization of command topology (P-0-1620.0.3) and display of a warning (E4016) with differing command and actual topologies (P-0-1610.0.3)

- Command function for ring recovery (C7100) via parameter P-0-1620.0.21

Redundancy

The redundancy in the master is a function that becomes active if a ring interruption is detected and the slaves activate LoopBack at the interruption point. The CC data that was previously exchanged directly between the slaves is then copied from one line to the other by the CCD master. This causes a sercos cycle offset with the CC data. This does not affect MS data. With differing parameterized command topology and actual topology, the CCD master displays the warning "E4016 CCD: Topology error" to indicate this condition.

The CCD master displays the address of the CCD slaves at the end of the lines in parameter "P-0-1610.0.21, CCD: Slave addresses at end of line" which is created as a list with two elements. This permits the ring break to be located.

Optional Device Functions

- List element 1: Address of slave at the end of the line at port 1
- List element 2: Address of slave at the end of the line at port 2

Ring recovery

The CCD master provides the command "P-0-1620.0.21, C7100 CCD: Command Close ring" (C7100) for ring recovery. With the command topology P-0-1620.0.3 = 4 (double ring) this allows to close the line or 2 lines to the double ring. Due to the change of topology, the ring delay is measured again, if necessary, transmitted to the slaves and the command S-0-1024 (Synchronization measuring procedure) activated. If an error occurs with the command C7100, the message "C7101 CCD: Impossible to close ring" is displayed. Possible causes for the message C7101:

- CCD group not in phase 4
- Topology is not line or double line
- No line between the last nodes of the lines.
- New ring delay could not be transmitted to the slave.
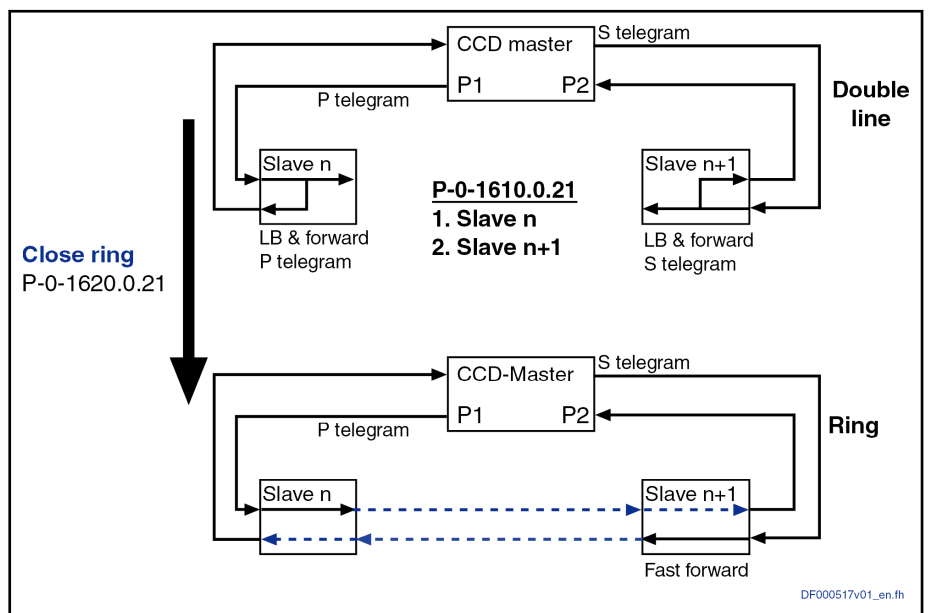
Fig.9-25:   Ring recovery

Dead Time Compensation

For command value linking (e.g. with Gantry axes) via CCD, it is necessary that the command values take effect at the same point of time in the individual axes. To prevent the master axis from preceding the slaves, dead time compensation was realized for the command value input to the slaves.

☞ In 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 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 for the internal processing dead times. The parameter of the CCD master to be transmitted to the CCD slave first is

Optional Device Functions

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.
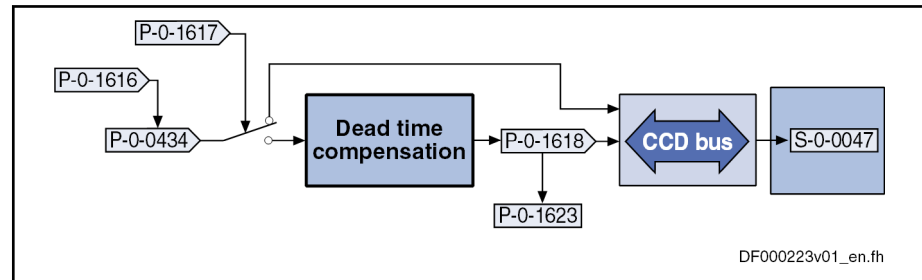
Fig.9-26: Command value extrapolation for dead time compensation of command values for the CCD slaves

Applicational example with configuration

The operating principle of the function is described for a gantry axis (position command value linking).

The CCD master is to preset the position 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 when a value not equal to "0" (default setting) is entered in parameter "P-0-1617, CCD: number of extrapolation steps".

- Enter the desired command value (with position command value linking → P-0-0434) into parameter "P-0-1616, CCD: extrapolated cmd value signal selection".

- In place of P-0-0434, the value of parameter "P-0-1618, CCD: extrapolated command value" is then entered for the slaves in parameter "P-0-1623, CCD: configuration list master cmd values".

☞ Due to the extrapolation, there are position deviations (worse profile) for the extrapolated command value as compared to the original command value, and the extrapolated command value becomes greater as the number of extrapolation steps (P-0-1617) increases.

9.3.3 Notes on Commissioning and Utilization

Navigation in IndraWorks

The dialogs for parameterizing CCD communication can be found in IndraWorks under the sercos III node (→ right mouse key):

Optional Device Functions
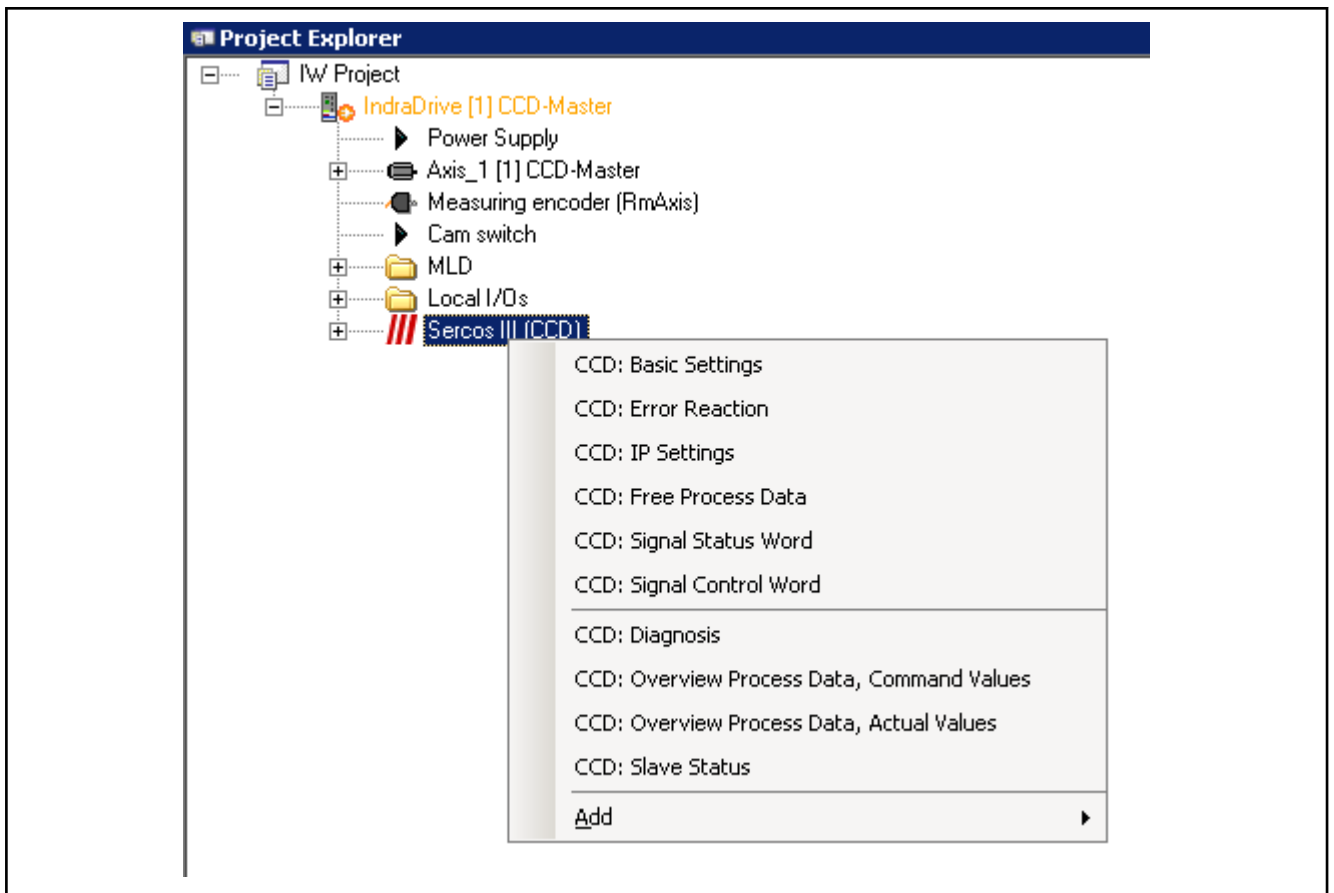
Fig.9-27:   Overview of IndraWorks dialog windows for CCD communication

In the same way as drives under a control unit, the slaves of the CCD group are displayed below a sercos III node in the project tree.
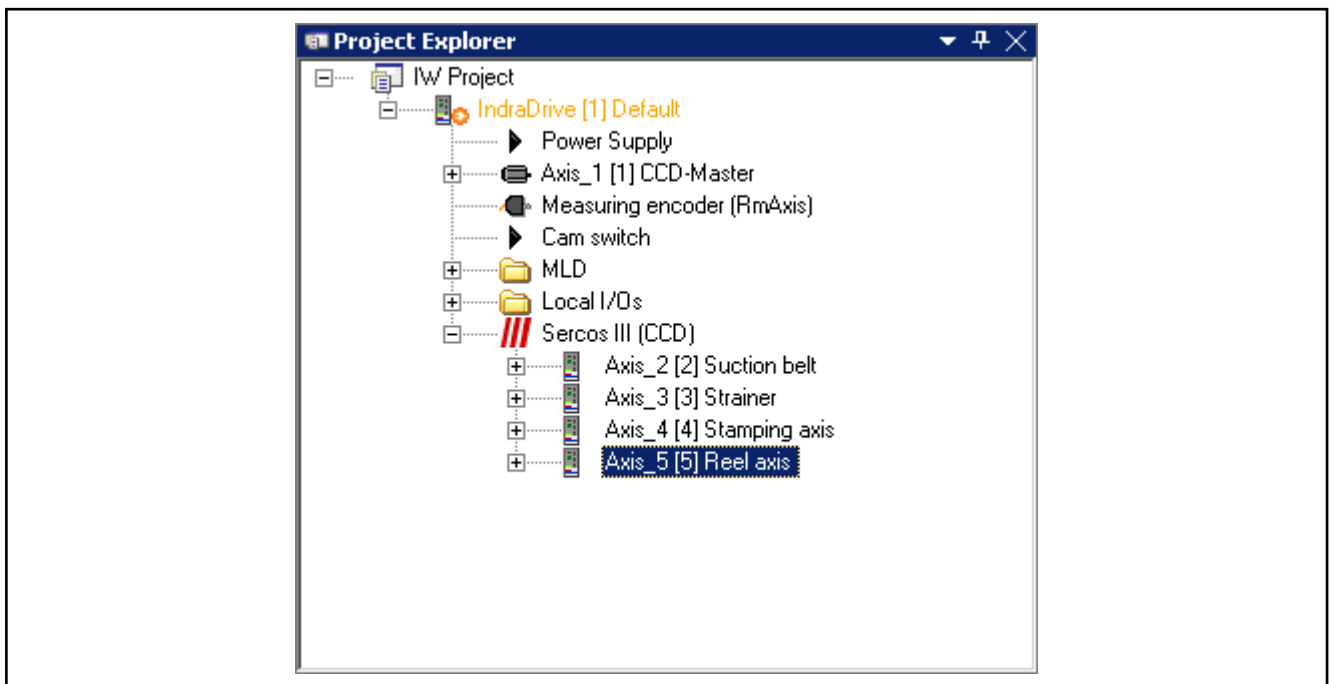
Fig.9-28:   CCD Display in the Project Explorer

Optional Device Functions

The slaves can be addressed in the same way as drives under a control unit. In offline mode, it is possible to drag drives from the library under the sercos III nodes. The configuration found is used in online mode.

Basic settings   The figure below shows the basic settings for parameterizing CCD communication.
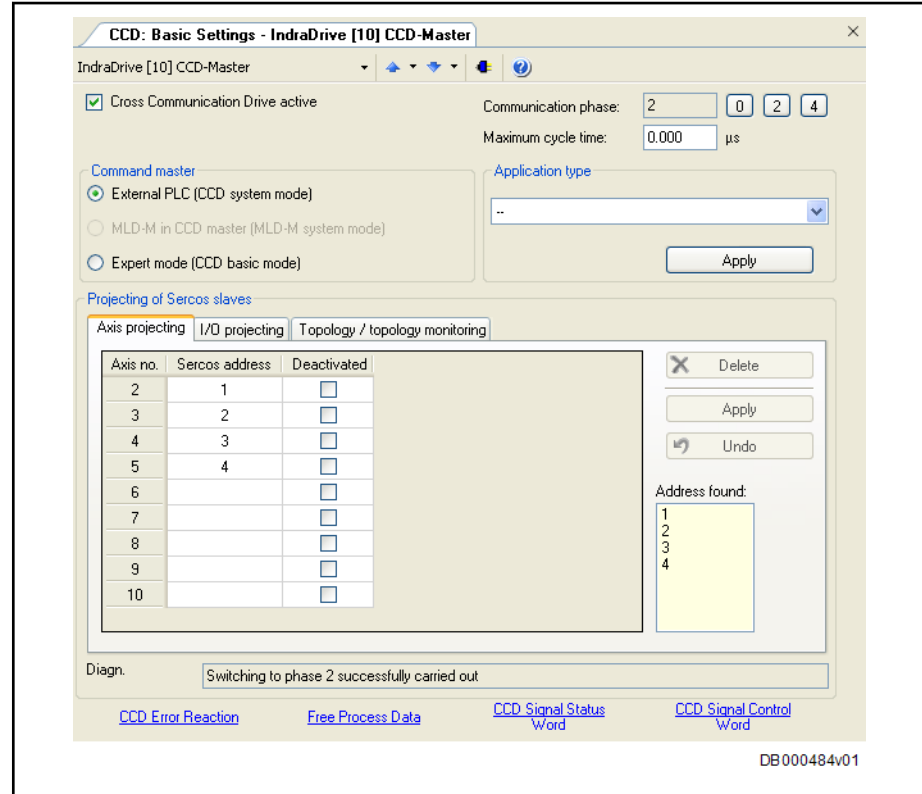
Fig.9-29:   IndraWorks dialog for basic settings of CCD communication

Selection of Cross Communication Modes

Applicational options of CCD modes   Due to their different properties, there are preferred applications for the respective CCD modes:

- Preferably use **CCD system mode (command triggering master: external PLC)**, when mere command value linking must be realized with field bus master communication and control over all drives is still 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 **CCD basic mode (expert mode)**, when an MLD with permanent control is used in at least one CCD slave

  - or -

  mere command value linking is to be realized with master communication "sercos", "parallel" or "analog" and control is still in the external control unit.

Optional Device Functions

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 **MLD-M system mode (command triggering master: MLD-M in the CCD master)**, when multi-axis motion is to be realized in the master and the MLD in the master is to access the remote axes (CCD slaves).

  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:
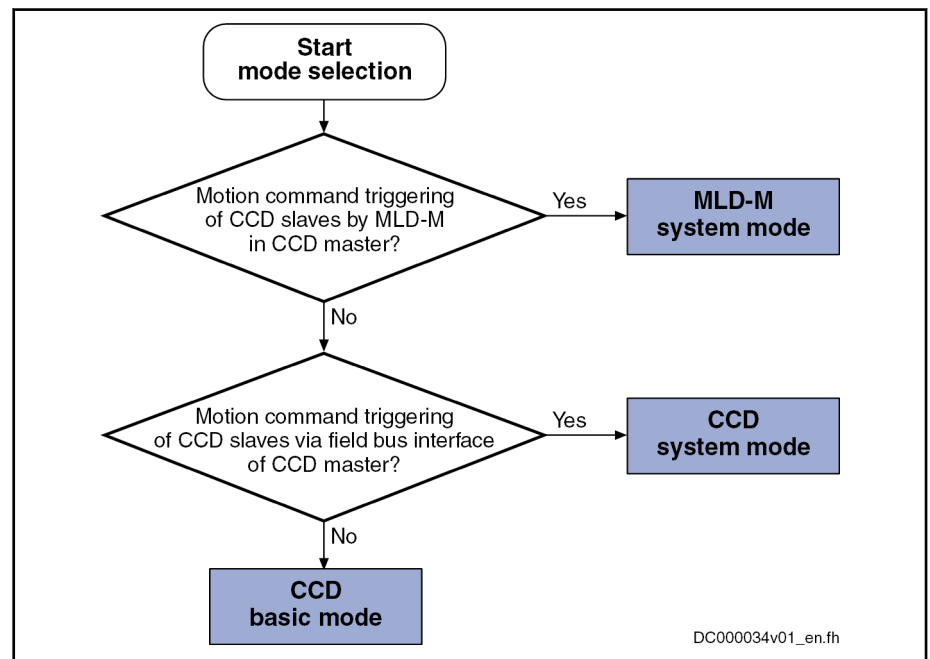
Fig.9-30:   Selection criteria for CCD mode (see P-0-1600)

Selection criteria   Using **CCD system mode** makes sense when:

- The external master is to have control over the CCD slaves,

- Process data (command values and actual values) must be exchanged between the external master (e.g. field bus interfaced PLC) and the CCD slaves,

- Other process data apart from the external process data is input by the CCD master to the CCD slaves (e.g. command value linking).

Using **CCD basic mode** makes sense when:

- The external master is to have control over the CCD slaves,

- Only process data is preset to the CCD slaves by the CCD master (e.g. command value linking),

Optional Device Functions

- An MLD with permanent control is used in the slave axes.

Using **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 is 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 must not be less than the slowest position loop clock in the CCD group:

- Advanced performance: 0.25 ms, 0.5 ms, 1 ms, 2 ms, 4 ms
- Basic performance: 0.5 ms, 1 ms, 2 ms, 4 ms
- Economy performance: 1 ms, 2 ms, 4 ms

☞   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 CCD mode selected (see "Performance Features").

☞   The CCD cycle time is always to 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.

Assigning the Addresses

By means of the fields for projecting the CCD slaves, for the drives and compact I/Os of the CCD group the sercos address is assigned to the slave number (Axis_x).

Axis no.   The axis no. (slave no.) refers to the CCD slave number in the CCD master relevant for the CCD configuration. This is also equivalent to the logic axis number axis_x of MLDM (axis2 to axis_10).

sercos address   The sercos address establishes an unequivocal relationship between the logic axis number and the physical device. Any access to the logic axis number by the CCD master or the MLD-M is executed on the device with this sercos address (S-0-1040 in the sercos slave) via the address entered here.

Deactivated   If a projected CCD slave does not exist physically, it can be deactivated by marking this field for the CCD master. This does not result in an offset of the logic order and the remaining CCD configuration can be maintained. This provides the advantage that projects with similar applications, only differing in the existence of individual slaves, can be changed.

Error Reaction

CCD error reaction   With regard to the error reaction of the CCD group, note 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.

Optional Device Functions

Kind of error reaction	Description
Independent error reaction	All axes in the group carry out an independent error reaction, when package reaction has not been activated and the CCD error reaction has not been activated either.
Package reaction	The axes operated in the axis group at a DC bus are interconnected via the module bus and carry out a collective coordinated error reaction (package reaction) in the case of error (see "Error Reactions: Package Reaction on Error")
CCD error reaction	For certain applications (e.g. gantry axes) it can be useful to shut down the complete CCD group in a controlled way or at least equally in all axes when an error occurs in a CCD slave or in the CCD master. If required, it is therefore possible to activate a CCD error reaction in the CCD master!

Fig.9-31:   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:
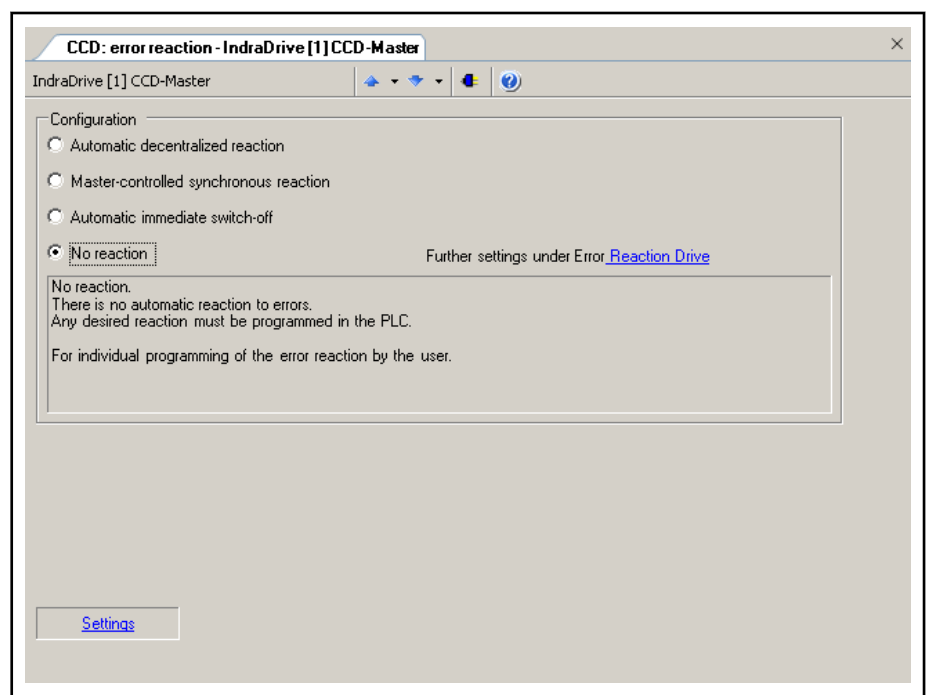
Fig.9-32:   IndraWorks dialog for configuring the CCD error reaction

Explanation of possible settings:

- **No reaction**

  With 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 MLD-M mode, motion function blocks of the MLD do not trigger any error with faulty parameter setting.

- **Automatic decentralized reaction**

  With errors in a CCD slave, the warning "E2140 CCD error at node" is displayed in the master (example of application: master-axis-synchronous deceleration).

  Note: In MLD-M mode, this warning is also displayed when a motion function block with faulty parameters is called up in MLD-M, if this has been set in "P-0-1367, PLC configuration".

- **Master-controlled synchronous error reaction**

Optional Device Functions

The error reactions of master and slaves take place depending on the error class (F2xxx, F4xxx, …) and the configuration in "P-0-1600, CCD: configuration"; see fig. below (example of application: mechanically coupled axes).

Note: In MLD-M mode, the error "E2140 CCD error at node" is displayed in the master, when a motion function block with faulty parameters is called up in MLD-M, if this has been set in parameter "P-0-1367, PLC configuration". With remote CCD slaves, automatic deceleration does not take place with a motion function block error, but the error reaction has to be programmed by means of MLD!

- **Automatic immediate switch-off**

  When the CCD master detects that an axis in the CCD group (master or slave) signals a class 1 diagnostics error, all axes are decelerated with "best possible deceleration" (see P-0-0119). The CCD master outputs the error message **F2140 CCD slave error**. If the CCD master is not in control, only the warning "E2140 CCD error at node" is displayed (the axes are nevertheless decelerated!).

Special case: Master-controlled synchronous error reaction

When the **master-controlled synchronous error reaction** is active, the content of the parameters P-0-170x ("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:

- With 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 pending, it is always the error reaction "best possible deceleration" which is triggered.

With regard to the master-controlled synchronous error reaction of the CCD group, we must basically distinguish between 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.
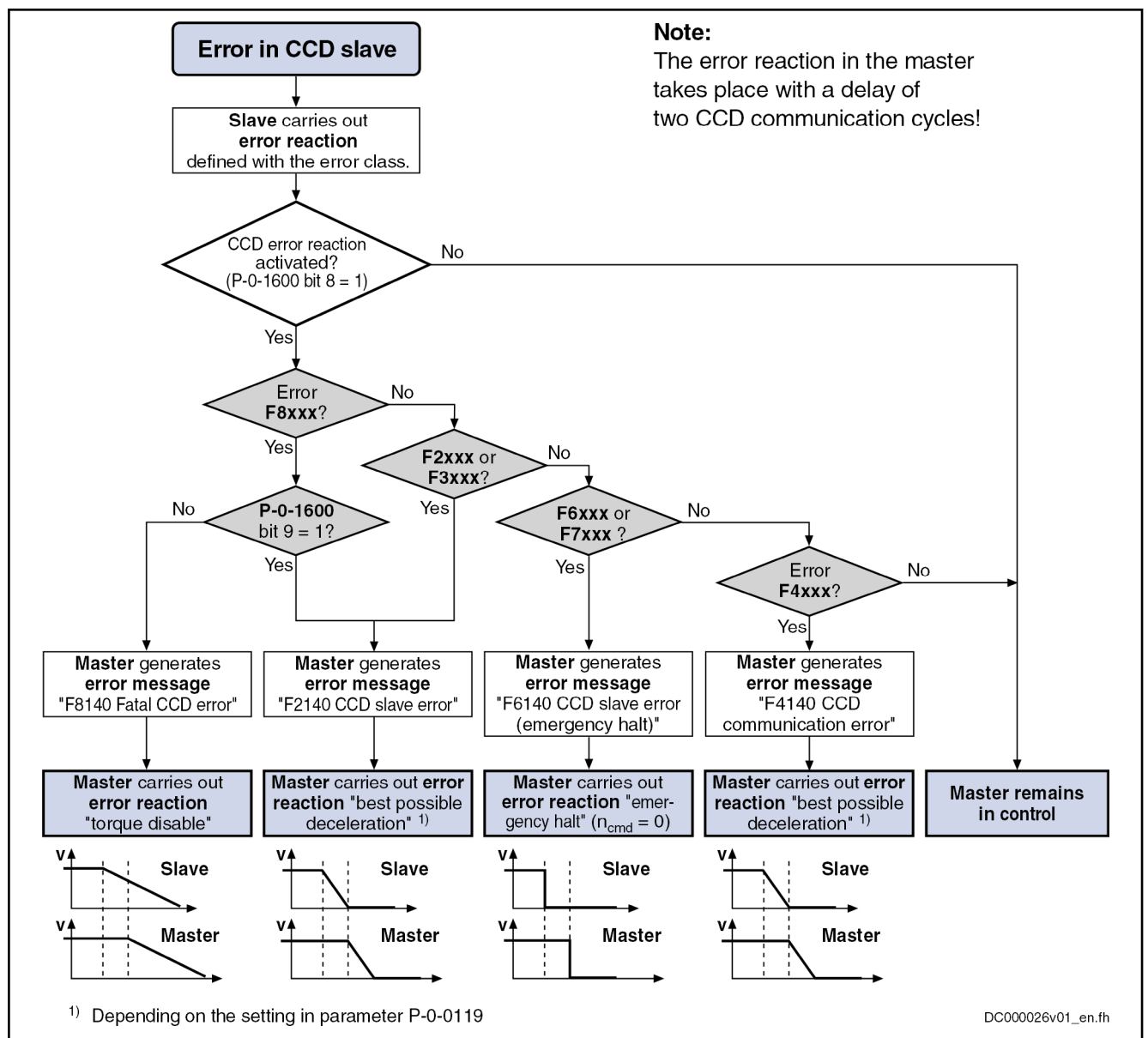
Fig.9-33:   CCD error reaction for master-controlled synchronous error reaction with errors in the slave

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
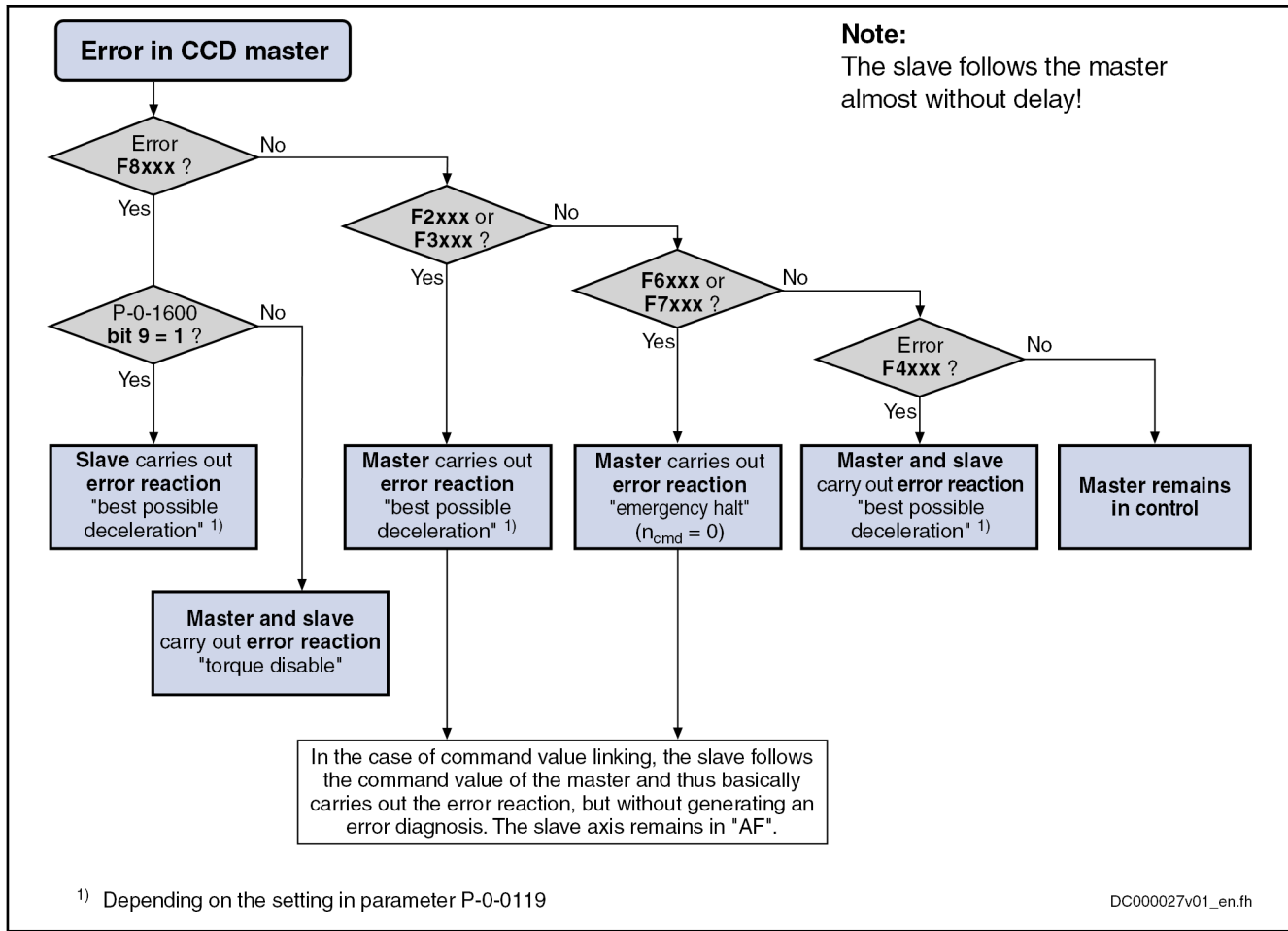
Fig.9-34:   CCD error reaction for master-controlled synchronous error reaction with errors in the master

IP Settings

To establish an EtherNet connection with the CCD master, the IP address of the Engineering Port can be read or set in the IndraWorks dialog window shown below.
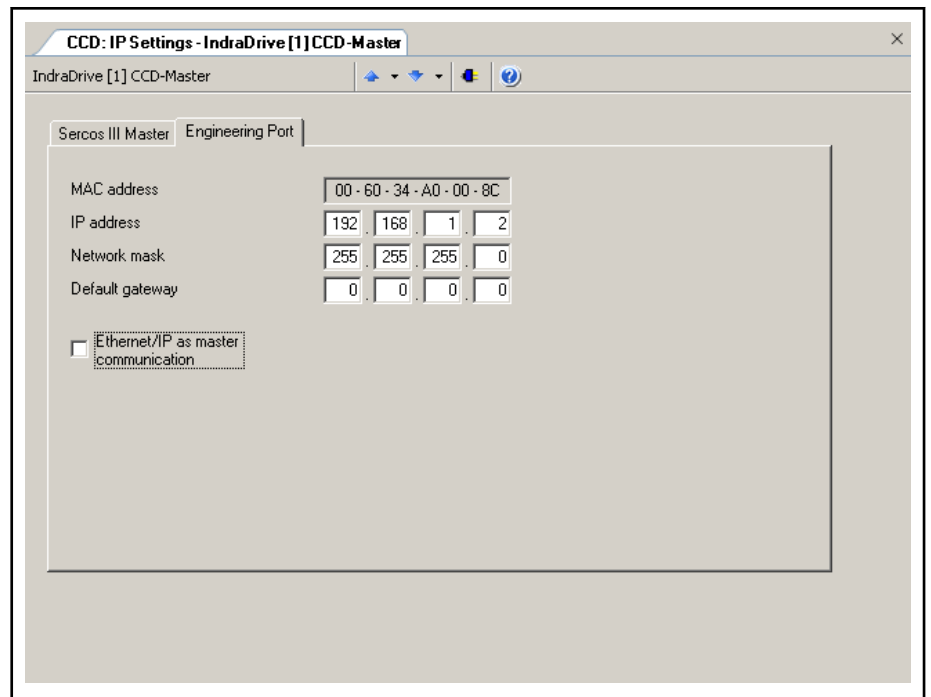
Fig.9-35:   IndraWorks dialog for IP settings

Free Process Data

By means of the free process data, parameter values of the CCD master (command values) can be copied to parameters of CCD slaves. Vice versa it is possible to copy parameter values of CCD slaves (actual values) to parameters of the CCD master.

Only in CCD system mode is it additionally possible to exchange data between the higher-level control unit and the CCD slaves.

Optional Device Functions
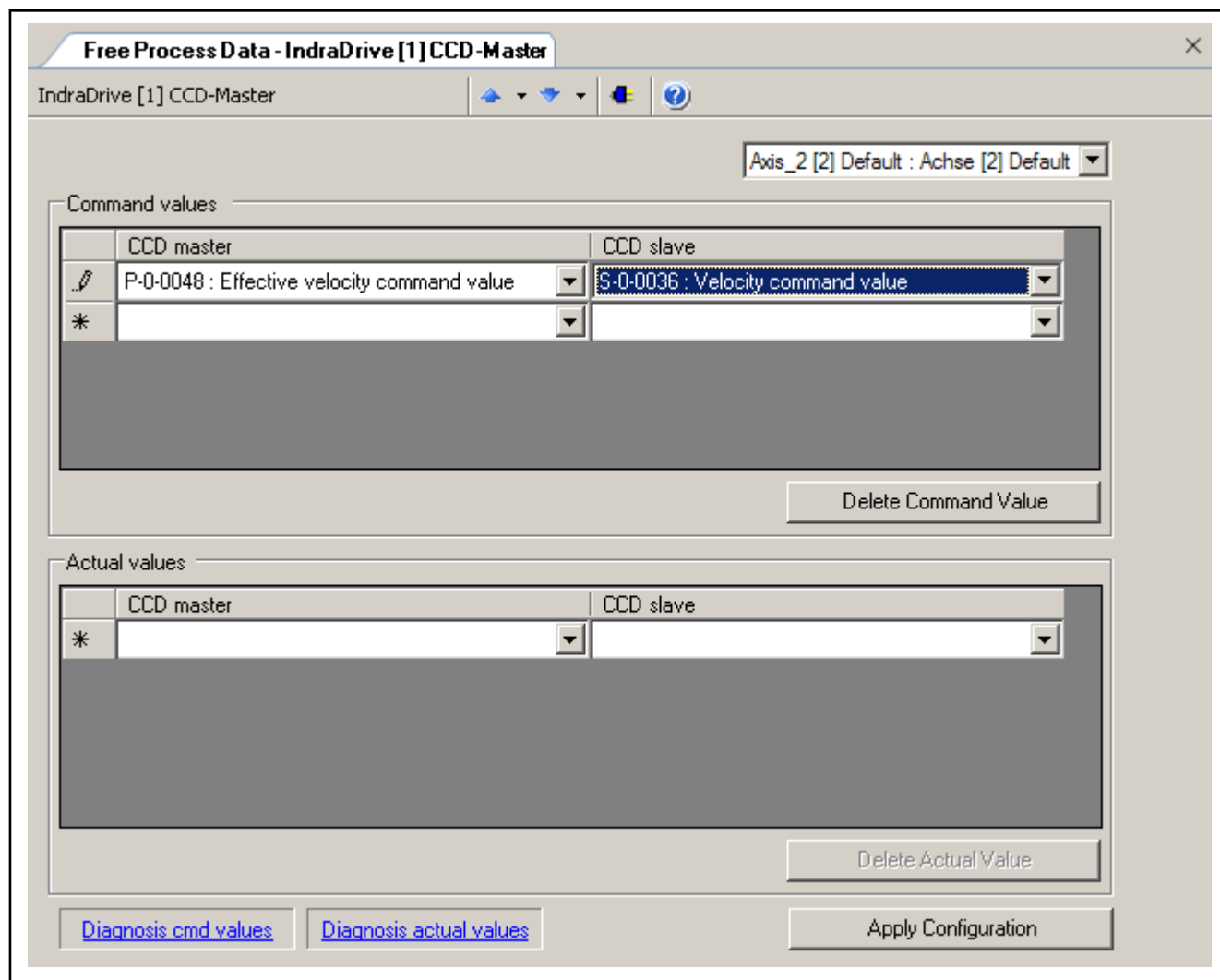
Fig.9-36:   IndraWorks dialog for configuring process data between CCD master
               and CCD slave

Under the command values in the column of the CCD master, enter the parameter the value of which is to be copied to the selected CCD slave. In the column of the CCD slave in the same row, set the parameter of the CCD slave to which this value is to be copied.

Under the actual values in the column of the CCD master, enter the parameter to which the parameter value of the CCD slave is to be copied. In the column of the CCD slave in the same row, set the parameter value of the CCD slave which is to be copied to the parameter of the CCD master.

Please note:

- First select for which CCD slave (Axis_x) the free process data is to be configured.

- With Axis_1 address the so-called "virtual slave". This slave is used for artificially delaying command values in the CCD master for dead time compensation and is automatically configured in the MLD-M system mode.

- The parameter of the CCD master and the belonging target or source parameter in the CCD slave must have the same data length.
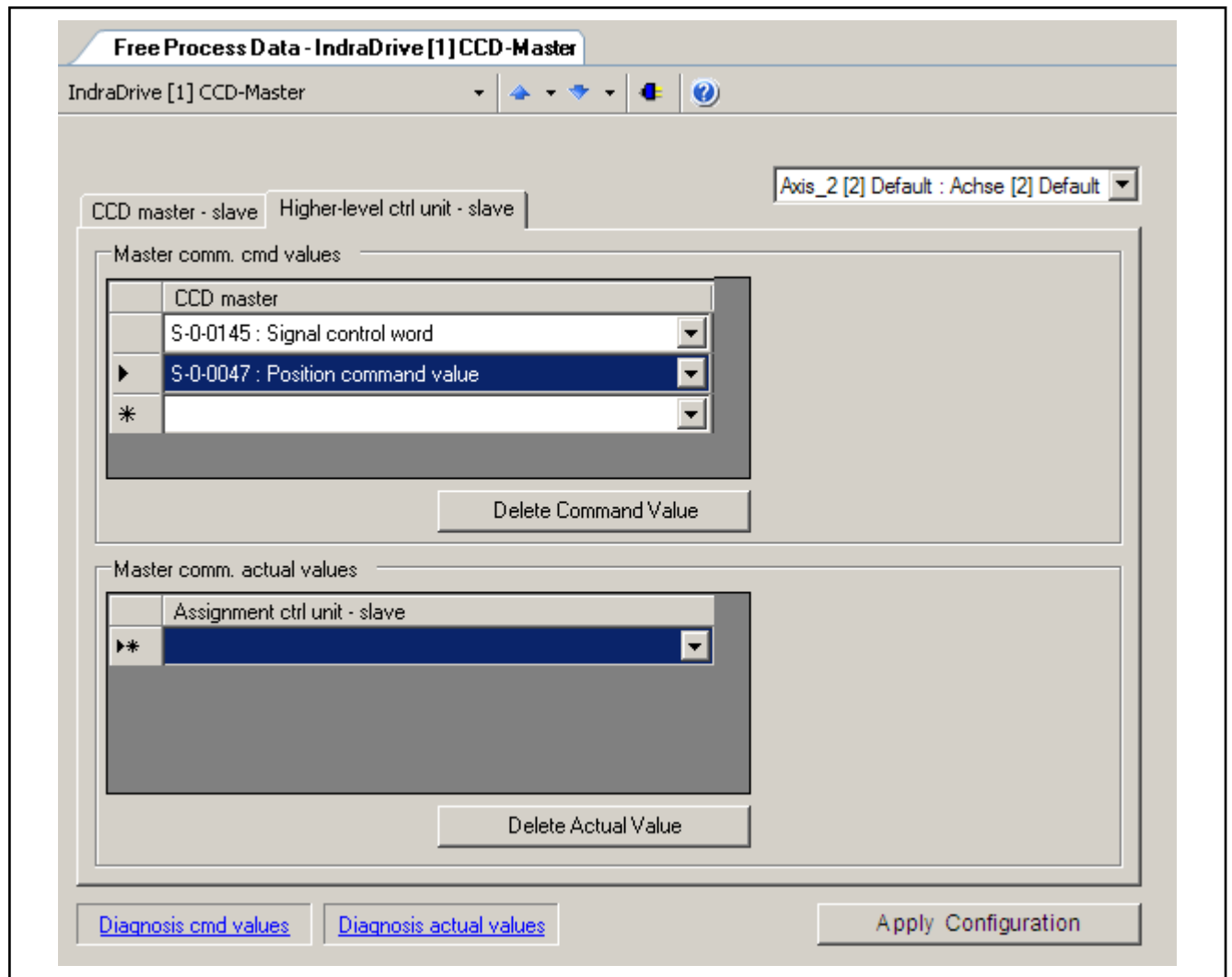
Fig.9-37:   IndraWorks dialog for configuring process data between higher-level control unit and CCD slave (only with CCD system mode)

With the command values of master communication, enter the parameters of the CCD slave, which are directly written by the external control unit. With 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 note:

- If the four unassigned bits of the signal control word (see below) are to be used, the parameter "S-0-0145, Signal control word" always has to be contained in the master communication command values.

- If the four unassigned bits of the signal status word (see below) are to be used, the parameter "S-0-0144, Signal status word" always has to be contained in the actual master communication values.

- A control word for the CCD slave, with a structure identical to the parameter "P-0-4077, Field bus: control word", is always contained in the master communication command values. It is not necessary to enter anything for this. 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").

Optional Device Functions

Via these bytes, the control unit can command each CCD slave individually like a normal field bus drive.

● A status word of the CCD slave, with a structure identical to the parameter "P-0-4078, Field bus: status word", is always contained in the actual master communication values. It is not necessary to enter anything for this. 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 CCD system mode (not applicable with EtherCAT and sercos II+III)

By means of the CCD signal status word, individual bits of the CCD slave can be directly read by the external control unit in 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 CCD signal status word.

☞ To read the CCD signal status word in the external control unit in 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 bits 12 to 15 can be configured. The other bits are reserved (bits 0 to 11 are always zero in the control unit)!

Use in MLD-M system mode

By means of the CCD signal status word, individual bits in the CCD slave in 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 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) has 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

IndraWorks supports the configuration of the signal status word using the dialog window below. This IndraWorks dialog is **not available in CCD basic mode**.

Optional Device Functions
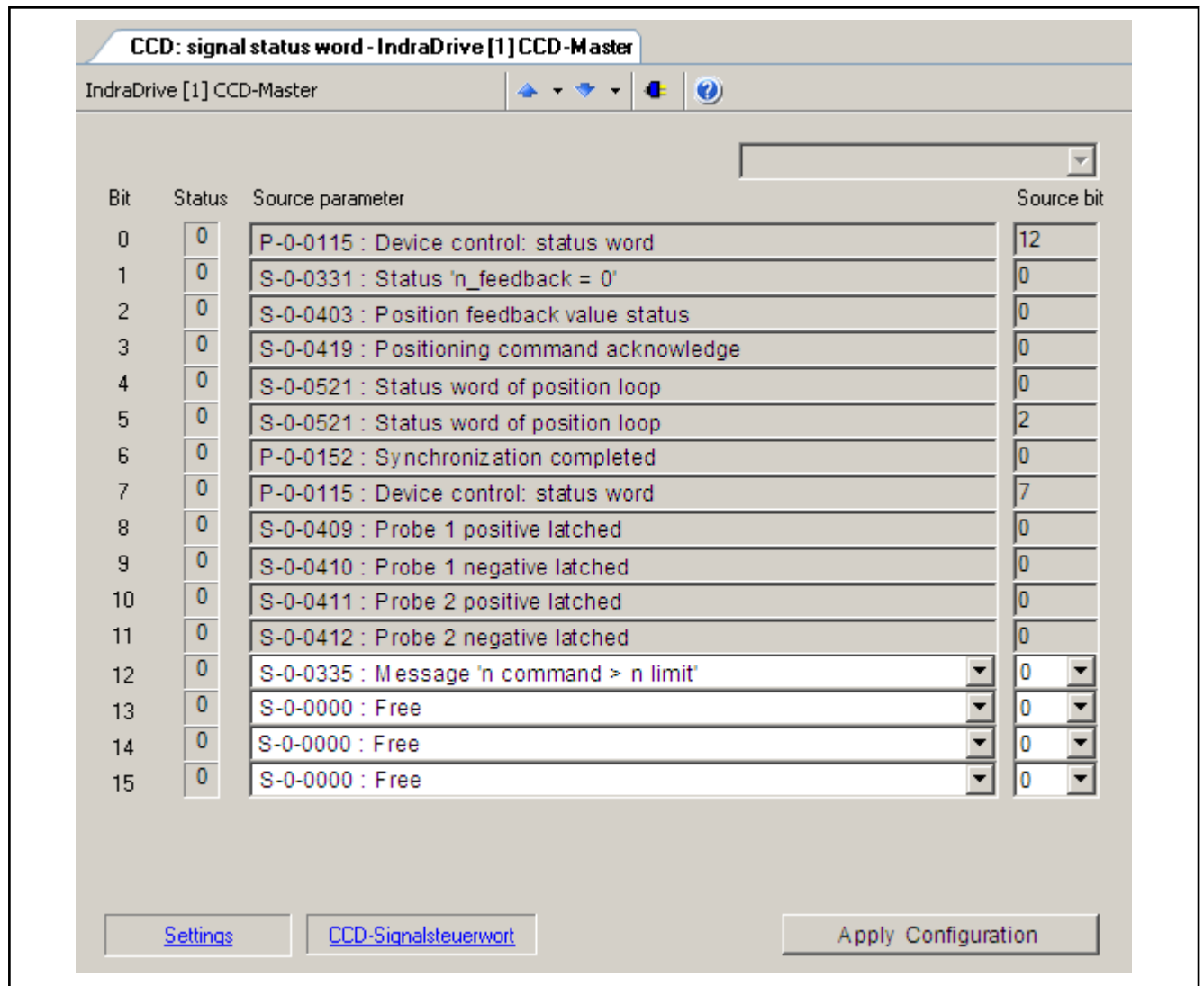
Fig.9-38:   IndraWorks dialog for configuring the signal status word

Signal Control Word

Use in CCD system mode (not applicable with EtherCAT and sercos II+III)

By means of the CCD signal control word, individual bits in the CCD slave can be directly addressed by the external control unit in CCD system mode (see "S-0-0145, Signal control word" with a normal field bus slave). It is necessary to indicate which bit of which parameter of the CCD slave is addressed by the corresponding bit in the CCD signal control word.

☞ To use the CCD signal control word of the external control unit in CCD system mode, the parameter S-0-0145 must have been entered into the (cyclically) free process data of the control unit to the corresponding CCD slave!

☞ Only bits 12 to 15 can be configured. The other bits are reserved.

Use in MLD-M system mode

By means of the CCD signal control word, individual bits in the CCD slave in 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

Optional Device Functions

which parameter of the CCD slave is addressed via the corresponding element of the AxisData structure.

Use in 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) has 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   IndraWorks supports the configuration of the signal control word using the dialog window below. This IndraWorks dialog is **not available in CCD basic mode**.
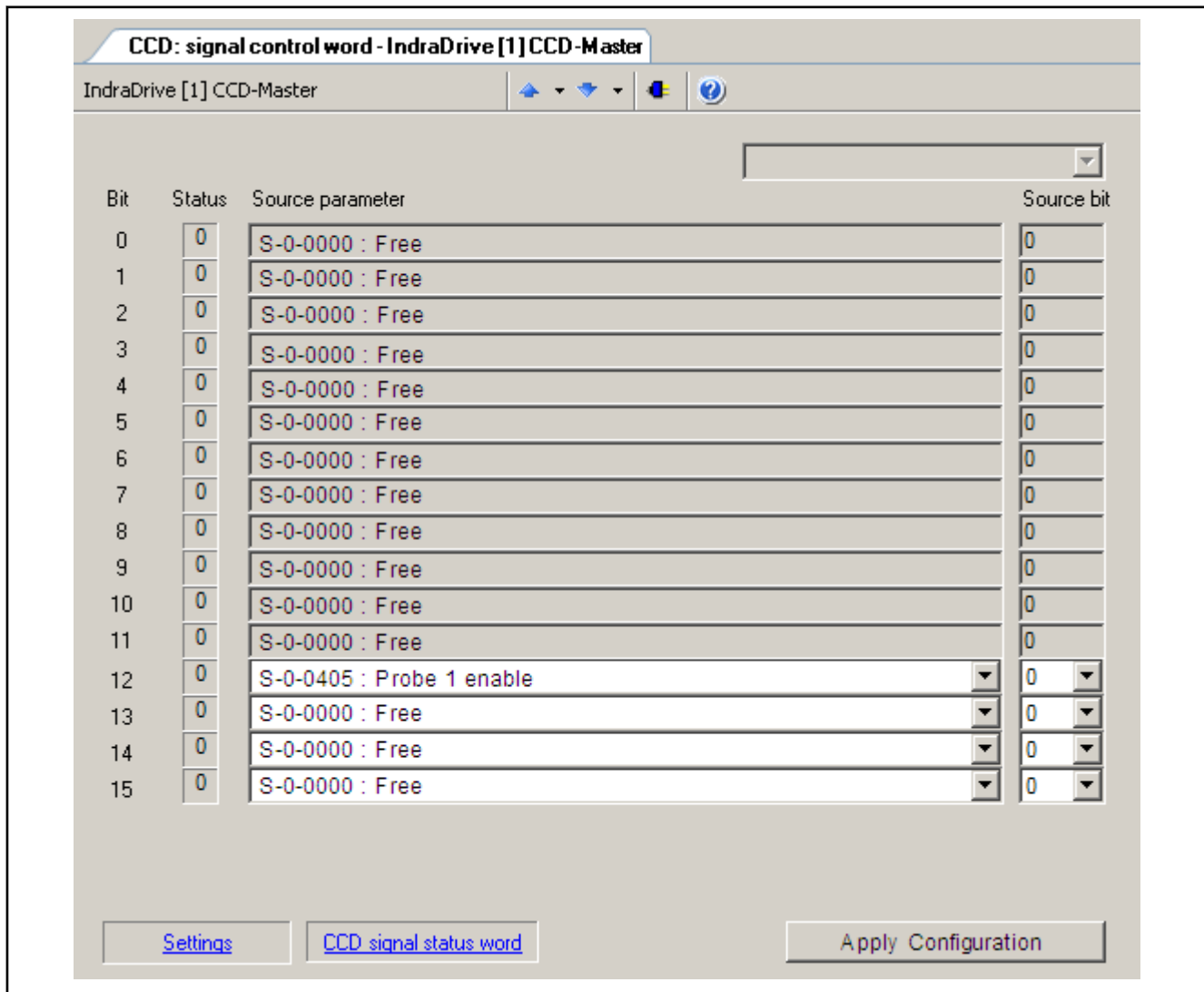
Fig.9-39:   IndraWorks dialog for configuring the signal control word

9.3.4   Diagnostic and Status Information

Diagnostic Information
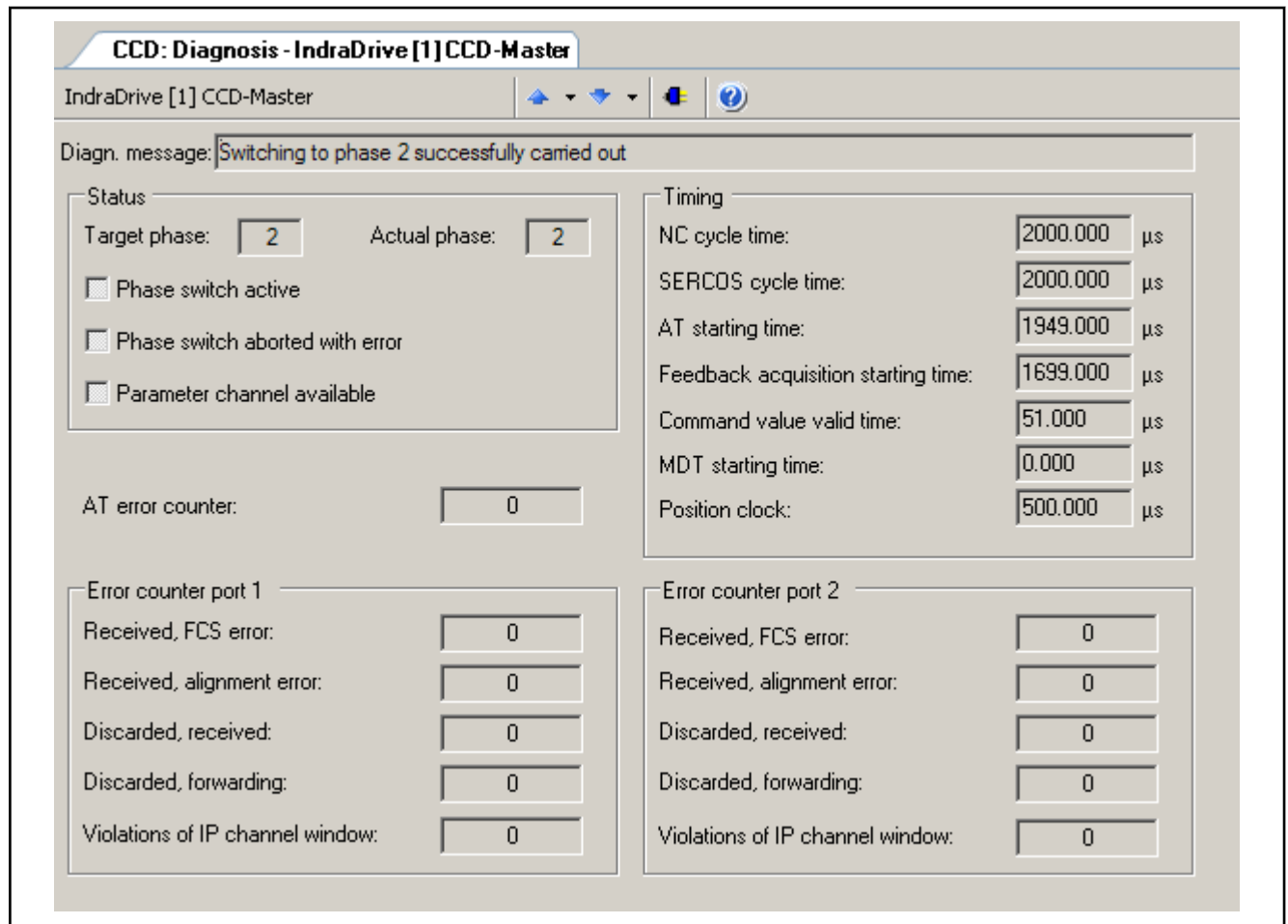
Fig.9-40:   Diagnostic information in IndraWorks for CCD communication

With problems with sercos cross communication between the CCD master and connected CCD slaves, different information can be obtained in this IndraWorks window:

- Diagnostic message text for CCD cross communication
- Status of phase switch of the entire CCD group
- Timing of the sercos III connection
- Number of AT telegrams which have failed in "AT error counter"
- Count of error counters of sercos FPGA according to sercos III specification in "Error counter port 1" and "Error counter port 2"

Optional Device Functions

Overview of Process Data, Command Values
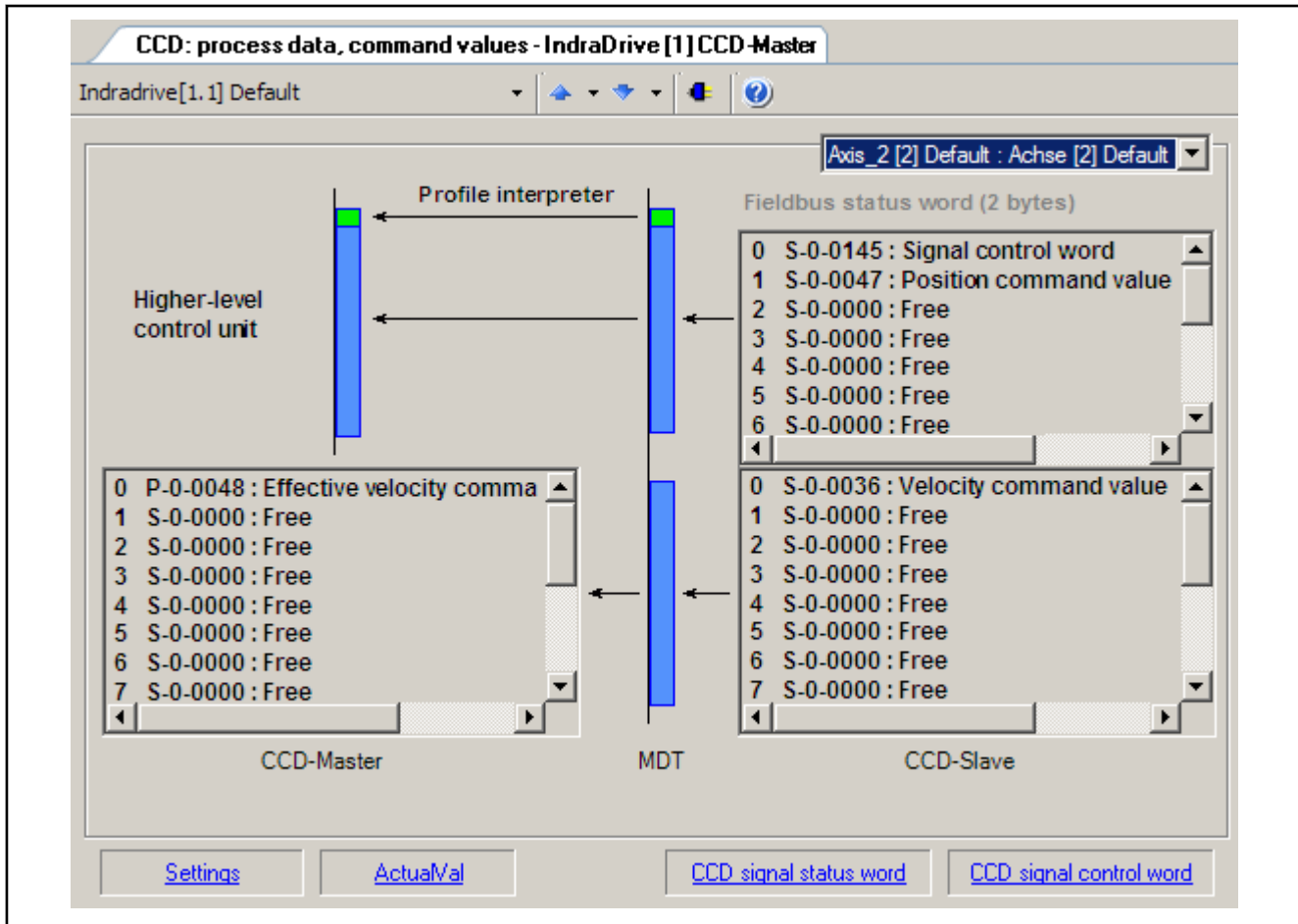
Fig.9-41:   IndraWorks overview window of process data command values

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 MLD-M system mode, the data configured in the AxisData structure is displayed here as well.

In 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 available is also displayed (and to be taken into account in the output data of the control unit) as well.

Optional Device Functions

Overview of Process Data, Actual Values
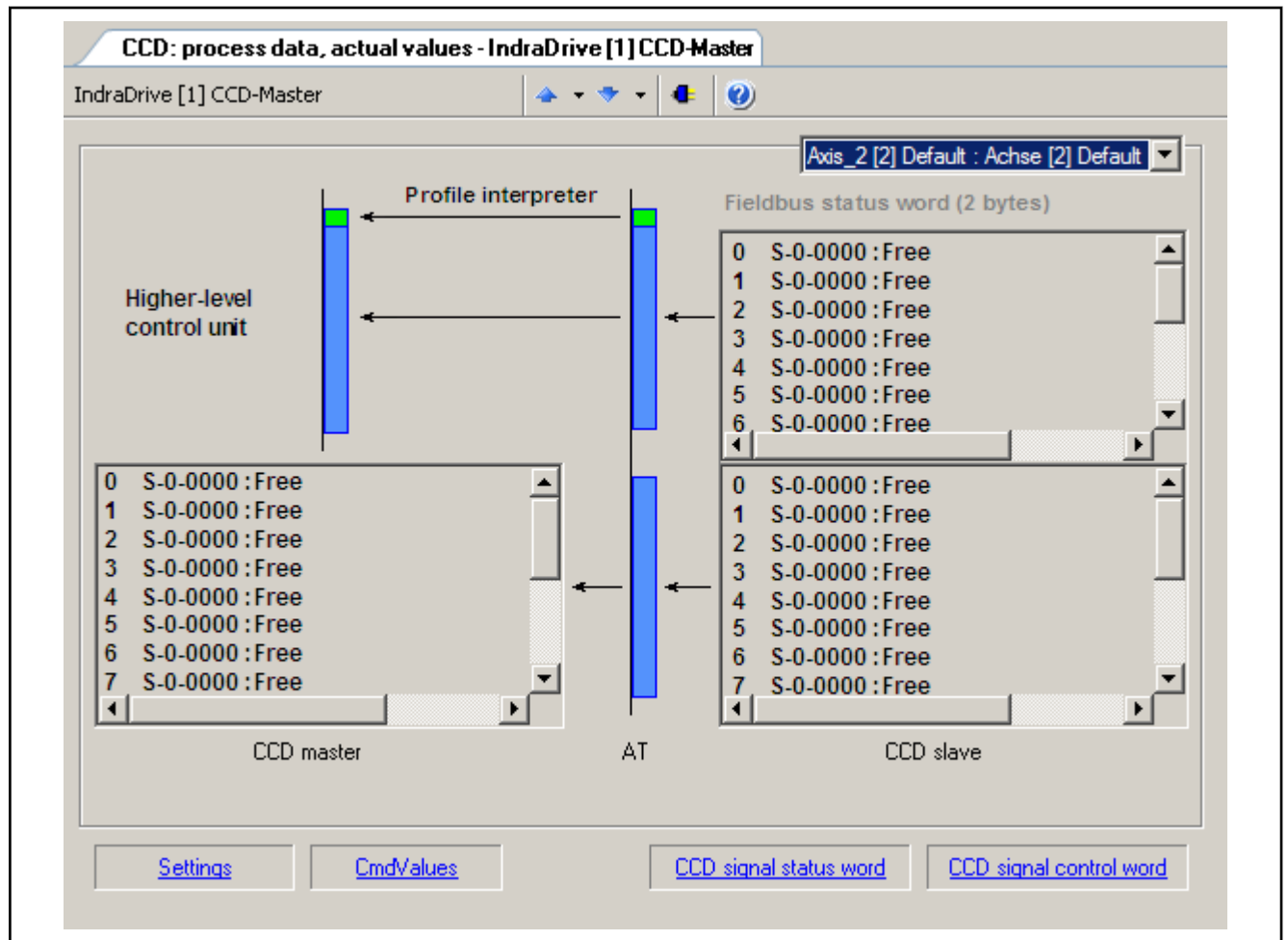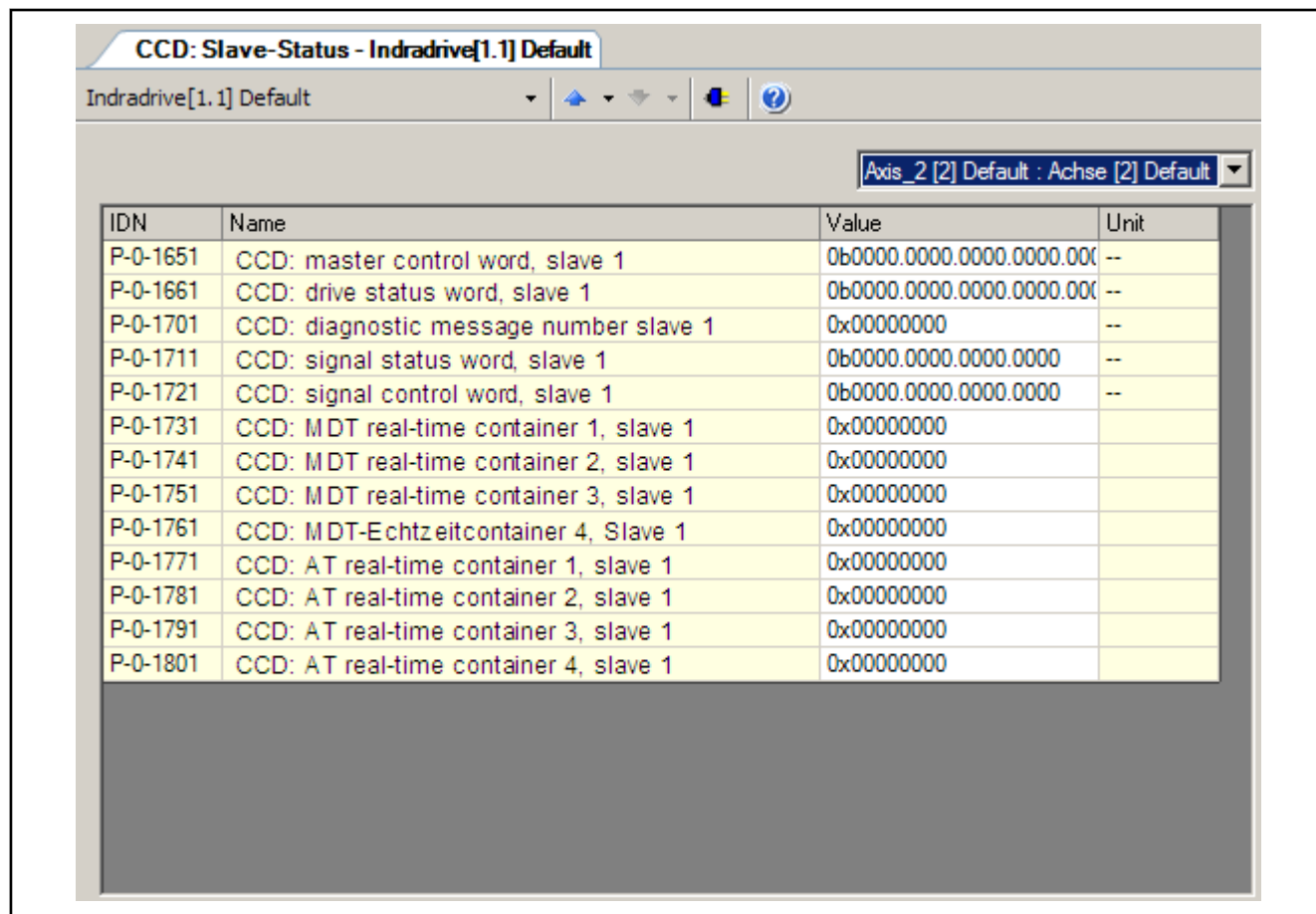
Fig.9-42:   IndraWorks overview window of actual process data values

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 MLD-M system mode, the data configured in the AxisData structure is displayed here as well.

In 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 available is also displayed (and to be taken into account in the input data of the control unit).

Optional Device Functions

Slave Status

Fig.9-43:   Overview window of slave status information

This overview displays all status information on the selected CCD slave available in the CCD master (incl. containers for copying).

9.4   Rexroth IndraMotion MLD (Drive-Integrated PLC)

9.4.1   Brief Description

> Assignment to functional firmware package: Extension package **IndraMotion MLD** (order code **ML, MA or TF**)

The optional extension packages "IndraMotion MLD" provide the function of a PLC integrated in the drive according to IEC 61131-3 with the following scope of functions:

- **Integrated logic control** (standard PLC tasks)
  - IEC-61131-3-conform
  - Online change
  - Debugging
  - Offline simulation
- **Integrated multi-axis/single-axis motion control**
  → Motion function block according to PLCopen positioning and synchronization operation

Optional Device Functions

- Programming via ST, SFC, AS. FBD and LD
- Library management with system and user libraries

- **Basis for technology functions**

  → Examples: Following-on cutting devices, process controller (register controller, winding computation, productivity agent, IndraMotion for handling, IndraMotion for metal forming,...

☞ This optional extension of drive functionality is described extensively in the separate document "Rexroth IndraMotion MLD" (DOK-INDRV*-MLD-S*VRS**-AW**-EN-P; Mat. no. R911306071).

Hardware requirements

According to design, the extension packages "IndraMotion MLD" require one of the following control section designs:

- **IndraMotion MLD-M** (multi-axis motion control)
  - Single axis ADVANCED (CSH01.**3**C)
- **IndraMotion MLD-S** (single-axis motion control)
  - Single-axis ADVANCED (CSH01.1C, CSH01.3C)
  - Single-axis BASIC (CSB01.1)

☞ The extension packages "IndraMotion MLD" are **not** available for double-axis control sections (CDB01.1C)!

Firmware requirements

In the firmware **MPx-07VRS**, the function "IndraMotion MLD" is available in the following variants:

- Advanced design (**MPH**)
- Basic single-axis design (**MPB**)
- Multi-axis design MLD-M (**MPC**)

☞ Using the function "IndraMotion MLD" generally requires the enabling of one of the additive extension packages **ML, MA or TF**.

See also sections:

- "Overview of Functions/Functional Packages"

- "Enabling of Functional Packages"

Features/Characteristic Values

The functional packages "IndraMotion MLD" include the following general features/characteristic values:

- 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:
  - MPH, MPB: 350 kbytes program memory (with MMC expandable to 2 MB)
  - MPC: 350 kbytes program memory (with MMC expandable to 4 MB)

Optional Device Functions

- MPH, MPB: 512 kbytes data memory
- MPC: 2 MB data memory
- 250 bytes retain or 32 kbytes with optional module MD1 or MD2 or control section design CSH01.3C

- Digital inputs/outputs:
    - 7...11 digital inputs, 0...4 digital outputs on x31/x32 (with advanced control section CSH)

      → PLC and drive share the inputs!
    - 12 digital inputs, 8 digital outputs on the optional module MD1 (optional)
    - 16 digital inputs, 16 digital outputs on the optional module MD2 (optional)
    - 16 digital inputs, 16 digital outputs on the optional module PL (for parallel master communication)
    - 1 relay output on x31/x32 (CSH control section)

      → PLC and drive share the inputs!

      Note: With BASIC control sections there are restrictions regarding the available inputs/outputs (see document "Control Sections for Drive Controllers; Project Planning Manual").

- Analog inputs/outputs:
    - 1 analog input (+/-10 V) on x31/x32 (CSH control section)
    - 2 analog outputs (0...5 V) on 31/x32 (CSH control section)
    - Analog inputs/outputs (+/-10 V) on MA1 (optional)

      Note: With BASIC control sections there are restrictions regarding the available inputs/outputs (see document "Control Sections for Drive Controllers; Project Planning Manual").

- Inputs/outputs on remote axes:
    - Digital and analog inputs/outputs of the slaves connected to sercos III can be read and written.
    - Number of inputs/outputs depends on the used control sections of the slaves

- sercos III I/O
    - Evaluation of digital block inputs/outputs (every block with 32 inputs or with 16 inputs and 16 outputs)

- Parameters for general purpose:
    - Parameters for process image: Inputs PIIs
        - 20 input words per 2 bytes
        - 8 input words per 4 bytes
    - Parameters for process image: Outputs POIs
        - 20 output words per 2 bytes
    - Global registers (4 bytes)
        - 32 buffered parameters
        - 32 unbuffered parameters
    - List parameters (4 bytes)
        - 1 list register with 8192 values (not buffered)

Optional Device Functions

- –   3 list registers with 1024 values (buffered)
  - –   2 global text registers with 255 characters each
  - –   Display format of the global register that can be parameterized
  - –   Name, unit and limit values of the global registers can be configured via PLC functions
- Other features:
  - –   Extensive debug possibilities (single-step, watch, force/write, breakpoints, powerflow)
  - –   File access from the PLC (save source code on MMC, ...)
  - –   Keep symbol file on MMC ready for access to PLC variables
  - –   Source download (only with MMC)
  - –   Access to serial interface
  - –   Access to Ethernet interface

Pertinent parameters   PLC parameters for general purpose

- P-0-1350, PLC control word
- P-0-1351, PLC status word
- P-0-1352, PLC user program administration data
- P-0-1362, 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

Process input images PIIs

- P-0-1390, PLC input WORD0 AT %IB0

  to

  P-0-1409, PLC input WORD19 AT %IB38
- P-0-1440, PLC input DWORD25 AT %IB100

  to

  P-0-1447, PLC input DWORD32 AT %IB128

Process output images POIs

- P-0-1410, PLC output WORD0 AT %QB0

  to

  P-0-1429, PLC output WORD19 AT %QB38

Global PLC registers, unbuffered:

- P-0-1270, PLC Global Register A0

  to

  P-0-1301, PLC Global Register A31

Optional Device Functions

Global text registers, unbuffered:

- P-0-1387, PLC Global Register AT0

  to

  P-0-1388, PLC Global Register AT1

Global list register, unbuffered:

- P-0-1368, PLC Global Register AL0

Global PLC registers, buffered:

- P-0-1370, PLC Global Register G0

  to

  P-0-1385, PLC Global Register G15

- P-0-1316, PLC Global Register G16

  to

  P-0-1331, PLC Global Register G31

Global list registers, buffered:

- P-0-1389, PLC Global Register GL0
- P-0-1311, PLC Global Register GL1
- P-0-1312, PLC Global Register GL2

To configure the display format of the registers:

- P-0-1386, PLC display format Global Register

9.4.2   Notes on Installation/System Configuration

Installation

When installing "IndraMotion MLD" on the PC, it is necessary to install the current version of the **"IndraWorks MLD" commissioning tool** on the PC.

After successful installation the **"IndraLogic" PLC programming system** and **"IndraWorks"** can simultaneously communicate with the drive.

Project Planning Manual

The system configuration of "IndraMotion MLD" is carried out via a PC with the "IndraLogic" program installed that communicates with the drive via a serial interface or TCP/IP communication (with CSH01.3).

The projects are filed on the PC. The generated binary code is loaded into the drive and stored in parameters or in the MMC. With the MMC plugged in, the source code, symbols and user files can also be stored there.

9.4.3   Overview of the Available Libraries

☞   This chapter only gives a short explanation of the basic libraries and functions. The details are described in the separate documentation "Rexroth IndraMotion MLD".

IndraLogic Libraries (compatible with "CoDeSys"):

- AnalyzationNew.lib

  → This library contains blocks for the analysis of expressions. If a composed expression has the total value FALSE, those components can be determined that contribute to this result. In the AS editor, the flag "SFCErrorAnalyzationTable" uses these functions implicitly for the analysis of the transition expressions.

- Lecsfc.lib

  → Apart from the simplified steps, the IEC steps conforming to standard are available in AS. In order to use the IEC steps, the special SFC library "lecsfc.lib" must be included in the project.

- NetVarUdp_LIB_V23.lib (system-internal library)

  → This library is automatically loaded by the system and serves internally for the processing of network variables. It does not contain any user-relevant contents. When using network variables, this library is automatically included in the library manager.

- Standard.LIB

  → This library is available as standard. It contains all functions and function blocks that are required by the IEC 61131-3 as standard blocks for an IEC programming system. The difference between a standard function and an operator is that the operator is implicitly known to the programming system while the standard blocks must be included in the project as library (standard.lib). When creating a new project, this library is automatically included in the library manager.

- SysLibCallback.lib (system-internal library)

  → This library is used by internal libraries. It does not contain any user-relevant contents. When using network variables, this library is automatically included in the library manager.

- SysLibSockets.lib

  → This library supports the access to sockets for communication via TCP/IP and UDP. When using network variables, this library is automatically included in the library manager.

- SysLibStr.lib

  → This library offers functions for the handling of strings. If the target system contains the functionality, the following library functions can be used to compare or to copy strings or to determine the length of the strings (synchronous processing).

- Util.lib

  → This library contains an additional collection of various blocks that can be used for BCD conversion, bit/byte functions, mathematical auxiliary functions, controllers, signal generators, function manipulators and for analog value processing.

IndraMotion MLD libraries:

- MX_Base.lib

  → When creating a new project, this library is automatically included in the library manager. It contains the functions below:
  – General functions
  – Functional blocks/functions for drive control
  – Functions for diagnostic messages
  – Functional blocks/functions for access to parameters
  – Functions for scaling
  – Data types or structures
  – Cyclic parameters as direct variables (system-wide variables)
  – Variables for addressing of axes
  – Global axis structures with cyclic data (AxisData)

- MX_CheckRtv.lib (system-internal library)

Optional Device Functions

→ This library contains testing functions, which ensure that errors such as "Dividing by zero" or invalid field addressing are detected during the program runtime and are signaled with an F6010 error reaction. When creating a new project, this library is automatically included in the library manager.

- MX_DSP.lib

    → This library contains variables and a functional block for operation or control of the (local) real-time channel. This serves for time-controlled synchronous exchange of data with the drive for special fields of applications such as customer-specific command value generators or controllers.

- MX_Internal.lib (system-internal library)

    → This library is used by internal libraries. It does not contain any user-relevant contents. When creating a new project, this library is automatically included in the library manager.

- MX_PLCopen.lib

    → This library contains functional blocks for motion control according to PLCopen. When creating a new project, this library is automatically included in the library manager.

- MX_SysLibCom.lib

    → This library supports the synchronous, serial communication via the serial interface. The library functions can be used in order to open and close a serial port and write or read data via the serial port.

- MX_SysLibDir.lib

    This library contains functions for the reading of directories at the (optional) MMC. The calls are synchronous so that the function only returns as soon as the task is completed.

- MX_SysLibFileAsync.lib

    → This library contains functional blocks for the access to files in the user directory of the (optional) MMC. The calls are asynchronous so that the blocks are called cyclically until they signal the status "completed".

- MX_SysLibIecTasks.lib

    → This library contains functions for calling information about the configuration and the status (e.g. runtime) of IEC tasks.

- MX_SysLibMem.lib

    → This library contains functions for copying, shifting or comparing memory ranges. Functions for the dynamic memory management are not included.

- RIL_CommonTypes.lib

    → This library contains general global data types and declarations of constants. When creating a new project, this library is automatically included in the library manager.

- RIL_VExUtil.lib

    This library ensures a safe key-type operation in conjunction with a VEx control station.

9.4.4   Overview of the Function of the Parameters for General Purpose

The following parameters are available for communication between "IndraMotion MLD" and "external devices":

- Global registers G0 to G31 (buffered)

→ P-0-1370 to P-0-1385 and P-0-1316 to P-0-1331

→ Global registers with a data length of 4 bytes; this parameter is a register with individual values for data exchange of the PLC with the drive or a higher-level PLC or control unit.

- Global registers A0 to A31 (unbuffered)

  → P-0-1270 to P-0-1301

  → Parameters for data exchange (input and output data) of the PLC with a higher-level control unit or HMI

- Global text registers AT (unbuffered)

  → P-0-1387, P-0-1388

  → Freely usable text parameter with a maximum of 255 characters plus terminating zero-character.

- Global list registers GL (buffered)

  → P-0-1389, P-0-1311, P-0-1312

  → List parameters with 1024 elements (4 bytes each) for data exchange of the PLC with an external control or HMI

- Global list register AL (unbuffered)

  → P-0-1368

  → List parameters with 8192 elements (4 bytes each) for data exchange of the PLC with an external control or HMI

- Process input images PIIs

  → P-0-1390 to P-0-1409 (with 2 bytes each → word-wise)

  → P-0-1440 to P-0-1447 (with 4 bytes each → double-word-wise)

  → Parameters contain the process image of the PLC inputs (PIIs); before the beginning of the task, the PLC reads the values in the PIIs and updates the process image of the inputs.

- Process output images POIs

  → P-0-1410 to P-0-1429 (with 2 bytes each → word-wise)

  → Parameters contain the process image of the PLC outputs (PIIs); At the end of the task, the PLC writes the value from the POIs in the outputs.

9.5   Digital Inputs/Outputs

9.5.1   Brief Description

General Information

> 💡 Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

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).

> ℹ️ See separate documentation "Control Sections for Drive Controllers; Project Planning Manual"

Optional Device Functions

Digital Inputs/Outputs on the 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 a 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 a respective 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 the 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 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

Optional Device Functions

- 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 other axis
- C0248 Dig. input assigned differently to axes
- C0249 Dig. I/Os: Bit number too large
- F2010 Error when initializing digital I/O (-> S-0-0423)
- F2033 External power supply X10 error

Digital Inputs/Outputs on Optional Module MD1

With the configurable ADVANCED control sections, it is possible to individually configure an extension of these inputs/outputs in addition to the standard digital inputs/outputs.

This requires the optional module MD1 which can be used for the following purposes:

- Making available digital inputs/outputs to the 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 the digital I/O extension by using the optional module MD1 is **only possible with 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 the 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 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

Optional Device Functions

9.5.2   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 element.

Direct bit transfer

As 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).

Differentiating cases when determining source and target

The IDNs entered in the list parameter P-0-0300 can have two different functions:

- **1. Input**

  With 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**

  With 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 examples of 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	
Negative limit switch	P-0-0222	1	0	
E-Stop	P-0-0223	0	0	

i = index   List element / terminal slot

Fig.9-44:   *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 "Control Sections for Drive Controllers; Project Planning Manual"

By way of example, the following figure illustrates the configuration of input I_4 (terminal connector X31.6) as an input signal on bit 1 of the parameter S-0-0222 (negative travel range limit switch); the configuration assignment takes place via list element 4 of "P-0-0300, Digital I/Os, assignment list" and "P-0-0301, Digital I/Os, bit numbers".
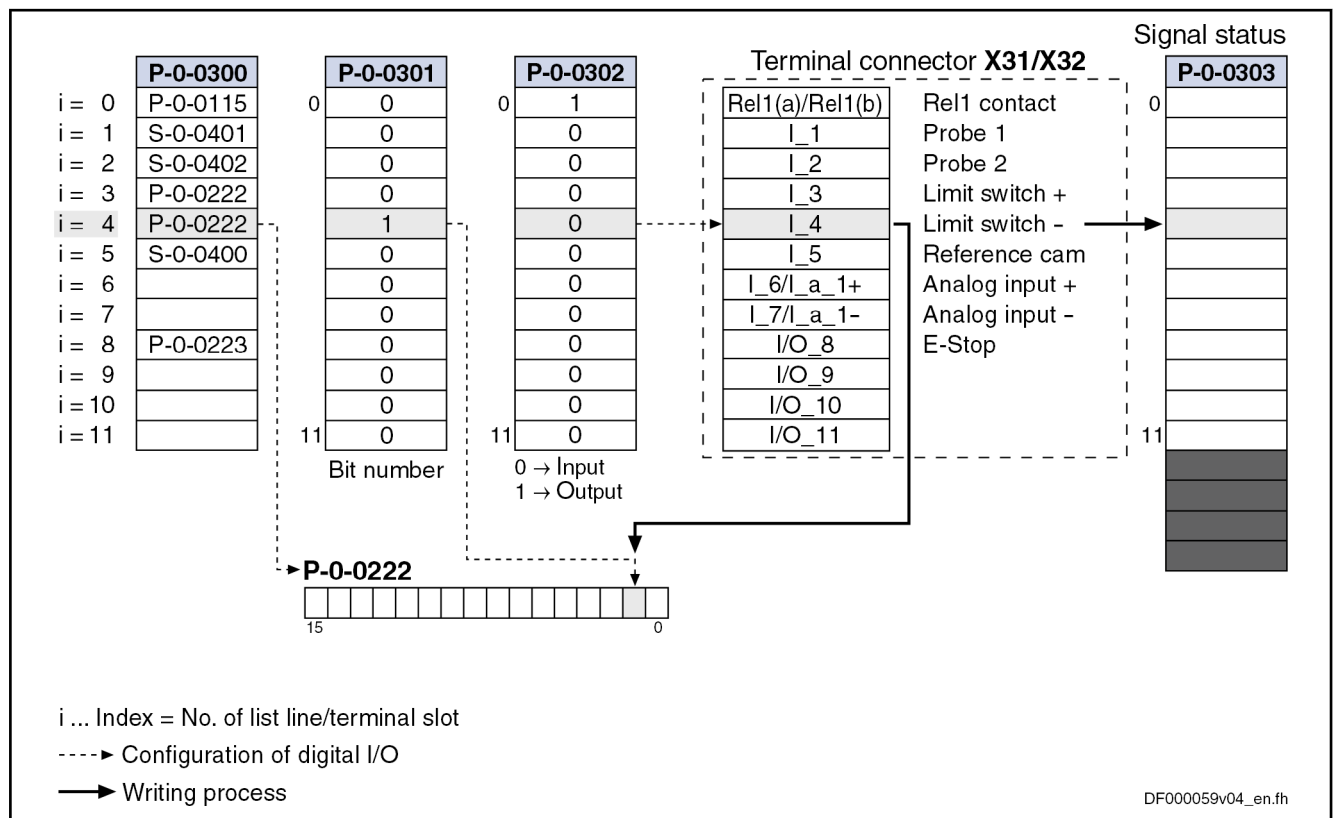
P-0-0300	Digital I/Os, assignment list
P-0-0301	Digital I/Os, bit numbers
P-0-0302	Digital I/Os, direction
P-0-0303	Digital I/Os, inputs

Fig.9-45:   *Configuring the digital inputs/outputs (configuration for ADVANCED control section with default settings)*

☞ 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.

☞ 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

Optional Device Functions

Deactivation   To deactivate an input/output, the IDN "S-0-0000" has to be entered 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 permitted 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, parameters P-0-0300, P-0-0301, P-0-0302 are available for both axes.

The following restrictions apply:

• 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 must 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 event 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. The probe function is an example. In this case, the entry in P-0-0301 is irrelevant, it is only a valid value that must be contained (e.g. "0").

All special functions are listed in the following table:

Function	P-0-0300[i]	P-0-0301[i]	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   List element / terminal slot

Fig.9-46:   *Special functions via digital inputs/outputs*

Optional Device Functions

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 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:

* Inclusion of parameter P-0-0303 in the group of cyclic actual values (sercos: S-0-0016, field bus: P-0-4080)

* Inclusion of 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 (in this case sercos)
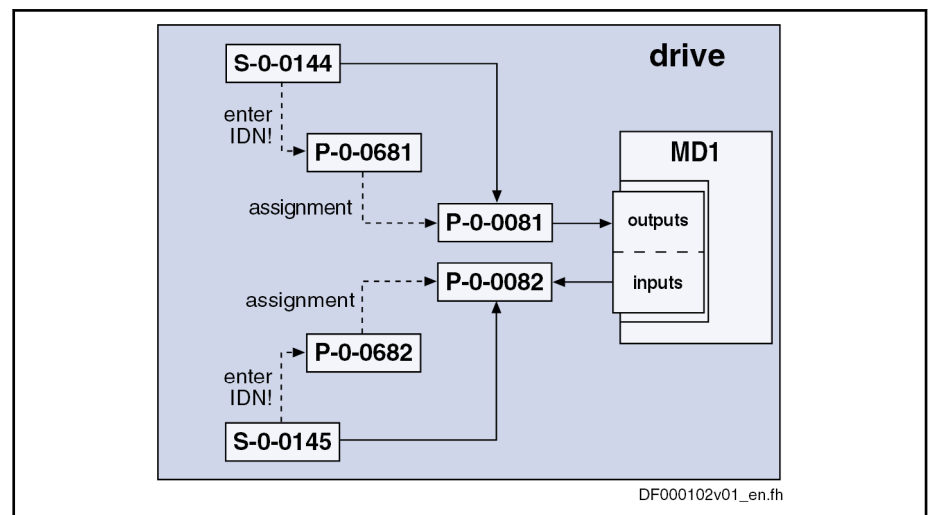
S-0-0016	Configuration list of AT
S-0-0024	Config. list of the master data telegram
P-0-0303	Digital I/Os, inputs
P-0-0304	Digital I/Os, outputs

Fig.9-47:   Access to digital inputs/outputs of the control section via sercos master communication

Behavior when master communication fails

When the cyclic communication fails, the value "0" is written to the parameters; this means that those digital outputs are cleared to which the master transmits data via the cyclic communication.

Optional Device Functions

Default Configurations of the Digital Inputs/Outputs of the 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 OPENLOOP	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
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

Optional Device Functions

Signal name	ADVANCED	BASIC UNIVERSAL single-axis	BASIC UNIVERSAL double-axis	BASIC OPENLOOP	BASIC sercos	BASIC PROFIBUS	BASIC ANA-LOG
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.9-48:   *Default setting of digital inputs/outputs of different control section designs*

i   See documentation "Control Sections for Drive Controllers; Project Planning Manual"

9.5.3 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

☞   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 the complete digital inputs or outputs to be assigned 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

Access options

There are the following possibilities for using the digital inputs/outputs on the optional module MD1:

- Direct access via the 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:

Optional Device Functions

– [P-0-0681] = "S-0-0000"

– [P-0-0682] = "S-0-0000"

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 (in this case sercos)
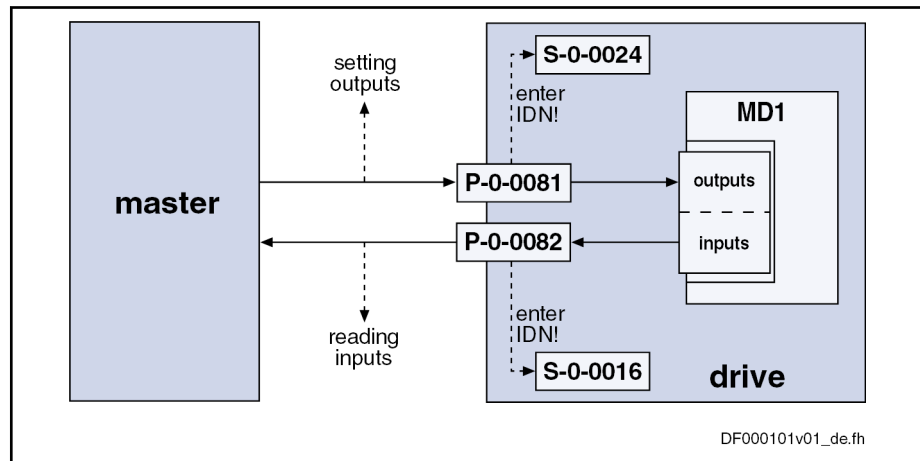
S-0-0016	Configuration list of AT
S-0-0024	Config. list of the master data telegram
P-0-0081	Parallel output 1
P-0-0082	Parallel input 1

Fig.9-49:   *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")

Optional Device Functions

☞   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:
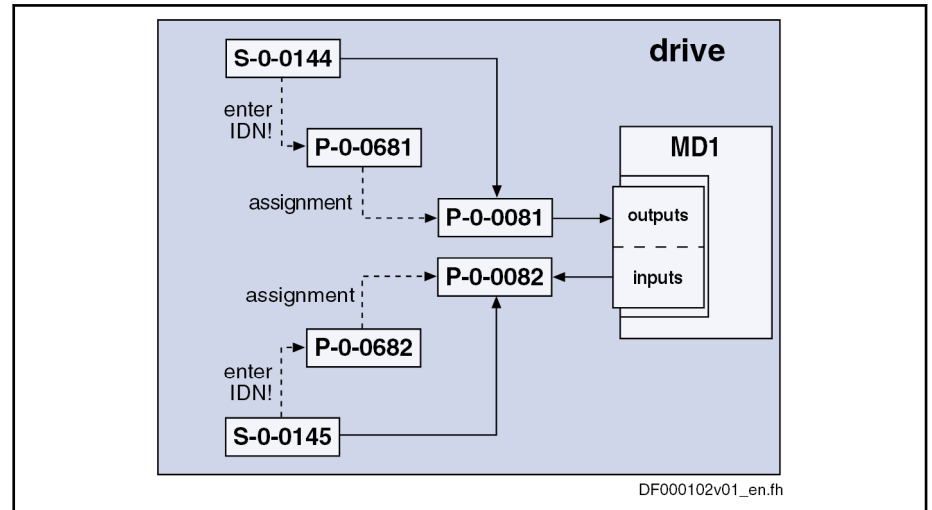
S-0-0144	Signal status word
S-0-0145	Signal control word
P-0-0081	Parallel output 1
P-0-0082	Parallel input 1
P-0-0681	Assignment IDN -> parallel output 1
P-0-0682	Assignment parallel input 1 -> IDN

Fig.9-50:   *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 "Control Sections for Drive Controllers; 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.

Applicational example (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:

Optional Device Functions

- 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 parameters P-0-0681 and P-0-0682:

- **Inputs** (e.g. "P-0-3212, Safety technology control word, channel 1")
- **Outputs** (e.g. "P-0-3214, Safety technology status word, channel 1")

9.5.4   Diagnostic and Status Messages

Digital Inputs/Outputs on the 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 into 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

☞ With invalid inputs or inputs/outputs that have not been configured yet, "-1" is displayed as the bit number.

Checks in transition command

The following monitoring functions are used to guarantee 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" appears when progressing to Operation mode. This message is output to avoid moving the drive without configured limit switch function.

- With 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 other axis" is 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" appears.

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 information regarding the digital output bits

- P-0-0082, Parallel input 1

  → Contains 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.

9.6   Analog Inputs

9.6.1   Brief Description

💡   Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

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. Double-axis control sections can alternatively also be equipped with an extension for analog master communication, if the control section is operated as an analog device (control section configuration CDB01.xC-AN…). The number and function of the analog outputs differs according to the type and configuration of the control section (see "Hardware Requirements" below).

Optional Device Functions
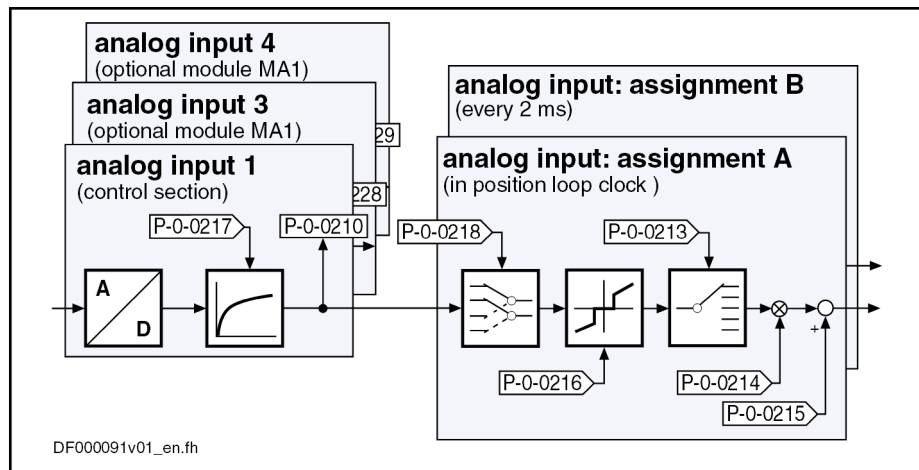
P-0-0210   Analog input 1
P-0-0213   Analog input, assignment A, target parameter
P-0-0214   Analog input, assignment A, scaling per 10 V full scale
P-0-0215   Analog input, assignment A, signal value at 0V
P-0-0216   Analog input, assignment A, dead zone
P-0-0217   Analog input 1, time constant input filter
P-0-0218   Analog input, control parameter

Fig.9-51:   *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 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 on the control section:

- Number and resolution of analog inputs dependent on the 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 has 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

Optional Device Functions

- Analog inputs designed as differential input
- Input voltage range of ± 10 V

Features of analog inputs on the optional module MA1:

The optional module MA1 was developed according to VDE 0411-part 500 (programmable logic controllers) and is to 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

Features of analog inputs on the optional module AN:

- 4 analog inputs with 14 bit resolution (by means of 8-fold oversampling for all analog channels)
- Low-pass filtering to be activated for both analog channels
- Analog inputs designed as differential input
- Input voltage range of ± 10 V
- Connection via 12-pole terminal board by Phoenix

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, at optional module MA1 or at optional module AN).

Control section type	Analog input no.					
	1	2	3	4	5	6
	... to be found …					
	On basic circuit board		Optional Module MA1			
CSH01.xC,	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.xC	--	--	Optional slot **2** X8 (2/9)	Optional slot **2** X8 (4/11)	--	--
CDB01.xC	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)

Optional Device Functions

Control section type	Analog input no.					
	1	2	3	4	5	6
	... to be found ...					
	On basic circuit board		Optional Module MA1			
CSB01.xN-AN	X32 (4/5)	X32 (1/2)	Control section type cannot be configured			
CSB01.xN-SE	--	--				
CSB01.xN-PB	--	--				
CSB01.xN-FC	X32 (4/5)[1]	X32 (1/2)[1]				
	X36 (1/2) [2]	X36 (2/3) [2]				
	On basic circuit board		Optional module AN			
CDB01.xC-AN	X32 (4/5)	--	X39 (1/2)	X39 (4/5)	X39 (7/8)	X39 (10/11)

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.9-52:   Overview of hardware requirements of analog inputs (incl. assignment of connection points)

ℹ️ See also section "Optional Module MA1" in the document "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 adjustment
- P-0-0220, C2800 Analog input adjustment command
- P-0-3901, Adjustment values of control section
- P-0-3904, Adjustment values analog I/O interface 3-4
- P-0-3905, Adjustment values analog I/O interface 5-6
- P-0-3906, Adjustment values analog inputs interface 3-6

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 adjustment command
- C2801 Analog input not configured
- C2802 Oscillations of input signal outside tolerance range
- C2803 Measured values at zero point and max. value identical
- C2804 Automatic adjustment failed

9.6.2   Functional Description

Reading and Assigning an Analog Input
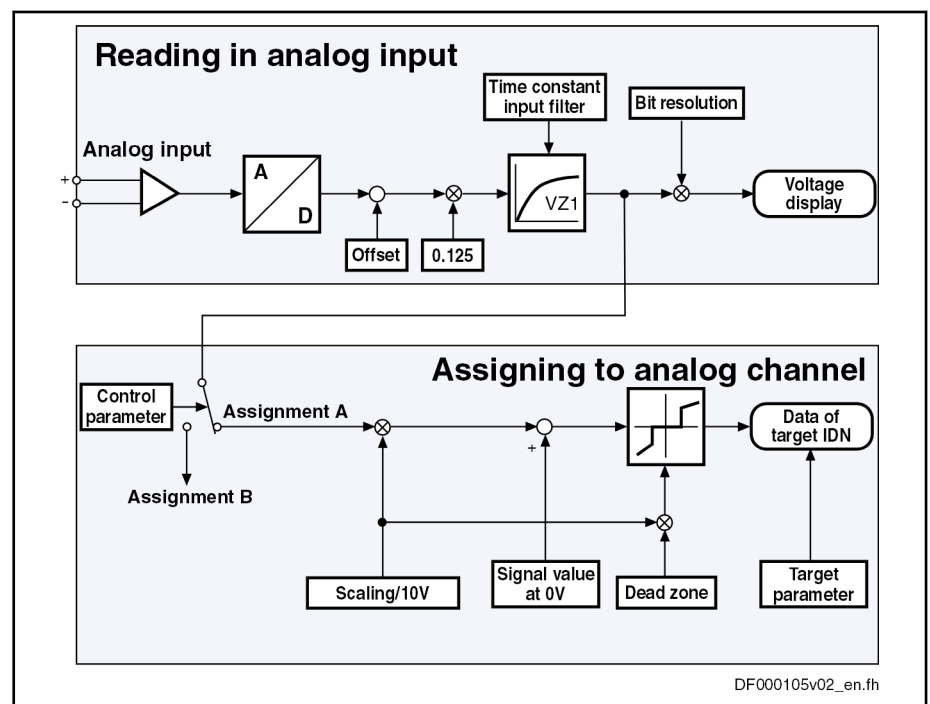
Fig.9-53:   Overview of functions: Reading and assigning an analog input

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

Optional Device Functions

- 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.9-54:   *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-adjustment   With the factory-adjustment of the control module or the optional modules MA1 or AN, the adjustment values for offset and amplification of the analog inputs are stored in the following parameters:

- P-0-3901, Adjustment values of control section
- P-0-3904, Adjustment values analog I/O interface 3-4
- P-0-3905, Adjustment values analog I/O interface 5-6
- P-0-3906, Adjustment values analog inputs interface 3-6

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   An analog input is assigned to an internal channel (assignment A or B) 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

ℹ️ See also Parameter Description "P-0-0218, Analog input, control parameter"

Optional Device Functions

> ☞ 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 are only describing assignment channel A. The description of assignment channel B corresponds to that of assignment channel A.
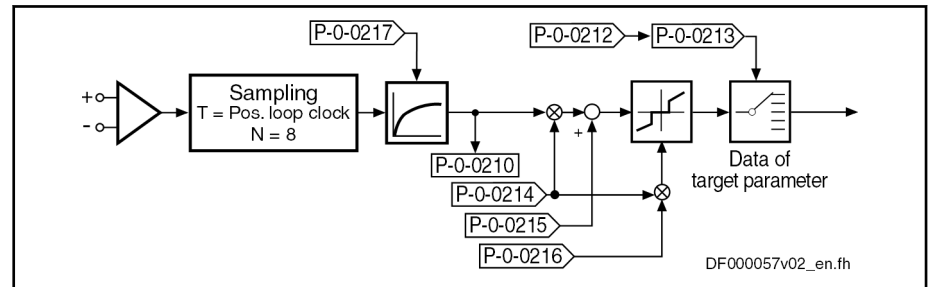
P-0-0210	Analog input 1
P-0-0212	Analog input, list of assignable parameters
P-0-0213	Analog input, assignment A, target parameter
P-0-0214	Analog input, assignment A, scaling per 10 V full scale
P-0-0215	Analog input, assignment A, signal value at 0V
P-0-0216	Analog input, assignment A, dead zone
P-0-0217	Analog input 1, time constant input filter

Fig.9-55:   Functional principle of analog input (example of 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 internal processing

Settings in parameter "P-0-0218, Analog input, control parameter" control the internal processing functions (adjustment and assignment):

- Bit 0 → Determining the adjustment mode (for "C2800 Analog input adjustment command")

- Bit 1 → Determining the assignment channel for the adjustment (for "C2800 Analog input adjustment 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 adjustment command".

With automatic scaling, 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.

Optional Device Functions

Zero point shifting	The zero point for processing the analog input value can be automatically shifted by activating command C2800 which a possibly existing offset to be compensated.

The following settings can be made in "P-0-0218, Analog input, control parameter":

- Bit 0 → Defines the step of adjustment ("0" → zero point shifting)
- Bit 1 → Defines the assignment channel for the adjustment (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 adjustment (bit 0 = 1 → amplification adjustment)
  - Bit 1 → Defines the assignment channel for the adjustment (A or B)
- P-0-0219, Analog input, maximum value for adjustment

  This parameter indicates the value to which the analog input is set when the amplification adjustment (P-0-0218, bit 0 = 1) is carried out.

The result of automatic amplification adjustment is directly entered in parameter

- P-0-0214, Analog input, assignment A, scaling 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".

Parameterizable "dead zone"	A so-called "dead zone" can be parameterized to "stabilize" the analog signal in the zero range:

- P-0-0216, Analog input, assignment A, dead zone
- P-0-0239, Analog input, assignment B, dead zone

☞	With noisy analog values, the dead zone enables a steady output signal of the analog channel assignment in the signal zero range.

Optional Device Functions

Assignment to Internal Drive Parameters

Assigning analog inputs to parameters

The analog input values are stored in the parameters below for display and internal value processing (depending on the design of the control section, not all parameters are always available):

- P-0-0210, Analog input 1
- P-0-0211, Analog input 2analog 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

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 parameters which are contained in the list parameter "P-0-0212, Analog input, list of assignable parameters" can be assigned.

Configuring the analog input

The assignment of an analog input to a parameter is activated when a value not equal to "S-0-0000" (S-0-0000 corresponding to "Off") is parameterized in parameter P-0-0213 or P-0-0236.

9.6.3   Notes on Commissioning

Performing Automatic Scaling (or Adjustment)

Automatic adjustment 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), define which channel is adjusted:

- Bit 1 = 0 → Scaling of assignment channel A
- Bit 1 = 1 → Scaling of assignment channel B

☞ When the adjustment is carried out via the control panel of the drive, there are the following restrictions:

- It is impossible to adjust the amplification or amplitude scaling (10 V adjustment).
- Parameter "P-0-0218, Analog input, control parameter" is preset with this function. (Preset value P-0-0218 = 0b0000.0000.0001.0010)

Configuration and Assignment to Drive Parameters

Assignment to the internal channel (assignment A or B)

The assignment of an analog input to an internal analog channel (assignment A or B) takes place via parameter "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

Optional Device Functions

ℹ️ 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 of the target parameters takes place in the following parameters:

- P-0-0213, Analog input, assignment A, target parameter
- P-0-0236, Analog input, assignment B, target parameter

☞ Assignment of the target parameters must be completed before the evaluation and the signal values for 0 V can be carried out in the parameters P-0-0214, P-0-0215, P-0-0237 and P-0-0238 (for assignment A and B).

Possibilities of Access via Master Communication and IndraMotion MLD

The analog input values of the analog inputs are stored in the parameters below for display and internal value processing (depending on the design of the control section, not all parameters are always available):

- 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

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 6) can be used without restriction by both axes of a double axis.

The evaluation and interpretation of the input voltage depends on how the individual axes have been parameterized (cf. assignment A and B).

☞ Parameters P-0-0210 to P-0-0239 are available separately for each axis. Parameters P-0-3901, P-0-3904, P-0-3905 and P-0-3906 are only available once per device!

9.6.4   Diagnostic and Status Messages

With regard to the "analog inputs" function, the following diagnostic command messages can occur:

- C2800 Analog input adjustment command
- C2801 Analog input not configured
- C2802 Oscillations of input signal outside tolerance range
- C2803 Measured values at zero point and max. value identical
- C2804 Automatic adjustment failed

ℹ️ See descriptions of these diagnostic messages in the separate documentation "Rexroth IndraDrive, MPx16, Diagnostic Messages"

Optional Device Functions

9.7 Analog Outputs

9.7.1 Brief Description

💡 Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

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 differs according to the type and configuration of the control section (see "Hardware Requirements" below).

The figure below illustrates the interaction of the two analog output channels with the analog outputs.
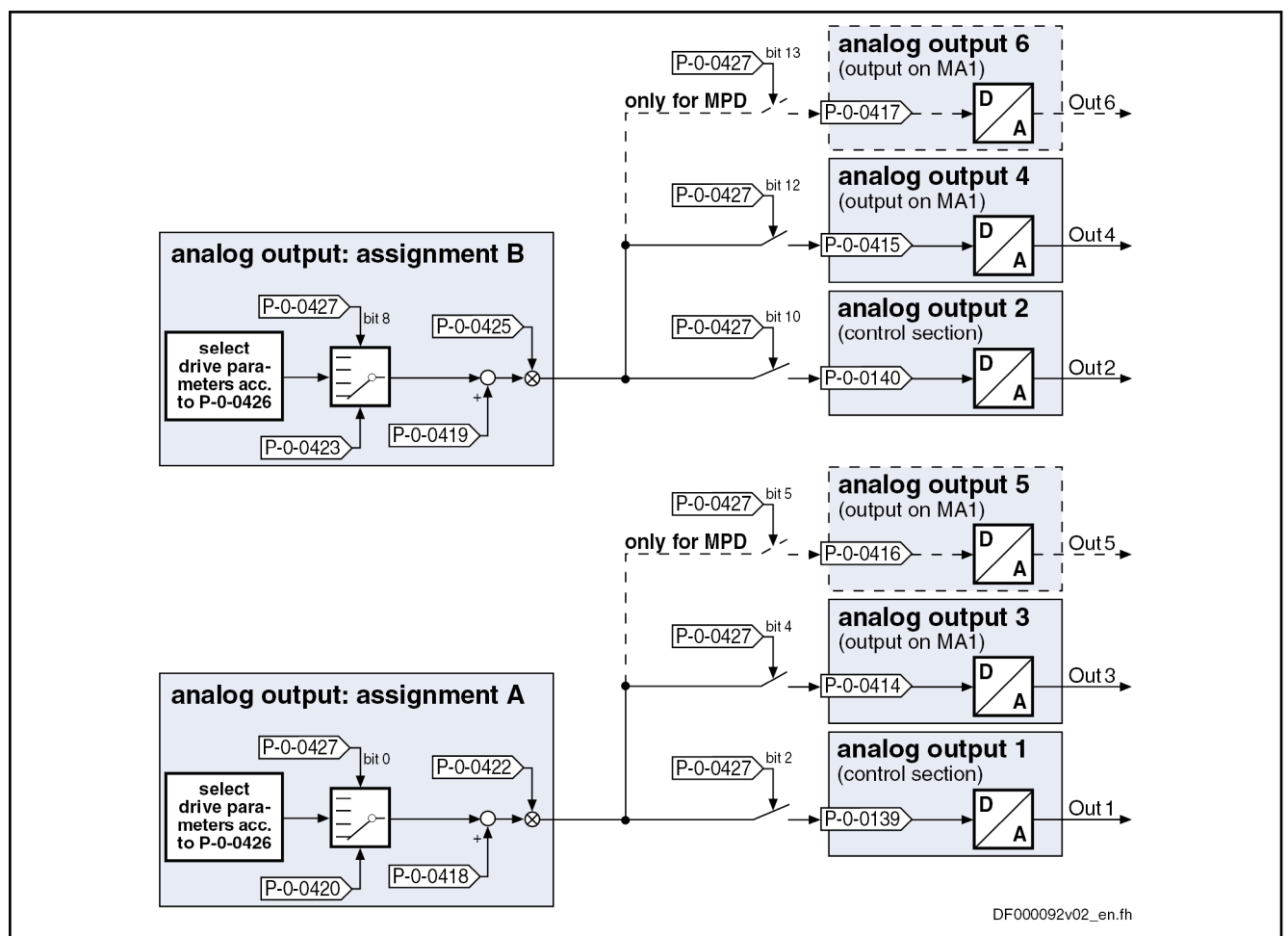
MA1   Optional module MA1 (analog I/O extension)

Fig.9-56:   *Assignment mechanism for the analog outputs*

The drive function "analog outputs" allows analog signal values to be used 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:

Optional Device Functions

- Number and characteristics of analog outputs depending on the type and configuration (with/without optional module MA1) of the control section

- Up to 6 analog outputs available according to the control section design

- Update of analog outputs in the velocity loop clock (see "Performance Date")

- 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 the output terminal connectors of the drive controller (see separate document "Control Sections for Drive Controllers; Project Planning Manual")

- Monitoring function with regard to double assignment of outputs

- Variable scaling of analog outputs

- Switching of the behavior at the limits of voltage range that can be displayed between overflow and limitation

- Parameterizable output offset or parameterizable reference value

Features of analog outputs on the 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 (= $5\,V/2^8$)

Features of analog outputs on the optional module MA1:

The optional module MA1 was developed according to VDE 0411-part 500 (programmable logic controllers) and is to be used according to the specifications contained in this standard.

Properties of analog outputs on the 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 (= $10\,V/2^{11}$)

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 the basic circuit board or on the optional module MA1).

Control section type	Analog output no.					
	1	2	3	4	5	6
	... to be found ...					
	On basic circuit board		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)
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 (9)	X35 (3)				

MA1   Optional module MA1 (analog I/O extension)

Fig.9-57:   *Overview of hardware requirements of analog inputs (incl. assignment of connection points)*

ℹ️   See also section "Optional Module MA1" in the document "Control Sections for Drive Controllers; Project Planning Manual"

☞   With 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

Optional Device Functions

- P-0-0414, Analog Output 3
- P-0-0415, Analog Output 4
- P-0-0416, Analog Output 5
- P-0-0417, Analog Output 6

9.7.2   Functional Description

General Information

When assigning the signal sources for the analog outputs of the drive control-ler, it is basically possible to choose between two methods:

- Direct output of **voltage signals** independently 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 stand-ard 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 param-eter 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 as-signed to the analog outputs can be directly written.

The following parameters used to display the output analog values are as-signed 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.

Behavior when master communi-cation fails   When cyclic communication fails, the value "0" is written to the parameters which causes 0 V to be output via the analog outputs.

Optional Device Functions

Output of Predefined Drive Parameters

List of assignable parameters Values of drive parameters are output on the basis of a predefined selection list. "P-0-0426, Analog output IDN list of assignable parameters" 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 into 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 individual bits of a binary format parameter to be outputted, 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.

With 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"

Optional Device Functions

9.7.3   Notes on Commissioning

Sequence of Setting for Analog Outputs
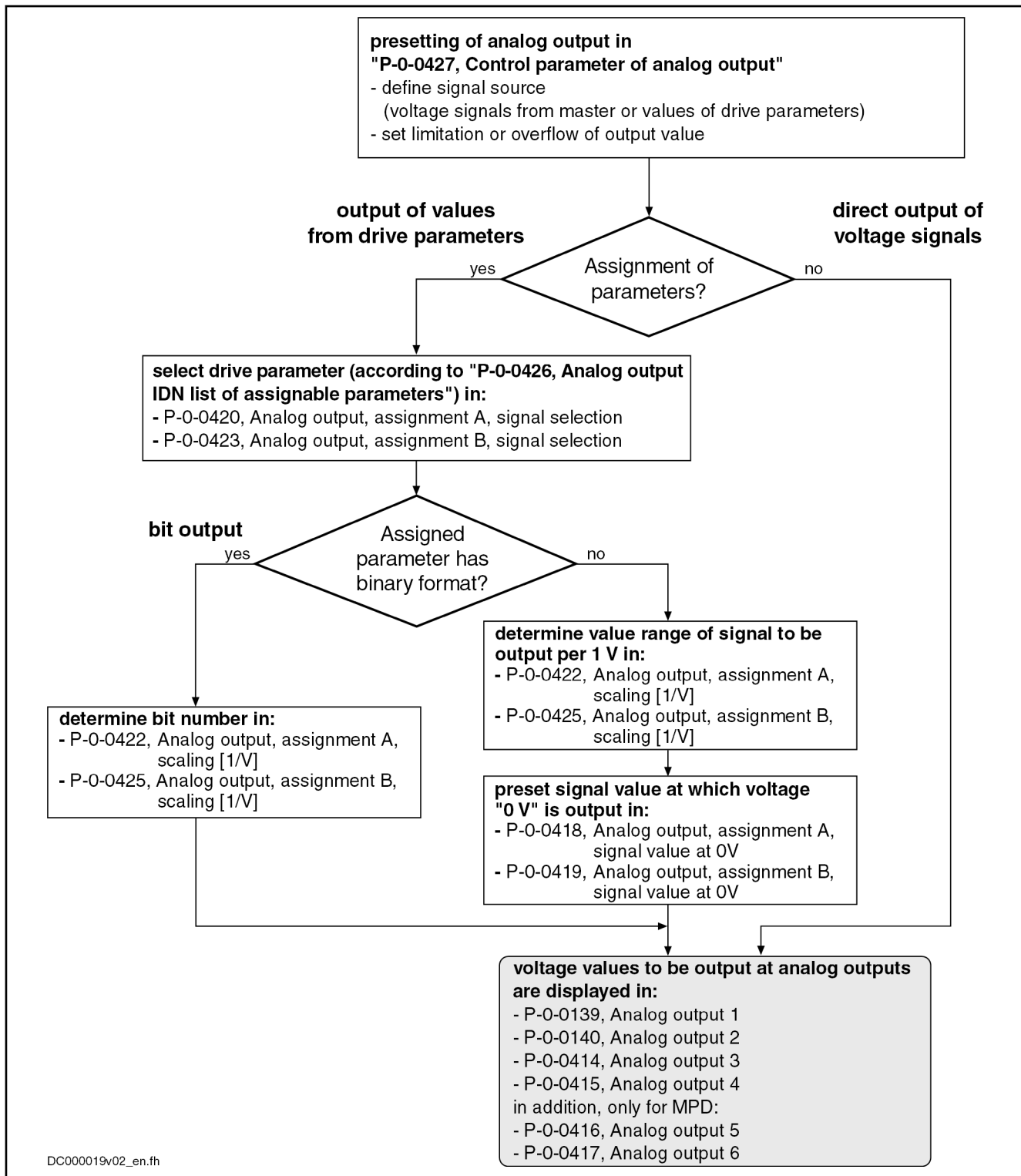
Fig.9-58:   *Commissioning the analog outputs*

Optional Device Functions

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 "scalable" output

e.g. speed scaling = 50min⁻¹/V   e.g. speed scaling = 100min⁻¹/V

DK000051v01_en.fh
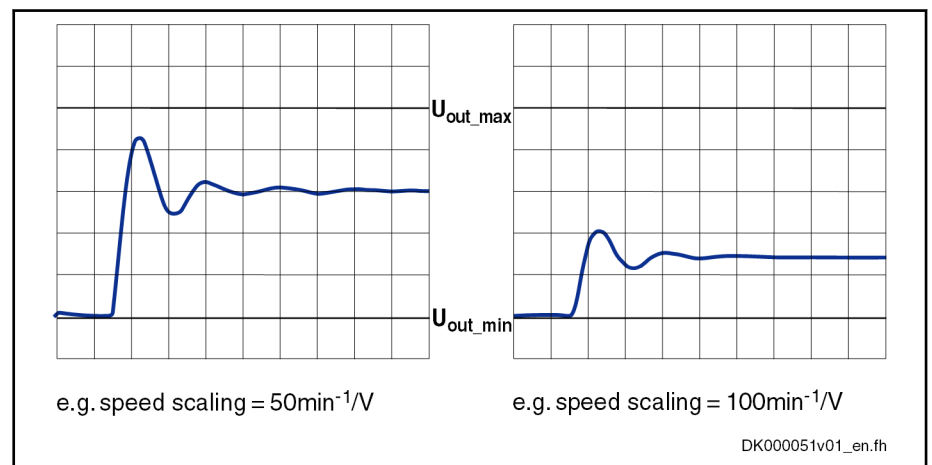
Fig.9-59:   Example of scalable analog output

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.

Optional Device Functions

Example of "reference-defined" output with analog output 1 and 2
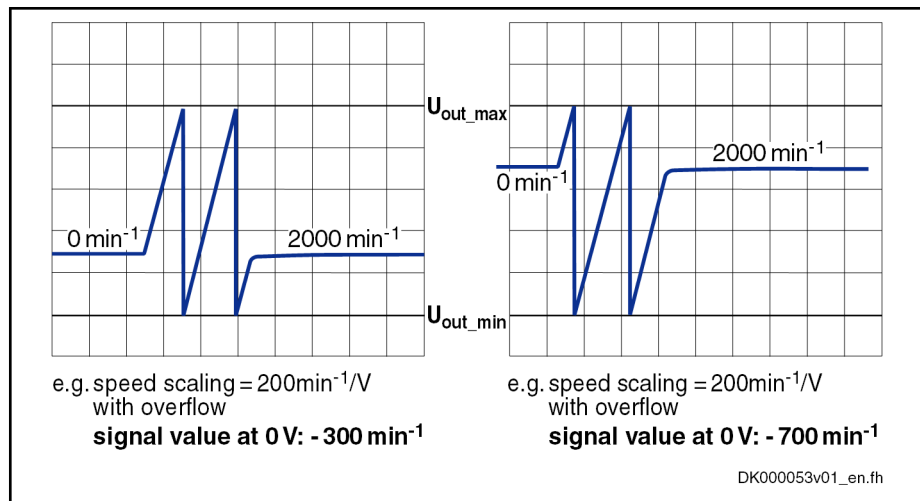
Fig.9-60:   *Example of reference-defined analog output*

Determining the Overflow Behavior

"P-0-0427, Control parameter of analog output" can be used 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
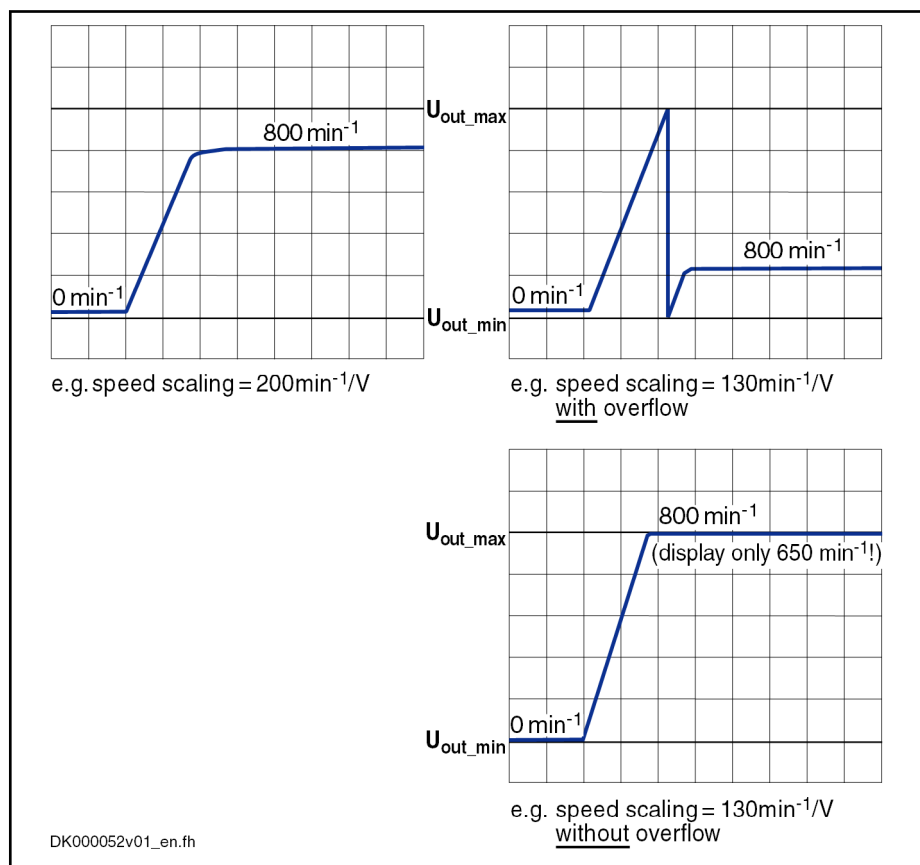
Fig.9-61:   *Example of limited or "overflowing" analog output*

Optional Device Functions

☞   With "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, …)

9.8 Virtual Master Axis Generator

9.8.1 Brief Description

💡   Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

The master axis generator is used to generate a master axis position, which is used as an input variable for position synchronization operation modes and the operation mode "velocity synchronization".

There are three ways of generating the master axis position:

- Format conversion of an actual position value or a command position value of the local axis or of an axis connected via CCD [1]

- Generating a virtual actual position value via a positioning motion and subsequent format conversion [2]

- Phase-synchronous motion of the master axis position to a primary master (secondary master mode) [3]

Optional Device Functions
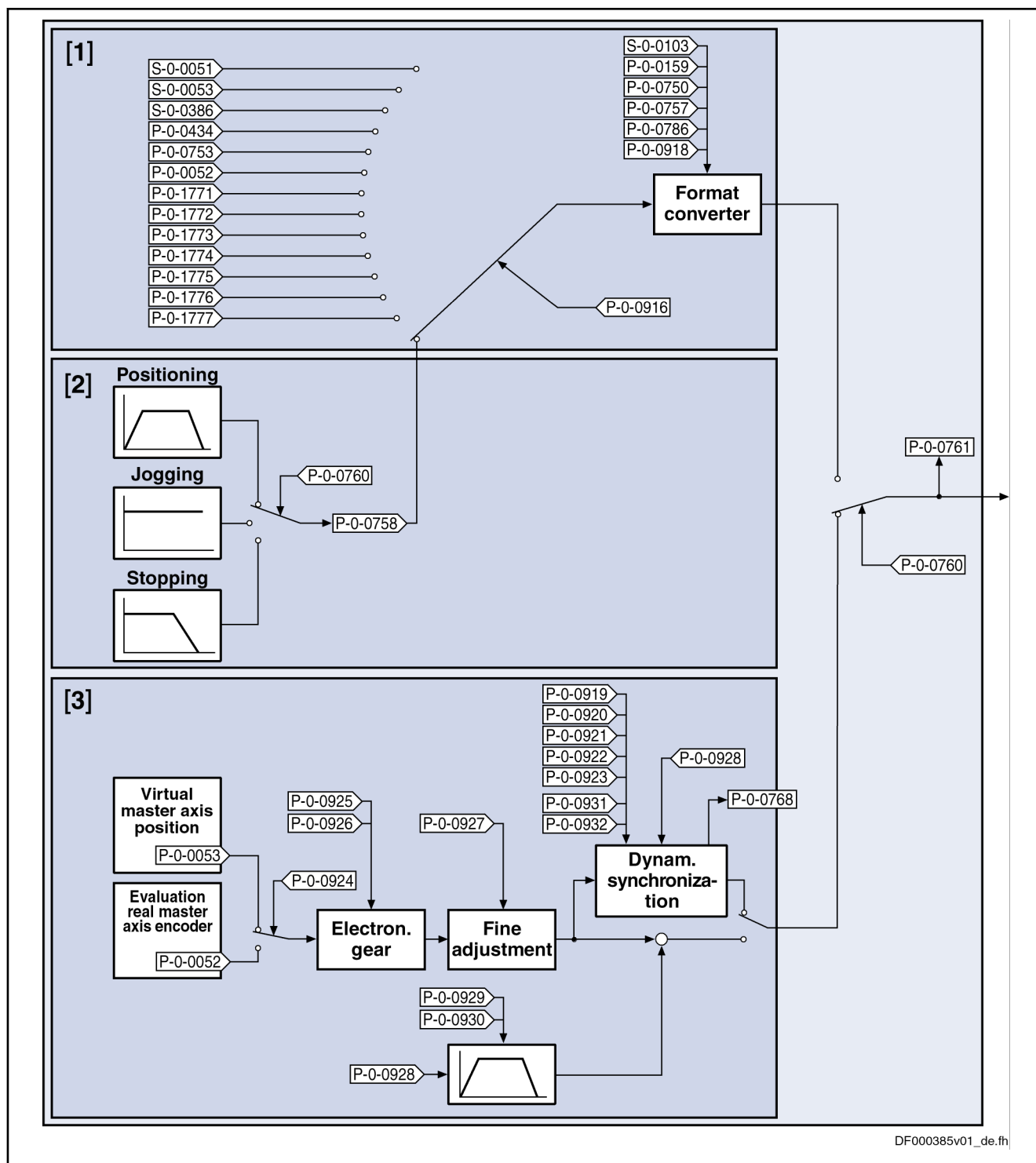
Fig.9-62:   Possibilities of generating the master axis position for the slave axis

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" → $2^{P-0-0084} \times$ 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.

Features of the secondary master mode:

- Real and virtual primary master can be selected
- Electronic gear with fine adjust
- Dynamic synchronization to the primary master
- Additive master axis position can be changed as offset with parameterized acceleration and velocity
- Activating by means of the functional block "MB_GearInPos"; deactivating by means of the functional block "MB_GearOut"

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

Optional Device Functions

- 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
- P-0-0919, Synchronization mode, secondary master
- P-0-0920, Synchronization acceleration, secondary master
- P-0-0921, Synchronization velocity, secondary master
- P-0-0922, Preferred synchronization direction, secondary master
- P-0-0923, Synchroniz. window for shortest distance, secondary master
- P-0-0924, Selection primary master
- P-0-0925, Master drive gear input revolutions, secondary master
- P-0-0926, Master drive gear output revolutions, secondary master
- P-0-0927, Master drive gear fine adjustment, secondary master
- P-0-0928, Additive master axis position, secondary master
- P-0-0929, Change velocity of add. master axis posit., secondary master
- P-0-0930, Change accel. of add. master axis posit., secondary master

Pertinent diagnostic messages
- E2100 Positioning velocity of master axis generator too high
- F2063 Internal overflow master axis generator
- F2064 Incorrect cmd value direction master axis generator

9.8.2   Functional Description

Positioning Mode of Virtual Master Axis Generator

The virtual master axis generator is activated or deactivated via parameter "P-0-0917, Control word of master axis generator".

The figure below illustrates the functional principle of generating the virtual actual position value with the virtual master axis generator and the effect of the individual parameters.
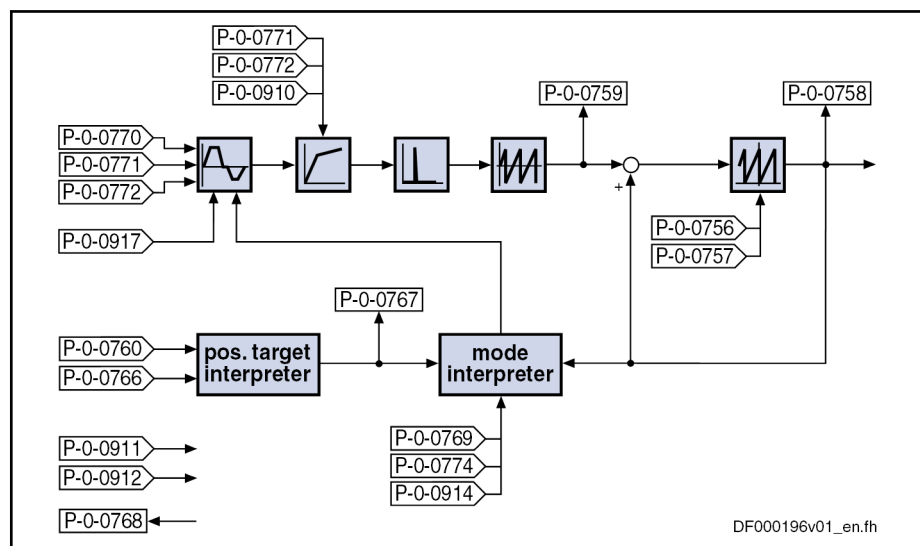
Fig.9-63:   Overview of "Virtual master axis generator" function

Positioning by means of the virtual master axis generator basically functions in the same way as with the positioning generator of the "drive-controlled po-

sitioning" Operation mode (see description of the Operation mode "Drive-controlled positioning").

Please note that the parameters which take effect for the virtual master axis generator are different from those for drive-controlled positioning (see comparative table below).

Name/significance of the parameter	Drive-controlled positioning	Virtual master axis generator
Positioning command value	S-0-0282	P-0-0766
Command value mode	S-0-0393	P-0-0769
Positioning velocity	S-0-0259	P-0-0770
Positioning acceleration	S-0-0260	P-0-0771
Positioning deceleration	S-0-0359	P-0-0772
Positioning control word	S-0-0346	P-0-0760
Positioning status	S-0-0437	P-0-0768
Positioning jerk	S-0-0193	P-0-0913
Positioning window shortest distance	S-0-0418	P-0-0774
Effective target position	S-0-0430	P-0-0767
Velocity threshold	S-0-0417	P-0-0914

Fig.9-64:   Parameter comparison

Differences to operation 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.

New values for positioning acceleration, positioning deceleration and positioning jerk can be accepted via the toggle bit (P-0-0760, bit 0). Acknowledgment of acceptance of command values, if accepted via toggle bit, can be taken from parameter "P-0-0768, Virtual master axis, positioning status" (bit 1).

"Halt" mode   When "Halt" mode is activated, the positioning deceleration and positioning jerk are accepted.

New values for positioning deceleration and positioning jerk can be accepted via the toggle bit (P-0-0760, bit 0). Acknowledgment of acceptance of command values, 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.

Optional Device Functions

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 ($2^{P-0-0084}$ 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 ($2^{P-0-0084}$ 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-0-0084, Number of bits per master axis revolution
- P-0-0159, Slave drive feed travel
- P-0-0750, Master axis revolutions per master axis cycle
- P-0-0753, Position actual value in actual value cycle
- P-0-0757, Virtual master axis, modulo value
- P-0-0761, Master axis position for slave axis

Optional Device Functions

- 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 value 1
- S-0-0053, Position feedback value 2
- 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-0-1270, PLC Global Register A0
- P-0-1271, PLC Global Register A1
- P-0-1272, PLC Global Register A2
- P-0-1273, PLC Global Register A3
- P-0-1274, PLC Global Register A4
- P-0-1275, PLC Global Register A5
- P-0-1276, PLC Global Register A6
- P-0-1277, PLC Global Register A7
- P-0-1771, CCD: Actual value data container 1, Slave 1 4Byte

  - to -

  P-0-1777, CCD: Actual value data container 1, Slave 7 4Byte

Conversion   The master axis format converter is activated by selecting a parameter not equal to 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**

$$P\text{-}0\text{-}0761 = \frac{S\text{-}0\text{-}0051}{S\text{-}0\text{-}0103} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

$$P\text{-}0\text{-}0761 = \frac{S\text{-}0\text{-}0053}{S\text{-}0\text{-}0103} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

$$P\text{-}0\text{-}0761 = \frac{S\text{-}0\text{-}0386}{S\text{-}0\text{-}0103} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-65:   Rotary/linear modulo scaling of the signal source

Optional Device Functions

$$P\text{-}0\text{-}0761 = \frac{S\text{-}0\text{-}0051}{360°} \times 2^{P\text{-}0\text{-}0084}$$

$$P\text{-}0\text{-}0761 = \frac{S\text{-}0\text{-}0053}{360°} \times 2^{P\text{-}0\text{-}0084}$$

$$P\text{-}0\text{-}0761 = \frac{S\text{-}0\text{-}0386}{360°} \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-66:   *Rotary absolute scaling of the signal source*

$$P\text{-}0\text{-}0761 = \frac{S\text{-}0\text{-}0051}{P\text{-}0\text{-}0159} \times 2^{P\text{-}0\text{-}0084}$$

$$P\text{-}0\text{-}0761 = \frac{S\text{-}0\text{-}0053}{P\text{-}0\text{-}0159} \times 2^{P\text{-}0\text{-}0084}$$

$$P\text{-}0\text{-}0761 = \frac{S\text{-}0\text{-}0386}{P\text{-}0\text{-}0159} \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-67:   *Linear absolute scaling of the signal source*

- **Signal source P-0-0052**

$$P\text{-}0\text{-}0761 = P\text{-}0\text{-}0052$$

Fig.9-68:   *For all scalings of the signal source*

- **Signal source P-0-0434 (special case)**

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0434}{360°} \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-69:   *Rotary absolute scaling*

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0434}{P\text{-}0\text{-}0159} \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-70:   *Linear absolute scaling*

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0434}{S\text{-}0\text{-}0103} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-71:   *Rotary/linear modulo scaling and no synchronous position control mode active*

Optional Device Functions

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0434}{P\text{-}0\text{-}0786} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-72:   *Rotary/linear modulo scaling and a synchronous position control mode active*

- **Signal source P-0-0753**

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0753}{P\text{-}0\text{-}0786} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-73:   *Rotary/linear modulo scaling of the signal source*

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0753}{360°} \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-74:   *Rotary absolute scaling of the signal source*

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0753}{P\text{-}0\text{-}0159} \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-75:   *Linear absolute scaling of the signal source*

- **Signal source P-0-0758**

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0758}{P\text{-}0\text{-}0757} \times P\text{-}0\text{-}0750 \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-76:   *Modulo scaling of the position data master axis generator (for P-0-0750 > 0)*

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0758}{P\text{-}0\text{-}0757} \times 4294967295 \text{ incr.} - 2147483648 \text{ incr.}$$

Fig.9-77:   *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.

$$P\text{-}0\text{-}0761 = \frac{P\text{-}0\text{-}0758}{P\text{-}0\text{-}0918} \times 2^{P\text{-}0\text{-}0084}$$

Fig.9-78:   *Absolute scaling of the position data master axis generator*

- **Signal sources P-0-1270 to P-0-1277**

Optional Device Functions

$$P\text{-}0\text{-}0761 \;=\; P\text{-}0\text{-}127x$$

x   Selected parameter from range P-0-1270 to P-0-1277
Fig.9-79:   *For all scalings of the signal source*

☞   Parameters P-0-1270 to P-0-1277 are only available with the additional package MLD.

- **Signal sources P-0-1771 to P-0-1777**

$$P\text{-}0\text{-}0761 \;=\; P\text{-}0\text{-}177x$$

x   Selected parameter from range P-0-1771 to P-0-1777
Fig.9-80:   *For all scalings of the signal source*

Secondary Master Mode

Activation/settings

For the output value of the format converter (P-0-0761, Master axis position for slave axis), the mode "secondary master" can be selected in bit 12 of the parameter "P-0-0760, Virtual master axis, positioning control word" .

If this option is selected, the master axis position for the slave axis (P-0-0761) synchronizes to a primary master and subsequently moves phase-synchronously to it.

In parameter "P-0-0924, Selection primary master", the real master axis, which is described by "P-0-0052, Actual position value of measuring encoder", or the external master axis position (P-0-0053) can be determined as primary master.

Electric gears and fine adjust

An electronic gear with fine adjust is arranged between the master-type master axis and the slave-type master axis. In this gear, the value of the primary master is multiplied by the quotient from the output and input revolutions of the gear as well as by the factor "1+ fine adjustment". The result is limited to the master axis cycle ($2^{P\text{-}0\text{-}0084} \times$ P-0-0750). After initializing the output of the electronic gear, the gear is differentially processed. An adjustment of the gear results in a velocity jump, not in a position jump.

Offset of the secondary master axis

Parameter "P-0-0928, Additive master axis position, secondary master" can be used to offset the secondary master with respect to the master axis position which is calculated from the primary master and the electronic gear with fine adjust.

With synchronization of the secondary master, the value of the additive master axis position is taken into account and moved with the synchronization parameter values for velocity and acceleration. The motion of the secondary master for a subsequent change of the additive master axis position is restricted by parameters "P-0-0929, Change velocity of add. master axis posit., secondary master" and "P-0-0930, Change accel. of add. master axis posit., secondary master".

If relative synchronization has been set in synchronization mode, only one velocity adjustment is made. In this case, the absolute value of "P-0-0928, Additive master axis position, secondary master" is then inactive. The following changes of this additive master axis position are processed in relative form i. e. they result in corresponding changes of the secondary master axis.

Synchronization of the secondary master axis

Double-step synchronization

Optional Device Functions

Synchronization is carried out in two steps. First, a velocity adjustment is carried out and then the position reference is established.

Relative or absolute synchronization can be selected for synchronization mode. With relative synchronization, only one velocity adjustment is carried out. The velocity of the secondary master is adjusted to the velocity of the primary master by acceleration or deceleration.

The value for acceleration or deceleration is determined in parameter "P-0-0920, Synchronization acceleration, secondary master".

With absolute synchronization, the velocity adjustment is followed by a position adjustment. The offset between the primary master and the secondary master is moved by an added motion of the secondary master with synchronization acceleration and synchronization velocity, so that subsequently the master axes are absolutely phase-synchronous.

At the end of the velocity adjustment with relative synchronization or position adjustment with absolute synchronization, bit 8 of parameter "P-0-0768, Virtual master axis, positioning status" is set ("synchronization completed").

Subsequently, the value of parameter P-0-0761 is directly generated from the position of the primary master (differential processing). In this process the electronic gear and the fine adjustment is taken into account.

For the synchronization range, it is possible to choose between a master axis revolution and the master axis cycle, which is determined by parameter "P-0-0750, Master axis revolutions per master axis cycle".

Single-step synchronization

As an alternative to double-step synchronization, a master-axis-synchronous, single-step synchronization method can be selected. Master-axis-synchronous means that the synchronization process of the secondary master is coupled to an area of the primary master to be passed.

It must be defined if the synchronization process is to start immediately (relatively master-axis-synchronous) or not until the primary master has passed a start angle (after gear and fine adjustment) (absolutely master-axis-synchronous). The start angle is the difference between parameters "P-0-0931, Synchronous position, secondary master" and "P-0-0932, Synchronization range, secondary master".

This synchronization motion is added to the synchronous motion. The additive master axis positions causing the synchronization motions are calculated for the required velocity in rest – motion by a 5th order polynomial: $f(x) = A_5 * x^5 + A_4 * x^4 + A_3 * x^3 + A_1 * x$.

The coefficients of the polynomial are calculated from the states at the beginning of the synchronization motion (synchronization area of the primary master axis, synchronization distance of the secondary master axis, velocities of the primary and secondary master axes). The position within the parameterized synchronization range provides the argument for calculation of a functional value of the polynomial. Parameters "P-0-0922, Preferred synchronization direction, secondary master" and "P-0-0923, Synchroniz. window for shortest distance, secondary master" are taken into account for modulo scaling of the secondary master (internal virtual master axis) when determining the synchronization distance.

If master-axis-synchronous synchronization has been set, a velocity adjustment is performed until the master axis start angle is passed i.e. the velocity of the secondary master is approximated to the velocity of the primary axis (after gear and fine adjustment) with the acceleration parameterized in parameter "P-0-0920, Synchronization acceleration, secondary master". If the

Optional Device Functions

synchronization acceleration has been set to 0, the slave axis maintains its velocity until the master axis start angle is passed (standstill at v=0)

> ☞   Single-step synchronization is only possible in conjunction with absolute synchronization.

Deactivating the slave-type master axis mode

To deactivate the slave-type master axis mode, reset bit 12 in parameter "P-0-0760, Virtual master axis, positioning control word". On the basis of the current velocity, the mode, which has been selected by bit 1 and bit 2 is then switched (positioning, jog or stop).

> ☞   For this switching, parameter "P-0-0758, Virtual master axis, actual position value" must be configured in the format converter.

9.9   Drive-Integrated Command Value Generator

9.9.1   Brief Description

> 💡   Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

The drive-integrated command value generator can be used for commissioning and controller optimization of drives. Different signal forms (square-wave, sine, noise, modified sine, sine sweep) are generated by the command value generator, which are added as additive command values in the closed control loop.

> ☞   In conjunction with the integrated oscilloscope function, the drive-integrated command value generator also provides the option of measuring the frequency response.

The figure below illustrates the points at which the drive-integrated command value generator can take effect:
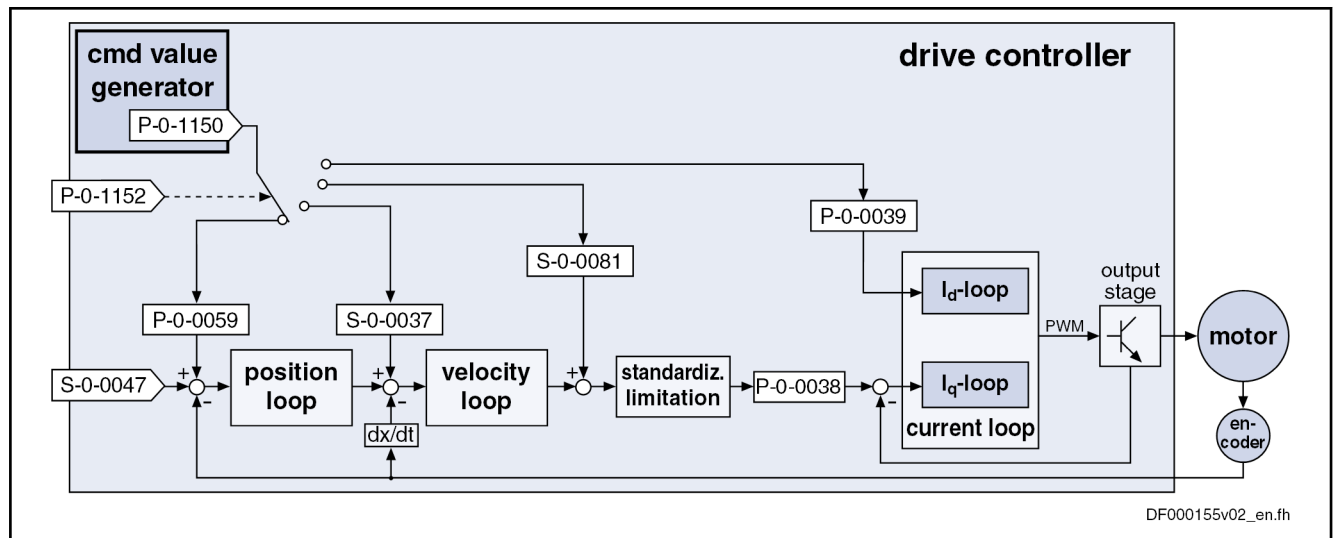
Optional Device Functions

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.9-81:   *Intervention points via "Command value generator" function*

Features
- Possibility of generating different signal forms that are added to the respective control loop command value (position, velocity or current) as additive command values.

  The following signal shapes are possible:
  - **Square-wave signals**
  - **Sine signals**
  - **Noise signals**
  - **Modified sine signals**
  - **Sine sweep**

- Generating **velocity and position command values** in the position loop clock; **current command values** in the velocity loop clock

- With regard to **amplitude and frequency**, generated command values can be freely defined

Pertinent parameters
- P-0-1150, Command value generator output
- P-0-1151, Command value generator, list of possible target parameters
- P-0-1152, Command value generator, target parameter assignment
- P-0-1153, Command value generator, control word
- P-0-1154, Command value generator, offset
- P-0-1155, Command value generator, amplitude
- P-0-1156, Command value generator, duration 1
- P-0-1157, Command value generator, duration 2
- P-0-1158, Command value generator, periodic time
- P-0-1159, Command value generator, starting frequency of sine sweep
- P-0-1160, Command value generator, end frequency of sine sweep

Optional Device Functions

- P-0-0028, Oscilloscope: control word
- P-0-0031, Oscilloscope: time resolution
- P-0-0032, Oscilloscope: size of memory

9.9.2   Functional Description

Setting/Activating the Function

Clock rate
The integrated command value generator provides the possibility of generating velocity and position command values in the position 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, it is possible to set that the enabling of the command value generator is automatically deactivated with drive errors. In this case, the enable signal has to be re-set after each drive error or after the control voltage has been switched on.

Drive enable
In order that the generated additive command values take effect, drive enable (bit "drive on" = 1) has to be set.

This can be done in the following ways:

- Via a digital input
- Via the serial interface in "Easy startup" mode
- Via the master communication
- Via the drive-integrated PLC (IndraMotion MLD)

Selecting the target parameter
The IDN of the 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

ℹ️ 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 the attribute and unit of the assigned parameter. S-0-0000, Dummy parameter can also be assigned as the target parameter for the command value generator in order to use the command value generator as a pure signal form generator.

Optional Device Functions

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".

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 with different prefixes and different periodic times

- **Sine sweep**

  → The sine sweep generator produces a sine, the frequency of which varies, with amplitude and offset. The frequency rises in a linear pattern from the starting frequency to the end frequency.

Advanced settings Other possible settings in the control word of the command value generator:

- Activation of **periodic signal generation**

  → Selected signal is cyclically generated and output with a periodic time (frequency) that can be defined

- **Switch-off delay**

  → The shutdown of the command value generator (command value generator output = "0") can be delayed, that is shutdown is delayed until the signal period is complete.

Pulse Generator (for Square-Wave Signal)

The pulse generator generates a square-wave signal that can be varied in the following properties:

- Frequency or periodic time of the signal
- Amplitude
- Direct component (DC offset; positive/negative)
- Pulse/pause relationship

The example below illustrates the output signal of the pulse generator with intervention options:

Optional Device Functions
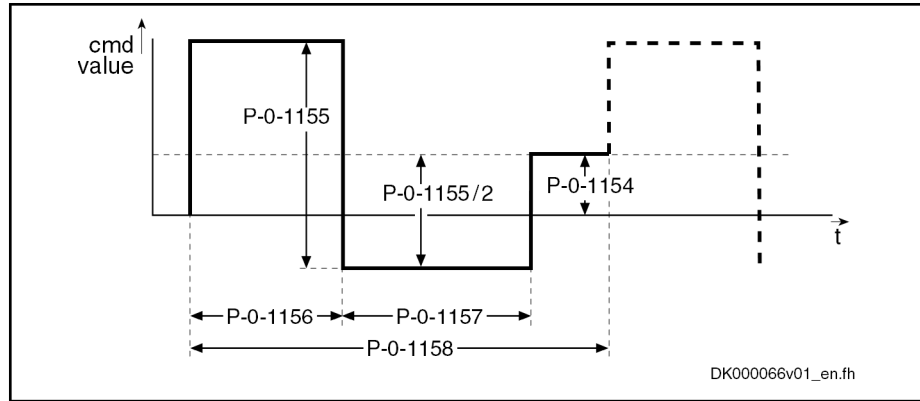
P-0-1154	Command value generator, offset
P-0-1155	Command value generator, amplitude
P-0-1156	Command value generator, duration 1
P-0-1157	Command value generator, duration 2
P-0-1158	Command value generator, periodic time

Fig.9-82:   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.

         With P-0-1158 = (P-0-1156) + (P-0-1157), there is a periodic
         square-wave signal resulting, if the periodic output has additional-
         ly been activated in the control word.

Sine Generator

The sine generator generates a sine, the following properties of which can be
varied:

- Frequency or periodic time of the signal

- Amplitude

- Direct component (DC offset; positive/negative)

The example below illustrates the output signal of the sine generator with in-
tervention options:
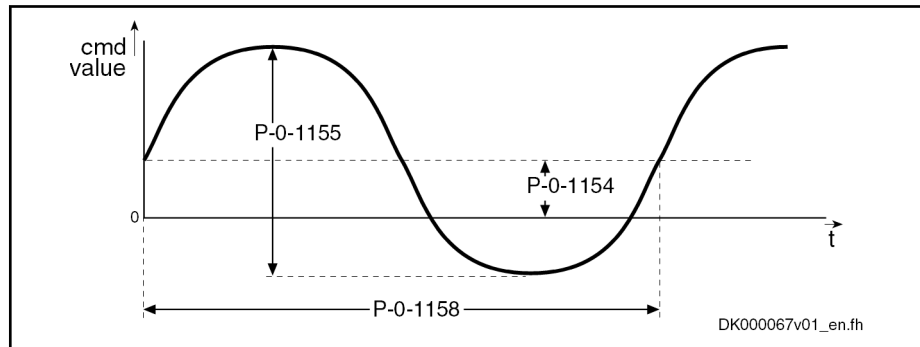
P-0-1154	Command value generator, offset
P-0-1155	Command value generator, amplitude
P-0-1158	Command value generator, periodic time

Fig.9-83:   Output signal of sine generator

Optional Device Functions

☞ 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 Extended settings can be entered in parameter "P-0-1153, Command value generator, control word":

- In many cases it is important that the sine signal contains no direct component (surface under the curve). The shutdown of the command value generator can therefore be delayed until the period is complete (P-0-1153, bit 6).

- If no target parameter (P-0-1152 = S-0-0000) is assigned for the output of the command value generator, the signal form of sine can be switched to cosine (P-0-1153, bit 9).

Noise Generator

The method of the feedback shift register is used for generating the random numbers. In each sequence a bit for the output is generated which is set or cleared at random so to speak. The periodic time of the noise signal in this case is set to 4095 clocks ($T_{A\_position}$ or $T_{A\_velocity}$).

☞ The generated noise signal is free of mean values over an entire period so that the drive does not drift due to the additional noise.

Output format (amplitude modulation) For outputting the 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 example below illustrates the output signal of the noise generator with intervention options:
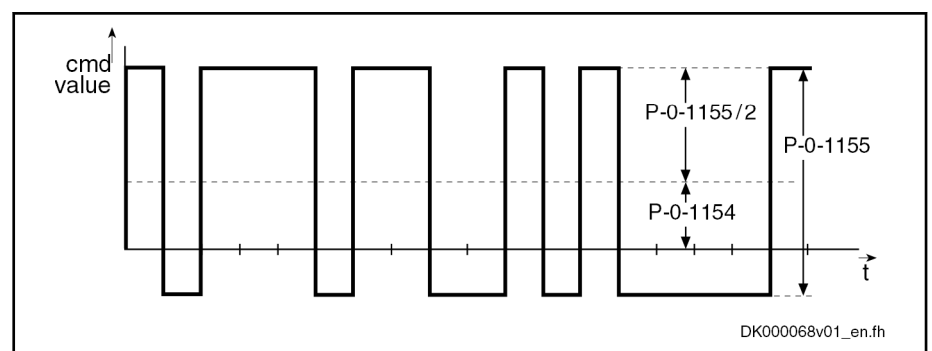
| P-0-1154 | Command value generator, offset |
| P-0-1155 | Command value generator, amplitude |

Fig.9-84:   *Output signal of noise generator*

Modified Sine Generator

In addition, a modified sine generator is available with two different half-waves of the same amplitude; the output signal of the generator can be varied in the following properties:

Optional Device Functions

- 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 example below illustrates the modifiable output signal of the sine generator with intervention options:
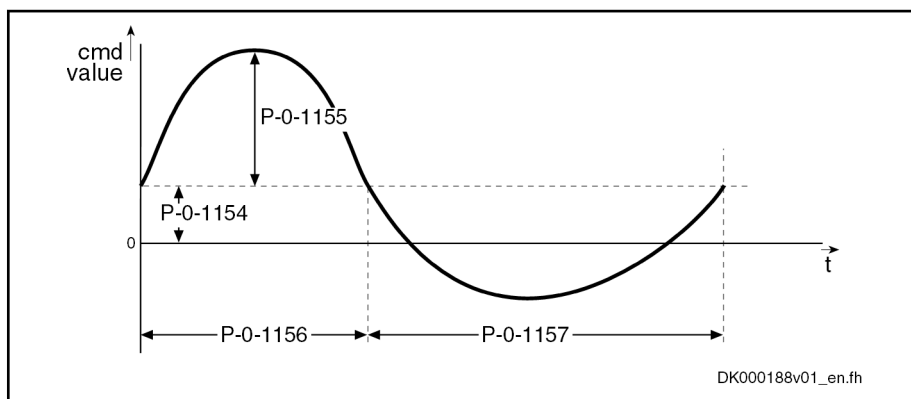
P-0-1154	Command value generator, offset
P-0-1155	Command value generator, amplitude
P-0-1156	Command value generator, duration 1
P-0-1157	Command value generator, duration 2

Fig.9-85:   Output signal of noise generator

Sine Sweep Generator

The sine sweep generator generates a sine with varying frequency. The frequency rises in a linear manner from the starting frequency to the end frequency ("up-wobbling") and then falls in a linear manner to the end frequency ("down-wobbling").

The following properties of the output signal can be varied:

- Starting frequency
- End frequency
- Periodic time of the signal (duration of "up-wobbling" and "down-wobbling" combined)
- Amplitude
- Direct component (DC offset, positive/negative)

The following diagram shows an example of a sine sweep with possible interventions:

Optional Device Functions
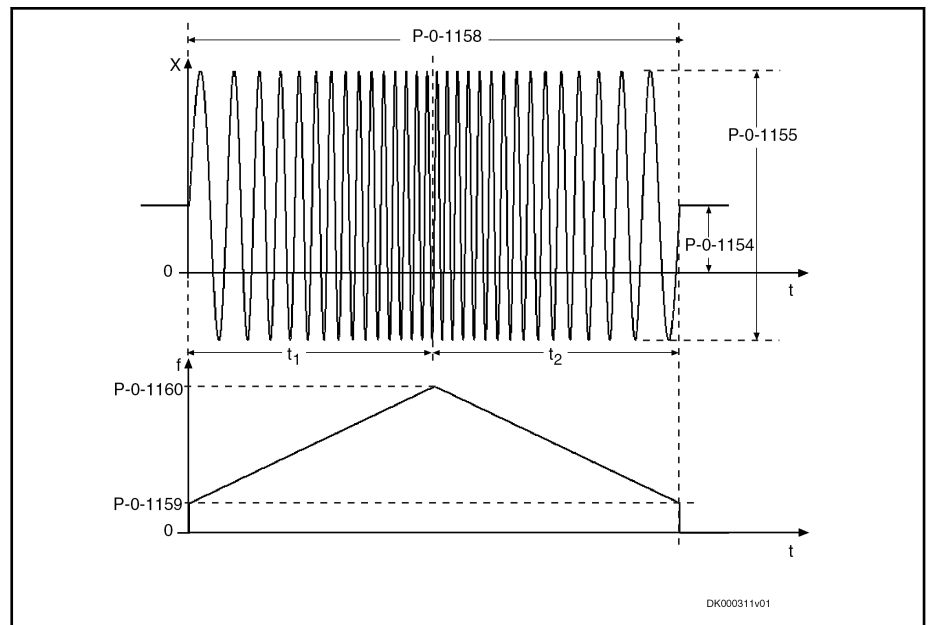
t_1	Duration of "up-wobbling"
t_2	Duration of "down-wobbling"
P-0-1154	Command value generator, offset
P-0-1155	Command value generator, amplitude
P-0-1158	Command value generator, periodic time
P-0-1159	Command value generator, starting frequency of sine sweep
P-0-1160	Command value generator, end frequency of sine sweep
Fig.9-86:	Starting signal of sine sweep generator

☞ The generated sine sweep without offset is free of mean values over the entire period duration ("up- and down-wobbling"). During "up-wobbling", a direct component is formed which is then reduced during "down-wobbling", as shown in the following diagram.

Optional Device Functions
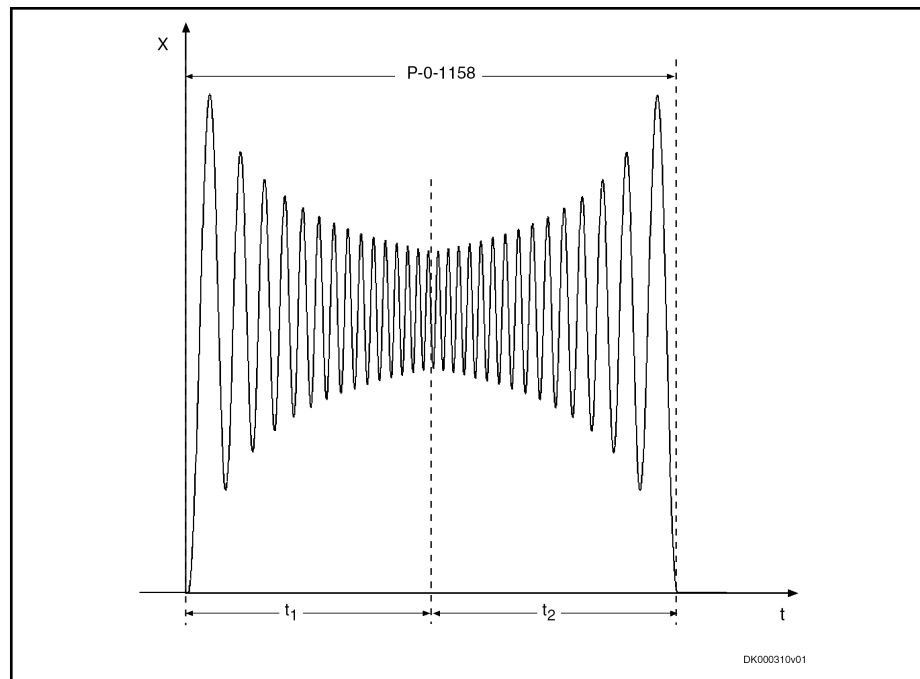
t_1	Duration of "up-wobbling"
t_2	Duration of "down-wobbling"
P-0-1158	Command value generator, periodic time
Fig.9-87:	*Integral sine sweep without direct components (offset, P-0-1154 = "0")*

9.9.3   Notes on Commissioning

Bandwidth and Frequency Response Measurement

Frequency response measurement always requires accordingly wide-band excitation that is provided by the noise generator or sine sweep generator. In addition to the generation of the excitation signal, the recording of measured values (= sampling) is required which is carried out with the oscilloscope function integrated in the drive.

It is therefore necessary to adjust the recording time of the oscilloscope function to the period of the excitation signal.

- • Noise signal
  - – The period produces: T_R= 4096 * $T_{excitation}$ (cycle time of excitation)

    The cycle time of excitation $T_{excitation}$ depends on the selected target parameters.
    - – Position and velocity commend values: $T_{excitation}$= $T_{A\_position}$(cycle time of position control)
    - – Current and torque command values: $T_{excitation}$= $T_{A\_velocity}$(cycle time of velocity control)
  - – Oscilloscope settings
    - – Oscilloscope, time resolution: P-0-0031 = $T_{excitation}$
    - – Oscilloscope, memory depth: P-0-0032 = 4096
    - – Trigger settings
      - – Trigger method: signal trigger
      - – Pre-trigger: 0%
      - – Trigger signal: P-0-1150

Optional Device Functions

- – Edge: rising edge

- – Trigger value: P-0-1154 + P-0-1155/2

● Sine sweep

As a maximum of 4096 values are used for frequency response measurement in the oscilloscope, it is sensible to coordinate the settings for sine sweep and the oscilloscope with each other.

1. Selecting starting (P-0-1159) and end frequency (P-0-1160) of sine sweep

2. Entering oscilloscope settings

   - – Oscilloscope, time resolution: selecting P-0-0031 = 1 / (2*P-0-1160)

   - – Oscilloscope, memory depth: P-0-0032 = 4096

   - – Trigger settings

     - – Trigger method: signal trigger

     - – Pre-trigger: 0%

     - – Trigger signal: P-0-1150

     - – Edge: rising edge

     - – Trigger value: P-0-1154 + 0,1*P-0-1155

3. Defining period duration of sine sweep (P-0-1158): P-0-1158 = 2*P-0-0031*P-0-0032

   As the parameterized period duration (P-0-1158) with sine sweep is made up of the time for "up-wobbling" and "down-wobbling" combined, it is sufficient to record half of the period duration.

With the noise signal, the bandwidth of the excitation signal is dependent on the cycle time of the excitation $T_{excitation}$, with which the signal is generated and, with sine sweep, it is dependent on the end frequency (P-0-1160)

● Noise signal: Bandwidth of excitation: $BB_{excitation}[Hz] = 1 / (2*T_{excitation})$;

● Sine sweep generator: Bandwidth of excitation: $BB_{excitation}[Hz] = P\text{-}0\text{-}1160$;

The overview below illustrates the possible excitation signals and measuring signals for the recording:

Control loop	Command value generator excitation signal	Cycle time of excitation $T_{excitation}$	Measuring signals of oscilloscope function
Torque	Additive torque/force cmd value (S-0-0081)	$T_{A\_velocity}$	Additive torque/force cmd value (S-0-0081) Torque/force feedback value (S-0-0084)
Current (Iq)	Torque-generating current, command value (P-0-0038)	$T_{A\_velocity}$	Torque-gener. current, command value (P-0-0038) Torque-generating current, actual value (P-0-0043)

Optional Device Functions

Control loop	Command value generator excitation signal	Cycle time of excitation $T_{exci-tation}$	Measuring signals of oscilloscope function
Current (Id)	Flux-generating current, cmd value (P-0-0039)	$T_{A\_velocity}$	Flux-generating current, cmd value (P-0-0039)
			Flux-generating current, actual value (P-0-0044)
Velocity	Additive velocity command value (S-0-0037)	$T_{A\_position}$	Effective velocity command value (P-0-0048)
			Velocity feedback value (S-0-0040)
Position	Additive position cmd val., controller (P-0-0059)	$T_{A\_position}$	Position command value controller (P-0-0434)
			Position feedback 1 value (S-0-0051) or
			Position feedback 2 value (S-0-0053)

$T_{A\_velocity}$ Velocity control cycle time
$T_{A\_position}$ Position control cycle time
Fig.9-88:   *Signals for excitation and recording*

The cycle times for position and velocity control are dependent on the control section version and the performance stage, see chapter "Control Section Design and Performance".

"IndraWorks Ds/D/MLD" has a dialog for bandwidth and frequency measurement, which automatically enters the settings for excitation and measurement according to the type of frequency response.

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 controller   The field-oriented current controller that takes effect in controlled operation ("closed loop"), provides 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.

Optional Device Functions

Velocity loop   To evaluate the velocity loop, the excitation has to be carried out via parameter "S-0-0037, Additive velocity command value" and parameters "P-0-0048, Effective velocity command value" and "S-0-0040, Velocity feedback value".

Position loop   To examine the position loop, the drive has to be in one of the operation modes "position control with cyclic command value input", "drive-internal interpolation", "drive-controlled positioning" or in the 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 value 1" or "S-0-0053, Position feedback value 2" have to be recorded with the oscilloscope function.

9.10   Drive-Internal "Command Value Box"

9.10.1   Brief Description

> 💡   Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

With IndraDrive controllers, a so-called "command value box" is internally available for manual drive optimization. It offers the possibility of internally (independent of the master) generating a command value characteristic that can be defined by the user. By means of this, an axis drive can be moved in the same way as with an external command value box, without an external command value being effective (→ drive-internal "command value box"). The drive enable must merely be applied to the drive.

The command value characteristic that can be defined by the user, allows for an axis to be moved within determinable position limits in continuous sequence in the velocity control loop or position control loop. This can be made use of in order to manually optimize the control loop parameters of the drive, by, for example, moving the drive with a low velocity command value and by evaluating the status variables "actual current value" and "actual velocity value".

> ☞   More details on the manual control loop setting are described in the "Overview of Drive Control: Notes on Commissioning for Control Loop Setting".

Using the internal command value box, an axis can be continuously moved in an "oscillating motion" (oscillating between two position limit values) or in "stepper mode" (unidirectional moving over a defined path or a travel range).

The internal command value box is configured via a command word, the command value characteristic is defined via the respective parameters. Activating the internal command value box is carried out via a command.

Pertinent parameters
- P-0-0162, C1800 Command Drive optimization / command value box
- P-0-0165, Drive optimization, control word
- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive
- P-0-0169, Drive optimization, travel distance
- P-0-0170, Drive optimization, acceleration
- P-0-0171, Drive optimization, velocity

Optional Device Functions

- P-0-0172, Drive optimization, dwell time

Pertinent diagnostic messages
- C1800 Command Drive optimization / command value box
- C1801 Start requires drive enable
- C1806 Travel range exceeded

9.10.2   Functional Description

Configuring and Activating the Function

The drive-internal command box is configured in parameter "P-0-0165, Drive optimization, control word". In this parameter, the presettings for a total of three functions are made which operate with internal command value input:

1. Recording table for cogging torque compensation (highest priority)
2. Configuring internal command value box (medium priority)
3. Configuring automatic control loop setting (lowest priority)

The functions mentioned above **cannot be used simultaneously**, although they can be selected simultaneously by means of the respective bits. Prioritization applies as stated in the list above.

The "internal command value box" function is activated, if the execution of "C1800 Command Drive optimization / command value box" is started with correct setting of parameter P-0-0165.

Operation mode
With the function activated, the controller can move the drive in one of the following operation modes:

- Velocity control
- Position control

Velocity control takes place via the motor encoder, position control via the position encoder selected in parameter "S-0-0520, Axis control word".

Type of motion
With both velocity control and position control, the types of motion below can be selected for the command value characteristic:

- Oscillating motion
- Stepper mode

Definition of the Internal Command Value Characteristic

Oscillating motion
With oscillating motion, the drive reciprocates between two position limit values that can be set. The limit values are determined by the parameters below:

- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive

Between the subsequent reciprocating movements of the oscillating operation, the axis dwells in a standstill position for a period that can be set in parameter "P-0-0172, Drive optimization, dwell time".

Stepper mode
With stepper mode, the axis only moves in one direction. The distance or angle is preset by the value of parameter "P-0-0169, Drive optimization, travel distance", the direction is determined by the sign of the value in parameter P-0-0169.

Between the subsequent travel motions of stepper mode, the axis dwells in a standstill position for a period that can be set in parameter "P-0-0172, Drive optimization, dwell time" .

Optional Device Functions

Velocity command value | For both velocity control and position control, the maximum velocity command value of the axis is preset in parameter "P-0-0171, Drive optimization, velocity".

Acceleration command value | In position control, the maximum acceleration of the axis in the parameter is preset in "P-0-0170, Drive optimization, acceleration".

In velocity control, parameter P-0-0170 is ineffective; the velocity command value is preset in an abrupt manner! Any acceleration limit possibly needed can, however, be realized via the command value ramp parameters (P-0-1201, P-0-1202,

9.10.3   Notes on Commissioning

Configuring the function | The drive-internal command box function is configured in parameter "P-0-0165, Drive optimization, control word". The following settings are to be made:

- Set operation mode "position control" or "velocity control"
- Select type of motion "oscillating motion" or "stepper mode"

  Note: The motion type "stepper mode" can only be used with axes with unlimited travel range (e.g. modulo axes). For axes with limited travel range, the motion type "oscillating motion" must be used!

☞ | It must be taken into account that the option "including the cogging torque compensation table", which can also be configured in parameter P-0-0165, has **not** been selected as it has a higher priority than the internal command value box.

Motion limits | For the oscillating motion the motion limits are set in the following parameters:

- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive

These limit values are effective for both position control and velocity control. In velocity control mode, the limit values cause a change in the polarity of the velocity command value.

Travel distance | In stepper mode, the travel distance or travel angle is set in parameter "P-0-0169, Drive optimization, travel distance" The sign determines the direction of movement!

Dwell time | The standstill time of the axis between the individual travel movements is preset in parameter "P-0-0172, Drive optimization, dwell time".

Velocity command value | The maximum velocity command value for both control modes (operation modes) is preset in parameter "P-0-0171, Drive optimization, velocity".

Acceleration command value | For position control the acceleration command value is preset in parameter "P-0-0170, Drive optimization, acceleration". With velocity control the predefined command value ramps (P-0-1201, P-0-1202, …) must be used, if necessary!

9.11   Encoder Emulation

9.11.1   Brief Description

💡 | Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

Optional Device Functions

With 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:

- **5 V 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, the signals in a higher-level master to be evaluated 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 the use of digital interfaces, such as a sercos interface.

See "Restrictions" in section "Commissioning"

Incremental encoder emulation

Incremental encoder emulation is the simulation of a real incremental encoder by the drive controller.

With incremental encoder emulation we distinguish between

- Signal emulation

  - and -

- Motor encoder emulation.

In the form of **incremental encoder signals**, a higher-level numeric control (NC) receives information about the velocity of the motor connected to the controller. By integrating these signals, the control unit receives the required position information and it is thereby possible to close a higher-level position control loop.

☞ Emulation takes place in scaling-dependent (see S-0-0076) or encoder-related form; the resolution is input in lines/revolution (1 line corresponding to 4 increments) or in mm or inch.

Features of incremental encoder emulation

- Cyclic calculation of the 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 (lines/revolution or mm / inch respectively)

- Encoder-related emulation (incremental)

- Dead time compensation that can be activated (P-0-0902, bit 3)

- Shiftable zero pulse (P-0-0904)

- Parameterizable cyclic zero pulse output for zero pulse distance (P-0-0904) and position data reference (P-0-0902)

- 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)

Optional Device Functions

- Signal-related or motor-encoder-related emulation to be freely selected (→ influence on position of zero pulse!)

Absolute encoder emulation

Absolute encoder emulation means that the drive controller has the option of simulating a real absolute encoder in **SSI data format**. It is thereby possible to transmit the position in the SSI data format to the connected control unit (NC) and to close the position control loop via the control unit.

☞   Emulation takes place in scaling-dependent form (see S-0-0076) and the resolution is input in bits.

Features of absolute encoder emulation

- Cyclic calculation of the position 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 (bits)
- Scaling-related emulation (S-0-0076)
- Synchronization of SSI emulation to SSI clock can be activated (only with ADVANCE control sections)

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

☞   The encoder emulation is a device function. It can therefore only be used once per device, i.e. in the case of double-axis devices (CDB), it is only available for one of the two axes as standard.

Special case:

With double-axes devices operated as purely analog devices with position feedback via encoder emulation, the encoder emulation can be used for each axis, if the control section configuration CDB01.1C-AN-EN*-MEM-EN*-MEM is available.

In this case the following must be observed: The assignment of the optional positions to the respective axis can be taken from the document "Control Sections for Drive Controllers, Project Planning Manual"

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

Optional Device Functions

> ☞ If the encoder emulation is operated as device function in the double-axis device (no "analog inputs" extension plugged), these parameters are available once per device, except the control parameter (P-0-0902). If the "analog inputs" (AN) extension is plugged in, these parameters are available once per axis.

Pertinent diagnostic messages
- C0242 Multiple configuration of a parameter (->S-0-0423)
- C0260 Incremental enc. emulator resol. cannot be displayed
- F2053 Incr. encoder emulator: Pulse frequency too high
- F2054 Incr. encoder emulator: Hardware error

9.11.2 Basic Information on the Function

Activating the Function

The kind of encoder emulation including its activation is determined via bit 0 and bit 1 of "P-0-0902, Encoder emulation control parameter".

The following settings can be selected via parameter P-0-0902:
- No encoder emulation activated
- Incremental encoder emulation (IGS) activated
    - Signal emulation
    - Motor encoder emulation
- Absolute encoder emulation (SSI) activated
    - Signal emulation

> ☞ The settings in parameter P-0-0902 only take effect after progression to operation 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 dependent on the following factors:
- Firmware version and enabled functional packages
- Hardware of the control section and its configuration
- With double-axis device utilization as axis or device function

> ☞ 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 (for incremental encoder emulation)
Bit 12 of "P-0-0902 Encoder emulation control parameter" determines 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 into parameter "P-0-0901, Encoder emulation signal selection".

Optional Device Functions

☞ The resolution of the emulated signal is determined for both kinds of emulation (SSI and IGS) in parameter "P-0-0903, Encoder emulation resolution".

9.11.3   Incremental Encoder Emulation

General Information

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 is calculated (see "Performance Data"). 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 is then corresponding 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, if there is position data reference (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:
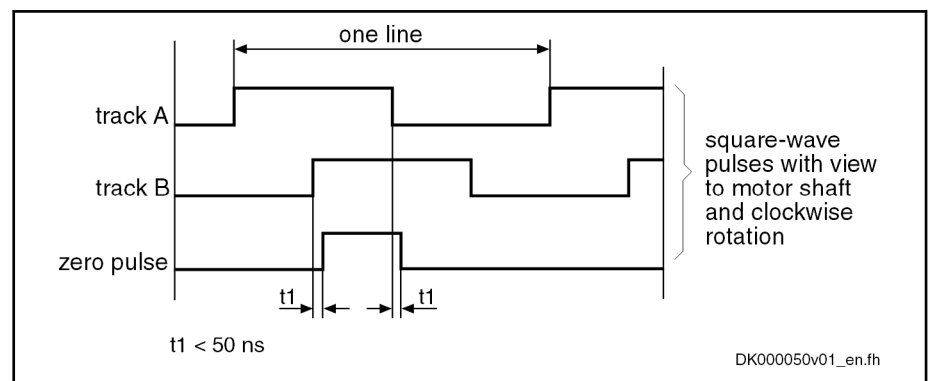
Fig.9-89:   Time flow of the incremental encoder signals

Resolution and Unit of the Emulated Signal

Resolution

The number of increments of the emulated incremental encoder can be determined in "P-0-0903, 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 motor
    - Rotary motors → lines/revolution
    - Linear motors → mm or inch
- Parameterized scaling (see "S-0-0076, Position data scaling type")

Optional Device Functions

> ☞ 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 operation mode in the distance of the lines in mm or inch respectively entered in parameter "P-0-0905, Encoder emulation zero pulse distance".

Zero pulse offset

With 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).

> ☞ With cyclic output, 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!

Emulation type

Depending on the type of emulation, the zero pulse is emulated with relation to the encoder mark or with relation to the signal. The emulation type 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)

With motor encoded-related emulation, emulation takes place with relation to the encoder shaft. With relation to the position of the encoder mark, the zero pulse is emulated under the following conditions:

- For relative measuring systems for which there is no absolute position reference when switching on, zero pulse output only takes place after an encoder mark of the encoder system has been passed for the first time (see figure below).

- For absolute measuring systems which have absolute position reference after switching on, output takes place immediately.

> ☞ In case the drive has not been homed (see S-0-0403), zero pulses are generated without reference to the machine zero point existing!

Optional Device Functions
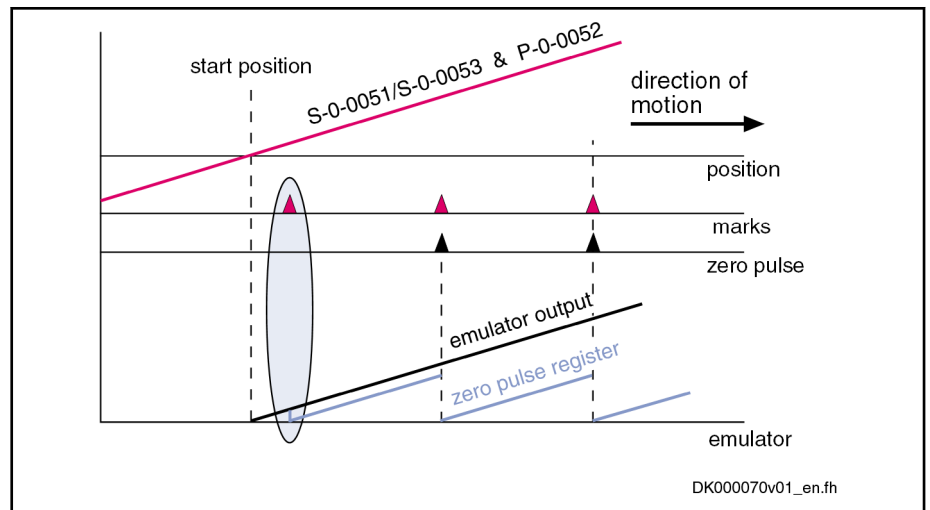
S-0-0051	Position feedback 1 value
S-0-0053	Position feedback 2 value
P-0-0052	Actual position value of measuring encoder

Fig.9-90:   *Zero pulse generation for incremental measuring system and motor encoder relation (P-0-0902, Bit 12 = 1)*

Emulation in relation to signal (P-0-0902, bit 12 = 0)

With signal-related emulation, the zero pulse is emulated with reference to the coordinate system. The zero pulse is output with reference to the zero point at "position 0" plus zero pulse offset. There are the following possible settings:

- The further zero pulses are defined via parameter "P-0-0905, 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 (see S-0-0403). The generated zero pulses are then always referring to the actual machine zero point!

The emulation signals that can be selected via parameter "P-0-0901, Encoder emulation signal selection" are divided into two groups:

- **Emulation of actual values**

  → For the output of zero pulses "reference" (see S-0-0403) is obligatory. For relative measuring systems, zero pulse output only takes place when the corresponding actual position value was homed (see figure below).

- **Emulation of command values**

  → Command values can always be considered as homed so that zero pulse output takes place independent of the "reference" (see 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:

Optional Device Functions
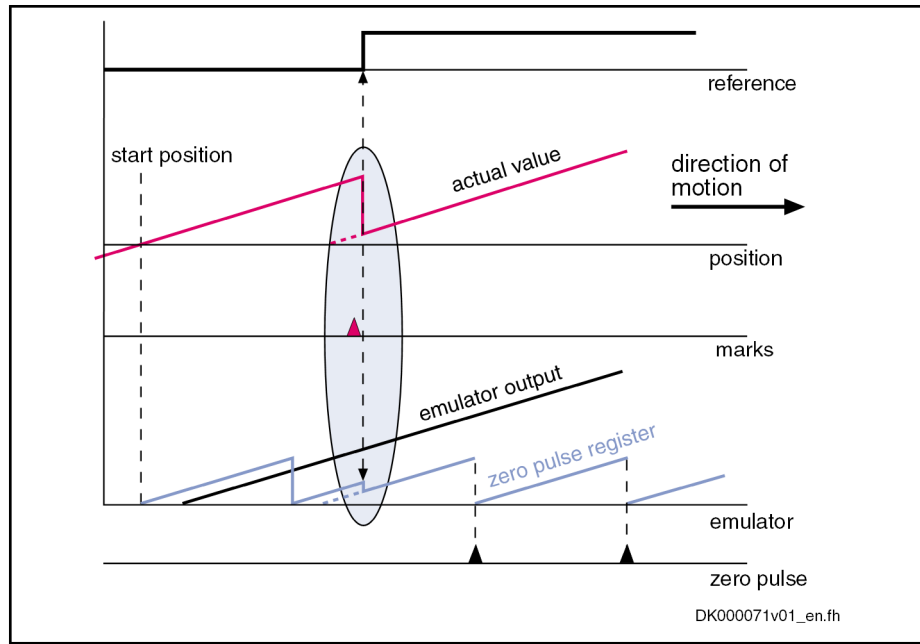
Fig.9-91:   Zero pulse generation for incremental system and signal relation
                 (P-0-0902, bit 12 = 0) with actual value signals

Example: Incremental measuring system and command value output with command value jump

With the emulation of command values, take into account that the master might possibly want to preset command value jumps that are not to be emulated or cannot be emulated. For this case, it is possible to stop emulation for a short time (see P-0-0902, 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 maladjustment 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.
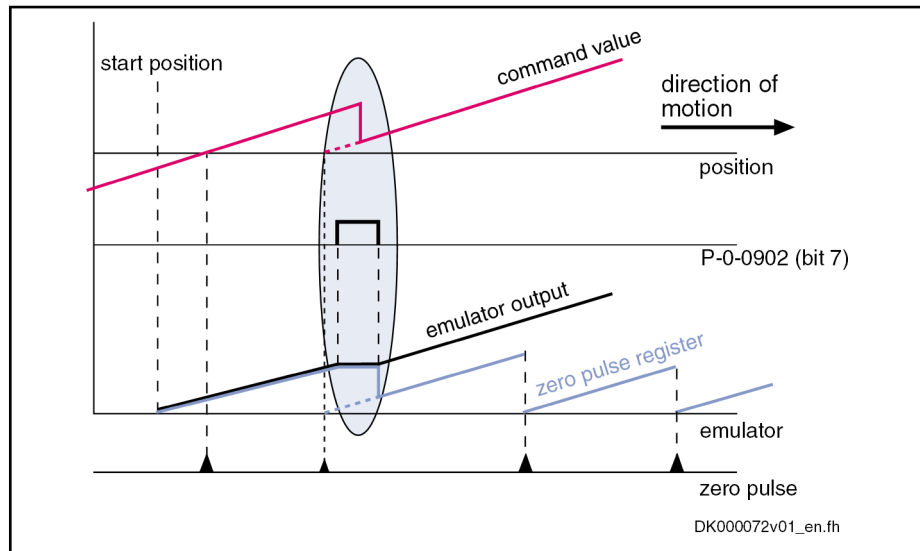
P-0-0902   Encoder emulation control parameter
Fig.9-92:   Zero pulse generation for incremental measuring system and signal
                 relation (P-0-0902, bit 12 = 0) with a command value jump

Establishing the Position Data Reference (Drive-Controlled Homing)

With signal-based emulation (P-0-0902, bit 12 = 0) of actual values and the use of incremental measuring systems, the drive must be homed to output a zero pulse (see also above section "Zero pulse output").

☞   When the homing procedure is carried out, the emulated signals jump from the original position to the reference position. **In this case, the error message" F2053" is suppressed on purpose.**

See "Establishing position data reference for relative measuring systems"

9.11.4   Absolute Encoder Emulation

General Information

Absolute encoder emulation provides a digital, coded, absolute position signal which can be serially read in the position loop clock (see "Performance Data"). The resolution of the absolute position, and therefore the travel range that can be displayed in absolute form, depends 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:
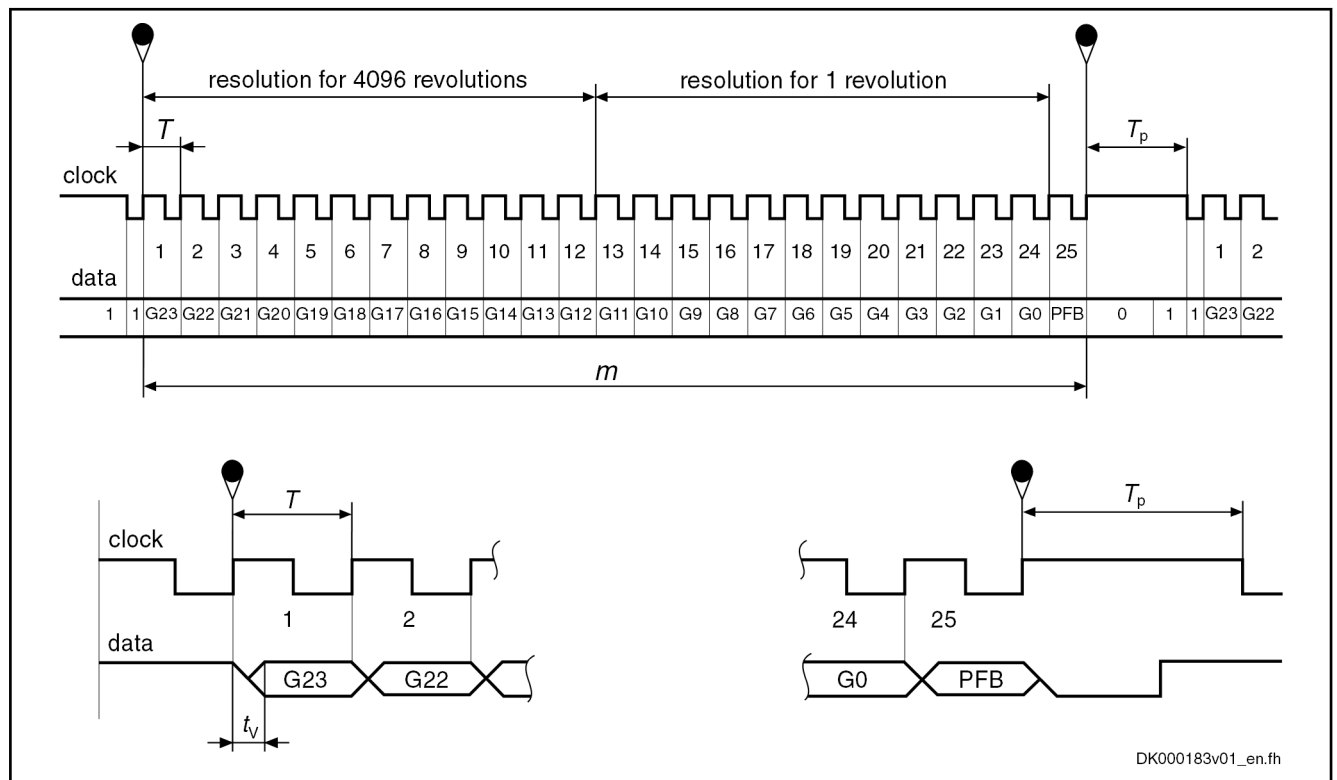
G0	Least significant bit in Gray code
G23	Most significant bit in Gray code
m	Stored parallel information
T	Clock time
T_P	Clock break ≥ 20 μs
t_V	Delay time max. 650 ns
PFB	Power failure bit (not used and always logically LOW)
Fig.9-93:	Pulse diagram - SSI format

☞   IndraDrive controllers do not support the power failure bit!

Optional Device Functions

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".

☞   The unit represented in parameter P-0-0903 is bits.

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 (see "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 value 1", "S-0-0053, Position feedback value 2" or "S-0-0047, Position command value" are synchronous. This simplifies, among other things, emulation control, e.g. with the commissioning tool "IndraWorks Ds/D/MLD".

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 Set absolute position procedure command", 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"

9.11.5   Notes on Commissioning

General Information

In contrast to a "real" encoder, encoder emulation uses a simulated encoder. In motion the real encoder signal and the output of the emulator can differ. The causes for such differences can be:

- Application errors (e.g. inadequate wiring, exceeded frequencies, voltage dips, incorrect programming)

Optional Device Functions

- 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 Incr. encoder emulator: Pulse frequency too high" is output.

☞   The max. output frequency always, i.e. independent of the selected number of lines, has to be taken into account for dimensioning the evaluation electronics.

The maximum output frequency f_{max} depends on the hardware design and is reduced as the clock increase is increased (see 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:

$$\text{Linear scaling} \quad (P\text{-}0\text{-}0903)_{max} = \frac{v_{max}}{f_{max}}$$

$$\text{Rotary scaling} \quad (P\text{-}0\text{-}0903)_{max} = \frac{f_{max}}{v_{max}}$$

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.9-94:   *Determining the maximum resolution of encoder emulation*

Delay between real and emulated position value

Between the position detection and output of the emulated pulses there is a delay (dead time) between real and emulated position value.

Solution:

When incremental encoder emulation has been activated (see P-0-0902, bit 0 = 1), it is possible to activate dead time compensation in "P-0-0902, Encoder emulation control parameter" with bit 4 = 1. The dead time compensation is only effective and useful if there are not 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

Optional Device Functions

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 (see 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 clearly reduces the zero pulse and frequency jitter.

Oscillating signal frequency within one output cycle

Due to internal signal processing, the periodic time and duty cycle of the output signals vary. The periodic time (or frequency) of the resulting cycles can therefore be shorter or longer, too.

This is why the signals of incremental emulation are **not** to 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.
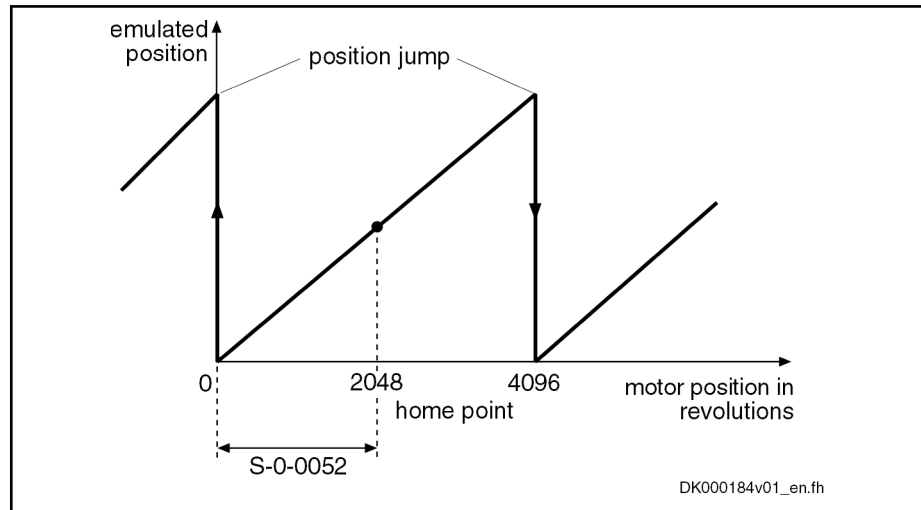
S-0-0052   Reference distance 1
Fig.9-95:   *Display limits with absolute encoder emulation*

This effect can be avoided by shifting the home point by executing "P-0-0012, C0300 Set absolute position procedure command".

Optional Device Functions

☞ **Note** By the correspondingly setting it in parameter "S-0-0052, Reference distance 1", the reference position is shifted 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

If 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.9-96:   *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"

☞ Note that the probe function (MT1) is occupied for this synchronization process and therefore no longer available for other purposes!

9.11.6   Diagnostic and Status Messages

The following diagnostic messages **can only occur with incremental encoder emulation**:

- **F2053 Incr. encoder emulator: Pulse frequency too high**

  → The output frequency resulting from the resolution that has been set (P-0-0903) and the travel velocity exceeds the value of the maximum pulse frequency of 1024 kHz.

- **F2054 Incr. encoder emulator: Hardware error**

  → 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**

  → With incremental encoder emulation, inadmissible overflow can occur for increment output. In order to avoid this overflow, P-0-0903 has to be parameterized accordingly.

Optional Device Functions

9.12 Programmable Position Switch

9.12.1 Brief Description

> 💡 Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

The firmware function "programmable position switch" can be used instead of a mechanical position switch that has to be externally mounted.

Features
- Realization of a maximum of **8 dynamic position switch points** (switch cams) in the position 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-0-0423)

9.12.2 Functional Description

Basic Principle of Cam Generation

The basis of the "programmable position switch" function is the registration of the information whether the selected reference value is within the range between switch-on and switch-off threshold or not.

Optional Device Functions
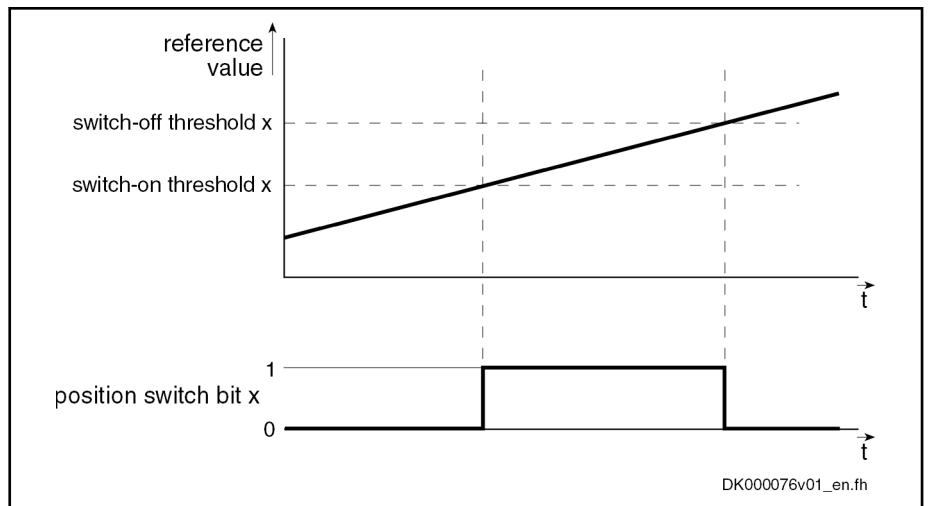
Fig.9-97:   General functional principle of the programmable position switch

☞   By setting the switch-on and switch-off threshold, the correspond-
ing bit in the status word of the programmable position switch can
be inverted.

We differentiate between 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]
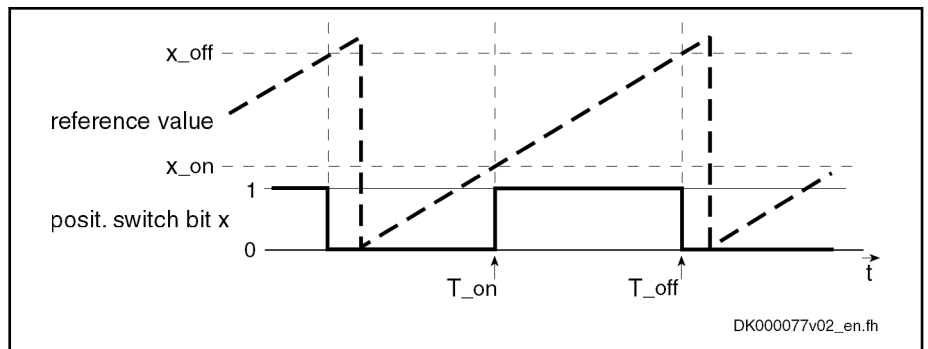
x_on   Switch-on threshold of position switch (P-0-0132)
x_off   Switch-off threshold of position switch (P-0-0133)
Fig.9-98:   Position switch bit with "switch-on threshold < switch-off threshold"
             (P-0-0132 [i] < P-0-0133 [i])

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]

Optional Device Functions
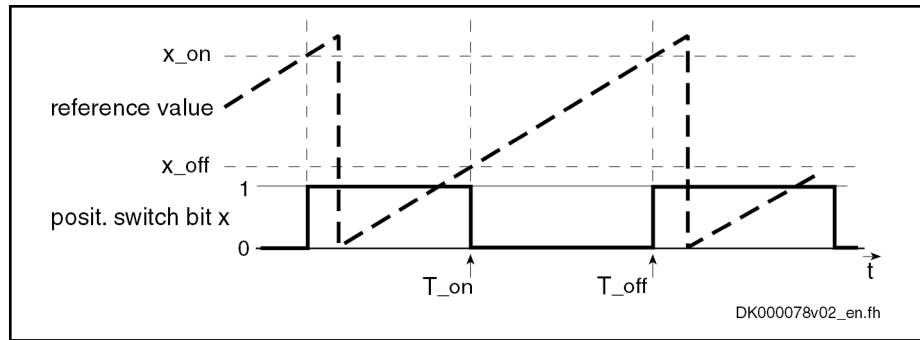
| x_on | Switch-on threshold of position switch (P-0-0132) |
| x_off | Switch-off threshold of position switch (P-0-0133) |

*Fig.9-99:   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 control-
led by a position switch bit can be compensated. To do this, a theoretical cor-
rection value for the respective switch-on and switch-off threshold is calcula-
ted from the programmed lead time and the current drive velocity. The posi-
tion 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 is to be constant.
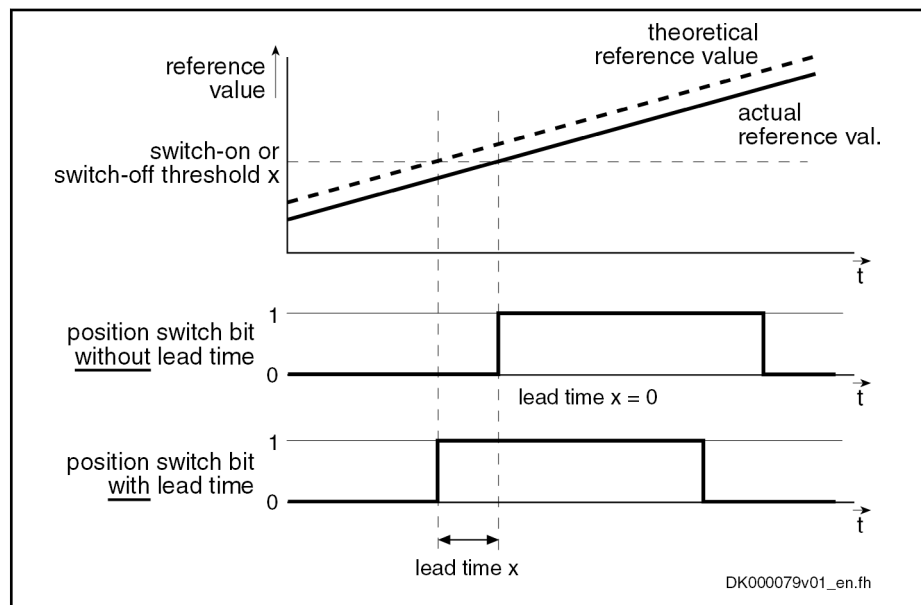
Fig.9-100:   Functional principle of "lead time" for programmable limit switches

9.12.3   Notes on Commissioning

General Information

☞ The reference value selected in parameter "P-0-0131, Position
switch signal selection" applies to all 8 cams, only the switch-on/
switch-off thresholds and lead times can be individually parame-
terized for each cam!

Optional Device Functions

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 With 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" is always to be parameterized completely (i.e. all 8 elements) even if the lead times are not used; if necessary, a lead time of "0" has to be entered.

☞ To compensate the internal processing dead time, a lead time of $t = T_{A\_position}$ has to be set!

9.12.4   Diagnostic and Status Messages

Status Message of the Individual Cams

The status of the individual cam bits is displayed in parameter "P-0-0135, Position switch status word". The cams, beginning with bit 0, are assigned in ascending order (see Parameter Description P-0-0135).

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-0-0423)" is generated!

Optional Device Functions

9.13 Probe Function

9.13.1 Brief Description

> 💡 Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

Features
- 2 probe inputs per axis; depending on the hardware design of the control section (CSH…, CSB…, CDB…) two rapid probe inputs or one rapid and one slow probe input
- Measuring signals can be actual position values of motor encoder, external encoder or measuring encoder, in addition master axis position 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!
- Dead time compensation can be set for every probe, separately for every positive or negative edge up to 50000µs
- 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.

A second, slower digital input (standard digital input) can be configured as probe input for BASIC control sections and for double axis control sections, which have one rapid digital input per axis. 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

Optional Device Functions

- – CSB01.1N-AN-… → BASIC ANALOG
- **One** rapid digital input and **one** slow digital input **per axis**
  - – CSB01.1N-SE-… → BASIC sercos
  - – CSB01.1N-PB-… → BASIC PROFIBUS
  - – CSB01.1C… → BASIC UNIVERSAL (single-axis)
  - – CDB01.1C-… → BASIC UNIVERSAL (double-axis)
- **Two** rapid digital inputs:
  - – CSH01.1C-... → ADVANCED
  - – IndraDrive Mi

The terminal designations of the "rapid" digital inputs can be taken from the section "I/O extensions" in the document "Control Sections for 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 selection probe 1
- S-0-0427, Signal selection probe 2
- S-0-0428, Probe, IDN-list signal selection
- S-0-0524, Dead time compensation, positive edge, probe 1
- S-0-0525, Dead time compensation, negative edge, probe 1
- S-0-0526, Dead time compensation, positive edge, probe 2
- S-0-0527, Dead time compensation, negative edge, probe 2
- P-0-0200, Start position probe function 2 active
- P-0-0201, End position probe function 2 active
- P-0-0202, Difference probe values 1
- P-0-0203, Difference probe values 2
- P-0-0204, Start position probe function 1 active
- P-0-0205, End position probe function 1 active
- P-0-0206, Probe 1, max. number of marker failures
- P-0-0207, Probe 2, max. number of marker failures
- P-0-0224, Probe 1, number of marker failures

Optional Device Functions

- 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
- A0403 Quick stop with probe detection is active
- C0250 Probe inputs incorrectly configured

9.13.2   Functional Description

General Probe Function

The probe input evaluates the voltage level of the probe signal in digital form, i.e. only the 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.

> ℹ️ 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.
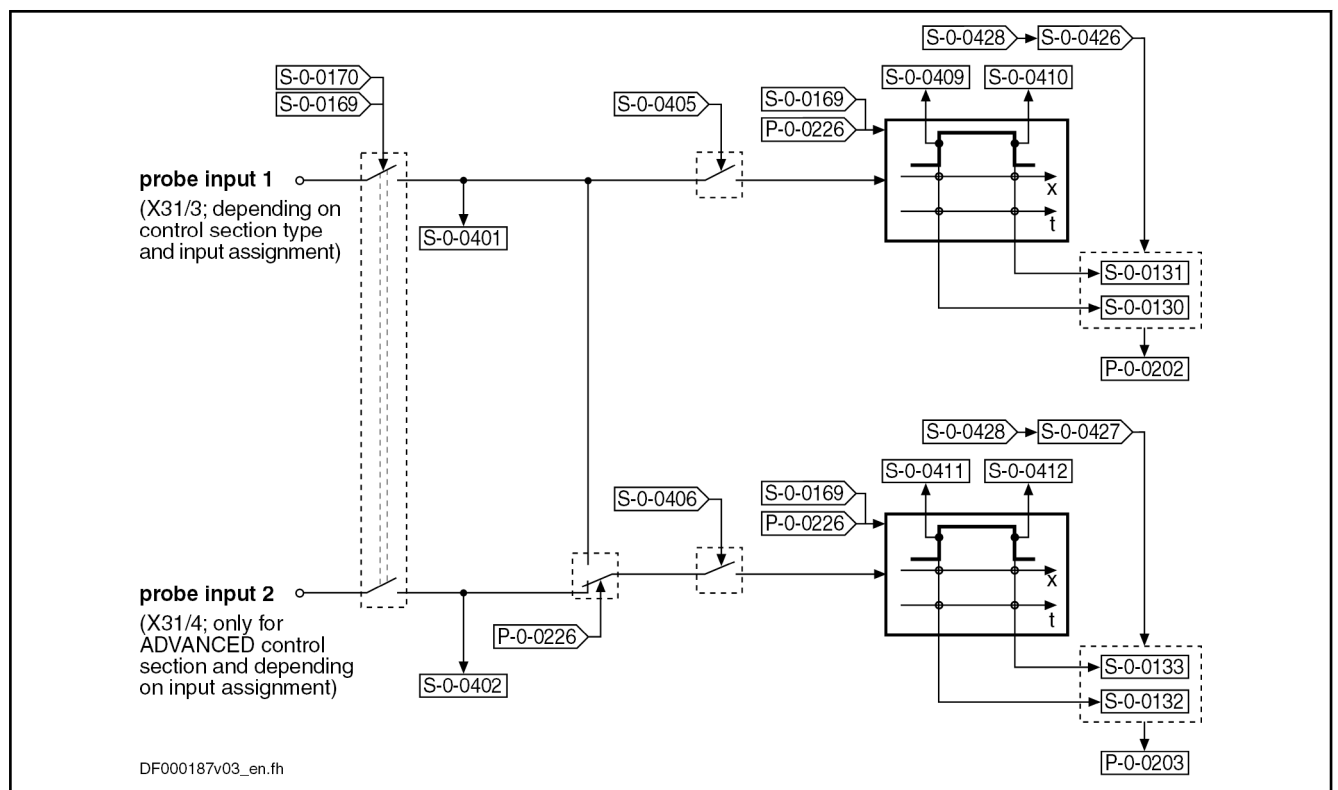
DF000187v03_en.fh

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.9-101:   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!

Optional Device Functions

☞   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 de-
tection

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 recor-
ded when the following requirements have been fulfilled:

- The presetting for measured value detection with positive and/or nega-
  tive switching edge at the respective probe input was activated in
  "S-0-0169, Probe control parameterProbe 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 Operation mode (OM)

  – Setting bit 8 in "S-0-0169, Probe control parameter"

    → At the transition from Parameter mode (PM) to Operation mode
    (OM), command S-0-0170 is automatically set (see Parameter De-
    scription 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").
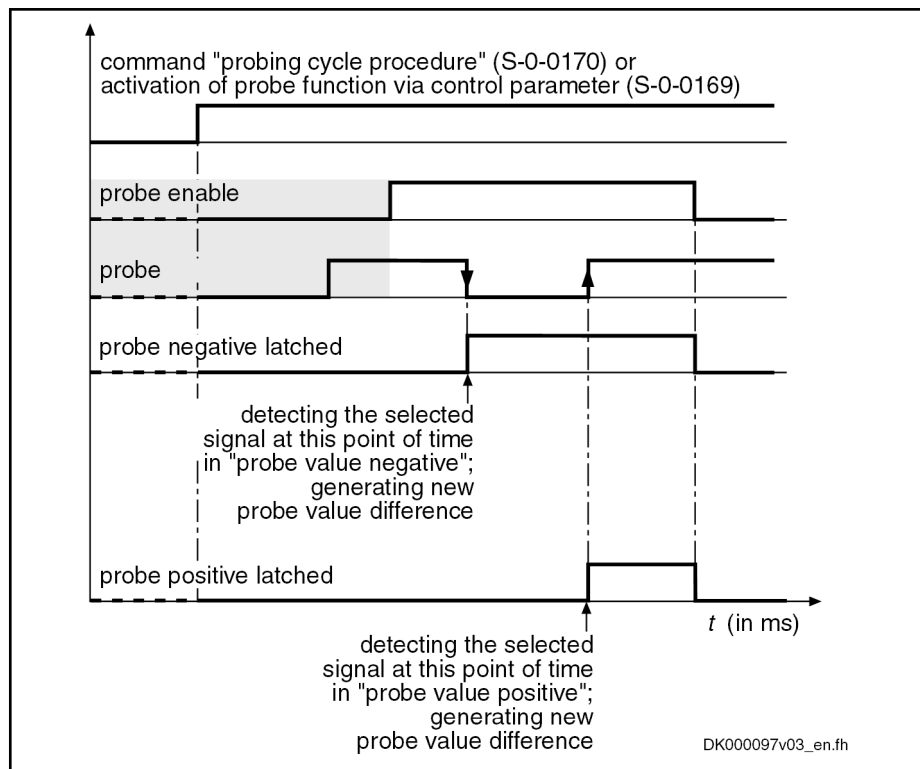
Fig.9-102:   *Evaluating the probe signal edges (evaluation of positive and negative*
              edges activated in parameter "S-0-0169, Probe control parameter")

Optional Device Functions

Mode of measured value record-ing

In parameter "S-0-0169, Probe control parameter", it is possible to set, separately for probe 1 and probe 2, in which mode the measurement is to take place. The measured value recording must have been activated.

The following enable modes are possible:

- **Single measurement**

    → After the respective probe has been enabled (S-0-0405 or S-0-0406), a value is only recorded at the first measured value trigger. Before every other measurement, repeated probe enable is required!

- **Continuous measurement**

    After the respective probe has been enabled (S-0-0405 or S-0-0406), a new measured value is recorded at each measured value trigger.

Time measurement, monitoring, simultaneous triggering

In addition, other modalities of measured value detection can be preset in parameter "P-0-0226, Probe, extended control word" :

- Switching from position measurement to time measurement.

- Limitation of a range for actual position values ("expectation window") in which measurements can take place. A "trigger failure monitor" can be activated for the "expectation window" which registers the passing through of this range without probe event.

- Simultaneous triggering of both probe evaluations via probe input 1, e.g. for simultaneous position and time measurement.

Selecting the measuring signal

The selection of the signal the value of which is measured at the respective measured value trigger takes place by entering the respective IDN in the corresponding parameter

- S-0-0426, Signal selection probe 1

- S-0-0427, Signal selection probe 2

The IDNs of the parameters assigned to the selectable measuring signals are listed in parameter "S-0-0428, Probe, IDN-list signal selection":

- S-0-0051, Position feedback value 1

- S-0-0053, Position feedback value 2

- P-0-0052, Actual position value of measuring encoder

- P-0-0227, Cam table, access angle

- P-0-0753, Position actual value in actual value cycle

- P-0-0775, Resulting master axis position

- P-0-0776, Effective master axis position

If the time measurement for a probe input is to be 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

Optional Device Functions

Storing measured values and measured value differences

Depending on the switching edge of the probe signal activated as the 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

With 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 parameter "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 measured signal value or relative time value corresponding to the time of the signal edge is determined by linear interpolation between the last and the next measured signal value or relative time value generated by the controller.

The accuracy of the measurement result depends mainly on the hardware used (controller type and periphery connected to the probe input, such as sensors, switches or line capacities). Depending on the controller type, a certain dead time is added to signal edge detection. This dead time is partly compensated by the firmware. The dependency of measuring accuracy on the control unit - type A design is described in section "Probes" in the document "Control Sections for Drive Controller; Project Planning Manual".

The additional dead time resulting from the connected periphery can also be compensated by the drive firmware for each edge of a probe within a range of up to 50000µs by presetting in the parameters

- S-0-0524, Dead time compensation, positive edge, probe 1

Optional Device Functions

- S-0-0525, Dead time compensation, negative edge, probe 1
- S-0-0526, Dead time compensation, positive edge, probe 2
- S-0-0527, Dead time compensation, negative edge, probe 2

.

Restart or deactivation of measured value recording

A restart of the single measurement or the continuous measurement is triggered by resetting (1 → 0) and repeated setting (0 → 1) of the parameters for probe enable:

- S-0-0405, Probe 1 enable
- S-0-0406, Probe 2 enable

When doing this, the following data is cleared:

- Information on probe value trigger status (S-0-0409/S-0-0410 or S-0-0411/S-0-0412) and bits for respective probe in parameter "S-0-0179, Probe status"
- The counter in parameter "P-0-0224, Probe 1, number of marker failures" or "P-0-0225, Probe 2, number of marker failures" (see below)

☞   By activating or deactivating the probe evaluation ("S-0-0170, Probing cycle procedure command" or via corresponding bit in "S-0-0169, Probe control parameter"), reinitialization (resetting all bits in parameter "S-0-0179, Probe status") is carried out.

Using the "Expectation window"

The position range of an axis or shaft within which probe signal edges cause measured values to be recorded can be limited. With limitation, measured value trigger signals are only expected within position limits that can be set, this range is therefore called the "expectation window". The measured value detection limited to the "expectation window" is activated in parameter "P-0-0226, Probe, extended control word".

Detecting marker failures with activated "expectation window":

- If the actual position value is outside of the "expectation window", probe signal edges do not cause measured values to be recorded!

  If no "marker" was detected causing a measuring value trigger, after completely passing through the expectation windows (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":

Optional Device Functions

- At "activation negative edge of probe", a negative signal edge was detected

- At "activation positive edge of probe", a positive signal edge was detected

- At "activation positive and negative edge of probe", positive and negative signal edges were detected

☞ When the measuring signal only enters the "expectation window" and leaves it on the same side, all detected signal edges are cleared. The parameter values of the marker failure counters P-0-0224 and P-0-0225, however, are not changed!

Setting the expectation window   The limitation values for the "expectation window" are set in the following parameters.

Setting for probe 1:

- P-0-0204, Start position probe function 1 active

- P-0-0205, End position probe function 1 active

Setting for probe 2:

- P-0-0200, Start position probe function 2 active

- P-0-0201, End position probe function 2 active

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:

$$\text{Probe 1} \quad s_{min} = (\text{P-0-0205}) - (\text{P-0-0204}) \geq v_{max} \times \Delta t$$
$$\text{Probe 2} \quad s_{min} = (\text{P-0-0201}) - (\text{P-0-0200}) \geq v_{max} \times \Delta t$$

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.9-103:   Determining the minimum value for the "expectation window"

With modulo scaling of the position data, a maximum value for the "expectation window" must not be exceeded, as otherwise it exceeds the modulo value range and therefore is without effect:

$$s_{max} = (\text{S-0-0103}) - s_{min}$$

s_{max}	Maximum value for "expectation window"
s_{min}	Minimum value for "expectation window"
S-0-0103	Modulo value

Fig.9-104:   Determining the maximum value for the "expectation window" with modulo scaling

Optional Device Functions

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 operation mode until the readiness for quick stop is reset.

To keep the delay between edge reversal of the signal and triggering of quick stop as short as possible, the rapid digital input for probe 1 is used for this function.

The rapid digital input (probe input 1) evaluates the voltage level of the stop signal in digital form, i.e. only the signal states "high" (1) or "low" (0) are recognized.

Quick stop is triggered at a rising (positive) switching edge.

ℹ️ 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:
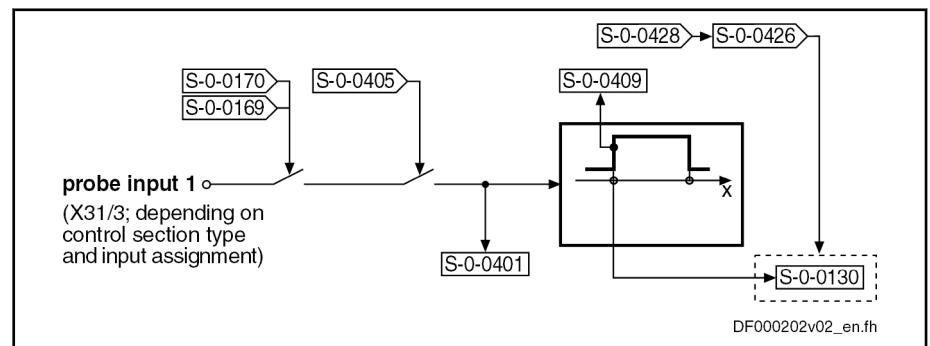
S-0-0130	Probe value 1 positive edge
S-0-0169	Probe control parameter
S-0-0170	Probing cycle procedure command
S-0-0401	Probe 1
S-0-0405	Probe 1 enable
S-0-0409	Probe 1 positive latched
S-0-0426	Signal select probe 1
S-0-0428	Probe, IDN list signal selection

Fig.9-105: 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.

Optional Device Functions

☞   The rapid digital input (probe 1) must have been assigned to pa-
rameter 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 selection probe 1".

The IDNs of the selectable parameters assigned to the status variables are
listed in "S-0-0428, Probe, IDN-list signal selection".

Storing measured values   The value of the signal selected from list parameter S-0-0428 is stored in pa-
rameter "S-0-0130, Probe value 1 positive edge" when the signal edge oc-
curs.

Activating readiness for quick stop   A positive switching edge (0 → 1) at the rapid digital input (probe input 1) trig-
gers 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 parame-
ter "S-0-0405, Probe 1 enable"
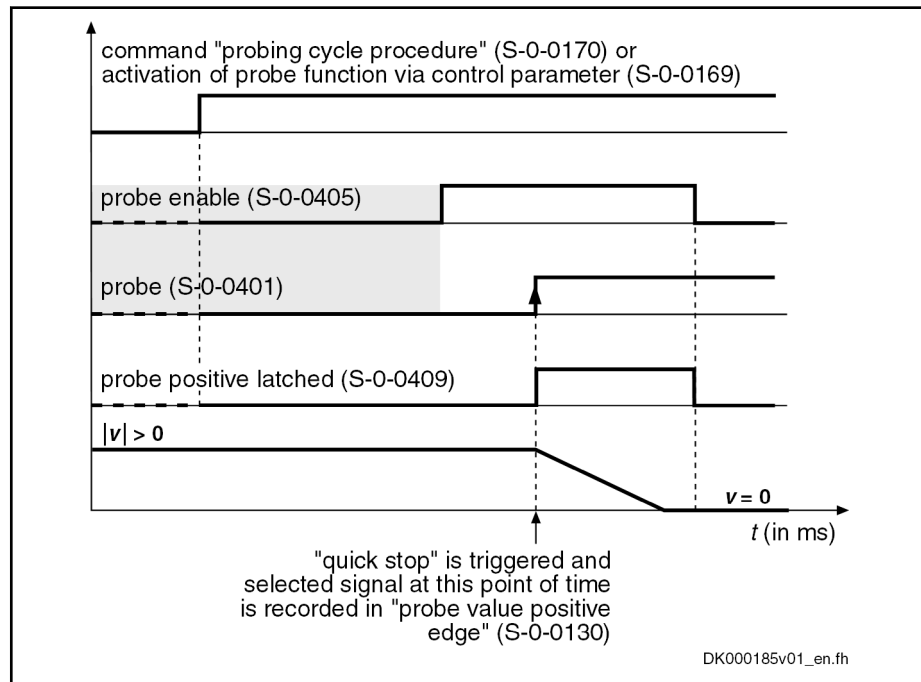
Fig.9-106:   Evaluating the signal for the quick stop function

Executing the quick stop function   The readiness for quick stop and the detection of the quick stop signal inter-
nally 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

Optional Device Functions

With quick stop, the drive ignores the setting of command values by the control master, decelerates in a drive-controlled way and remains in a drive-internal operation mode until the readiness for quick stop is reset. Quick stop is displayed by the drive by means of diagnostic status message "A0403 Quick stop with probe detection is active" in parameter "S-0-0095, Diagnostic message" and by means of the **operation status "AR" in the display** of the control panel.

Behavior after deactivation of quick stop function   With deactivation of the readiness for quick stop, the drive leaves the quick stop status and again follows the command value of the control master.

9.13.3   Notes on Commissioning

Commissioning the Probe Function

Presettings   Make the following settings in "S-0-0169, Probe control parameter":

- Evaluation of probe signal edge as measured value trigger
- Select enabling mode of probe (single measurement or continuous measurement)

Make further settings in parameter "P-0-0226, Probe, extended control word":

- Activation of expectation window and failure monitor
- Activation of time measurement
- 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 selection probe 1
- S-0-0427, Signal selection probe 2

Activating the measurement   The measured value detection can be activated via:

- "S-0-0170, Probing cycle procedure command" (only in Operation mode)

- or -

- "S-0-0169, Probe control parameter" (bit 8)

  → S-0-0170 is automatically activated during transition PM → OM

Then enable the probe input for triggering the measured value recording:

- S-0-0405, Probe 1 enable
- S-0-0406, Probe 2 enable

Single measurement   Every repeated "single measurement" has to be enabled by resetting and repeatedly setting S-0-0405 or S-0-0406.

Continuous measurement   If enabling of the probes via S-0-0405 or S-0-0406 has been set with "continuous measurement", a measured value is stored at every measured value trigger. How many measured values were stored by positive or negative trigger of the respective probe, is contained in the status information on the

Optional Device Functions

Identifying the measured value detection

measured value trigger (see below "Identifying the Measured Value Detection").

When a measuring event has taken 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:

$$P\text{-}0\text{-}0202 = \left|(S\text{-}0\text{-}0130) - (S\text{-}0\text{-}0131)\right|$$

$$P\text{-}0\text{-}0203 = \left|(S\text{-}0\text{-}0132) - (S\text{-}0\text{-}0133)\right|$$

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.9-107:   *Subtraction of the measured values*

☞ The differences from the measured values of the positive and negative edges are always generated, even if only one edge polarity has been activated for the measured value trigger!

Setting the "expectation window"

Set the limits of the "expectation window" taking the minimum value and, if necessary, the maximum value (for modulo scaling) into account. The "expectation window" must have been activated in parameter P-0-0226.

Setting for probe 1:

- P-0-0204, Start position probe function 1 active
- P-0-0205, End position probe function 1 active

Setting for probe 2:

- P-0-0200, Start position probe function 2 active
- P-0-0201, End position probe function 2 active

If "marker failure monitoring" has been activated (P-0-0226), the number of times the "expectation window" is passed through without marker detection is displayed in:

- P-0-0224, Probe 1, number of marker failures
- P-0-0225, Probe 2, number of marker failures

The user can set a threshold for the counted marker failures:

- • P-0-0206, Probe 1, max. number of marker failures
- • P-0-0207, Probe 2, max. number of marker failures

When the number of marker failures has reached the threshold, the respective bit is set in:

- • S-0-0179, Probe status

Resetting   The measuring data, the measured value trigger status and the information on the marker failure are cleared by writing data to:

- • S-0-0405, Probe 1 enable
- • S-0-0406, Probe 2 enable
- • 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", select the parameter of the measuring signal the value of which is stored when the quick stop signal is read. Enter the selected parameter in:

- • S-0-0426, Signal selection probe 1

Activating readiness for quick stop   With the corresponding presetting, the readiness for quick stop can now be activated via the enable signal of the rapid digital input (probe 1) by setting:

- • S-0-0405, Probe 1 enable

Measured value at quick stop request   When quick stop is executed, the measured value belonging to the quick stop signal edge is stored in:

- • S-0-0130, Probe value 1 positive edge

Deactivation   The quick stop situation or the readiness for quick stop is deactivated by

- • Resetting "S-0-0405, Probe 1 enable"

- or -

- • Deactivating "S-0-0170, Probing cycle procedure command"

- or -

- • Resetting bit 8 in "S-0-0169, Probe control parameter"
  - → Function only deactivated when changing to parameter mode

☞   If the control master operates the drive in cyclic position control, set the actual position value of the drive as start value for the cyclic position command values, when the quick stop function is deactivated!

9.14   Measuring Encoder

9.14.1   Brief Description

💡   Assignment to functional firmware package, see chapter "Availability of the Optional Device Functions".

Optional Device Functions

Position measurement	Measuring encoders are used for position evaluation of a rotary motion that takes effect as a command variable for drive control. The actual position value of the measuring encoder therefore is of command value nature for drive control, the measuring encoder 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	With 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	With absolute position measurement, the encoder signals actual position values with a fixed encoder-dependent dedicated 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 is displayed!

[i] See also separate documentation "Control Sections for Drive Controllers; 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-0-0084, Number of bits per master axis revolution
- P-0-0087, Actual position value offset of measuring encoder

- P-0-0097, Absolute encoder monitoring window for measuring encoder
- P-0-0127, Input revolutions of measuring gear
- P-0-0128, Output revolutions of measuring gear
- P-0-0179, Absolute encoder buffer 3 (measuring encoder)
- P-0-0326, Multiplication of measuring encoder
- P-0-0327, Encoder resolution of measuring encoder
- P-0-0328, Type of position encoder for measuring encoder
- P-0-0329, Smoothing of actual position value 3 of measuring encoder
- P-0-0330, Control word of measuring encoder
- P-0-0331, Status of measuring encoder
- P-0-0332, Actual velocity value of measuring encoder
- P-0-0334, Absolute encoder range of measuring encoder
- P-0-0347, Encoder 3, cosine signal
- P-0-0348, Encoder 3, sine signal
- P-0-0765, Modulo factor measuring encoder
- P-0-1020, Kind of encoder 3, encoder memory
- P-0-1021, Encoder 3 resolution, encoder memory
- P-0-1022, Absolute encoder offset 3, encoder memory

Pertinent diagnostic messages

- C0161 Incorr. prarmeterization 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

9.14.2   Functional Description

Basics on Measuring Encoder, Resolution

The measuring encoder is mechanically connected to an axis or shaft and detects its position data. This 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 assignment is made in parameter "P-0-0076, Encoder type 3 (measuring encoder)".

Scaling of measuring encoder position data

The scaling of the position data generated with a measuring encoder is rotary and axis- or shaft-related. Due to the infinite motion range of the measuring encoder and the limited value range of the position data, modulo scaling is set automatically.

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:

Optional Device Functions

$$\text{Modulo range} = \boldsymbol{n} \times (\text{axis or shaft revolutions})$$
$$\boldsymbol{n} = (\text{P-0-0765}) \leq 2^{31-(\text{P-0-0084})} - 1; \quad \boldsymbol{n} \in \boldsymbol{N}$$
$$\text{If (P-0-0765)} = 0 \rightarrow \boldsymbol{n} = 2^{32-(\text{P-0-0084})}$$

n	Number of revolutions at axis or shaft
P-0-0084	Number of bits per master axis revolution
P-0-0765	Modulo factor measuring encoder
Fig.9-108:	*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.9-109:	*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):

$$\text{Modulo range} = \boldsymbol{n} \times 2^{(\text{P-0-0084})} (\text{increments})$$
$$\boldsymbol{n} = (\text{P-0-0765}) \leq 2^{31-(\text{P-0-0084})} - 1; \quad \boldsymbol{n} \in \boldsymbol{N}$$
$$\text{If (P-0-0765)} = 0 \rightarrow \boldsymbol{n} = 2^{32-(\text{P-0-0084})}$$

n	Number of revolutions at axis or shaft
P-0-0084	Number of bits per master axis revolution
P-0-0765	Modulo factor measuring encoder
Fig.9-110:	*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:

Optional Device Functions

$$\text{Measuring encoder resolution} = \text{(P-0-0326)} \times \text{(P-0-0327)}$$

internal limitation:

$$\text{P-0-0326} = 2^{30} \times \frac{\text{(P-0-0128)}}{\text{(P-0-0127)} \times \text{(P-0-0327)} \times \text{(P-0-0765)}} \leq 2^{n}$$

$$n \leq 15 \text{ (in round numbers)}$$

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.9-111:	*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 formulae "drive-internal measuring encoder resolution" characterizes the encoder dimensioning.
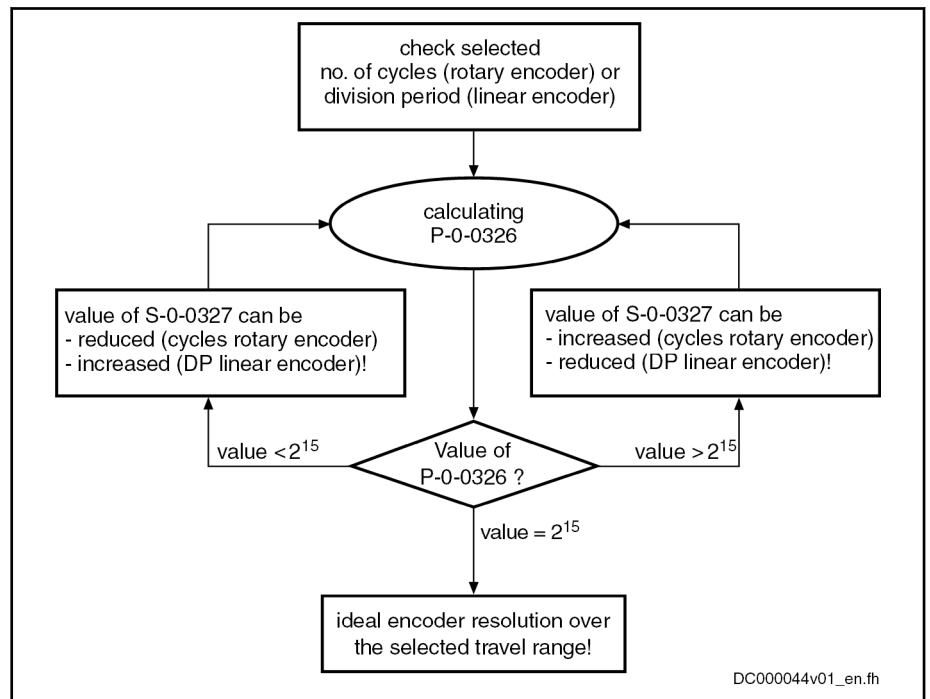
P-0-0326	Multiplication of measuring encoder
P-0-0327	Encoder resolution of measuring encoder
Fig.9-112:	*Checking the selected resolution and determining the ideal resolution for the measuring encoder*

☞   The value of P-0-0326 calculated according to the formulae "drive-internal measuring encoder resolution" is normally never 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!

Optional Device Functions

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 correspond 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

☞　　　Error message F2037 can be deactivated by reconfiguring it into a warning (E2037). This takes place in "P-0-0173, List of configurable axis-specific monitors". There is then no drive-side error reaction. It is then the responsibility of the user to initiate an appropriate reaction via the control master.

Monitoring the axis or shaft position

When the drive is switched off, the current encoder data of an absolute measuring encoder is 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 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 no longer exists. It sets "P-0-0331, Status of measuring encoder" to "not homed" and

Optional Device Functions

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".

| **NOTICE** | When the position data reference is established, the actual position value of the measuring encoder can change abruptly! |

⇒ If the actual position value is used as the command variable of the drive, the control master has to take this into account when establishing the position data reference!

Establishing Position Data Reference for Measuring Encoder to be Evaluated in Absolute Form

Activating "set absolute 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 Set absolute position procedure command".

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, Set absolute position control". 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".

Optional Device Functions

$$[P\text{-}0\text{-}0052]_{NEW} = P\text{-}0\text{-}0087$$

P-0-0052   Actual position value of measuring encoder
P-0-0087   Actual position value offset of measuring encoder

Fig.9-113:   Actual position value of the measuring encoder after "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 enables recognition of 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.

"Set absolute position" procedure

The command "set absolute measuring" can only be activated when the drive is ready for operation but inactive ("bb", "AB") for the measuring encoder.

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.

☞   With 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.

Optional Device Functions

☞ When reference mark evaluation has been activated, only the reference mark that was read first is evaluated, other reference marks are ignored!

The new actual position value at the dedicated position after homing is the value of parameter "P-0-0087, Actual position value offset of measuring encoder".

$$[P\text{-}0\text{-}0052]_{NEW} \quad = \quad P\text{-}0\text{-}0087$$

P-0-0052   Actual position value of measuring encoder
P-0-0087   Actual position value offset of measuring encoder
Fig.9-114:   *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 is then to be deactivated in the respective bit of parameter "P-0-0330, Control word of measuring encoder"!

☞ When a measuring encoder gear is used, the occurrence of the reference mark of the encoder with reference to the actual position value of the axis or shaft to be measured mostly is not unequivocal! On the control side, it is necessary to make sure that the reference mark evaluation is activated at the appropriate axis or shaft position (identification by initiator or similar)!

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) into parameter P-0-0087.

9.14.3   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

Optional Device Functions

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 less than the absolute encoder range of the measuring encoder, it can be evaluated as an 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 the 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

Optional Device Functions

☞ 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, Set absolute position control".

Actual position value at reference position
Determine the actual position value at the reference position in parameter
- P-0-0087, Actual position value offset of measuring encoder.

Executing "set absolute measuring"
Start "P-0-0012, C0300 Set absolute position procedure command"; after its execution the command has to be cleared again.

See also "Basic Functions of Master Communication: Command processing"

Checking the position data reference
The position status of the measuring encoder is displayed in parameter
- P-0-0331, Status of measuring encoder.

Loss of reference
If the position data reference of the measuring encoder evaluated in absolute form was lost, the following message appears:
- F2176 Loss of measuring encoder reference.

The position data reference must be established again!

Establishing Position Data Reference for Relative Measuring Encoder

Activating homing procedure of measuring encoder
Activate reference mark detection in the respective bit of parameter

- P-0-0330, Control word of measuring encoder.

Actual position value at reference position
Determine the actual position value at the reference 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. prarmeterization 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 Safety Instructions

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

- Keep free and clear of the ranges of motion of machines and moving machine parts.

- Prevent personnel from accidentally entering the machine's range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).

- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.

- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

10.2 Parameters, Basics

10.2.1 Properties/Features of Parameters

Brief Description

The firmware of the controller uses data to map the drive to an internal mathematical model. All operating data relevant for this is mapped to parameters. An identification number (IDN) is assigned to each parameter. The IDN permits access to 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 and 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

Handling, Diagnostic and Service Functions

Element no.	Designation	Notes
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 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 or temporarily 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 operation data for CP2

* S-0-0019, IDN-list of operation data for CP3

The control master can query the IDNs of the parameters with invalid operating data (parameter values) via:

* S-0-0021, IDN-list of invalid operation data for CP2

* S-0-0022, IDN-list of invalid operation data for CP3

* S-0-0423, IDN-list of invalid data for parameterization levels

The data status is signaled when the control master executes a write command to the data block element no. 1 of a parameter. This allows the control master to recognize the status of a command started.

See "Basic Functions of Master Communication: Command processing"

Language selection   Parameter "S-0-0265, Language selection" is used to set the language in which parameter names and text in units of parameter values are displayed.

☞   The language selection made via parameter S-0-0265 only takes effect in parameter "S-0-0095, Diagnostic message", when the diagnostic message also changes after language selection.

Handling, Diagnostic and Service Functions

Notes on Commissioning

During the drive-internal check of parameter values carried out when changing from parameter mode to operating mode, the following command errors can be signaled:

- C0201 Invalid parameters (->S-0-0423)
- C0202 Parameter limit error (->S-0-0423)

- or -

- C0201 Invalid parameters (->S-0-0423)
- C0202 Parameter limit error (->S-0-0423)
- C0203 Parameter conversion error (->S-0-0423)

When errors of this category are detected, the IDNs of the parameters with the incorrect operating data are listed in:

- S-0-0021, IDN-list of invalid operation data for CP2
- S-0-0022, IDN-list of invalid operation data for CP3
- S-0-0423, IDN-list of invalid data for parameterization levels

A valid value has to be written to the listed IDNs. The value range limits are contained in the data block elements no. 5 and no. 6. When inputting single parameters, the limits are directly displayed via the "IndraWorks Ds/D/MLD" commissioning tool.

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.

10.2.2   Loading, Storing and Saving Parameters

Brief Description

Parameters   All relevant operating data is 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)

Handling, Diagnostic and Service Functions

Application-specific parameter values can be saved via:

- MMC → Copying the parameter values by command
- "IndraWorks Ds/D/MLD" 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 serial 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)

Options for 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 Ds/D/MLD" 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 all backup operation data
- S-0-0262, C07_x Load defaults procedure command
- S-0-0263, C2300 Load working memory procedure command
- S-0-0264, C2200 Backup working memory procedure command
- S-0-0269, Storage mode
- S-0-0270, IDN-list of selected backup operation data
- S-0-0293, C2400 Selectively backup working memory procedure command
- S-0-0326, Parameter checksum
- S-0-0327, IDN list of checksum parameter
- S-0-0531, Checksum of backup operation data
- P-0-0013, List of all IDNs not corresponding to default value
- P-0-4023, C0400 Communication phase 2 transition
- P-0-4065, Active non-volatile memory
- P-0-4070, Parameter storage configuration
- P-0-4090, Configuration for loading default values

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- 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):

- C0700 Load defaults proced. command (motor-spec. controller val.)
- C0702 Default parameters not available
- C0703 Default parameters invalid
- C0704 Parameters not copyable
- C0706 Error when reading the controller parameters

Load defaults procedure (loading basic parameters):

- C0750 Load defaults procedure command (factory settings)
- 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

Selective 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 control-
ler**   All operating data that relates to hardware is stored in the drive controller and 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 also stored in the flash memory.

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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

With 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.

Storage medium MultiMediaCard (MMC)

The MultiMediaCard (MMC) is a non-volatile storage medium that can be permanently or temporarily plugged into the slot provided for this purpose on the front of the drive controller. The MMC is not essentially required!

Depending on the setting in parameter "P-0-4070, Parameter storage configuration" the MMC can be used as:

- Programming module

  → Permanently plugged medium for saving the firmware and the application-specific parameter values

- or -

- Update/init medium

  → Temporarily plugged medium for firmware update or for transmission of application-specific parameter values

- or -

- Backup medium

  → Temporarily plugged medium for intermediate storage of backup data (access via command or by file services)

Parameter and operation 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
- Operation mode (OM).

As a matter of principle, all parameters that can be changed can be written in Parameter mode.

"Load defaults procedure" command (loading basic parameters)

Command "S-0-0262, C07_x Load defaults procedure command" is used 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 def. proc. for safety techn."

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→ See separate documentation "Integrated Safety Technology"

- **Scaling of command execution** (bits 4...7):

  With the command "load basic parameters", there is an 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 PLC parameters

  ℹ️ See also Parameter Description "P-0-4090, Configuration for loading default values"

Storage mode

Depending on "S-0-0269, Storage mode", the application-specific parameter values are stored in the controller in volatile form (in the working memory) or non-volatile form (in the flash memory).

Non-volatile storage is carried out with each write access to the respective operating data.

Volatile storage of parameter values is recommended when application-specific parameters are cyclically written. Otherwise, the service life of the non-volatile storage media is affected.

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

⇒ During the execution of some commands (see Description of the Respective Diagnostic Command Message; e.g. C0500), data is written to the internal memory (flash), too. This memory, however, only allows a limited number of write access. For this reason, ensure that write access like this is not performed too often.

Parameter IDN lists

To save the relevant application-specific parameter values the drive makes lists of IDNs that support the complete storage of the values of parameter groups:

- S-0-0192, IDN-list of all backup operation data
- S-0-0270, IDN-list of selected backup operation data

Parameter S-0-0192 contains a list of IDNs that cannot be modified. Parameter S-0-0270 contains an empty list in which it is possible to enter certain IDNs according to application-specific requirements.

To save all parameter values, the drive offers 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, List of all IDNs not corresponding to default value.

"Backup working memory procedure" or "Selective backup working memory procedure" command

If the option "volatile storage" has been 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 by starting "S-0-0264, C2200 Backup working memory procedure command".

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

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activated. Unless the storage mode (S-0-0269) is changed, the values once saved in the flash memory via the commands C2200 or C2400 remain unchanged.

"Load working memory procedure" command

"S-0-0263, C2300 Load working memory procedure command" is used to copy the values from the non-volatile flash memory 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!).

- **"IndraWorks Ds/D/MLD"commissioning tool**

  → The parameter values of the list of S-0-0192 are stored on an external data carrier (hard disk, floppy disk or the like); 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 "P-0-4091, C2500 Copy IDN from optional memory to internal memory"**

  → 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.

- **"IndraWorks Ds/D/MLD"commissioning tool**

  → 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 via list parameter S-0-0327

When reading the parameter "S-0-0326, Parameter checksum", the checksum of all parameter values is formed, 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 have been no IDNs entered in parameter S-0-0327!

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Parameter checksum via list parameter S-0-0192

When reading the parameter "S-0-0531, Checksum of backup operation data", the checksum of the active non-volatile memory of the parameters is formed, the IDs of which are contained in parameter "S-0-0192, IDN-list of all backup operation data".

> ☞   In list parameter S-0-0192, the IDNs of those parameters are stored, the values of which are axis-specific and for regular operation have to be loaded to the drive of the respective axis.

When the installation has been completely set up, the checksum for each drive can be read via parameter S-0-0531. The control master can store these values. By comparing the checksum which was saved to the new checksum which was read, it is possible to find out whether data relevant to operation have changed.

Notes on Commissioning

Initial commissioning

At the beginning of the initial commissioning of a motor or a machine axis, first make sure the desired firmware is active in the drive. To do this, read parameter

- S-0-0030, Manufacturer version.

If the desired firmware is not available in the controller, carry out firmware update or firmware upgrade (see "Firmware Replacement").

Loading 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. Make definitions in parameter "P-0-4090, Configuration for loading default values".

2. Start of "S-0-0262, C07_x Load defaults procedure command"

Respective diagnostic command message:

- C07_1 Load defaults procedure command (factory settings)

Respective diagnostic messages with possibly occurring command errors:

- C0751 Parameter default value incorrect (-> S-0-0423)

- C0752 Locked with password

See also "Initial Commissioning/Serial Commissioning"

Loading motor-specific control loop parameter values

After 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 "Esc" on the control panel

- or -

- Starting the 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 with motors with encoder data memory, by starting

- S-0-0262, C07_x Load defaults procedure command.

NOTICE	By executing this command, control loop parameter values that have already been optimized are possibly overwritten!

⇒ Enter optimized control loop parameter values again!

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| ☞ | By automatic reset, the parameter "P-0-4090, Configuration for loading default values" is correctly preset! |

| ☞ | With 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 Ds/D/MLD" commissioning tool. |

Respective diagnostic command message:

- C0700 Load defaults proced. command (motor-spec. controller val.)

Respective diagnostic messages with possibly occurring 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" has been set in parameter "S-0-0269, Storage mode", the parameter values are not automatically stored in the drive-internal flash memory. After complete input, the application-specific parameter values therefore have to be saved drive-internally in the flash memory by

- Start of "S-0-0264, C2200 Backup working memory procedure command".

This guarantees that the parameter values suitable for the axis are automatically loaded to the controller's working memory from the flash memory after the drive is switched on again.

Respective diagnostic command message:

- C2200 Backup working memory procedure command

Respective diagnostic messages with possibly occurring command errors:

- C2202 Error when writing data to non-volatile memory

After all application-specific parameter values are saved (C2200), it is also possible to only save selected parameter values in the flash memory. These parameters are overwritten with a current value. This is done by

- Start of "S-0-0293, C2400 Selectively backup working memory procedure command".

The C2400 command can be used for internally saving a parameter group the values of which have to be optimized again during operation, for example. It is advisable to determine the IDNs of this parameter group by clearing IDNs that are not required from the default setting of the list parameter

- S-0-0270, IDN-list of selected backup operation data.

| ☞ | In the case of the "volatile storage" mode, the command C2200 has to be executed at least once before starting the command C2400, because otherwise basic parameter values are maintained for some parameter values in the flash memory. |

Respective diagnostic command message:

- C2400 Selectively backup working memory procedure command

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Respective diagnostic messages with possibly occurring 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 Ds/D/MLD"

An appropriate master communication interface or the serial interface can be used for loading and saving parameter values via the control master or "IndraWorks Ds/D/MLD".

Loading saved parameter values according to list parameter S-0-0192 to re-establish the initial status after initial commissioning is impossible with drives with absolute value encoder and modulo scaling (see note).

NOTICE	The backup of the parameter values made after initial commissioning according to. S-0-0192 cannot reestablish the initial parameter status. The actual position value after the loading process would be incorrect, but this cannot be detected on the controller side!

With drives with absolute value encoder and modulo scaling, the backup of parameter values made after initial commissioning acc. to S-0-0192 must not be loaded for reestablishing the initial parameter status!

For how to reestablish the initial status of parameters for drives with absolute value encoder and modulo scaling, see "Initial Commissioning/Serial Commissioning"!

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 starting the commands "S-0-0127, C0100 Communication phase 3 transition check" and "S-0-0128, C5200 Communication phase 4 transition check" one after the other!

When reading and writing individual parameters via the control master or "IndraWorks Ds/D/MLD" (without command), the following error messages can 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

10.2.3   IDN Lists of Parameters

General Information

Some of the parameters stored in the drive contain, as their operating data (parameter value), a list of IDNs of drive parameters corresponding to a specific, given criterion. These so-called IDN lists enable the master or a commissioning software to handle drive parameters in a specific way.

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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 all Backup Operation Data (S-0-0192)

The parameter "S-0-0192, IDN-list of all backup operation data" contains the IDNs of all parameters that are stored in the non-volatile memory [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 Operation Data for Phase 2 (S-0-0021)

In parameter "S-0-0021, IDN-list of invalid operation data for CP2" the IDNs of those parameters are automatically entered which the drive software detects as being invalid when executing the command "S-0-0127, C0100 Communication phase 3 transition check".

Parameters are detected as being invalid, if:

- Their checksum does not match the operating data [the checksum is stored together with the operating data in a non-volatile memory (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 operation data for CP2" upon negative acknowledgement of command "S-0-0127, C0100 Communication phase 3 transition check" must be corrected.

IDN List of Invalid Operation Data for Phase 3 (S-0-0022)

In parameter "S-0-0022, IDN-list of invalid operation data for CP3" the IDNs of those parameters are automatically entered which the drive software detects as being invalid or prohibitively configured when executing the command "S-0-0128, C5200 Communication phase 4 transition check".

Parameters are detected as being invalid, if:

- Their checksum does not match the operating data [the checksum is stored together with the operating data in a non-volatile memory (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 operation data for CP3" upon negative acknowledgement of command "S-0-0128, C5200 Communication phase 4 transition check" must be corrected.

IDN List of Invalid Data for Parameterization Levels (S-0-0423)

When the command "C0200 Exit parameterization level procedure command" is executed, the drive parameters are checked and converted. If errors occur during this check, the IDNs of the faulty parameters are written to the list parameter "S-0-0423, IDN-list of invalid data for parameterization levels".

IDN List of Operation Data 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 operation data for CP2".

IDN List of Operation Data for Communication Phase 3 (S-0-0019)

The IDNs that are checked for validity when the command "S-0-0128, C5200 Communication phase 4 transition check" is executed are stored in the operating data of parameter "S-0-0019, IDN-list of operation data for CP3".

IDN List of all Command Parameters (S-0-0025)

The IDNs of all the command parameters available in the drive are stored in the operating data of parameter "S-0-0025, IDN-list of all procedure commands".

IDN List of Selected Backup Operation Data (S-0-0270)

The IDNs of parameters that are to be saved when command "S-0-0293 , C2400 Selectively backup working memory procedure command" is executed are stored in the parameter "S-0-0270, IDN-list of selected backup operation data".

IDN List of Password-protected 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 have not been any IDNs entered in this parameter.

IDN List of Checksum Parameters (S-0-0327)

The parameter "S-0-0327, IDN list of checksum parameter" contains the IDNs of those parameters from which the content of parameter "S-0-0326, Parameter checksum" is to be generated. By default, there have not been any IDNs entered in this parameter.

IDN List of all Parameter Values not Corresponding to the Default Value (P-0-0013)

All parameters the operating data of which was changed with regard to the default value are stored in "P-0-0013, List of all IDNs not corresponding to default value".

10.2.4   Using a Password

Brief Description

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

- Parameters that are write-protected as standard, such as motor parameters, hardware code parameters, encoder parameters, error memory, etc. ("administration parameters"). The values of these parameters guarantee the correct function and performance of the drive.

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- 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 all backup operation data
- S-0-0267, Password
- S-0-0279, IDN-list of password-protected operation data
- P-0-4064, Password level

Functional Description

The activation and deactivation of the write protection for parameter values by the three hierarchically different passwords is carried out by an input in parameter "S-0-0267, Password".

Customer password   By a password defined by the customer, the parameters of a parameter group to be defined can be protected against unauthorized or accidental write access.

The customer password has to comply with the following conditions:

- At least 3 characters long
- A maximum of 10 characters long
- May only contain the characters a…z, A…Z and the numbers 0…9

The group of parameters the values of which can be protected by the customer password is defined in "S-0-0279, IDN-list of password-protected operation data". In the condition as supplied the parameter S-0-0279 does not yet contain any data. In the list parameter S-0-0279 it is possible to enter parameter IDNs according to application-specific requirements.

☞ The customer password is not obligatory! If it has not been activated, the values of the parameters listed in the list parameter S-0-0279 can still be written.

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Control password After entering the firmware-specific control password defined by the manufacturer, it is also possible to write parameters protected by a customer password. The control password therefore allows the NC control unit to ignore the write protection established by the individual (unknown) customer password.

> ☞ The control password valid for the respective firmware is only available from the manufacturer on demand!

Master password The master password is defined by the manufacturer, too, but is exclusively available to the Bosch Rexroth development and service staff.

> ☞ The master password is secret! It must not be used on the control unit side or by the customer, because it also allows changing the values of "administration parameters" (motor parameters, hardware code parameters, encoder parameters, error memory, etc.).

Activating/deactivating write protection In the condition as supplied "S-0-0267, Password" contains the value "007". The write protection is activated and deactivated by means of the customer password according to the following procedure:
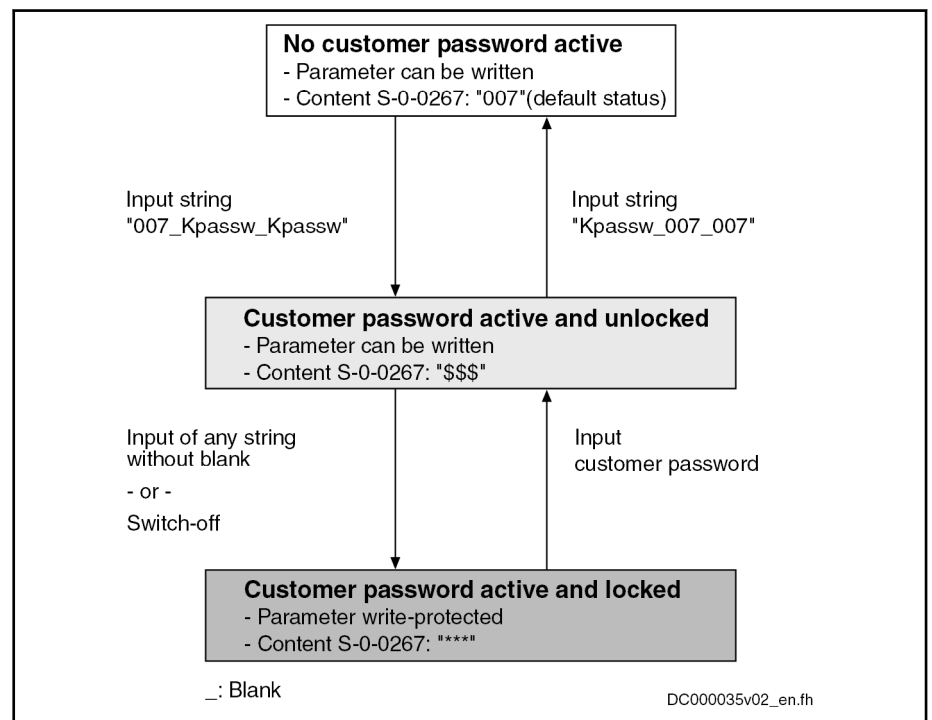
Fig. 10-2:   *Activating and deactivating write protection by means of the customer password*

The write protection activated via the 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 for the Bosch Rexroth development and service staff!

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NOTICE	Incorrect control of motors when changing parameter values write-protected on the firmware side ("administration parameters")!

⇒ The master password must not be used on the control 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, Password level.

Diagnostic message When trying to write data to a write-protected parameter, an error code is sent to the sercos master via the non-cyclic data channel, according to the sercos specification. The master then recognizes that the respective parameter is write-protected and that it is impossible to write data to it.

10.3   Device Configuration

10.3.1   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

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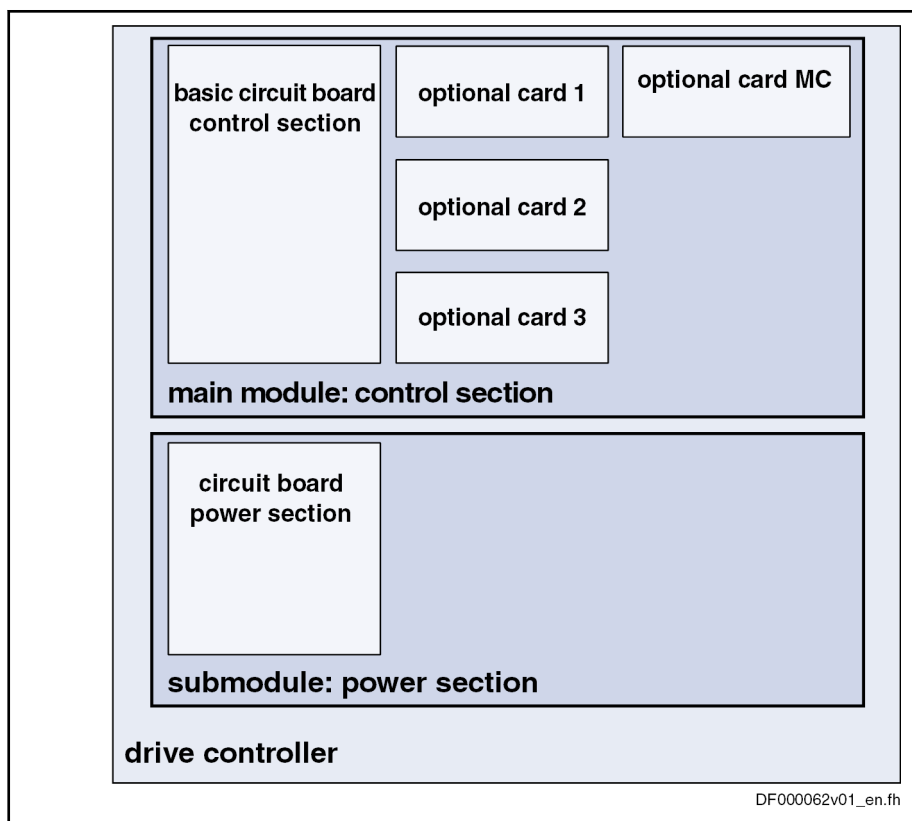
MC   Master communication

Fig. 10-3:   *Example of design including device, modules and circuit boards for IndraDrive controllers*

The modular structure of the IndraDrive controllers allows combinations of control sections and power sections.

Control section	Power section					
	HMS01	HMS02	HMD01	HCS02	HCS03	HCS04.2 (preliminary)
CSH01.1 C [1]	▪	▪	-	▪	▪	-
CSH01.2 C [1]	▪	▪	-	▪	▪	-
CSH01.3 C [1] (preliminary)	▪	▪	-	▪	▪	▪
CSB01.1 N [2]	▪	▪	-	▪	▪	▪

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Control section	Power section					
	HMS01	HMS02	HMD01	HCS02	HCS03	HCS04.2 (preliminary)
CSB01.1 C [1]	■	■	-	■	■	■
CDB01.1 C [1]	-	-	■	-	-	-

■   Allowed
-        Not allowed
1)   Control section can be configured
2)   Control section cannot be configured
Fig.10-4:   *Combination Control Section - Power Section*

☞   **Do not exceed maximum number of plug-in actions!**

For a drive controller, the control section must not be mounted and dismounted more than a maximum of **20 times**. If this number is exceeded, the electrical data of the internal connection can be above the specified minimum requirements. This can cause malfunction of the drive controllers.

Power sections require control sections with appropriate firmware.

Control section type [1]				Firmware version
CSB01	.	1	N	-FC	as of MPB-02VRS
CSB01	.	1	N	-AN	as of MPB-02VRS
CSB01	.	1	C		as of MPB-02VRS
CDB01	.	1	C		as of MPD-02VRS
CSH01	.	1	C		as of MPH-02VRS
CSH01	.	2	C		as of MPH-04VRS to MPH-05VRS
CSH01	.	3	C		as of MPC-06V06

1)   Basic type without configuration
Fig.10-5:   *Required Firmware Version for Control Sections*

Handling, Diagnostic and Service Functions

Product Line		Type current			Design	Supported as of firmware version
HMS01.1N	-	W0020	-	A-07-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0036	-	A-07-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0054	-	A-07-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0070	-	A-07-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0110	-	A-07-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0150	-	A-07-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0210	-	A-07-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0350	-	A-07-	NNNN	MPH-02VRS; MPB-02VRS
HMS02.1N	-	F0028	-	A-07-	NNNN	MPH-05V16; MPB-05V16
	-	F0070	-	A-07-	NNNN	MPH-05V16; MPB-05V16
	-	F0110	-	A-07-	NNNN	MPH-05V16; MPB-05V16
	-	F0110	-	A-07-	S003	MPH-05V16; MPB-05V16
	-	F0150	-	A-07-	NNNN	MPH-05V16; MPB-05V16
	-	F0210	-	A-07-	NNNN	MPH-05V16; MPB-05V16
	-	W0028	-	A-07-	NNNN	MPH-02V24; MPB-02V24 MPH-03V12; MPB-03V12
	-	W0054	-	A-07-	NNNN	MPH-02V24; MPB-02V24 MPH-03V12; MPB-03V12
HMD01.1N	-	W0012	-	A-07-	NNNN	MPD-02VRS
	-	W0020	-	A-07-	NNNN	MPD-02VRS
	-	W0036	-	A-07-	NNNN	MPD-02VRS

Fig.10-6:   Required Firmware Versions for Inverters

Handling, Diagnostic and Service Functions

Product Line		Type current			Design	Supported as of firmware version
HCS02.1E	-	W0012	-	A-03-	LNNN	MPH-02VRS; MPB-02VRS
	-	W0012	-	A-03-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0012	-	A-03-	NNNV	MPH-02V20; MPB-02V20
	-	W0028	-	A-03-	LNNN	MPH-02VRS; MPB-02VRS
	-	W0028	-	A-03-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0028	-	A-03-	NNNV	MPH-02V20; MPB-02V20
	-	W0028	-	S-03-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0054	-	A-03-	LNNN	MPH-02VRS; MPB-02VRS
	-	W0054	-	A-03-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0054	-	A-03-	NNNV	MPH-02V20; MPB-02V20
	-	W0070	-	A-03-	LNNN	MPH-02VRS; MPB-02VRS
	-	W0070	-	A-03-	NNNN	MPH-02VRS; MPB-02VRS
	-	W0070	-	A-03-	NNNV	MPH-02V20; MPB-02V20
HCS03.1E	-	W0070	-	A-05-	LNBV	MPH-02VRS; MPB-02VRS
	-	W0070	-	A-05-	LNNV	MPH-02V11; MPB-02V11
	-	W0070	-	A-05-	NNBV	MPH-02VRS; MPB-02VRS
	-	W0070	-	A-05-	NNNV	MPH-02V11; MPB-02V11
	-	W0070	-	A-15-	PSPV	MPH-02VRS; MPB-02VRS
	-	W0100	-	A-05-	LNBV	MPH-02VRS; MPB-02VRS
	-	W0100	-	A-05-	LNNV	MPH-02V11; MPB-02V11
	-	W0100	-	A-05-	NNBV	MPH-02VRS; MPB-02VRS
	-	W0100	-	A-05-	NNNV	MPH-02V11; MPB-02V11
	-	W0150	-	A-05-	LNBV	MPH-02VRS; MPB-02VRS
	-	W0150	-	A-05-	LNNV	MPH-02V11; MPB-02V11
	-	W0150	-	A-05-	NNBV	MPH-02VRS; MPB-02VRS
	-	W0150	-	A-05-	NNNV	MPH-02V11; MPB-02V11
	-	W0210	-	A-05-	LNBV	MPH-02VRS; MPB-02VRS
	-	W0210	-	A-05-	LNNV	MPH-02V11; MPB-02V11
	-	W0210	-	A-05-	NNBV	MPH-02VRS; MPB-02VRS
	-	W0210	-	A-05-	NNNV	MPH-02V11; MPB-02V11
HCS04.1E	-	F0500	-	A-05-	NNBV	MPH-04V10; MPB-04V10
	-	W0500	-	A-05-	NCBV	MPH-04V10; MPB-04V10
	-	W0500	-	A-05-	NNBV	MPH-04V10; MPB-04V10

Handling, Diagnostic and Service Functions

Product Line		Type current			Design	Supported as of firmware version
HCS04.2E	-	W0290 ...	-	N-04-	NNNN	MPH-06V08; MPB-06V08
	-	W1540	-	N-04-	NNBN	MPB-06V08

Fig.10-7:   *Required Firmware Versions for Converters*

Distributed servo drives KSM01

Product Line		Size, length		Other features	Supported as of firmware version
KSM01.2B	-	041C	-	-	MPB-04V20
	-	061C	-		
	-	071C	-		
	-	076C	-		

Fig.10-8:   *Required Firmware Versions for Distributed Servo Drives*

Distributed drive controllers KMS01

Product Line	Features	Supported as of firmware version
KMS01	B-A018-P-D7-SE-ENH-NN-NN	MPB-06VRS
	B-A018-P-D7-SE-NNN-NN-NN	

Fig.10-9:   *Required Firmware Version for Distributed Drive Controllers*

> ☞ The devices are configured at the factory and can be read via parameters, if required.

10.3.2 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 "Control Sections for Drive Controllers; Project Planning Manual").

An individual parameter is assigned to each slot for a 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 is stored in these parameters.

> ☞ The circuit board codes are stored directly on the circuit board or the respective optional module.

Handling, Diagnostic and Service Functions

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.10-10:   Device configuration and circuit board code with 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 of 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 "Control Sections for Drive Controllers; Project Planning Manual"):

- F8118 Invalid power section/firmware combination
- F8120 Invalid control section/firmware combination

10.3.3   Operating Hours Counter

Brief Description

There are operating hours counters available in the drive that separately record the operating time for the control section and power section. The respective operating time is displayed in 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.

Handling, Diagnostic and Service Functions

In addition, there is an operating hours counter for motors with which the dynamic operating data of the motor is collected and stored.

See section "Diagnostic Data of Motor Operation"

10.3.4   Error Memory (Power Section and Control Section)

Brief Description

In the drive, all errors that occur 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 ensured 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 the 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 have occurred.

Handling, Diagnostic and Service Functions

☞ 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 the power section   If the error concerns the power section, it is additionally stored in parameter "P-0-0194, Error memory power section".

The last 13 errors that occurred and the respective count of the operating hours counter (see P-0-0191) are stored in this parameter.

The error "F8060 Overcurrent in power section", for example, is an error which could occur in the power section. This error would be displayed both in parameter P-0-0193 and in parameter P-0-0194.

10.4   Diagnostic System

10.4.1   Coded Diagnostic Messages of the Drive

Brief Description

The drive provides a diagnostic system including different options that are basically divided into two groups:

- Recognizing and displaying the current drive status by means of drive-internal, priority-dependent generation of diagnostic messages

- Collective messages for various status messages

Additionally, there are parameters for all important operating data the values of which can be transmitted both via master communication (e.g., SERCOS) and a parameterization interface (RS-232/485 in the ASCII protocol or SIS protocol; see "Serial Communication").

Pertinent Parameters   • S-0-0030, Manufacturer version

- S-0-0095, Diagnostic message

- S-0-0140, Controller type

- S-0-0142, Application type

- S-0-0375, Diagnostic numbers list

- 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, Extended safety technology diagnosis

☞ 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 from parameter "P-0-3219, Extended safety technology diagnosis" 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 transferred to a master (control) and displayed and evaluated in service and commissioning software (e.g., "IndraWorks Ds/D/MLD").

Handling, Diagnostic and Service Functions

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, Diagnostic numbers list", the last 50 diagnostic message numbers of parameter S-0-0390 are recorded in chronological order. When reading this list, the number of the diagnostic message that last occurred is displayed as parameter element 1.

Priorities of Display   The following priorities apply for displaying the current diagnostic message:
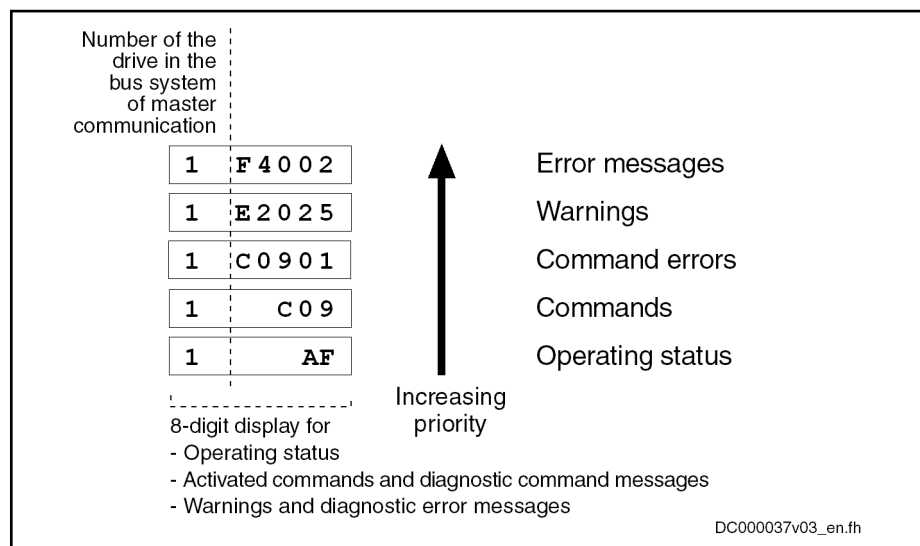
Fig.10-11:   *Priorities of Displays (with Example Displays)*

The documentation "Troubleshooting Guide (description of diagnostic messages)" contains an overview of all diagnostic messages and their meanings.

Handling, Diagnostic and Service Functions

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 "F2028, Excessive deviation", for example, has the following structure:
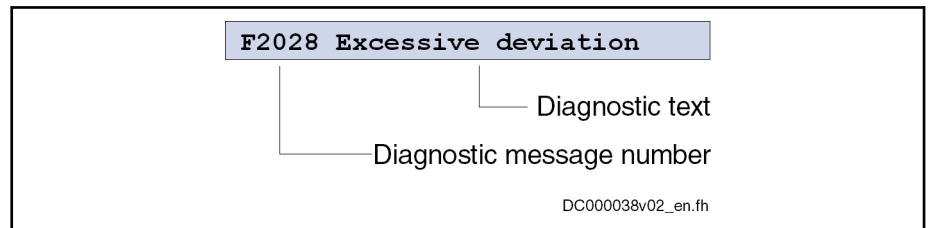
Fig.10-12:   Structure of a Diagnostic Message

"F2028" flashes on the display of the control panel. The display "F2028" is also output via parameter "P-0-0007, Display text of diagnostic message", too. The diagnostic message number is contained in parameter "S-0-0390Diagnostic message number" in hexadecimal form (for this example: 0x00F2028). Parameter "S-0-0095, Diagnostic message" contains the diagnostic message number and the diagnostic text as string "F2028 Excessive deviation". "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
Operation mode e.g. velocity control	A0101	AF

Fig.10-13:   Overview of Diagnostic Messages Displayed

Handling, Diagnostic and Service Functions

The current operation 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 display text of the diagnostic message. 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 to 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, error "F2028 Excessive deviation" with diagnostic message number "(0x)F2028" results in error number "2028".

List of diagnostic numbers

The last 50 diagnostic message numbers displayed are stored in chronological order in parameter "S-0-0375, Diagnostic numbers list". Every change in the content of "S-0-0390, Diagnostic message number" means that the old content is applied to S-0-0375. When reading 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-0-0265Language selection", it is possible to define or change the language of diagnostic message texts.

⚲ See also Parameter Description "S-0-0265, Language selection"

10.4.2   Status Classes, Status Displays, Control Parameters

General Information

In the drive there are many parameters with important status information (bit lists). Some of the bits contained in these lists can be used for configuring real-time status bits and additionally can be assigned to digital outputs or to the configurable signal status word.

See "Digital Inputs/Outputs"

See "Configurable Signal Status Word"

Status Classes

Brief Description

The drive differentiates between 3 states (error, warning and message) for which there is status information. To make the status information available, there are so-called class diagnostics parameters (S-0-0011, S-0-0012, S-0-0013) which contain the respective status bits.

In addition to these class diagnostics parameters, there are change bits contained in the status word of the field bus (e.g. S-0-0135 in the case of SERCOS) which display changes in one of the above-mentioned class diagnostics parameters (collective information).

Features
- Class diagnostics parameter for **errors** (cf. S-0-0011)
- Class diagnostics parameter for **warnings** (cf. S-0-0012)
- Class diagnostics parameter for **messages** (cf. S-0-0013)
- **Change bits in status word** of master communication (e.g. S-0-0135 in case of SERCOS)
- Change bits of class 2 and 3 diagnostics (S-0-0097 and S-0-0098) **can be masked** in the status word of master communication (e.g. S-0-0135 in case of SERCOS) to suppress individual bits or status messages

Pertinent Parameters
- S-0-0011, Class 1 diagnostics
- S-0-0012, Class 2 diagnostics
- S-0-0013, Class 3 diagnostics
- S-0-0097, Mask class 2 diagnostics
- S-0-0098, Mask class 3 diagnostics
- S-0-0135, Drive status word

Functional Description

Status Class Parameters
- **S-0-0011, Class 1 diagnostics** (status parameter for drive errors)
  - In case a drive error occurs, the bit assigned to the error is set in parameter S-0-0011. A separate bit is assigned in S-0-0011 to errors defined according to SERCOS.

    Manufacturer-specific errors cause bit 15 to be set in parameter S-0-0011 (see also Parameter Description "S-0-0011, Class 1 diagnostics").
  - In case a drive error occurs, bit 13 (drive interlock; error in class 1 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in 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.

Handling, Diagnostic and Service Functions

Manufacturer-specific warnings cause bit 15 to be set in parameter S-0-0012 (see also Parameter Description "S-0-0012, Class 2 diagnostics").

– In case a drive warning occurs, bit 12 (change bit class 2 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in case of SERCOS), when the content of S-0-0012 changes (i.e. at least one bit toggles).

– The bits in parameter S-0-0012 are automatically cleared when the warning disappears. The change bit in the status word of the master communication (S-0-0135 in case of SERCOS) remains set, however, until parameter S-0-0012 has been read once.

☞ 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").

– If a drive message occurs, bit 11 (change bit class 3 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in case of SERCOS).

– The bits in parameter S-0-0013 are automatically cleared when the message disappears. The change bit in the status word of the master communication (S-0-0135 in case of SERCOS) remains set, however, until parameter S-0-0013 has 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 case of SERCOS). A change bit in the status word (bit 11 or 12) is always set due to a change of the parameter content of S-0-0012 or S-0-0013. This enables the master to recognize very quickly whether a change occurred in S-0-0012 or S-0-0013.

A read access to one of the two parameters clears the respective change bit again.

Masking the Change Bits   By means of the parameters "S-0-0097, Mask class 2 diagnostics" and "S-0-0098, Mask class 3 diagnostics", it is possible to mask certain bits in terms of their effect on the change bit of the status word (bit 12 or bit 11).

The figure below illustrates the principle of masking by means of an example:

Handling, Diagnostic and Service Functions
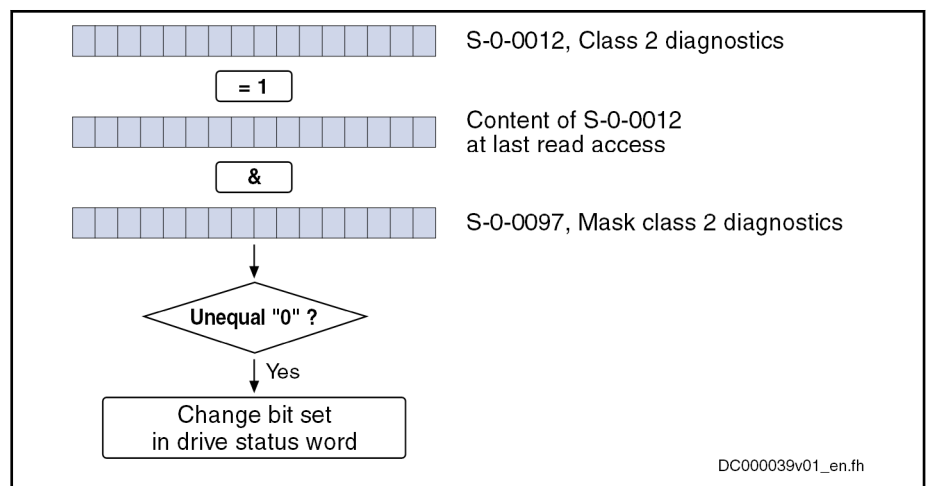
Fig.10-14:   *Generating the Change Bit of Class 2 Diagnostics*

Notes on Commissioning

The figure below illustrates the handling of the change bits in the status word and of the status class parameters:

Handling, Diagnostic and Service Functions
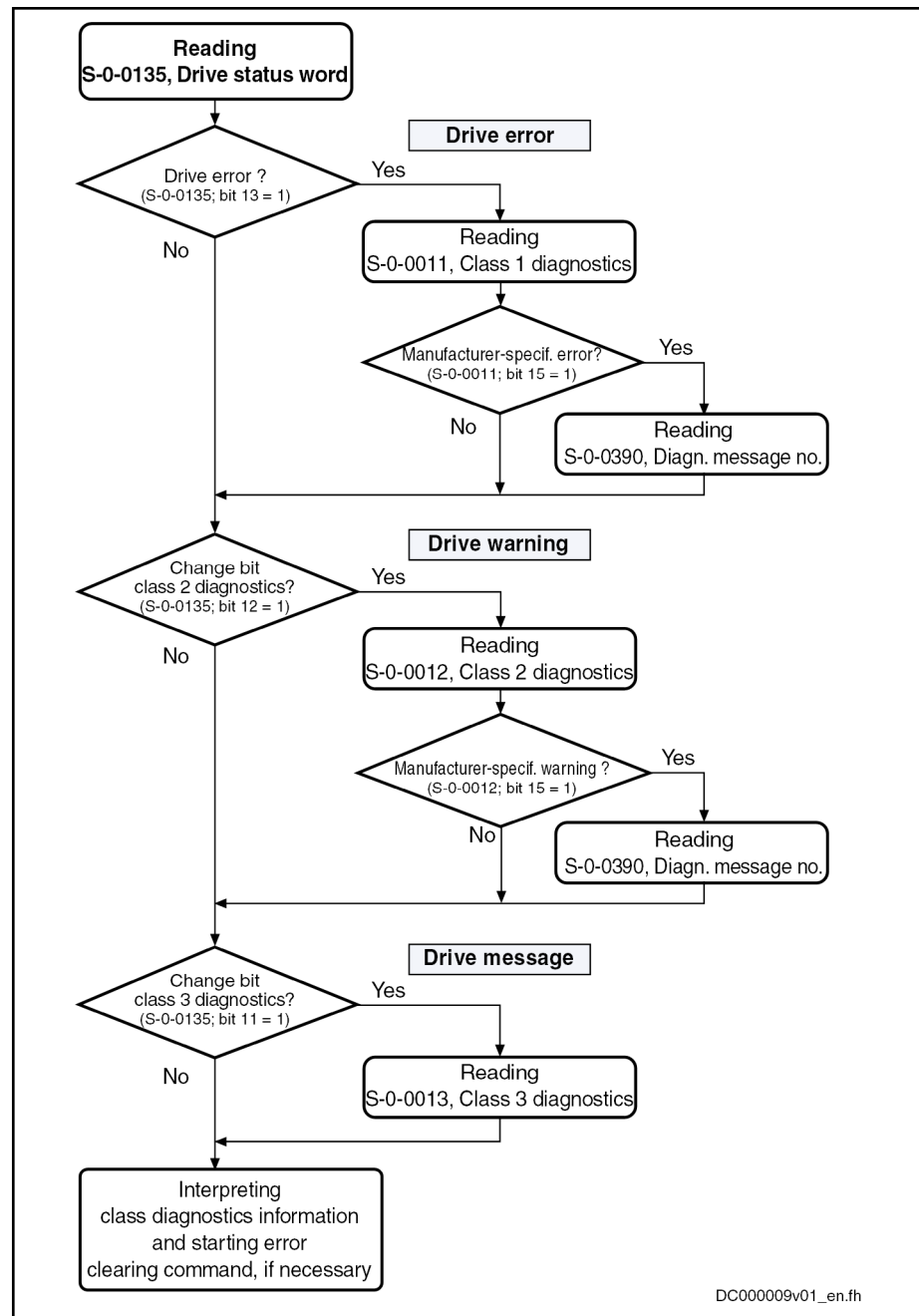
Fig.10-15:   Handling the Change Bits and Status Class Parameters

Fixed Status Displays

Function-Related Status Parameters

In the drive there are parameters the content of which has a direct relation to the status of the sequence of different drive functions. These parameters are used to display the current status information of the assigned function.

The following parameters are available for function-related status display:

- **S-0-0014, Interface status**

  This parameter displays the status of the communication phase transition and the cyclic communication.

- **S-0-0135, Drive status word**

This is the status word of the master communication (SERCOS) and contains all essential status information for the master.

- **S-0-0403, Position feedback value status**

  This parameter contains status bits for the position data reference of the individual measuring systems.

- **S-0-0419, Positioning command acknowledge**

  This status information is used for acknowledgment in "drive-controlled positioning" mode.

- **P-0-0046, Status word of current controller**

  This parameter contains status bits of the internal motor control (e.g. overvoltage in DC bus).

- **P-0-0115, Device control: status word**

  This parameter contains status bits of device control (see also "Device Control and State Machines").

- **P-0-0222, Travel range limit switch inputs**

  This parameter displays the status of the travel range limit switch inputs (see also "Limitations: Travel Range Limit Switches").

- **P-0-0223, E-Stop input**

  This parameter displays the status of the E-Stop input (see also "E-Stop Function").

- **P-0-0455, Acceleration feedforward actual value**

  This parameter contains status bits to display the activation of torque/current limitation (see also "Limitations: Current and Torque/Force Limitation").

- **P-0-0539, Holding brake status word**

  This parameter contains status bits for the status of the motor holding brake (see also "Motor Holding Brake").

- **P-0-0555, axis controller messages**

  This parameter displays messages with regard to velocity and limits that have been reached.

- **P-0-4029, Diagnostic report SCSB module**

  Parameter for reading master communication settings and states (with SERCOS 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, Status "n_feedback = n_command"
- S-0-0331, Status "n_feedback = 0"
- S-0-0332, Status "n_feedback < nx"
- S-0-0333, Status "T >= Tx"
- S-0-0334, Status "T >= Tlimit"

Handling, Diagnostic and Service Functions

- S-0-0335, Status "n_command > n_limit"
- S-0-0336, Status "In position"
- S-0-0337, Status "P >= Px"
- S-0-0341, Status "In coarse position"
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0409, Probe 1 positive latched
- S-0-0410, Probe 1 negative latched
- S-0-0411, Probe 2 positive latched
- S-0-0412, Probe 2 negative latched

Control Parameters

Apart from the parameters for status display, there are parameters available in the drive that are used to control the drive functions (see also description of corresponding parameter):

- P-0-0045, Control word of current controller
- P-0-0427, Control parameter of analog output
- P-0-0522, Control word for commutation setting
- P-0-0556, Config word of axis controller
- P-0-0612, Set absolute position control
- P-0-4028, Device control word

10.4.3   Diagnostic Data of Motor Operation

Brief Description

For preventive maintenance and service purposes, the firmware provides the option of collecting dynamic operating data from the motor and storing it in the controller and in the motor.

The operating hours counter for motors allows planning maintenance intervals, minimize machine downtimes and reduce maintenance costs.

Features
- Recording the total time during which:
  - Operating status "AF" available
  - Velocity is not equal to zero
  - Motor temperature is greater than 10 K below shutdown threshold ("S-0-0204, Motor shutdown temperature")
- Recording the maximum velocity of the motor in operation
- Determining the average value of the motor velocity in operation
- Recording the maximum temperature of the motor winding in motor operation
- Determining the average value of the motor winding temperature, referring to the duration of the operating status "AF"
- Determining the operational performance of the motor by multiplying average speed and duration with velocity unequal zero

Pertinent parameters
- P-0-2051, Operating hours counter, motor
- P-0-2052, Thermal operating data, motor
- P-0-2053, Mechanical operating data, motor

Handling, Diagnostic and Service Functions

- P-0-2054, Operational performance, motor
- P-0-2055, Serial number, motor
- P-0-3051, Encoder memory, operating hours counter, motor
- P-0-3052, Encoder memory, thermal operating data, motor
- P-0-3053, Encoder memory, mechanical operating data, motor

Pertinent diagnostic messages
- C0284 Invalid motor data in encoder memory (->S-0-0423)

Functional Description

General Information

The drive controller records the operating hours, the thermal and mechanical data of the motor in a cycle of 8 ms and stores them in the following parameters:

- P-0-2051, Operating hours counter, motor
- P-0-2052, Thermal operating data, motor
- P-0-2053, Mechanical operating data, motor
- P-0-2054, Operational performance, motor

Due to the limited number of write accesses to the flash, the data is first stored in the volatile memory of the controller and every 60 min it is written to the active, non-volatile memory of the controller ("Flash" or MMC).

If the control voltage is switched off before the hourly save has taken place, the motor's operating data which has not yet been saved will be lost.

Motors with Encoder Data Memory

When equipped with encoder option "-x1" or "-x2" (as supplied as of 3rd quarter 2007), Rexroth motors of the "IndraDyn S" and "IndraDyn A" device ranges provide the option of writing the operating data of the motor to the encoder data memory and thereby making it available in the respective motor itself. This means that important information for service and maintenance work is stored directly at the object and can be called there.

Each motor can be unequivocally identified by its serial number (type plate data under "SN") which can also be found in the encoder data memory. After the control voltage has been switched on, the serial number of the motor connected to the drive controller is read and compared to the serial number of the last operated motor which has been internally stored in the controller.

If the serial number is the same, the operating hours counter in the encoder data memory is compared to the operating hours counter in the controller and synchronized if necessary. Depending on the value of the operating hours counter in the encoder data memory (P-0-3051), the following action is carried out:

- Value in P-0-3051 **greater** than value in controller (P-0-2051)

  → Operating data of motor from encoder data memory is applied to the controller (always when switching to "bb", "Ab" or "OM")

- Value in P-0-3051 **smaller** than value in controller (P-0-2051)

  → Operating data of motor from controller is applied to the encoder data memory of the motor (only after control voltage has been switched on)

If the serial number stored in the controller does **not** match the one from the connected motor, the operating data of the new motor is written from its encoder data memory to the corresponding parameters of the controller.

The table below contains an overview of cases to be distinguished and the resulting storage processes for synchronization.

Handling, Diagnostic and Service Functions

| Motor data | Serial number of motor unchanged | | Serial number of motor changed |
| | Comparison operating hours counter | | |
	(P-0-3051) > (P-0-2051)	(P-0-3051) < (P-0-2051)	
Operating hours counter	(P-0-3051) → (P-0-2051) [1]	(P-0-2051) → (P-0-3051) [2]	(P-0-3051) → (P-0-2051) [1]
Thermal operating data	(P-0-3052) → (P-0-2052) [1]	(P-0-2052) → (P-0-3052) [2]	(P-0-3052) → (P-0-2052) [1]
Mechanical operating data	(P-0-3053) → (P-0-2053) [1]	(P-0-2053) → (P-0-3053) [2]	(P-0-3053) → (P-0-2053) [1]

[1]   Operating data of motor is read from encoder data memory when switching to operating mode

[2]   Operating data of motor is stored in encoder data memory only after control voltage has been switched on

Fig. 10-16:   Synchronizing the operating data of the motor after switching controller on

☞   To use the diagnostic data of motors with encoder data memory, observe the following points:

- To store, in the case of servicing, the current operating data of the motor, which has been stored in the controller, in the encoder data memory, switch control voltage on again before replacing the motor!

- With Rexroth motors with encoder data memory, it is impossible to reset the operating hours counter!

Motors without encoder data memory

Due to their type of construction, kit motors do not have a predetermined motor encoder. Third-party motors equipped with a motor encoder typically do not have an encoder data memory.

Therefore, storing the operating data of the motor in the encoder data memory either is impossible or, if the mechanical motor/motor encoder connection has been disconnected for service work, does not make sense.

When these motors are used, their operating data is written to the non-volatile memory of the drive controller, too, as it is done for motors with encoder data memory. For diagnostic purposes, the user can evaluate these data which refer to a specific motor.

☞   The operating data of the motor stored in the controller can be changed in communication phase 2. Therefore, the initial state can be set manually. The operating data of the motor are saved hourly in the non-volatile memory of the controller or they are stored at switch-off.

Notes on Commissioning

Motors with Encoder Data Memory   For Rexroth motors of the "IndraDyn S" and "IndraDyn A" device ranges, when equipped with encoder option "-x1" or "-x2" (as supplied as of 3rd quarter of 2007), the operating data of the motor are automatically initialized and stored correctly.

Motors without encoder data memory   For motors without encoder data memory, the operating data is to be manually set to start values during initial commissioning:

- P-0-2051, Operating hours counter, motor

- P-0-2052, Thermal operating data, motor
- P-0-2053, Mechanical operating data, motor
- P-0-2054, Operational performance, motor

☞ It is possible to use all values of the allowed range of values!

Recommendation: → Enter "0" as the respective start value!

As long as the motor (without encoder data memory) is operated at the same drive controller, its operating data is stored in the controller every hour. When servicing, when the motor or controller is replaced, the values of parameters P-0-2051, P-0-2052, P-0-2053 and P-0-2054 are to be externally backed up and assigned to the specific motor.

How to proceed after replacement:

- After having **replaced the controller**, load the values of parameters P-0-2051, P-0-2052 and P-0-2053 specific to the operated motor from the external storage medium to the new controller.

- After having **replaced the motor**, set the values of parameters P-0-2051, P-0-2052 and P-0-2053 to useful values for the replacement motor, e.g. start values "0" for a new motor or the specific values of a repaired motor.

10.4.4 Load Preview

Brief Description

There is a loss of power when operating electrical drives, if power or torque/force is emitted from the motor. There is a maximum permissible operating temperature, based on the materials used, up to which the equipment can be operated safely in the long term for electrical equipment and electrical components. This temperature determines the permitted continuous load of the electrical components.

Overload capacity   The current-based rise in temperature of electrical components dissipates with its thermal time constants. Providing the maximum permissible operating temperature has not be reached, an electrical component can also be overloaded, that is to say short-term operation with more than the permitted continuous load. This leads to a faster rise in temperature but is not problematical providing the permitted operating temperature is not exceeded.

If the permitted operating temperature is reached, the overload must be reduced to the permitted continuous load so that there is no damage to the electrical components. There are functions for limiting overload with Bosch Rexroth drives for the different power-relevant drive components:

- Motor
- Controller inverter
- Braking resistor of the supply unit or converter

Protection functions   The functions to protect against impermissible loading are provided on the hardware or firmware side:

- Hardware-side temperature measurement in the motor windings and on the controller's heat sink
- Firmware-side temperature model calculation for temperatures on temperature-sensitive components not measurable on the hardware side.

With hardware-side temperature measurement, only temperature rises within the second range can be recorded, although faster rises in temperature can still be monitored by means of firmware-side model calculation.

Handling, Diagnostic and Service Functions

Overload limits

The high overload capacity of electrical drives can only be provided safely by temperature model calculation and automatic overload limits:

- Current limitation by controller temperature modeling (inverter)
- Current limitation by motor temperature modeling
- Lower limitation by braking resistance temperature modeling

Load preview

Automatically intervening limits admittedly provide protection against damage to the electrical components, but impair the drive's torque and power output and can possibly lead to shutdown by sequential errors or rejection during machining. Forward-looking recognition and signaling of threatening limits is possible for the three aforementioned temperature modeling calculations with the "Load preview" function:

- Shutting down of the machining cycle with the heaviest load
- Determining the rise of the load curve (difference between the maximum value and the starting value)
- Defining a threshold value for the load, at which the anticipated load rise is still possible within the limits
- Signaling when the thermal load has reached the defined threshold value.

Pertinent parameters

- P-0-0141, Thermal drive load
- P-0-0441, Drive load warning threshold
- P-0-0446, Thermal motor load
- P-0-0465, Maximum value thermal drive load
- P-0-0466, Maximum value thermal motor load
- P-0-0467, Maximum value thermal load of Braking resistor
- P-0-0468, Prewarning threshold of therm. motor load
- P-0-0469, Prewarning threshold of therm. load of braking resistor
- P-0-0844, thermal load of Braking resistor

Pertinent diagnostic messages

- E2051 Motor overtemp. prewarning
- E2061 Device overload prewarning
- E2820 Braking resistor overload prewarning

Functional Description

Thermal Load

The firmware-side temperature models determine the thermal load of the

- Motor
- Controller inverter
- Braking resistor of the supply unit or converter

The thermal load of these components is displayed in

- P-0-0141, Thermal drive load
- P-0-0446, Thermal motor load
- P-0-0844, thermal load of Braking resistor

☞   For more information on the limits caused by these temperature models, please refer to the chapter entitled "Dynamic Current Limitation"

Handling, Diagnostic and Service Functions

Estimating the continuous load

These parameters can also be pre-assigned with values for test purposes in order to be able to estimate the effectively expected continuous loading by conducting load cycles. The load at the end and at the start of one or more load cycles is to be compared for this purpose:

- Falling value: Pre-assigned value was higher than the effectively expected continuous load

- Rising value: Pre-assigned value was lower than the effectively expected continuous load
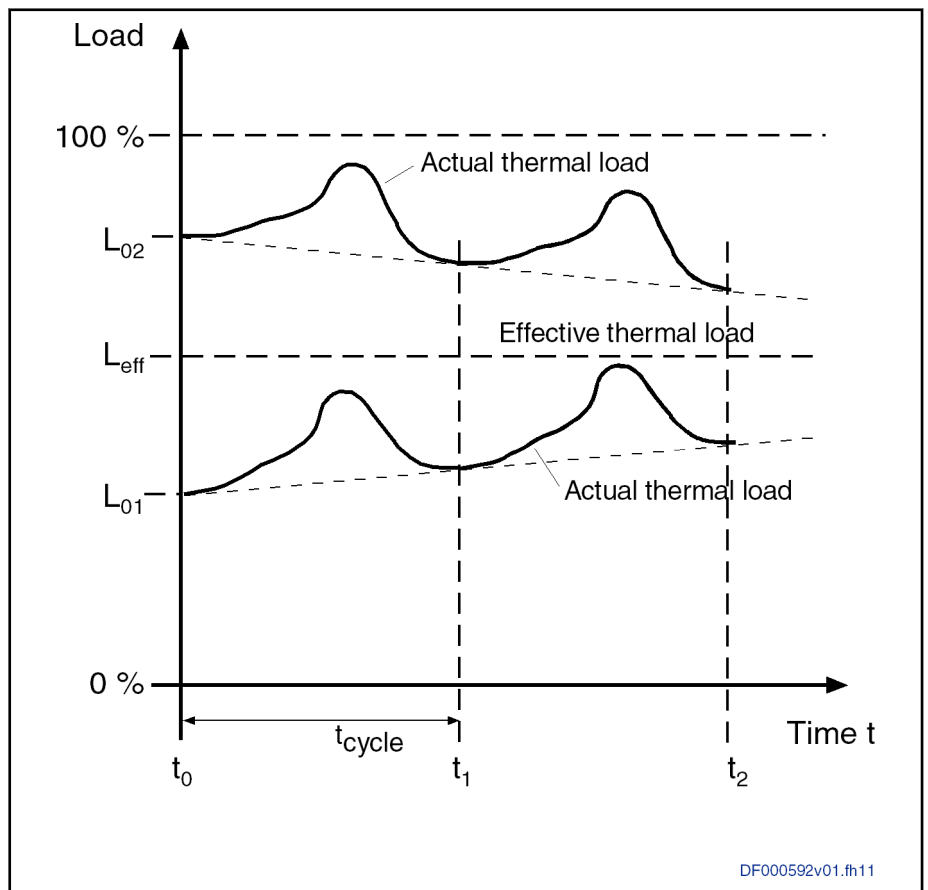
L_{01}	Pre-assignment with a low starting load value
L_{eff}	Effective continuous thermal load, theoretical end value
L_{02}	Pre-assignment with a high starting load value

Fig. 10-17:   Diagrammatic load curves with differing load pre-assignment

Conditions for estimating continuous load

It is possible to estimate the continuous load if the duration of the load cycle is within the range of the thermal time constants of the respective components (milliseconds to seconds with controls and braking resistors, minutes to hours with motors). With frequent repetition of the load cycle, it is possible to slowly increase the level of load before the limit intervenes, particularly with motors and controls with a high current strength, if the effective continuous load is closer to 100% than the load rise of a load cycle:

Handling, Diagnostic and Service Functions
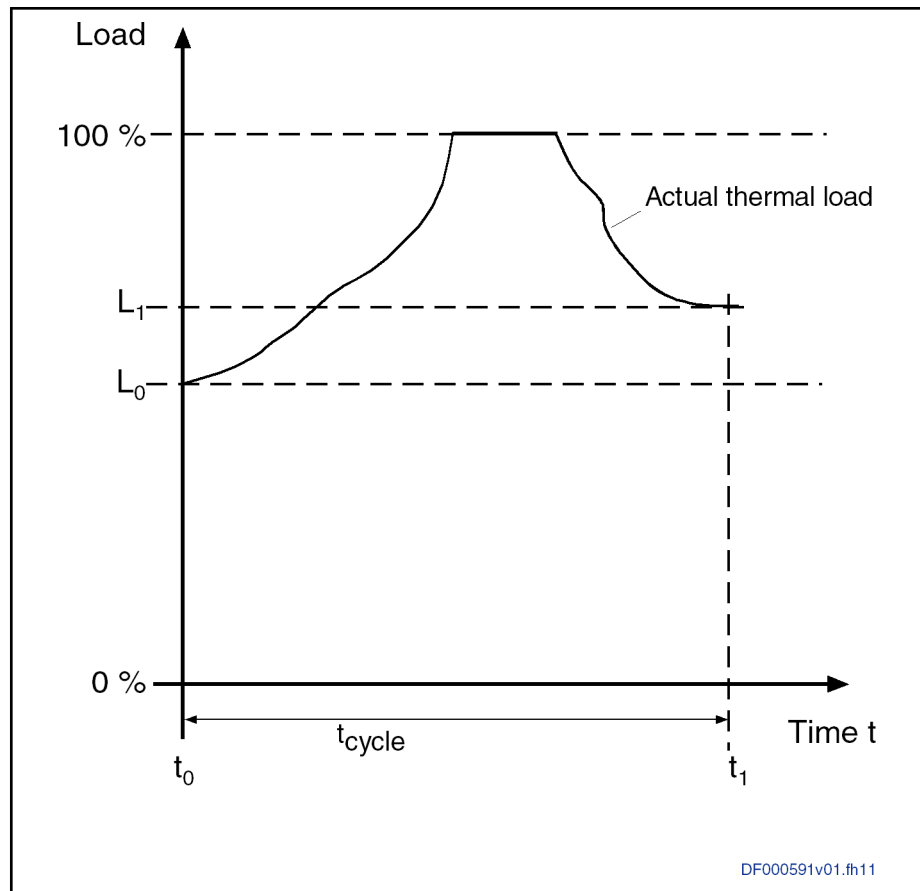
L_0	Thermal load at the start of the machining cycle
Thermal load	Thermal load of the components
L_1	Thermal load at the end of the machining cycle

Fig. 10-18:   *Example of a load curve of a load cycle with intervening limit*

Maximum Load Value and Load Preview

Load rises are produced when performing load cycles. The maximum value of the load produced is stored on the firmware-side in parameters

- P-0-0465, Maximum value thermal drive load
- P-0-0466, Maximum value thermal motor load
- P-0-0467, Maximum value thermal load of Braking resistor

Load rise   The renewed storage of maximum values can be forced if the value "0" is inputted into these parameters. The maximum value of the next load cycle is then stored. The difference between the maximum value and the starting value of the thermal load is the "load rise":
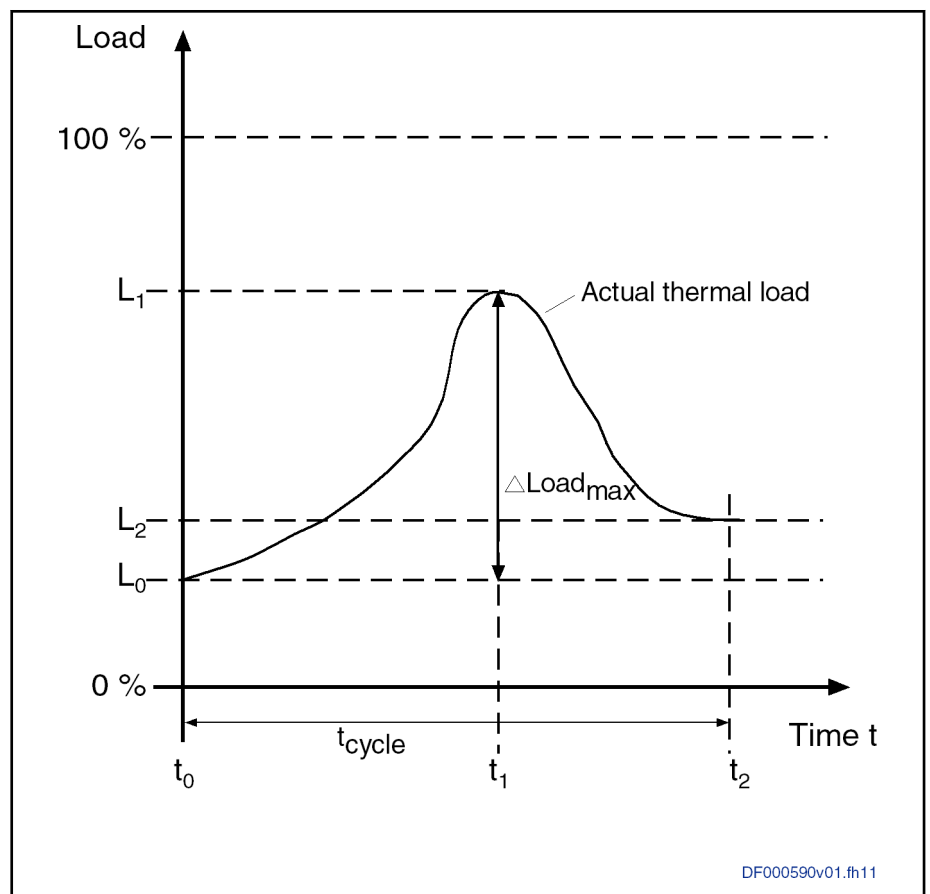
Handling, Diagnostic and Service Functions

L_0	Thermal load at the start of the machining cycle
L_1	Maximum value of the load (is stored)
Actual thermal load	Thermal load of the components
L_2	Thermal load at the end of the machining cycle

Fig. 10-19:   *Example of load rise in a load cycle*

Load preview   A "load preview" is possible by means of an appropriately set prewarning threshold. This generates a signal for a limit to intervene when at the next load rise the thermal load comes close to 100%, as anticipated, and there is a risk to the drive. The respective threshold value can be set in:

- P-0-0441, Drive load warning threshold

- P-0-0468, Prewarning threshold of therm. motor load

- P-0-0469, Prewarning threshold of therm. load of braking resistor

$$\text{Prewarning threshold } \leq 100\% - (\Delta Load_{max}) = 100\% - (L_1 - L_0)$$

L_0	Thermal load at the start of the machining cycle
$\Delta Load_{max}$	Expected load rise of the machining cycle
L_1	Maximum value of the load in the machining cycle

Fig. 10-20:   *Calculating the value of the prewarning threshold, selecting percentage safety factor*

Signaling "limit risk"   The respective prewarning threshold being reached is signaled by the associated warning:

- E2051 Motor overtemp. prewarning

- E2061 Device overload prewarning

Handling, Diagnostic and Service Functions

- E2820 Braking resistor overload prewarning

The prewarning is shown in "S-0-0012, Class 2 diagnostics" and is to be read by the control master via this. It is to be anticipated after the triggering of the prewarning that on the next regular machining cycle, the intervention of the limit is to be expected. The control master now has the option to react preventatively to this in an appropriate way.

Overview of thermal protection functions and associated diagnostic messages

Compo-nent	Diagnostic message	Cause	Drive reaction	Status bit	Display
Motor	E2051, Motor over-temp. prewarning	Motor temperature model Load > P-0-0468	None	S-0-0012 bit 2	P-0-0446
		Temperature sensor Temperature > S-0-0201			S-0-0383
	E8055, Motor overload, current limit active	Motor temperature model Load > 100%	Motor current limit	S-0-0012 bit 0	P-0-0446
	F2019, Motor overtemperature shutdown	Temperature sensor Temperature > S-0-0204	P-0-0119, Best possible deceleration	S-0-0011 bit 2	S-0-0383
	F2021, Motor temperature monitor defective	Temperature sensor defective	P-0-0119, Best possible deceleration after 30 s, immediately with sensor KTY84		S-0-0383
Amplifier	E2061, Device overload prewarning	Amplifier temperature model Load > P-0-0441	None	S-0-0012 bit 1	P-0-0141
	E8057, Device overload, current limit active	Amplifier temperature model Load > 100%	Starting current limit	S-0-0012 bit 0	P-0-0141
	E2050, Device overtemp. Prewarning	Temperature sensor Temperature > prewarning threshold (threshold is device-specific)	F2018 after 30 s	S-0-0012 bit 1	S-0-0384
	E2040, Device overtemperature 2. prewarning		F2040 after 30 s		P-0-0816
	F2018, Device overtemperature shutdown	Temperature sensor Temperature > shutdown threshold (threshold is device-specific)	P-0-0119, Best possible deceleration and shutdown of power supply	S-0-0011 bit 1	S-0-0384
	F2040, Device overtemperature 2. shutdown				P-0-0816
Braking Resistor	E2820, Braking resistor overload prewarning	Temperature model Load > P-0-0469	None	S-0-0012 bit 1	P-0-0844
	F2820, Braking resistor overload	Temperature model Load > 110%	P-0-0119, Best possible deceleration and shutdown of power supply	S-0-0011 bit 1	P-0-0844

Fig.10-21:   Thermal protection functions of IndraDrive and associated diagnostic messages

Handling, Diagnostic and Service Functions

Notes on Commissioning

IndraWorks Dialog Boxes for Setting the Load Preview

The parameters for setting the load preview can be found in the

- "Power supply" for braking resistor dialog box
- "Current Limit" subdialog of the "Torque/Force Limits" dialog for the motor and controller
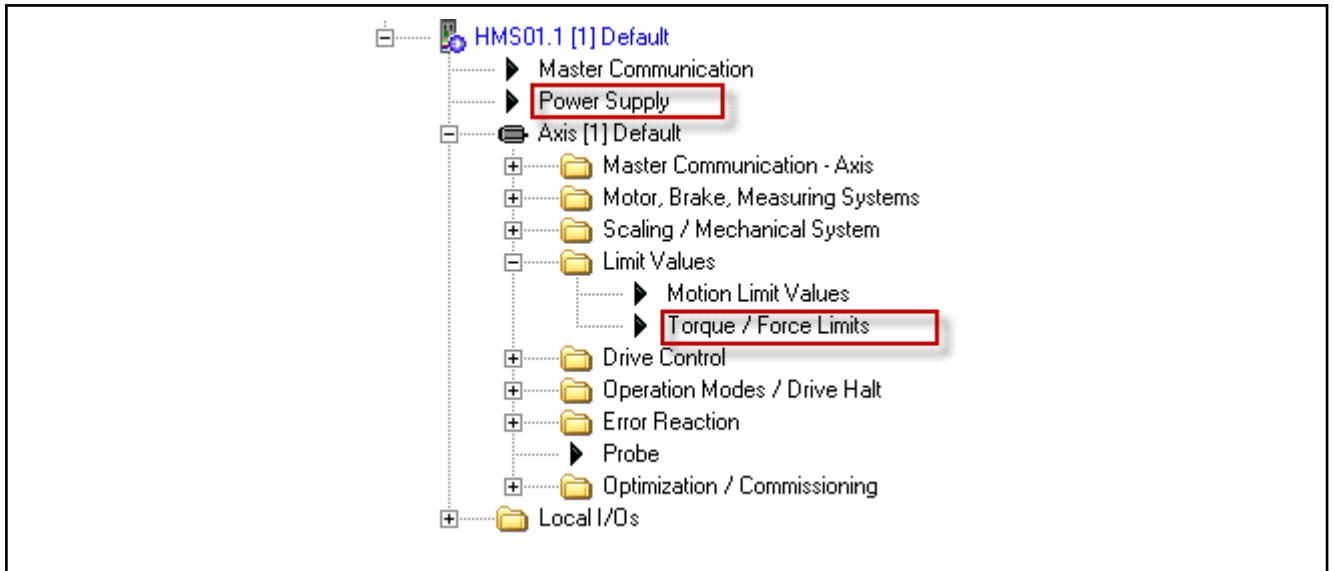
Fig.10-22:   *IndraWorks Explorer with indicators showing how to find the dialogs for load and load preview*
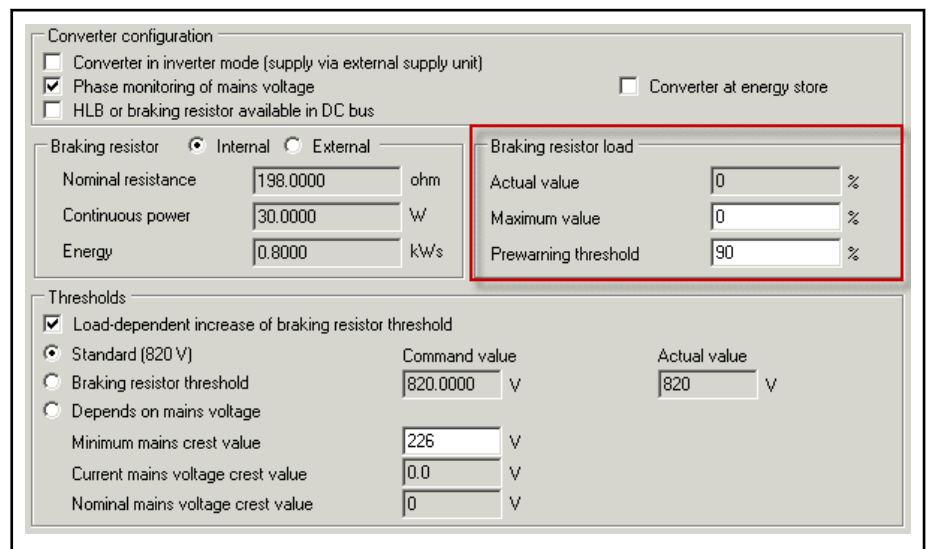
Fig.10-23:   *IndraWorks "Power supply" dialog with setting options for the prewarning threshold*

Handling, Diagnostic and Service Functions
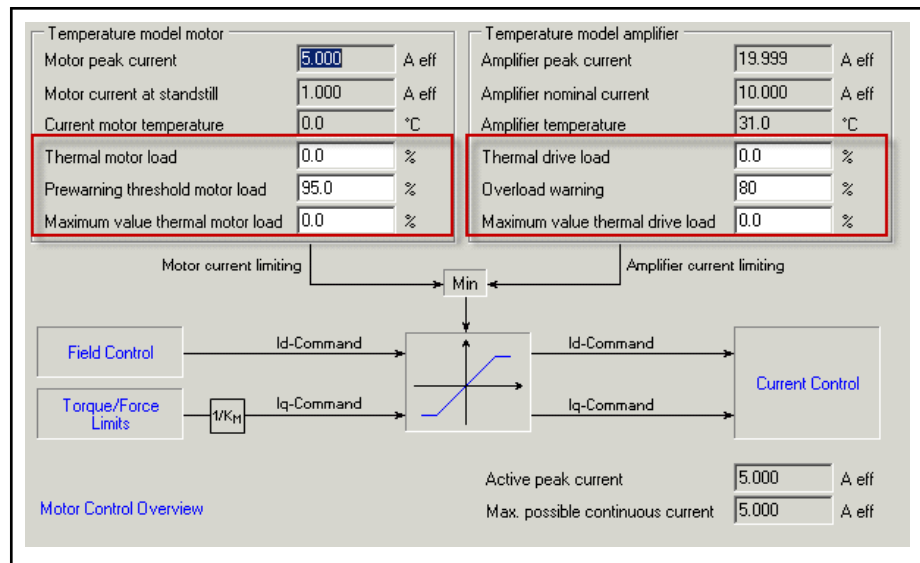
Fig.10-24:   IndraWorks "Current limit" subdialog within "Torque/Force Limits" with setting options for the prewarning threshold for the motor and control load

Procedure for Estimating Effective Continuous Thermal Load

The effective thermal load can be estimated as follows with controls and with braking resistors:

*   Prior to running the load cycle, give the value of the thermal load an estimated starting value for the effective continuous load. Note the starting value.

*   After running the machining cycle, compared the load value with the noted starting value.

    –   If the load has increased, enter a significantly higher starting value for the next machining cycle

    –   If the load has decreased, enter a significantly lower starting value for the next machining cycle

*   Repeat the process, at the same time adapting the starting values, until the load remains approximately similar before and after the machining cycle. The load value shown then corresponds to the continuous thermal load caused by this machining cycle.

The maximum value of thermal load stored is not to reach 100% if the drive is to operate without the risk of a limit.

☞   This process does not generally produce any reliable data on continuous load

Procedure for Adjusting the Load Preview

The effective continuous load of motors can only be estimated very imprecisely by observing a few load cycles. The most accurate data can be achieved from the temperature sensor, although this requires long-term operation of more than 5 times the duration of the thermal time constants.

The "load preview" can be advantageously used with motors to avoid load-related intervention of limits. It is possible to identify in advance from when the motor runs the risk of being limited in relation to its power or torque/force output.

Procedure:

Handling, Diagnostic and Service Functions

- Enter a "0" as the maximum value of thermal load before running the load cycle.

- After running the machining cycle, note the value of the thermal load and subtract it from the automatically stored maximum value. Subtract the difference from 100%, possibly reducing the remaining value somewhat for safety reasons, and enter it into the parameter for the prewarning threshold.

- Request the signaling of the prewarning threshold having been reached in the relevant bit of S-0-0012 and take appropriate measures on the control master side prior to running the next machining cycle.

☞ It is also possible to use the "load preview" for controls and braking resistors! There are advantages of using it in particular with controls with large current strength and braking resistors with large energy storage capacity.

10.5 Control Panels of the IndraDrive Controllers

10.5.1 General Information on the Operation Options

Control Panel Variants

IndraDrive controllers are equipped with a "control panel"; its front consists of a display with keys located underneath it. The display shows operating states, command and error diagnostics, as well as any pending warnings. The keys are used to enter settings, call information and trigger some commands.

Fig.10-25:   Standard 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.

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.

10.5.2 Control Panel

Brief Description

IndraDrive controllers are equipped with a control panel, the front of which, the so-called "control panel", consists of a display and 4 keys located underneath it. The four keys can be used to display extended diagnostic messages and trigger simple commands (in addition to master communication, IndraWorks or NC control).

Handling, Diagnostic and Service Functions
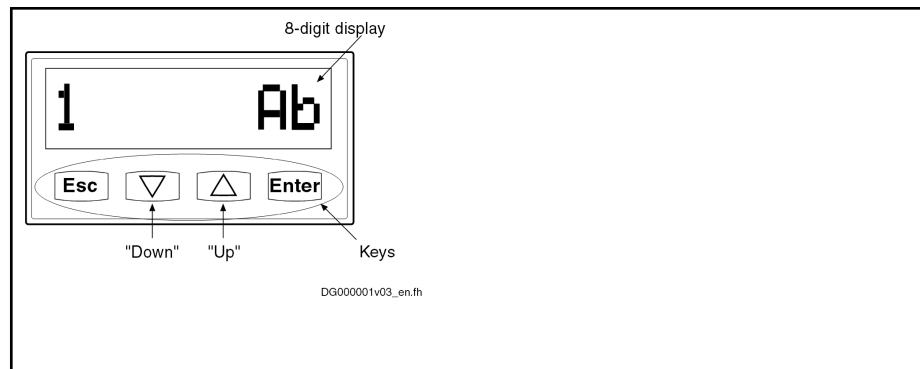
Fig.10-26:   Schematic diagram of the control panel (sample display)

Control panel display options

The display of the IndraDrive controller automatically shows:

- Status of the master communication
- Operating status
- Commands and diagnostic command messages
- Warnings and diagnostic error messages
- Extended displays such as contents of 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)

Setting options using the control panel

The following settings can be performed using the control panel:

- Setting the drive address (drive number in the bus system of the master communication)
- Setting the length of the fiber optic cable
- Activating "Easy startup" mode for initial commissioning
- Setting the master communication protocol
- Setting IP addresses for Engineering

Activating commands via the control panel

The following commands can be activated using the control panel:

- Activating "S-0-0262, C07_x Load defaults procedure command" (loading controller parameters or basic parameters)
- Activating other commands, such as:
    - C0200 Exit parameterization level procedure command
    - C0300 Set absolute position procedure command
    - C0400 Activate parameterization level 1 procedure command
    - C2000 Command Release motor holding brake
    - C2200 Backup working memory procedure command
    - C2300 Load working memory procedure command
    - C2800 Analog input adjustment command
    - C2900 Command Firmware update from MMC

VCP control terminal

It is also possible to connect a stand-alone **VCP control terminal** that can, for example, be integrated into the front of the control cabinet, to the controller via an Engineering interface.

VCP control terminals are separate components (terminals) that can be used in addition to the control panel. They are connected to the controller serially or by Ethernet.

Handling, Diagnostic and Service Functions

VCPs are programmable by the user and it is possible to access all the drive's parameters and the MLD's variables.

Functional Description

Standard displays

The displays have priorities, because it is impossible to display several messages simultaneously.
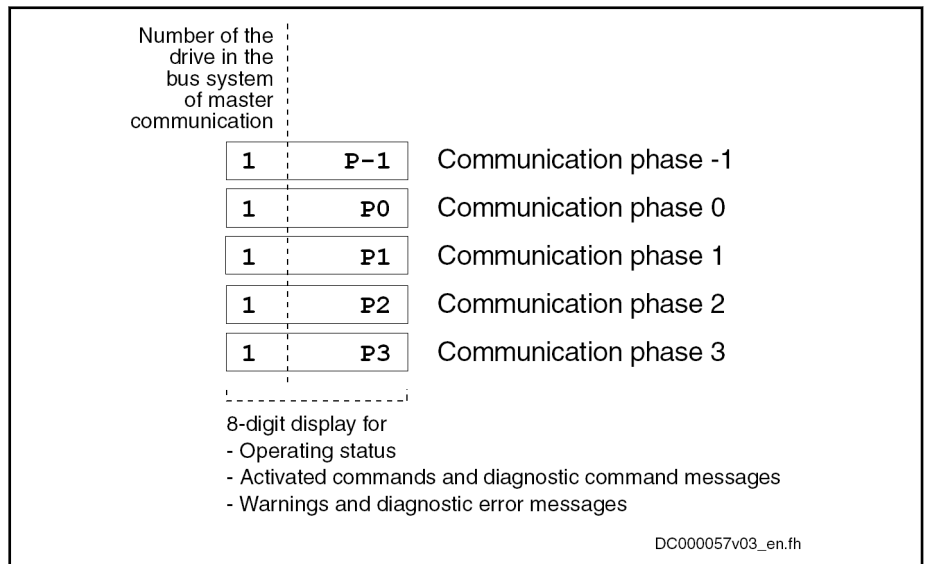
Fig.10-27:   Displays during phase progression of the master communication
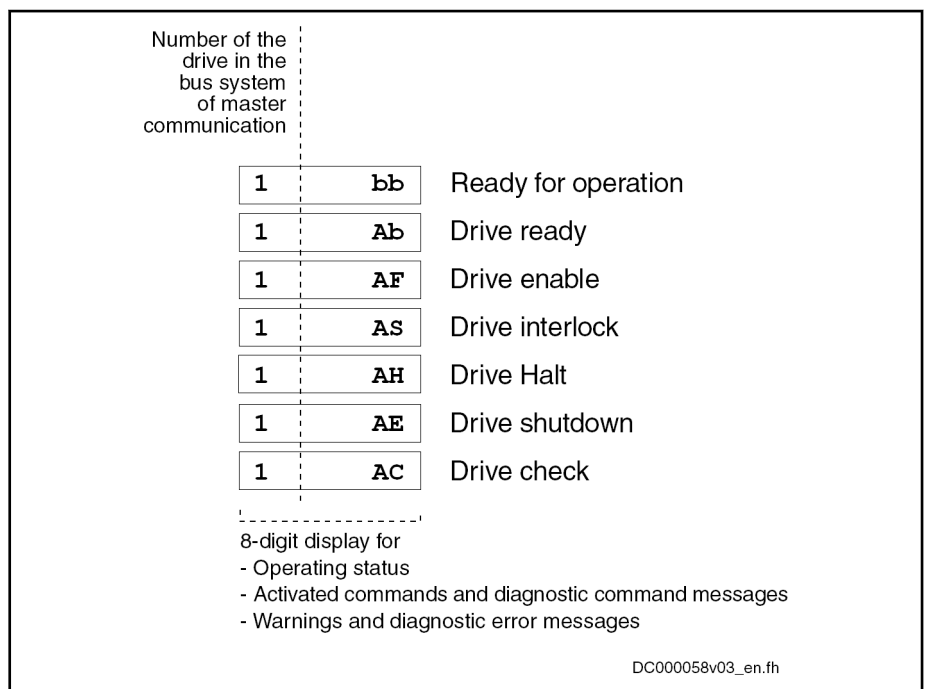
Fig.10-28:   Displays during phase progression of the master communication

Handling, Diagnostic and Service Functions
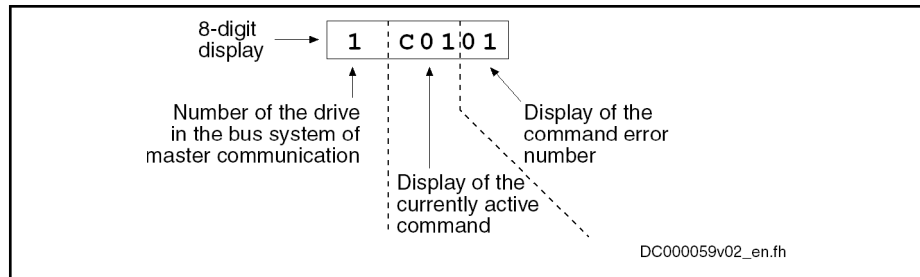
Fig.10-29:   Explanation of command error displays
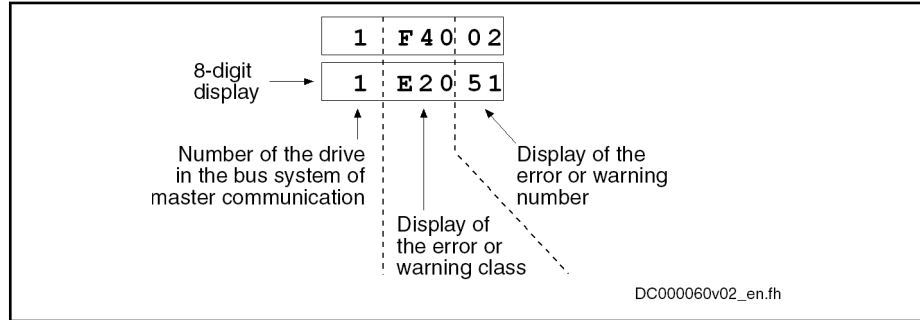
Fig.10-30:   Explanation of error and warning displays

Priorities of display   The current drive status is displayed with highest priority.
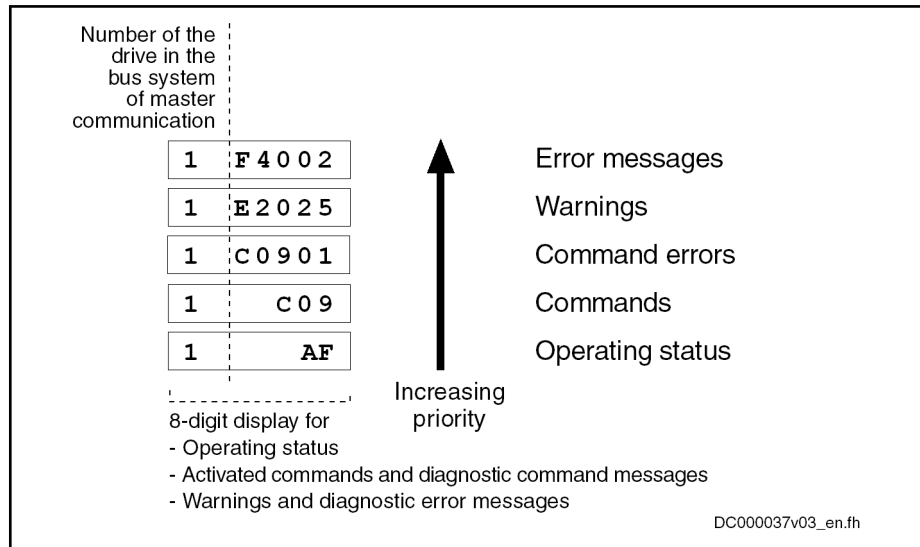
Fig.10-31:   Priorities of displays (with sample displays)

With error messages, warnings and command errors, the diagnostic message text is displayed on the standard display in the form of a marquee text in the standard operating panel, in addition to the flashing diagnostic message number (see also Parameter Description "S-0-0095, Diagnostic message").

Activating extended display, Command menu, Service menu and Easy menu   The easy menu can always (without unlocking) be accessed by pressing the "Enter" key.

Simultaneously pressing the "Esc" and the "Enter" keys in the standard display (for 8 s when activated for the first time) accesses the extended menu.
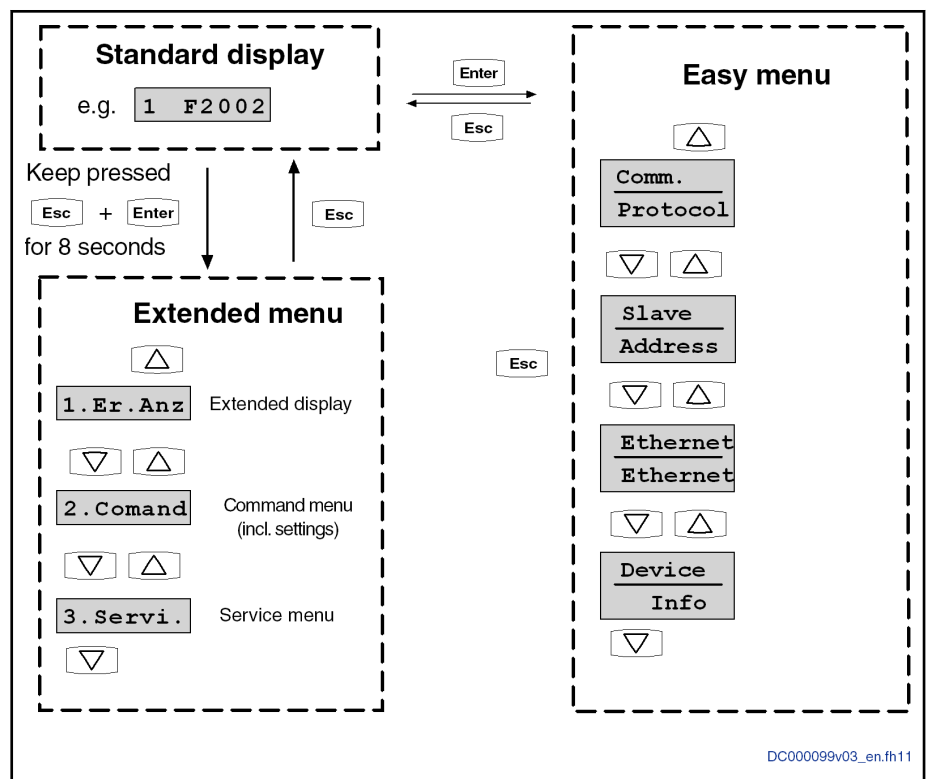
Fig.10-32:   Activating the extended display, the command menu and the easy menu

Easy menu
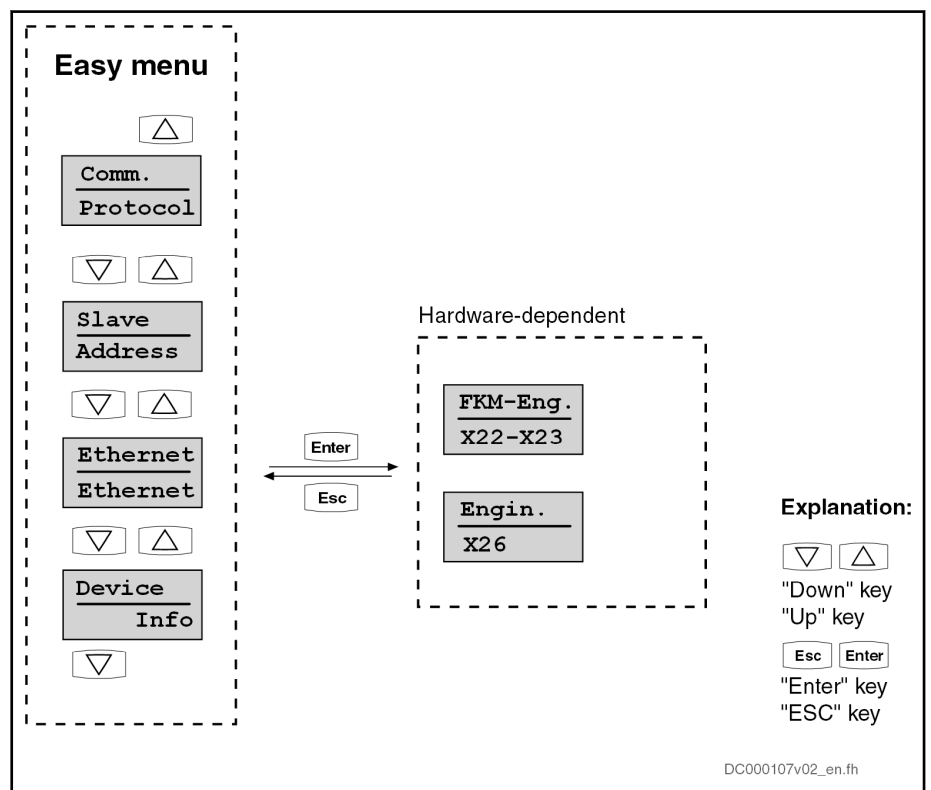
Fig.10-33:   Easy menu

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Control panel text:	Comment / note:
"Comm.___" "Protocol"	This submenu shows the current field bus protocol and can be changed, if required.
"Slave___" "_Address"	This submenu shows the current drive address. It can be changed, if required.
"Ethernet" "Ethernet"	In this menu the Ethernet connection can be viewed or set. The menu structure below "Ethernet" may vary, depending on the hardware (see "Easy menu" on page 1025).
"Device__" "___Info"	This submenu shows the information on the hardware to be used, e.g. firmware string (S-0-0030). **No settings can be made in this submenu.**
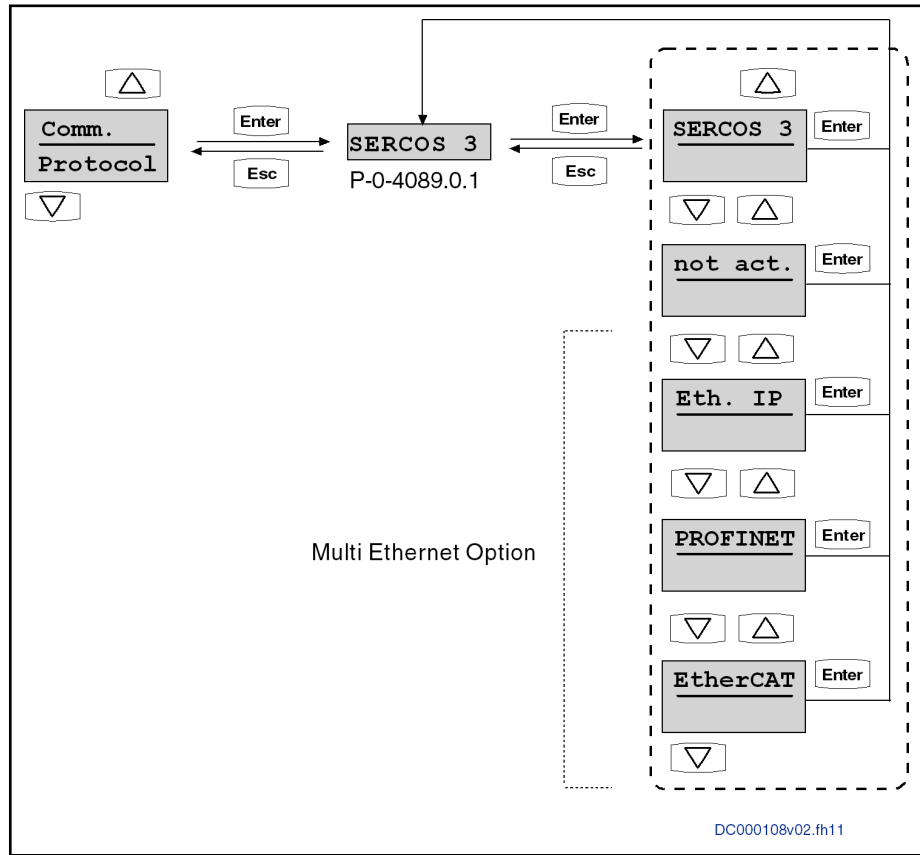
Fig.10-34:   Submenu of "Comm.___" "Protocol"

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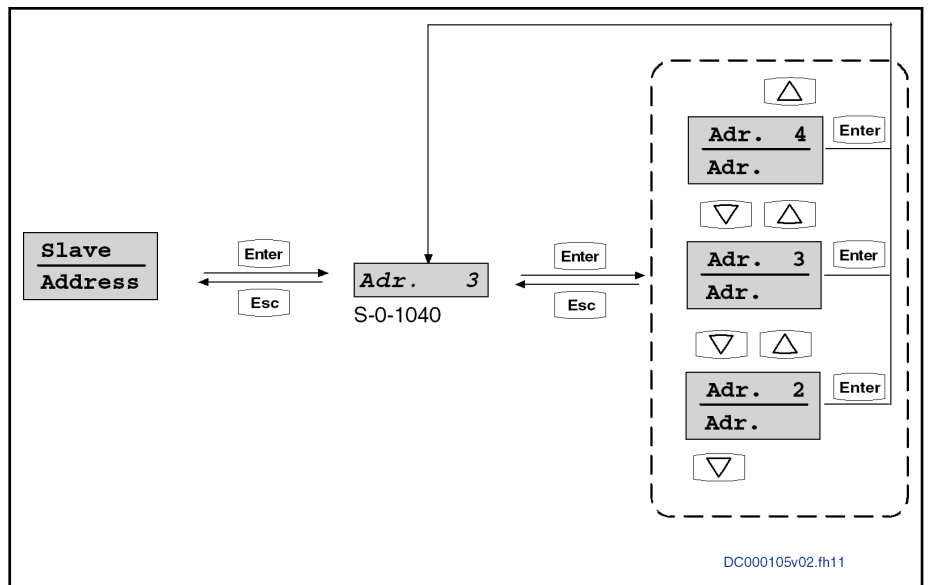
Fig.10-35:   Submenu of "Slave___" "_Address"
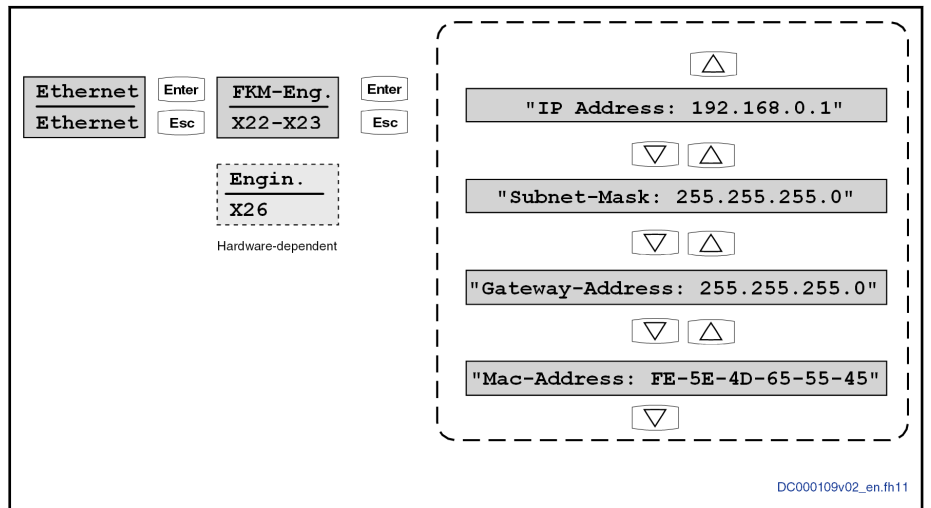
Fig.10-36:   Submenu of "Ethernet" "Ethernet"

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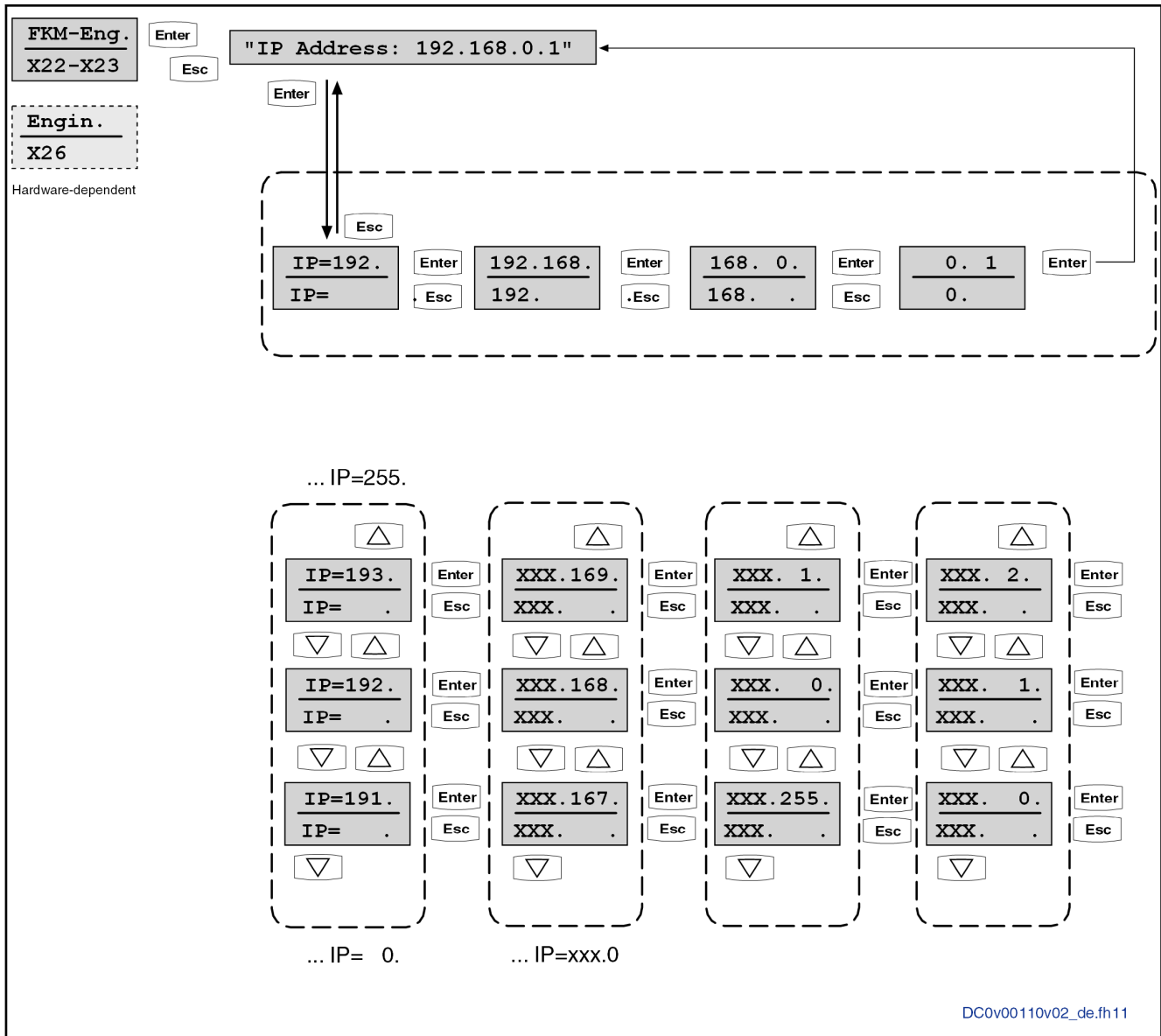
*Fig.10-37:   Example for setting the IP address for "Master Communication Eng."
"X22-X23"*

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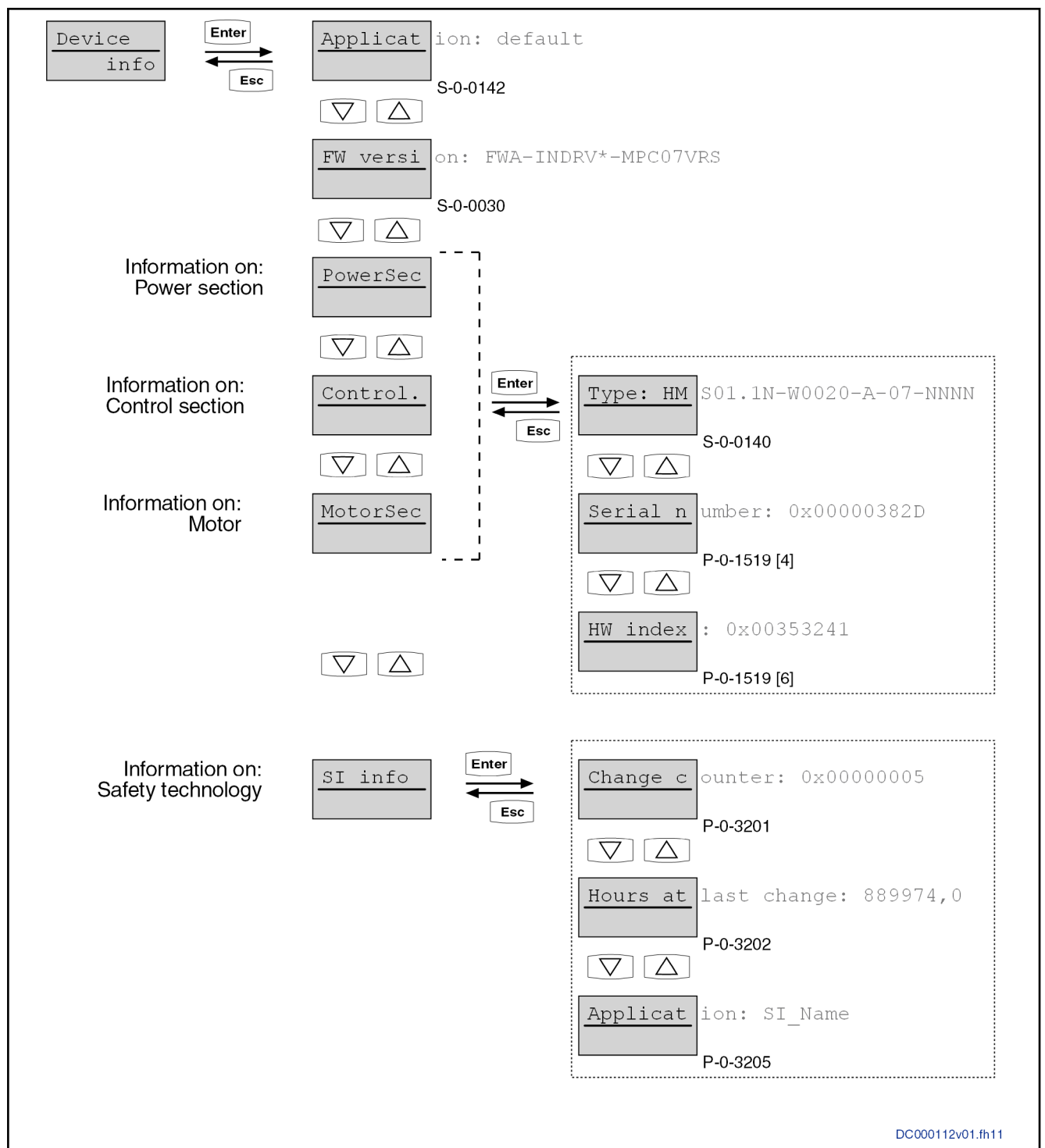
Fig.10-38:   Easy Menu, Structure Under "Device__" "____Info"

Assignment of the Entries in the "Device__""____Info" Menu to the Parameters Used

Menu	Entry	Parameters used
-	Application	Text in "S-0-0142, Application type"
-	FW version	Text in "S-0-0030, Manufacturer version"

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Menu	Entry	Parameters used
PowerSec	Type	Text in "S-0-0140, Controller type"
	Serial number	"P-0-1519, Module code of power section", 5th element
	HW index	"P-0-1519, Module code of power section", 7th element
Control.	Type	Text in "P-0-1520, Control section type"
	Serial number	"P-0-1518, Module code of control section", 5th element
	HW index	"P-0-1518, Module code of control section", 7th element
MotorSec	Type	Text in "S-0-0141, Motor type"
	Serial number	"P-0-3000, Module code of motor, encoder memory", 5th element
	HW index	"P-0-3000, Module code of motor, encoder memory", 7th element
SI info	Change counter	"P-0-3201, Change counter of safety technology memory"
	Hours at last change	"P-0-3202, Operating hours at last change of memory"
	Application	"P-0-3205, Safety technology device identifier"

Extended display   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)
- Diagnostic field bus message (P-0-4073)

Field bus:
Diagnostic message
`1.12` `P-0-4073`

Diagnostic messages depend on master communication and master communication status, see parameter description P-0-4073

`...X-XX-XX-XX-XX-X...`
`...X-XX-XX-XX-XX-X...`
`...X-XX-XX-XX-XX-X...`
`...X-XX-XX-XX-XX-X...`
`...X-XX-XX-XX-XX-X...`

XX = hex values from 00 to FF

Master communication:
MAC address
`1.11` `S-0-1019`

CCD:
MAC address
(if existing)
`1.10` `P-0-1640`

Control section:
MAC address
(if existing)
`1.9` `P-0-1530`

Safety tech. device identifier
(if existing)
`1.8` `P-0-3205`

Operating hours
at last change of memory
`1.7` `P-0-3202`

Change counter of
safety tech. memory
`1.6` `P-0-3201`

Firmware
type description
`1.5` `S-0-0030`

`FWA-INDRV*-...`

Operating hours counter
power section
`1.4` `P-0-0191`

`XXXXX.XX`

Operating hours counter
control section
`1.3` `P-0-0190`

`XXXXX.XX`

Diagnostic message memory
`1.2` `S-0-0375`

`0:A0002`

Use "Up/Down" keys to scroll through list lines

Error memory
`1.Er.Anz`

`1.1` `P-0-0192`

`0: F4002` (e.g.)

Use "Up/Down" keys to scroll through list lines

Extended display   **Display**   **Display**

Explanation: `Y.Y` `XXXXXXXX`   Display changes (flashes) between "Y.Y" and "XXXXXXXX"

"Down" key
"Up" key

"Enter" key
"ESC" key

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Fig.10-39:   Activating the extended displays

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For more details on diagnostic messages, error messages and operating hours counters, see the respective sections of this document.

Command menu

Starting from the extended display, the command menu is activated by pressing the "Up" key. This menu is used to enter different settings:

- Setting the drive address (drive number in the bus system of the master communication)
- Additional communication settings (IP address, gateway addresses and subnet mask)
- Activating the easy master communication mode "easy startup"
- Activating "S-0-0262, C07_x Load defaults procedure command" (load controller parameters or basic parameters)
- Switching the communication phases between operation mode (OM) and parameter mode (PM)
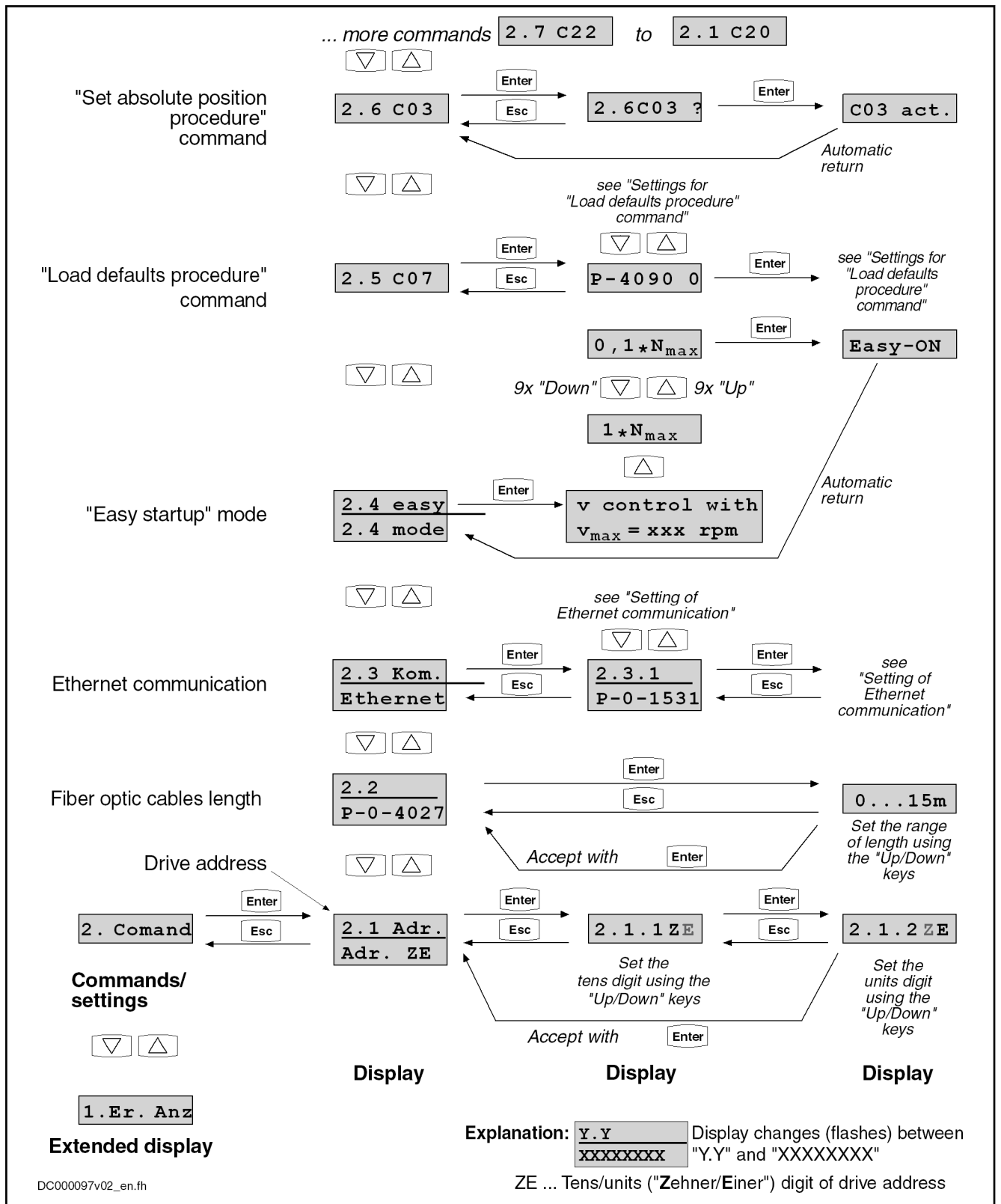
Fig.10-40: *Activating commands/settings that can be accessed via the control panel (commands 2.1 to 2.6)*

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DC000098v02_en.fh
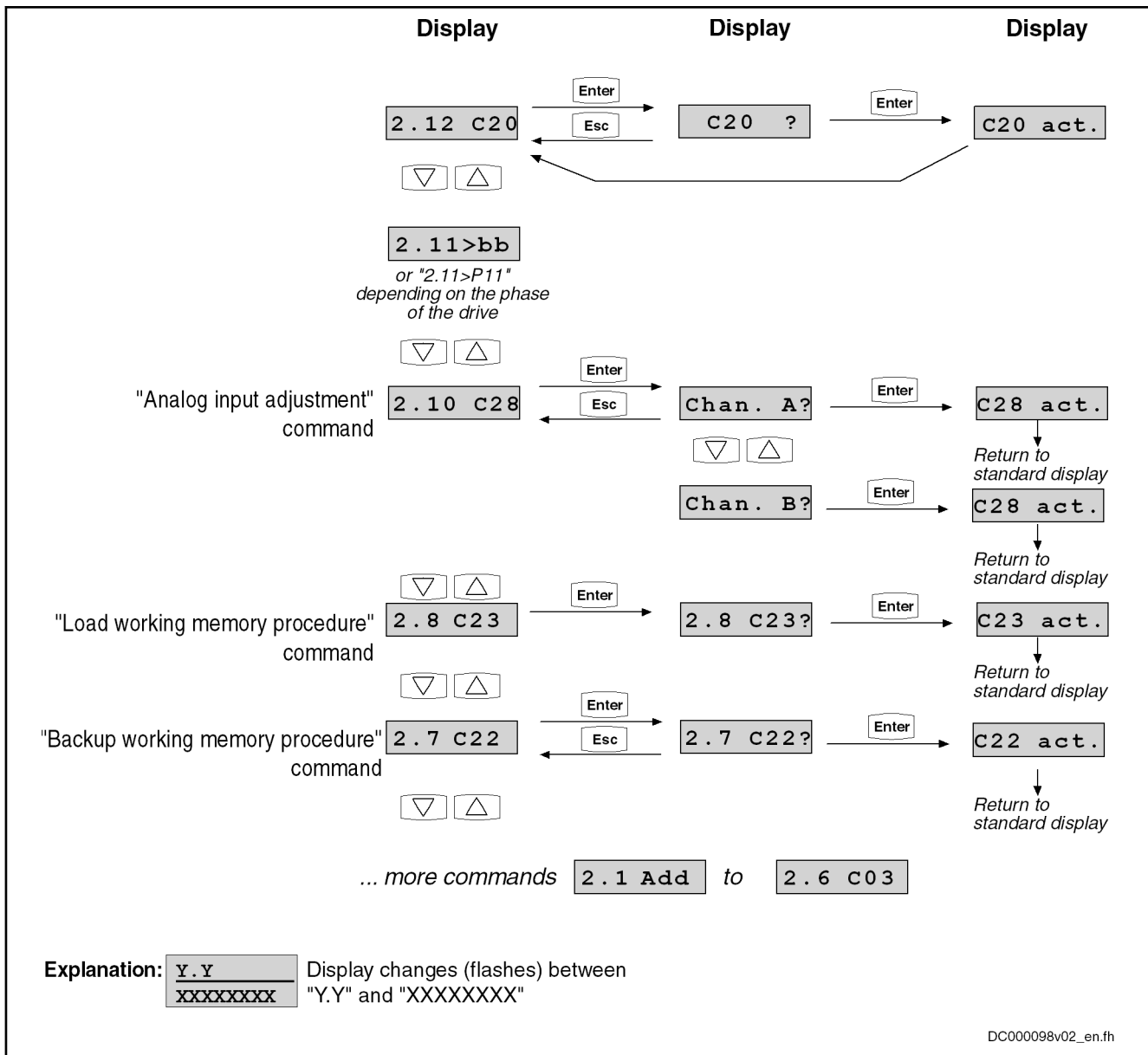
Fig.10-41:   Activating commands/settings that can be accessed via the control panel (commands 2.7 to 2.12)

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**

☞ After the command C07_x has been executed, the parameter P-0-4090 is automatically reset to its default value (0x0000)!
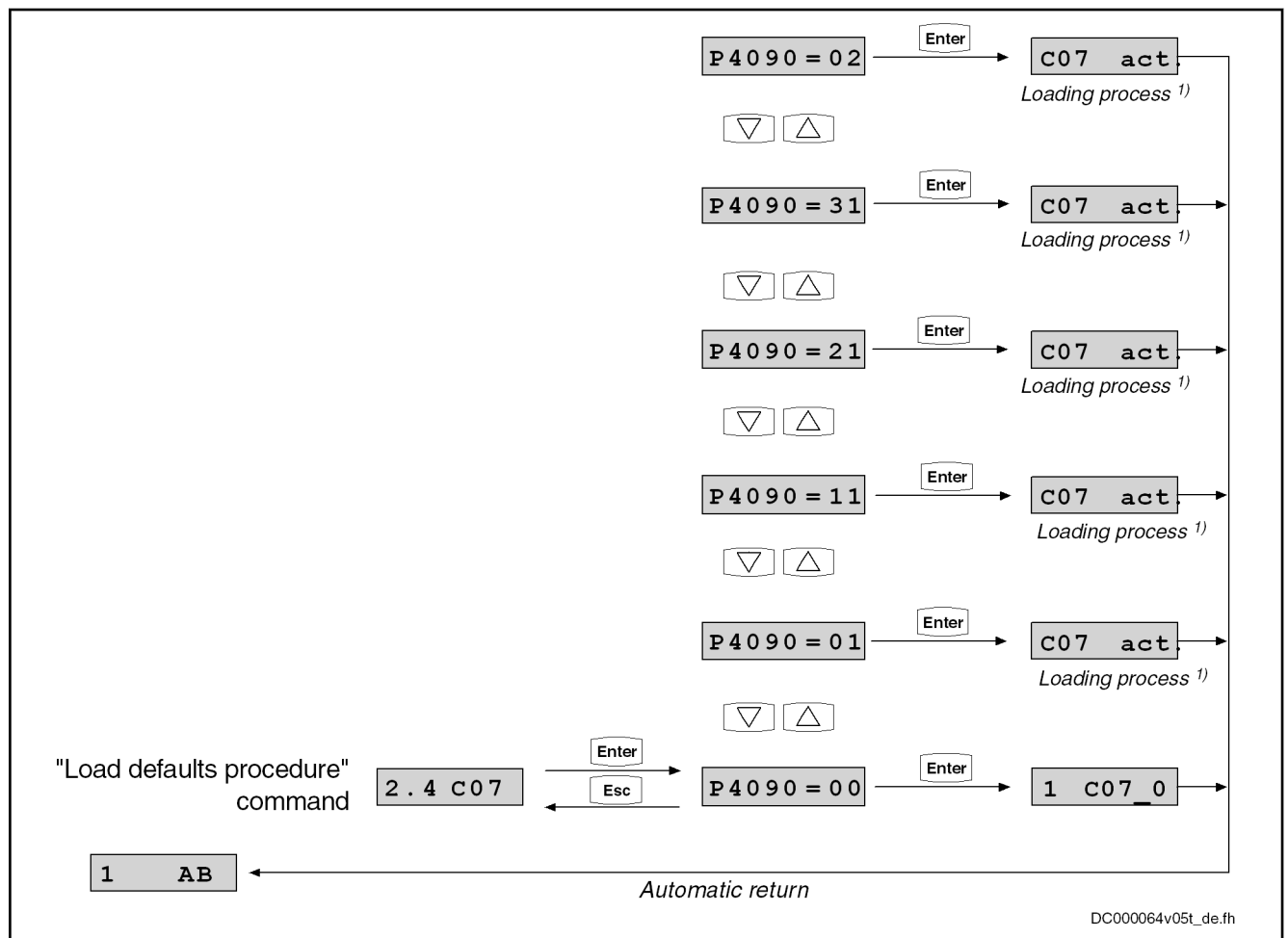
Fig.10-42:   Setting parameter P-0-4090 for "load defaults procedure" via the standard control panel

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 "Easy startup" mode active!

☞ In order to execute "C07_1 Load defaults procedure com. (load basic parameters)", the parameter mode (PM) has to be activated.

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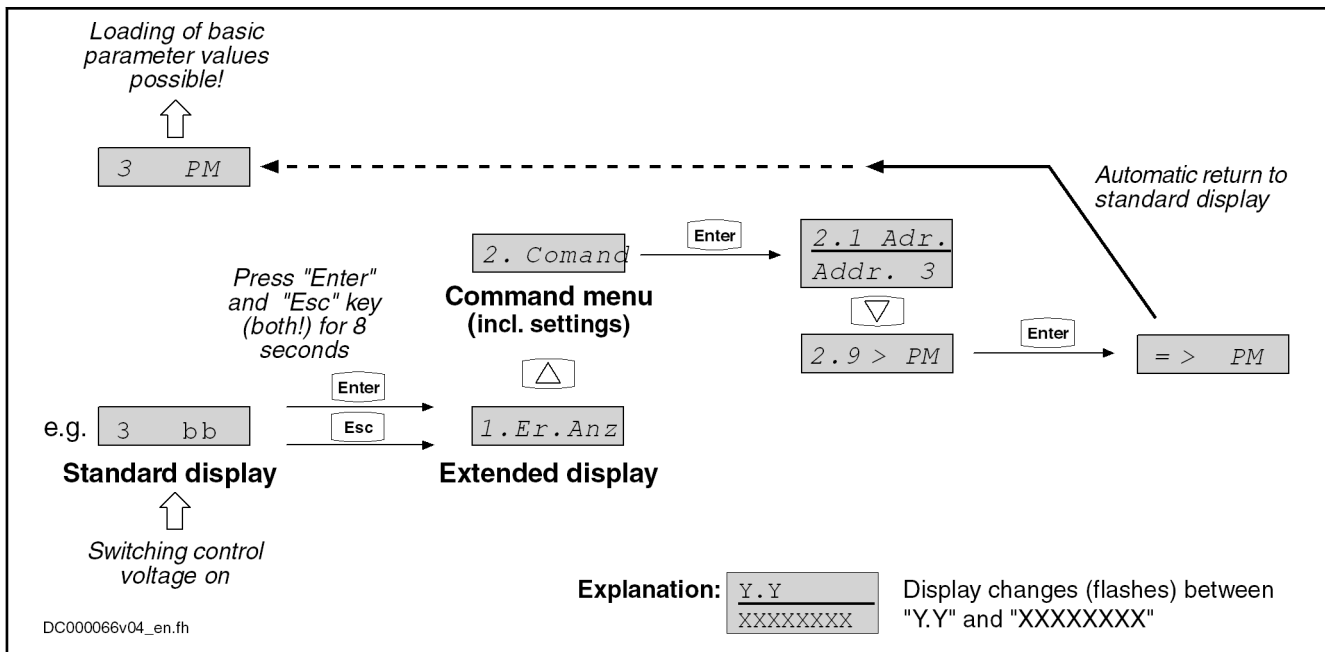
Fig.10-43:   Activating parameter mode via the control panel
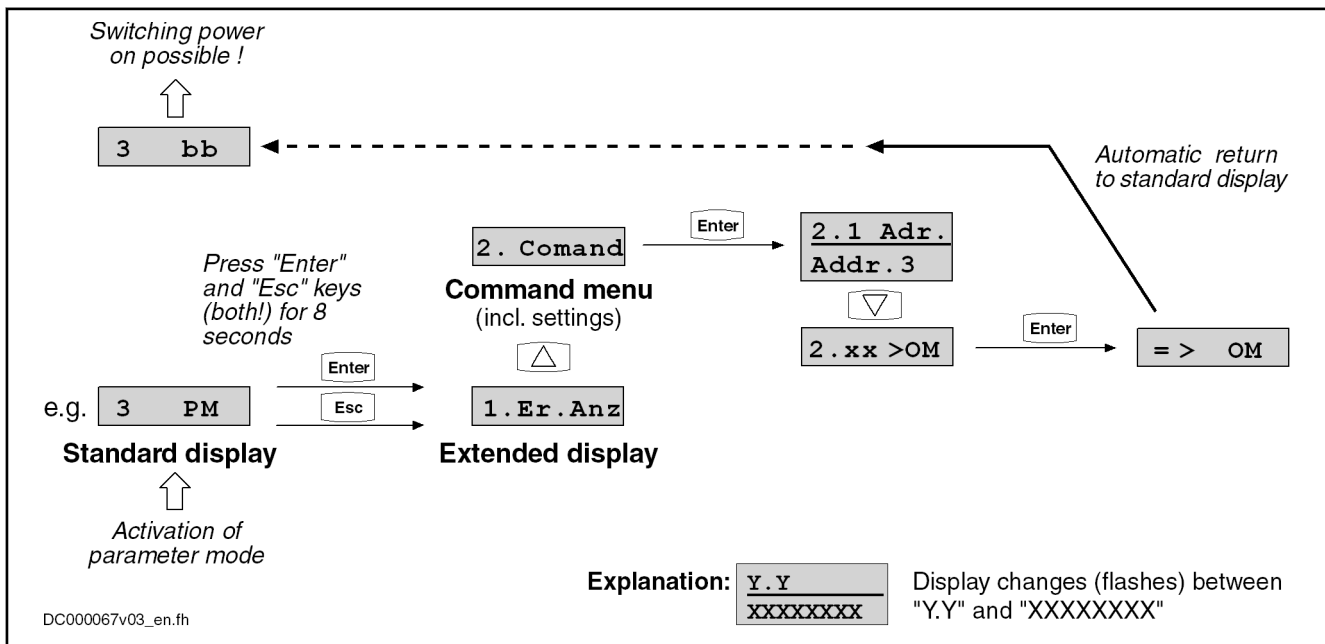
Fig.10-44:   Switching back from parameter mode to operation mode via the control panel

Defining MMC storage mode

Parameter "P-0-4070, Parameter storage configuration" defines how the controller handles the (optional) MMC memory card. This setting can be defined directly via the command menu of the control panel (2.10). The following storage modes are possible for operating the MMC:

- MMC as programming module
- MMC as update medium
- MMC as backup medium

MMC as programming module

If the MMC has been defined as "programming module", all parameters are stored on the MMC. With an active controller, the MMC must be permanently plugged into the control section. If the controller is switched on without MMC

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or the MMC is removed from the active controller, the controller signals an error.

MMC as update medium   When the MMC has been defined as "update medium", the control section checks during the booting process whether an MMC was plugged in or not. The display asks whether the parameters are to be loaded from the MMC. If there is a newer firmware on the MMC, a request is issued as to whether this firmware is to be loaded. The parameters are not stored on the MMC, but in the onboard flash memory.

MMC as backup medium   When the MMC has been defined as "backup medium", it is used as a demand-dependent storage location for parameter settings. The parameter values are stored via a command, via the FTP server or file services (MLD).

When the MMC operation has been defined as "update medium" or as "backup medium", it is **not** necessary to have the MMC permanently plugged into the control section. The MMC can be plugged in or removed with the drive active. Loading and storing parameter sets, however, is only possible with the MMC plugged in!

☞   The options for using the MMC in the IndraDrive controller are described in detail in the section "MultiMediaCard (MMC)".
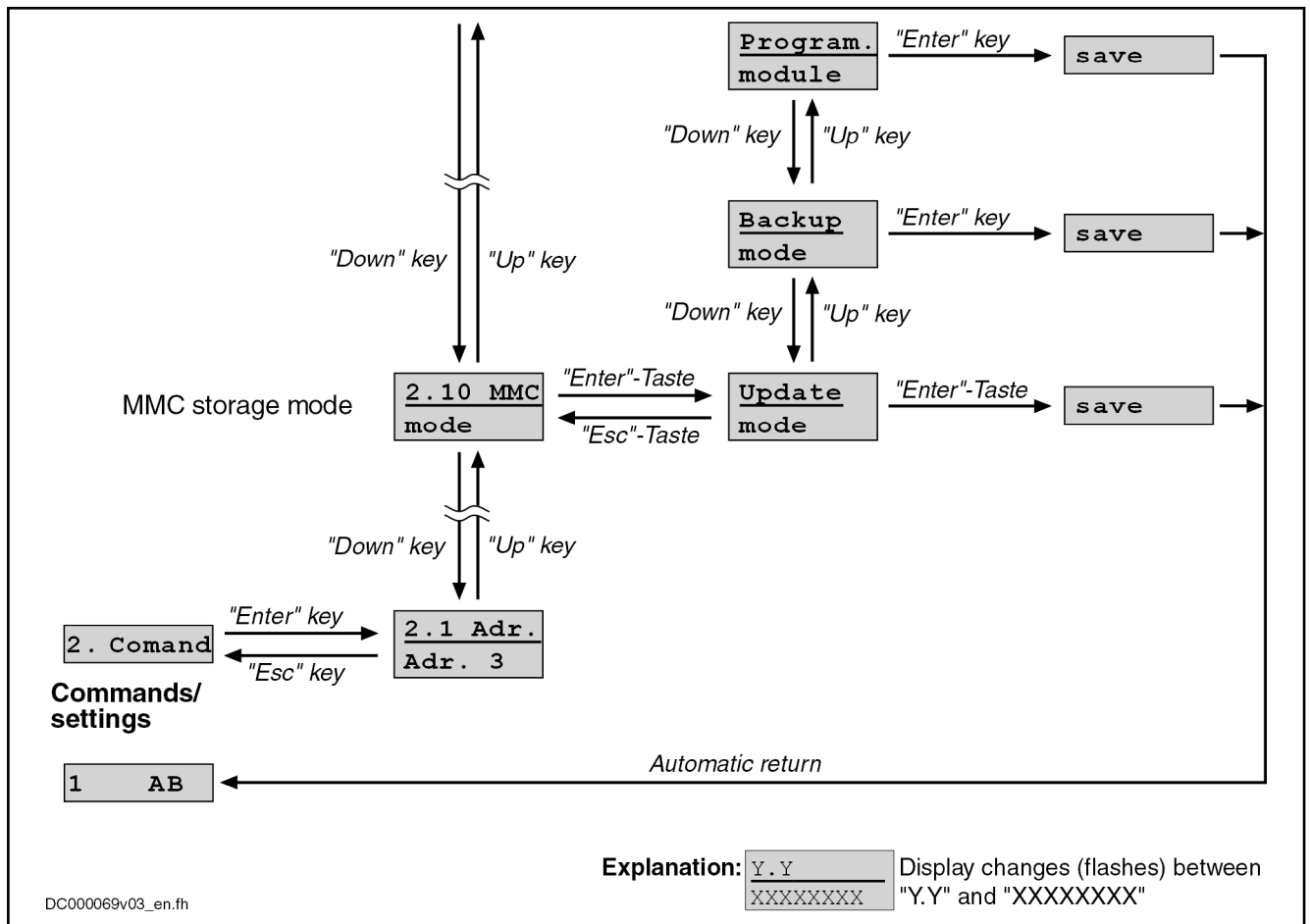
Fig.10-45:   Setting the MMC Storage Mode With the Control Panel

Service menu   Starting from the command menu, activate the service menu by pressing the "Up" key. It supports the following actions:

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- 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" has no 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 is 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 is stored on the MMC.

- Copying 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

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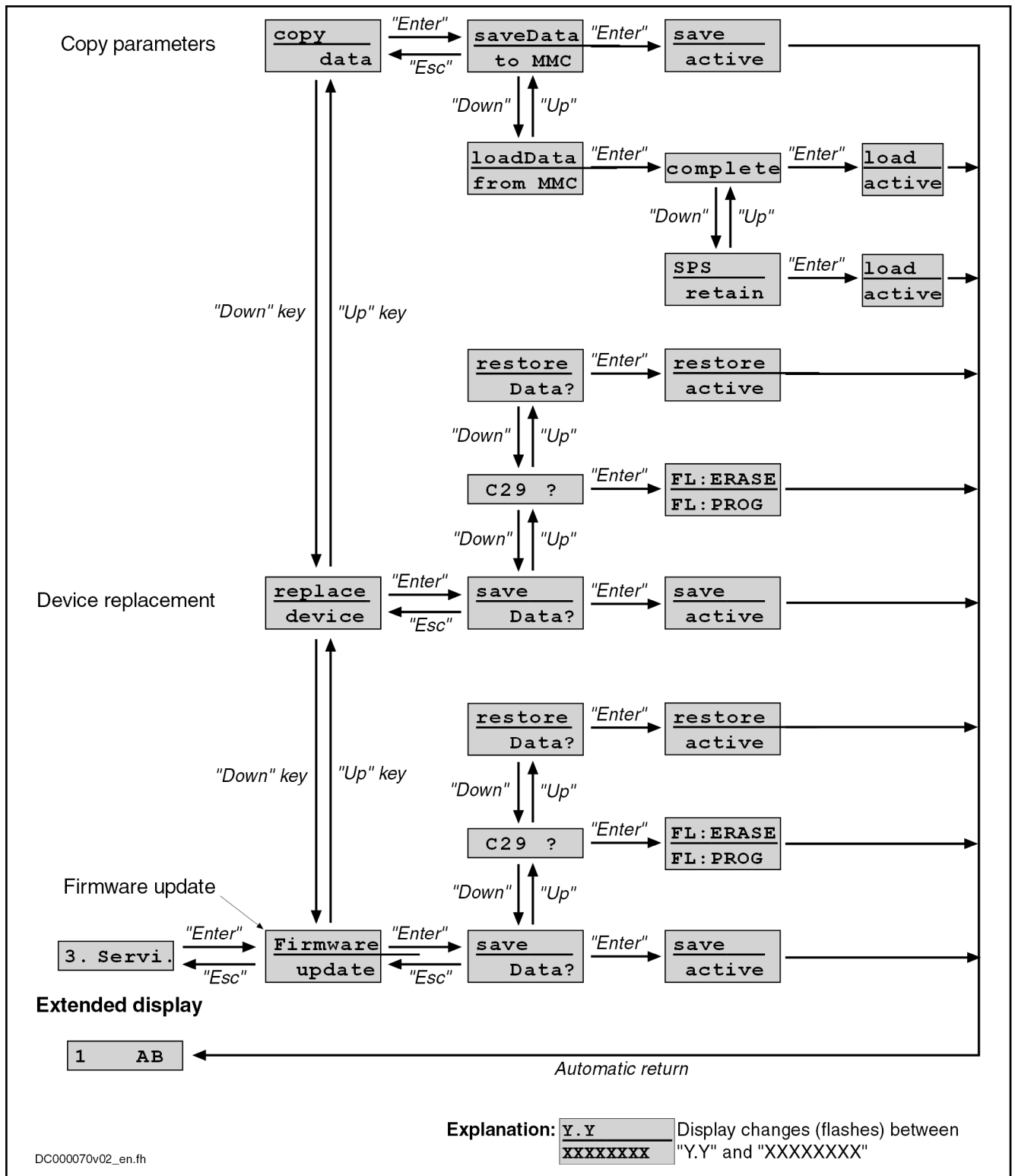
Fig.10-46:   *Activating the functions of the service menu*

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10.6   MultiMediaCard (MMC)

10.6.1   Brief Description

The MultiMediaCard (MMC) is a storage medium that can be inserted into the slot provided for this purpose on 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 a **stationarily** (permanently) plugged storage medium, the MMC can be used as a:

*   "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 (backup or init/update 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)

    Note: Not for drives with absolute value encoder and modulo format!

    See "Initial Commissioning/Serial Commissioning"

*   Storing/reestablishing parameters centrally from the control master (MLD)

    Note: 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 or temporary backup MMC" to the status "device with stationarily plugged MMC (programming module mode)" 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)! For storage media of other manufacturers we cannot assume any guarantee for faultless operation.

Pertinent parameters
*   P-0-4065, Active non-volatile memory
*   P-0-4066, MMC identification number (CID)
*   P-0-4070, Parameter storage configuration
*   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

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- • 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
- • F2120 MMC: Defective or missing, replace

10.6.2   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.

☞   If it is necessary to reformat an MMC of type PFM02.1-****-FW, ensure that FAT, FAT12 or FAT16 formatting is used! FAT32 formatting is not supported and therefore cannot be used!

When used in IndraDrive devices, the MMC has to have the following folder structure:
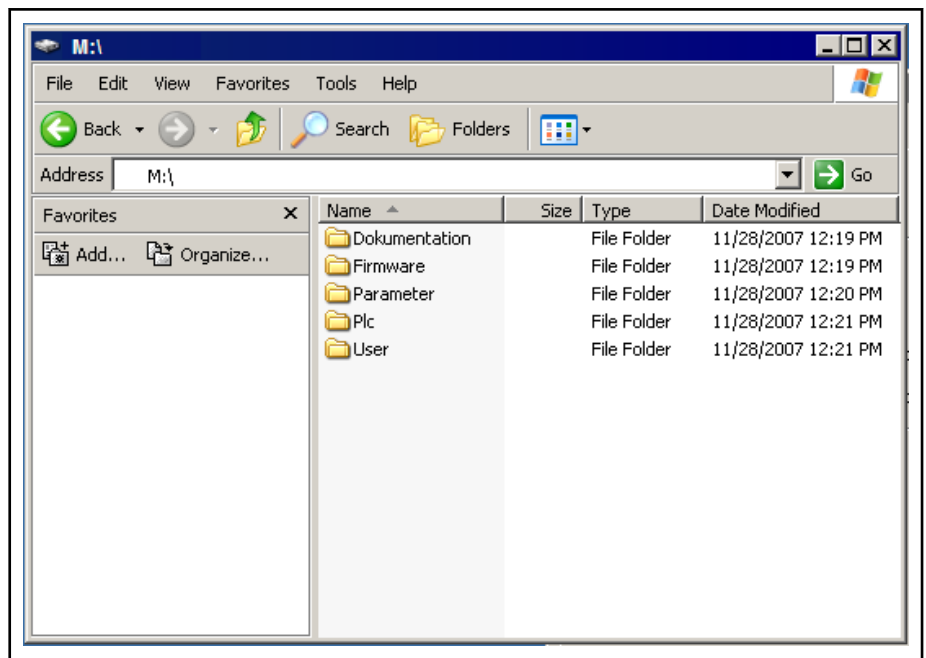
Fig.10-47:   Required MMC folder structure

The folders on the MMC are provided for the following contents:

"Firmware" folder   The file with the drive firmware has to be filed in this folder. The file extension must be **".ibf"**.

The following firmware versions are possible:

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- FWA-INDRV*-MPC-… (Advanced single-axis)
- 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"!

"Parameter" folder 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 according to "S-0-0192, IDN-list of all backup operation data"

- A file with the extension "....#1.rbf" (size 16kB)

  → "Retain" data for replacement of device according to "P-0-0195, IDN list of retain data (replacement of devices)"

Storage takes place automatically when the MMC is used as a "programming module" (stationarily plugged). Storage takes place by a command, if the MMC has only been plugged temporarily.

☞ With the firmware version "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".

"Documentation" folder 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.

"Plc" folder 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.

"User" folder 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").

10.6.3   Controller With or Without MMC

General Information

Depending on the setting in "P-0-4070, Parameter storage configuration" it may be necessary to make decisions at switch-on with regard to parameter update and firmware exchange. If an error status is detected, progression to operating mode ("OM") is prevented.

Changes in parameter P-0-4070 only become effective after rebooting the axis. The device status as regards the MMC is displayed in parameter "P-0-4065, Active non-volatile memory".

Switching on Controller Without MMC Plugged-in
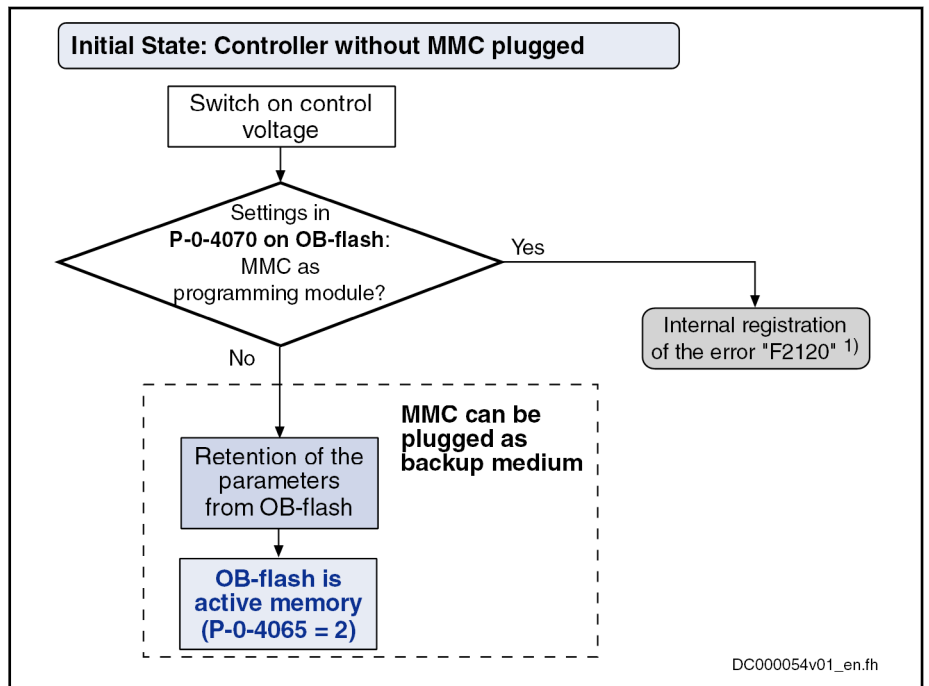
MMC	MultiMediaCard (type PFM02.1-…)
OB-flash	Non-volatile memory in the controller (OnBoard)
P-0-4065	Non-volatile memory active
P-0-4070	Parameter storage configuration
1)	At the end of the boot process the error message "F2120 MMC: Defective or missing, replace" is displayed.

Fig.10-48:   *Switching on controller without MMC plugged-in*

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Switching on Controller With MMC Plugged-in

Initial State: Controller with MMC plugged

Switch on control voltage

Setting in **P-0-4070 on MMC**: MMC as programming module? — Yes →

MMC is the programming module

CID of the MMC is equal to the CID saved in P-0-4066? — No →

No ↓

Setting in **P-0-4070 on OB-flash**: MMC as programming module? — Yes → Internal registration of the error "F2120" [1)]

Confirmation new programming module for control section: **"Activate new MMC ?"** — No → ESC → Internal registration of the error "F2120" [1)]

Yes → ENTER

CID of the new MMC in P-0-4066

Safety techn. messages [2)]

Retention of the parameters from MMC

MMC is active memory (P-0-4065 = 1)

No ↓

MMC is backup or init /update medium

Setting in **P-0-4070 on MMC**: MMC is the backup medium — No →

Yes ↓

MMC is the backup medium   **MMC is the init/update medium**

Retention of the parameter of MMC: **"Load Par from MMC ?"** — No → ESC

Yes → ENTER

Retention of the parameters from OB-flash

Retention of the parameters from MMC in OB-flash

Retention of the parameters from OB-flash

OB-flash is active memory (P-0-4065 = 2)

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MMC	MultiMediaCard (type PFM02.1-…)
OB-flash	Non-volatile memory in the controller (OnBoard)
CID	MMC-IDN
P-0-4065	Non-volatile memory active
P-0-4066	MMC identification number (CID)
P-0-4070	Parameter storage configuration
1)	At the end of the boot process the error message "F2120 MMC: Defective or missing, replace" is displayed.
2)	Only with safety technology option available, further messages appear (see documentation "Integrated Safety Technology").

Fig. 10-49:   *Switching on controller with MMC plugged-in*

If the stationarily plugged MMC (as programming module) 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 appears again!

10.6.4   Using the MMC in the Drive Controller

Replacing Firmware With MMC

The MMC allows drive firmware to be transmitted to the drive controller in a quick and uncomplicated way. We basically distinguish between stationarily and temporarily plugged-in 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 "Firmware Replacement"

MMC When Replacing Devices

See "Notes on How to Replace the Devices"

Saving Parameter Values on MMC

Put MMC into the controller after boot phase ("hot plug"). In communication phase 2, the following action is to be carried out via control panel or appropriate master communication:

- **Via control panel**

  → Activating the command "saveData" in the service menu of the control panel

- **Via master communication**

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→ 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 Ds/D/MLD" 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, the following action is to be carried out via control panel or appropriate master communication:

- **Via control panel**

  → Activating the command "loadData" in the service menu of the control panel

- **Via 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.

☞   With 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 the 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.

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Change in Device Status Regarding MMC (Stationary/Temporary)

Device with stationarily plugged-in MMC → Device Without MMC

Sequence for status change "device with stationarily plugged MMC" (programming module mode) to "device without MMC" (backup or init/update medium):

1. Store axis-specific parameter values stored on the previously active MMC via command "C2500 Copy IDN from optional memory to internal memory" in non-volatile memory of controller.

2. Switch from "P-0-4070, Parameter storage configuration" to option "MMC as init/update medium"

3. Switch control voltage of drive off and remove previously active MMC from controller.

4. Switch drive on again without MMC plugged.

Boot process is completed and drive then waits for other commands or is put into readiness for operation via the control master.

☞   If "P-0-4070, Parameter storage configuration" has not been changed, the error message "F2120 MMC: Defective or missing, replace" appears after booting.

In order to clear the error message the setting in parameter P-0-4070 must be corrected and then switched on and off again.

Device without MMC → Device with stationarily plugged-in MMC

Sequence for status change "device without MMC" (backup or init/update medium) to "device with stationarily plugged MMC" (programming module mode):

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 transmit axis-specific parameter values stored in controller to MMC via command "C2600 Copy IDN from internal memory to optional memory".

3. Switch "P-0-4070, Parameter storage configuration" to "programming module mode" option.

4. Switch control voltage of drive off, leave new MMC in controller and switch drive on again.

5. When controller is "booted", the message "Firmware update?" appears on display, if the firmware stored on MMC differs from the firmware stored in device. Acknowledge this message by pressing "Enter" key (control pane)!

6. New firmware now is possibly loaded to controller (firmware update); display shows corresponding download messages.

7. In the course of the boot process, display shows message "Activate new MMC?". Acknowledge this message by pressing the "Enter" key (control panel). Further messages appear if the safety technology option is fitted, (see documentation "Integrated Safety Technology"). Also acknowledge these messages by pressing "Enter" (on the control panel). The new MMC is now the 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.

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> ☞ By confirming the message "Activate new MMC?" with "Esc", the parameters are loaded from the OB-Flash and the error message "F2120 MMC: Defective or missing, replace" is displayed.

> ☞ If the parameters stored on the MMC are also to be stored in the device-internal non-volatile memory, 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.

10.7   Firmware Replacement

10.7.1   General Notes on How to Replace the Firmware

Basic Principles

Explanation of terms   For firmware replacement, we distinguish between the following cases:

- **Release update**

  An older firmware release in the device (for example MPH08**V02**) is replaced by a newer firmware release (for example MPH08**V04**).

- **Version upgrade**

  The older firmware version in the device (for example MPH**07**V08) is replaced by a new firmware version (for example MPH**08**V02).

> ☞ The paragraphs below describe the recommended options for firmware replacement to 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 "IndraWorks Ds/D/MLD" software**

> ☞ The commissioning software "IndraWorks Ds/D/MLD" can be ordered from one of our sales and service facilities. "IndraWorks Ds/D/MLD" includes a document describing the operation of the program.

Preparations and Conditions for Firmware Replacement

Preparing for firmware replacement   Make the following preparations for firmware replacement:

1. Drive controller must be on (24 V supply).

2. It is imperative that parameter values are saved before any firmware version upgrade (this is also recommended for relase updates), as otherwise complete (re-)commissioning of the drive is required.

   See also Firmware functional description "Loading, Storing and Saving Parameters"

3.

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General notes on replacing firm-ware

Observe the following points when replacing firmware:

● Do not switch off the 24 V control voltage while replacing the firmware.

● The firmware in devices with MultiEthernet interface (ET option) must be replaced using an MMC.

●

●

☞ When the firmware is replaced in conjunction with the option "Safe Torque Off" (L2), this does not require any specific measures, i.e. the additional measures described below only apply to the use of option "S2"!

10.7.2 Firmware Release Update

General Information

When firmware in a drive controller is replaced by firmware of a **newer release date**, this is called firmware release update (e.g. FWA-INDRV*-MPH-07**V02**-D5 replaced by FWA-INDRV*-MPH-07**V04**-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:

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```
                              ┌─────────────────┐
                              │ Control section │
                              │     type?       │
                              └────────┬────────┘
            ┌──────────────────────────┴──────────────────────────┐
     ┌──────────────┐                                       ┌──────────────┐
     │  CSH0x.x     │                                       │  CSB0x.xN    │
     │  CDB0x.x     │                                       │              │
     │  CSB0x.xC    │                                       │              │
     └──────┬───────┘                                       └──────┬───────┘
            │                                                      │
     ┌──────┴───────┐   No                                         │
     │     MMC      │────────────┐                                 │
     │  plugged in? │            │                                 │
     └──────┬───────┘            │                                 │
         Yes│               ┌────┴──────────┐   No *               │
            │               │Firmware update│- - - - - - - ->      │
     ┌──────┴───────┐       │ without PC?   │                      │
     │ MMC plugged in│      └────┬──────────┘                      │
     │  operation    │        Yes│                                 │
     │ → MMC with old│           │                                 │
     │   firmware    │           │                                 │
     └──────┬───────┘            │                                 │
     ┌──────┴───────┐    ┌───────┴────────┐              ┌─────────┴──────┐
     │ Request new  │    │Request MMC with│              │ Request new    │
     │firmware (ibf │    │ new firmware!  │              │firmware (ibf   │
     │  file)!      │    │                │              │  file)!        │
     └──────┬───────┘    └───────┬────────┘              └─────────┬──────┘
     ┌──────┴───────┐            │                                 │
     │Load new      │            │                                 │
     │firmware to   │            │                                 │
     │MMC!          │            │                                 │
     └──────┬───────┘            │                                 │
            ├────────────────────┘                                 │
     ┌──────┴───────┐                                              │
     │ MMC with new │                                              │
     │  firmware    │                                              │
     └──────┬───────┘                                              │
   Variant 1│                                          Variant 2   │
     ┌──────┴───────┐                                  ┌───────────┴──────┐
     │Release update│                                  │ Release update   │
     │  with MMC    │                                  │     with         │
     │              │                                  │IndraWorks Ds/D/MLD│
     └──────────────┘                                  └──────────────────┘
                                                             DC000148v01.fh
```
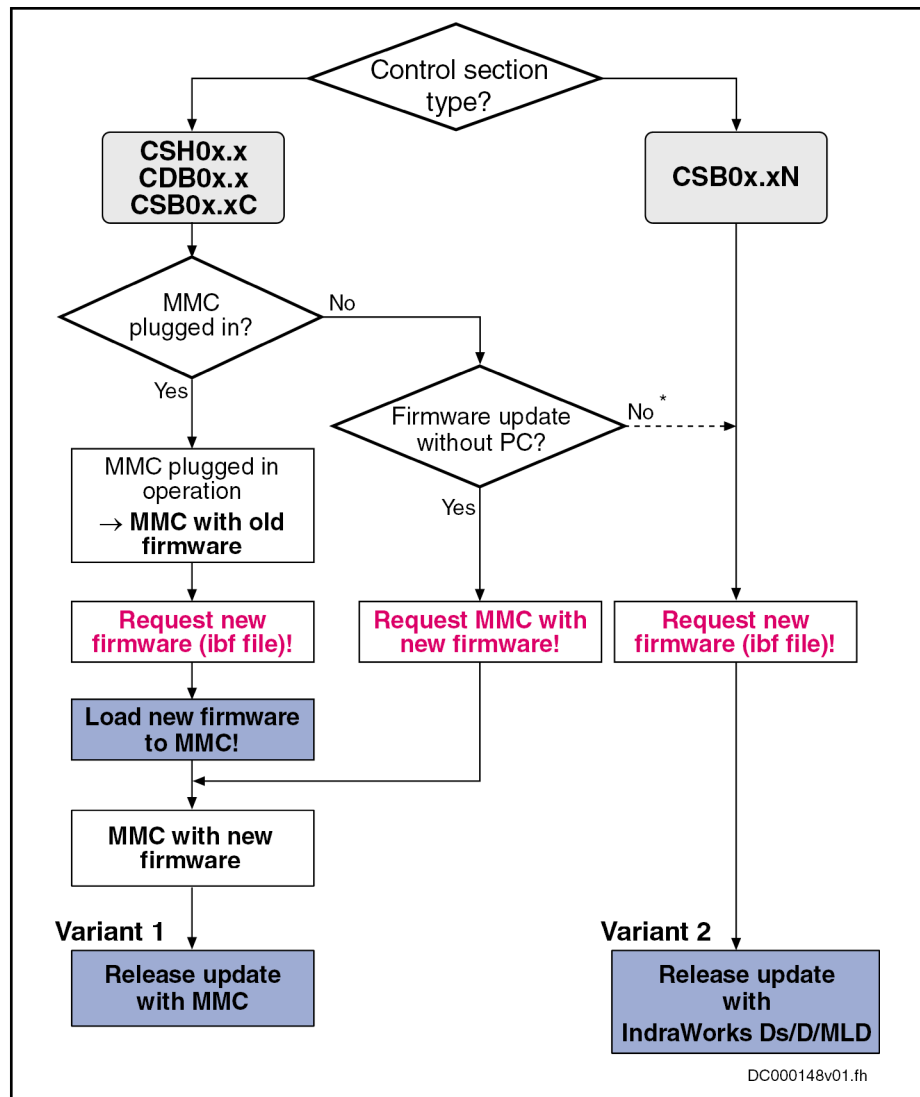
*	Only possible with devices without an ET option
CSH0x.x	ADVANCED single-axis control section
CDB0x.x	BASIC double-axis control section
CSB0x.xC	BASIC single-axis control section (configurable)
CSB0x.xN	BASIC single-axis control section (not configurable)
Active memory	"Programming module" operation of MMC (see P-0-4065)

Fig.10-50: 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.

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2. Plug MMC into MMC reader and open "Firmware" folder on MMC.

3. Delete old firmware (e.g. FWA-INDRV_-MPH-07**V02**-D5.ibf)!

4. Copy new firmware (e.g. FWA-INDRV_-MPH-07**V04**-D5.ibf) to folder "Firmware".

☞   Only one firmware file may be stored in the "Firmware" folder on the MMC. With several firmware files, the message "MMC not correct" appears on the display of the drive after the booting process.

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 drive firmware to be transmitted to the drive controller in a quick and uncomplicated way.

☞   As the MMC is a storage medium that can be written simply (for example via a PC), it is recommended that the MMC content is checked before downloading the firmware. Ensure 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 on the controller.

⇒ Restart drive with MMC plugged!

After the drive has been booted, the following message appears:

- "Firmware update?"

⇒ Acknowledge this message by pressing "Enter" on the control panel, thereby loading firmware from the plugged-in MMC to the drive.

One of the following messages is 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 drive functions!

3. **Check safety technology parameters** (only when safety technology has been activated in the drive)

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With a release update, the safety technology parameters are retained. With safety technology activated, the following steps are additionally required:

⇒ Check whether the correct safety technology parameter settings for drive are still available!

To do this, check the following points:

- Data in the 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 the firmware release update, the safety technology acceptance test must be carried out again!

Variant 2: Release Update With "IndraWorks Ds/D/MLD"

Selection criterion   The following requirements are to be met to ensure that carrying out the firmware release update with "IndraWorks Ds/D/MLD" 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 Ds/D/MLD"   Carrying out the firmware release update with "IndraWorks Ds/D/MLD" requires the following steps:

1. **Load firmware**

   ⇒ Start "IndraWorks".

   ⇒ 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 up "Firmware management" in the context menu.

   A new window opens and firmware currently available in the drive is displayed on its right side. On left side of window, firmware available in the current firmware directory is displayed.

   ⇒ Highlight new firmware (*.ibf file) and start firmware download via "Download" button.

   Firmware download runs automatically and all required firmware components are loaded to the drive.

☞   IndraWorks automatically goes into offline mode. A request is made as to whether a backup of the parameters is to be made. Refuse this with "No".

⇒ After the 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 drive functions!

3. **Check safety technology parameters** (only when safety technology has been activated in the drive)

With a firmware release update, the safety technology parameters are retained. With safety technology activated, the following steps are additionally required:

⇒ Check whether the correct safety technology parameter settings for drive are still available!

To do this, check the following points:

- Data in the 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")

10.7.3   Firmware Version Upgrade

General Information

When firmware in a drive controller is replaced by firmware of a **more recent version**, this is called firmware version upgrade (e.g. FWA-INDRV*-MPH-**06**V10-D5 replaced by FWA-INDRV*-MPH-**07**V02-D5).

☞   **Before** carrying out the firmware version upgrade, all parameters have to be saved (for instance using "IndraWorks"). **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:
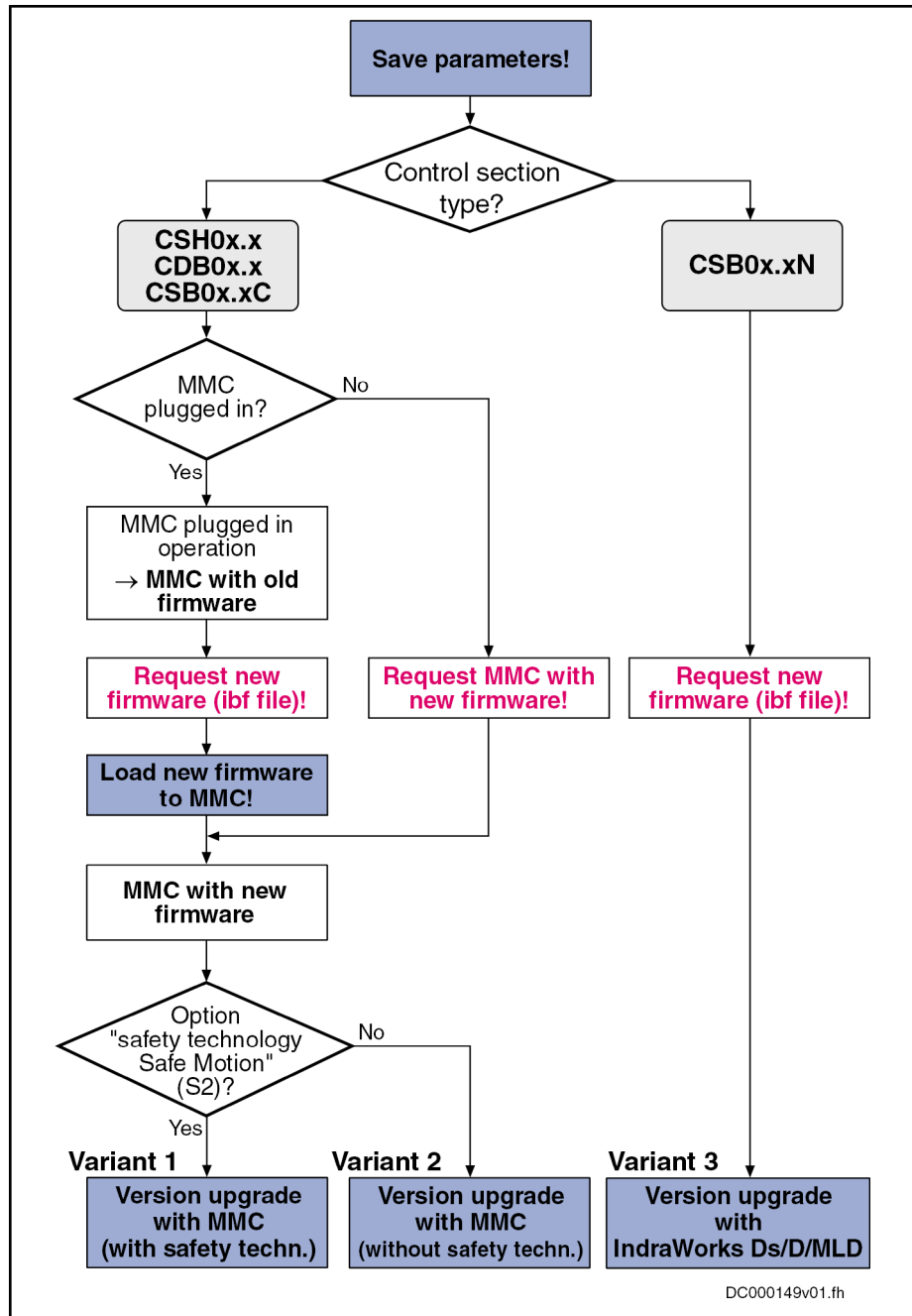
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CSH0x.x	ADVANCED single-axis control section
CDB0x.x	BASIC double-axis control section
CSB0x.xC	BASIC single-axis control section (configurable)
CSB0x.xN	BASIC single-axis control section (not configurable)
Active memory	"Programming module" operation of MMC (see P-0-4065)

Fig.10-51: 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.

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Saving Parameter Values

Before the firmware upgrade, all application-specific parameter values must be saved on a data carrier. The parameter backup can be carried out by means of:

- **Commissioning software "IndraWorks Ds/D/MLD"**

  → 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 is 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 "Firmware" folder on MMC.
3. Delete old firmware (e.g. FWA-INDRV*-MPH-06V10-D5.ibf)!
4. Copy new firmware (e.g. FWA-INDRV*-MPH-07V02-D5.ibf) to folder "Firmware".

   Note: Only one firmware file may be stored in the "Firmware" folder on the MMC. With several firmware files, the message "MMC not correct" appears on the display of the drive after the booting process.

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 are to be met to ensure 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 "Safe Motion" (S2).
- 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 on the controller.

   ⇒ Restart drive with MMC plugged!

   After the drive has been booted, the following message appears:

   - "Firmware update?"

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⇒ Acknowledge this message by pressing "Enter" on the control panel, By doing this, firmware is loaded from plugged MMC to controller.

One of the following messages is 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 the drive has been restarted, the error message "F8201" is generated (F8201 Safety command for basic initialization incorrect).

⇒ 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 backed-up parameter file!

⇒ Switch off drive and restart or execute Reboot command to activate parameterization.

4. **Entire commissioning of integrated safety technology**

⇒ Switch drive to operating mode (communication phase 4).

The error message "F3152 Incorrect backup of safety technology data" appears, as the safety technology parameter set between firmware versions 02, 03, 04 and 05 has changed.

⇒ Clear error message.

⇒ Activate command "Synchronize and store safety technology IDN". (C3000 Synchronize and store safety technology IDN)

⇒ Activate safety technology by inputting safety technology password (P-0-3206, Safety technology password).

⇒ Carry out new acceptance test.

[i] See sections "Activating Safety Technology" and "Acceptance Test" in the separate document "Integrated Safety Technology According to IEC61508" (DOK-INDRV*-SI2-**VRS**-AW**-EN-P; Mat. no. R911327663)

⚠ **DANGER**	Dangerous movements possible! Danger to life, risk of injury, serious injury or property 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 (S2).

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⇒ Back up safety technology parameters, compile acceptance test protocol and add it to safety-relevant document for the machine.

5. Put machine into ready-for-operation status

⇒ Put machine into ready-for-operation status again according to machine manufacturer's instructions.

⇒ Check drive functions!

Variant 2: Version Upgrade With MMC (Without Safety Technology)

Selection criterion
The following requirements are to be met to ensure 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 "Safe Motion" (S2).
- 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 on the controller.

⇒ Restart drive with MMC plugged!

After the drive has been booted, the following message appears:

- "Firmware update?"

⇒ Acknowledge this message by pressing "Enter" on the control panel, By doing this, firmware is loaded from plugged MMC to controller.

One of the following messages is 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 the number of parameters to be buffered has changed, "PL" appears on the display (if errors are pending, remove them first). Pressing "Esc" sets all buffered parameters to their default values. During this time, message "C07 Load default parameters" appears on the display. If errors are pending, they first have to be removed and the command C07_1 must then be manually activated!

3. Load parameter values

⇒ Load backed-up parameter file!

⇒ Switch off the drive and restart or execute the Reboot command, to activate parameterization.

4. Put machine into ready-for-operation status

⇒ Put machine into ready-for-operation status again according to machine manufacturer's instructions.

⇒ Check drive functions!

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Variant 3: Version Upgrade With "IndraWorks Ds/D/MLD"

Selection criterion

The following requirements are to be met to ensure that carrying out the firmware version upgrade with "IndraWorks Ds/D/MLD" makes sense:

- Controller has been equipped with BASIC single-axis control section.
- Current parameter setting of axis was saved.

Firmware upgrade with "IndraWorks Ds/D/MLD"

Carrying out the firmware version upgrade with "IndraWorks Ds/D/MLD" requires the following steps:

1. **Load firmware**

   ⇒ Call up "IndraWorks".

   ⇒ 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 up "Firmware management" in the context menu.

   A new window opens and firmware currently available in the drive is displayed on its right side. On left side of window, firmware available in the 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 the drive.

   ⇒ After the 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 the project has been switched online, a message signals that "IndraWorks" could not establish communication to the drive via the serial interface, as drive-internal settings for serial communication were reset.

   ⇒ Reconfigure communication via button "Search for devices".

   ⇒ As firmware in the drive no longer complies with the version stored in project, a corresponding message is displayed. To adjust the firmware version in the project, first select option "Repair" and then options "Delete existing drive from project" and "Add new drive to project".

   ⇒ As the number of parameters to be buffered has changed, "PL" appears on the display (if errors are pending, remove them first). Pressing "Esc" sets all buffered parameters to their default values. During this time, message "C07 Load default parameters" appears on the 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 backed-up parameter file!

4. **Put machine into ready-for-operation status**

   ⇒ Put machine into ready-for-operation status again according to machine manufacturer's instructions.

   ⇒ Check drive functions!

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10.7.4   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 the 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 is not valid firmware available in the control section in this case, the loader is started. The drive display signals "LOADER". The loader only allows the firmware of the control section to be updated. Optional modules, such as "Safe Motion" (S2) or "Cross communication" (CCD), cannot be programmed in this state. 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".

☞ | 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 the control section in the event of an error   The following steps are required for loading the firmware to the control section in the case of error:

1. Call up "IndraWorks Ds/D/MLD".
2. In the menu, call up Firmware management under "Tools→ Drive → Firmware management".
3. Select the device and COM interface.

   A new window opens and the firmware available in the current firmware directory is displayed on the left side.
4. Highlight new firmware (*.ibf file) on the left side and start firmware download via "Download" button.

   Firmware download runs automatically and all required firmware components are loaded to the drive.
5. After the firmware download has been completed, close the "Firmware management" window.
6. Restart drive!

If there are no optional modules, such as "Safe Motion" (S2) or "Cross communication" (CCD), follow the instructions for release update or version upgrade! Otherwise, carry out the release update or version upgrade again to program the optional modules.

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10.8   Notes on How to Replace the Devices

10.8.1   Replacing the Supply Unit

General Information

The concept of Rexroth supply units includes safe, quick and uncomplicated replacement of devices. This allows production downtimes, caused by failures of these devices, to be reduced 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 document "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.

Replacing the Supply Unit

Procuring a replacement device
Identify the device to be replaced by means of the type plate; procure the supply unit of same type from Bosch Rexroth!

i See also documentation of the respective supply unit

Completing the fault report
In the document for the respective supply unit, there is 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 supply unit
De-energize drive system; wait for DC bus to discharge; then replace defective supply unit!

⚠ WARNING	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!

i For notes on how to dismount and mount the supply unit, see document for the respective supply unit

Putting drive system into operation again
Put machine into operation again according to machine manufacturer's instructions!

10.8.2   Replacing the Controller

Overview

A controller of the IndraDrive range consists of the components power section and control section (incl. firmware). The control section can be configured with additional components (encoder interface, optional safety technology module,...). In the case of a defect, it is basically possible to replace one of the two components (control section or power section). As control section

and power section are firmly connected and one of the two components may only be replaced by Rexroth service engineers or especially trained users, the paragraphs below describe how to replace the complete controller as regards safety technology. The mounting and dismounting of the entire drive controller is described in the Project Planning Manual for the power section.

☞ Only applies to Rexroth service engineers or especially trained users. The replacement of a defective power section does not require any specific handling due to integrated safety technology; i.e. it is not necessary to repeat safety technology commissioning and acceptance test.

When a controller is replaced for which the control section has been configured with the option "Safe Torque Off" (L2), this does not require any specific measures, i.e. the additional measures only apply to the use of option "Safe Motion" (S2)!

☞ No firmware version upgrade is to be undertaken when replacing the controller, as it is otherwise necessary to repeat the safety technology acceptance test!

When replacing a controller with activated safety technology, observe that **safety technology is not active** for **controllers in their condition as supplied**:

- The status of "P-0-3207, Safety technology password level" is zero and
- "INDRASAVE" has been inputted into "P-0-3206, Safety technology password".

☞ A controller supplied for replacement, which has already been operational, must be returned to its delivery state (see document "Integrated Safety Technology", keyword "Deactivating safety technology").

The figure below illustrates the basic individual steps required.

Handling, Diagnostic and Service Functions
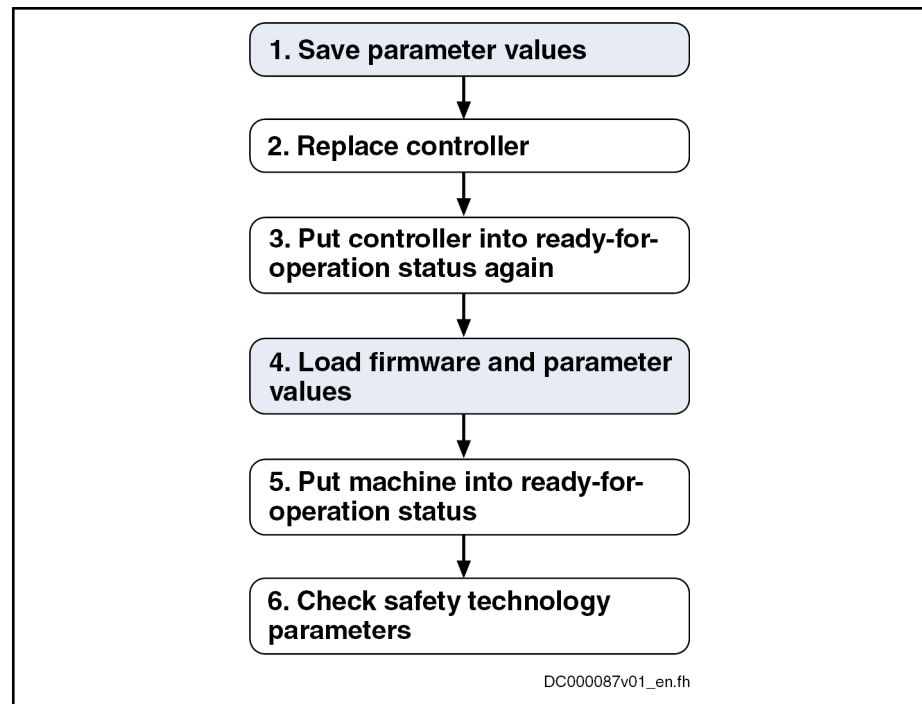
Fig.10-52:   General sequence for controller replacement

Controller Replacement Without Stationarily Plugged-in MMC

1. **Saving parameter values**

   Before dismantling the defective device, save the drive parameter values, if possible.

   When the controller is to be replaced by means of the MMC, make sure before starting the replacement that the MMC folder "Firmware" contains the firmware required for the drive (e.g. FWA-INDRV*-MPH-07V02-D5.IBF).

   ☞   If backing up the parameter values before replacing the device is 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 "Loading Parameter Values in Case of Total Breakdown of Device")!
   ---

   1. Switch drive off and on again

   2. Switch to Parameter mode (PM or P2)

   Parameter values of the defective device are saved via the control panel with with the MMC temporarily plugged in ("hot plug").

   ☞   If the MMC does not remain stationarily (permanently) plugged in the device, it may be temporarily plugged **into the switched-on device at the end of the booting phase** and removed again ("hot plug" and "hot unplug" respectively).
   ---

   3. Go to the Service menu.

   ⇒By simultaneously pressing "Esc" and "Enter" for at least 8 seconds, it is possible to call up extended displays; subsequently pressing the "Up" key (twice) activates the Service menu.

Handling, Diagnostic and Service Functions

Select the "Device replace" submenu using the arrow keys and activate it with "Enter".

⇒The active parameter values [according to "S-0-0192, IDN list of backup operation data" and "P-0-0195, IDN list of retain data (replacement of devices)"] and the PLC retain data is copied from the controller-internal memory to an MMC temporarily plugged into the controller.

Activate "save Data?" command
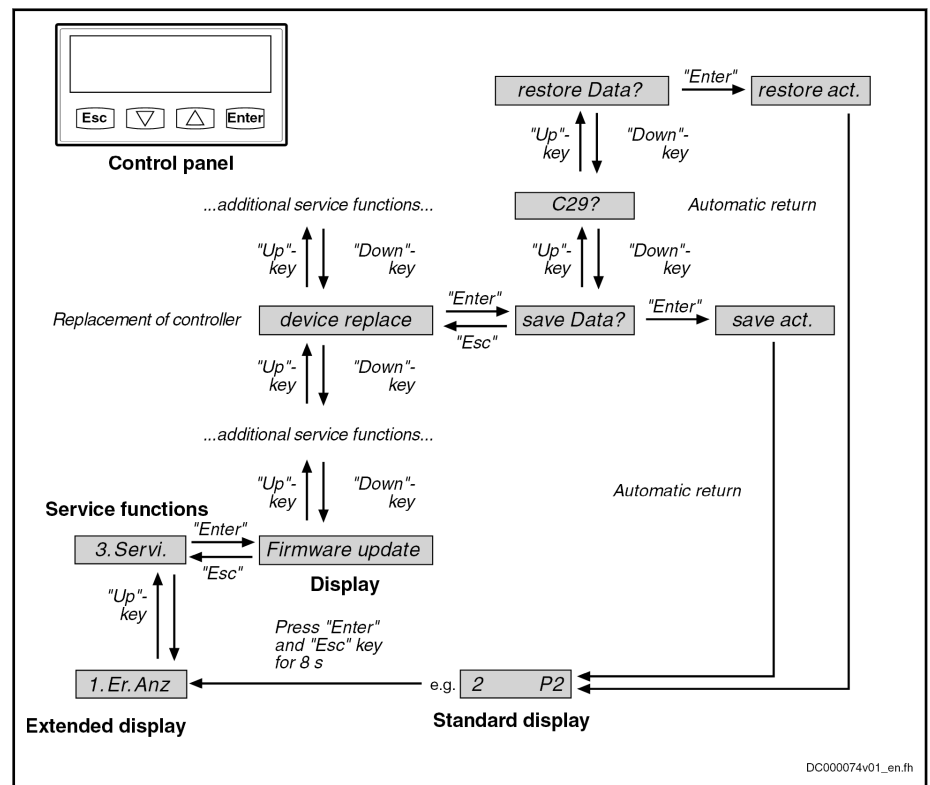
Fig.10-53:   Activating "save Data?" and "restore Data?" commands when replacing the controller using the control panel

2. **Replace controller**

   WARNING! Lethal electric shock by live parts with more than 50 V! Make sure drive controller is completely de-energized. Wait at least **30 minutes** after switching off the supply voltages to allow discharging. To shorten the waiting time until voltage has fallen below 50 V, you can use a discharging device (see chapter "Appendix").

   1. Open main switch
   2. Make sure main switch cannot be switched on again
   3. Remove touch guard
   4. Check whether the voltage has dropped below 50 V before touching the live parts!
   5. Disconnect connecting lines from the drive controller
   6. Unscrew bolts on top and bottom of housing
   7. Take drive controller out of the drive system
   8. Fit new drive controller
   9. Connect new drive controller as specified in the machine circuit diagram

Handling, Diagnostic and Service Functions

        10. Mount touch guard

3. **Put controller into ready-for-operation status again**

Put machine into ready-for-operation status again according to machine manufacturer's instructions.

4. **Load firmware and parameter values via MMC**

If firmware and drive parameters are to be transmitted via MMC to the replacement controller, ensure that the MMC folder "Firmware" contains the firmware required for the drive and the MMC folder "Parameters" contains the parameters backed up before replacing the device.

1. Disconnect replacement controller from the control voltage.

2. Put MMC into the replacement controller.

3. Supply device with control voltage again.

4. Depending on the "previous configuration" of the replacement device, the message "Firmware update?" can appear during the booting phase. Acknowledge this message by pressing "Enter" (on the control panel). By doing this, firmware is loaded from the plugged-in MMC into the controller.

☞   If the message "Firmware update?" does not appear, the firmware update must be started via the display.

           "3. Service" → "Firmware update" → "FWA update"

---

5. Then one of the messages below might be displayed:

●   "Load new param.?"

●   "Load Par from MMC?"

⇒ Acknowledge this message by pressing "Enter" on the control panel. The drive parameters are now loaded from the MMC to the volatile memory of the device; the message "Load new safety?" may possibly appear.

⇒ Acknowledge this message by pressing "Enter" on the control panel. Safety technology parameters are now loaded from the MMC to the memory of the optional safety technology module.

6. Switch to Parameter mode (PM or P2).

The step below depends on the utilized firmware version:

7. Go to the Service menu.

⇒By simultaneously pressing "Esc" and "Enter" for at least 8 seconds, it is possible to call up extended displays; subsequently pressing the "Up" key (twice) activates the Service menu.

Select the "Device replace" submenu using the arrow keys and activate it with "Enter".

⇒Store PLC retain data and parameters from the MMC to the internal, non-volatile memory of the controller via the control panel by activating the command "Restore data?" (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, the drive waits for further actions from the control master.

Handling, Diagnostic and Service Functions

☞ If safety technology is to be activated in the replacement device (in accordance with the replaced device), the drive must be switched to operating mode (OM) or communication phase (P4) after loading the safety technology parameters before it is switched off!

8. Switch controller off.

9. Remove MMC from the device.

10. Switch controller on again.

11. The message "Load new param.?" can then be displayed. Acknowledge this message by pressing "Enter" (on the control panel). The drive parameters are now loaded from the non-volatile memory ("Flash") to the volatile memory (RAM) of the device. From now on, device behaves like device without MMC plugged.

5. **Put machine into ready-for-operation status**

1. Put machine into ready-for-operation status again according to machine manufacturer's instructions.

2. Check functions of the drive

6. **Check safety technology parameters**

Finally when the safety technology is activated, it is necessary to check whether the right safety technology parameters have been loaded for the drive. To do so, check the data in "P-0-3205, Safety technology device identifier" (machine types unit, drive for .. axis/spindle) and compile a protocol with the following contents and add it to safety-relevant documentation for the machine:

- Drive controller replaced on (date)
- Change counter of safety technology memory (P-0-3201) is at (value)
- Operating hours at last change of memory (P-0-3202) is at (value)
- Serial number of control section (see type plate on the device)
- Serial number of power unit (see type plate on the device)
- (Date), (name), (signature)

Handling, Diagnostic and Service Functions

Fig.10-54:   Calling up safety technology characteristic data via the control panel

Controller Replacement With Stationarily Plugged-in MMC

1. **Saving parameter values**

    If the firmware characteristic IndraMotion MLD with firmware type code:

    ● FWA-INDRV*-MPH-08VRS-D5-1-***-**ML**

    ● FWA-INDRV*-MPC-08VRS-D5-1-***-**ML**

    is activated and the controller to be replaced is configured in one of the following optional modules, the retain data of the drive PLC must be stored on the MMC before dismantling the defective device.

    ● Module Digital I/O (control section type code: CSH01.**-**-***-***-**MD1**-**-S-NN-FW)

    ● Module Digital I/O and SSI encoder interface (control section type code: CSH01.**-**-***-***-**MD2**-**-S-NN-FW)

Handling, Diagnostic and Service Functions

☞ If backing up the PLC retain data before replacing the device is impossible due to a total breakdown of the device, the parameter values and retain data backed up after initial commissioning must be loaded when the parameter values are loaded later on (see "Loading Parameter Values in Case of Total Breakdown of Device")!

1. Switch drive off and on again

2. Switch to Parameter mode (PM or P2).

3. Switch drive to the Service menu using the display

⇒By simultaneously pressing "Esc" and "Enter" for at least 8 seconds, it is possible to call up extended displays; subsequently pressing the "Up" key (twice) activates the Service menu.

4. Select the "device replace" submenu using the arrow keys and activate it with "Enter".

5. Activate "save Data?" command

⇒The active PLC retain data is copied from the controller-internal memory to an MMC temporarily plugged into the controller.
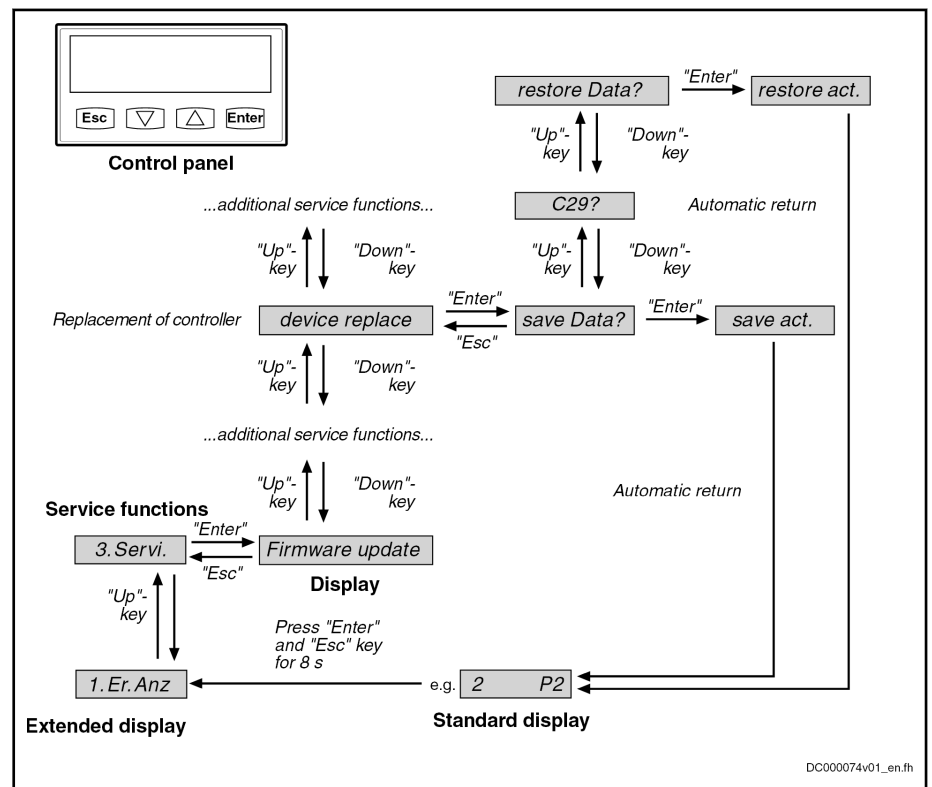
Fig. 10-55:   Activating "save Data?" and "restore Data?" commands when replacing the controller using the control panel

6. Disconnect controller from control voltage (this automatically saves parameter values).

7. Remove MMC from the controller.

2. **Replace controller**

WARNING! Lethal electric shock by live parts with more than 50 V! Make sure drive controller is completely de-energized. Wait at least **30 minutes** after switching off the supply voltages to allow discharging.

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To shorten the waiting time until voltage has fallen below 50 V, you can use a discharging device (see chapter "Appendix").

1. Open main switch

2. Make sure main switch cannot be switched on again

3. Make sure the drive controller is completely de-energized

4. Remove touch guard and separate connecting lines from drive controller

5. Unscrew bolts on top and bottom of housing

6. Take drive controller out of the drive system

7. Fit new drive controller

8. Connect new drive controller as specified in the machine circuit diagram

9. Mount touch guard

3. **Put controller into ready-for-operation status again**

Put machine into ready-for-operation status again according to machine manufacturer's instructions.

4. **Load firmware and parameter values via MMC**

If firmware and drive parameters are to be transmitted via MMC to the replacement controller, ensure that the MMC folder "Firmware" contains the firmware required for the drive and the MMC folder "Parameters" contains the parameters backed up before replacing the device.

1. Disconnect replacement controller from the control voltage.

2. Put MMC into the replacement controller.

3. Supply device with control voltage again.

4. Depending on the "previous configuration" of the replacement device, the message "Firmware update?" can appear during the booting phase. Acknowledge this message by pressing "Enter" (on the control panel). By doing this, firmware is loaded from the plugged-in MMC into the controller.

☞   If the message "Firmware Update?" does not appear, the firmware update must be started via the display.

"3. Service" → "Firmware update" → "FWA update"

---

5. Then one of the messages below might be displayed:

● "Load new param.?"

● "activate new MMC?"

⇒ Acknowledge this message by pressing "Enter" on the control panel. The drive parameters are now loaded from the MMC to the volatile memory of the device; the message "Load new safety?" may possibly appear.

⇒ Acknowledge this message by pressing "Enter" on the control panel. Safety technology parameters are now loaded from the MMC to the memory of the optional safety technology module.

After parameter loading process has been completed, the drive waits for further actions from the control master.

Handling, Diagnostic and Service Functions

☞ If safety technology is to be activated in the replacement device (in accordance with the replaced device), the drive must be switched to operating mode (OM) or communication phase (P4) after loading the safety technology parameters before it is switched off!

---

5. **Put machine into ready-for-operation status**

   1. Put machine into ready-for-operation status again according to machine manufacturer's instructions.

   2. Check functions of the drive

6. **Check safety technology parameters**

   Finally when the safety technology is activated, it is necessary to check whether the right safety technology parameters have been loaded for the drive. To do so, check the data in "P-0-3205, Safety technology device identifier" (machine types unit, drive for .. axis/spindle) and compile a protocol with the following contents and add it to safety-relevant documentation for the machine:

   - Drive controller replaced on (date)
   - Change counter of safety technology memory (P-0-3201) is at (value)
   - Operating hours at last change of memory (P-0-3202) is at (value)
   - Serial number of control section (see type plate on the device)
   - Serial number of power unit (see type plate on the device)
   - (Date), (name), (signature)

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Fig.10-56:   Calling up safety technology characteristic data via the control panel

Controller Replacement Without MMC

☞   The execution of a **controller replacement without MMC** only makes sense if the controller is equipped with a **BASIC single-axis control section**.

If the controller is equipped with another control section, it cannot be ensured that after the replacement of the device all parameterized device functions are available again when carrying out the process described below. Therefore, for such controllers, **replacement is only recommended with MMC**.

1. **Saving parameter values**

    Before dismantling the defective device, save the drive parameter values, if possible.

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> ☞ If backing up the parameter values before replacing the device is 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 "Loading Parameter Values in Case of Total Breakdown of Device")!

1. Switch drive off and on again

2. Switch to Parameter mode (PM or P2)

3. Saving the parameter values of the defective device can take place via the commissioning tool "IndraWorks Ds/D/MLD" or the control master:

- Commissioning tool "IndraWorks Ds/D/MLD":

  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.

2. **Replace controller**

   WARNING! Lethal electric shock by live parts with more than 50 V! Make sure drive controller is completely de-energized. Wait at least **30 minutes** after switching off the supply voltages to allow discharging. To shorten the waiting time until voltage has fallen below 50 V, you can use a discharging device (see chapter "Appendix").

   1. Open main switch

   2. Make sure main switch cannot be switched on again

   3. Make sure the drive controller is completely de-energized

   4. Remove touch guard and separate connecting lines from drive controller

   5. Unscrew bolts on top and bottom of housing

   6. Take drive controller out of the drive system

   7. Fit new drive controller

   8. Connect new drive controller as specified in the machine circuit diagram

   9. Mount touch guard

3. **Put controller into ready-for-operation status again**

   Put machine into ready-for-operation status again according to machine manufacturer's instructions.

4. **Load firmware and parameter values**

   When firmware and drive parameters are to be transmitted to the replaced controller, the required firmware and a parameter backup of the respective axis must be available.

   1. Supply controller with control voltage

   2. Depending on the "previous configuration" of the replacement device, one of the following messages can appear during the booting phase:

   - "F2120 MMC: defective or missing, replace"

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> ⇒ Acknowledge this message by pressing "Esc" on the control panel.
>
> • "Load new param.?"
>
> ⇒ Acknowledge this message by pressing "Enter" on the control panel,

3. By selecting the respective menu item in "IndraWorks Ds/D/MLD", the firmware stored on an external data carrier (hard disk, floppy disk or similar) is loaded to the controller (serial communication with the controller).

4. Loading the parameter values can take place via the commissioning tool "IndraWorks Ds/D/MLD" or the control master:

• Commissioning tool "IndraWorks Ds/D/MLD"

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). With safety technology available, further actions are required (see "Replacing the controller without stationarily plugged-in MMC").

• Control master

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. With safety technology available, further actions are required (see "Replacing the controller without stationarily plugged-in MMC").

5. **Put machine into ready-for-operation status**

1. Put machine into ready-for-operation status again according to machine manufacturer's instructions.

2. Check functions of the drive

Possible Problems During Controller Replacement

The paragraphs below give a brief description of critical problems and their recommended handling.

Loading parameter values in the event of total breakdown of the device

If it was no longer possible 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 backed up following initial commissioning are to be loaded.

☞   With 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 the parameter "S-0-0403, Position feedback value status"!

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NOTICE	The parameter values saved after initial com-missioning are not generally suited for rees-tablishing the operability of the drive after re-placement of devices!

⇒ Check actual position values and active target position before drive enable!

10.9   Enabling of Functional Packages

10.9.1   Brief Description

The scope of functionality of the IndraDrive firmware can be scaled by the user. This allows the scope of firmware functions to be adjusted to the respective requirements and, if necessary, its complexity reduced.

The drive functionality is scaled by licensing (enabling) optional extension packages that are available in addition to the standard base package of the respective IndraDrive firmware.

☞ With drives of double-axis design (firmware variant MPD), it is only possible to enable the same functional packages for both axes. When 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 Configuration changed. Restart

10.9.2   Functional Description

Changing the Active Functional Package Selection

The functionality of the drive firmware is divided into several functional packages. By enabling certain packages, it can be adjusted to the requirements of the respective application.

Basically, there are the following possibilities of subsequent scaling of the drive functionality:
- **Reducing** the already licensed scope of functions in order to reduce the complexity of the firmware
- **Extending** the scope of functions originally ordered (additional licensing)

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☞ Non-licensed functional packages may not be used. Enabling functional packages which are not part of the originally ordered scope of functions requires additional licensing that is not free of charge! Using an unlicensed function negates any guarantee on the part of Rexroth.

The count of the operating hours counter at the change of access enable for functional packages is stored in parameter P-0-2002. Rexroth staff can therefore provide evidence of non-licensed drive functions that have been enabled.

Parameter P-0-2003 is available for selecting the functional packages; parameter P-0-2004 for displaying the activated packages.

The following assignment applies:

Bit No.	Name of package (Bit = 1 → Package has been selected)	Rules for selection via P-0-2003
0	Base package "open-loop"	- As an alternative to bit 1 - Not with safety technology
1	Base package "closed-loop"	- As an alternative to bit 0 - Not with CSB-01.1N-FC
2	Not used	--
3	Not used	--
4	Extension package "servo function" (SRV)	- As an alternative to bit 5 or 6 - Not with "Open-Loop"
5	Extension package "synchronization" (SNC)	- As an alternative to bit 4 or 6 - Not with CSB-01.1N-FC
6	Extension package "main spindle" (MSP)	- As an alternative to bit 4 or 5 - Not with "Open-Loop" for CDB01.1C
7	Not used	--
8	Additional package "IndraMotion MLD Advanced" (MA)	- only for MPH - only in conjunction with bit 1 (closed-loop) and bit 9 (IndraMotion MLD)
9	Additional package "IndraMotion MLD" (ML or TF)[1]	- Not with CDB01.1C
10 to 31	Not used	--

1)   MLD design "ML" for MPH firmware; "TF" for MPB firmware

Fig.10-57:   *Selecting the Functional Packages via Parameter P-0-2003*

☞ There is an option to purchase the functional package option "ALL" and thereby license all three above-mentioned extension packages (SRV, SNC, MSP). This enables any of these extension packages to be used.

Example   Enabling the base package "closed loop" and the extension 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 extension 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 a repeated booting process.

The figure below illustrates the interaction of the parameters involved in enabling of functional packages.

P-0-2003: selection for enabled functional packages

booting the drive firmware:
→ The information is transferred from P-0-2003.

P-0-2004: active enabled functional packages

DC000042v01_en.fh
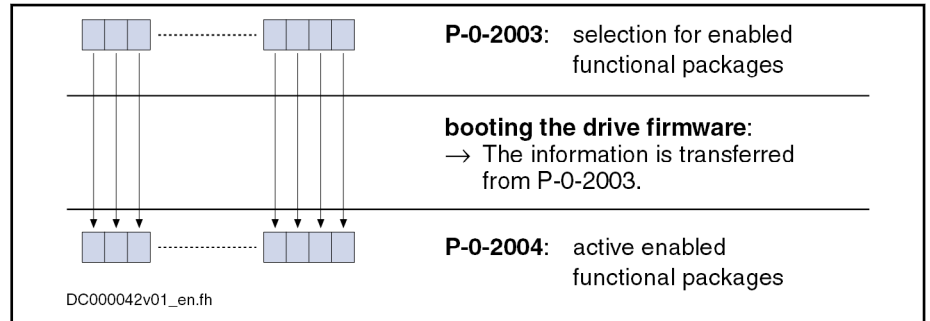
Fig.10-58:   Interaction of parameters for functional package selection

Every change of the selected functional packages is recorded via an entry of the current count of the operating hours counter in parameter "P-0-2002, Oper. hours of contr. sect. at change of functional packages".

☞   Rexroth can at any time provide evidence of non-licensed functional packages that have been enabled subsequently.

The table below shows the current possible combinations for input into parameter "P-0-2003, Selection of functional packages". **Whether the respective combination can be used, depends on the available hardware design.**

Base package/extension package(s)	Content of P-0-2003
Open-loop packages	
Open-loop **without extension packages**	0x0000 0001
Open loop **with synchronization (SNC)**	0x0000 0021
Open-loop **with main spindle (MSP)**	0x0000 0041
Open-loop **with IndraMotion MLD (ML)**[1]	0x0000 0201
Open-loop **with synchronization (SNC) + IndraMotion MLD (ML)**[1]	0x0000 0221
Open-loop **with main spindle (MSP) + IndraMotion MLD (ML)**[1]	0x0000 0241
Closed-loop packages	
Closed-loop **without extension packages**	0x0000 0002
Closed loop **with servo function (SRV)**	0x0000 0012
Closed loop **with synchronization (SNC)**	0x0000 0022
Closed loop with **main spindle (MSP)**	0x0000 0042
Closed-loop **with IndraMotion MLD (ML)**[1]	0x0000 0202
Closed-loop **with servo function (SRV) + IndraMotion MLD (ML)**[1]	0x0000 0212
Closed-loop **with synchronization (SNC) + IndraMotion MLD (ML)**[1]	0x0000 0222
Closed-loop **with main spindle (MSP) + IndraMotion MLD (ML)**[1]	0x0000 0242
Closed-loop **with IndraMotion MLD Advanced (MA)**[2]	0x0000 0302
Closed-loop **with servo function (SRV) + IndraMotion MLD Advanced (MA)**[2]	0x0000 0312

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Base package/extension package(s)	Content of P-0-2003
Closed-loop **with synchronization (SNC)** + IndraMotion MLD Advanced (MA)[2]	0x0000 0**32**2
Closed-loop **with main spindle (MSP)** + IndraMotion MLD Advanced (MA)[2]	0x0000 0**34**2

	1)	MLD design for MPB firmware has type designation "TF"
	2)	"MA" (IndraMotion MLD Advanced) also includes the functionality of the MLD design "ML"

Fig.10-59:   Possible combinations of functional packages of MPx08 firmware

☞   Changes in parameter "P-0-2003, Selection of functional packages" are only accepted by the drive after repeated booting process.

Reducing the Active Functional Packages

The user can at any time reduce the scope of functions of the firmware by deactivating individual functional packages. To do this, the bits assigned to the functional packages which are not required are reset in "P-0-2003, Selection of functional packages".

Subsequent Extension (Additional Licensing)

The required functions are normally licensed by ordering the IndraDrive firmware. At delivery, the licensed functions are indicated as firmware type on the type plate of the control section and in addition internally registered by Rexroth.

☞   Rexroth can at any time prove which scope of functions has been activated and thus licensed at delivery. Using an unlicensed function negates any guarantee on the part of Rexroth.

In individual cases, it is possible apply for an additional license, if other functions are to be enabled than the ones contained in the ordered and paid for functionality. The procedure is described in the following section "Notes on Commissioning".

10.9.3   Notes on Commissioning

Condition as Supplied

When a drive is delivered, the licensed functional packages have been enabled. For package "ALL", the package "servo function" (SRV) has been enabled ex-works.

☞   The firmware type printed on the firmware type plate has to comply with the content of "S-0-0030, Manufacturer version" (or contain the package identifier "ALL").

The content of S-0-0030 can be read via the standard control panel (see "Control Panels of IndraDrive Controllers").

The following example shows the connection for firmware MPH08V02 and functional package "Closed-loop, Synchronization and IndraMotion":

Example   • Content of S-0-0030 → FWA-INDRV*-MPH08V02-MS-1-SNC-ML

•   Imprint on type plate → FWA-INDRV*-MPH08V02-MS-1-SNC-ML

- or (with complete licensing) -

→ FWA-INDRV*-MPH08V02-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 Ds/D/MLD" 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 (Extension 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 an unlicensed functional package is used permanently, any guarantee on the part of Rexroth will expire!

Additional licensing   For additional licensing proceed as follows:

1. Enable required functional packages in P-0-2003

2. Reboot drive and check content of P-0-2004 (content must comply with that of P-0-2003!)

3. Take firmware type from "S-0-0030, Manufacturer version" and note it down; this parameter displays the current firmware configuration defined via P-0-2003.

4. Take serial number of control section from "P-0-1511, Circuit board code control section" (list element 3) and note it down

5. Send purchase order to Rexroth indicating serial number (from P-0-1511) and desired firmware configuration (from S-0-0030)

6. Receive adjusted firmware type plate from Rexroth to stick it on type plate of control section so that content of S-0-0030 complies with firmware description on type plate

If no functional package has previously been enabled by the customer, additional licensing can start with step 4. In step 5, the desired new firmware configuration then cannot be read from S-0-0030, but has to be taken from the overview of firmware types (see "Firmware Types" in section "Overview of Functions/Functional Packages").

☞ For handling the purchase order, please contact your Rexroth sales representative!

Scope of supply   The scope of supply consists of

- Ordered new firmware type as FWA file incl. parameter file (as files or on MMC)

  - and -

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- Adjusted firmware type plate (to stick on).

10.9.4 Verifying the Enabled Functional Packages

When the transition command "C0200 Exit parameterization level procedure command" is executed, a check is run to find out whether the value entered in parameter "P-0-2003, Selection of functional packages" corresponds to a valid enabled package. If not, the diagnostic command message C0202 is generated and the parameter IDN "P-0-2003, Selection of functional packages" entered in list parameter "S-0-0423, IDN-list of invalid data for parameterization levels".

ℹ️ See also description of the diagnostic message "C0202 Parameter limit error (->S-0-0423)"

When the enabling of functional packages has been changed, reboot the drive so that the change becomes active and is applied to 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 P-0-2003 corresponds to the value in P-0-2004. If there is a difference, the diagnostic command message "C0299 Configuration changed. Restart" is displayed.

ℹ️ See also description of diagnostic message "C0299 Configuration changed. Restart"

10.10 Extended Diagnostic Possibilities

10.10.1 Monitoring Function

Brief Description

☞ The so-called "monitoring 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 from 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. A 132-column display is recommended.

Pertinent parameters
- P-0-4021, Baud rate RS-232/485
- P-0-4025, Drive address of master communication
- P-0-4095, RS-232/485 Parity

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 is no output appearing at the terminal.

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 no "echo" appears 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 up like normal commands. The submenu is exited by entering

→ "**exit**".

☞   With the "exit" command. "monitoring" mode is also exited and the drive switches to normal RS232 communication again.

The content of the screen can be cleared with the command "cls".

10.10.2   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

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by the logbook function allows the internal firmware sequence to be repro-
duced if required.

Pertinent parameters
- P-0-0478, Logbook event
- P-0-0479, Logbook time stamp

Functional Description
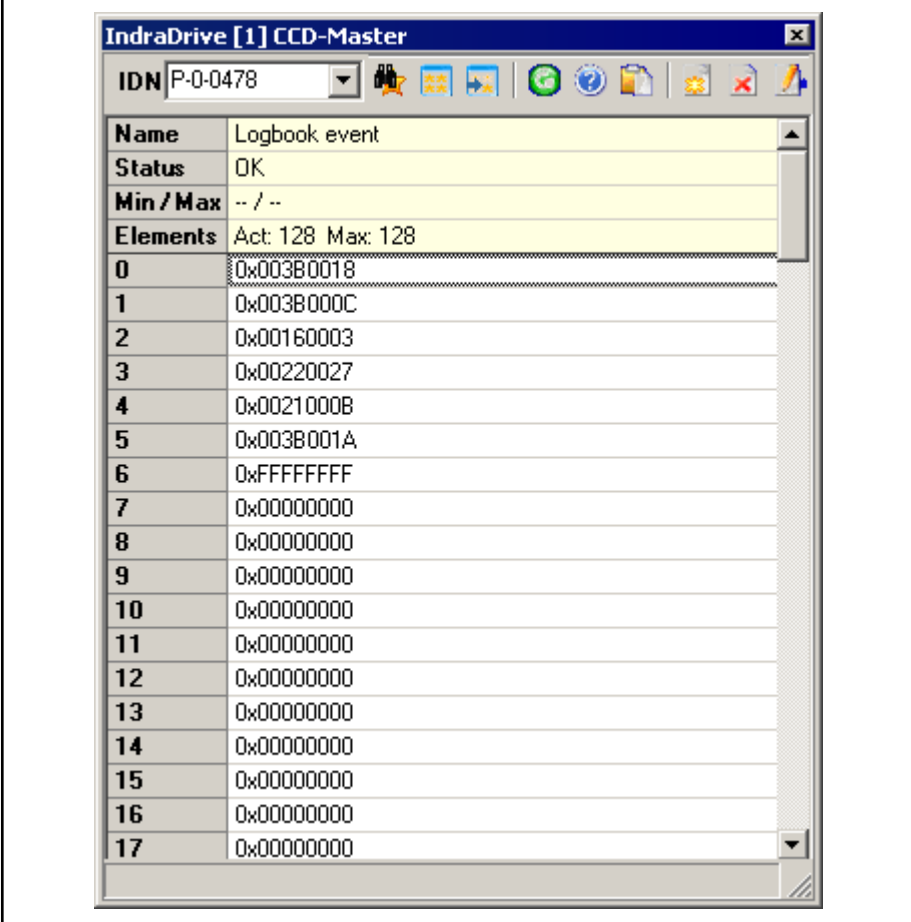
The list parameters"P-0-0478, Logbook event" and "P-0-0479, Logbook time
stamp" are organized as ring buffers and can contain 128 elements. The en-
tries in these parameters are realized automatically by the controller subject
to internal states. The entry in P-0-0478 marks the event (or the status); 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 follow-
ing 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.
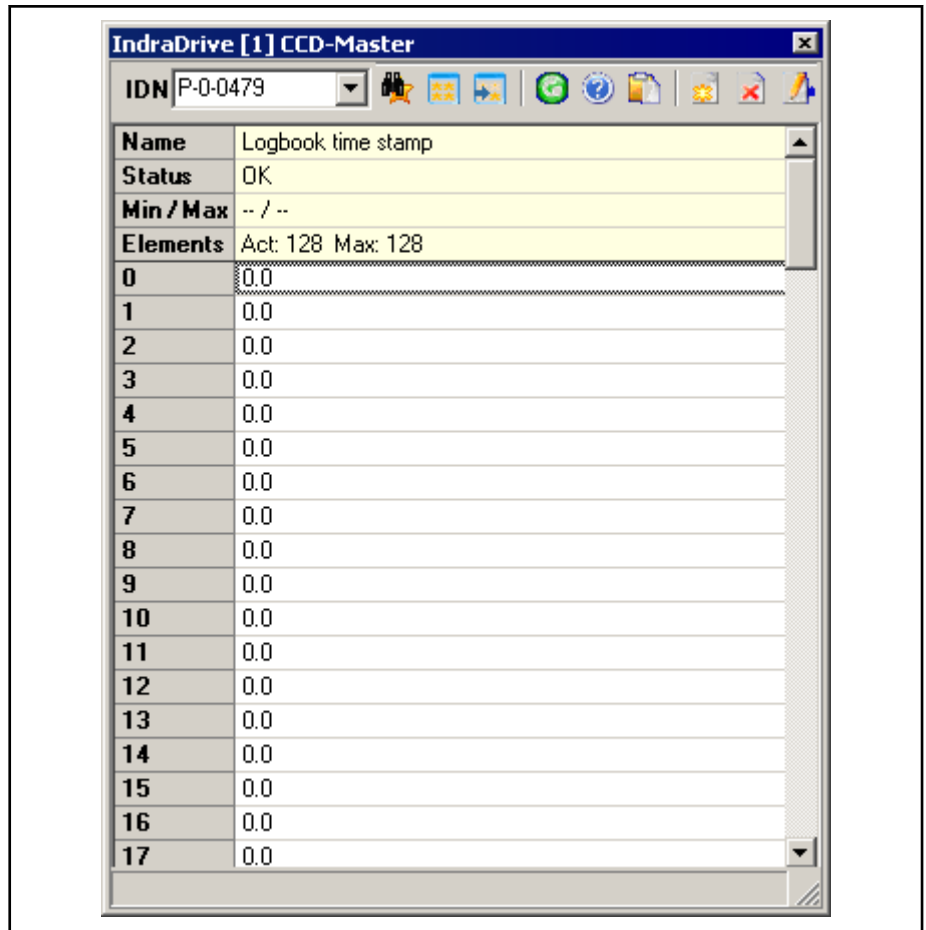
Fig. 10-60:   Logbook entries (Example)

☞   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".

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The entries in P-0-0479 contain the operating hours of the control section in seconds at the time of the respective event.

Fig.10-61:   *Content of Parameter P-0-0479 (Example)*

10.10.3   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.

The PLC patch function serves for diagnosis of internal signal states and internal data of the PLC by developers and instructed users.

☞   When using the patch display in the oscilloscope, take into account the fact that first the patch address and then the oscilloscope signal is assigned. This must be repeated after every change in the patch address.

☞   As it is a **function for exclusive use by the development staff**, the patch display parameters P-0-0485 and P-0-0491 are 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.

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Pertinent parameters	General patch function:

General patch function:
- P-0-0480, Patch function 1, source pointer
- P-0-0481, Patch function 1, attribute
- P-0-0482, Patch function 1, bit maskP
- 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

PLC patch function:
- P-0-0492, PLC patch function 1, data source
- P-0-0493, PLC patch function 1, display
- P-0-0494, PLC patch function 2, data source
- P-0-0495, PLC patch function 2, display
- P-0-0496, PLC patch function 3, data source
- P-0-0497, PLC patch function 3, display
- P-0-0498, PLC patch function 4, data source
- P-0-0499, PLC patch function 4, display

Functional Description of General Patch Function

Read Access (Displaying Internal Storage Locations/Signals)

The patch function allows any storage location to be transformed into a data object that can be read via the master communication. For this purpose, a storage location is specified via parameters "P-0-0480, Patch function 1, source pointer" and "P-0-0486, Patch function 2, source pointer". The access to this address is configured via bits 0 to 2 of parameters "P-0-0481, Patch function 1, attribute" and "P-0-0487, Patch function 2, attribute". INT4 reads a 4-byte integer value starting from the source pointer, INT2/INT1 read 2 bytes or 1 byte accordingly. FLOAT8 reads an 8-byte floating-point value (DOUBLE), FLOAT4 reads 4 bytes accordingly (FLOAT).

Due to the processor architecture, the possible memory accesses are subject to certain restrictions. A 4-byte access, for example, is only allowed for storage locations the address of which can be divided by 4. The table below contains a complete overview of the allowed and prohibited memory accesses.

☞ Changing the access mode via bits 0 to 2 of the patch attribute parameters (P-0-0481/P-0-0487) is only possible if the patch source pointer that has just been set (P-0-0480/P-0-0486) permits the new access mode (see table).

	Possible access to source addresses that …		
Access as...	...can be divided by 4 (DWORD-aligned)	… can be divided by 2, but not by 4 (WORD-aligned)	... do not have any particular alignment (BYTE-aligned)
INT4	■	–	–
INT2	■	■	–

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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)
INT1	■	■	■
FLOAT8	■	–	–
FLOAT4	■	–	–

■   Access allowed
–   Access prohibited

Fig.10-62:   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 the value read as a decimal number with or without sign to be interpreted as a hexadecimal number or as a binary number. When selecting "BOOL" as the display type, "1" is output when a value not equal to zero was read, otherwise "0" is displayed.

If a storage location is read as an integer and output in a non-float format, the value read is ANDed with the bit mask set via the patch bit mask parameters (P-0-0482/P-0-0488). The standard setting of this mask is "0xFFFFFFFF" so that the value read is not changed.

When a storage location is read as a float value and a non-float format is selected for display, the value read is multiplied with $10^{-exponent}$. This allows making an adjustment to the displayed value range (-2147483648 to 2147483647, value range of a "signed int"). The exponent can be set via parameters "P-0-0483, Patch function 1, exponent" or "P-0-0489, Patch function 2, exponent".

☞   If the value read and scaled with the exponent is outside the possible range of display, one of the extreme values is displayed. In this case, it is necessary to select a different exponent.

Write Access (Changing Internal Storage Locations/Signals)

In analogy to read access, it is possible to write any storage location. A bit mask possibly set (P-0-0482/P-0-0488) is taken into account (ANDed) as is a preset patch exponent (P-0-0483/P-0-0489).

☞   Please observe that in the "BOOL" display mode, it is impossible to write the storage location, because it is impossible to assign an unequivocal numerical value to the value "TRUE" (displayed as "1"). Any value unequal zero is interpreted as "TRUE".

NOTICE   **Write access to even addresses in the INT1 mode can lead to undefined hardware behavior.**

As with read access, odd addresses with write access are only allowed in INT1 mode. In contrast to read access, the write access is directly carried out as a byte access. 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

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desired patch display (P-0-0485/P-0-0491) has to be entered in one of parameters "P-0-0420, Analog output, assignment A, signal selection" or "P-0-0423, Analog output, assignment B, 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, 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"

Functional Description - PLC Patch Function

General Information

For reading internal PLC data four patch channels are introduced. Each channel consists of one parameter for data source and one for display.

Input Data Sources

The parameters of the "data source" group ("channel no." and "data source") are defined as character string with maximum 265 values. Definition can be carried out in two formats:

- By input of range and offset
- By input of a symbol string

Input of range and offset   Range and offset are set as follows:

- (Range/offset), data type, output format

The addresses can be generated offline in IndraLogic by creating a symbol file. The defined input string (range/offset) is registered; the values are entered as decimal numbers. A storage address is determined via the range value, the offset is added.

The following strings are permitted:

- BOOL (1 byte)
- BYTE USINT (1 byte without prefix)
- SINT (1 byte with prefix)
- WORD, UINT (2 bytes without prefix)
- INT (2 bytes with prefix)
- DWORD, UDINT (4 bytes without prefix)
- DINT (4 bytes with prefix)
- REAL (4 bytes)

In the case that none of these strings is detected or no string is entered, "BYTE" is the default string type.

After a "point" as separator for data type, the output format is read.

The following strings are evaluated:

- 2# → binary display
- 10# → decimal display
- 16# → hexadecimal display

The hash sign "#" must be the last sign of the string output format. If none of the output formats is identified, "decimal" is the default setting.

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The data type "REAL" is always displayed as float value, so that an additional parameter exponent becomes superfluous. The "BOOL"data type is always displayed as "boolean".

Example for input of range and offset

The following example illustrates a possible input for "range/offset":

- (4/1000),WORD,2#

  → Variable range 4, offset 1000, data type WORD, display binary

Input via symbol string

For this type of addressing a symbol file is required in the drive. For this an MMC is required and the desired signals must be configured.

The input is evaluated as character string and a symbol string is extracted from it. The requested storage address is read in the symbol table by means of the symbol string.

For the input "symbol string" the data type from the symbol table is provided, the optionally read type is ignored.

Example: symbol string

Example for the input of a symbol string:

- PLC_PRG.bVar1,16#

  → Data type is known, display format is hexadecimal

Display of PLC Data

The output is carried out via parameters of the "Display" group ("channel no." and "display").

Write Access

Writing on PLC data is **not permitted**.

10.10.4   Effective Value Creators in the Drive

Brief Description

Fields of Application

The total effective value of the starting current of the end stage is the decisive characteristic value for evaluating the thermal load of drive control and motor over a machine cycle.

Overview of Functions

The drive cyclically forms the effective value of the starting current of the end stage. The start and end of the cycle is defined via a control bit.

Pertinent Parameters

- P-0-0610, Current effective value creator control word
- P-0-0011, Current effective value

Pertinent Diagnostic Messages

None

Functional Description

The creation of the effective value is switched on and off via the control bit "P-0-0610, Current effective value creator control word" bit 0. If the control bit is set, the effective value of the starting current of the end stage is formed as follows:

1. Integration of the current square and recording of the current integration time
2. Creation of the quotient from the sum of the current square and the integration time

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The effective value is thereby cyclically formed and the respective current value is displayed in "P-0-0611, Current effective value". Deleting the control bit stops the calculation and the last value formed is frozen. A rising edge at the control bit deletes the effective value and the formation is restarted.

Notes on Commissioning

Proceed as follows to define the total effective current value at the output of the drive controller over a defined machine cycle:

1. Set control bit P-0-0610, bit 0 at the start of the cycle
2. Delete control bit P-0-0610, bit 0 at the end of the cycle

The total effective current value over the defined machine cycle is displayed in P-0-0611. If the value is greater than the maximum permissible continuous current of the motor or controller, this machine cycle cannot be run continuously. The motor or controller would be subjected to thermal overload.

10.11   Oscilloscope Function

10.11.1   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, operation 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 Ds/D/MLD"

    – More than 100 different measuring and trigger signals (cf. P-0-0149)

    – Expanded oscilloscope function using patch function

- **Trigger function**

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–   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: Trigger control offset
- P-0-0036, Oscilloscope: external trigger signal
- P-0-0037, Oscilloscope: internal trigger signal

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10.11.2 General Information on the Oscilloscope Function

Sequence of a Measurement (Status Diagram)
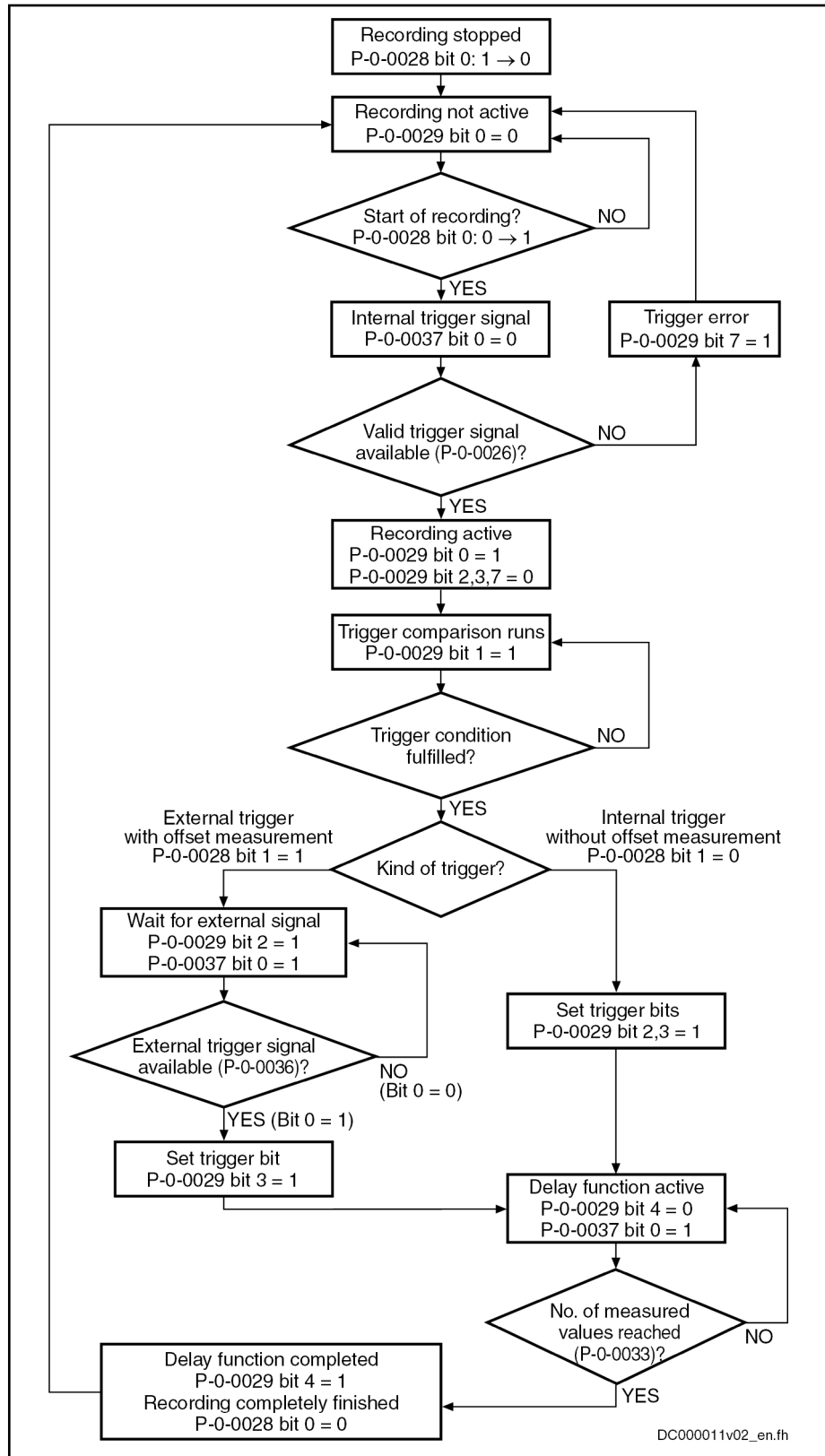
Fig.10-63:   *Status diagram of oscilloscope function*

Handling, Diagnostic and Service Functions

Configuring the Measured Value Channels

A measured value channel is configured by inputting the IDN of the desired parameter into 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.

P-0-0149 contains all parameters that are suitable as trigger signal (P-0-0026) or measuring signal (P-0-0023, P-0-0024, P-0-0147, P-0-0148). By reading P-0-0149, the master can recognize the signals that can be recorded in the drive.

☞   At present, all cyclically configurable parameters (> 100) are contained in the list!

Example of signal selection   Example of the signal selection of the oscilloscope function:

- "S-0-0051, Position feedback value 1" is selected as the 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, the actual position value of axis 1 is recorded in the oscilloscope and transmitted to the master.
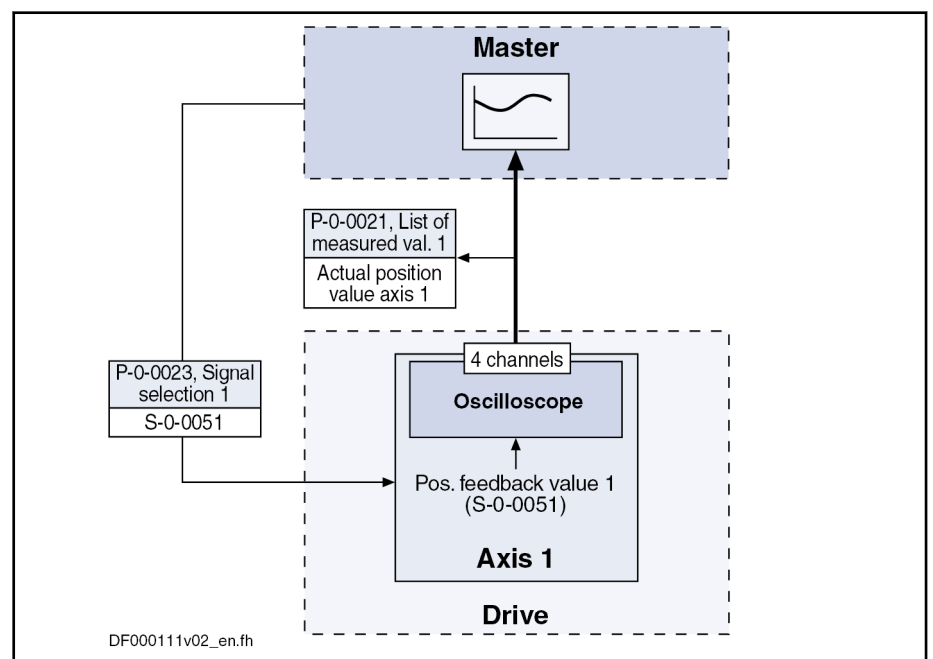
Fig.10-64:   Example of signal selection

Expanded Oscilloscope Function (Patch Function)

Besides recording parameter content via the oscilloscope function, the drive provides the possibility of recording any internal signal, i.e. memory address (patch function).

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☞   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 the detection of a valid edge the measured values keep being written to the measured value memory until the number of measured values defined in "P-0-0033, Oscilloscope: number of measured values after trigger event" has been reached (delay function).

☞   With sercos master communication, start of signal recording and of trigger evaluation are delayed until the next feedback acquisition starting time T4 (S-0-0007 and S-0-1007).

This causes the recording data and the data in the AT telegram to be identical and several drives at one sercos bus to simultaneously start recording within one sercos cycle.

After the defined number of measured values has been recorded, the bit "delay function completed" (bit 4) is set in parameter "P-0-0029, Oscilloscope: status word". The recording is complete and automatically terminated. Bit 0 in parameter P-0-0028 is reset and the list of measured values can be read.

☞   Depending on the parameterization of the size of memory, the time resolution, the number of measured values after trigger event and the point of time the trigger event occurs, the entire measured value memory for the current measurement is not always written.

This means that there may still be old measured values in the memory that are not valid for the current measurement!

10.11.3 Trigger Function

Trigger Signal Selection

The drive provides extensive and flexible possibilities of triggering.

Handling, Diagnostic and Service Functions

Triggering at standard signals	The trigger signal is selected in parameter "P-0-0026, Oscilloscope: trigger signal selection" by directly inputting parameter IDNs. Only such IDNs are allowed that are contained in the list "P-0-0149, Oscilloscope: signal selection list".

> ☞ If there is no valid trigger signal available when the oscilloscope function is activated, bit 7 for "trigger error" is set in parameter "P-0-0029, Oscilloscope: status word".

"P-0-0026, Oscilloscope: trigger signal selection" determines which signal is monitored with regard to the parameterized edge reversal or threshold value.

Triggering at any signal	Besides the triggering of parameter contents, the drive provides the possibility of recording any internal signal, i.e. memory address (patch function).

> ☞ Using the patch function is only possible with information about the structure of the internal data memory; therefore, this function can be used effectively only by the developers of the IndraDrive firmware.

Patch function	In order to trigger at internal signals (memory address contents), "P-0-0485, Patch function 1, display" or "P-0-0491, Patch function 2, display" have to be configured in P-0-0026.

See also "Patch Function"

Internal or External Trigger

The kind of trigger can be selected in parameter "P-0-0028, Oscilloscope: control word".

P-0-0028, bit 1:

- Bit 1 = 0 → Internal trigger without offset measurement
- Bit 1 = 1 → External trigger with offset measurement

Trigger event	The trigger event is the point of time at which trigger signal (P-0-0026) and trigger level (P-0-0027) are matching, taking the determined trigger edge into account (P-0-0030). When the trigger event occurs, the internal trigger is released.
Internal trigger (without offset measurement)	When "Internal trigger" is selected (P-0-0028; bit 1 = 0), the external trigger source (P-0-0036, bit 0) is not taken into account. Until the trigger event is reached the current status 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. Independently of the trigger source, the bit indicates the end of the recording.

When the 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).

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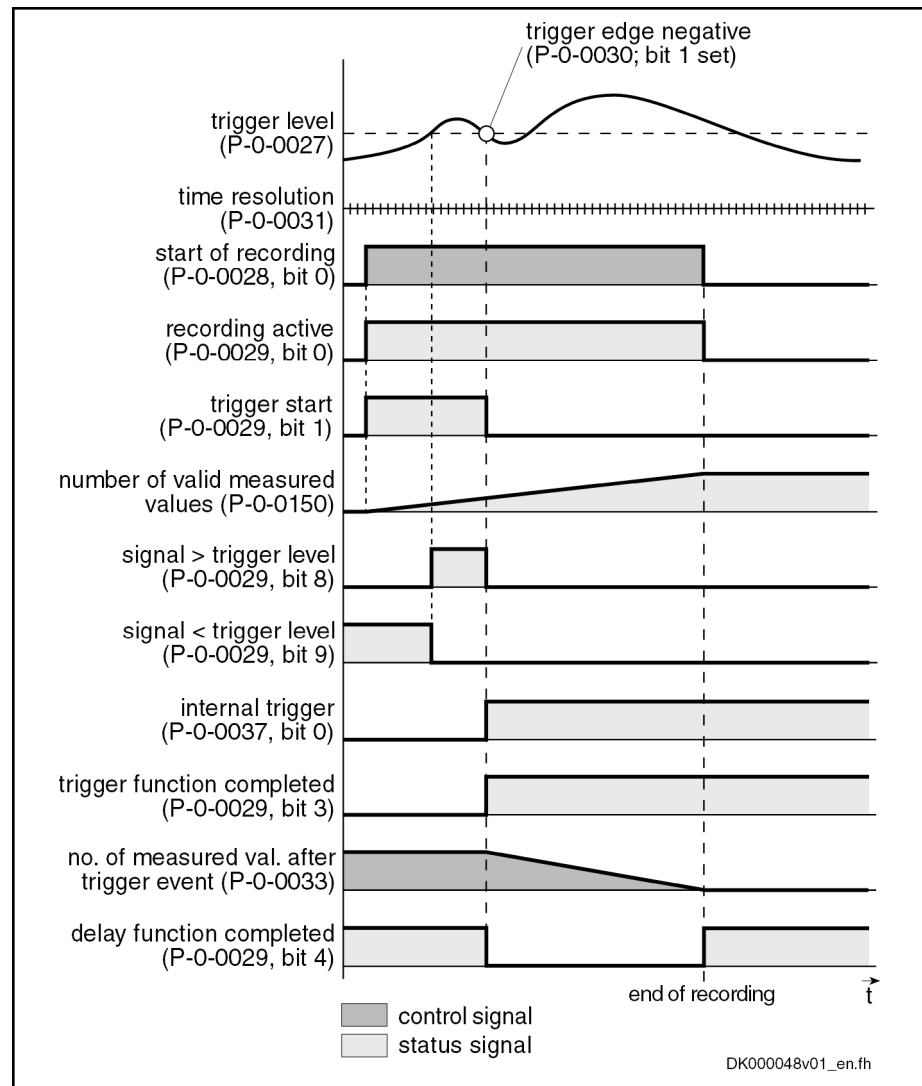
Fig. 10-65:   Internal trigger without offset measurement (P-0-0028; bit 1 = 0)

☞   Parameterizing P-0-0036 (external trigger signal) in "P-0-0026, Oscilloscope: trigger signal selection" allows the internal trigger function to be released 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 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.
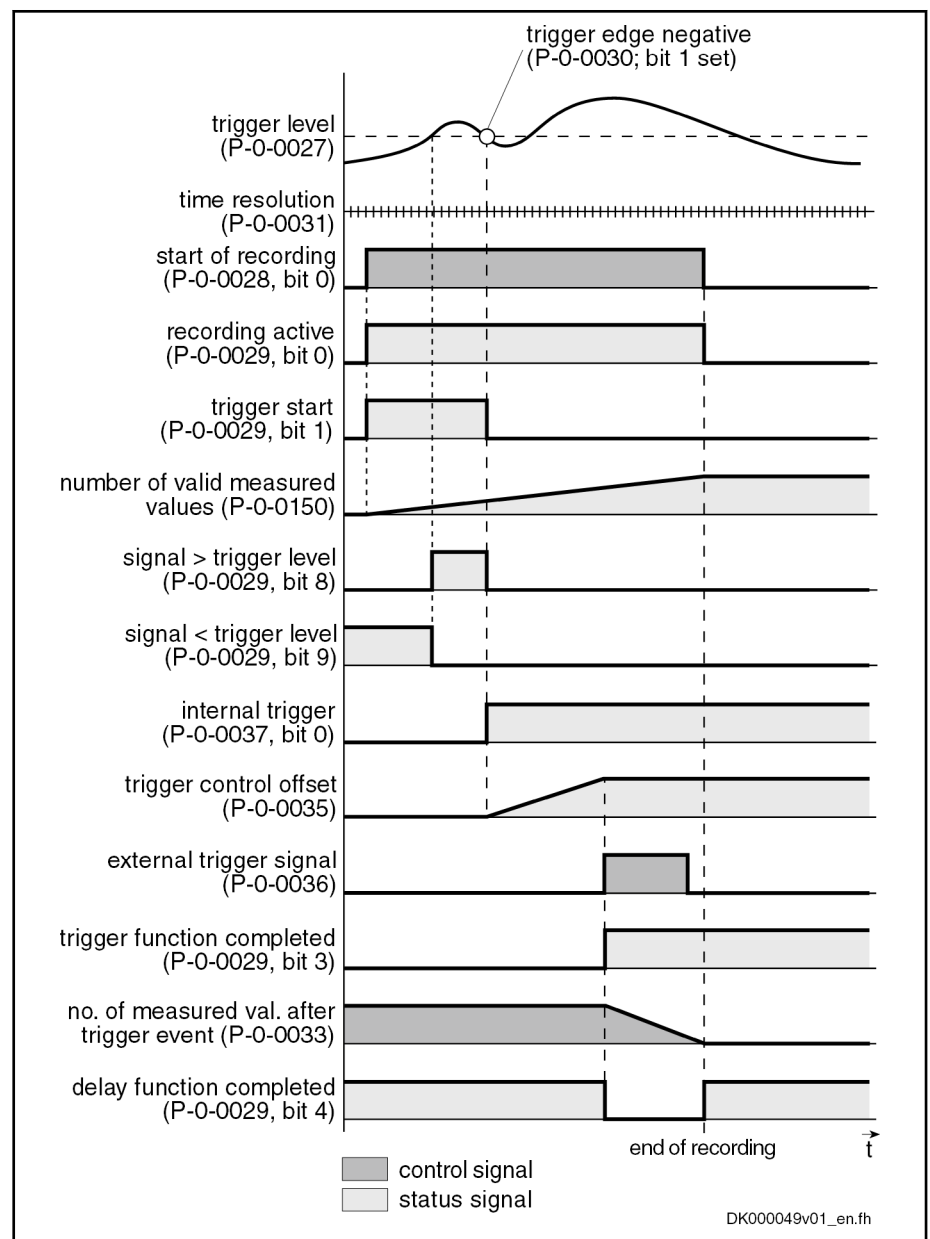
Fig. 10-66:   External trigger with offset measurement (P-0-0028; Bit 1 = 1)

☞   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" it is possible to set at which edge of the trigger signal the internal trigger is released. The following options are available:

- Triggering at the **positive** edge
- Triggering at the **negative** edge
- Triggering at **both** edges
- Triggering when trigger signal **equals** trigger level

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> [i] See Parameter Description "P-0-0030, Oscilloscope: trigger edge"

Setting the Trigger Delay

Trigger delay function   Via "P-0-0033, Oscilloscope: number of measured values after trigger event" it is possible to reach a trigger delay independently 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).
>
> Entering "0" in P-0-0033 only displays data available before the trigger event is recorded.
>
> If the value of parameter P-0-0032 is entered, only the measured values that occurred after the trigger event are recorded.
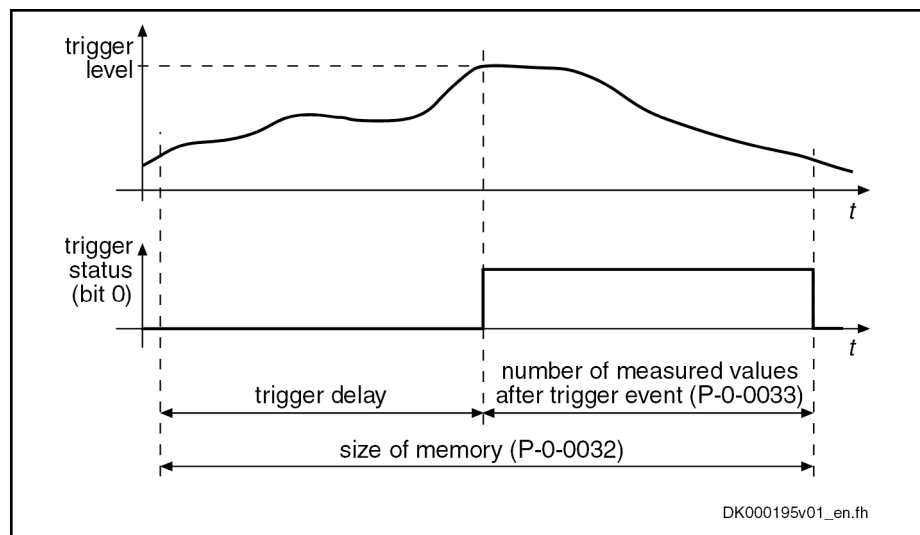
Fig.10-67:   Trigger delay: number of measured values after trigger event

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.

> [i] See Parameter Description "P-0-0025, Oscilloscope: trigger mask"

Trigger level (P-0-0027)   The trigger level can be freely set via parameter "P-0-0027, Oscilloscope: trigger level", the attribute, unit, etc. being adjusted to the selected trigger signal.

> [i] See Parameter Description "P-0-0027, Oscilloscope: trigger level"

10.11.4   Synchronizing the Measuring Signals of Several Axes

The parameter "P-0-0035, Oscilloscope: Trigger control offset" contains the number of measured values between the occurrence of the internal trigger event (P-0-0029; bit 2) and the external trigger event (P-0-0036; bit 0).

Handling, Diagnostic and Service Functions

Trigger control offset (P-0-0035) The transmission of the trigger event via the master causes a delay between the detection of the trigger event and the release of the trigger. This delay is measured by drive 1 (master drive) and stored in parameter "P-0-0035, Oscilloscope: Trigger control offset". A time-correct display of the signals of several drives can be guaranteed by taking this parameter into account for the visualization of the measured values.

See also "Internal or External Trigger" above
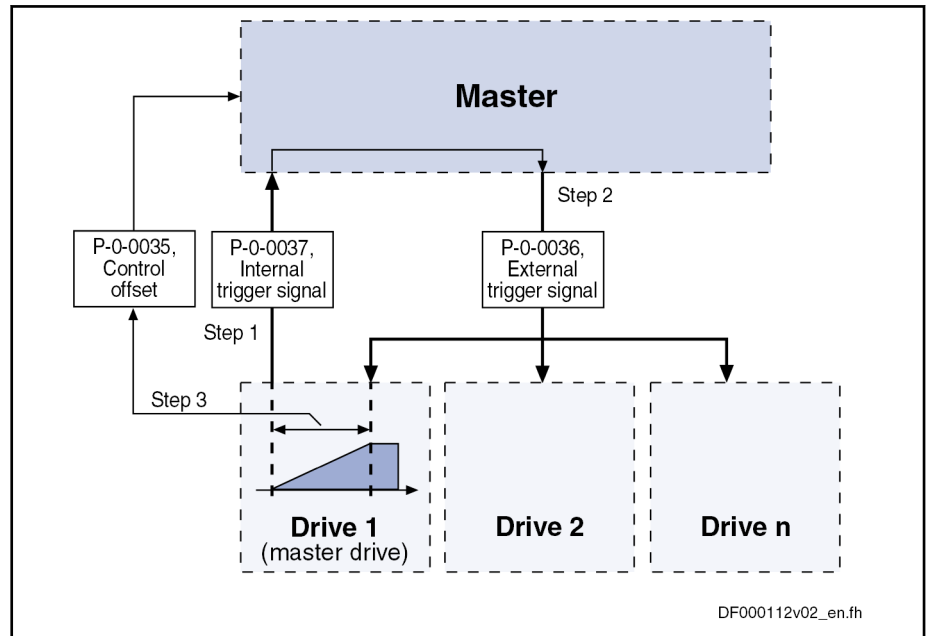
Fig. 10-68: *Application for trigger source "External" with determination of trigger offset*

☞ The value in parameter P-0-0035 can be used by the master for synchronizing the measuring signals of several axes with the internal trigger event of the master axis.

Handling, Diagnostic and Service Functions
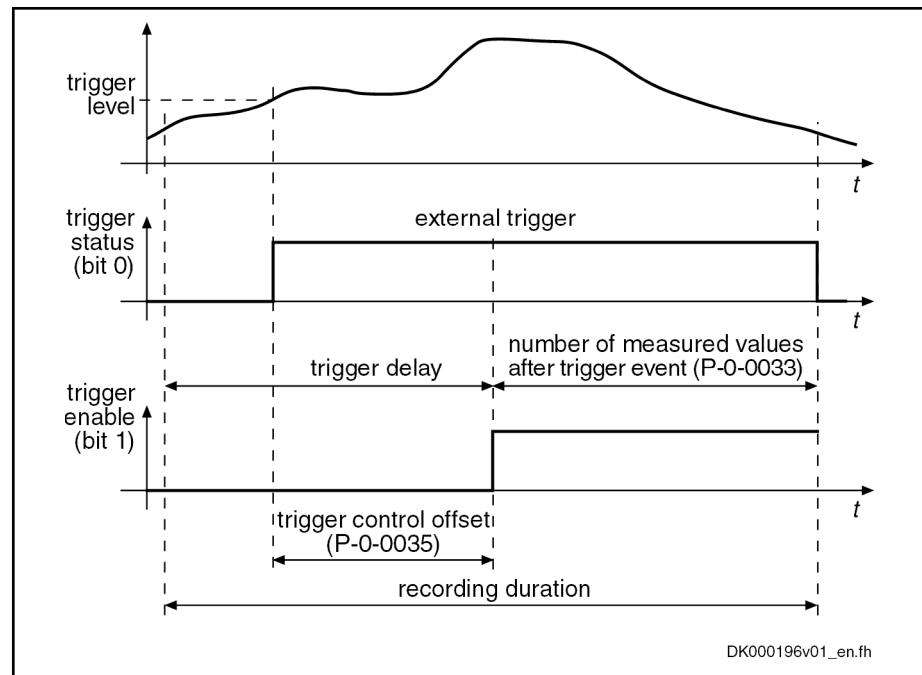
Fig. 10-69:   *Trigger control offset*

Status of internal trigger (P-0-0037)

Upon successful comparison of trigger signal and trigger condition, bit 0 is set in parameter "P-0-0037, Oscilloscope: internal trigger signal" (trigger status), but the trigger is not released. It is thereby possible for the master to signal the trigger event via the real-time status bits and real-time control bits to several drives at the same time and to release the trigger.

External trigger signal (P-0-0036)

"P-0-0036, Oscilloscope: external trigger signal" can be parameterized as real-time control information, both in the real-time channel of the interface and as hardware input. This allows triggering at external signals that are preset via

● the master communication

- or -

● an analog or digital input.

10.11.5   Parameterizing the Oscilloscope Function

Recording Duration

The recording duration is determined according to the following relationship:

$$t_A = (P\text{-}0\text{-}0031) \times (P\text{-}0\text{-}0032)$$

t_A Recording duration (in µs)
P-0-0031   Oscilloscope: Time resolution
P-0-0032   Oscilloscope: Size of memory
Fig. 10-70:   *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

Handling, Diagnostic and Service Functions

- 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 "Trigger Function" above

Parameterizing Time Resolution and Size of Memory

The recording range or the recording duration can be adjusted to the measurement requirements via the following parameters:

- P-0-0031, Oscilloscope: time resolution

- P-0-0032, Oscilloscope: size of memory

Size of memory of the oscilloscope function

The number of measured values is determined via "P-0-0032, Oscilloscope: size of memory". A maximum of 8192 measured values per channel can be recorded.

Time resolution of the oscilloscope function

"P-0-0031, Oscilloscope: time resolution" determines the time intervals in which measured values are recorded (sampling rate). It is possible to select the time resolution on the time base of the position loop clock ($T_{os\text{-}ci}$ = 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"

10.11.6   Diagnostic and Status Messages

Status of the Oscilloscope Function

Parameter "P-0-0029, Oscilloscope: status word" displays the current status of the oscilloscope function.

P-0-0029 contains, for example, status information on:

- Start/end of recording

- Trigger function

- Status of the trigger signal

- Delay function

ℹ️ 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

After a measurement, the parameter "P-0-0150, Oscilloscope: number of valid measured values" displays the number of detected measured values in the ring buffer. When the ring buffer has been completely filled with the length determined in parameter "P-0-0032, Oscilloscope: size of memory", the size of memory is displayed in this parameter.

Handling, Diagnostic and Service Functions

See also Parameter Description "P-0-0150, Oscilloscope: number of valid measured values"

DOK-INDRV*-MP*-08VRS**-AP01-EN-P   Bosch Rexroth AG   1099/1183
Rexroth IndraDrive Firmware for Drive Controllers MPH-, MPB-, MPD-, MPC-08

Engineering/Diagnostic Interfaces

11 Engineering/Diagnostic Interfaces

11.1 Safety Instructions

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

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

11.2 Serial Communication

11.2.1 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 firmware, for locating errors and for other services. The physical standard used is RS232 (with accessory HAS05.1-005 "RS232/RS485 converter", and 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 a terminal or commissioning tool in parallel to the existing master communication
- Connecting a control terminal (BTV04)
- Firmware download using "IndraWorks Ds/D/MLD" 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

Interface Mode

The serial interface can optionally be operated in one of the following modes:
- RS232 mode

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- 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).

Different cables need to be used depending on the mode (see relevant "Project Planning Manual").

Transmission Protocols

Two different protocols are supported on the drive side:

- ASCII protocol
- SIS protocol

When the 24 V supply voltage is switched on, automatic protocol detection is activated when signals are received via the serial interface.

As soon as either

- a valid ASCII start sequence

- or -

- a valid SIS telegram

has been received, the drive internally switches to the respective kind of protocol.

Properties of ASCII protocol
- Transmission rates of 9600 and 19200 baud
- 8-bit ASCII protocol
- No parity bit
- One stop bit

☞ No telegram frame is used, but the transmitted ASCII signals 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 signal ("0x02")
- Defined structure of the telegram frame
- Possible triggering of motions (e.g. jogging)

11.2.2   Protocol-independent Functional Principle

Basic State After Applying Control Voltage

After the control voltage has been switched on, the serial communication in the drive is in "passive mode". No communication is possible in passive mode.

Determining the protocol
To establish serial communication with the drive, the type of communication (protocol) has to be determined by

- a CHANGE DRIVE command (with ASCII protocol)

- or -

- a valid SIS telegram (with 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 Ds/D/MLD" commissioning tool.

Exception: If the value "256" (default value) is 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 mandatory** 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. Independently of the setting in parameter P-0-4022, the address "128" is always valid.

RS485 mode
With communication via the RS485 bus, it is mandatory to set the drive address, because each bus node is addressed via a specific bus address.

☞   To avoid access conflicts, each drive address may be assigned only once.

Communication via RS232 Interface

The RS232 interface is specifically intended to be used for connecting a PC with the installed "IndraWorks Ds/D/MLD" commissioning tool.

Features
- Transmission rates of 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
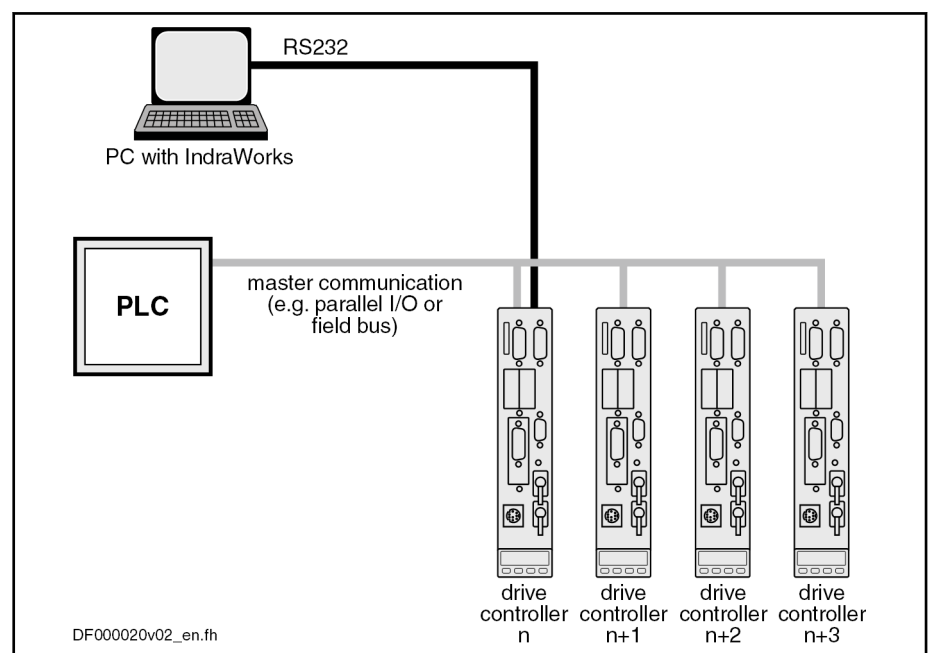
Fig. 11-1:   Communication via RS232 interface (example: "IndraWorks Ds/D/MLD")

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Communication via RS485 Interface

General Information

Communication via the RS485 interface permits a serial bus with the following data to be realized:

Features
- Connecting of up to 31 drives with one bus master
- Transmission rates of 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.

Operation of Several Drives with "IndraWorks Ds/D/MLD"

Applicational benefits
- Commissioning of several drive controllers without plugging the interface cable into a different connection (central parameterization and diagnosis connection)
- Realizing a central PC-based visualization unit
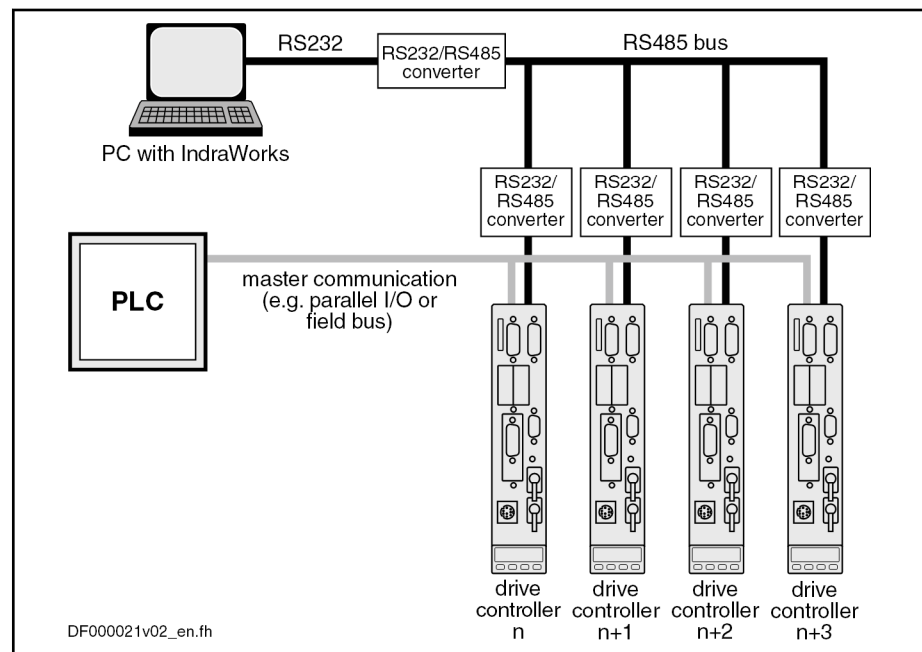
Fig.11-2:   Operation of several drives with "IndraWorks Ds/D/MLD"

☞ Using "IndraWorks Ds/D/MLD" via the RS485 interface is only possible from version 05 onwards.

Parameterization and Diagnosis via a PLC

Applicational benefits
- Parameters can be changed via a PLC (e.g. adjustment of positioning blocks)
- Extended diagnostic possibilities for the PLC by reading in the error code
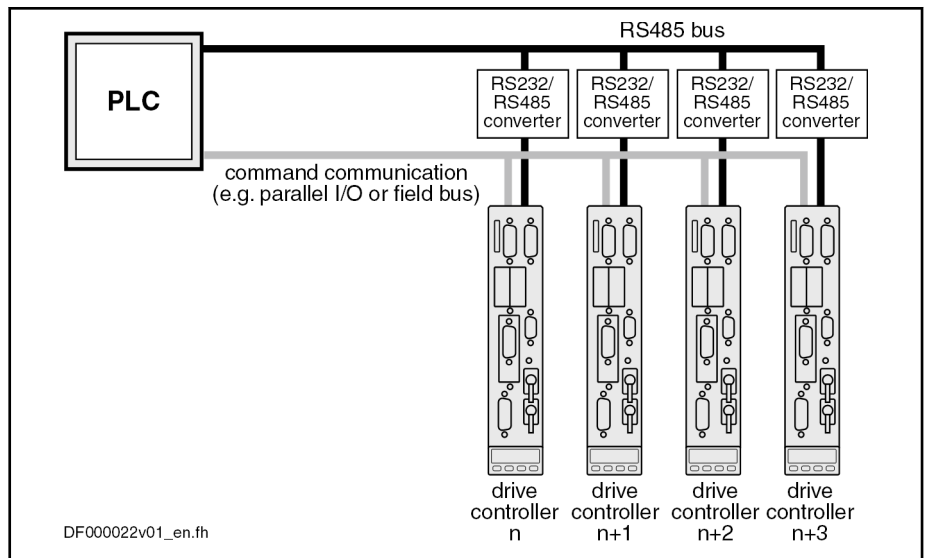
Fig.11-3:   *Parameterization and diagnosis via a PLC*

Parameterization and Diagnosis of Drive Groups by an Operator Unit

Applicational benefits   • Realizing a central visualization unit
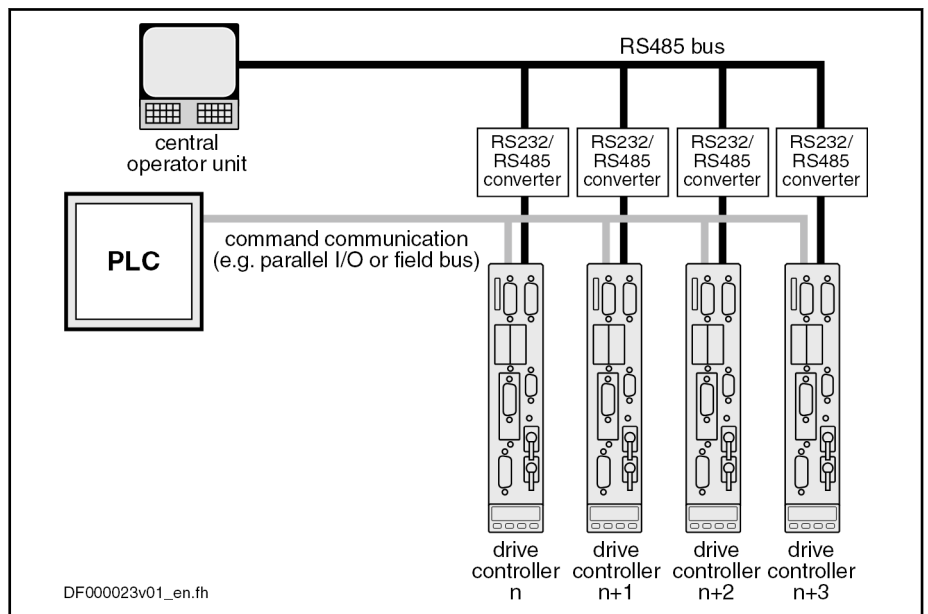
Fig.11-4:   *Parameterization and diagnosis of drive groups by an operator unit*

Connection System

ℹ️ See separate documentation "Control Sections for Drive Controllers; 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 of sercos Interface", section entitled "Service channel error messages"). These codes are also used in the event of incorrect access to control and system parameters.

Engineering/Diagnostic Interfaces

Error code		
Hexadecimal	Decimal	Explanation
0x1001	4097	No IDN
0x1009	4105	Invalid access to element 1
0x2001	8193	No name
0x2002	8194	Name transmission too short
0x2003	8195	Name transmission too long
0x2004	8196	Name cannot be changed (read only)
0x2005	8197	Name is write-protected at this time
0x3002	12290	Attribute transmission too short
0x3003	12291	Attribute transmission too long
0x3004	12292	Attribute cannot be changed (read only)
0x3005	12293	Attribute is write-protected at this time
0x4001	16385	No units
0x4002	16386	Unit transmission too short
0x4003	16387	Unit transmission too long
0x4004	16388	Unit cannot be changed (read only)
0x4005	16389	Unit is write-protected at this time
0x5001	20481	No minimum input value
0x5002	20482	Minimum input value transmission too short
0x5003	20483	Minimum input value transmission too long
0x5004	20484	Minimum input value cannot be changed (read only)
0x5005	20485	Minimum input value is write-protected at this time
0x6001	24577	No maximum input value
0x6002	24578	Maximum input value transmission too short
0x6003	24579	Maximum input value transmission too long
0x6004	24580	Maximum input value cannot be changed (read only)
0x6005	24581	Maximum input value is write-protected at this time
0x7002	28674	Operation data transmission too short
0x7003	28675	Operation data transmission too long
0x7004	28676	Operation data cannot be changed (read only)
0x7005	28677	Operation data is write-protected at this time (reason: communication phase or mode)
0x7006	28678	Operation data is smaller than the minimum input value
0x7007	28679	Operation data is greater than the maximum input value
0x7008	28680	Invalid operation data (e.g. IDN not supported, invalid bit number, invalid bit combination, invalid list length)
0x7009	28681	Operation data write protected by a password

Engineering/Diagnostic Interfaces

Error code		Explanation
Hexadecimal	**Decimal**	
0x700A	28682	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	28683	Invalid indirect addressing (e.g., data container, list handling)
0x700C	28684	Operation data is write protected, due to other settings (e.g., parameter, operation mode, drive enable, drive on etc.)
0x7010	28688	Procedure command already active
0x7011	28689	Procedure command not interruptible
0x7012	28690	Procedure command at this time not executable (e.g., in this phase the procedure command cannot be activated)
0x7013	28691	Procedure command not executable (invalid or false parameters)

Fig.11-5:   SERCOS Error Codes

11.3   TCP/IP Communication

11.3.1   Brief Description

☞   The section entitled "TCP/IP Communication" describes all information required for standard Ethernet communication. Apart from TCP/IP communication, communication via UDP/IP is possible, too.

To avoid any confusion with the master communication "EtherNet/IP™ interface", the designation "Ethernet communication" has been omitted in this case.

It is possible to communicate with an IndraDrive controller via standard Ethernet telegrams. These Ethernet telegrams contain TCP/IP or UDP/IP telegrams for application-side connection. The CSMA/CD access method is used for communication with the device. A variety of interfaces are available as connection options, such as the Engineering Port of the control section CSH01.2 or a free port of a sercos III interface (master or slave).

With sercos III, in addition to the time-controlled transmission of sercos-type Ethernet telegrams (MDT and AT), there is also an NRT channel (NonReal-Time or IP channel) with which telegrams are sent in a specially reserved time slot.

Therefore, there is another option for asynchronous data transmission with sercos III in addition to the existing service channel, that is particularly suitable for large volumes of data due to the maximum lengths of useful data of approx. 1500 bytes.

Possible applications   There are different application options available when utilizing the Ethernet communication in the drive, which are summarized in the following table.

Connection	Server application	Possible client applications
SIS protocol	Parameterization via SIS-based parameter services, integrated in TCP	Addressed on the client side by SCP in IndraWorks
Com-Server	Access to parameters and PLC variables for HMI connection	VCP / VEP

Engineering/Diagnostic Interfaces

Connection	Server application	Possible client applications
3S-TCP	Programming/debugging/boot program download for IL run-time	1. IL programming environment 2. See 3S Gateway for OPC Server
3S-UDP	Cyclic exchange of network variables between Codesys-based controls	
FTP server	FTP server for uploading (writing to target device) and downloading (reading from target device) of files on the MMC	FTP client program on the master computer, Engineering PC, ...

Fig.11-6:   Overview of possible applications

Pertinent parameters

- S-0-1019, Master comm. engineering over IP: MAC address
- S-0-1020, Master comm. engineering over IP: IP address
- S-0-1021, Master comm. engineering over IP: Network mask
- S-0-1022, Master comm. engineering over IP: Gateway address
- P-0-1044, Master comm. engineering over IP: Status IP communication
- P-0-1534, C6100 Command Activate IP settings
- P-0-1530, Engineering: MAC address
- P-0-1531, Engineering: IP address
- P-0-1532, Engineering: Network mask
- P-0-1533, Engineering: Gateway address
- P-0-1544, Engineering: Status IP communication
- P-0-1640, CCD: MAC address
- P-0-1641, CCD: IP address
- P-0-1642, CCD: network mask
- P-0-1643, CCD: gateway address
- P-0-1644, CCD: status IP communication

Pertinent diagnostic messages

- C6101 Incorrect IP settings
- F2190 Incorrect Ethernet configuration

11.3.2   Functional Description

Basic Information on the Function
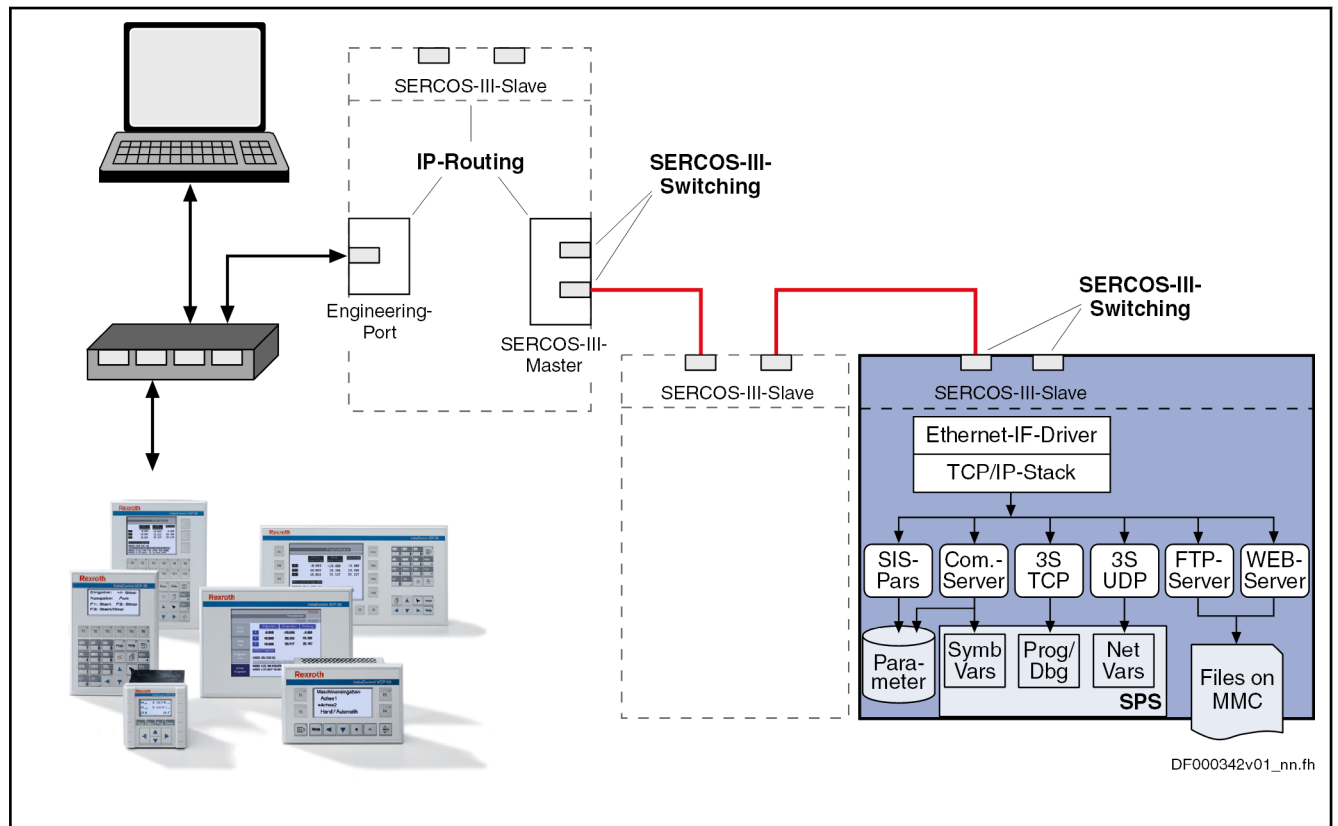
Fig.11-7:   Overview of TCP/IP communication

Components for TCP/IP communication A maximum of up to three components can be available in one drive (see Device Class C*), via which TCP/IP communication is possible. These components are:

- Industrial Ethernet slave interface

- sercos III master interface

- Ethernet Engineering interface (with control section CSH01.2/CSH01.3)

These three components are devices that are independent of each other with regard to TCP/IP communication (comparable with network cards in a PC). Therefore, from a network point of view, an IP address containing different IP sub-networks must be set for each device.

☞   If the same IP sub-networks are used for the devices, they must be connected to each other.

Configuration The minimal IP address and network mask must be set for IP communication, for each device.

In addition, a gateway address can be set in every device, which is generally used as the default gateway for the device.

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> ☞ Only one default gateway is possible in every device. If a gateway is indicated in several devices, the following sequence for the settings within the device is utilized for the default gateway:
>
> 1. Industrial Ethernet slave
> 2. sercos III master
> 3. Ethernet Engineering
>
> The setting in the respective other devices has no meaning.

The setting of the above mentioned information is carried out in the drive by means of the respective parameters. An independent set of parameters is available for this for every device.

Interface	IP address	Network mask	Gateway address
Industrial Ethernet slave	S-0-1020	S-0-1021	S-0-1022
sercos III master	P-0-1641	P-0-1642	P-0-1643
Ethernet Engineering	P-0-1531	P-0-1532	P-0-1533

Fig.11-8:   Parameters for setting addresses and network masks

Changes become effective through a restart or activation of a drive command.

Structure of the IP address   The IP address of a communication node always consists of a network address (network ID) and a host address (host ID).

In accordance with the sercos III definitions, there can be no more than 250 nodes in one ring. Therefore, the supported sub-networks are defined as class C networks (network mask 255.255.255.0) for IP communication. The network ID corresponds to the first three bytes of the IP Address. The host ID is the fourth byte of the IP address.
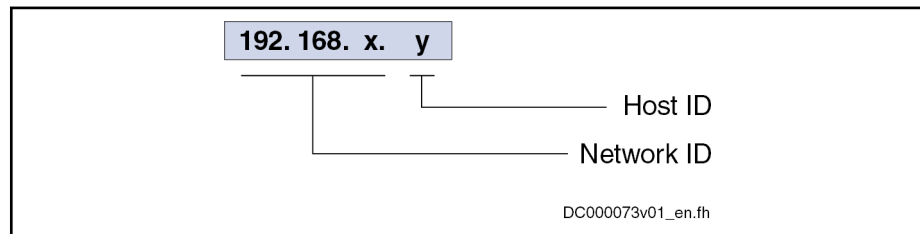
Fig.11-9:   Structure of the IP address

A "private" area is always to be utilized for the IP address range for communication in the IP channel of sercos III. The defined areas of the following networks are available

- Class A networks (10.x.x.x),
- Class B networks (172.16.x.x) or
- Class C networks (192.168.x.x).

Utilization of the private class C networks (192.168.x.x) is recommended for the IP address area or as the default setting.

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Interface	IP address	Network mask	Gateway address
Industrial Ethernet slave	192.168.0.0	255.255.255.0	192.168.0.254 [1]
sercos III master	0.0.0.0	255.255.255.0	0.0.0.0
Ethernet Engineering	0.0.0.0	255.255.255.0	0.0.0.0

[1]   Automatically allocated; stored value corresponds to 0.0.0.0

Fig. 11-10:   Default values of the IP address setting

The values set in the parameters are not necessarily reset to the aforementioned values when loading the basic parameters.

By appropriate selection for the loading of the default values, the setting for Ethernet Engineering or even the entire settings can be maintained instead. If the "Index for load defaults procedure" is set with the option "Except serial communication", the settings for the Engineering port are retained. If the communication parameters are completely excepted from the load defaults procedure, all parameter values for IP communication are also retained.

Automatic Settings

☞ The settings of the IP information indicated in the parameters and utilized for communication can be different.

The IP settings made can be activated by the command "C1600 Command activate IP settings". Changes in a gateway are activated by switching off and on.

Default gateway address   The default gateway address is only set automatically if no gateway address has been manually set in any device.

The compilation of the gateway IP address is carried out with the network ID of the device and the maximal possible host ID (in a class C network this corresponds to "254"). The respective device is utilized in the sequence described above for setting.

IP address of the sercos III slave   The IP address of a sercos III slave is set automatically if no or only limited manual settings have been carried out and if the network mask has been set for a class C network.

The IP address consists of:

• Network ID → Utilization 192.168.0 (network mask 255.255.255.0)

• Host ID → Master communication address

IP address of the sercos III master   The IP address of the sercos III master can only be manually set to a limited extent.

In this case, the network ID has to be set manually.

If the host ID is not set manually, in a class C network the value is automatically set to "254"

IP address of the Engineering port   Automatic setting of the IP address of the Engineering port is impossible.

IP Port List

The following table contains an overview of the IP ports used in the drive and their configurability.

Communication	Port	Protocol	Port configurable?
IndraWorks drive parameterization	5002	TCP	No
IndraLogic MLD programming system[1]	1200	TCP	No

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Communication	Port	Protocol	Port configurable?
Network variables MLD (IndraLogic)[1]	1202	UDP	Yes
ComServer	6042	TCP	No
ComServer UDPS	6040	UDP	No
WebServer[2][3]	80	TCP	No
EtherNet/IP™	44.818	TCP/UDP	No
EtherNet/IP™	2222	UDP	No
FTP[3]	20 and 21	TCP	No
FTP - additional ports, dynamic[3]	1023 et seq.	TCP	Yes
Recommended ports for individual programming in MLD[1]	49.152 to 65.535		
Global port list "well known ports"	http://www.iana.org/assignments/port-numbers		

1)   Only with activated MLD
2)   Only in conjunction with MPC firmware
3)   Only with MMC plugged in
Fig.11-11:   *IP port list*

sercos Networks

For the setting of the IP configuration, in the determinations below it is pre-supposed that the individual sercos III rings are set as class C IP networks. Carry out the relevant settings when using another network class.

Simple sercos ring   With a simple sercos III ring, automatic IP setting is possible for the sercos III interfaces (when using the IP network 192.168.0.x). However, the existing Engineering ports must be set manually.
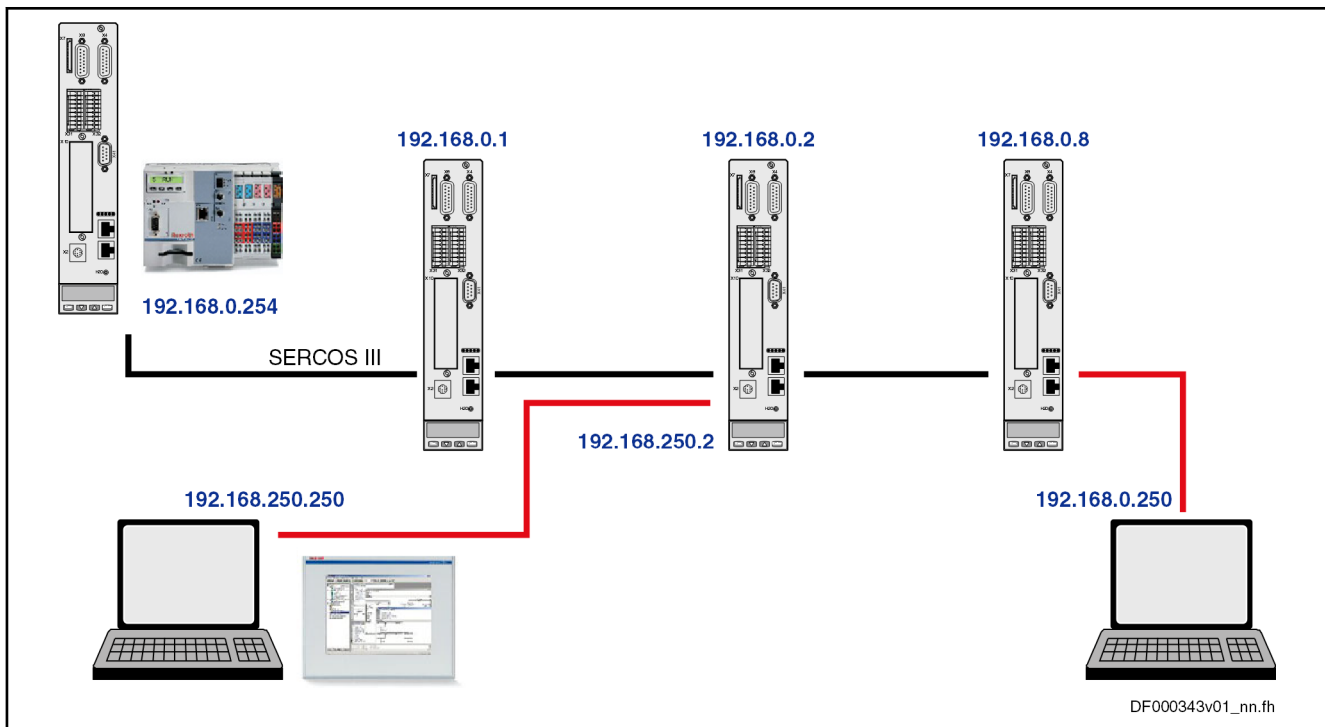
Fig.11-12:   *Example of a simple sercos III Ring*

Sequence when configuring the sercos network:

1. Set network ID in every node

2. Host ID of the master is "254"

3. Set default gateway to the address of the master in every slave

A proprietary sub-network must be set manually to configure an Engineering port.

The following must be taken into consideration when configuring external communication nodes (sercos line).

● Utilize a free IP address from the IP network

● Set host ID to a value between "250" and "253"

Control ring with subcarrier rings   With a control ring with subcarrier sercos III rings, an unambiguous network ID must be set manually in all rings (every node). "192.168.254" is recommended for the network ID in the control ring.

The master of a subcarrier ring contains the network ID 192.168.<master communication> (<master communication> corresponds to the address of the master communication in the control ring). "254" is assigned to the host ID.
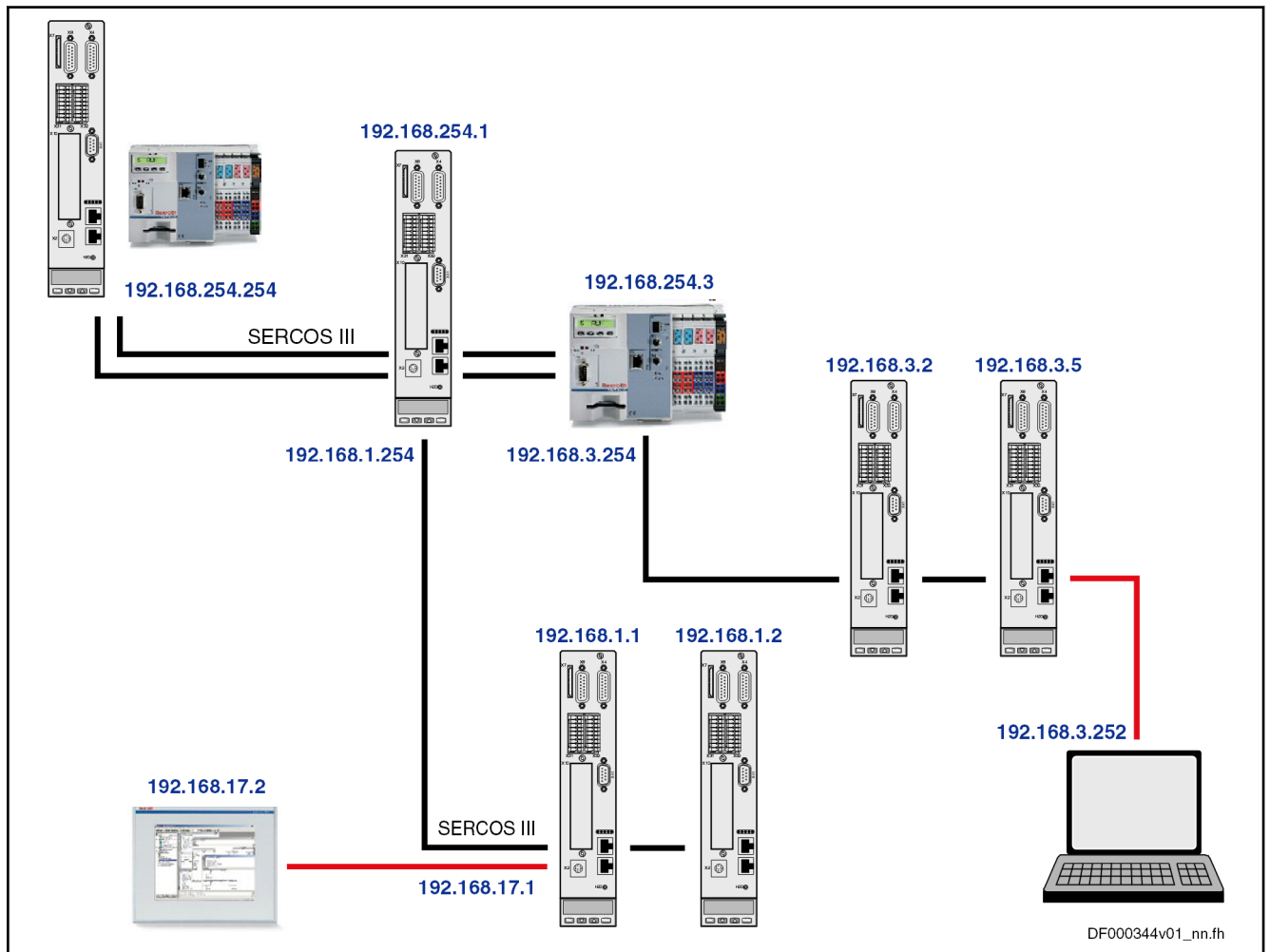
Fig.11-13:   Example of a control ring with a subcarrier ring

The following conditions and recommendations apply in a network like this:

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- Network ID in the subcarrier ring corresponds to that of the respective master
- Host ID → Master communication address
- Set default gateway to the address of the master in every slave
- Definitions for the Engineering port (external nodes) as with the simple sercos ring

"Golden Unit" network   The setting of such a network must be executed manually, as with the previous sercos network.

The master communication address in the network ID cannot always be used for a sercos master outside of the control ring.

SERCOS III

SERCOS III   SERCOS III   SERCOS III

SERCOS III

DF000345v01_nn.fh
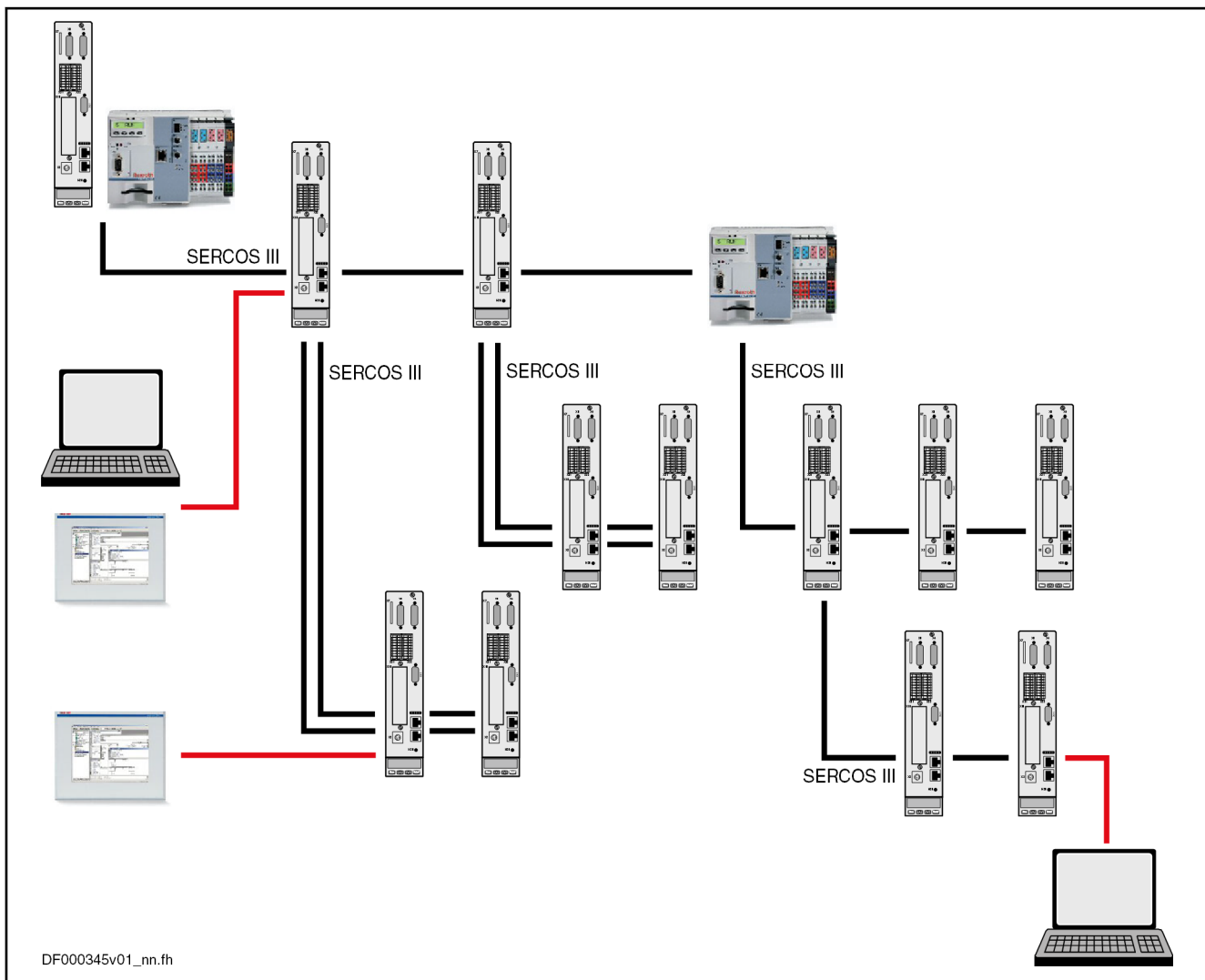
Fig.11-14:   *Example of a "Golden Unit" network*

11.4   S/IP Protocol

11.4.1   Brief Description

Fields of Application

S/IP permits simple access to all the parameters of the drive.

Typical applications include:

Engineering/Diagnostic Interfaces

- Communicating with the drive for Engineering via a proprietary company tool
- Replacing cyclic bus communication to control simple axis applications without realtime requirements e.g. in positioning block mode or with drive-controlled positioning

Overview of Functions

Features

- TCP/IP-based protocol
- The protocol focuses on the exchange of data and requires minimal administration overhead.
- User-defined busy timeout (time until the drive sends a defined response)
- User-defined lease timeout (time from which the connection is re-enabled, if no new requests are received)
- Proprietary service for reading all the information from a parameter in a request
- Up to 2 connections are possible simultaneously

Pertinent Diagnostic Messages

The following error messages are defined and are returned directly from the drive in its own service:

Name	Value in the telegram	Meaning
CONNECTION_ERROR	1	Error when establishing the connection
ABORTED	2	Process was terminated
UNKNOWN_MES-SAGE_TYPE	3	Message type in the header is unknown
SERVICE_SPECIFIC	4	Service-specific error, e.g. "Data is read-only"

Fig.11-15:   S/IP error classes

11.4.2   Functional Description

General Information

S/IP is the abbreviation for sercos Internet Protocol

The following section provides an overview of the services available in the S/IP protocol and explains the individual services. Sample requests and responses are presented in the "Notes on Commissioning".

A service always consists of a request and a response. The request is always sent from the client, the server (drive) can respond to a request with different responses. If the request can be processed and answered immediately, then the drive sends the associated response to the request directly (idR Service number response = Service number request + 1). If the drive is busy with another request, a busy response (service number: 68) can be transmitted. If the telegram was incorrectly formatted, if the service is not supported or if another error has occurred, an exception response (service number: 67) is transmitted back.

Every telegram consists of a static part and a service-specific part. A package number can be issued in the static part, to assign the request and re-

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sponse to each other. Furthermore, it also specifies the service carried out with this telegram.
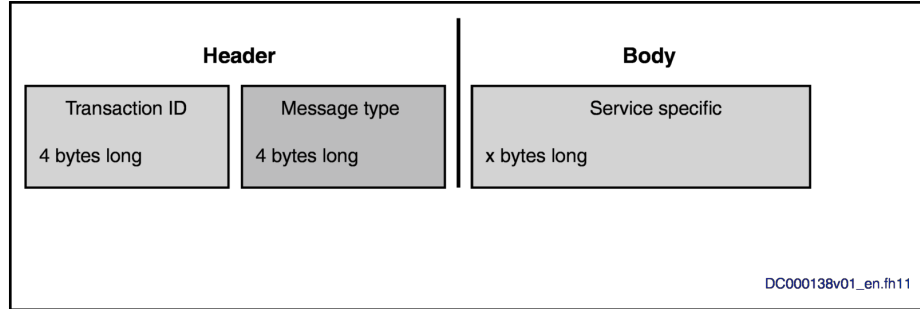
Fig.11-16:   Principle structure of an S/IP telegram

The header consists of 8 bytes:

- Bytes 1 - 4 give the "Transaction ID", an identification number that defines this request. This number is specified again with a response.

- Bytes 5 - 8 define the "Message Type". The Message Type is the service number (list of services supported by the drive, see below). As currently only services with a length of 1-byte are used, the "low byte" is relevant.

Variable definitions   The "ReadEverything Response" and "ReadDescription Response" services send a 2-byte value in addition to the data, indicating which elements are valid in the response. This "ValidElements" value consists of the following:

Bit	Description
0x01	Data status is valid
0x02	Description and DescriptionLength are valid
0x04	Attribute is valid
0x08	Unit and UnitLength are valid
0x10	Minimum value is valid
0x20	Maximum valid is valid
0x40	The Value and ValueLength are valid

Fig.11-17:   Valid elements

The "ReadEverything Request", "ReadOnlyData Request", "ReadOnlyDescription Request", "ReadDataStatus Request", "WriteData Request" and "WriteDataBits Request" services require information about the parameters for which the action is to be performed.

A 4-byte value is transmitted to the drive for this. The structure corresponds to the following diagram.

Bit No.	Description		Value range	Notes
31-24	Parameter instance/structure instance (SI)		0-255	
23-16	Parameter element/structure element (SE)	sercos-defined SE	0-127	defined by sercos (bit 15 = 0)
		product-specific SE	128-255	not in use

Bit No.	Description		Value range	Notes
15	sercos-speci-fied or product-specific IDN (S or P)	Standard IDN (S-0-nnnn)	0	SE (0-127), SI and parameter number are de-fined via sercos
		Product-specif-ic IDN (P-0-nnnn)	1	Product-specif-ic parameters
14-12	Parameter set		0-7	see also "Pa-rameter Set Switching"
11-0	Parameter number		0-4095	

Fig.11-18:   Structure of the 4-byte value

Supported services   The following table provides an overview of the services supported by the drive and the associated "Message Types" for the request and response respectively.

Service name	Service number	
	Request	Response
Connect	63	64
Ping	65	66
Exception	-	67
Busy	-	68
ReadEverything	69	70
ReadOnlyData	71	72
ReadDescription	73	74
ReadDataStatus	87	88
WriteData	83	84
WriteDataBits	85	86
Nameplate	89	90

Fig.11-19:   IndraDrive-supported S/IP services

Connect

Request   Structure:

The Connect service connects the client to the drive. Message Type "63" is transmitted for this. The so-called Busy Timeout and Lease Timeout times are also proposed by the client in this telegram.

- **Busy Timeout:** Indicates how much time may elapse before a response telegram to a request is received.

- **Lease Timeout:** Indicates after what time the drive automatically closes the connection if no new requests are received

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It also specifies which protocol version of S/IP is used for communication. The drive supports specification 1.0 and accordingly the value "1" is to be entered in the "Version" field.

```
┌─────────────────────────────────────────────────────────┐
│ ▐  Connect request                                       │
│ ▐ ──────────────────────────────────────────────────    │
│                                                          │
│  ┌──────────────┐  ┌──────────────┐  ┌──────────────┐    │
│  │ SIP version  │  │ Busy timeout │  │ Lease timeout│    │
│  │              │  │              │  │              │    │
│  │ 4 bytes long │  │ 4 bytes long │  │ 4 bytes long │    │
│  └──────────────┘  └──────────────┘  └──────────────┘    │
│                                                          │
│                                          DC000139v01_en.fh11 │
└─────────────────────────────────────────────────────────┘
```
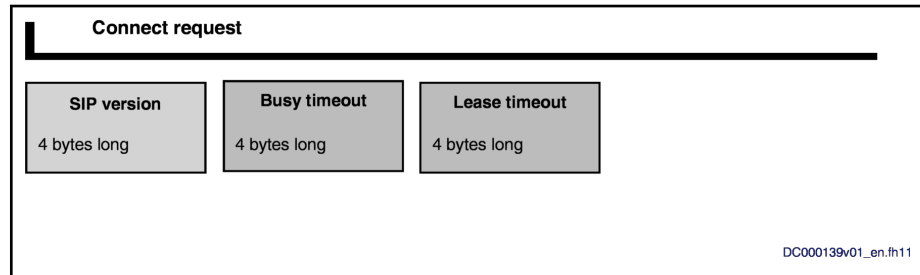
Fig.11-20:   Illustration of a Connect request

Response   The Connect response is transmitted as a response to a Connect request, if the connection could be established correctly. The service is identified with service number "64" and provides information about the connection:

- Which Busy Timeout is actually used
- Which Lease Timeout is actually used
- Which protocol version is actually used
- An array of all the drive's supported services (requests)

Byte offset	Length (byte)	Name	Meaning	Example
0	4	Version	Protocol version of the drive used	1
4	4	BusyTimeout	The drive's Busy Timeout used	500
8	4	LeaseTimeout	The drive's Lease Timeout used	15.000
12	4	NumberMessageTypes	Number of services that the drive supports	12
16	NumberMessageTypes * 4	MessageTypes	Array consisting of 4-byte values which contain the drive's available services	-

Fig.11-21:   Structure of Connect response

Ping

Ping request   The ping request is identified via service number "65". This is an empty telegram, that is to say the telegram contains 0 bytes of useful data. The service can be used to:

- Maintain the connection, as the drive rejects the connection at the end of Lease Timeout
- Measure the minimum time that a response requires from the drive

Ping Response   The Ping response is transmitted as a response to a Ping request. The telegram contains no useful data.

Busy & Exception

The "Busy" and "Exception" services are special services. These services can be transmitted as a response to any request.

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Busy response   The Busy response is transmitted if the response telegram cannot yet be transmitted at the end of the Busy Timeout. The Busy response contains no data. This response can virtually be suppressed by setting the Busy Timeout to higher values. However, high values do not guarantee that no Busy responses are transmitted.

Exception response   The Exception response is transmitted if a general error has occurred in the communication. There are various possibilities to explain why an Exception response is transmitted.

ReadEverything

ReadEverything request   The ReadEverything request is used to collectively request all data from a parameter. The service is identified via service number "69". The SlaveIndex and SlaveExtension are also needed for this. The parameter that is to be read is also transmitted.
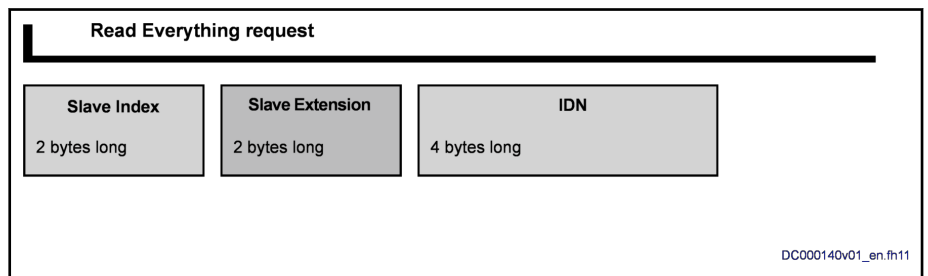
Fig.11-22:   Illustration of a ReadEverything request

Byte offset	Length (byte)	Name	Meaning	Example
0	2	SlaveIndex	reserved - always 0	0
2	2	SlaveExtension	reserved - always 0	0
4	4	IDN	Parameter to be read	0x30

Fig.11-23:   Structure of ReadEverything request

ReadEverything response   The ReadEverything response contains the data for the "ReadEverything request" request. The service is identified via service number "70".

The following values are transmitted:

- Data Status
- Attribute
- Minimum value and maximum value
- Maximum length of the list in bytes (if list parameter)
- Current length of the data in the parameter in bytes
- Current length of the unit of the parameter in bytes
- Current length of the name in bytes
- Parameter data in binary format
- Parameter unit as a string
- Parameter as a string

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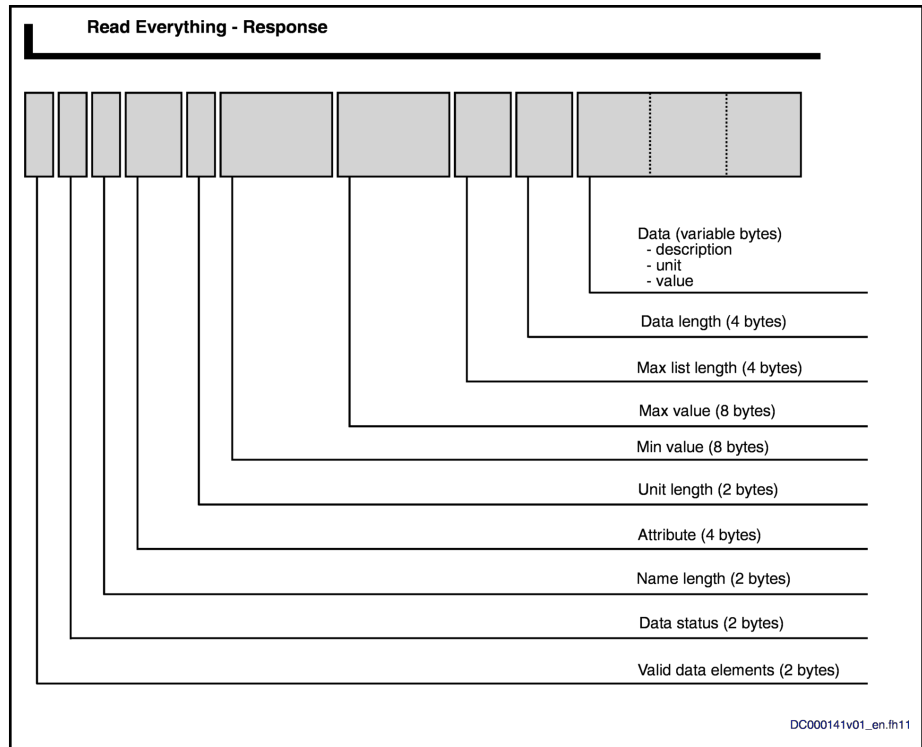
Fig.11-24:   *Illustration of the ReadEverything response*

Byte offset	Length (byte)	Name	Meaning	Example
0	2	ValidElements	Bit list in which the valid elements are coded	0b0000.0000.0100.11111
2	2	DataStatus	Data status of the parameter (valid/invalid) or command status with command parameters	1
4	2	NameLength	Length of the string, which contains the name of the parameter in the language set in S-0-0265	0x20
6	4	Attribute	The attribute of the parameter contains information about decimal places, display format, maximum length, write protection and whether the parameter is a command parameter	0x77560000
10	2	UnitLength	Length of the string, which contains the unit of the parameter (scaling-dependent)	6
12	8	Min	Lower input limit of this parameter	-

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Byte offset	Length (byte)	Name	Meaning	Example
20	8	Max	Upper input limit of this parameter	-
28	4	MaxListLength	Maximum length of the list parameter in bytes (only valid with list parameters)	8196
32	4	DataLength	Current length of the parameter	38
36	Name-Length	Name	Name of parameter	"Firmware version"
36 + Name-Length	UnitLength	Unit	Unit of the parameter	""
36 + Name-Length + UnitLength	Data-Length	Data	The value of the parameter	"FWA-INDRV****"

Fig.11-25:   Structure of ReadEverything response

ReadOnlyData

ReadOnlyData request   The "ReadOnlyData request" is used to read the data. The request for "ReadOnlyData" is identical to the "ReadEverything request", and service number "71" is transmitted in the header.

ReadOnlyData response   The "ReadOnlyData response" is identified by service number "72". The following data is transmitted:
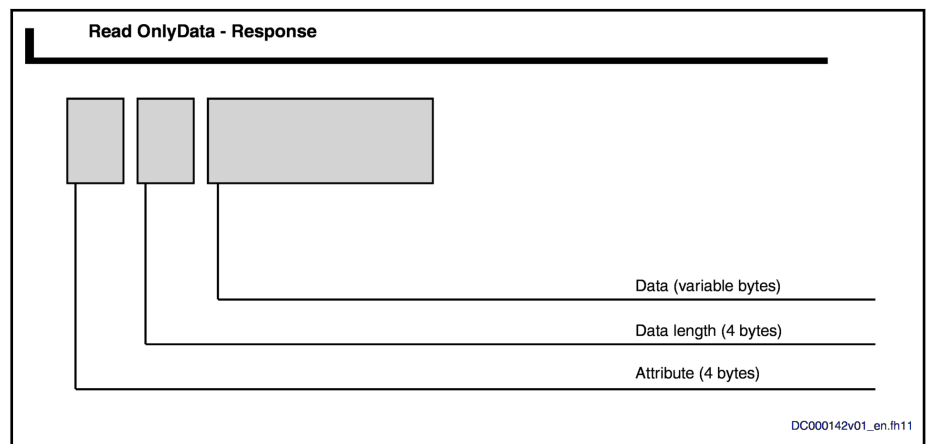
Fig.11-26:   Illustration of the ReadOnlyData response

Byte offset	Length (byte)	Name	Meaning	Example
0	4	Attribute	Attribute of parameter	0x77560000
4	4	Length	Length of the data field in bytes	2
4	Length	Data	The parameter data	0x1345

Fig.11-27:   Structure of ReadOnlyData response

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ReadDescription

ReadDescription request   The "ReadDescription request" is used to request all information about the parameter, with the exception of the operating data per se. The request for "ReadDescription" is completely identical to the "ReadEverything request", except that service number "73" is used.

ReadDescription response   The "ReadDescription response" is identified by service number "74". The following data is transmitted:
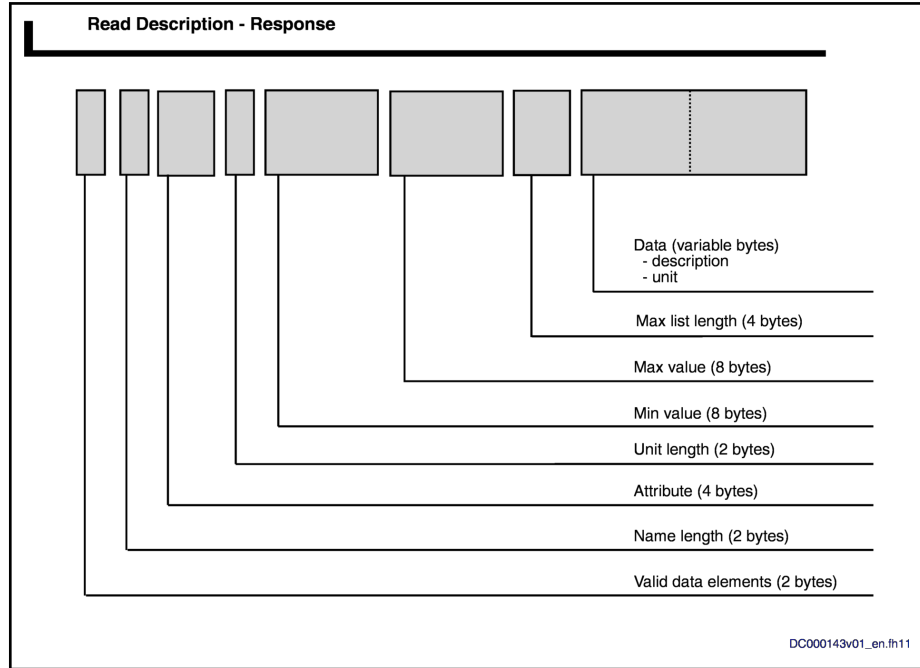
Fig. 11-28:   *Illustration of the ReadDescription response*

Byte offset	Length (byte)	Name	Meaning	Example
0	2	ValidElements	Bit list in which the valid elements are coded	0b0000.0000.0100.11111
2	2	NameLength	Length of the string, which contains the name of the parameter in the language set in S-0-0265	0x20
4	4	Attribute	The attribute of the parameter contains information about decimal places, display format, maximum length, write protection and whether the parameter is a command parameter	0x77560000
8	2	UnitLength	Length of the string, which contains the unit of the parameter (scaling-dependent)	6

Byte offset	Length (byte)	Name	Meaning	Example
10	8	Min	Lower input limit of this parameter	-
18	8	Max	Upper input limit of this parameter	-
22	4	MaxListLength	Maximum length of the list parameter in bytes (only valid with list parameters)	8196
26	4	DataLength	Current length of the parameter	38
30	Name-Length	Name	Name of parameter	"Firmware version"
30 + Name-Length	UnitLength	Unit	Unit of the parameter	""

Fig.11-29:   Structure of ReadDescription response

ReadDataStatus

ReadDataStatus request

The "ReadDataStatus request" is used to read the data status directly. The request for "ReadDataStatus" is identical to the "ReadEverything request", and service number "87" is used.

ReadDataStatus response

The "ReadDataStatus response" is identified by service number "88". The following data is transmitted:

Byte offset	Length (byte)	Name	Meaning	Example
0	2	DataStatus	Data status of the requested parameter	1

Fig.11-30:   Structure of ReadDataStatus response

WriteData

WriteData request

The "WriteData request" is used to read the data. Service number "83" is used for this.

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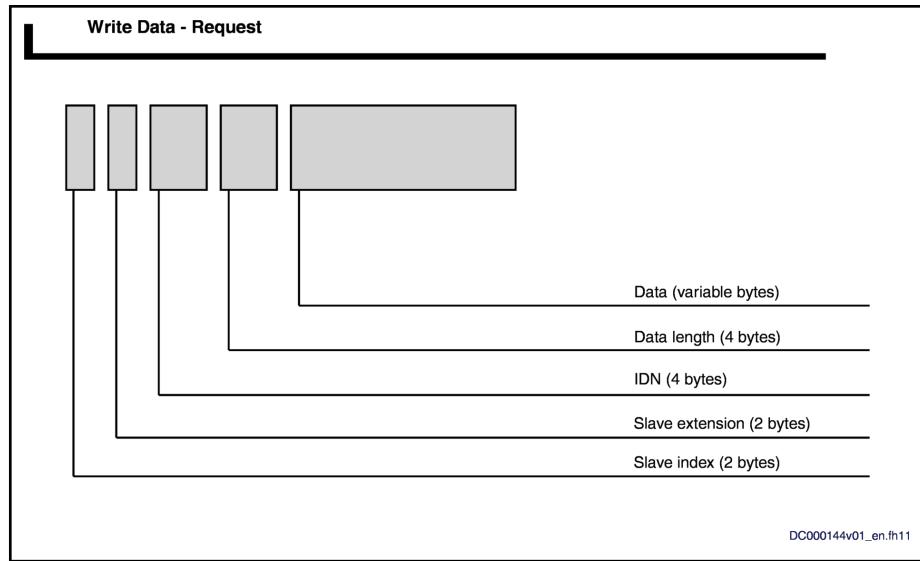
Fig.11-31:   Illustration of the WriteData request

Byte offset	Length (byte)	Name	Meaning	Example
0	2	SlaveIndex	reserved - always 0	0
2	2	SlaveEx-tension	reserved - always 0	0
4	4	IDN	Parameter to be read	0x30
4	4	Data-Length	Length of transmitted data	2
8	Data-Length	Data	The operating data to be transmitted	0x1234

Fig.11-32:   Structure of WriteData request

WriteData response   The "WriteData response" is identified by service number "84". No data is transmitted.

WriteDataBits

WriteDataBits request   The "WriteDataBits request" is used to individually write individual bits of a parameter. The request for "WriteDataBits" is identified by service number "85".

Any number of bits of a parameter value can be written in a request. The bits written depend on the DataMask, which forms part of the request. It is therefore possible to change an individual bit at any position in the parameter or write all bits. The bits that are written must be selected at the correspond position in the "DataMask". If bit 7 is to be written, then bit 7 must be set to 1 in the "DataMask".
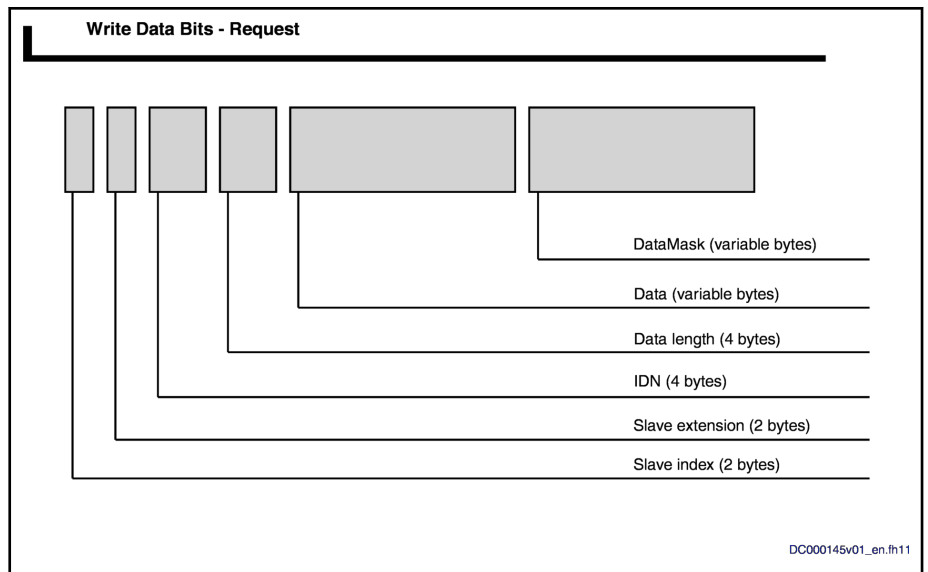
Fig.11-33:   Illustration of the WriteDataBits request

Byte offset	Length (byte)	Name	Meaning	Example
0	2	SlaveIndex	reserved - always 0	0
2	2	SlaveExtension	reserved - always 0	0
4	4	IDN	Parameter to be read	0x30
4	4	DataLength	Length of transmitted data	2
8	DataLength	Data	The operating data to be transmitted	0x1234
8 + DataLength	DataLength	DataMask	The bits to be updated	

Fig.11-34:   Structure of WriteDataBits request

WriteDataBits response   The "WriteDataBits response" is identified by service number "86". No useful data is transmitted. In the event of an error, an "Exception response" is returned instead of the WriteData response.

Nameplate

Nameplate request   In preparation

Nameplate response   In preparation

11.5   SIS Ethernet Parameter Channel

11.5.1   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 access options. The following sections also refer to the parameter structure below.

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Element no.	Data block element	Access option
1	Identification number	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.11-35:   Parameter structure

11.5.2   Telegram Structure, Telegram Scope

Basic Telegram Structure

In principle, a SIS telegram is divided into 3 blocks:

- Telegram header
- Useful data header
- Useful data

Telegram header	Useful data header	Useful data

Fig.11-36:   Structure of an 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 consists of 8 bytes 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. Clearing the "CS" byte 2. All characters in the telegram are added byte by byte 3. Saving the negated sum in the "CS" byte The result of the byte-by-byte addition of all characters in an SIS telegram always has the value zero!
3	DatL	Data length → The "DatL" byte contains the length of the telegram without the static telegram header. **The total length of an SIS telegram is limited to 255 bytes.** Therefore, only a maximum of 247 bytes of useful data can be transmitted.
4	DatLW	Data length repetition

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Byte	Name	Description of the bytes in the static part of the telegram header
5	Ctrl	Control byte (Control) → In the control byte, the telegram type and the structure of the dynamic telegram header are declared: • Bit 0…2 → Not used in the static part of the drive • Bit 3 → Specifies whether the dynamic telegram header contains "PackageN" (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 → Not used by the drive in command telegrams; in reaction telegrams, system status change is signaled • Bit 6 → Not used in command telegrams; in reaction telegrams, bit 6 signals a system warning in the slave • Bit 7 → Not used 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 of the service. 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 independently 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.11-37:   SIS Telegram Header, Static Part

Dynamic part of the telegram header   The dynamic part of the telegram header can contain up to 8 bytes. The telegram number ("PacketN" 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 sub-addresses are required, they are omitted in the telegram. When a command telegram is transmitted from one hierarchical level to the hierarchical level below it, the sub-address block is reduced by one address. On the way back, one address is added to the sub-address block in the reaction telegram.

Byte	Name	Meaning 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

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Byte	Name	Meaning of the bytes in the dynamic part of the telegram header
11	AdrES3	Slave address in the 3rd sublevel
12	AdrES4	Slave address in the 4th sublevel
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 (if bit 3 is set in "Ctrl" byte): ● At the first request with a package number <>0 this is processed. The reaction telegram is stored and transmitted by the slave. ● When the request is repeated (with the same package number), it is not processed. The slave transmits 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 transmitted by the slave. ● When there is a request with package number = 0, it is always processed. The reaction telegram is transmitted 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 transmitted by the slave but not stored. Reaction telegrams that are still stored are maintained! It is only possible with package monitoring to repeat individual sequential telegrams that were incorrectly transmitted, without canceling the running sequential telegram cycle!

Fig.11-38:   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, there is a distinction between the command telegram and the reaction telegram.

Command Telegram

The command telegram is the telegram the master (drive) transmits to the slave (master → slave).
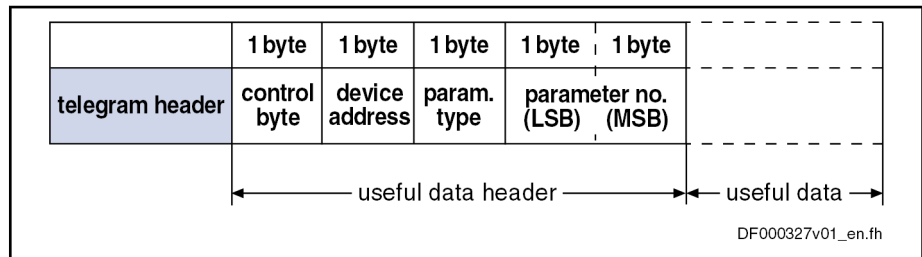
Fig.11-39:   Structure of the useful data header in the command telegram

Meaning of the useful data header   In the command telegram the useful data header describes the kind of request.

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Control byte
: The control byte indicates the parameter element (data, 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 must be entered in the "Device Address" block.

Parameter type and parameter number
: The parameter number has the format defined in the specification for the sercos interface. A byte for characterizing the parameter type precedes the address to be able to also address the control parameters.

bit 0:	reserved
bit 1:	reserved
bit 2:	reserved
bit 3...5:	**element**
000:	channel not active
001:	IDN
010:	name
011:	attribute
100:	unit
101:	min. input value
110:	max. input value
111:	operating data
bit 6:	reserved
bit 7:	reserved

DP000007v01_en.fh
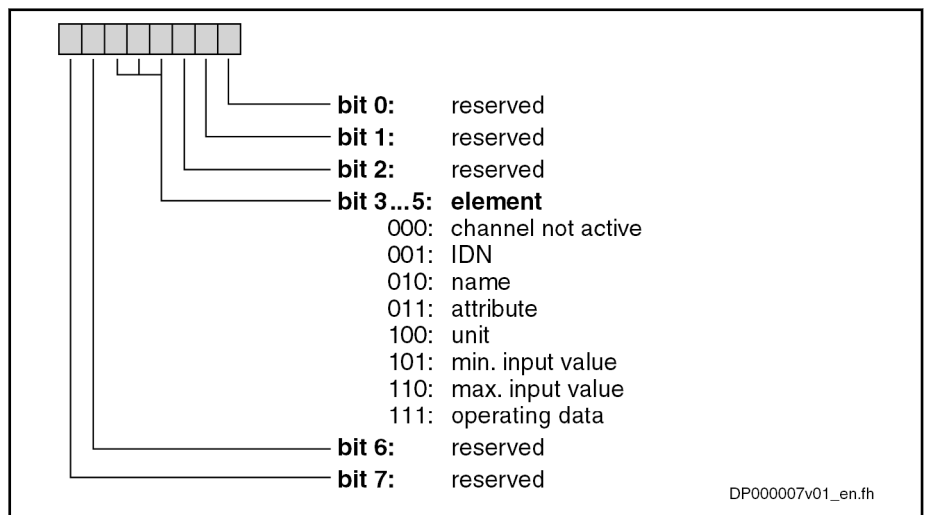
Fig.11-40:   *Structure of the control byte*

bit 0 ... 11:	parameter number (0*0001 ... 0*FFF)
bit 12...14:	parameter set (0 ... 7)
bit 15:	parameter type [1]
	0000: S-parameter (drive)
	0001: P-parameter (drive)
	0010: not used in the drive
	0100: not used in the drive
	1000: not used in the drive
bit 0 ... 2:	parameter type [1]
bit 3 ... 7:	reserved (always zero)

[1] parameter type uses bit 15 in "parameter number" and three further bits in the "parameter type" byte

DP000008v01_en.fh

Fig.11-41:   *Parameter type and parameter number in the useful data header*

Reaction Telegram

The reaction telegram is the telegram the slave (drive) transmits to the master (slave → master).
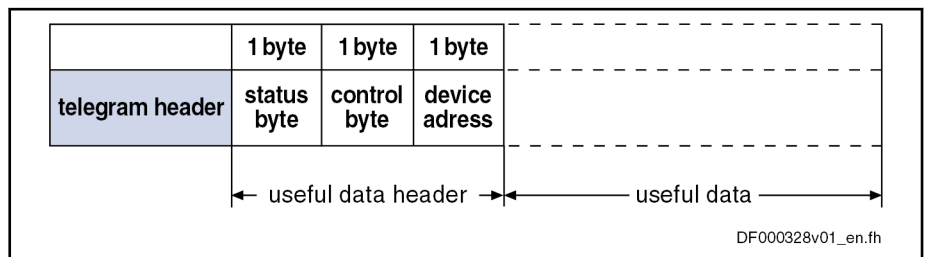
Fig.11-42:   *Structure of the useful data header in the reaction telegram*

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Status byte	In the status byte an error code is returned, if necessary. With an error-free transmission, 0x00 is returned in the status byte.
Control byte	The control byte contains information relating to 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	The device address set in parameter "P-0-4022, Drive address of serial interface" must be entered in the "Device address" block.
Structure of the useful data field	Any values can be entered in the useful data bytes that are interpreted in a different way depending on the 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 the useful data header are entered in the "DatL" and "DatLW" bytes.

Status messages

Status byte	Description	Type of error
0x00	Error-free transmission	Without error
0x01	An error occurred during execution of the requested service. 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	Data in the useful data header, the transmitter address or the service has changed in the sequential telegram.	Telegram error
0xF9	The command telegram contains sub-addresses. The routing of telegrams is not supported by the slave.	Telegram error
0xFA	Useful data is 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. 11-43:   List of defined telegram statuses

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 operation mode (as of FWA-MPx02VRS)

Error code	Service	Description
0x9102	0x02	Firmware was deleted
0x9104	0x02	Reboot not allowed in phase 4 (in FWA-MTx01VRS instead of 0x9110)
0x9110	0x02	Reboot not allowed in operation 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	File creation is not allowed
0xA503	0x02	Insufficient memory space
0xA601	0x02	Error when writing
0xA602	0x02	Access to file not allowed

Fig.11-44:   List of defined error codes

11.5.3   Communication via SIS Protocol

Addressing a Drive

When communicating with SIS protocols, a distinction is made 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.

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 held at "0" in the control byte of the reaction telegram until the last reaction telegram is transmitted. In the last reaction telegram, bit 2 is set to "1".

The transmission of a sequential reaction telegram is activated by the repeated transmission of the unchanged command telegram.

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Sequential telegram access   When the writing or reading of a parameter with sequential telegrams has been started in the drive, this process must be completed or cancelled before another service with sequential telegrams can be started. If another service has nevertheless been started, the "0x800C unauthorized access" error code is transmitted in the reaction telegram. The service with sequential telegram that was previously started can then be normally processed or cancelled with the next command telegram.

Supported Services and Subservices

SIS service	Description	Subservices	Subservice description	Notes
0x00	Node identification	0x01	Reads SIS version	Subservice is implemented but not active
		0x02	Reads firmware version	Supplies content of S-0-0030
		0x03	Reads controller type	Supplies content of S-0-0140
		0x04	Reads supported baud rates	9600 baud, 19200 baud, 38400 baud, 57600 baud, 115200 baud
0x01	Cancels data transmission	None		
0x02	Flash operations	0x90	Shutdown	Switches drive firmware to loading mode
		0x91	Reboot	Triggers 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 SIS communication	0x01	Determines TrS	Initializes max. reaction time in the slave
		0x02	Determines TzA	Initializes max. character interval on the bus
		0x03	Determines Tmas	Subservice is implemented but not active
		0x07	Determines baud rate	Initializes the baud rate of the serial transmission
		0x08	Time-controlled baud rate test	Allows temporary change of the baud rate
		0xFF	Accepts the determined values	Activates the values initialized with the subservices 0x01, 0x02 and 0x07
0x10	Reads parameter	None		0x10 = 0x80
0x11	Reads list segment	None		Segment information in byte

SIS service	Description	Subservices	Subservice description	Notes
0x1E	Writes list segment	None		Segment information in byte
0x1F	Writes parameter	None		0x1F = 0x8F
0x80	Reads parameter	None		0x80 = 0x10
0x81	Reads list segment	None		Segment information in word
0x8E	Writes list segment	None		Segment information in word
0x8F	Writes parameter	None		0x8F = 0x1F

Fig.11-45:   Supported services and subservices

Service 0x01: Canceling a Data Transmission

This service is used to cancel a sequential telegram sequence. The sequential telegram channel is unlocked with the "Canceling a data transmission" service when the device address and the service to be cancelled correspond to the sequential telegram sequence. This service is always executed when the command telegram is transmitted without the device address and without the service to be cancelled.

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 is no error, the reaction telegram has the following structure:

Telegram header	Useful data header

Fig.11-46:   Structure of the reaction telegram

In the event of an error, the useful data that contains the error code is transmitted. The useful data header corresponds to the SIS specification.

Telegram header	Useful data header	Useful data

Fig.11-47:   Structure of the reaction telegram in the event of an error

☞   If no sequential telegrams have been processed and this service was nevertheless transmitted, no error reaction telegram is transmitted!

Service 0x80: Reading a Parameter

Command telegram   A one-time read access is completed with a transmission step. The master enters the following information into the command telegram:

- The required element is selected in bits 3 ... 5 ("element") in the control byte. Bit 2 is set to "1" (last transmission).
- The device address is entered.
- Parameter type and number are entered.
- No useful data is transmitted.

Reaction telegram   The answer to a read access contains the following data:

- Bit 4 is set to "1" in the Ctrl byte of the telegram header to identify it as a reaction telegram.
- The status byte of the useful data header contains the information on whether an error has occurred during processing of the command telegram.

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- 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 parameter "S-0-0044, Velocity data scaling type" from the drive with the address "03". The parameter has the value "0x0042".

Command telegram:

telegram header	3C	03	00	2C	00
	control byte	device address	param. type	parameter no. (LSB) (MSB)	

useful data header

DF000329v01_en.fh
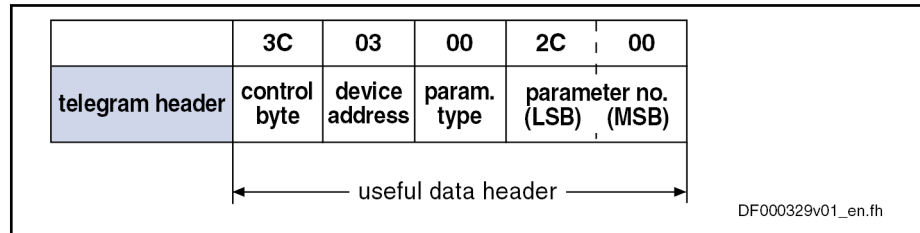
Fig.11-48:   Reading parameter S-0-0044 (command telegram)

Reaction telegram:

telegram header	00	3C	03	42	00
	status byte	control byte	device address	useful data (LSB) (MSB)	

useful data header

DF000330v01_en.fh
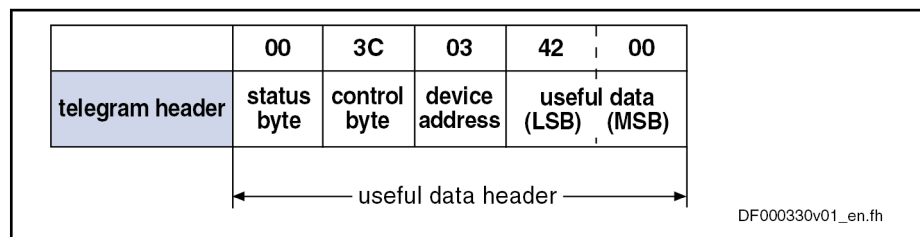
Fig.11-49:   Reading parameter S-0-0044 (reaction telegram)

Service 0x8F: Writing a Parameter

☞   This service is used to start all available commands in the drive.

Command telegram   A one-time write access is completed with a transmission step. The master enters the following information into the command telegram:

- Enter "0x8F" in the service of the telegram header.
- Enter the parameter to be written in the "Parameter type" and "Parameter number" bytes of the useful data header.
- Enter the value to be written in the useful data.
- The device address is entered.
- The operating data is selected in bits 3 ... 5 ("element") in the control byte. Bit 2 is set to "1" (last transmission).
- The identification number of the parameter to be written is written into the parameter number.
- The value of the operating data is written to the useful data.

Reaction telegram   The response to a write access contains the following data:

- Bit 4 is set to "1" in the Ctrl byte of the telegram header to identify it as a reaction telegram.
- The status byte of the useful data header contains the information on whether an error has occurred during 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.
- No useful data is transmitted.

Example   The following example illustrates the transmission of the parameter "S-0-0044, Velocity data scaling type" to the drive with the address "03". The value "0x0042" is written to the parameter.

Command telegram:

telegram header	3C	03	00	2C	00	42	00
	control byte	device address	param. type	parameter no. (LSB) (MSB)		useful data	

useful data header

DF000331v01_en.fh
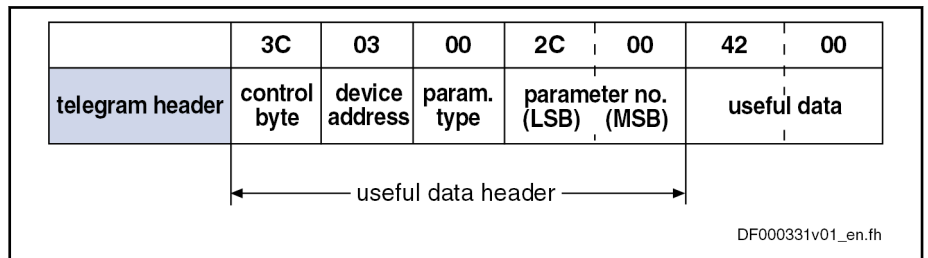
Fig.11-50:   Writing parameter S-0-0044 (command telegram)

Reaction telegram:

telegram header	00	3C	03
	status byte	control byte	device address

useful data header

DF000332v01_en.fh
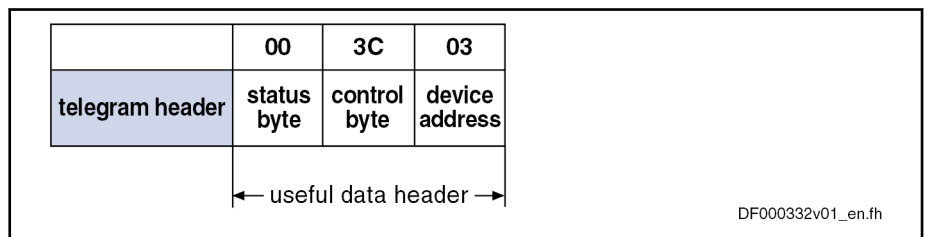
Fig.11-51:   Writing parameter S-0-0044 (reaction telegram)

Starting a Command   Service 0x8F "Writing a parameter" is used to start all commands in the drive via the SIS protocol.

Telegram header	Useful data header	2 bytes of useful data

Fig.11-52:   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 number of the parameter to be read in the useful data header.
- Enter the offset 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
- The current/last transmission is marked with bit 2 in the control byte of the reaction telegram.

☞   The output of a sequential telegram is activated by the repeated transmission of the unchanged command telegram.

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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 number of the parameter to be read in the useful data header.
- Enter the offset 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
- Any error that occurs 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 sequential telegram mode is not possible.

11.5.4   Applicational Examples (Sequential Telegrams)

Service 0x8F: Write Access (With Sequential Telegrams)

Parameters or elements longer than 243 bytes 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.

1. Step
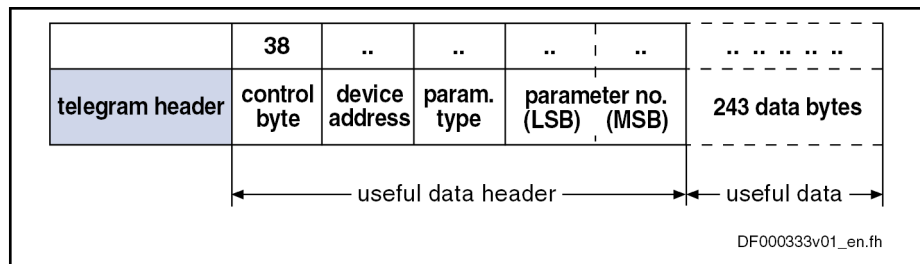
Fig.11-53:   Writing with sequential command telegram (step 1)
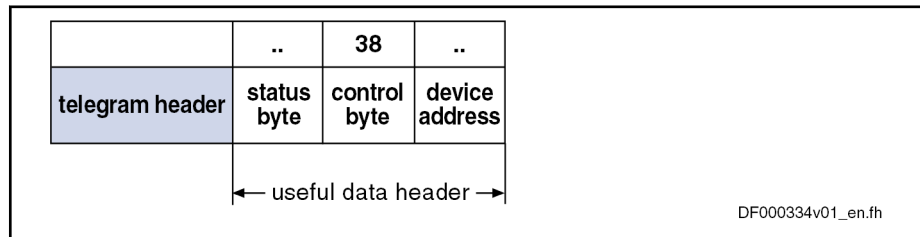
Fig.11-54:   Writing with sequential reaction telegram (step 1)

2. Step
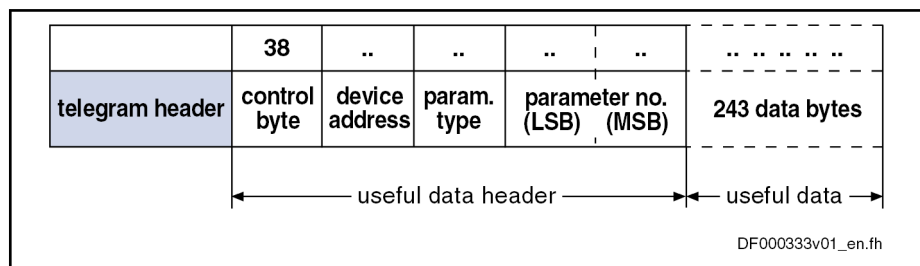
Fig.11-55:   Writing with sequential command telegram (step 2)
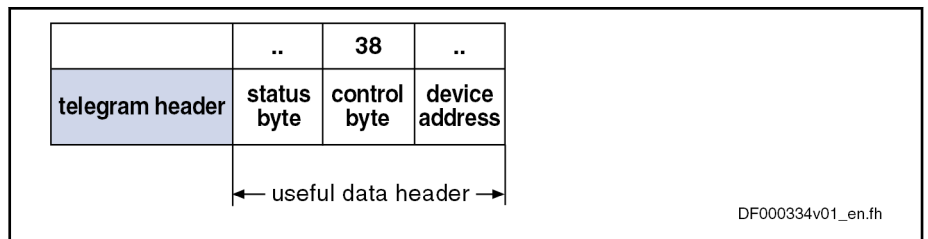
Fig.11-56:   Writing with sequential reaction telegram (step 2)

3. Step
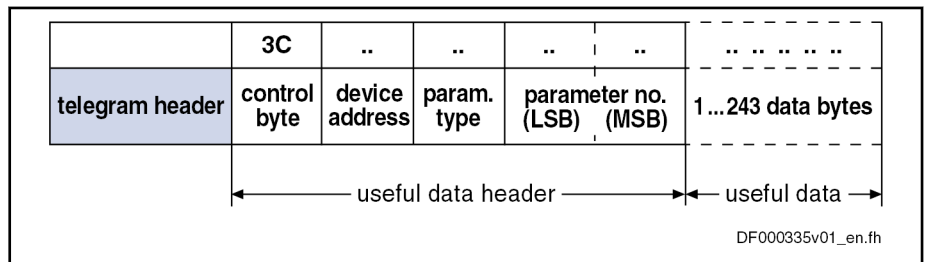
Fig.11-57:   Writing with sequential command telegram (step 3)
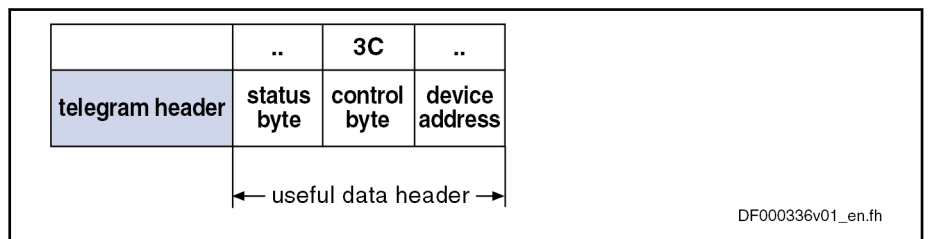
Fig.11-58:   Writing with sequential reaction telegram (step 3)

Service 0x80: Read Access (With Sequential Telegrams)

Parameters or elements whose length exceeds the maximum data field length of 245 bytes 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.

1. Step
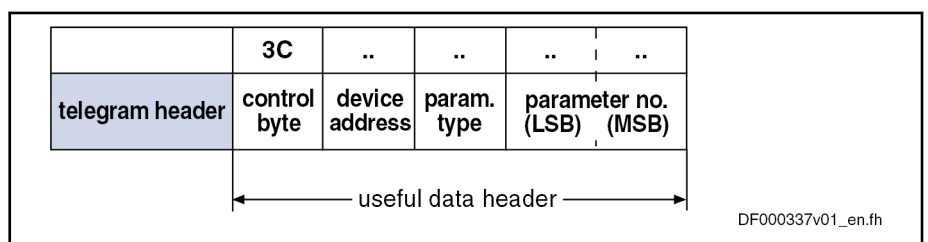
Fig.11-59:   Reading with sequential command telegram (step 1)
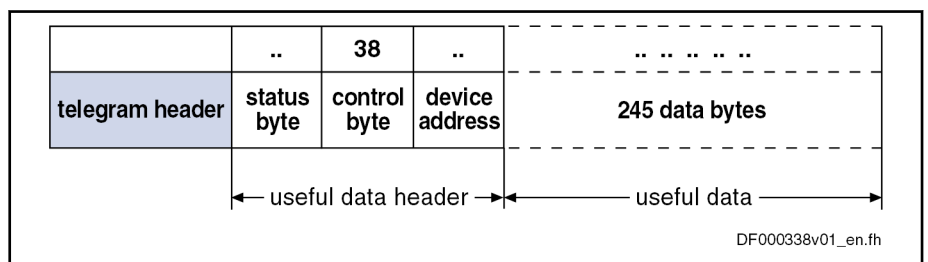
Fig.11-60:   Reading with sequential reaction telegram (step 1)

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2. Step
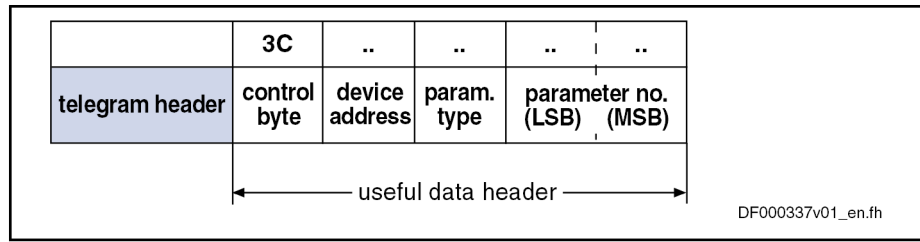
Fig.11-61:   Reading with sequential command telegram (step 2)
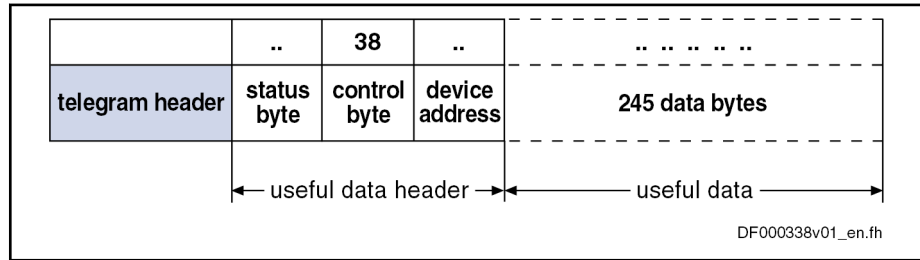
Fig.11-62:   Reading with sequential reaction telegram (step 2)

3. Step
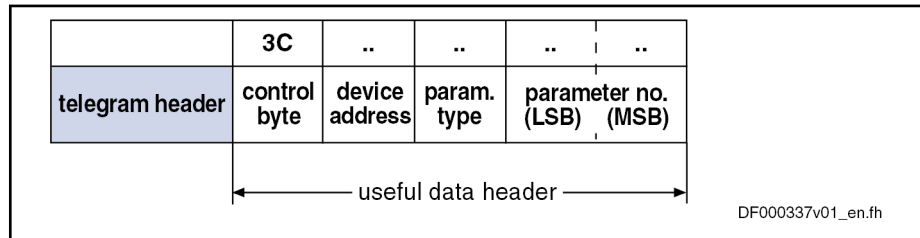
Fig.11-63:   Reading with sequential command telegram (step 3)
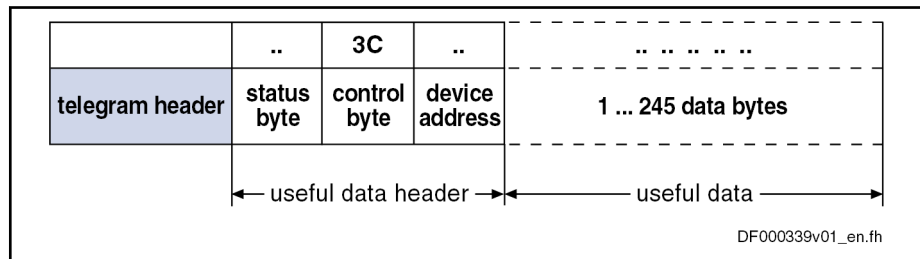
Fig.11-64:   Reading with sequential reaction telegram (step 3)

11.5.5   Error with SIS Communication

Error During Parameter Transmission

If an error occurs during transmission of parameters, 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.

The following errors can occur during parameter transmission:

Error code	Explanation
0x0000	No error
0x0001	Service channel not open
0x0009	Invalid access to element 0

Error code	Explanation
0x8001	"Service channel currently occupied (BUSY)" → The desired access is currently impossible because the service channel is occupied.
0x8002	"Fault 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.11-65:   Error messages in the serial protocol

Execution and Protocol Acknowledgement

A status byte is transmitted with each reaction telegram. 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.11-66:   Definition of the status byte

Protocol error	Code number	Description of error
Invalid service	0xF0	The requested service is not specified or is not supported by the addressed node.

Fig.11-67:   Definition of the protocol error

Execution error	Code number	Description of error
Error during parameter transmission	0x01	An error occurred when reading or writing a parameter.

Fig.11-68:   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 error message "0x7004" ("Data cannot be changed").

Command telegram:

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telegram header	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
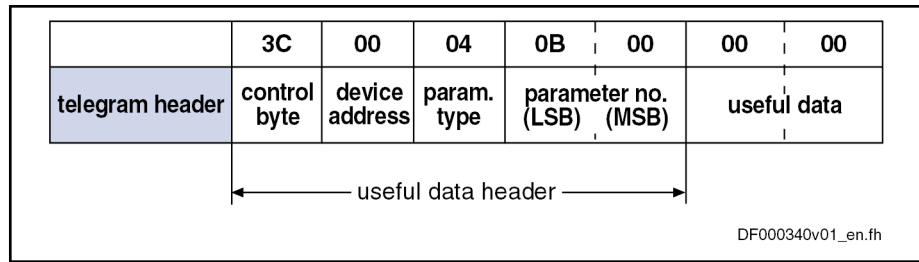
Fig.11-69:   Writing parameter S-0-0106 (command telegram)

Reaction telegram:

telegram header	01	3C	00	04	70
telegram header	status byte	control byte	device address	useful data	

⟵— useful data header —⟶

DF000341v01_en.fh
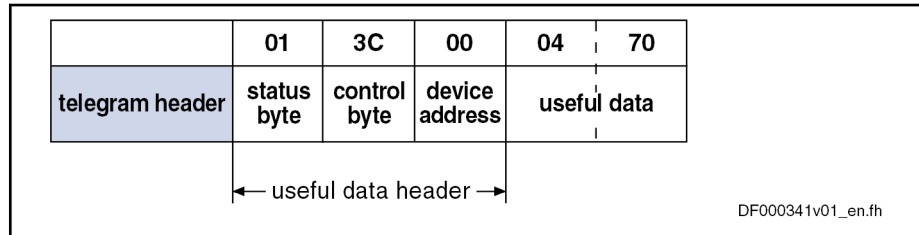
Fig.11-70:   Reading parameter S-0-0106 (reaction telegram)

11.6   File Handling by FTP via Ethernet

11.6.1   Brief Description

> 💡 **Base package** of all firmware versions in **open-loop and closed-loop** characteristic

IndraDrive devices with Ethernet communication can access the data of the MMC programming module by means of FTP connection via an integrated FTP server. This enables data/directories to be read or written on the MMC.

DF000683v01_en.fh
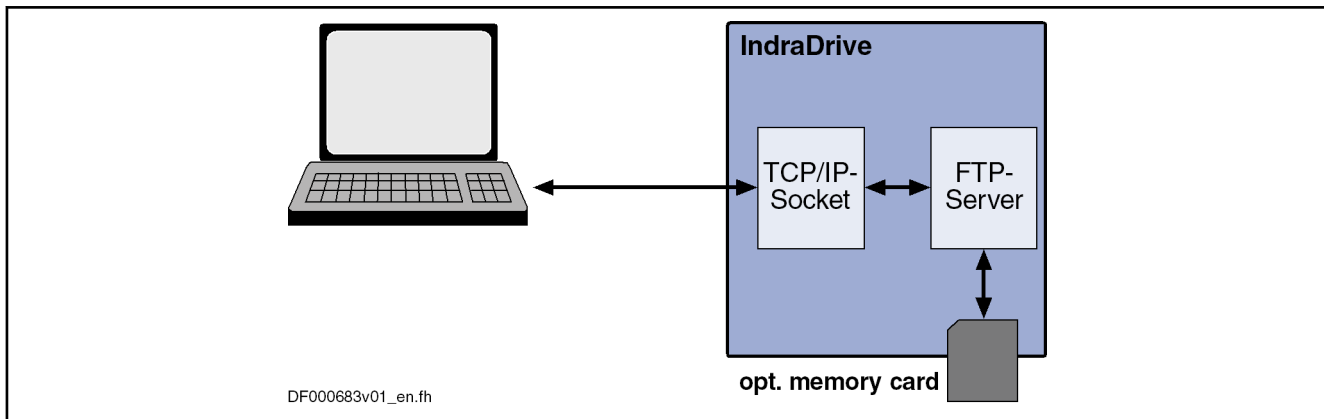
Fig.11-71:   Schematic illustration of FTP file handling

Features   The FTP server of an IndraDrive device has the following features:

- Two kinds of login to the FTP server:
  - Anonymous login (read-only data access)
  - User login (read and write access to data)
- A maximum of 2 simultaneous connections
- Effective transmission rate depends on the communication port used and processor load

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The transmission rate at the Engineering Port of CSH01.2, for example, is approx. 20 kbyte/s for download (STOR command) and 50 kbyte/s for upload (RETR command). If both FTP connections are active at the same time, the transmission rate is distributed accordingly.

Hardware requirements   The following hardware requirements must be met:

- Use of a control section with Ethernet communication (e.g. CSH01.2C or CSH01.1C-S3)
- Plug in MMC before booting

Pertinent parameters
- S-0-1020, Master comm. engineering over IP: IP address
- P-0-4070, Parameter storage configuration

Additionally when using a CSH01.2 control section:
- P-0-1531, Engineering: IP address
- P-0-1641, CCD: IP address

11.6.2   Functional Description

Connections

A maximum of 2 connections to the FTP server can be simultaneously established.

Establishing the connection   After the drive has been booted, the FTP connection is not yet active. To establish the connection, log in to the FTP server using the correct IP address.

Terminating the connection   When there is no more data traffic, the drive automatically terminates the FTP connection after 5 min. If the connection is to be maintained, the FTP command "NOOP" can be cyclically sent.

FTP Login

It is necessary to login to the FTP server each time the connection is established. IndraDrive supports two kinds of login: standard login and anonymous login.

Standard login   With standard login to the FTP server, log in under the user name "boschrexroth" with the password "boschrexroth" (login based on Bosch Rexroth standard).

Upon successful standard login, it is possible to access all files and directories on the MMC and carry out read access or write access.

☞   Only write access to the directory "/user/" and its subdirectories "/PLC/" and "documentation" is supported. Access to the system directories "Firmware" and "Parameters" is not allowed!

After each login, the FTP server opens the "USER" directory of the MMC. User data may only be stored in this area.

☞   If the MMC is operated as a programming module (P-0-4070), there is only read-only access to the drive parameter files in the "Parameters" folder.

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```
A: .
+ - - - Documentation
|
+ - - - Firmware
|          FWA-INDRV_-MPH-05V02-D5.ibf
|
+ - - - Parameters
|          Application_Type#1.pbf
|          Application_Type#2.pbf
|          Retain#1.rbf
|          Retain#2.rbf
|
+ - - - Plc
|          SPS_Retain.pbf
|
\ - - - User
```
DC000053v01_en.fh

Fig.11-72:   Directory structure of the MMC via FTP access (example)

Anonymous login

Anonymous login to the FTP server is also possible. For this purpose, use the user name "anonymous" and any e-mail address as a password (IndraDrive-specific login). With this kind of login, there is only read-only access to all data and directories of the MMC.

After each login, the FTP server opens the "USER" directory of the MMC. This is the area in which the user data has been stored.

FTP Data Handling

File date

Files created on MMC via FTP are created there as new files. The time from parameter "P-0-0197, System time" is used as the file date; the minimum date used as the start value is "1980-01-01".

File names

Observe the following rules and restrictions when selecting file names and directory names:

- File names may only contain the following characters:
  - !#$%&'()+-0123456789=?
  - ABCDEFGHIJKLMNOPQRSTUVWXYZ[]^_
  - abcdefghijklmnopqrstuvwxyz{}~
- Lower case letters "a" to "z" are converted into uppercase letters "A" to "Z".
- Files may not start with ".".
- The lengths of file names (incl. file path) may not exceed 80 characters.

FTP commands

The FTP server accepts the commands contained in the following table. If commands are entered via a user interface (e.g. FTP client), some different commands are used (e.g. "dir" instead of "LIST"). The FTP client converts the commands, which the user entered, to the syntax below.

Command syntax	Description
USER xxxx	Log in with user name xxxx
PASS xxxx	Enter password xxxx
TYPE x	Enter transmission type: x = "A" for ASCII; x = "I" for IMAGE (binary)
STOR xxxx	Store a file with name xxxx on MMC

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Command syntax	Description
RNFR xxxx RNTO yyyy	Rename file xxxx, new name yyyy
CWD xxxx	Change working directory to xxxx
SYST	Request system information from FTP server
CDUP	Change working directory, go one level "up"
QUIT	Terminate the connection
STRU F	Set data structure type to "File"
APPE xxxx	Append data to file xxxx or create file xxxx
LIST	Request directory structure from server
STAT	Request status message of current settings of TYPE, STRU and MODE
RMD xxxx	Delete directory xxxx
XRMD xxxx	Delete directory xxxx
ACCT xxxx	Change user ID to xxxx
PORT xxxx	Transmit port number of host for data transfer
MODE S	Set transfer mode to "Stream"
ABOR	Abort current transmission
NLST	Transmit a file list to the client
HELP	Transmit a list of supported FTP commands to the client
PWD	Show current working directory
XPWD	Show current working directory
MKD xxxx	Create directory xxxx
XMKD xxxx	Create directory xxxx
PASV	Open FTP server as "passive" connection
RETR xxxx	Transmit file xxxx to client
DELE xxxx	Delete file xxxx on server
NOOP	"No Operation"→ Can be transmitted periodically to maintain connection

Fig.11-73:   Function commands for FTP data handling

12   Commissioning

12.1   Safety Instructions

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

- Keep free and clear of the ranges of motion of machines and moving machine parts.

- Prevent personnel from accidentally entering the machine's range of motion (e.g., by safety fence, safety guard, protective covering, light barrier).

- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.

- In addition, observe the safety message "Protection Against Dangerous Movements" in the chapter "Safety Instructions for Electric Drives and Controls".

12.2   Commissioning the Motor

12.2.1   Checking the Installation/Assembly

Checking the Assembly

ℹ 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

ℹ Check the wiring of control cabinet and machine with regard to correct implementation, according to the data contained in the Project Planning Manual and the recommendations in the documentation "Electromagnetic Compatibility (EMC) in Drive and Control Systems".

12.2.2   Initial Commissioning/Serial Commissioning

Brief Description

The drive can be commissioned once it has been correctly assembled and installed.

Initial commissioning   The initial commissioning of a drive differs from the commissioning of other identical drives (serial commissioning).

Initial commissioning is carried out using the following steps:

- Establishing the operability of the drive (including the requisite 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 aforementioned steps, values of relevant parameters are adjusted to requirements on site. The result of initial commissioning is a drive,

Commissioning

the behavior of which is precisely adjusted to the axis. The drive behavior can be reproduced by storing the initial commissioning values in the form of a parameter set.

Serial commissioning

The set of parameter values defined during initial commissioning is loaded into the respective controller when commissioning other identical axis drives on machines of the same type (serial commissioning). This allows

- the drive behavior to be reproduced precisely

- and -

- effort for further commissioning to be reduced to minimal adjustment work and, possibly, the search for and elimination of assembly/installation errors.

Commissioning options

In principle, commissioning can be carried out using

- The "IndraWorks Ds/D/MLD" commissioning tool by Bosch Rexroth, connected to the drive via a sercos interface, via a serial interface, via Ethernet or a field bus.

- The control panel of the controller and digital and analog input signals,

- A control unit connected to the drive via a master communication interface.

Two-step commissioning

It is recommended in principle to always perform both initial commissioning and serial commissioning in two stages:

- 1st objective: Initial start of the motor

- 2nd objective: Providing drive functions for the machine axis
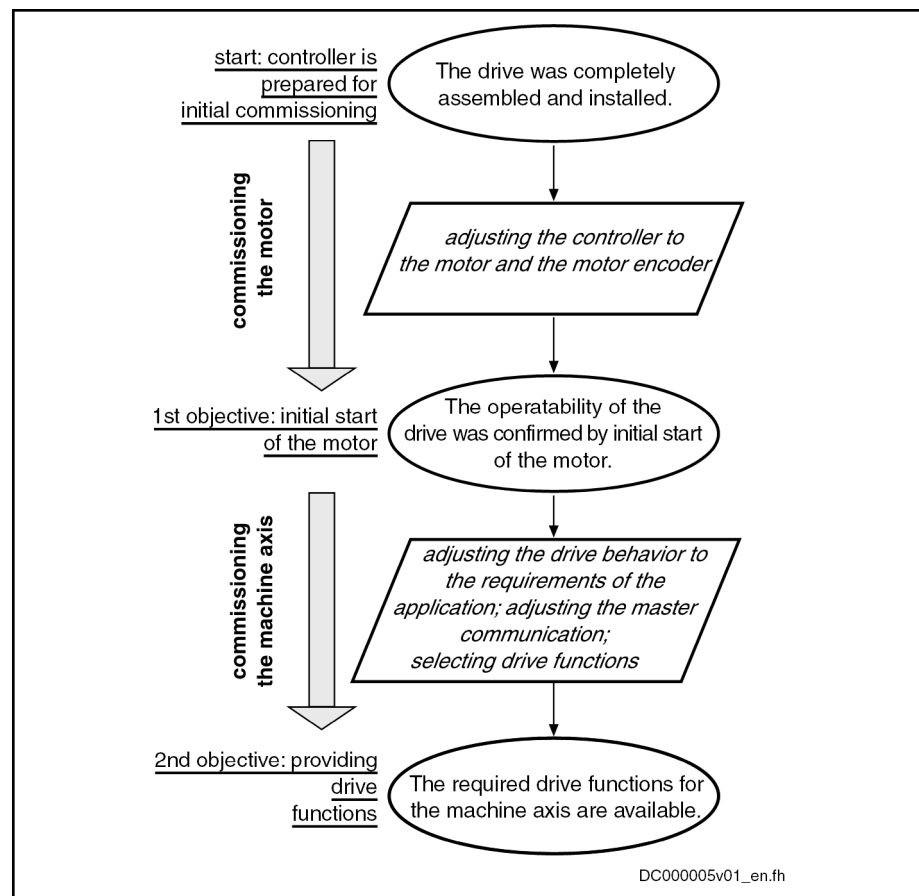
Fig.12-1:   *Two-step drive commissioning (diagram)*

Commissioning

In the first stage, the two-step procedure ensures the operability of the drive (1st objective with initial commissioning and serial commissioning). In the second stage, the drive functions required for the machine axis and the drive's useful properties are individually adjusted to the machine axis in a sensible order (2nd objective during initial commissioning) and the expected functional principle is checked (2nd objective during serial commissioning).

☞　　In principle, it is beneficial to establish the operability of a drive independently of a higher-level control system. The drive is therefore to be commissioned first as a self-contained unit using "IndraWorks Ds/D/MLD" or in "Easy startup" mode!

Refer to the following sections:

- "Initial Start in "Easy Startup" Mode"

- "Initial Start with the Commissioning Tool"

Notes on Commissioning

Initial start of the motor　See "Initial Start in "Easy Startup" Mode"

See "Initial Start with the Commissioning Tool"

Providing drive functions　See "Commissioning Machine Axes"

Initial commissioning　The defined application-specific parameter values must be saved after initial commissioning has been carried out. The saved parameter values enable the drive behavior required at the respective machine axis to be reproduced.

☞　　The drive provides parameter lists to support the complete storage of the relevant parameter values when saving parameter values.

By reloading the saved parameter values, the initial status after initial commissioning can be re-established for the axis drive!

See also "Parameters, Basics: Loading, Storing and Saving Parameters"

Re-establishing the initial state　**Attention:** For drives with absolute encoders, it is necessary to reestablish the initial state after initial commissioning!

NOTICE	**Material damage is possible with drives with absolute encoders caused by incorrect actual position value after reloading parameter values saved according to S-0-0192!**

⇒ Save parameter values using correspondingly modified IDN list of parameter S-0-0270 (see below)

With drives with absolute value encoder and modulo scaling it is recommended that the parameter set for saving the parameter values after initial commissioning is defined by means of a list of "S-0-0270, IDN-list of selected backup operation data", modified by the customer, so that there can be no actual position value errors when the saved parameter values are reloaded into the same axis drive.

☞　　This is only possible via a control master. MMC and "IndraWorks Ds/D/MLD" only work with the content of the list parameter S-0-0192!

Commissioning

In its initial state, the content of the list parameter S-0-0270 first corresponds to list parameter S-0-019 and is to be modified as follows:

- Remove the identification numbers P-0-0177 and P-0-0178

These parameters contain information on the current position data of the absolute encoders at the time of parameter backup. If the current data of P-0-0177 and P-0-0178 during the loading of the saved parameter values was overwritten with data relating to a different axis position current at the time of parameter backup, the actual position values would then correspond to the other axis position! The actual position values remain valid (S-0-0403, Position feedback value status), as the same absolute value encoder as before applies.

☞ The incorrect actual position value generated in this case cannot be detected on the drive side, as otherwise unjustified errors would be generated in service cases when devices are replaced!

See also "Notes on How to Replace the Devices"

☞ The list of S-0-0270, modified as described, can also be used for saving and loading the parameter values of axes with relative measuring systems, as parameters P-0-0177 and P-0-0178 do not contain relevant information in this case!

☞ The content, possibly modified, of list parameter S-0-0270 is also contained in parameter S-0-0192! This means that when the backup is made with parameter S-0-0192, the content of parameter S-0-0270 can be read from the saved list, so that only these individually selected parameter values are loaded!

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 into the controllers of the respective axis drives of other machines of the same type. This permits the behavior of the drives of a "model machine" to be easily reproduced!

After the application-specific parameter set of an axis drive has been loaded, very few 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"

12.3   Initial Start in "Easy Startup" Mode

12.3.1   Brief Description

So-called ""Easy startup" mode" enables the drive to be moved without a control unit (or master communication master) or external command value box being connected or active. 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.

☞   "Easy startup" mode is therefore particularly suitable for the **initial commissioning** of individual axes, as well as for maintaining **emergency mode** in the event of failure of the control unit.

Features
- **Activation** of "Easy startup" mode is possible in two ways:
  – By activating the command parameter "P-0-4085, C4700 Command Activate easy startup mode" via a serial interface or digital input
  – By the controller's control panel (pressing the corresponding keys in a certain order triggers activation of P-0-4085)
- Automatic **deactivation** of the master communication interface (see P-0-4077, S-0-0134) and activation of "P-0-0120, Control word easy startup"
- Activation of **Drive enable** (P-0-0120, bit 15) via:
  – The digital input assigned to the drive enable (differs according to hardware designs, see default assignment under "Automatic Configuration of the Inputs")
  – Serial interface when the previous configuration of digital inputs for "Easy startup" mode entered has been removed
- Drive moves in "Velocity control" mode with a parameterizable velocity command value (cf. P-0-1206) without external command value box
- Selection of the **direction of travel** (positive/negative) via digital input signals (see parameter "P-0-1200, Control word 1 velocity control")

Commissioning
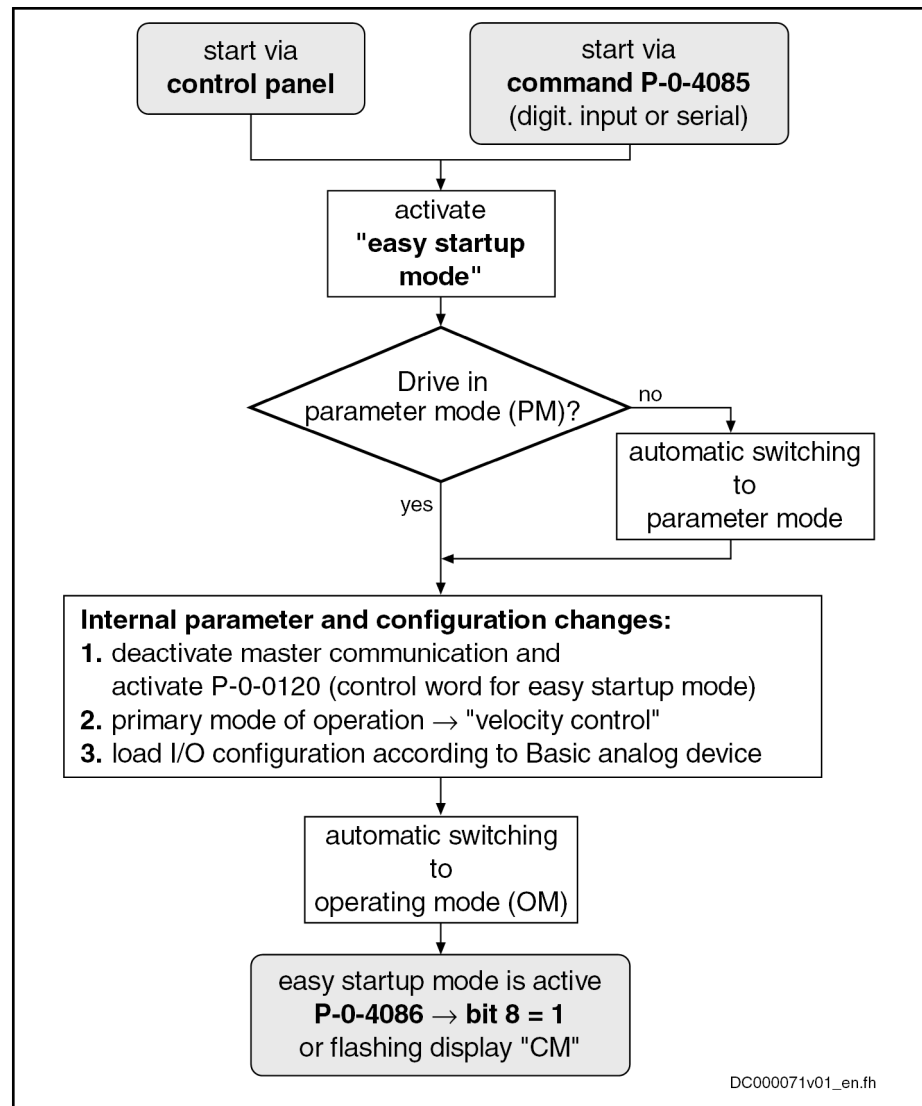
Fig. 12-2:   Activating "Easy startup" mode, overview

Hardware requirements

Control sections BASIC sercos, BASIC PROFIBUS, BASIC UNIVERSAL and ADVANCED

Digital inputs and outputs (X31, X32) must be connected as follows when using "Easy startup" mode:

- Connect 24 V/0 V power supply to respective terminal connectors
- X31/4: +24 V for activating drive enable
- X32/7 and X32/8: 0 V/+24 V for activating positive or negative direction of rotation

  or → X31/3 and X31/7 for control of motor potentiometer

Control sections BASIC UNIVERSAL double-axis

Digital inputs and outputs (X33, X34) must be connected as follows when using "Easy startup" mode:

- Axis 1:
  - Connect 24 V/0 V power supply to respective terminal connectors
  - X33/1: +24 V for activating drive enable

Commissioning

– X33/2 and X33/3: 0 V/+24 V for activating positive or negative direction of rotation

or → X33/4 and X33/5 for control of motor potentiometer

- Axis 2:
  – Connect 24 V/0 V power supply to respective terminal connectors
  – X34/1: +24 V for activating drive enable
  – X34/2 and X34/3: 0 V/+24 V for activating positive or negative direction of rotation

    or → X34/4 and X34/5 for control of motor potentiometer

Control sections BASIC OPENLOOP and BASIC ANALOG

"Easy startup" mode actually is not required for drives with these control sections, because these drives can easily be moved with an analog command value (see "Analog Interface").

IndraDrive Mi

Digital inputs and outputs (X37, X38) must be connected as follows when using "Easy startup" mode:

- Connect 24 V/0 V power supply to respective terminal connectors
- X37/2: +24 V for activating drive enable
- X37/4 and X38/4: 0 V/+24 V for activating positive or negative direction of rotation

Pertinent parameters
- S-0-0032, Primary operation mode
- S-0-0091, Bipolar velocity limit value
- P-0-0120, Control word easy startup
- P-0-0300, Digital 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-0-4085, C4700 Command Activate easy startup mode
- P-0-4086, Master communication status

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

- When "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 "Easy startup " mode via the control panel").

12.3.2   Functional Description

Requirements   The following requirements and conditions must be met when using "Easy startup" mode:

- The drive is fully and correctly wired.
- No master communication is to be active.

  Attention: "Easy startup" mode switches off any master communication that may be active!

Commissioning

- The controller must be supplied with control voltage and it must be possible to switch power on.
- There may not be any error messages.

There is no commissioning PC required with Rexroth motors with encoder data memory; otherwise the motor parameters have to be set during commissioning, if necessary using a PC.

General information on how to activate "Easy startup" mode

"Easy startup" mode can be activated both in Parameter mode (phase 2) and in Operating mode (phase 4), by activating "P-0-4085, C4700 Command Activate easy startup mode".

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

"Easy startup" mode can be activated via:

- The controller's control panel
- A digital input
- The serial interface

☞   By activating "P-0-4085, C4700 Command Activate easy startup mode", the drive automatically switches to Parameter mode and configures "Velocity control" mode with values from the fixed command value memory (P-0-1206).

Activation via the control panel

The figure below illustrates how "Easy startup" mode is activated via the control panel of the IndraDrive controllers:

Fig.12-3:   Activating "Easy startup" mode via the control panel

See also "Control Panels of IndraDrive Controllers"

Activation via digital input   If "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 the serial interface   If "Easy startup" mode is activated via the serial interface, parameter P-0-4085 has to be written via SIS telegrams.

See "Serial Communication"

> "P-0-4085, C4700 Command Activate easy startup mode" can also be written directly via the master communication (e.g. sercos or field bus), but the master would then deactivate itself!

Acknowledging active "Easy startup" mode   The active "Easy startup" mode is acknowledged by:

Commissioning

- Setting bit 8 in "P-0-4086, Master communication status"

- Changing the display on the control panel between "CM" (Commissioning mode) and the drive address

Automatically configuring inputs
The following actions are performed when automatically configuring the inputs:

- Deactivating the master communication interface and activating drive enable in parameter "P-0-0120, Control word easy startup"

- Setting the "Velocity control" operation mode with values from the fixed command value memory (P-0-1206)

- Assigning the command velocity selected via the control panel (in percent) from "S-0-0091, Bipolar velocity limit value" to element 1 or element 2 of "P-0-1206, Memory of velocity command values" (with positive prefix to element 1, with negative prefix to element 2).

- Assigning the allocation of inputs

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

☞ The inputs/outputs for "Easy startup" mode are automatically configured **in volatile form**, that is any existing I/O configuration is re-established when the command is completed. This is not the case, if the I/O configuration was specifically (manually) changed with the command active.

IndraDrive single-axis control sections (CSB, CSH)			
Connection	Signal	Function	I/O assignment
X31.3	I_1	Motor potentiometer, ramp +	P-0-1200, Control word 1 velocity control (bit 8)
X31.4	I_2	Drive enable	P-0-0120, Control word easy startup (bit 15)
X31.7	I_5	Motor potentiometer, ramp –	P-0-1200, Control word 1 velocity control (bit 9)
X32.7	I/O_9	Selection of fixed command value memory	P-0-1200, Control word 1 velocity control (bit 0)
X32.8	I/O_10	Selection of fixed command value memory	P-0-1200, Control word 1 velocity control (bit 1)

Fig. 12-4:   Automatic I/O configuration for "Easy startup" mode with single-axis control sections

IndraDrive double-axis control sections (CDB)				
Connection	Signal	Axis	Function	I/O assignment
X33.4	I_15	1	Motor potentiometer, ramp +	P-0-1200, Control word 1 velocity control (bit 8)
X33.1	I_12	1	Drive enable	P-0-0120, Control word easy startup (bit 15)
X33.5	I_16	1	Motor potentiometer, ramp –	P-0-1200, Control word 1 velocity control (bit 9)
X33.2	I_13	1	Selection of fixed command value memory	P-0-1200, Control word 1 velocity control (bit 0)
X33.3	I_14	1	Selection of fixed command value memory	P-0-1200, Control word 1 velocity control (bit 1)
X34.4	I_21	2	Motor potentiometer, ramp +	P-0-1200, Control word 1 velocity control (bit 8)
X34.1	I_18	2	Drive enable	P-0-0120, Control word easy startup (bit 15)

Commissioning

IndraDrive double-axis control sections (CDB)				
Connection	Signal	Axis	Function	I/O assignment
X34.5	I_22	2	Motor potentiometer, ramp –	P-0-1200, Control word 1 velocity control (bit 9)
X34.2	I_19	2	Selection of fixed command value memory	P-0-1200, Control word 1 velocity control (bit 0)
X34.3	I_20	2	Selection of fixed command value memory	P-0-1200, Control word 1 velocity control (bit 1)

Fig. 12-5:   *Automatic I/O configuration for "Easy startup" mode with double-axis control sections*

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

Fig. 12-6:   *Automatic I/O for "Easy startup" mode with IndraDrive Mi*

☞   IndraDrive Mi (distributed "KSM" servo drive) only has a limited number of digital inputs/outputs (4 no.) and has no analog input and no control panel!

ℹ   See also "Optional Modules for Control Sections" in the separate document "Control Sections for Drive Controllers; Project Planning Manual"

Commissioning

"Loading basic parameters" with impermissible parameter settings

After activating "Easy startup" mode, the drive is normally ready for operation ("bb" or "Ab" → communication phase 4). When the drive stops in communication phase 3 due to impermissible parameter values, valid basic parameter values can be loaded via the control panel.

See also "Control Panels of IndraDrive Controllers"

Controlling the drive

Different control words are effective depending on the master communication or setting of the device control. Internally, however, all relevant control bits are always displayed in "P-0-0116, Device control: control word".
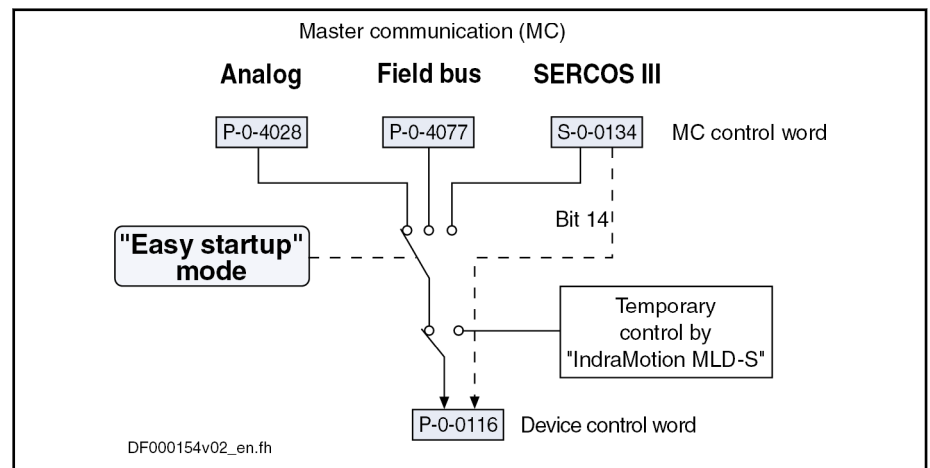
Fig. 12-7:   Controlling the drive in "Easy startup" mode

☞ With temporary control of the PLC, bit 14 (drive enable) is nevertheless taken from "S-0-0134, Master control word" with the sercos interface! Only with stand-alone "Motion Control" does the PLC also control bit 14. Bit 14 is activated internally with field buses.

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

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

- Via digital inputs, if they were previously correspondingly configured
- Via the serial interface by directly writing P-0-0120

  → In this case, the parameter has to be actively written at least every 2 s, otherwise the drive automatically clears drive enable!

Terminating "Easy startup" mode

"Easy startup" mode can only be terminated by switching off the controller!

After "Easy startup" mode has been terminated, the controller is in its initial state once again and all configurations specifically made for this mode have been undone.

After successful command execution, the drive is automatically switched to operating mode again, if it was in phase 4 before the start of the command!

☞ If required, "Easy startup" mode must be activated again.

12.3.3   Notes on Commissioning

Invalid commands

The commands for backing up the working memory ("P-0-0120, Control word easy startup" and "C2400 Selectively backup working memory procedure command") are not to be triggered in "Easy startup" mode, as otherwise the

Commissioning

"Easy startup" mode settings are stored in the non-volatile memory and are reactivated when the drive is switched on the next time!

Initial commissioning

In "Easy startup" mode, initial commissioning of Rexroth motors with encoder data memory is easily done without the need for the commissioning tool, because the required parameter settings for motor control and motor encoder are automatically made via the command "Load default values (motor-specific control values) ".

For the "Load default values 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 "Easy startup" mode in conjunction with an "IndraWorks Ds/D/MLD" commissioning tool in order to load or enter the values for motor control parameters and motor encoder parameters. With synchronous motors with absolute measuring system, the commutation offset only has to be determined at initial commissioning. With synchronous motors with relative measuring system, the commutation offset is automatically determined every time drive enable is set for the first time after transition "PM → OM".

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

See "Initial Start with the Commissioning Tool"

⚠ CAUTION	Danger of material damage during initial start in "Easy startup" mode caused by incorrect parameter values!

⇒ With motors without encoder data memory, the required motor and controller parameters must be checked before initial start in "Easy startup" mode!

Re-commissioning

In "Easy startup" mode, re-commissioning (after initial commissioning has been carried out) of drives is possible with ease, as the correct values of the motor control parameters and motor encoder parameters are already available in the drive.

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

⚠ CAUTION	Danger of material damage caused by errors when controlling motors!

⇒ The digital input signals must be applied with due caution!

The figure below summarizes the commissioning sequence in "Easy startup" mode:

1. Activate "Easy startup" mode
via control panel, digital input, serial interface or Engineering interface

"CM" and address flash in the display

Initial commissioning completed?

Yes / No

Rexroth motor with encoder data memory?

Yes / No

"CM" and "RL" flash in the display

Load motor and motor control parameters with commissioning tool via serial interface or Engineering interface

Load control parameters to adjust controller to the motor by pressing "Esc"

2. Switch on power

Synchronous motor ?

Yes / No

Set commutation offset

2. Switch on power

The display "Ab" appears in the display.

3.Enable drive
0-1-edge (24 V) to the respective enable input

The drive is thereby enabled and is in velocity control.
The display "AF" appears in the display.

4. Move the axis in "Easy startup" mode
Switch the inputs to move the axis in accordance with the I/O configuration for "Easy startup" mode [1]

Note:
The maximum speed corresponds to the value of the parameter S-0-0091;
the effective command value can be reduced using the control panel up to 10% of the maximum speed.

See Fig. "Activating "Easy startup" mode via the control panel"

DC000072v02_en.fh

| [1] | See assignment tables for the different hardware designs under "Automatic Configuration of Inputs" |

Fig. 12-8:   Commissioning sequence with "Easy startup" mode

12.4   Initial Start with the Commissioning Tool

12.4.1   Brief Description

Establishing the operability of the drive

After complete and correct assembly and wiring of the drive or drives it is advisable to establish their operability. With drives of the IndraDrive family, this

Commissioning

can be done very easily by means of initial start in "Easy startup" mode (velocity-controlled operation, master communication master is not required) in conjunction with the Rexroth"IndraWorks Ds/D/MLD" commissioning tool.

Initial commissioning of the motor is supported as follows depending on the available equipment:

- If there is **no** commissioning tool (e.g. PC) available, Rexroth motors with encoder data memory can be easily commissioned in "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 the 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 database of the commissioning tool to the controller via the serial interface. This also allows initial commissioning in "Easy startup" mode for these motors.

Available commissioning tools   Rexroth offers for IndraDrive drives the IndraWorks Ds/D/MLD commissioning tool (software)

IndraWorks Ds/D/MLD   "IndraWorks Ds/D/MLD" is a component of the "IndraWorks" software range which supports parameterization and commissioning of control units and drives by Rexroth. "IndraWorks Ds/D/MLD" has been designed for interaction with the sercos master SYSDA02.2. Direct communication with the drive via serial communication (RS232/RS485).

The "IndraWorks Ds/D/MLD" commissioning tool provides the following options and advantages:

- The functions and features provided by the drive are structurally visualized, the respective parameter values are displayed in their functional context.

- Parameter values can be immediately changed and thereby adjusted to the respective requirements.

- The parameter values available in the drive can be saved as a group (parameter set) drive-externally, e.g. on the PC hard disk, and can be reloaded from the hard disk.

- Diagnostic messages and operating status messages are displayed in a clearly laid out manner.

- Commands can be started for the purpose of commissioning.

- With "Easy Startup" mode, individual IndraDrive drives can be started up and operated by direct serial communication. If this is to happen with several drives, it is possible with the sercos Master SYSDA02.2.

12.4.2   Functional Description

The following steps must be carried out for the initial start of the motor:
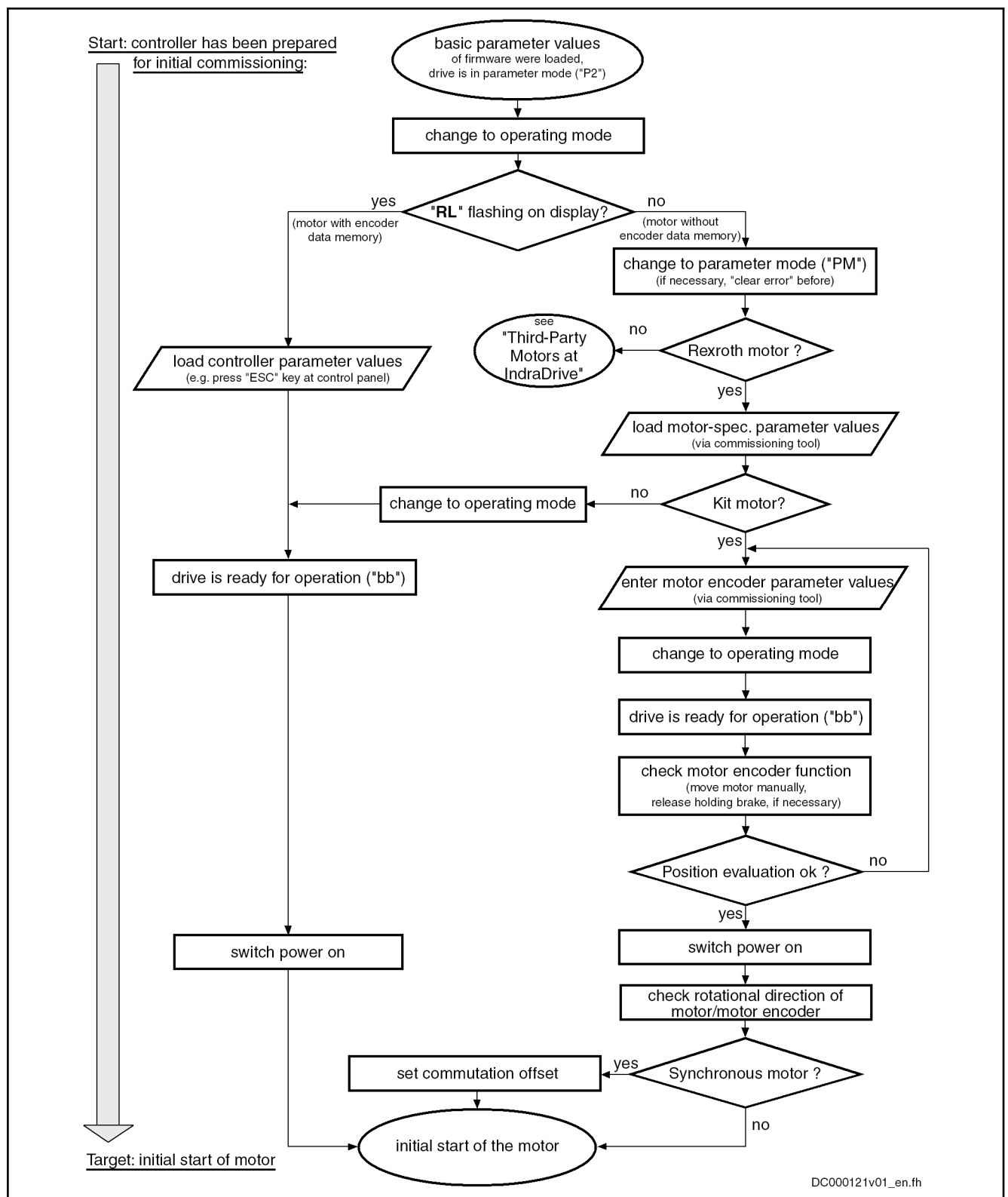
Fig. 12-9:   *Commissioning steps for initial start of a Rexroth motor (motor with encoder)*

12.4.3   Notes on Commissioning When Using "IndraWorks Ds/D/MLD"

The sequence shown in the diagram "Commissioning steps for the initial startup of a Rexroth motor" (see above) can be executed in conjunction with

Commissioning

"IndraWorks Ds/D/MLD" with a Rexroth motor without encoder data memory by serial communication (without sercos Master) .

With "IndraWorks Ds/D/MLD", the values for the motor, motor control and motor encoder parameters, for motors without encoder data memory, can be loaded from the internal data base of the commissioning tool via the serial interface of the controller.
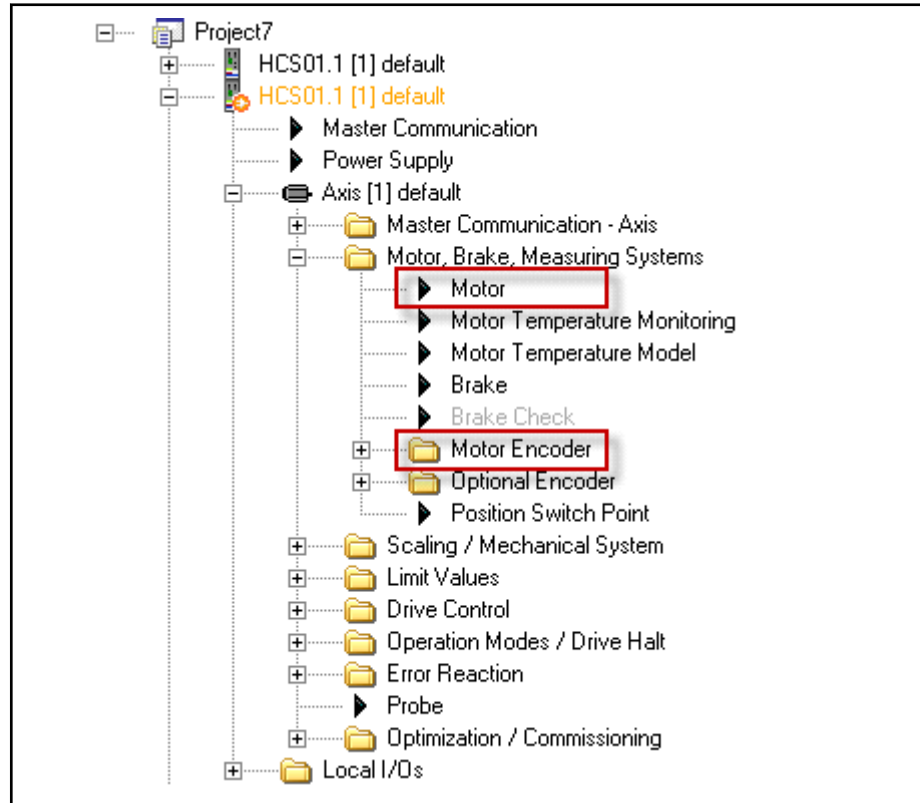
Fig. 12-10:   IWD Explorer with indicators for finding the dialog for inputting or IWD-supported uploading of motor parameters

The motor is selected using a type key configurator, the motor and motor control parameters of which are to be uploaded into the drive:
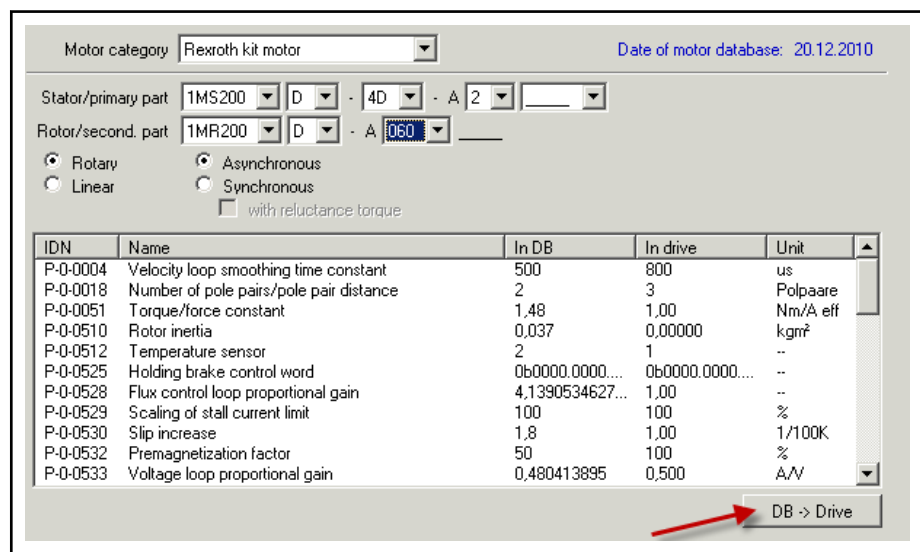
Fig. 12-11:   Selection of the motor, comparison of the values to be uploaded with those already in the drive, interface for starting the loading process

The initial start of the motor can be done in "Easy startup" mode, which can also be operated with IWD using the serial interface. Activation / deactivation is done via an interface (initial startup without active master communication):
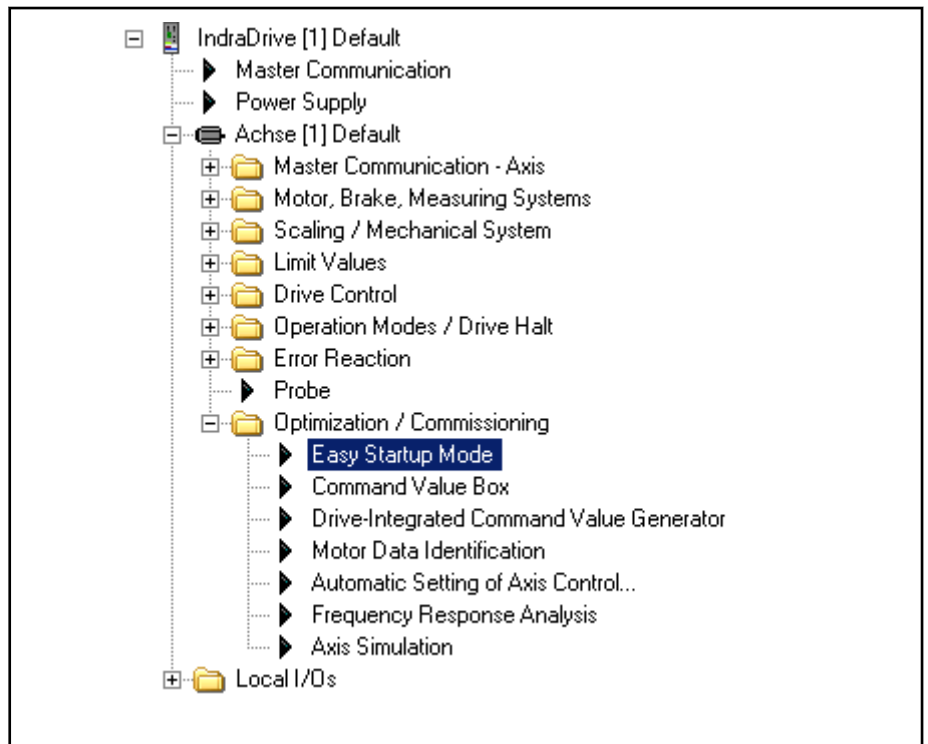
Fig.12-12:   IWD Explorer with indicators for finding the "Easy startup" mode dialog
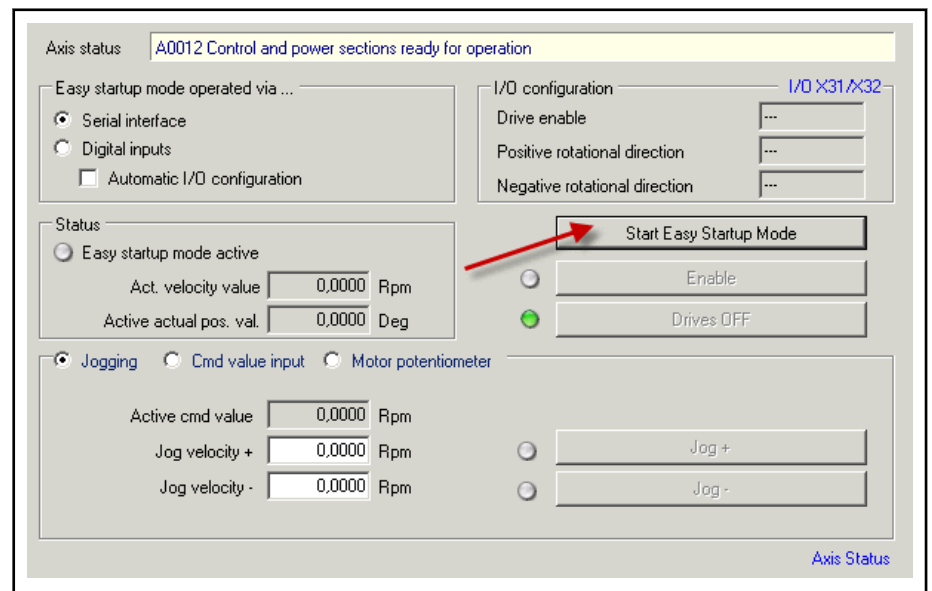
Fig.12-13:   IWD "Easy startup" mode dialog, interface for activation/deactivation

Commissioning
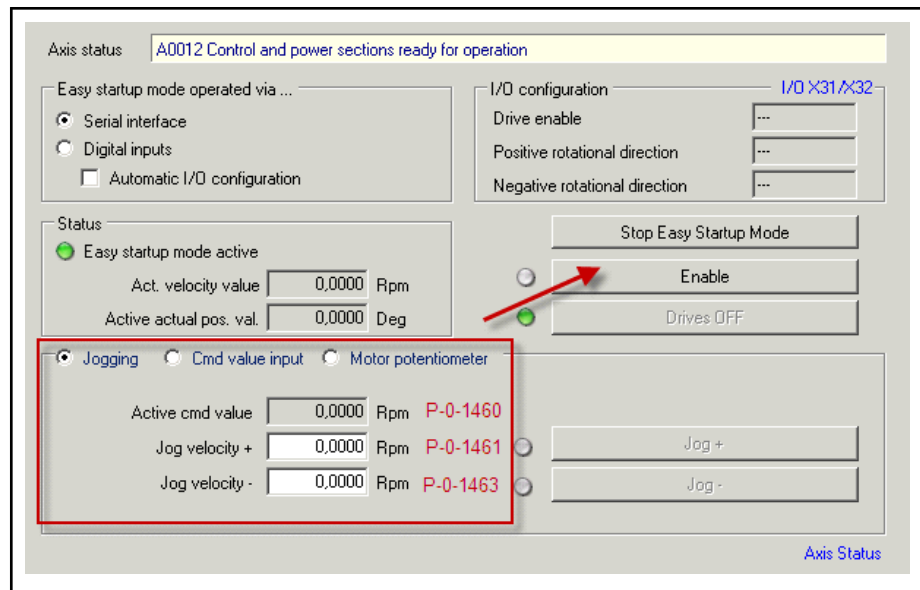
Fig.12-14:

The drive is now automatically in "velocity control". If the drive is in "Ab", it can be enabled ("AF") via an interface or switched off again respectively. Velocity is possible by "typing", stationary "command value input" or the "motor potentiometer".

☞   For synchronous kit motors, the commutation setting has to be carried out first (see "Commutation setting"), the sequence required for this is supported by commands. "Easy startup" mode must be active to supply current to the motor!

See "Initial Start in "Easy Startup" Mode"

12.5   Commissioning Machine Axes

12.5.1   Procedure for Commissioning

The drive supports different commissioning procedures. The type of commissioning depends on the existing machine components (control, drive controllers, motor, mechanical system). Commissioning is made using one of the commissioning tools available.

Commissioning Procedure
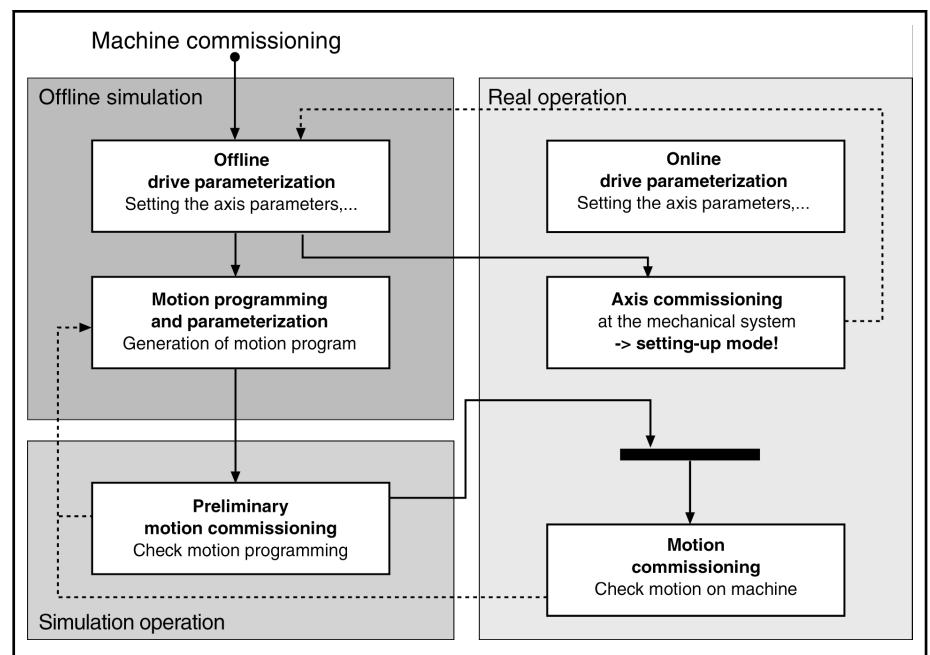
Fig.12-15:   Overview of Procedures for Commissioning

Real Operation In real operation all necessary components are available. The parameterization of the drive controller is made online; then commissioning of the axis system can be made in setting-up mode. The commissioning of the machine is made by means of a control.

Offline Simulation The offline simulation does not require any machine component. The parameterization of the drive controller is made offline. The parameters are applied to the drive controller during transition to real operation. The parameterization for a drive-internal control (MLD) can also be made offline, as well as creation of motion programs.

Simulation Mode In simulation mode only the drive controller is required, parameterization is made online. With the axis simulation the velocity and actual position values are simulated, the drive can be operated in velocity- and position-controlled operation modes. A higher-level control unit can thus test its motion programs even without motor or mechanical system.

12.5.2   Commissioning Real Operation

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 most practical way to do this is by starting up the drive with the PC-based "IndraWorks Ds/D/MLD" commissioning tool by Bosch Rexroth (see "Initial Start with Commissioning Tool").

The commissioning of machine axis-specific functions is also to be carried out via "IndraWorks Ds/D/MLD", if possible. The advantage is that the correct sequence of an axis-specific function can be configured and ensured independently of the control unit. Further commissioning of the drive, with largely complete configuration, is then easier for the control unit.

Schematic Sequence

Commissioning procedure as a sequence of steps:

Commissioning
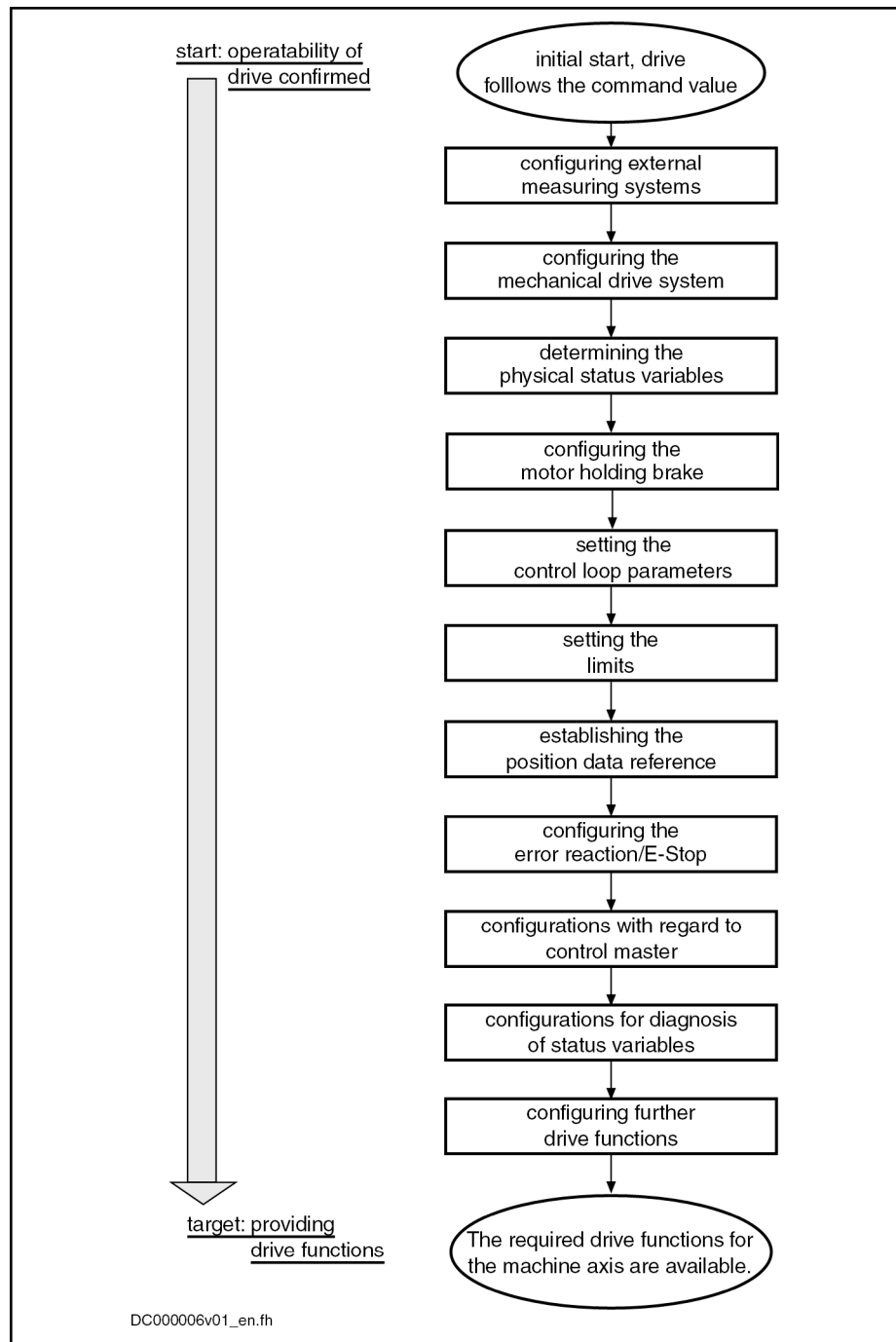
Fig. 12-16:   Steps for machine axis-related commissioning

Notes on the Commissioning Steps

The subjects of the individual commissioning steps are treated in detail in different chapters of this firmware documentation. The information contained in the chapter is basically divided into:

- Brief Description
- Functional Description
- Notes on Commissioning

To explain the individual commissioning steps, we refer to the Notes on Commissioning for the respective subject, if possible.

Detailed information on the parameters is only contained in the separate documentation "Rexroth IndraDrive, Parameter Description" (reference list of all IndraDrive parameters).

Configuring the Measuring Systems

General information	Configuring the controller and encoder (set travel range, if necessary)
	See "Notes on Commissioning" under "Basics on Measuring Systems, Resolution"
Relative encoders	Setting initial position value; configuring distance-coded measuring systems
	See "Notes on Commissioning" under "Relative Measuring Systems"
Absolute encoders	Checking whether absolute encoder evaluation is possible (depending on travel range), setting initial position value
	See "Notes on Commissioning" under "Absolute Measuring Systems"
Position monitoring	Setting position monitors:

- Monitoring axis position (position at time drive is switched on) with absolute encoders
- Monitoring position difference of motor encoder and external encoder
- Configuring spindle encoder monitor

See "Notes on Commissioning" under "Monitoring the Measuring Systems"

Configuring the Mechanical Axis System

Enter the following settings depending on the mechanical properties:

- Enter load gear ratio
- Enter feed constant
- Enter motor encoder gear ratio
- Enter gear ratio for external encoder

See "Notes on Commissioning" under "Mechanical Axis System and Arrangement of Measuring Systems"

Determining the Physical Status Variables

Enter scaling settings for position, velocity, acceleration, torque/force and temperature data.

See "Notes on Commissioning" under "Scaling of Physical Data"

Configuring the Holding Brake

Enter the following settings 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):

- Enter maximum "Drive off" delay time
- Enter holding brake data (external brake), if necessary
- Configure type, functioning principle and brake monitoring in holding brake control word

See "Notes on Commissioning" under "Motor Holding Brake"

Setting the Control Loop Parameters

Set the controller and filter parameters for the control loops:

- Velocity control loop
- Position control loop

Commissioning

See "Notes on Commissioning for Control Loop Setting" under "General Information on Closed-Loop Axis Control"

Setting the Limits

The controller offers the option of limiting the drive's physical status variables. Limit values can be set for the following depending on the application:

- Torque/force command value
- Velocity command value
- Position command values and actual position values

Limiting the torque/force command value

On the user side, limits are available for:

- Maximum permitted torque/force (S-0-0092, P-0-0109)
- Motor and regenerative load at stationary velocity (S-0-0082, S-0-0083)

The limit values currently effective due to the user-side limit settings are displayed in:

- P-0-0444, Actual value peak torque limit
- P-0-0442, Actual value torque limit positive (stationary)
- P-0-0443, Actual value torque limit negative (stationary)

Current command values are displayed in:

- P-0-0049, Effective torque/force command value
- P-0-0038, Torque-generating current, command value

ℹ️ See description of the respective parameter in the separate documentation "Rexroth IndraDrive, Parameter Description"

In addition to the user-side limits, there are further limits effective 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, "Torque/force control" mode permits the actual velocity value to be limited to the lower value of

- $1.125 \times$ Bipolar velocity limit value (S-0-0091)
  - and -
- Maximum motor velocity (S-0-0113)

.

See also "Torque/force control"

Limiting the velocity command value

On the user side, "Velocity control" mode permits the velocity command value to be limited via

- Bipolar velocity limit value (S-0-0091)

and, in "Position control" mode, limitation of the

- Position command value difference (to values of S-0-0091 and S-0-0113)

.

See also "Velocity Control" and "Position Control with Cyclic Command Value Input"

Limiting the position

The following user-side options are available to limit the position:

Commissioning

- Limiting the actual position value (firmware "limit switch")
- Limiting the travel range of the axis (hardware limit switch)

See also "Limitations: Position Limitation/Travel Range Limit Switches"

Establishing the Position Data Reference

Measuring systems to be evaluated in absolute form

With measuring systems that can be evaluated in absolute form, the position data reference must be established once during initial commissioning.

See "Notes on Commissioning" under "Establishing Position Data Reference for Absolute Measuring Systems"

Relative measuring systems

With relative measuring systems, all settings must be made in such a way that the position data reference can be established internally and automatically (after switching on the machine at a command of the control master to the respective axis drive).

See "Notes on Commissioning" under "Establishing Position Data Reference for Relative Measuring Systems"

Configuring the Error Reaction/E-Stop

The desired reaction of the drive to errors detected on the drive side has to be set.

See "Error Reactions"

The setting has to be entered to determine 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 be performed.

See "E-Stop Function"

Configurations With Regard to Control Unit (Master)

The following settings are required with regard to master-controlled drive operation:

- Presetting of operation modes (primary operation mode and secondary operation modes)

  See "General Information on Operation Modes: Operation Mode Handling"

- Settings for the determined primary or secondary operation modes

  See description of the respective operation mode in the chapter "Operation Modes"

With regard to the master communication interface used by the control master, presettings can be entered for:

- sercos interface

  → This is only appropriate via serial communication when using the "IndraWorks Ds/D/MLD" commissioning tool!

- PROFIBUS-DP
- Parallel interface
- Analog interface

See description of the respective master communication interface

Configurations for Diagnosis of Status Variables

If the drive's status variables are to be evaluated during operation, these status variables can be transmitted to the control master in different ways.

Diagnostic options with sercos interface:

Commissioning

- Content of a cyclically updated parameter that can be cyclically transmitted and which contains the value of the respective status variable

  sercos interface

- Message indicating whether a threshold value of the status variable has been 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 indicating whether a threshold value of the status variable has been exceeded, by assigning bits from "S-0-0144, Signal status word"

  See "Digital Inputs/Outputs"

Configuring Further Drive Functions

Other configurable drive functions include:

- Drive halt
- Friction torque compensation
- Detecting the marker position
- Positioning the spindle
- Probe function
- Digital inputs/outputs
- Analog inputs
- Analog outputs

See description of the respective function

12.6   Simulation Mode

12.6.1   Brief Description

The **base package** includes variants **MPH, MPC, MPB and MPD** in **open-loop and closed-loop** versions.

"Simulation mode" function is available for the functional testing of control units. It allows the control unit to execute a program test without the axis moving. For this purpose, only the drive control section is required, the power supply, motor, as well as the encoder, are not used; in "Operation" mode, the drive is therefore directly ready for enabling "AB".

The function is performed with the "parking axis" command. For this purpose, the "permanently parked axis" function is activated with parameter "P-0-0399, Configuration of simulation mode". The command, and with it axis simulation, are automatically started during transition to "Operation" mode.

Pertinent parameters
- P-0-0399, Configuration of simulation mode
- P-0-0612, Set absolute position control
- S-0-0139, C1600 Parking axis procedure command

- S-0-0147, Homing parameter

12.6.2   Functional Description

The "permanently parked axis" function is activated with bit 0 in "P-0-0399, Configuration of simulation mode". The parameter can only be activated in "Parameter" mode (communication phase "P2" or "P3"). When the switch to "Operation" mode takes place, the "parking axis" command is automatically started and "Simulation" mode becomes active. "Simulation" mode has the following effects:

- Switching off current control and PWM control
- Switching off hardware monitoring of encoder
- Disabling of commands for brake control
- Switching to "AB" without power
- Alternate displaying of "SA" and axis number in the display of the operating panel
- Displaying of "AB" or "AF" in the control panel and displaying of the operation mode in the diagnostic system

Simulation mode can only be terminated by switching off bit 0 in "P-0-0399, Configuration of simulation mode". This is only possible in "Parameter" mode.

Simulation mode A simulation encoder (motor encoder and external encoder) is defined; it adds up an actual position value from the command value of the velocity loop. It is thereby possible to use the operation modes with velocity control and position control. The axis runs with an ideal velocity loop, i.e. the command value input is applied to the actual value / mechanical system in (t = 0).

"Torque/force" mode is not simulated and therefore is not to be used. This also applies to the "positive stop drive procedure" function. Torque limitation in the V-loop remains active, the values for the nominal torque and maximum torque are preset with exemplary values.

Simulation encoder An internal encoder type is defined for the simulation encoder. In a proprietary evaluation function, the encoder value is integrated from the velocity command value of the V-loop, further position processing thereafter remains unchanged. The simulation encoder cannot be directly selected in the parameter (P-0-0074/0075) and is only set internally.

The simulation encoder is defined as an encoder with 1024 lines (S-0-0116/0117), the multiplication (S-0-0256/0257) is calculated, as is known, based on the maximum travel range (S-0-0278).

The simulation encoder has been defined as an absolute encoder and can be homed with the "set absolute position" procedure. If the "homing" function is also required, "homing" must be permitted in "P-0-0612, Set absolute position control" and "homing without home switch" and "homing without home marker" must be set in "S-0-0147, Homing parameter".

☞   The external encoder is only simulated when the encoder type 2 [P-0-0075, Encoder type 2 (optional encoder)] has been set.

13   Service and Support

The Bosch Rexroth service helpdesk at out headquarters in Lohr, Germany, and our worldwide service provide 24/7 support and assistance.

	Helpdesk	Worldwide service hotline
Phone	+49 (0) 9352 40 50 60	Outside Germany, please contact your sales/service office first.
Fax	+49 (0) 9352 40 49 41	
E-mail	service.svc@boschrexroth.de	For hotline numbers, refer to the sales office addresses on the internet.
Internet	For additional information on service, maintenance (e.g. delivery addresses) and training, please go to http://www.boschrexroth.com	

Required information

Please provide the following information:

- Detailed description of malfunction and circumstances leading to the malfunction
- Type plate name of the affected products, in particular type codes and serial numbers
- Phone and fax numbers as well as your e-mail address

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