Rexroth IndraDrive
Firmware for Drive Controllers
MPH-02, MPB-02, MPD-02

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Functional Description

Title	Rexroth IndraDrive
	Firmware für Drive Controllers
	MPH-02, MPB-02, MPD-02
Type of Documentation	Functional Description
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Purpose of Documentation	This documentation describes all functional features of the IndraDrive firmware in the variants MPH-02, MPB-02 and MPD-02.

Record of Revisions

Description	Release Date	Notes
DOK-INDRV*-MP*-02VRS**-FK01-EN-P	03.2004	First Edition

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1   System Overview

1.1   General Information

Overview of Drive Firmware

Firmware Variants

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

- **MTH**: Drives for Machine Tool Applications with SERCOS interface (**Advanced** Performance and Functionality)

- **MPX**: Drives for General Automation (Incl. Machine Tool Applications) with SERCOS interface, Profibus, as well as Parallel and Analog Interface
  (the variants of design are **MPH**, **MPB** and **MPD**; see below)

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

- **MT:** "Machine Tool" → Drives for Machine Tool
  Applications with SERCOS interface
  (drive profile according to SERCOS)

- **MP:** "Multi Purpose" → Drives for General Automation
  (Incl. Machine Tool Applications) with
  SERCOS interface, Profibus, as well as Parallel and
  Analog Interface
  (drive profile according to SERCOS)

The **third letter** of the firmware designation identifies the hardware and performance and functionality of the firmware (**X** includes **H, B and D**):

- **H**: **single-axis** firmware with **advanced** performance and functionality

- **B**: **single-axis** firmware with **basic** performance and functionality

- **D**: **double-axis** firmware with **basic** performance and functionality

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This documentation describes the functionality of the following firmware variants:

- **FWA-INDRV*-MPH-02VRS-MS**

- **FWA-INDRV*-MPB-02VRS-MS**

- **FWA-INDRV*-MPD-02VRS-MS**

The "DriveTop" commissioning tool in version DTOP16 is available for commissioning these firmware variants.

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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 basic package** and various **additional functional packages** (e.g. drive-integrated safety technology, IndraMotion MLD-S) that can be optionally activated.

Note:	The scope of functions of the functional packages and their possible combinations are described in the section "Functional Packages" in the same chapter.

Terms, Basic Principles

Parameters

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

Parameters are used for:

- determining the configuration
- parameterizing the control loop
- triggering and controlling drive functions and commands
- transmitting command values and actual values (according to requirements, cyclically or acyclically)

All operating data are mapped to parameters!

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

Data Storage and Parameter Handling

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

- in the controller
- in the motor encoder (depending on motor type)
- as a MultiMediaCard (MMC), optional

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

Condition As Supplied Condition as supplied of the Rexroth drive components:

- The controller memory contains the drive firmware and the controller-specific parameter values.
- The motor encoder memory contains the encoder-specific and, depending on the motor type, the motor-specific parameter values.
- The MMC contains the drive firmware and the basic parameter sets.

Storing the Application-Specific Parameter Values The application-specific parameter values are stored in the controller. Due to the limited number of writing cycles of non-volatile storage media, application-specific parameter values can be stored in the working memory (volatile memory), too.

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
- "DriveTop" 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 original status (repeated loading of the values saved after initial commissioning)
- replacing the controller for servicing (loading the current parameter values saved before servicing)

Possibilities of loading parameter values to the controller:

- motor encoder data memory → loading the parameter values by command or via the control panel during initial motor commissioning
- MMC → loading the parameter values by command
- "DriveTop" commissioning tool → loading the parameter values from external data carrier
- control master → loading the parameter values from master-side data carrier

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

Password

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

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

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

- **Customer password**

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

- **Control password**

  Parameters protected by a customer password can be written; "administration parameters" remain write-protected.

- **Master password**

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

Commands

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

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

Note: Each command that was started must be actively cleared again.

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

Kinds of Commands   There are 3 different kinds of commands:

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

See also "Command Processing" in chapter "Master Communication"

Operating Modes

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

One of the four operating modes defined in the parameters S-0-0032 to S-0-0035 is always active when 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
- "Drive Halt" function has not been activated
- no drive control command is active
- no error reaction is carried out

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

Note: All implemented operating modes are stored in the **S-0-0292, List of all operating modes** parameter.

See also chapter "Operating Modes"

Warnings

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

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

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.

Note: The warning class can be recognized by the diagnostic message.

The following classes of warnings are distinguished:

- **without** drive reaction   → diagnostic message numbers **E1xxx to E7xxx**
- **with** drive reaction   → diagnostic message number **E8xxx**

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

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Errors

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

Error Classes

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

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

Diagnostic message number	Error class
F2xxx	non-fatal error
F3xxx	non-fatal safety technology error
F4xxx	interface error
F6xxx	travel range error
F7xxx	safety technology error
F8xxx	fatal error
F9xxx	fatal system error
E-xxxx	fatal system error "processor exception"

Fig. 1-1:   Overview of error classes

Note:	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. Boot errors and firmware download errors are separately described in the documentation "Troubleshooting Guide".

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 is torque-free.

See also "Error Reactions" in chapter "Drive Functions"

Clearing Error Messages

Error messages are not cleared automatically but by the following action:

• activating the **S-0-0099, C0500 Reset class 1 diagnostics** command

- or -

• actuating the "Esc" button on the standard control panel

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

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

To reactivate the drive:

- clear the error message and
- input a positive edge for drive enable again. |
| **Error Memory** | The diagnostic message numbers of occurring errors are written to an error memory. This memory contains the diagnostic message numbers of the last 50 errors that occurred and the time when they occurred. Errors caused by a shutdown of the control voltage (e.g. **F8070 +24Volt DC error**) are not stored in the error memory.

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

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 reasonable, 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.

$\boxed{\mathbf{i}}$ The detailed description of the parameters, their function and structure is contained in the separate documentation "Rexroth IndraDrive, Parameter Description".

$\boxed{\mathbf{i}}$ The detailed description of the diagnostic messages, their causes and remedies is contained in the separate documentation "Rexroth IndraDrive, Troubleshooting Guide" (description of diagnostic messages).

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

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

$\boxed{\mathbf{i}}$ The detailed description of the diagnostic messages, their causes and remedies is contained in the separate documentation "Rexroth IndraDrive, Troubleshooting Guide" (description of diagnostic messages).

Markers and Terms

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

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

Base package of all variants

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

- firmware **range**   e.g. IndraDrive
- firmware **design**   single-axis, double-axis (multi-axis)
- firmware **variant**   e.g. MP**H**, MP**B**, MP**D**
- firmware **version**   e.g. MPH-**02**VRS
- firmware **characteristic**   open-loop/closed-loop
- Firmware **performance**   basic/advanced
- firmware **type**   complete firmware type designation

> **Note:** In many cases the availability of certain functions within the functional packages also depends on design, variant and characteristic of the firmware.
>
> The exact dependence of the firmware functions on the design of hardware and firmware can be seen in the tables in section "Functional Packages".

Cross References

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

Cross references to other sections or documentations follow this scheme:

- references to sections in the same chapter by indicating title without chapter

- references to sections in a different chapter by indicating title of section and chapter

- References to another documentation are additionally marked by the "info icon" unless they are contained in a note or put in parentheses.

Further Documentations

Firmware documentation:

- Parameter Description
  DOK-INDRV*-GEN-**VRS**-PA**-EN-P; part no. R911297317

- Troubleshooting Guide (description of diagnostic messages)
  DOK-INDRV*-GEN-**VRS**-WA**-EN-P; part no. R911297319

- Firmware Version Notes
  DOK-INDRV*-MPX-02VRS**-FV**-EN-P; part no. R911297315

- Drive-integrated safety technology
  DOK-INDRV*-SI*-**VRS**-FK**-EN-P; part no. R911297838

- IndraMotion MLD-S (drive-integrated PLC)
  DOK-INDRV*-MLD-S*VRS**-AW**-EN-P; part no. R911306084

Hardware documentation (Project Planning Manuals):

- Power sections
  DOK-INDRV*-HMS+HMD****-PR**-EN-P; part no. R911295014

- Control sections
  DOK-INDRV*-CSH********-PR**-EN-P; part no. R911295012

- IndraDrive M supply units
  DOK-INDRV*-HMV-*******-PR**-EN-P; part no. R911299229

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1.2   Drive Controllers

Overview

Design of the IndraDrive Controllers

An IndraDrive controller basically consists of two hardware components:

- power section
- control section
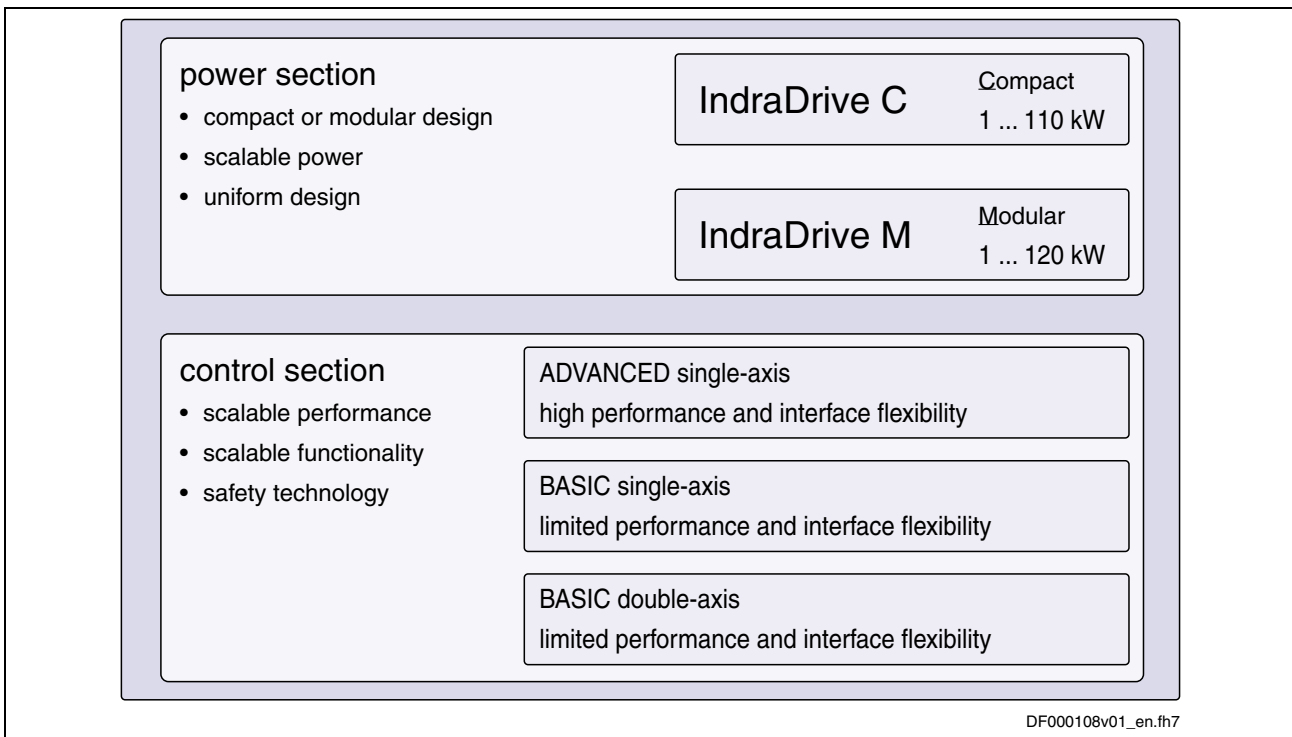
Fig. 1-2:   Design and types of the IndraDrive controllers

Power Section   The following are connected to the power section:

- power supply unit (DC bus voltage)
- 24 V control voltage
- motor

Note: Each of the two types of the control section is described in the separate documentation; e.g. "IndraDrive Drive Controllers, Power Sections, Project Planning Manual" (DOK-INDRV*-HMS+HMD****-PR**-EN-P; part no. R911295014).

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

Note:	The available control sections are described in the separate documentation "IndraDrive Drive Controllers, Control Sections, Project Planning Manual" (DOK-INDRV*-CSH********-PR**-EN-P; part no. T911295012).

Power Sections

The following power sections can be operated with this firmware:

IndraDrive M

Single-Axis The following single-axis power sections can be operated with the **FWA-INDRV*-MPH02VRS** and **FWA-INDRV*-MPB02VRS** firmware:

- HMS01.1N-W020
- HMS01.1N-W036
- HMS01.1N-W054
- HMS01.1N-W070
- HMS01.1N-W150
- HMS01.1N-W210

Double-Axis The following double-axis power sections can only be operated with the **FWA-INDRV*-MPD02VRS** firmware:

- HMD01.1N-W012
- HMD01.1N-W020
- HMD01.1N-W036

IndraDrive C

The following single-axis converters can be operated with the **FWA-INDRV*-MPH02VRS** and **FWA-INDRV*-MPB02VRS** firmware:

300mm Type
- HCS02.1-W0012
- HCS02.1-W0028
- HCS02.1-W0054
- HCS02.1-W0070

400mm Type
- HCS03.1-W0070
- HCS03.1-W0100
- HCS03.1-W0150
- HCS03.1-W0210

Control Sections

The following control sections can be operated with the **FWA-INDRV*-MP*-02VRS** firmware:

- ADVANCED (single-axis; type designation CSH01.1C-...)
- BASIC OPENLOOP (single-axis; type designation CSB01.1N-FC-...)
- BASIC SERCOS (single-axis; type designation CSB01.1N-SE-...)
- BASIC PROFIBUS (single-axis; type designation CSB01.1N-PB-...)
- BASIC ANALOG (single-axis; type designation CSB01.1N-AN-...)
- BASIC UNIVERSAL (single-axis; type designation CSB01.1C-...)
- BASIC UNIVERSAL double-axis (type designation CDB01.1C-...)

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Control Section Configuration

The parts of the type designations listed below describe the differences with regard to the possibilities of configuration. The following abbreviations are used:

Master communication:

- **SE**   → SERCOS interface
- **PB**   → PROFIBUS-DP
- **PL**   → parallel interface
- **AN**   → analog interface
- **FC**   → FC special

Standard optional modules:

- **NNN** → not equipped
- **EN1** → encoder interface for HSF, resolver
- **EN2** → encoder interface for EnDat, 1Vpp sine and TTL signals
- **ENS** → encoder interface for MSK motors and HIPERFACE encoders
- **MA1** → analog I/Os
- **MD1** → digital I/Os
- **MEM** → encoder emulator

Safety option:

- **NN**   → not equipped
- **L1**   → starting lockout
- **S1**   → module for safety technology

Note: The basic structure of the type codes of the individual types of IndraDrive control sections is described in the separate documentation "IndraDrive Drive Controllers, Control Sections, Project Planning Manual" (DOK-INDRV*-CSH********-PR**-EN-P; part no. T911295012).

Supported Control Section Configurations

Note: The lists below contain the theoretically possible configurations of the control sections.

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

ADVANCED Single-Axis (CSH01.1)   The firmware **FWA-INDRV*-MPH-02VRS** for configurable ADVANCED single-axis control sections supports control sections with the following type designations:

- **CSH01.1C-xx[1]-xxx[2]-xxx[3]-xxx[4]-xx[5]-S-NN-FW**

Possible types:

[1] … Master communication:
    SE → SERCOS interface
    PB → PROFIBUS-DP
    PL → parallel interface
    AN → analog interface

[2] … optional module 1 (X4):
    NNN → not equipped
    EN1 → encoder interface for HSF/resolver
    EN2 → encoder interface for EnDat/1Vpp sine/TTL signals
    ENS → encoder interface for Rexroth standard/HIPERFACE/1Vpp
    MA1 → analog I/Os
    MEM → encoder emulator

[3] … optional module 2 (X8):
    NNN → not equipped
    EN1 → encoder interface for HSF/resolver
    EN2 → encoder interface for EnDat/1Vpp sine/TTL signals
    ENS → encoder interface for Rexroth standard/HIPERFACE/1Vpp
    MA1 → analog I/Os
    MEM → encoder emulator

[4] … optional module 3, technology slot (X10):
    NNN → not equipped
    EN1 → encoder interface for HSF/resolver
    EN2 → encoder interface for EnDat/1Vpp sine/TTL signals
    ENS → encoder interface for Rexroth standard/HIPERFACE/1Vpp
    MA1 → analog I/Os
    MD1 → digital I/Os
    MEM → encoder emulator

[5] … safety option (X41):
    NN → not equipped
    L1 → starting lockout
    S1 → module for safety technology

BASIC Single-Axis (CSB01.1)

The firmware **FWA-INDRV*-MPB-02VRS** for BASIC single-axis control sections supports standard control sections (**not configurable**) with the following type designations:

- **CSB01.1N-FC-NNN-NNN-NN-S-NN-FW** → BASIC OPENLOOP
- **CSB01.1N-SE-ENS-NNN-NN-S-NN-FW** → BASIC SERCOS
- **CSB01.1N-PB-ENS-NNN-NN-S-NN-FW** → BASIC PROFIBUS
- **CSB01.1N-AN-ENS-NNN-NN-S-NN-FW** → BASIC ANALOG

This firmware additionally supports **configurable** BASIC single-axis control sections with the following type designations:

- **CSB01.1C-xx[1]-xxx[2]-xxx[3]-xx[5]-S-NN-FW**
  → BASIC UNIVERSAL (single-axis, configurable)

Possible types of BASIC UNIVERSAL (single-axis):

[1] … Master communication:
    SE → SERCOS interface
    PB → PROFIBUS-DP
    PL → parallel interface
    AN → analog interface

[2] … encoder interface "on board" (X4):
    ENS → encoder interface for Rexroth standard/HIPERFACE/1Vpp

3) … optional module 2 (X8):
    NNN → not equipped
    EN1 → encoder interface for HSF/resolver
    EN2 → encoder interface for EnDat/1Vpp sine/TTL signals
    ENS → encoder interface for Rexroth standard/HIPERFACE/1Vpp
    MA1 → analog I/Os
    MEM → encoder emulator

5) … safety option (X41):
    NN → not equipped
    L1 → starting lockout

BASIC Double-Axis (CDB01.1)

The firmware **FWA-INDRV*-MPD-02VRS** for configurable BASIC UNIVERSAL double-axis control sections supports control sections with the following type designations:

- **CDB01.1C-xx[1)]-xxx[2)]-xxx[3)]-xxx[4)]-xxx[5)]-xx[6)]-S-NN-FW**

Possible types:

1) … master communication, for both axes:
    SE → SERCOS interface
    PB → PPOFIBUS-DP

2) … optional module 1 (X4.1), axis 1:
    NNN → not equipped
    EN1 → encoder interface for HSF/resolver
    EN2 → encoder interface for EnDat/1Vpp sine/TTL signals
    ENS → encoder interface for Rexroth standard/HIPERFACE/1Vpp

3) … optional module 2 (X8.1), axis 1:
    NNN → not equipped
    EN1 → encoder interface for HSF/resolver
    EN2 → encoder interface for EnDat/1Vpp sine/TTL signals
    ENS → encoder interface for Rexroth standard/HIPERFACE/1Vpp
    MA1 → analog I/Os
    MEM → encoder emulator

4) … optional module 1 (X4.2), axis 2:
    NNN → not equipped
    EN1 → encoder interface for HSF/resolver
    EN2 → encoder interface for EnDat/1Vpp sine/TTL signals
    ENS → encoder interface for Rexroth standard/HIPERFACE/1Vpp

5) … optional module 2 (X8.2), axis 2:
    NNN → not equipped
    EN1 → encoder interface for HSF/resolver
    EN2 → encoder interface for EnDat/1Vpp sine/TTL signals
    ENS → encoder interface for Rexroth standard/HIPERFACE/1Vpp
    MA1 → analog I/Os
    MEM → encoder emulator

6) … safety option, for both axes (X41.1 and X41.2):
    NN → not equipped
    L1 → starting lockout
    S1 → module for safety technology

1.3   Motors and Measuring Systems

Supported Motors

The following Rexroth motors can be operated at IndraDrive controllers:

Housing Motors
- MHD
- MKD
- MKE
- MSK
- 2AD
- ADF
- MAD
- MAF
- MAL
- SF (Bosch)

Kit Motors
- MLF
- MBS (standard)
- MBS (high speed)
- MBT
- LSF
- 1MB

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:

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

Measuring Encoders

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

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

Note: Resolvers cannot be evaluated as measuring encoders!

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1.4   Master Communication

In the firmware version FWA-INDRV*-MP*-02VRS (MPH, MPB and MPD types) the following master communication interfaces are available:

- SERCOS interface
- PROFIBUS interface
- parallel interface (not for double-axis type MPD02)
- analog interface (not for double-axis type MPD02)

SERCOS interface

General Features SERCOS interface

- cyclical data exchange of command values and actual values in equal time intervals (max. 32 bytes per data direction; minimum cycle time of 500 µs)
- data transfer by means of fiber optic cable
- service channel for parameterization and diagnosis
- telegram contents can be freely configured (large number of parameter IDNs configurable in the MDT and AT)
- synchronization between time command value takes effect and measurement starting time of the actual values for all drives on a ring

PROFIBUS Interface

General Features PROFIBUS Interface

- cyclical data exchange of command values and actual values (max. 32 bytes per data direction; minimum cycle time of 250 µs)
- parameter channel for parameterization and diagnosis via the field bus
- telegram contents can be freely configured (large number of cyclically configurable parameter IDNs)

Parallel Interface (not for MPD-02)

General Features Parallel Interface

- complete control of the drive via digital inputs/outputs
- 16 inputs and 16 outputs
- serial interface for parameterization and diagnosis
- free configuration of digital inputs and outputs

Analog Interface (not for MPD-02)

General Features Analog Interface

- basic unit has an analog input with 12-bit A/D converter and an input voltage range of ± 10 V
- sampling is done with 8-fold oversampling in the position controller clock
- assignment to command value/limit value/control parameters of the drive possible by means of adjustable scaling
- parameterizable dead zone to suppress the zero drift
- low-pass filter to smooth the analog input signals
- zero adjust of the analog input signals by command

- "drive enable", "Drive Halt" and "clear error" preset via digital inputs
- diagnostic messages such as drive errors and warnings are output via digital outputs

---

Note: In addition to analog command value input, the actual position value has to be transmitted back to the master, too. This requires encoder emulation (see "Encoder Emulation" in chapter "Extended Drive Functions").

1.5   Overview of Functions

Supported Operating Modes

The following operating modes are supported by the IndraDrive firmware MPX-02:

- torque/force control
- velocity control
- position control with cyclic command value input
- drive-internal interpolation
- drive-controlled positioning
- positioning block mode
- synchronization modes:
  - velocity synchronization with real/virtual master axis
  - phase synchronization with real/virtual master axis
  - electronic cam shaft with real/virtual master axis

Drive Functions

The following list contains the most important drive functions of the IndraDrive firmware MP*-02VRS:

- Drive Halt
- friction torque compensation
- probe function
- E-Stop function
- spindle positioning
- undervoltage monitor
- output of control signals
- establishing the position data reference
  - drive-controlled homing
  - setting absolute measuring
- limitations that can be parameterized
- drive error reactions
  - best possible deceleration
  - package reaction on error
  - NC reaction on error
- numerous diagnostic possibilities

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- drive-internal generation of diagnostic messages
- analog output
- status displays, status classes
- oscilloscope function
- monitoring function
- patch function
- code of optional card
- parameter value check
- operating hours meter, logbook function, error memory

1.6   Functional Packages

Overview

The application-specific scope of usable functions of the **FWA-INDRV*-MPX-02VRS** drive firmware depends on

- the available control section and, if available, its configuration

  - and -

- the licensed functional firmware packages.

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

Scaling the Drive Functionality

Firmware Scaling by Control Section Configuration

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

- **master communication** (SERCOS interface, Profibus DP, parallel or analog interface)
- **safety technology** (starting lockout, standard safety technology)
- **analog I/O add-on card**
- **digital I/O add-on card**

Note: 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-S"
      (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.

Note: 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 section "Enabling of Functional Packages" in chapter "Handling, Diagnostic and Service Functions".

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

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The figure below illustrates the possibilities of functional scaling depending on the control performance:
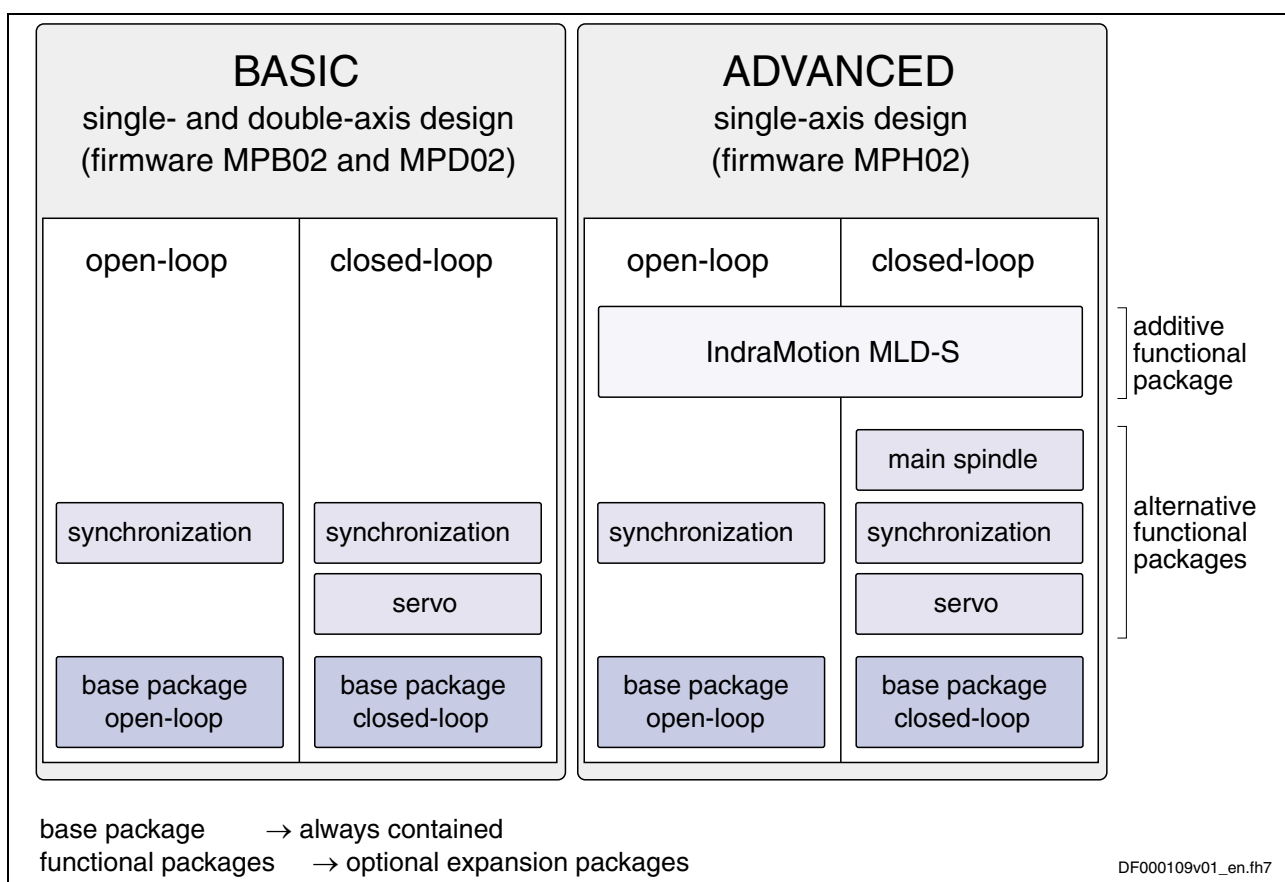
Fig. 1-3:   Functional packages of the IndraDrive firmware MPX02

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*-MPX-02VRS** supports the functional packages listed below.

Note: 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:

- **"Open-loop" base package**
  motor control without encoder, no position control modes
  → no position evaluation and functions depending thereof

- **"Closed-loop" base package**
  motor control with encoder (can be switched to control without encoder)
  → position evaluation and functions and operating modes depending thereof is possible

Alternative Functional Packages The following alternative functional packages are available:

- **Servo functions** [1]:
  This package contains all specific expansions for servo applications, such as compensations and correction functions (e.g. axis error correction, quadrant error correction).

- **Main spindle functions** [1]:
  This package contains the specific functions for the use of main spindles (e.g. spindle positioning).

- **Synchronization** [1]:
  With this package the possibilities of synchronization of the drive can be used (support of synchronization modes, measuring encoder function, probe function ...).

Note: [1]: These functional packages cannot be activated simultaneously (only individually)! → **Alternative expansion packages**

Additive Functional Packages There is also an additional functional package available:

- **IndraMotion MLD-S**

Note: This expansion package can be activated in addition to a possibly available alternative package.

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

Firmware type →			FWA-INDRV*-**MPB**-02VRS		FWA-INDRV*-**MPD**-02VRS		FWA-INDRV*-**MPH**-02VRS	
Control section design →			**CSB0.1.1** (Basic single-axis)		**CDB0.1.1** (Basic double-axis)		**CSH0.1.1** (Advanced single-axis)	
		performance	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)
base package	basic functions		X	X	X	X	X	X
	base package "open-loop" (U/f)	Basic	X	X	X	X	X	X
		Advanced					X	X
	base package "closed-loop" (Servo)	Basic		X		X		X
		Advanced						X
alternative functional packages	servo	Basic		X		X		X
		Advanced						X
	synchronizat.	Basic	X	X	X	X		
		Advanced					X	X
	main spindle	Basic						
		Advanced						X
additive functional package	IndraMotion MLD-S	Basic						
		Advanced					X	X

Fig. 1-4:   Dependence of functional packages on hardware and firmware variant

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Firmware Types That Can Be Ordered

Structure of the Firmware Type Designation

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

	IndraDrive firmware	Base package (depending on control section)	Version	Release	Language	Open-/closed-loop	Alternative expansion packages	Additive expansion packages
Basic single-axis	FWA-INDRV*	-MP**B**-	02	VRS-	D5-	x-	xxx-	xx
Basic double-axis	FWA-INDRV*	-MP**D**-	02	VRS-	D5-	x-	xxx-	xx
Advanced single-axis	FWA-INDRV*	-MP**H**-	02	VRS-	D5-	x-	xxx-	xx

Fig. 1-5: Basic structure of the firmware type code

Firmware Types That Can Be Ordered The individual functional packages can be combined to form the following firmware types that can be ordered:

Control section	Firmware range	Base package	Version	Release	Language	Open-/closed-loop	Alternative functional packages	Drive PLC	Scope of functional packages
Basic single-axis	FWA-INDRV*-	MPB-	02	VRS-	D5-	0-	NNN	-NN	base package (open-loop)
	FWA-INDRV*-	MPB-	02	VRS-	D5-	0-	SNC	-NN	base package (open-loop) + synchronization
	FWA-INDRV*-	MPB-	02	VRS-	D5-	1-	NNN	-NN	base package (closed-loop)
	FWA-INDRV*-	MPB-	02	VRS-	D5-	1-	SRV	-NN	base package (closed-loop) + servo function
	FWA-INDRV*-	MPB-	02	VRS-	D5-	1-	SNC	-NN	base package (closed-loop) + synchronization
	FWA-INDRV*-	MPB-	02	VRS-	D5-	1-	ALL	-NN	base package (closed-loop) + all altern. functions
Basic double-axis	FWA-INDRV*-	MPD-	02	VRS-	D5-	0-	NNN	-NN	base package (open-loop)
	FWA-INDRV*-	MPD-	02	VRS-	D5-	0-	SNC	-NN	base package (open-loop) + synchronization
	FWA-INDRV*-	MPD-	02	VRS-	D5-	1-	NNN	-NN	base package (closed-loop)
	FWA-INDRV*-	MPD-	02	VRS-	D5-	1-	SRV	-NN	base package (closed-loop) + servo function
	FWA-INDRV*-	MPD-	02	VRS-	D5-	1-	SNC	-NN	base package (closed-loop) + synchronization
	FWA-INDRV*-	MPD-	02	VRS-	D5-	1-	ALL	-NN	base package (closed-loop) + all altern. functions
Advanced single-axis	FWA-INDRV*-	MPH-	02	VRS-	D5-	0-	NNN	-NN	base package (open-loop)
	FWA-INDRV*-	MPH-	02	VRS-	D5-	0-	SNC	-NN	base package (open-loop) + synchronization
	FWA-INDRV*-	MPH-	02	VRS-	D5-	0-	ALL	-NN	base package (open-loop) + all altern. functions
	FWA-INDRV*-	MPH-	02	VRS-	D5-	0-	NNN	-ML	base package (open-loop) + IndraMotion MLD-S
	FWA-INDRV*-	MPH-	02	VRS-	D5-	0-	SNC	-ML	base package (open-loop) + synchronization + IndraMotion MLD-S
	FWA-INDRV*-	MPH-	02	VRS-	D5-	0-	ALL	-ML	base package (open-loop) + all altern. functions + IndraMotion MLD-S
	FWA-INDRV*-	MPH-	02	VRS-	D5-	1-	NNN	-NN	base package (closed-loop)
	FWA-INDRV*-	MPH-	02	VRS-	D5-	1-	SRV	-NN	base package (closed-loop) + servo function
	FWA-INDRV*-	MPH-	02	VRS-	D5-	1-	SNC	-NN	base package (closed-loop) + synchronization
	FWA-INDRV*-	MPH-	02	VRS-	D5-	1-	MSP	-NN	base package (closed-loop) + main spindle
	FWA-INDRV*-	MPH-	02	VRS-	D5-	1-	ALL	-NN	base package (closed-loop) + all altern. functions
	FWA-INDRV*-	MPH-	02	VRS-	D5-	1-	NNN	-ML	base package (closed-loop) + IndraMotion MLD-S
	FWA-INDRV*-	MPH-	02	VRS-	D5-	1-	SRV	-ML	base package (closed-loop) + servo functions + IndraMotion MLD-S
	FWA-INDRV*-	MPH-	02	VRS-	D5-	1-	SNC	-ML	base package (closed-loop) + synchronization + IndraMotion MLD-S
	FWA-INDRV*-	MPH-	02	VRS-	D5-	1-	MSP	-ML	base package (closed-loop) + main spindle + IndraMotion MLD-S
	FWA-INDRV*-	MPH-	02	VRS-	D5-	1-	ALL	-ML	base package (closed-loop) + all altern. functions + IndraMotion MLD-S

Fig. 1-6:   Overview of firmware types and functional packages they are containing

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Base Packages

In the base packages of the firmware the minimum scope of functionalities in the respective operating mode ("open-loop" or "closed-loop") is available. 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 base functions of a digital drive (available as firmware characteristics "open-loop" and "closed-loop"):

- numerous diagnostic possibilities
    - drive-internal generation of diagnostic messages
    - monitoring function
    - analog output
    - patch function
    - status displays, status classes
    - oscilloscope feature
    - code of optional card
    - parameter value check
    - operating hours meter, logbook function, error memory
- undervoltage monitor
- output of control signals
- limits 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").

The following overview shows the available scope of functions of the respective base package:

	Firmware variant →	FWA-INDRV*-**MPB**-02VRS (Basic single-axis)		FWA-INDRV*-**MPD**-02VRS (Basic double-axis)		FWA-INDRV*-**MPH**-02VRS (Advanced single-axis)	
	Functions of the base packages	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)
Master communi-cation	signal control / signal status word	X	X	X	X	X	X
	SERCOS interface	X[1)2)]	X[1)2)]	X[1)2)]	X[1)2)]	X[1)]	X[1)]
	PROFIBUS-DP	X[1)2)]	X[1)2)]	X[1)2)]	X[1)2)]	X[1)]	X[1)]
	parallel interface	X[1)3)]	X[1)3)]			X[1)]	X[1)]
	analog interface	X	X				
Motors and encoders	Rexroth housing motors, synchronous, with encoder data memory		X		X		X
	Rexroth housing motors, asynchronous, with encoder data memory	X	X	X	X	X	X
	Rexroth kit motors, synchronous, without encoder data memory		X		X		X
	Rexroth kit motors, asynchronous, without encoder data memory	X	X	X	X	X	X
	third-party motors, synchronous		X		X		X
	third-party motors, asynchronous (standard motors)	X	X	X	X	X	X
	motor holding brake	X[4)]	X	X[4)]	X	X[4)]	X
	motor encoder		X		X		X
	optional control encoder		X[3)]		X		X
	encoder correction		X		X		X
	overload protection (temperature monitoring)	X	X	X	X	X	X
Motor control	U/f operation	X	X	X	X	X	X
	field-oriented current control, with encoder		X		X		X
	commutation setting		X		X		X
Axis control	velocity loop		X		X		X
	position loop		X		X		X
	automatic axis control loop setting		X		X		X
	current limitation	X	X	X	X	X	X
	torque/force limitation	X	X	X	X	X	X

Fig. 1-7:   Scope of functions of the basic firmware packages (to be continued on next page)

	Firmware type →	FWA-INDRV*-**MPB**-02VRS (Basic single-axis)		FWA-INDRV*-**MPD**-02VRS (Basic double-axis)		FWA-INDRV*-**MPH**-02VRS (Advanced single-axis)	
	Functions of the base packages	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)
Operating modes	torque/force control		X		X		X
	velocity control	X	X	X	X	X	X
	position control		X		X		X
	drive-internal interpolation		X		X		X
	drive-controlled positioning		X		X		X
	positioning block mode		X		X		X
Drive functions	Drive Halt	X	X	X	X	X	X
	travel range limit switch	X	X	X	X	X	X
	position limit values software limit switch)		X		X		X
	detecting marker position		X		X		X
	positive stop drive procedure	X	X	X	X	X	X
	drive-controlled homing		X		X		X
	setting absolute measuring		X		X		X
Error reactions	E-Stop function	X	X	X	X	X	X
	torque disable	X	X	X	X	X	X
	v_{cmd} set to zero ("emergency halt")	X	X	X	X	X	X
	v_{cmd} set to zero with ramp and filter ("quick stop")	X	X	X	X	X	X
Expanded drive functions	analog I/Os (on basic device or optional module)	X[1]	X[1]	X[1]	X[1]	X[1]	X[1]
	digital I/Os (on basic device or optional module)	X[1][5]	X[1][5]	X[1][5]	X[1][5]	X[1]	X[1]
	encoder emulation		X[1]		X[1]		X[1]
	position switch points		X		X		X
Handling, diagnosis, service	MMC support	X[3]	X[3]	X	X	X	X
	firmware handling	X	X	X	X	X	X
	standard control panel	X	X	X	X	X	X
	scaling/standardization	X	X	X	X	X	X
	option. parameteriz. interface	X	X	X	X	X	X
	oscilloscope feature	X	X	X	X	X	X
	patch function	X	X	X	X	X	X

1)   depending on hardware configuration

2)   max. 24 byte MDT/AT data per axis and min. Tscyc = 1000 µs

3)   only with control section "BASIC UNIVERSAL"

4)   brake check and brake abrasion not possible

5)   no digital I/Os on optional module for basic design

Fig. 1-8:   Scope of functions of the basic firmware packages (continuation)

Alternative Functional Packages

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

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

- expanded servo function

- synchronization

- main spindle function

Servo Function

Depending on the firmware variant and characteristic, the expansion package "servo" (only possible with "closed-loop") has the following scope of functions:

Firmware type →	FWA-INDRV*-**MPB**-02VRS (Basic single-axis)		FWA-INDRV*-**MPD**-02VRS (Basic double-axis)		FWA-INDRV*-**MPH**-02VRS (Advanced single-axis)	
Functions of the expansion package "servo"	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)
quadrant error correction						X
friction torque compensation		X		X		X
set/shift coordinate system		X		X		X
axis error correction		X[1]		X[1]		X
probe function		X[2]		X[2]		X[2]
relative return motion		X		X		X

1) only single reversal clearance; no correction tables

2) for Advanced single-axis 2 probes; for Basic single-axis only 1 probe; for Basic double-axis 2 probes per controller

Fig. 1-9: Overview expansion package "servo"

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

Synchronization

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

Firmware type →	**FWA-INDRV*-MPB-02VRS** (Basic single-axis)		**FWA-INDRV*-MPD-02VRS** (Basic double-axis)		**FWA-INDRV*-MPH-02VRS** (Advanced single-axis)	
Functions of the expansion package "synchronization"	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)
measuring wheel mode		X		X		X
velocity synchronization	X	X	X	X	X	X
phase synchronization		X		X		X
electronic cam shaft		X		X		X
set/shift coordinate system		X		X		X
probe function	X[2)3)]	X[2)]	X[2)3)]	X[2)]	X[3)]	X[2)]
measuring encoder	X[4)]	X[4)]	X	X	X	X

2) for Advanced single-axis 2 probes; for Basic single-axis only 1 probe; for Basic double-axis 2 probes per controller

3) in parameter **S-0-0428, Probe, IDN list signal selection** the following signals are not available S-0-0051, S-0-0052, P-0-0227

4) only with control section "BASIC UNIVERSAL"

Fig. 1-10:   Overview expansion package "synchronization"

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

Main Spindle Function

The expansion package "main spindle" (only possible with "closed-loop") has the following scope of functions:

Firmware type →	FWA-INDRV*-**MPB**-02VRS (Basic single-axis)		FWA-INDRV*-**MPD**-02VRS (Basic double-axis)		FWA-INDRV*-**MPH**-02VRS (Advanced single-axis)	
Functions of the expansion package "main spindle"	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)	without encoder (open-loop)	with encoder (closed-loop)
spindle positioning						X
set/shift coordinate system						X

Fig. 1-11:   Overview expansion package "main spindle"

-

Additive Functional Packages

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

At present, there is the following additive functional package available:

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

> **Note:**   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-S (Drive-Integrated PLC)

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

- **integrated logic control** (standard PLC tasks)

- **integrated single-axis motion control**
  motion function block according to PLC-Open for single-axis positioning and synchronization mode (synchronous running, cam shaft)
  → "low-level motion functions"

- **basis for technology functions**
  examples: following-on cutting devices, pick & place, process controller (register controller, winding computation, etc.), preventive maintenance, free function block combination

> **Note:**   The expansion package "IndraMotion MLD-S" is only available in conjunction with ADVANCED control sections (CSH-***)!

Drive-Integrated Safety Technology

> **Note:**   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 module **S1** depending on the control section configuration.

The following safety functions are supported:

- **safety related stopping process:**
  - safety related standstill
  - safety related operational stop
  - safety related starting lockout

- **safety related motion:**
  - safety related reduced speed
  - safety related direction of motion
  - safety related limited increment
  - safety related limited absolute position
  - safety related acceleration/deceleration

- **safety related feedback:**
  - safety related diagnosis outputs
  - safety related safety door

- **Safety related maximum velocity**

- **Safety related end position (in preparation)**

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Notes

2 Important directions for use

2.1 Appropriate use

Introduction

Rexroth products represent state-of-the-art developments and manufacturing. They are tested prior to delivery to ensure operating safety and reliability.

The products may only be used in the manner that is defined as appropriate. If they are used in an inappropriate manner, then situations can develop that may lead to property damage or injury to personnel.

Note: Bosch 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 product takes 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.

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Areas of use and application

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

Control and monitoring of the motors may require additional sensors and actors.

Note: The drive controllers may only be used with the accessories and parts specified in this document. If a component has not been specifically named, then it may not be either mounted or 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 function descriptions.

Every drive controller has to be programmed before starting it up, making it possible for the motor to execute the specific functions of an application.

The drive controllers of the IndraDrive family are designed for use in single or multiple-axis drive and control applications.

To ensure an application-specific use, the drive controllers are available with differing drive power and different interfaces.

Typical applications of drive controllers belonging to the IndraDrive family are:

- handling and mounting systems,

- packaging and foodstuff machines,

- printing and paper processing machines and

- machine tools.

The drive controllers may only be operated under the assembly, installation and ambient conditions as described here (temperature, system of protection, humidity, EMC requirements, etc.) and in the position specified.

2.2 Inappropriate use

Using the drive controllers outside of the above-referenced areas of application or under operating conditions other than described in the document and the technical data specified is defined as "inappropriate use".

Drive controllers may not be used if

- they are subject to operating conditions that do not meet the above specified ambient conditions. This includes, for example, operation under water, in the case of extreme temperature fluctuations or extremely high maximum temperatures or if

- Rexroth has not specifically released them for that intended purpose. Please note the specifications outlined in the general safety instructions!

3   Safety Instructions for Electric Drives and Controls

3.1   Introduction

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

Do not attempt to install or start up this equipment without first reading all documentation provided with the product. Read and understand these safety instructions and all user documentation of the equipment prior to working with the equipment at any time. If you do not have the user documentation for your equipment, contact your local Bosch Rexroth representative to send this documentation immediately to the person or persons responsible for the safe operation of this equipment.

If the equipment is resold, rented or transferred or passed on to others, then these safety instructions must be delivered with the equipment.

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

3.2   Explanations

The safety instructions describe the following degrees of hazard seriousness in compliance with ANSI Z535. The degree of hazard seriousness informs about the consequences resulting from non-compliance with the safety instructions.

Warning symbol with signal word	Degree of hazard seriousness according to ANSI
⚠️ **DANGER**	Death or severe bodily harm will occur.
⚠️ **WARNING**	Death or severe bodily harm may occur.
⚠️ **CAUTION**	Bodily harm or material damage may occur.

Fig. 3-1:   Hazard classification (according to ANSI Z535)

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3.3   Hazards by Improper Use

DANGER

**High voltage and high discharge current!
Danger to life or severe bodily harm by electric
shock!**

DANGER

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

WARNING

**High electrical voltage due to wrong
connections! Danger to life or bodily harm by
electric shock!**

WARNING

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

CAUTION

**Surface of machine housing could be extremely
hot! Danger of injury! Danger of burns!**

CAUTION

**Risk of injury due to improper handling! Bodily
harm caused by crushing, shearing, cutting and
mechanical shock or incorrect handling of
pressurized systems!**

CAUTION

**Risk of injury due to incorrect handling of
batteries!**

3.4   General Information

- Bosch Rexroth AG is not liable for damages resulting from failure to observe the warnings provided in this documentation.

- Read the operating, maintenance and safety instructions in your language before starting up the machine. If you find that you cannot completely understand the documentation for your product, please ask your supplier to clarify.

- Proper and correct transport, storage, assembly and installation as well as care in operation and maintenance are prerequisites for optimal and safe operation of this equipment.

- Only persons who are trained and qualified for the use and operation of the equipment may work on this equipment or within its proximity.

  - The persons are qualified if they have sufficient knowledge of the assembly, installation and operation of the equipment as well as an understanding of all warnings and precautionary measures noted in these instructions.

  - Furthermore, they must be trained, instructed and qualified to switch electrical circuits and equipment on and off in accordance with technical safety regulations, to ground them and to mark them according to the requirements of safe work practices. They must have adequate safety equipment and be trained in first aid.

- Only use spare parts and accessories approved by the manufacturer.

- Follow all safety regulations and requirements for the specific application as practiced in the country of use.

- The equipment is designed for installation in industrial machinery.

- The ambient conditions given in the product documentation must be observed.

- Use only safety features and applications that are clearly and explicitly approved in the Project Planning Manual.
  For example, the following areas of use are not permitted: construction cranes, elevators used for people or freight, devices and vehicles to transport people, medical applications, refinery plants, transport of hazardous goods, nuclear applications, applications sensitive to high frequency, mining, food processing, control of protection equipment (also in a machine).

- The information given in the documentation of the product with regard to the use of the delivered components contains only examples of applications and suggestions.
  The machine and installation manufacturer must

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

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

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

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- Operation is only permitted if the national EMC regulations for the application are met.
  The instructions for installation in accordance with EMC requirements can be found in the documentation "EMC in Drive and Control Systems".
  The machine or installation manufacturer is responsible for compliance with the limiting values as prescribed in the national regulations.

- Technical data, connections and operational conditions are specified in the product documentation and must be followed at all times.

3.5   Protection Against Contact with Electrical Parts

Note: This section refers to equipment and drive components with voltages above 50 Volts.

Touching live parts with voltages of 50 Volts and more with bare hands or conductive tools or touching ungrounded housings can be dangerous and cause electric shock. In order to operate electrical equipment, certain parts must unavoidably have dangerous voltages applied to them.

DANGER

High electrical voltage! Danger to life, severe bodily harm by electric shock!

⇒ Only those trained and qualified to work with or on electrical equipment are permitted to operate, maintain or repair this equipment.

⇒ Follow general construction and safety regulations when working on high voltage installations.

⇒ Before switching on power the ground wire must be permanently connected to all electrical units according to the connection diagram.

⇒ Do not operate electrical equipment at any time, even for brief measurements or tests, if the ground wire is not permanently connected to the points of the components provided for this purpose.

⇒ Before working with electrical parts with voltage higher than 50 V, the equipment must be disconnected from the mains voltage or power supply. Make sure the equipment cannot be switched on again unintended.

⇒ The following should be observed with electrical drive and filter components:

⇒ Wait five (5) minutes after switching off power to allow capacitors to discharge before beginning to work. Measure the voltage on the capacitors before beginning to work to make sure that the equipment is safe to touch.

⇒ Never touch the electrical connection points of a component while power is turned on.

⇒ Install the covers and guards provided with the equipment properly before switching the equipment on. Prevent contact with live parts at any time.

⇒ A residual-current-operated protective device (RCD) must not be used on electric drives! Indirect contact must be prevented by other means, for example, by an overcurrent protective device.

⇒ Electrical components with exposed live parts and uncovered high voltage terminals must be installed in a protective housing, for example, in a control cabinet.

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To be observed with electrical drive and filter components:

DANGER

High electrical voltage on the housing!
High leakage current! Danger to life, danger of injury by electric shock!

⇒ Connect the electrical equipment, the housings of all electrical units and motors permanently with the safety conductor at the ground points before power is switched on. Look at the connection diagram. This is even necessary for brief tests.

⇒ Connect the safety conductor of the electrical equipment always permanently and firmly to the supply mains. Leakage current exceeds 3.5 mA in normal operation.

⇒ Use a copper conductor with at least 10 mm² cross section over its entire course for this safety conductor connection!

⇒ Prior to startups, even for brief tests, always connect the protective conductor or connect with ground wire. Otherwise, high voltages can occur on the housing that lead to electric shock.

3.6 Protection Against Electric Shock by Protective Low Voltage (PELV)

All connections and terminals with voltages between 0 and 50 Volts on Rexroth products are protective low voltages designed in accordance with international standards on electrical safety.

WARNING

High electrical voltage due to wrong connections! Danger to life, bodily harm by electric shock!

⇒ Only connect equipment, electrical components and cables of the protective low voltage type (PELV = Protective Extra Low Voltage) to all terminals and clamps with voltages of 0 to 50 Volts.

⇒ Only electrical circuits may be connected which are safely isolated against high voltage circuits. Safe isolation is achieved, for example, with an isolating transformer, an opto-electronic coupler or when battery-operated.

3.7   Protection Against Dangerous Movements

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

- improper or wrong wiring of cable connections

- incorrect operation of the equipment components

- wrong input of parameters before operation

- malfunction of sensors, encoders and monitoring devices

- defective components

- software or firmware errors

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

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

DANGER

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

⇒ Ensure personal safety by means of qualified and tested higher-level monitoring devices or measures integrated in the installation. Unintended machine motion is possible if monitoring devices are disabled, bypassed or not activated.

⇒ Pay attention to unintended machine motion or other malfunction in any mode of operation.

⇒ Keep free and clear of the machine's range of motion and moving parts. Possible measures to prevent people from accidentally entering the machine's range of motion:

  - use safety fences

  - use safety guards

  - use protective coverings

  - install light curtains or light barriers

⇒ Fences and coverings must be strong enough to resist maximum possible momentum, especially if there is a possibility of loose parts flying off.

⇒ Mount the emergency stop switch in the immediate reach of the operator. Verify that the emergency stop works before startup. Don't operate the machine if the emergency stop is not working.

⇒ Isolate the drive power connection by means of an emergency stop circuit or use a starting lockout to prevent unintentional start.

⇒ Make sure that the drives are brought to a safe standstill before accessing or entering the danger zone. Safe standstill can be achieved by switching off the power supply contactor or by safe mechanical locking of moving parts.

⇒ 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

  - ensuring sufficient equilibration of the vertical axes

  The standard equipment motor brake or an external brake controlled directly by the drive controller are not sufficient to guarantee personal safety!

⇒ Disconnect electrical power to the equipment using a master switch and secure the switch against reconnection for:

- maintenance and repair work

- cleaning of equipment

- long periods of discontinued equipment use

⇒ Prevent the operation of high-frequency, remote control and radio equipment near electronics circuits and supply leads. If the use of such equipment cannot be avoided, verify the system and the installation for possible malfunctions in all possible positions of normal use before initial startup. If necessary, perform a special electromagnetic compatibility (EMC) test on the installation.

3.8 Protection Against Magnetic and Electromagnetic Fields During Operation and Mounting

Magnetic and electromagnetic fields generated near current-carrying conductors and permanent magnets in motors represent a serious health hazard to persons with heart pacemakers, metal implants and hearing aids.

WARNING

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

⇒ Persons with heart pacemakers, hearing aids and metal implants are not permitted to enter the following areas:

- Areas in which electrical equipment and parts are mounted, being operated or started up.

- Areas in which parts of motors with permanent magnets are being stored, operated, repaired or mounted.

⇒ If it is necessary for a person with a heart pacemaker to enter such an area, then a doctor must be consulted prior to doing so. Heart pacemakers that are already implanted or will be implanted in the future, have a considerable variation in their electrical noise immunity. Therefore there are no rules with general validity.

⇒ Persons with hearing aids, metal implants or metal pieces must consult a doctor before they enter the areas described above. Otherwise, health hazards will occur.

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3.9   Protection Against Contact with Hot Parts

<table>
<tr>
<td>

⚠ **CAUTION**

</td>
<td>

Housing surfaces could be extremely hot! Danger of injury! Danger of burns!

⇒ Do not touch housing surfaces near sources of heat! Danger of burns!

⇒ After switching the equipment off, wait at least ten (10) minutes to allow it to cool down before touching it.

⇒ Do not touch hot parts of the equipment, such as housings with integrated heat sinks and resistors. Danger of burns!

</td>
</tr>
</table>

3.10   Protection During Handling and Mounting

Under certain conditions, incorrect handling and mounting of parts and components may cause injuries.

<table>
<tr>
<td>

⚠ **CAUTION**

</td>
<td>

Risk of injury by incorrect handling! Bodily harm caused by crushing, shearing, cutting and mechanical shock!

⇒ Observe general installation and safety instructions with regard to handling and mounting.

⇒ Use appropriate mounting and transport equipment.

⇒ Take precautions to avoid pinching and crushing.

⇒ Use only appropriate tools. If specified by the product documentation, special tools must be used.

⇒ Use lifting devices and tools correctly and safely.

⇒ For safe protection wear appropriate protective clothing, e.g. safety glasses, safety shoes and safety gloves.

⇒ Never stand under suspended loads.

⇒ Clean up liquids from the floor immediately to prevent slipping.

</td>
</tr>
</table>

3.11 Battery Safety

Batteries contain reactive chemicals in a solid housing. Inappropriate handling may result in injuries or material damage.

CAUTION

Risk of injury by incorrect handling!

⇒ Do not attempt to reactivate discharged batteries by heating or other methods (danger of explosion and cauterization).

⇒ Never charge non-chargeable batteries (danger of leakage and explosion).

⇒ Never throw batteries into a fire.

⇒ Do not dismantle batteries.

⇒ Do not damage electrical components installed in the equipment.

Note: Be aware of environmental protection and disposal! The batteries contained in the product should be considered as hazardous material for land, air and sea transport in the sense of the legal requirements (danger of explosion). Dispose batteries separately from other waste. Observe the legal requirements in the country of installation.

3.12 Protection Against Pressurized Systems

Certain motors and drive controllers, corresponding to the information in the respective Project Planning Manual, must be provided with pressurized media, such as compressed air, hydraulic oil, cooling fluid and cooling lubricant supplied by external systems. Incorrect handling of the supply and connections of pressurized systems can lead to injuries or accidents. In these cases, improper handling of external supply systems, supply lines or connections can cause injuries or material damage.

CAUTION

Danger of injury by incorrect handling of pressurized systems !

⇒ Do not attempt to disassemble, to open or to cut a pressurized system (danger of explosion).

⇒ Observe the operation instructions of the respective manufacturer.

⇒ Before disassembling pressurized systems, release pressure and drain off the fluid or gas.

⇒ Use suitable protective clothing (for example safety glasses, safety shoes and safety gloves)

⇒ Remove any fluid that has leaked out onto the floor immediately.

Note: Environmental protection and disposal! The media used in the operation of the pressurized system equipment may not be environmentally compatible. Media that are damaging the environment must be disposed separately from normal waste. Observe the legal requirements in the country of installation.

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Notes

4   Master Communication

4.1   Basic Functions of Master Communication

The basic functions of master communication apply to each type of master communication, in the case of IndraDrive devices to SERCOS interface, field bus interface, parallel and analog interface.

The following are the basic functions:

- address assignment
- command processing
- device control (status machine)

Possibility of control for all IndraDrive master communications via:

- signal control word/signal status word

Address Assignment

Each drive is identified by its own address. Multiple addressing is not allowed.

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

Note: The address entered in parameter **P-0-4025, Drive address of master communication** takes effect during the transition from P0 → P1. The active device address is displayed in parameter **S-0-0096, Slave arrangement (SLKN)**.

Address Setting via Control Panel

The drive address for IndraDrive controllers can be set via the standard control panel at the front of the device.
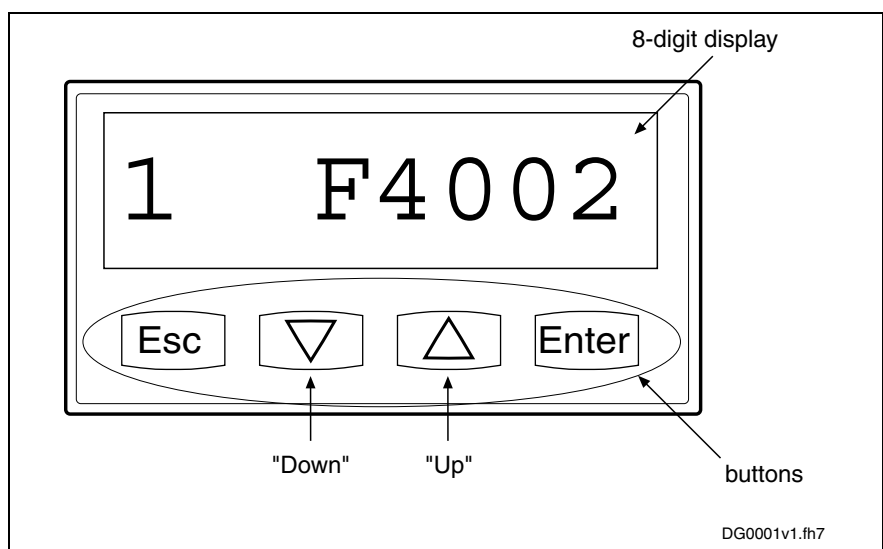
Fig. 4-1:   Standard control panel (example of display)

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The address is set via the control panel as follows:

1. change to "commands/settings" mode
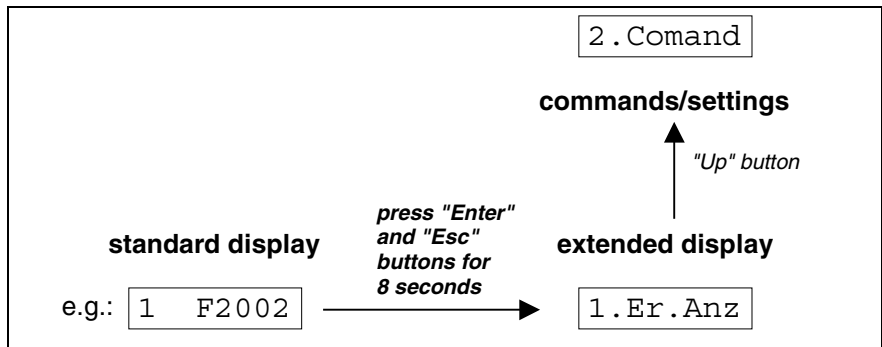
Fig. 4-2:   Activating the "commands/settings" mode

2. select element "2.1 drive address" by means of "Up/Down" buttons, then confirm by means of "Enter" button

3. set drive address by means of "Up/Down" buttons, then confirm by means of "Enter" button

   - first set **tens digit**:
     → the display reads "2.1.1 drive address"

   - then set **units digit**:
     → the display reads "2.1.2 drive address"

Note: The tens or units digit is accepted by pressing the "Enter" button. To return press the "Esc" button.
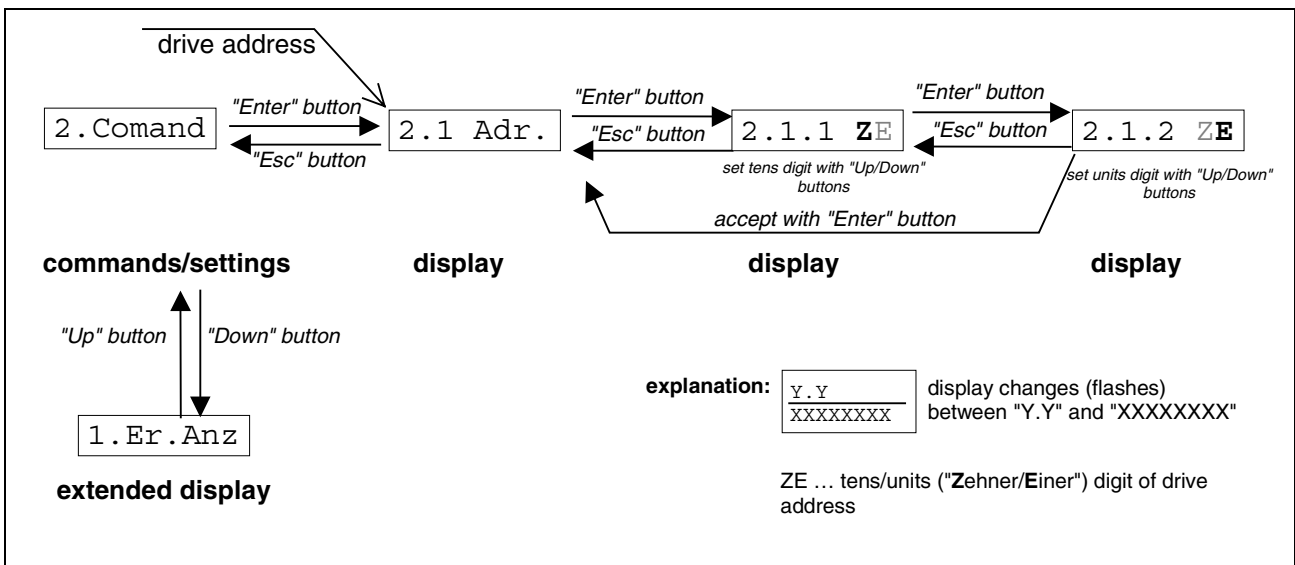
Fig. 4-3:   Selecting and setting the drive address

Address Setting via Parameter

The drive address can also be set by writing the **P-0-4025, Drive address of master communication** parameter. 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" in chapter "Handling, Diagnostic and Service Functions"

Command Processing

Basics

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.

The higher-level master can start, interrupt or clear commands. Belonging to each command there is a parameter with which the command can be controlled.

While a command is being executed, the diagnostic message "Cx" appears on the display, "x" representing the number of the command.

Note: Each command that was started by a control unit must be actively cleared again.

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

Kinds of Commands   There are 3 different kinds of commands:

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

Command Input and Acknowledgment

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

Command Input   The command input can be:

- 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.

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

Command Status   The command status can be:

- 0x0:   not set and not enabled
- 0x7:   in process

- 0xF: error, command execution impossible
- 0x5:   command execution interrupted
- 0x3:   command correctly executed

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

- The bit is set by the drive when the command acknowledgment changes from the "in process" (0x7) status to the "error, command execution impossible" (0xF) or "command correctly executed" (0x3) status.

- The bit is cleared when the master clears the input (0x0).
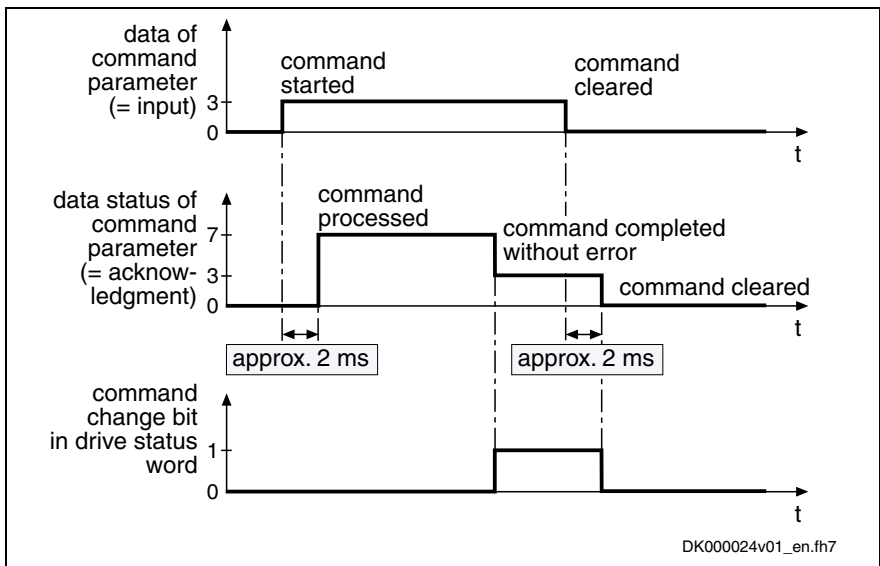
Fig. 4-4:   Input, acknowledgment and command change bit **in the case of correct execution**
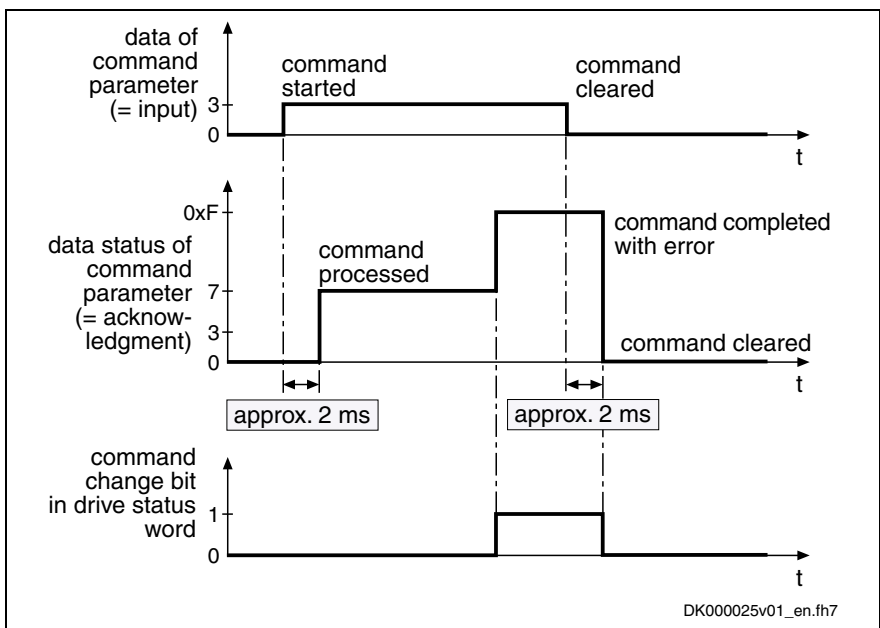
Fig. 4-5:   Input, acknowledgment and command change bit **in the case of incorrect execution**

Device Control (Status Machine)

Brief Description

The drive status (e.g. Drive Halt, drive errors) represents a specific internal and external drive behavior. The drive status can be exited by defined events (e.g. drive commands, switching of operating modes). Corresponding status transitions are assigned to the events. The status transitions or the interaction of control and status bits are called status machine. The figure below shows the schematic diagram of the device control (status machine) of an IndraDrive device.

P-0-0116, Device control: control word
  Bit 15   → drive ON
  Bit 14   → drive enable
  Bit 13   → Drive Halt
P-0-0115, Device control: status word
  Bit 15...14   → readiness for operation
  Bit 13   → drive error
  Bit 4   → Drive Halt
  Bit 3   → drive follows command value
S-0-0014, Interface status
  Bit 2...0   → active communication phase

command execution
P-0-0115:   Bit 15...13 = 110
            Bit 4,3 = 00
S-0-0014:   Bit 2...0 = 100

e.g. spindle positioning
      homing
      set absol. measuring

WARNING
P-0-0115:   Bit 2 = 1

start command   complete command

error situation
(e.g. F8060)

drive enable (AF)
P-0-0115:   Bit 15...13 = 110
            Bit 4,3 = 01
S-0-0014:   Bit 2...0 = 100

Fxxx
P-0-0115:   Bit 15...13 = 101
            Bit 4,3 = 00
S-0-0014:   Bit 2...0 = 100

P-0-0116:
Bit 15...13 = 110

Drive Halt (AH)
P-0-0115:   Bit 15...13 = 110
            Bit 4,3 = 10
S-0-0014:   Bit 2...0 = 100

P-0-0116:
Bit 15...13 = 111

sec. oper. mode 3
sec. oper. mode 2
sec. oper. mode 1
prim. mode of oper.

error reaction
(depending on error class
and parameterization)

drive in control

P-0-0116:
Bit 15...13 = 011

P-0-0116:
Bit 15...13 = x0x

P-0-0116:
Bit 15...13 = 01x

C0400 (P-0-4023)
(not for SERCOS)

torque disable
(only for SERCOS)

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

C0500
(S-0-0099)

C0401
P-0-0115:   Bit 15...13 = 11x
            Bit 4,3 = 0x
S-0-0014:   Bit 2...0 = 100

drive ready (Ab)
P-0-0115:   Bit 15...13 = 100
            Bit 4,3 = 00
S-0-0014:   Bit 2...0 = 100

power ON   power OFF

ready for oper. (bb)
P-0-0115:   Bit 15...13 = 010
            Bit 4,3 = 00
S-0-0014:   Bit 2...0 = 100

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)
(not for SERCOS)

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

communic. phase 3 (P3)
P-0-0115:   Bit 15...13 = 000
            Bit 4,3 = 00
S-0-0014:   Bit 2...0 = 011

initializing PLL
check of master communication
configuration (timing, configuration lists, ...)

C0100
(S-0-0127)

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

communic. phase 2 (P2)
P-0-0115:   Bit 15...13 = 000
            Bit 4,3 = 00
S-0-0014:   Bit 2...0 = 010

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

self test, hardware initialization, parameter
initialization, motor initialization

booting process

DC000012v01_en.fh7

Fig. 4-6:   Device control (general status machine)

Pertinent Parameters
- **S-0-0011, Class 1 diagnostics**
- **S-0-0012, Class 2 diagnostics**
- **S-0-0013, Class 3 diagnostics**
- **S-0-0014, Interface status**
- **S-0-0021, IDN list of invalid operating data for communication phase 2**
- **S-0-0022, IDN list of invalid operating data for communication phase 3**
- **S-0-0032, Primary mode of operation**
- **S-0-0033, Secondary operating mode 1**
- **S-0-0034, Secondary operating mode 2**
- **S-0-0035, Secondary operating mode 3**
- **S-0-0099, C0500 Reset class 1 diagnostics**
- **S-0-0127, C0100 Communication phase 3 transition check**
- **S-0-0128, C0200 Communication phase 4 transition check**
- **S-0-0134, Master control word**
- **S-0-0135, Drive status word**
- **S-0-0144, Signal status word**
- **P-0-0115, Device control: status word**
- **P-0-0116, Device control: control word**
- **P-0-4023, C0400 Communication phase 2 transition**
- **P-0-4028, Device control word**
- **P-0-4068, Field bus: control word IO**
- **P-0-4077, Field bus: control word**
- **P-0-4078, Field bus: status word**
- **P-0-4086, Master communication status**

Control Word and Status Word of Master Communication

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

Depending on the master communication, different parameters are used:
- SERCOS interface
  - **S-0-0134, Master control word**
  - **S-0-0135, Drive status word**
- field bus interface (e.g. PROFIBUS)
  - **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 parameters are used drive-internally:
- **P-0-0115, Device control: status word**
- **P-0-0116, Device control: control word**

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The figure below illustrates the interaction of the above control and status words:
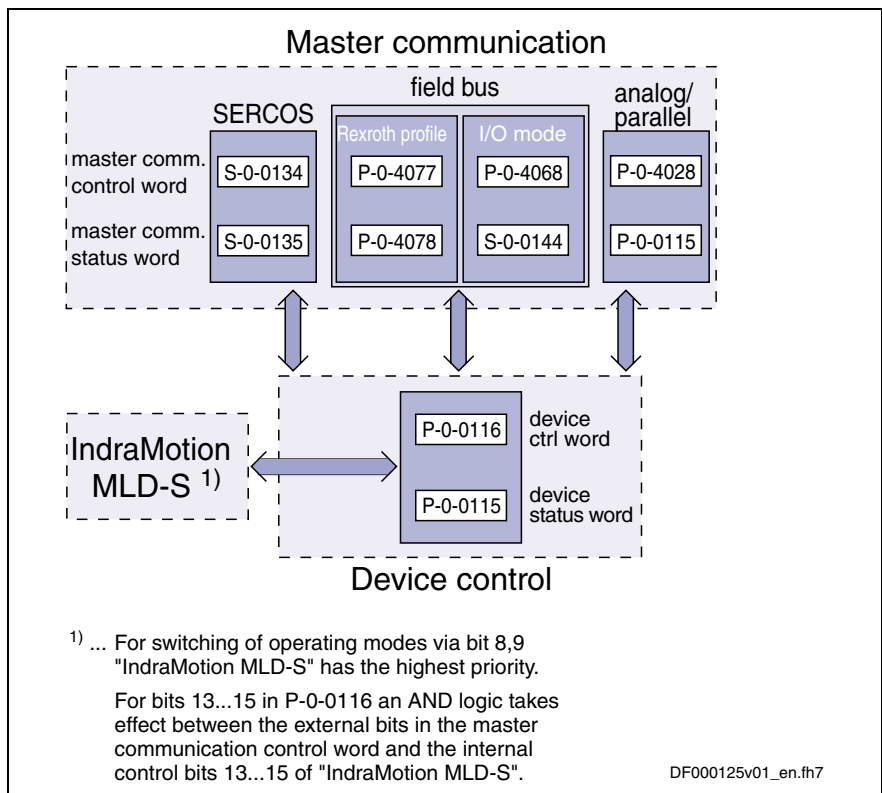
Fig. 4-7:   Interaction of the available control and status words

> **i** See also separate documentation "IndraMotion MLD-S"

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

Timing Diagrams for Device Control

Note: The control bits in parameter S-0-0134, Master control word are input externally via the master communication (the following examples are valid for SERCOS)!

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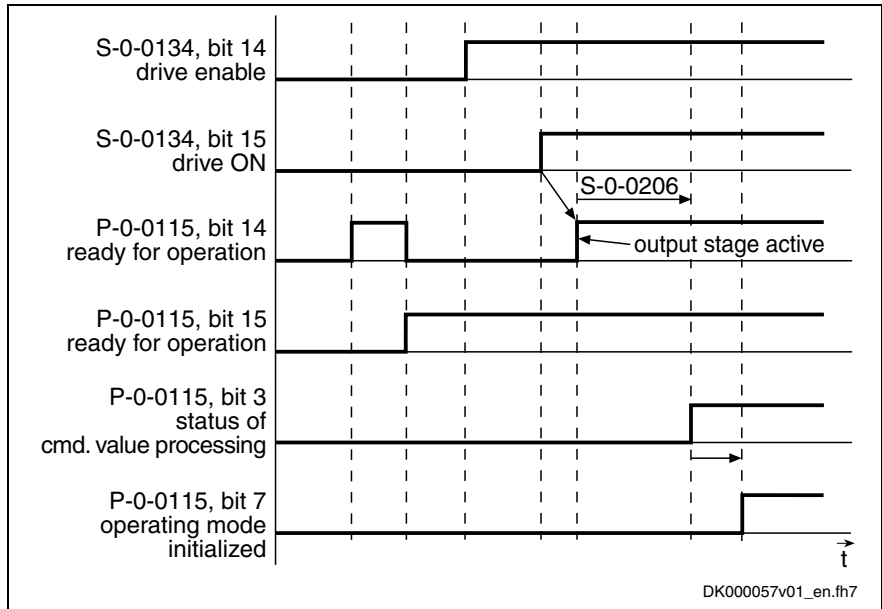
S-0-0206:   drive on delay time

Fig. 4-8:   Bit sequence during switch-on process

Bit Sequence During Switch-Off Process
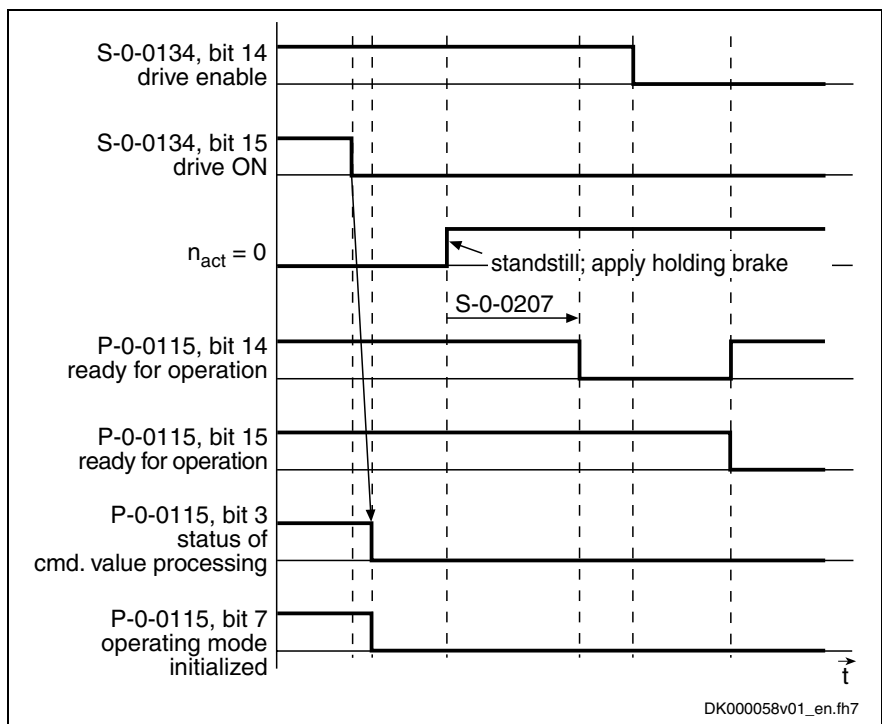
S-0-0207:   drive off delay time

Fig. 4-9:   Bit sequence during switch-off process

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Bit Sequence During Error Reaction

DK000059v01_en.fh7
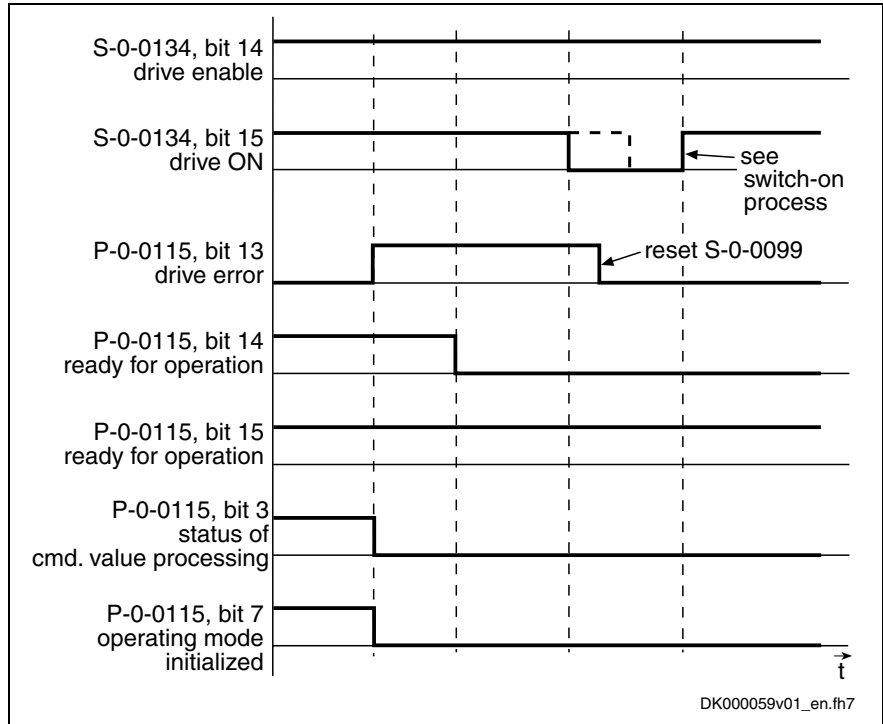
S-0-0099:   C0500 Reset class 1 diagnostics

Fig. 4-10:   Bit sequence during error reaction

Bit Sequence During Change of Operating Modes

DK000060v01_en.fh7
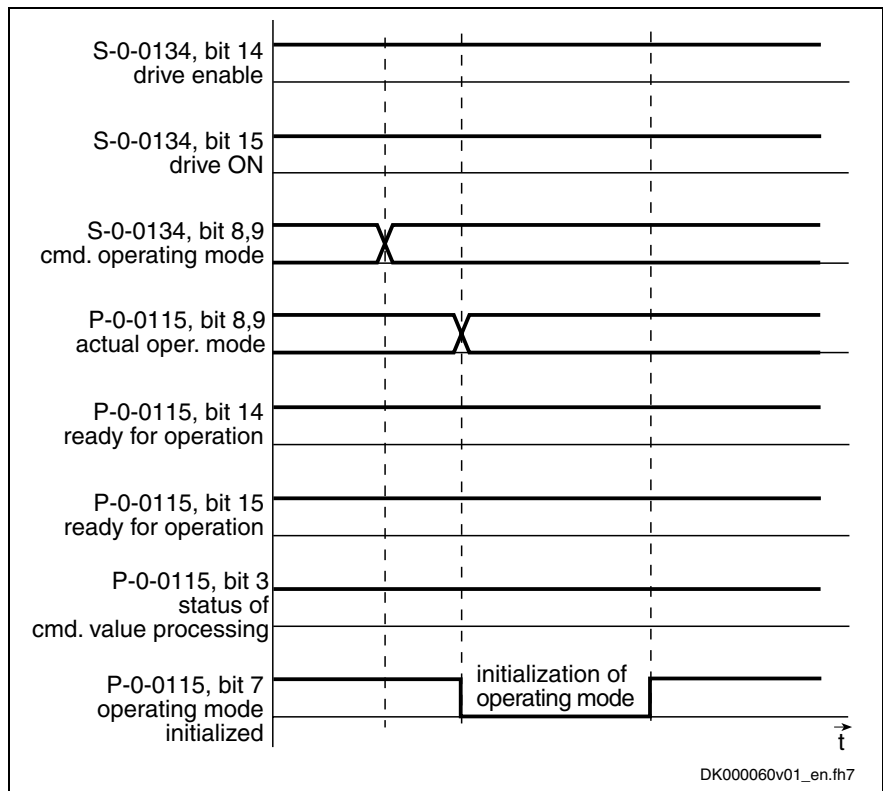
Fig. 4-11:   Bit sequence during change of operating modes

Communication Phases According to SERCOS Specification

Note: For drives of the IndraDrive range the communication phases according to SERCOS specification are valid for all kinds of master communication. The only restriction is that for field bus and parallel/analog interface only the communication phases 2, 3 and 4 are supported.
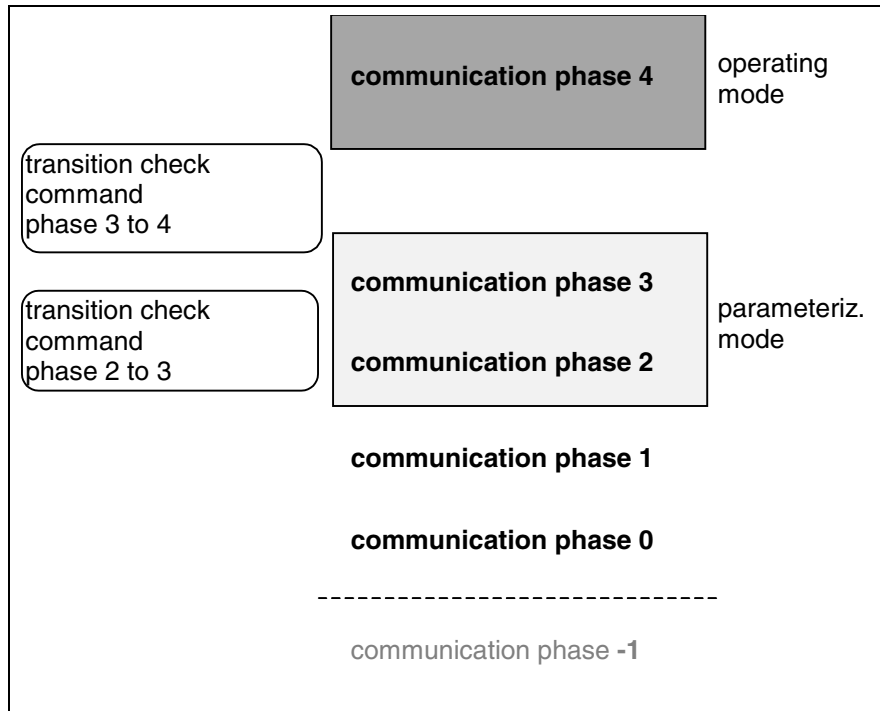
Fig. 4-12: Communication phases of the drive according to SERCOS specification

Note: The currently valid communication phase is contained in parameter **S-0-0014, Interface status** (bit 0...2). For field bus drives there also is the parameter **P-0-4078, Field bus: status word** (bit 0, 1) for this purpose.

The individual phases (states) have the following functions:

- **P-1**: After it is switched on, the drive goes to phase –1 and carries out a baud rate scan. As soon as the drive receives valid SERCOS telegrams from the master, it changes to phase 0.

- **P0**: The master checks the SERCOS ring by sending synchronization telegrams. During phase 0 communication between master and drive isn't possible yet.

- **P1**: When the ring is closed, the master changes to phase 1 and scans the slaves. In addition, it checks the configuration of the ring.

- **P2**: In phase 2 the complete drive parameterization can be carried out.

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

  - communication parameters (according to SERCOS)

  - motor configuration parameters, holding brake parameters

  - encoder configuration parameters

  - mechanical transmission elements (gear, feed constant)

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- scaling and polarity parameters, position data format, modulo value

- drive control configuration (sampling times, pulse width modulation frequency)

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

- **P3**: When changing from P2 → P3 the parameters that can be changed in phase 2 (see above) are checked and scaling-dependent limit values are determined.

  In phase 3 the following parameters can be changed:

  - parameters for operating mode configuration

  - error reaction settings

  - configuration of analog and digital inputs/outputs

  - configuration of switch on / switch off sequence of drive enable (waiting times, ...)

Note: According to SERCOS specification, the parameterization mode is divided into phases 2 and 3. In phase 3 the limit values for all scaling-dependent parameters are known. If these parameters are written in phase 3, an extreme value check is carried out. This makes masters that distinguish between phase 2 and phase 3 more comfortable when establishing the readiness for operation.

- **P4**: In phase 4, the so-called operating mode, only the cyclic data can be changed, the configuration parameters cannot. The switch to the operating mode always causes a new initialization of all functions available in the drive.

The supported communication phases, as well as the handling of the switching between the communication phases (e.g. parameterization and operating mode) are depending on the master communication that is used. The control information preset for master communication is displayed in parameter **P-0-4086, Master communication status**.

- **SERCOS interface**
  For SERCOS devices **all 5 communication phases** (as well as phase −1 → baud rate scan) are supported. According to SERCOS specification, switching takes place by setting the communication phase by the master.

- **Field bus interface**
  For field bus devices **only the communication phases 2 to 4** are supported!

  Switching takes place in the freely configurable operating mode (P-0-4084 = 0xFFFE) by presetting the desired mode via bit 1 in **P-0-4077, Field bus: control word**.
  Switching can also take place by executing the transition check commands (see below).

- **Parallel/analog interface**
  For devices with analog or parallel interface **only the communication phases 2 to 4** are supported!

  Switching always takes place when the transition check commands (see below) are executed.

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

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

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

- **S-0-0127, C0100 Communication phase 3 transition check**
- **S-0-0128, C0200 Communication phase 4 transition check**
.
When the drive has reached communication phase 4 without error, the display reads "bb".
The corresponding diagnostic message is:

- **A0013 Ready for power on**

Transition Check Commands

To switch from communication phase 2 to 3 and from 3 to 4 it is necessary to activate transition check commands in the drive:

- **S-0-0127, C0100 Communication phase 3 transition check**
- **S-0-0128, C0200 Communication phase 4 transition check**

Note: In order to get back from the operating mode to the parameterization mode, there is the command **P-0-4023, C0400 Communication phase 2 transition**.

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 command errors:

- General checks
  - **C0131 Switching to phase 3 impossible**
  - **C0199 Functional package selection changed. Restart**
- Checking the validity of the parameters required for switching to phase 3
  If one of these parameters has never been written or the backup was carried out incorrectly, the error message "C0101" is generated. The IDNs of the faulty parameters are listed in parameter **S-0-0021, IDN list of invalid operating data for communication phase 2**. These parameters have to be set valid by writing correct values to them.
  - **C0101 Invalid parameters (->S-0-0021)**
  - **C0102 Limit error in parameter (-> S-0-0021)**
  - **C0103 Parameter conversion error (->S-0-0021)**
  - **C0138 Invalid control section data (->S-0-0021)**
- Checking the 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.

  Diagnostic messages for SERCOS interface:
  - **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**

  Diagnostic messages for field bus interface:
  - **C0154 Field bus: IDN for cycl. command val. not configurable**

- • **C0155 Field bus: max. length for cycl. command val. exceeded**
- • **C0156 Field bus: IDN for cycl. actual val. not configurable**
- • **C0155 C0157 Field bus: length for cycl. actual values exceeded**
- • **C0158 Field bus: Tcyc (P-0-4076) incorrect**
- • **C0159 Field bus: P-0-4077 missing for cycl. command values**
- Checking the timing parameters for SERCOS communication in phases 3 and 4 for plausibility and compliance with limiting conditions
  - • **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)**
  - • **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)**
- Checking the device and motor configuration
  - • **C0132 Invalid settings for controller cycle times**
  - • **C0135 Type of construction of motor P-0-4014 incorrect**
  - • **C0137 Error during initialization of motor data (->S-0-0021)**
  - • **C0153 Error at init. of synchr. motor with reluctance torque**
- Checking the motor and encoder configuration and parameter contents
  - • **C0119 Max. travel range too large**
  - • **C0120 Error when reading encoder data => motor encoder**
  - • **C0121 Incorrect parameterization of motor encoder (hardware)**
  - • **C0122 Incorr. parameteriz. of motor enc. (mechanical system)**
  - • **C0123 Modulo value for motor encoder cannot be displayed**
  - • **C0124 Motor encoder unknown**
  - • **C0125 Error when reading encoder data => optional encoder**
  - • **C0126 Incorrect parameterization of optional enc. (hardware)**
  - • **C0127 Incorr. parameteriz. of opt. enc. (mechanical system)**
  - • **C0128 Modulo value for optional encoder cannot be displayed**
  - • **C0129 Optional encoder unknown**
  - • **C0130 Maximum travel range cannot be displayed internally**
  - • **C0134 Invalid motor data in encoder memory (->S-0-0021)**
  - • **C0136 Several motor encoders connected**
  - • **C0140 Rotary scaling not allowed**
  - • **C0160 Error when reading encoder data => measuring encoder**
  - • **C0161 Incorr. parameterization of measuring enc. (hardware)**
  - • **C0162 Measuring encoder unknown**
  - • **C0163 Modulo value for measuring encoder cannot be displayed**
  - • **C0164 Incorrect measuring encoder configuration**

Communication Phase 4 Transition Check	With the **S-0-0128, C0200 Communication phase 4 transition check** command the following checks and initializations are carried out that can possibly cause the listed command errors:

- General system checks
  - **C0212 Invalid control section data (->S-0-0022)**
  - **C0243 Brake check function not possible**
  - **C0244 Act. modulo value cycle greater than max. travel range**
  - **C0245 Operating mode configuration (->S-0-0022) not allowed**
- Checks during encoder initialization
  - **C0220 Error when initializing position of encoder 1**
  - **C0221 Initialization velocity encoder 1 too high**
  - **C0224 Error when initializing position of encoder 2**
  - **C0225 Initialization velocity encoder 2 too high**
  - **C0227 Error when initializing position of encoder 3**
  - **C0228 Initialization velocity measuring encoder too high**
  - **C0257 No encoder assigned to slot 1**
- Initializing the optional additional functions (digital I/Os)
  - **C0246 Trav. range lim. switch not ass. to dig. input**
  - **C0247 Dig. output already assigned to another axis**
  - **C0248 Dig. input assigned differently to axes**
  - **C0249 Dig. I/Os: bit number too large**
  - **C0250 Probe inputs incorrectly configured**
- Limit value check, interface configuration
  - **C0201 Invalid parameters (->S-0-0022)**
  - **C0202 Parameter limit error (->S-0-0022)**
  - **C0203 Parameter calculation error (->S-0-0022)**
  - **C0242 Multiple configuration of a parameter (->S-0-0022)**
- Checking the master communication
  - **C0251 Error during synchronization to master communication**
  - **C0258 Error in relation TNcyc (S-0-0001) to fine interpol.**
- Initialization of integrated safety technology
  - **C0255 Safety command for system init. incorrect**
  - **C0256 Plausibility error of safety control words**

4.2   Possibilities of Control/Additional Functions

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.

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

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)

Note: For SERCOS and field bus interface the **S-0-0145, Signal control word** parameter must be accordingly configured in the cyclic data so that the configure control bits are evaluated.

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

Notes on Commissioning the Signal Control Word

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

Configuring the IDNs   In the **S-0-0027, Configuration list signal control word** parameter 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**.

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

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

Exceptions
- If the assigned parameter is a command, the bit number in the **S-0-0329, Assign list signal control word** parameter is irrelevant.
- If the parameter assigned is parameter **S-0-0346, Positioning command strobe**, a positive edge in the respective bit of the control word causes toggling of parameter S-0-0346.

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

Diagnostic Messages and Error Messages

When entering data in the parameters **S-0-0027, Configuration list signal control word** and **S-0-0329, Assign list signal control word** the following check is run:

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

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

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 containing all status information of the drive relevant for the control unit.

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

Pertinent Parameters

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

Notes on Commissioning the Signal Status Word

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

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

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

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

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

Bit no. in S-0-0144, Signal status word	S-0-0026 IDN of original parameter	S-0-0328 Bit no. of original parameter	Meaning
0	S-0-0403	0	position status

Fig. 4-13:   Example of configuration of signal status word

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

Diagnostic Messages and Error Messages

The following check is run when inputting data in the parameters **S-0-0328, Assign list signal status word** and **S-0-0026, Configuration list signal status word**:

- Check whether the IDN specified in S-0-0026 has variable data length (list parameter) or a so-called online read function. If yes, the service channel error message "0x7008 Invalid data" is generated.
  Parameters with online read function generally are parameters with physical units (position, speed, acceleration and currents), as well as the parameters **S-0-0135, Drive status word** and **S-0-0011, Class 1 diagnostics**.

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

4.3   Profile Types (with Field Bus Interfaces)

Overview

When a field bus interface is used for master communication, IndraDrive controllers support two profile types (modes).

- **I/O mode** (functionality similar to parallel interface)
- **freely configurable mode** (functionality similar to SERCOS)
  → Rexroth profile type

Supported Profile Types

Content P-0-4084, Profile type	Master communic-ation	Field bus or drive operating mode	Description
Profile type: I/O mode			
FF82h	PROFIBUS	I/O mode can be freely expanded (positioning block mode, encoder 1, lagless + expandable real-time channel)	This profile type allows controlling up to 64 positioning blocks via the field bus. Apart from the control and status word it is possible to configure further real-time data in the list parameters P-0-4080 and P-0-4081. The determination of the bits in the signal status word can be freely defined via the "configurable signal status word" function.
Profile type: freely configurable mode			
FFFEh	PROFIBUS	freely configurable operating mode (without profile interpreter)	This profile type allows using the complete drive functionality by free configuration of the real-time data and selection of the operating mode. Control word and status word have a Rexroth-specific structure. This selection is suitable for operation with analog command values in the commissioning phase.

Fig. 4-14:   Supported profile types of FWA-INDRV*-MPX-02VRS

Explanation of Terms

Drive Profile   The drive profile defines

- the structure of the field bus control word (P-0-4077) and of the field bus status word (P-0-4078),
- the structure and content of real-time channel (P-0-4080, P-0-4081),
- the active operating mode (S-0-0032, S-0-0033, S-0-0034, S-0-0035)
- the drive states and their transitions (status machine of I/O mode or Rexroth profile type).

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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 independent of the bus, the transfer of applications from one field bus to the other is also facilitated.

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

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

Assignment to the Drive-Internal Operating Modes

Note: By selecting the I/O mode (P-0-4084 = 0xFF82) the primary mode of operation active in the drive is defined. "Jogging" or "drive-controlled positioning - jog mode" is automatically set as the 1st secondary operating mode.

There are the following relationships between the parameters **P-0-4084, Profile type** and **S-0-0032, Primary mode of operation**:

- **I/O mode** with 16-bit status word and 16-bit control word
  (P-0-4084 = 0xFF82 → functionally compatible with DKC3.1)

  This means that the drive is operated in the mode "positioning block mode, encoder 1, lagless"!

- **Freely configurable mode**
  - no profile-dependent settings and checks
  - free configuration of real-time channel by configuration lists P-0-4080 and P-0-4081
  - allows analog operation for initial commissioning

Pertinent Parameters

- **S-0-0026, Configuration list signal status word**
- **S-0-0144, Signal status word**
- **S-0-0328, Assign list signal status word**
- **P-0-4068, Field bus: control word IO**
- **P-0-4071, Field bus: length of cyclic command value data channel**
- **P-0-4074, Field bus: data format**
- **P-0-4077, Field bus: control word**
- **P-0-4078, Field bus: status word**
- **P-0-4080, Field bus: config. list of cyclic actual value data ch.**
- **P-0-4081, Field bus: config. list of cyclic command value data ch.**
- **P-0-4082, Field bus: length of cyclic actual value data channel**

- **P-0-4083, Field bus: length of parameter channel**
- **P-0-4084, Field bus: profile type**

I/O Mode

Brief Description

Features

- The drive is operated in "positioning block mode without lag error with encoder 1" (see also "Positioning Block Mode" in chapter "Operating Modes").
- In this operating 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**. As the 1st secondary operating mode, "drive-controlled positioning" was set (see also "Drive-Controlled Positioning" in chapter "Operating Modes").
- For PROFIBUS-DP it is possible to activate an optional parameter channel with **P-0-4083, Field bus: length of parameter channel** (a maximum of 6 words). (default: P-0-4083 = 0 → without parameter channel)
- In the I/O mode each 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).

Structure of Real-Time Channel Master → Slave

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

Parameters	Format
P-0-4068, Field bus: control word IO	u16 (1 word)

Structure of Real-Time Channel Slave → Master

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

Parameters	Format
S-0-0144, Signal status word	u16 (1 word)

Content of Data in Real-Time Channel

Data direction	Word1
master → slave	P-0-4068
slave → master	S-0-0144

Status Machine in I/O Mode

Note: The content of parameter **P-0-4068, Field bus: control word IO** is only relevant for profile type "I/O mode" (P-0-4084 = 0xFF82).

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 cannot be changed by the user. If additional control bits should be required, the parameter **S-0-0145, Signal control word** has to be configured accordingly and transmitted to the real-time channel of the field bus.

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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 mode (P-0-4084 = 0xFF82) the parameter **S-0-0144, Signal status word** is transmitted instead of the field bus status word (P-0-4078). The configuration of S-0-0144 is preset by a default setting (see below) that corresponds to the standard I/O mode (cf. ECODR3-FGP-20VRS)

- If required, the structure of parameter S-0-0144 can be freely defined via the two configuration parameters **S-0-0026, Configuration list signal status word** and **S-0-0328, Assign list signal status word**.

Bit	Assignment	Significance
0	active operating mode	**1:** jogging (S-0-0437) **0:** positioning
1	position switch point (PSP)	**1:** to the right of PSP **0:** to the left of PSP (S-0-0060)
2	in reference	**1:** drive has been homed (S-0-0403)
3	in motion	**0:** in motion (S-0-0331)
4	in position	**1:** drive is in positioning window & no sequential block (P-0-4061)
5	drive error (error flag)	**1:** error (P-0-0115) **0:** no error
6	readiness for operation; display "bb"	**1:** ready for operation (P-0-0115)
7	power switched on; display "Ab"	**1:** power has been switched on (P-0-0115)
8…13	positioning block acknowledgment	**P-0-4051, Positioning block acknowledgment**
14…15	not assigned	

Fig. 4-15:   Default assignment of parameter **S-0-0144, Signal status word** in I/O mode (P-0-4084 = 0xFF82)

Note: 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 Parameter Description "S-0-0144, Signal status word"

Interaction of control and status bits (status machine):
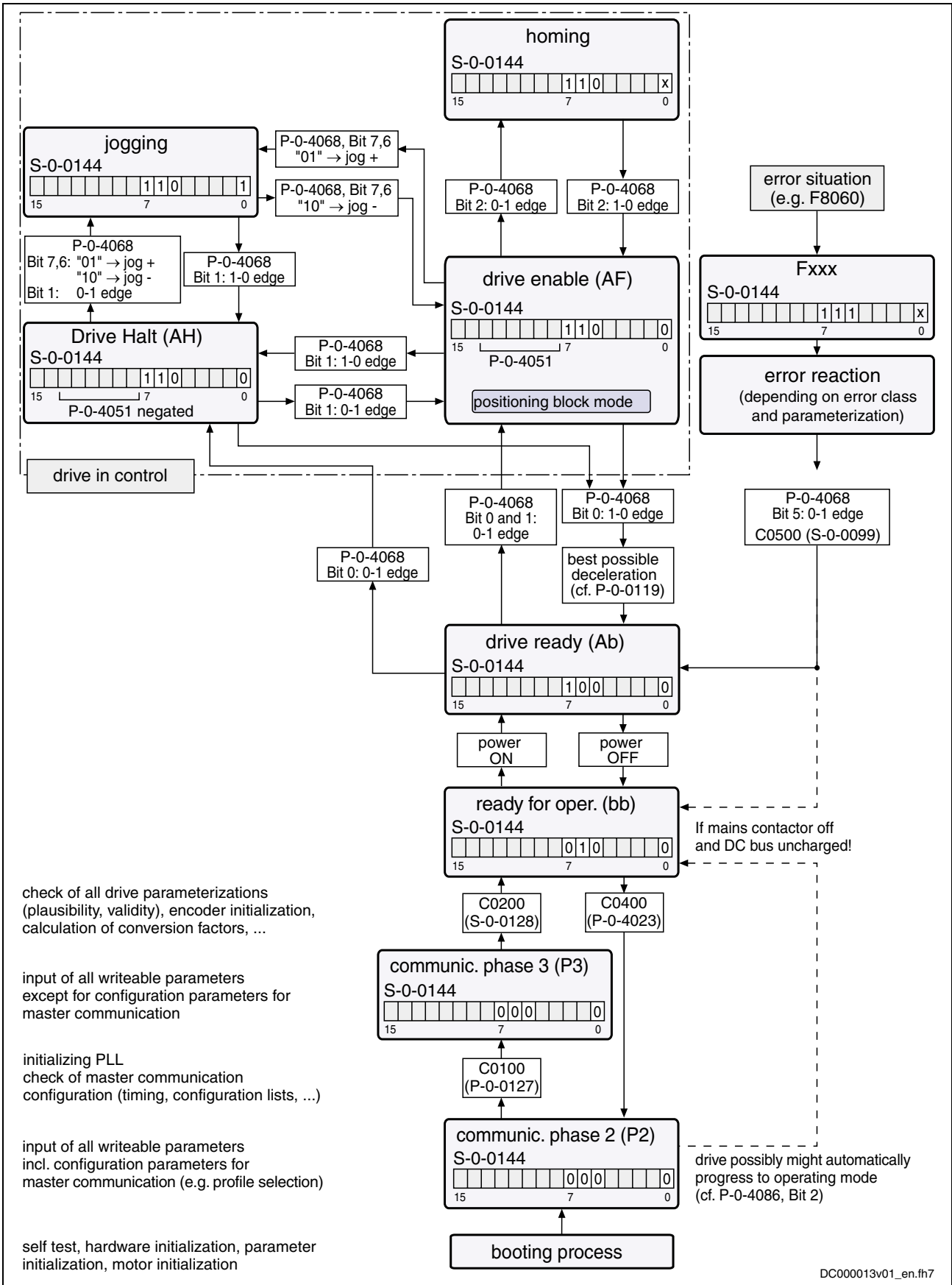
Fig. 4-16:   Device control in I/O mode (status machine of I/O mode)

Note:	The data for the field bus status word refer to the I/O mode with block acknowledgment (default configuration).

Notes on Parameterization/Commissioning

Features with Default Configuration

The following settings are made in the I/O mode as default setting:

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

- Bits 0...5 of **P-0-4051**, **Positioning block acknowledgment** are copied to bits 8...13 of **S-0-0144, Signal status word**.

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

Note:	With this profile selection, the functional compatibility to the DKC3.1 drive controllers is established! Control units that process the real-time data in Motorola format have the high byte and low byte interchanged compared to the DKC3.1!

Features and Settings with Free Configuration or Expansion

There are the following possibilities for free configuration/expansion:

- The user can freely expand the length of cyclic data channel P-0-4082 or P-0-4071 up to a maximum of 9 words. Apart from the control and status word, further 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 signal status word** and **S-0-0328, Assign list signal status word**.

Freely Configurable Mode (Rexroth Profile Type)

Brief Description

To use the extensive and numerous functions of a Rexroth drive with field bus interface it is necessary, in addition to the I/O mode (downwards compatible to the DKC3.1), to define another profile, the freely configurable mode. This implies the use of a new controls 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 the Rexroth-specific definitions for the field bus control and status words 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 operating modes.

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

- The primary and secondary modes of operation can be freely selected via S-0-0032, S-0-0033, S-0-0034 and S-0-0035.

Note: The parameter **P-0-4077, Field bus control word** or **P-0-4078, Field bus status word** must always be contained in the 1st place in the configuration parameters P-0-4080 and P-0-4081.

Structure of Real-Time Channel
Master → Slave

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

Parameters	Format	Object
P-0-4077, Field bus: control word	u16 (1 word)	6040
optional command values	:	

Note: The IDNs of the parameters of the cyclically configurable command values are listed in **S-0-0188, List of configurable data in the MDT**.

Structure of Real-Time Channel
Slave → Master

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

Parameters	Format	Object
P-0-4078, Field bus: status word	u16 (1 word)	6041
Optional actual values	:	

Note: The IDNs of the parameters of the cyclically configurable actual values are listed in **S-0-0187, List of configurable data in the AT**.

Content and Order of Data in
Real-Time Channel

Data direction	Word1	Word2	...	Word n
master → slave	P-0-4077	command value 1	...	
slave → master	P-0-4078	actual value 1	...	

Status Machine in Freely Configurable Mode (Rexroth Profile Type)

Each field bus drive of Bosch Rexroth, regardless of the command communication interface, is equipped with a uniform "status 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"

For this profile type the field bus control word or status word is preset by Bosch Rexroth and cannot be changed by the user. 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.

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

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

Note: 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 inherent part of the real-time channel.

See also "Device Control" in section "Basic Functions of Master Communication"

Interaction of control and status bits (status machine):

homing
P-0-4078
| 1 | 1 | 0 | 0 | x | | | | 1 | 0 | | | | 1 | 0 |
| 15 | | | | | | | 7 | | | | | | | 0 |

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

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 2 = 1

P-0-4077 Bit 2 = 0

error situation (e.g. F8060)

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

P-0-4077 Bit 13 = 0

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

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

drive enable (AF)
P-0-4078
| 1 | 1 | 0 | 0 | x | | | | 0 | 0 | | | | 1 | 0 |
| 15 | | | | | | | 7 | | | | | | | 0 |

P-0-4077 Bit 13 = 0

P-0-4077 Bit 13 = 1

11 sec. oper. mode 3
10 sec. oper. mode 2
01 sec. oper. mode 1
00 prim. mode of oper.

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

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

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

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

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!

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

C0200 (S-0-0128)

C0400 (P-0-4023)

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

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

initializing PLL check of master communication configuration (timing, configuration lists, ...)

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

self test, hardware initialization, parameter initialization, motor initialization

communic. phase 3 (P3)
P-0-4078
| 0 | 0 | 0 | 0 | x | | | | 1 | 0 | | | | 0 | 1 |
| 15 | | | | | | | 7 | | | | | | | 0 |

C0100 (P-0-0127)

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

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)

booting process

DC000014v01_en.fh7

Fig. 4-17: Device control in freely configurable mode (status machine of Rexroth profile type)

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Exemplary Configurations

All of the following examples of configuration are referring 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 with filter and ramp" must have been set as the primary mode of operation in parameter S-0-0032 (see also "Velocity Control" in chapter "Operating Modes").

- Via the field bus the content of parameter **S-0-0036, Velocity command value** is cyclically transmitted in the command value data channel and the contents of **S-0-0040, Velocity feedback value**, **S-0-0051, Position feedback 1 value** and **S-0-0390, Diagnostic message number** are cyclically transmitted in the actual value data channel.

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

- The length of the cyclic data channel has been defined with:
  - P-0-4082 = 12 bytes
  - P-0-4071 = 6 bytes

Structure of Real-Time Channel Master → Slave

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

Parameters	Format
P-0-4077, Field bus: control word	u16 (1 word)
S-0-0036, Velocity command value	i32 (2 words)

Structure of Real-Time Channel Slave → Master

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

Parameter	Format
P-0-4078, Field bus status word	u16 (1 word)
S-0-0040, Velocity feedback value	i32 (2 words)
S-0-0051, Position feedback 1 value	i32 (2 words)
S-0-0390, Diagnostic message number	u32 (2 words)

Content and Order of Data in Real-Time Channel:

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)

Drive-Internal Interpolation

Features/Settings

- "Drive-internal interpolation, encoder 1, lagless" must have been set as the primary mode of operation in parameter S-0-0032 (see also "Drive-Internal Interpolation" in chapter "Operating Modes").

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

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

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

- The length of the cyclic data channel has been defined with:

  - P-0-4082 = 12 bytes
  - P-0-4071 = 10 bytes

Note: 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 Real-Time Channel Master → Slave

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

Parameters	Format
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)

Structure of Real-Time Channel Slave → Master

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

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

Content and Order of Data in Real-Time Channel:

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)

Drive-Controlled Positioning

Features/Settings
- "Drive-controlled positioning, encoder 1, lagless" must have been set as the primary mode of operation in parameter S-0-0032 (see also "Drive-Controlled Positioning" in chapter "Operating Modes").

- The Rexroth-specific definitions for the field bus control and status words are applying (also see section "Freely Configurable Mode (Rexroth Profile Type)").

- By configuring the content of **S-0-0282, Positioning command value** as a cyclic command value, 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 Real-Time Channel Master → Slave

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

Parameters	Format
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)

Structure of Real-Time Channel Slave → Master

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

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

Content and Order of Data in Real-Time Channel:

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)

Using the Signal Control Word and 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 transmitted in addition to 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" in section "Possibilities of Control/Additional Functions"

Features
- By using the parameters S-0-0144 and S-0-0145 there are 16 more freely configurable control and status bits available.

- This allows, among other things, starting commands contained in parameter **S-0-0399, IDN list of configurable data in the signal control word** (see "Configurable Signal Control Word").

- It is possible to read any bit in any parameter (see "Configurable Signal Status Word").

The following settings are required:

Settings
- To configure the bit lists the list parameters S-0-0026, S-0-0328 (for **S-0-0144, Signal status word**) and S-0-0027, S-0-0329 (for **S-0-0145, Signal control word**) can be used.

- To use the function, select profile type "freely configurable mode" (P-0-4084 = 0xFFFE).

- Set "drive-controlled positioning, encoder 1, lagless", for example, in parameter **S-0-0032, Primary mode of operation**.

- Parameterize the configuration lists P-0-4080 and P-0-4081 as follows:

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

Parameters	Format
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)

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

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

Content and Order of Data in Real-Time Channel:

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

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

4.4 SERCOS interface

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 all 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, granularity 2
                (multiples of position clock 250 μs or 500 μs can be set)
- SERCOS compatibility class C
- baud rate: optionally 2, 4, 8 or 16 MBaud
- automatic baud rate detection; active baud rate displayed in a parameter
- adjustable transmitting power (set via control panel)
- max. number of configurable data in the MDT: 32 byte
- max. number of configurable data in the AT: 32 byte

Note: The number of configurable byte 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 = pos. cycle time   → max. length 16 byte

SERCOS cycle time > pos. cycle time   → max. length 32 byte

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i   For more detailed information please see the SERCOS specification.

Pertinent Parameters

- **S-0-0001, NC cycle time (TNcyc)**
- **S-0-0002, SERCOS cycle time (TScyc)**
- **S-0-0003, Minimum AT transmit starting time (T1min)**
- **S-0-0004, Transmit/receive transition time (TATMT)**
- **S-0-0005, Minimum feedback acquisition time (T4min)**
- **S-0-0006, AT Transmission starting time (T1)**
- **S-0-0007, Feedback acquisition starting time (T4)**
- **S-0-0008, Command valid time (T3)**
- **S-0-0009, Beginning address in master data telegram**
- **S-0-0010, Length of master data telegram**
- **S-0-0014, Interface status**
- **S-0-0015, Telegram type parameter**
- **S-0-0016, Configuration list of AT**

- S-0-0024, Config. list of the master data telegram
- S-0-0028, MST error counter
- S-0-0029, MDT error counter
- S-0-0088, Receive to receive recovery time (TMTSY)
- S-0-0089, MDT Transmit starting time (T2)
- S-0-0090, Command value proceeding time (TMTSG)
- S-0-0096, Slave arrangement (SLKN)
- S-0-0097, Mask class 2 diagnostics
- S-0-0098, Mask class 3 diagnostics
- S-0-0134, Master control word
- S-0-0135, Drive status word
- S-0-0143, Sercos interface version
- S-0-0185, Length of the configurable data record in the AT
- S-0-0186, Length of the configurable data record in the MDT
- S-0-0187, List of configurable data in the AT
- S-0-0188, List of configurable data in the MDT
- S-0-0301, Allocation of real-time control bit 1
- S-0-0303, Allocation of real-time control bit 2
- S-0-0305, Allocation of real-time status bit 1
- S-0-0307, Allocation of real-time status bit 2
- S-0-0413, Bit number allocation of real-time control bit 1
- S-0-0414, Bit number allocation of real-time control bit 2
- S-0-0415, Bit number allocation of real-time status bit 1
- S-0-0416, Bit number allocation of real-time status bit 2
- P-0-4027, Transmission length SERCOS interface
- P-0-4029, SCSB diagnostics
- P-0-4087, Baud rate SERCOS interface

Pertinent Diagnostic Messages

- C0104 Config. IDN for MDT not configurable
- C0105 Maximum length for MDT exceeded
- C0106 Config. IDNs for AT not configurable
- C0107 Maximum length for AT exceeded
- C0108 Time slot parameter > Sercos cycle time
- C0109 Position of data record in MDT (S-0-0009) even
- C0110 Length of MDT (S-0-0010) odd
- C0111 ID9 + Record length - 1 > length MDT (S-0-0010)
- C0112 TNcyc (S-0-0001) or TScyc (S-0-0002) error
- C0113 Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error
- C0114 T4 > TScyc (S-0-0002) - T4min (S-0-0005)
- C0115 T2 too small
- C0116 T3 (S-0-0008) within MDT (S-0-0089 + S-0-0010)
- C0139 T2 (S-0-089) + length MDT (S-0-010) > TScyc (S-0-002)
- F4001 Double MST failure shutdown
- F4002 Double MDT failure shutdown
- F4003 Invalid communication phase shutdown
- F4004 Error during phase progression

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- **F4005 Error during phase regression**
- **F4006 Phase switching without ready signal**

Commissioning the SERCOS interface

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
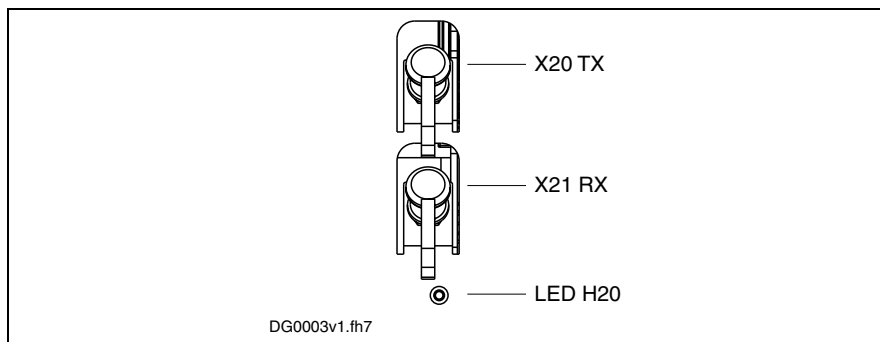
X20 TX: optical output (transmitter)
X21 RX: optical input (receiver)
H20:   distortion indicator LED
Fig. 4-18:   Master communication SERCOS interface

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!

Note: 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).
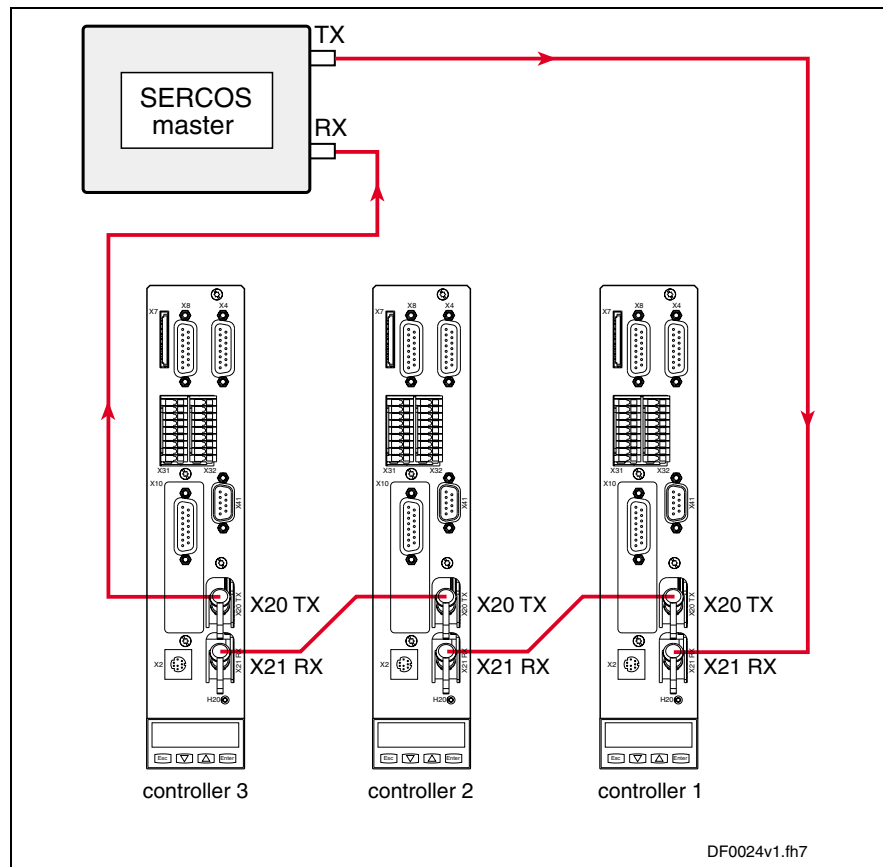
Fig. 4-19: Connecting the fiber optic cables (example)

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

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

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

Setting the Drive Address

The drive address is set in the **P-0-4025, Drive address of master communication** parameter (instead of using the address selector switch as so far). 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 the **P-0-4027, Transmission length SERCOS interface** parameter.

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.

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Ranges of length for the connected fiber optic cable:

- up to 15 m
- 15 m to 30 m
- 30 m to 45 m
- more than 45 m and glass fiber

Transmission Rate of the SERCOS interface

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

Note: 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 "Settings of the SERCOS interface").

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).

Note: 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).

Checking the Transmission Rate

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

Checking 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.

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.

Cyclic Data Transfer

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

The content of master data telegram (MDT) and drive telegram (AT = **A**ntriebs**t**elegramm) can be configured.

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

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

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

Master Control Word

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

- drive on
- drive enable
- Drive Halt
- interpolator clock
- command operating mode
- real-time control bits 1 and 2
- control information for the service channel

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

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

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

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.

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 the S-0-0095 parameter is **A0012 Control and power sections ready for operation**.

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

Drive Halt

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

Drive Status Word

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

• readiness for operation of the control and power sections

• drive error

• change bits class 2 and 3 diagnostics

• current operating mode

• real-time status bits 1 and 2

• status information for the service channel

Note: 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 **S-0-0002, SERCOS cycle time (TScyc)**). For diagnostic purposes, the drive status word can be read via the **S-0-0135, Drive status word** parameter.

Acknowledging Drive Enable

The drive acknowledges the drive enable setting in the drive status word of the drive telegram. In the drive status word, bits 14 and 15 change from "10" (control and power sections ready for operation, without torque) to "11" (in operation, with torque) when drive enable is activated and has been accepted.

The time that passes between the setting of the drive enable and its acknowledgment is needed by the drive to establish its complete

readiness for operation. For example, in the case of asynchronous motors this time is used to magnetize the motor.

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

- the setting of the 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.
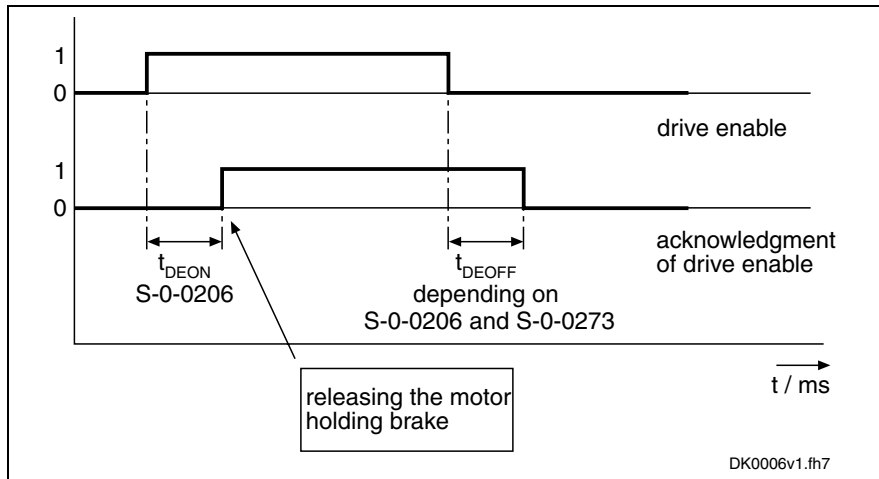
Fig. 4-20: Acknowledging drive enable

Typical values for t$_{DEON}$ (S-0-0206) are about 8 ms for synchronous motors or 300 ms for asynchronous motors.

Note: During the t$_{DEON}$ 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 "acknowledge of drive enable")!

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.

Interface Errors and Diagnostic Possibilities

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

Possible error messages could be:

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

Diagnosing the 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 and
- the correct CRC checksum.

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

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.

Real-Time Control Bits and Real-Time Status Bits

Brief Description

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

- **S-0-0301, Allocation of real-time control bit 1**
- **S-0-0303, Allocation of real-time control bit 2**
- **S-0-0305, Allocation of real-time status bit 1**
- **S-0-0307, Allocation of real-time status bit 2**
- **S-0-0398, IDN list of configurable data in signal status word**
- **S-0-0399, IDN list of configurable data in the signal control word**
- **S-0-0413, Bit number allocation of real-time control bit 1**
- **S-0-0414, Bit number allocation of real-time control bit 2**
- **S-0-0415, Bit number allocation of real-time status bit 1**
- **S-0-0416, Bit number allocation of real-time status bit 2**

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

Notes on Commissioning

Selection List S-0-0399   Only parameters contained in **S-0-0399, IDN list of configurable data in the signal control word** can be assigned to the parameters S-0-0301 or S-0-0303 (assignment of real-time control bit 1 or 2).

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

Selection List S-0-0398   Only parameters contained in **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 (assignment of real-time status bit 1 or 2).

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

4.5   PROFIBUS-DP

Brief Description

Overview

Drive controllers of the IndraDrive range have a master communication module with PROFIBUS interface. Via this module it is possible to exchange real-time data with a PROFIBUS-DP master.

The following communication channels are distinguished:

- **cyclic data channel** (PROFIBUS-DP)
  The field bus provides data containers in which useful data can be cyclically transmitted. This section is called cyclic data channel. The cyclic data channel is divided into

  - a safety related process data channel (optional) that allows, depending on the firmware, transmitting safety-relevant signals,

  - a device-specific **parameter channel** (optional) for reading and writing all parameters via PROFIBUS-DP,

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

  - a **process data channel** (real-time channel) containing firmly specified 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

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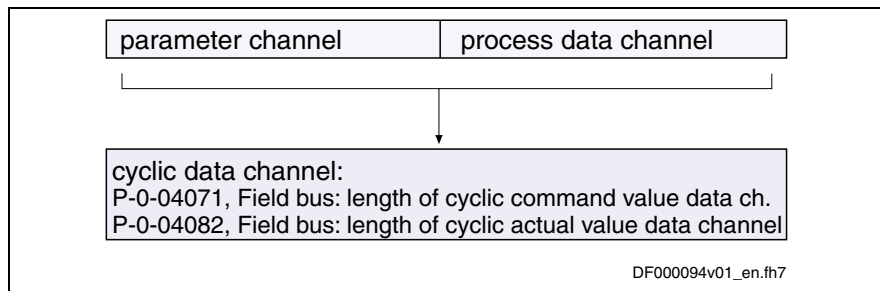
Fig. 4-21: Structure of cyclic data channel

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

The slave PROFIBUS-DP circuit with master communication module PL has the following functional features:

Features

- support of RS485 interfaces according to **IEC61158-2**

- support of all **data rates** according to **IEC61158-2**, 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 **cyclical data** up to 8 parameters (incl. field bus control word and field bus status word) in both data directions ($\rightarrow$ max. 30 bytes or 15 words)

- additional optional **parameter channel** in the cyclic channel with up to 16 byte (8 words)

- monitoring of the cyclical data exchange (watchdog function)

- LED for diagnosing the PROFIBUS interface

- supported DPV0 services:
    - Slave_Diag (read diagnostic data)
    - Get_Cfg (read configuration data)
    - Set_Prm (send parameterization data)
    - Chk_Cfg (check configuration data)
    - Data Exchange (transfer I/O data)
    - Global Control (synchronization)
    - RD_Outp (read output data)
    - RD_Inp (read input data)

- parameter access with DPV1-class-1 services
    - DDLM_Initiate (establishment of connection)
    - DDLM_Read (acyclic read access)
    - DDLM_Write (acyclic write access)
    - DDLM_Abort (connection clearance)
    - DDLM_Idle (connection monitoring)

- support of up to five DPC1-class-2 connections

- supported field bus profiles:
    - 0xFF82: I/O mode with configurable real-time data
    - 0xFFFE: freely configurable mode

- mapping of all device parameters to manufacturer-specific ProfiDrive objects

Pertinent Parameters

- **P-0-4068, Field bus: control word IO**
- **P-0-4069, Field bus: module diagnosis**
- **P-0-4071, Field bus: length of cyclic command value data channel**
- **P-0-4073, Field bus: diagnostic message**
- **P-0-4074, Field bus: data format**
- **P-0-4075, Field bus: watchdog**
- **P-0-4076, Field bus: cycle time (Tcyc)**
- **P-0-4077, Field bus: control word**
- **P-0-4078, Field bus: status word**
- **P-0-4079, Field bus: baud rate**
- **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**

The following parameters are additionally used:

- **S-0-0026, Configuration list signal status word**
- **S-0-0027, Configuration list signal control word**
- **S-0-0144, Signal status word**
- **S-0-0145, Signal control word**
- **S-0-0328, Assign list signal status word**
- **S-0-0329, Assign list signal control word**
- **S-0-0187, IDN-list of configurable data in the AT**
- **S-0-0188, IDN-list of configurable data in the MDT**

Pertinent Diagnostic Messages

- **C0154 Field bus: IDN for cycl. command val. not configurable**
- **C0155 Field bus: max. length for cycl. command val. exceeded**
- **C0156 Field bus: IDN for cycl. actual val. not configurable**
- **C0155 C0157 Field bus: length for cycl. actual values exceeded**
- **C0158 Field bus: Tcyc (P-0-4076) incorrect**
- **C0159 Field bus: P-0-4077 missing for cycl. command values**
- **F4009 Bus failure**
- **F4012 Incorrect I/O length**

Configuring the PROFIBUS-DP Slave

Device Data Sheet for IndraDrive

Like every other PROFIBUS slave, IndraDrive controllers have to be configured in the field bus master This requires the respective device data sheet "**RX010107.GSD**" that has to be included in the project. This device data sheet file, when configuring the bus master, is required for each node.

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Note: The device data sheet for IndraDrive controllers supports all hardware types and enabling of functional packages.

IndraDrive controllers assign their data to ten modules all of which have to be configured:

- module 1: F-module (optional)
- module 2: parameter channel
- module 3: inputs axis 0
- module 4: outputs axis 0
- module 5: inputs axis 1 (only for double-axis devices)
- module 6: outputs axis 1 (only for double-axis devices)
- module 7: inputs axis 2 (only for triple-axis devices)
- module 8: outputs axis 2 (only for triple-axis devices)
- module 9: inputs axis 3 (only for quadruple-axis devices)
- module 10: outputs axis 3 (only for quadruple-axis devices)

The default configuration stored in the device data sheet is the I/O mode (single-axis device) without safety technology and without parameter channel. The device data sheet also contains the

- **IDN 107 hex**

allocated to the IndraDrive controller by the PROFIBUS User Organization.

Note: During the DriveTop installation the device data sheet is stored in the "Indramat\DeviceDataSheets" directory.

Module 1: F-Module   This (optional) module is used to configure a safety related process data channel (with the corresponding hardware and enabling of functional packages). When the optional module is not used, the blank module "**no F-Modul**" has to be assigned to it.

Module 2: 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 0 Words (Off)" has to be selected. For a parameter channel with the standard length of 5 words the module "ParamCh 5 Words" has to be included.

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

The drive automatically recognizes the configuration of the master and adjusts accordingly.

Note: This active setting is displayed in bytes in parameter **P-0-4083, Field bus: length of parameter channel**.

Module 3: Inputs   These modules are used to set the **length of the input data** in words. All of these modules begin with the denomination "**Input**". For successful data exchange the length has to equal the value in parameter **P-0-4071,**

Field bus: length of cyclic command value data channel that indicates the length in bytes.

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

Module 4: Outputs

This module corresponds to module 3 but defines the **outputs**. The module denomination is "**Output**" and has to correspond with the value of parameter **P-0-4082, Field bus: length of cyclic actual value data channel**.

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

Modules 5 to 10

These modules are provided for multi-axis devices and the blank modules "**Input not used**" or "**Output not used**" should be assigned to them.

Configuring the Process Data Channel

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

Parameter	Meaning	I/O mode	Interpolation
P-0-4082	length of cyclic data channel IN (slave → master) in bytes	2	12
P-0-4071	length of cyclic data channel OUT (master → slave) in bytes	2	10
P-0-4083	length of parameter channel in bytes	0	10

Fig. 4-22:   Parameters to configure the cyclic data channel

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

See also section "Profile Types"

Configuration List Cyclic Actual Value Data Channel

The structure and therefore the number of words and their assigned objects (indices) for the process input data (slave → master) are mapped to the **P-0-4080, Field bus: config. list of cyclic actual value data ch.** parameter. 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

The structure of the process output data (master → slave) is mapped to the **P-0-4080, Field bus: config. list of cyclic actual value data ch.** parameter. This enables the read-out via the parameter channel of the current structure and thus the assignments in the field bus.

Note:	It is possible to configure up to 8 real-time parameters (incl. control or status word) on the bus in each data direction.

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

Within the cyclic channel, the parameter channel (optional) and the process data channel, in which the real-time data of the drive controller are transmitted, are arranged.

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

Note: The length currently effective is contained in the parameters **P-0-4082, Field bus: length of cyclic actual value data channel** and **P-0-4071, Field bus: length 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.

Length of Process Data Channel   The length of the process data channel can range between 1...16 words or 2...32 bytes in either direction.

The length of the process data channel results from the content of the configuration lists P-0-4080 or P-0-4081 and is contained in the following parameters:

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

- **P-0-4082, Field bus: length of cyclic actual value data channel** (slave → master)

The setting becomes effective with the initialization of the drive controller to the operating mode, so it has to be set before.

Note: 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 has to be in accordance with the projected length in the master. Otherwise the error message **F4012 Incorrect I/O length**.

Parameter Channel in the Cyclic Channel (Device-Specific)

Since it must be possible to parameterize the drive via the field bus, a configurable parameter channel was implemented in the cyclic channel of the IndraDrive the length of which can be set to 0...16 bytes. The parameter channel consists of a control or status word and up to a maximum of 7 words for data.

Note: The parameter channel is always at the beginning of the cyclical data channel. The length of the parameter channel can be set in **P-0-4083, Field bus: length of parameter channel**.

Structure of the parameter channel:

- control word: 2 bytes
- data: 2 to 14 bytes

Object Directory for PROFIBUS-DP (ProfiDrive)

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

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

The data of an object are accessed via:

- index
- sub-index

Generating Law for Object Index
- index = 0x2000 + IDN (S-0-XXXX) **S-parameters**
- index = 0x3000 + IDN (P-0-XXXX) **P-parameters**

Generating Law for Object Sub-Index

Example 1: accessing data of S-0-0051

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

Example 2: accessing data of P-0-0051

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

Structure of Control Word in Parameter Channel

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

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

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

Fig. 4-23: Structure of control word in parameter channel

Structure of Status Word in Parameter Channel

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

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

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

Fig. 4-24: Structure of status word in parameter channel

Configuration of the Parameter Channel

The parameter channel is made up of:

- control word/ status word
- user data

Without considering a fragmentation or an error, the parameter channel when **writing a parameter** is made up of:

	Control word	Index	Sub-index	Data
M → S	2 bytes	2 bytes	2 bytes	max. 80 bytes
	Status word			
S → M	2 bytes			

Without considering a fragmentation, the parameter channel when **reading a parameter** is made up of:

	Control word	Index	Sub-index	
M → S	2 bytes	2 bytes	2 bytes	
	Status word		Data	
S → M	2 bytes	max. 80 bytes	

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

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

Fig. 4-25:   Basic setting for parameter channel

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

The value is 100.

Parameter mapping:

- index   = 2039h
- sub-index   = 7h

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

Fig. 4-26:   Non-fragmented reading

Non-Fragmented Writing without Error

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

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

Parameter mapping:

- index   = 2039h
- sub-index   = 7h

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

Fig. 4-27:   Non-fragmented writing without error message

Non-Fragmented Writing with Error Message

The control unit writes a new operating data to parameter S-0-0057.

The value is 20000 and above the allowed maximum. The drive returns an error message, in this case 7006h.

Parameter mapping:

- index   = 2039h
- sub-index   = 7h

	Control word/status word						User data							
	Res	G/F	L	T	FL	GL	B2	B3	B4	B5	B6	B7	B8	B9
M → S	0	1	1	0/1	8	8	20h	39h	00h	07h	00h	00h	4Eh	20h
S → M	0	1	1	0/1	2	2	70h	06h	-	-	-	-	-	-

Fig. 4-28:   Non-fragmented writing with error message

Fragmented Reading

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

Parameter mapping:

- index   = 2010h
- sub-index   = 11h → 17 → 7 elements

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

Fig. 4-29:   Fragmented reading

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Fragmented Writing

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

Parameter mapping:

- index = 3FA6h
- sub-index = 10h → 16 → 6 elements

length: 4-byte header + (6 * 4 bytes of data) = 28 bytes

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

Fig. 4-30: Fragmented writing

Requesting the Next Fragment

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

$$GL_{transmit} = GL_{receive} - FL_{receive}$$

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

FL: length of user data in fragment (4 bits)

Fig. 4-31: GL calculation

DPV1 Parameter Communication (ProfiDrive)

Overview of Acyclic Communication

DP Master Class-1

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

- DDLM_Read (MSAC1_Read)
- DDLM_Write (MSAC1_Write)

DP Master Class-2

A maximum of five acyclic communication relationships of type MSAC_C2 to a DP master class-2 (MSAC_C2) are supported. The following DP services are available for this communication relationship:

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

Parameter Exchange via DPV1 Services

The parameter exchange described below is executed via DPV1 telegram frame. The following sequence is run:
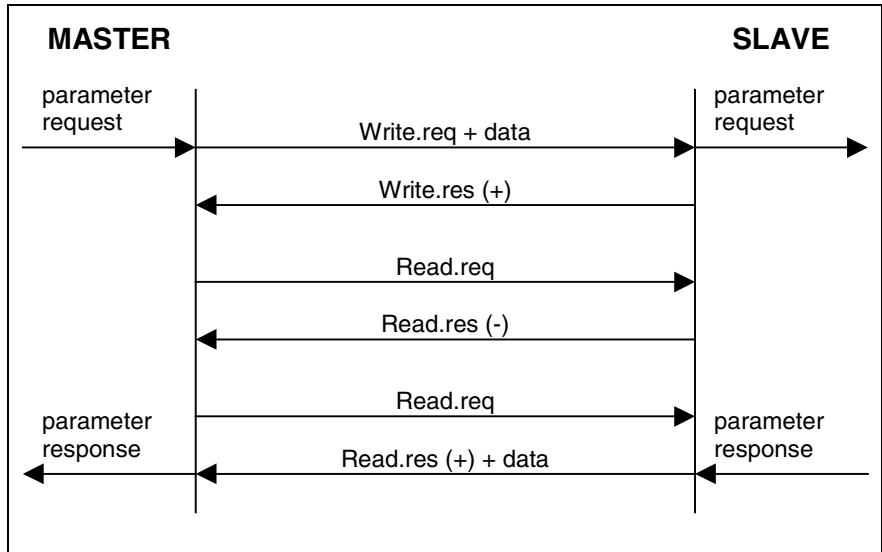
The individual parameters are accessed with the services "**request parameter**" or "**change parameter**".

Note: Multiple parameter requests are not supported!

Request Parameter   ProfiDrive parameter request via DPV1

request header	request reference 1 to 255	request ID 1 = request parameter
	axis 0	number of parameters 1
parameter address	attribute 16 = value	number of elements 1
	parameter number	
	sub-index	

ProfiDrive parameter response

response header	request ref. mirrored 1 to 255	response ID 1 = positive acknowledgment 129 = negative acknowledgm.
	axis mirrored 1	number of parameters 1
parameter value(s)	format 65 = bytes 66 = word 67 = double word	number of values 1 to 10
	value(s) or error value	
	...	

Change Parameter   ProfiDrive parameter request via DPV1

request header	request reference 1 to 255	request ID 2 = change parameter
	axis 0	number of parameters 1
parameter address	attribute 16 = value	number of elements 1
	parameter number	
	sub-index	
parameter value(s)	format 65 = bytes 66 = word 67 = double word	number of values 1 to 10
	value(s)	
	...	

DPV1 parameter response

response header	request ref. mirrored 1 to 255	response ID 2 = positive acknowledge 130 = negative acknowledge
	axis mirrored 1	number of parameters 1

Cyclic Communication via Process Data Channel

Communication Cycle Time

Cyclic communication via the process data channel takes place in the so-called communication cycle (cf. **P-0-4076, Field bus: cycle time (Tcyc)**). The communication cycle indicates the time intervals in which the cyclic data are transmitted or processed.

Cycle times of the interface:

- basic design   → 1 ms to 65 ms (in steps of 1 ms)
- advanced design   → 500 µs to 65 ms (in steps of 500 µs)

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 operating modes such as "position control with cyclic command value input", but only for positioning modes and velocity control.

In the drive only a limited number of cyclic data can be processed (Basic: 16 Byte; Advanced: 32 Byte).

Note: There is no limit value check for the cyclically transmitted command values and they are not stored in volatile form.

Configuring the Process Data Channel

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

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. It is displayed in parameter **P-0-4075, Field bus: watchdog** (in ms).

Note:	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
- diagnostic parameter **P-0-4073, Field bus: diagnostic message**

Diagnostic LED "H30"

The LED display "H30" is active when the drive is in the PROFIBUS status "Data_Exchange". This means that real-time data are exchanged between IndraDrive device and master.

P-0-4073, Field bus: diagnostic message

This parameter contains the status of the field bus master communication in plain text. The contents of parameter P-0-4073 have the following significance:

Text	Significance
"OFFLINE":	initialization value of the diagnostic message
"Power-On":	A PROFIBUS-DP card has been recognized as master communication and the hardware is checked.
"Baud-Search":	The hardware is okay; the PROFIBUS interface is monitored in order to recognize the baud rate used.
"Wait-Prm":	The baud rate has been found, the drive waits for a parameterization telegram of the master that contains its IDN (contained in the device data sheet).
"Wait-Cfg":	The IndraDrive device has received a valid parameterization telegram and now waits for the configuration telegram in which the master tells the drive for which modules it is waiting 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. 4-32:   Significance of the entries in parameter P-0-4073

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Error Codes of PROFIBUS Communication

Parameter Channel Errors

Error code	Significance
0x0082	number of all transmitted data is too low, i.e. less than 4 bytes
0x0083	number of data still to be transmitted is greater than the internal buffer
0x0088	The length of the valid data indicated in the control word is longer than the parameter channel
0x008C	status conflict, a new request was sent although there are still data to be transmitted
0x008D	length of data that are still to be transmitted indicated in the control word is incorrect

Fig. 4-33:   Overview parameter channel errors

DPV1 Errors

Error code	Significance	Name 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. 4-34:   Overview DPV1 errors

Parameter Access Errors   The error values are transmitted in word format.

Error number (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 the minimum input value
0x7007	Operation data is greater than the 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. 4-35:   Overview parameter access errors

4.6   Parallel Interface

Brief Description

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

The master communication interface with parallel interface is optionally available for the following configurable control sections:

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

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)

Pertinent Parameters

- **S-0-0026, Configuration list signal status word**
- **S-0-0027, Configuration list signal control word**
- **S-0-0144, Signal status word**
- **S-0-0145, Signal control word**
- **S-0-0328, Assign list signal status word**
- **S-0-0329, Assign list signal control word**
- **S-0-0346, Positioning control word**
- **S-0-0398, IDN list of configurable data in signal status word**
- **S-0-0399, IDN list of configurable data in the signal control word**
- **S-0-0437, Positioning status word**
- **P-0-0115, Device control: Status word**
- **P-0-0116, Device control: control word**
- **P-0-4026, Positioning block selection**
- **P-0-4028, Device control word**
- **P-0-4060, Positioning control word**
- **P-0-4061, Message end position reached**

Pertinent Diagnostic Messages

- **F2044 External power supply X15 error**

Functional Description

Controlling the Drive

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

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

See also "Device Control" in section "Basic Functions of Master Communication"

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

- There mustn't be any drive error present.

- The drive must be in operating mode (phase 4).

- Power must have been switched on and the DC bus voltage must be above the defined minimum threshold (see also "Voltage Monitor in DC Bus" in chapter "Drive Functions").
  The drive displays this status on the control panel with "Ab". The diagnostic drive message in parameter **S-0-0095, Diagnostic message** is **A0012 Control and power sections ready for operation**.

→ The signal "ready" in parameter **P-0-0115, Device control: Status word** must 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.

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

Clearing Errors   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.

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

Configurable Digital Inputs

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

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

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

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

Fig. 4-36:   Assignment of signal control word to digital inputs

See also "Configurable Signal Control Word" in chapter "Master Communication"

Note: Connector pin assignment is described in the separate documentation "Project Planning Manual for Control Sections" in chapter "Interfaces".

Configurable Digital Outputs

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

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

Note: 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
11	X15 pin 16
12	X15 pin 17
13	X15 pin 36
14	X15 pin 18
15	X15 pin 37

Fig. 4-37:   Assignment of signal status word to digital outputs

See also "Configurable Signal Status Word" in chapter "Master Communication"

Note:	Connector pin assignment is described in the separate documentation "Project Planning Manual for Control Sections" in chapter "Interfaces".

Notes on Commissioning/Parameterization

Positioning Block Mode with Parallel Interface

See also "Positioning Block Mode" in chapter "Operating Modes"

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

Positioning Block Selection, Start Signal

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

Block Selection Acknowledgement, "In-Pos" Message

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

Jogging Inputs

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

Note:	The jogging inputs are also 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 $\rightarrow$ jogging +
- bit 2, 1 = 10 $\rightarrow$ jogging -
- bit 2, 1 = 11 $\rightarrow$ positioning stop

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

Fig. 4-38:   Default configuration for positioning block mode via digital inputs

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

Fig. 4-39:   Default configuration for positioning block mode via digital outputs

Change of Operating Mode via Parallel Interface

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

Main Spindle Drive with Analog Interface and Parallel Interface

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

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

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

The following commands are relevant for main spindle drives:

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

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

Fig. 4-40:   Example of configuration for main spindle drive via digital inputs

The following messages are relevant for main spindle drives:

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

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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	status of device control "ready"
1	S-0-0330 bit 0	n_actual = n_command
2	S-0-0403 bit 0	status reference encoder
3	S-0-0331 bit 0	n_feedback = 0
4	S-0-0332 bit 0	nactual < nx
5	P-0-0115 bit 2	status of device control "warning"
6	S-0-0333 bit 0	T >= Tx
7	S-0-0334 bit 0	T >= Tlimit
8	S-0-0335 bit 0	n command > n limit
9	S-0-0336 bit 0	In position
10	S-0-0337 bit 0	P >= Px
11 … 15	--	

Fig. 4-41:   Example of configuration for main spindle messages via digital outputs

See also section "Spindle Positioning" in chapter "Drive Functions"

Diagnostic and Status Messages

Monitoring the Digital Inputs/Outputs

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

- undervoltage of 24 V supply
- incorrect polarity of the supply of a port
- overload of an output
- short circuit of an output

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

4.7   Analog Interface

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).

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

The figure below illustrates the overall structure of a drive solution with analog interface and encoder emulation.
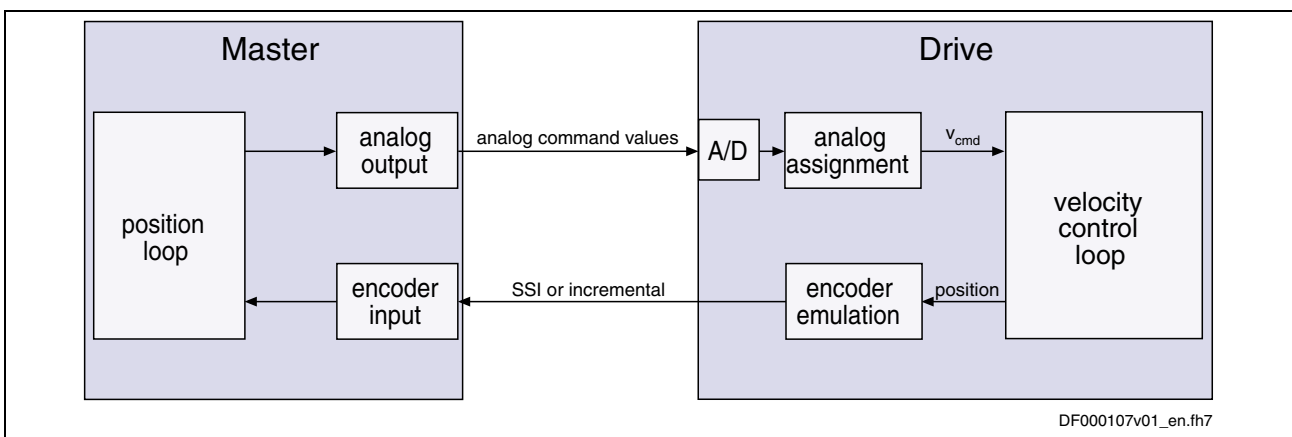
Fig. 4-42:   Control loop structure (control with analog command value input and SSI emulation)

Hardware Requirements   The master communication interface with analog interface is optionally available for the following control sections:

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

This chapter 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 explained in separate chapters.

See also "Encoder Emulation" in chapter "Extended Drive Functions"

See also "Analog Inputs" in chapter "Extended Drive Functions"

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Features

The analog interface is an interface for master communication with analog command values and digital I/Os (drive enable, Drive Halt...) with the following features:

- analog inputs (12 bit) to be assigned to parameters, with offset and scaling to be set (number depending on control section design)

- sampling rates for the analog inputs:

  - channel A: position loop clock $T_{position}$
    (Advanced: T = 250 µs; Basic: T = 500 µs)

  - channel B: T = 2 ms

- assignment of analog inputs to two drive parameters (command values) is possible

- 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)

- **absolute encoder emulation:**

  - reference to be set via **P-0-0012, C0300 Command Set absolute measuring**

  - resolution to be set, only binary resolution (incr./motor rev. or mm)

  - power failure bit available

- **incremental encoder emulation:**

  - emulation of the reference pulse

  - reference pulse to be set; dead time compensation

  - resolution to be set (incr./motor rev. or mm)

  - maximum frequency monitoring

- 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

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

Pertinent Parameters

- **P-0-0115, Device control: status word**
- **P-0-0116, Device control: control word**
- **P-0-4028, Device control word**

Digital I/Os
- **P-0-0300, Digital I/Os, assignment list**
- **P-0-0301, Digital I/Os, bit numbers**
- **P-0-0302, Digital I/Os, direction**
- **P-0-0303, Digital I/Os, status display**

Encoder Emulation
- **P-0-0900, List of emulator signals**
- **P-0-0901, Emulator signal selection**
- **P-0-0902, Emulator control parameter**
- **P-0-0903, Emulator resolution**
- **P-0-0904, Reference pulse offset of incremental encoder emulator**

Analog Inputs
- **P-0-0210, Analog input 1**
- **P-0-0211, Analog input 2** (only for MPB02 firmware!)
- **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 adjust**
- **P-0-0219, Analog input, maximum value for adjust**
- **P-0-0220, C2800 Analog input adjust command**
- **P-0-0228, Analog input 3**
- **P-0-0229, Analog input 4**
- **P-0-0231, Analog input 2, time constant input filter** (only for MPB02 firmware!)
- **P-0-0232, Analog input 3, time constant input filter**
- **P-0-0233, Analog input 4, time constant input filter**
- **P-0-0236, Analog input, assignment B, target parameter**
- **P-0-0237, Analog input, assignment B, scaling per 10V full scale**
- **P-0-0238, Analog input, assignment B, signal value at 0V**
- **P-0-0239, Analog input, assignment B, dead zone**
- **P-0-3901, Adjust values of control section**
- **P-0-3904, Adjust values analog I/O interface**

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Functional Description

Controlling the Drive

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** parameter IDNs are assigned to the pins of connectors X31, X32, X33 and X11 on the control section. Depending on the control section design, there is a default assignment of IDNs to the pins of these terminal strips. The preset default assignment can be modified according to the application-specific requirements.

$\boxed{\mathbf{i}}$ See Parameter Description "P-0-0300, Digital I/Os, assignment list"

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

$\boxed{\mathbf{i}}$ See section "Interfaces" in the separate documentation "Project Planning Manual for Control Sections"

Drive Enable   The activation of the drive requires a positive edge of the "drive enable" signal (connector pin assignment see section "Interfaces" in the separate documentation "Project Planning Manual for Control Section").

Note:	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" in section "Basic Functions of Master Communication"

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

- There mustn't be any drive error present.

- The drive must be in operating mode (phase 4).

- Power must have been switched on and the DC bus voltage must be above the defined minimum threshold (see also "Voltage Monitor in DC Bus" in chapter "Drive Functions").
  The drive displays this status on the control panel with "Ab". The diagnostic drive message in parameter **S-0-0095, Diagnostic message** is **A0012 Control and power sections ready for operation**.

"Drive Halt" Signal	When drive enable is set and the "Drive Halt" signal is active (P-0-4028 or P-0-0116, bit 13 = 0),

* the display of the control panel changes to "AH" and
* the diagnostic drive message then is **A0010 Drive HALT** and thereby signals the activation of "Drive Halt".

If the "Drive Halt" signal is then deactivated (P-0-4028 or P-0-0116, bit 13 = 1),

* the display of the control panel changes to "AF" and
* the diagnostic drive message is dependent on the active mode of operation (see Troubleshooting Guide).

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

Clearing Errors	A positive edge at the "clear error" input starts the command for error clearing. To do this, the command C0500 has to be assigned to a digital input:

* configure parameter **S-0-0099, C0500 Reset class 1 diagnostics** in **P-0-0300, Digital I/Os, assignment list**
* in parameter **P-0-0301, Digital I/Os, bit numbers** set bit 0 for the element of S-0-0099
* in parameter **P-0-0302, Digital I/Os, direction** set the data direction for the element of S-0-0099 to input (value "0")

See also "Digital Inputs/Outputs" in chapter "Extended Drive Functions"

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

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
(advanced: T = 250µs, basic: T = 500µs)
* assignment channel B works in 2ms clock

See also "Analog Inputs" in chapter "Extended Drive Functions"

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" in chapter "Extended Drive Functions"

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" in chapter "Extended Drive Functions"

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

Analog Inputs

For inputting the cyclic command value you should preferably use assignment channel A as it has a higher sampling rate than assignment channel B.

In spite of their high degree of functionality and performance, the analog inputs available for IndraDrive devices are subject to certain restrictions. These restrictions are explained in detail in section "Analog Inputs"

See also "Analog Inputs" in chapter "Extended Drive Functions"

Note: 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 "spindle positioning" 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 "spindle positioning" command has to be started via a digital input. To do this, the main spindle messages are assigned to the digital outputs, the command parameter to a digital input.

The following **messages** are relevant for main spindle drives:

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

- in target position during spindle positioning
  (**S-0-0336, Message In position**)

- torque limit value reached (**S-0-0334, Message 'T >= Tlimit'**)

- torque threshold exceeded (**S-0-0333, Message 'T >= Tx'**)

- speed threshold exceeded
  (**S-0-0335, Message 'n command > n limit'**)

- power threshold exceeded (**S-0-0337, Message 'P >= Px'**)

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

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

Fig. 4-43:   Example of configuration for main spindle messages via digital outputs

The following **command** is relevant for main spindle drives:

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

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

Fig. 4-44:   Example of configuration for main spindle command drive via digital inputs

See also "Spindle Positioning" in chapter "Drive Functions"

Diagnostic and Status Messages

Information on General Drive Status

All important status bits of the status machine of the drive are mapped to parameter **P-0-0115, Device control: Status word**. Reading and interpreting parameter P-0-0115 provides information on the current status of the drive.

i   See Parameter Description "P-0-0115, Device control: status word"

Status of Digital Inputs/Outputs and Analog Inputs

All digital and analog input values can already be read via parameters before assignment to the internal drive parameters. The following applies:

- digital inputs/outputs of the control module are mapped to parameter P-0-0303

- analog inputs values are displayed in the following parameters:

    - **P-0-0210, Analog input 1**

    - **P-0-0211, Analog input 2** (only for MPB02 firmware!)

    - **P-0-0228, Analog input 3**

    - **P-0-0229, Analog input 4**

See also in chapter "Extended Drive Functions":

- section "Digital Inputs/Outputs: Diagnostic and Status Messages"

- section "Digital Inputs: Diagnostic and Status Messages"

- section "Encoder Emulation: Diagnostic and Status Messages"

5 Motor, Mechanical Axis System, Measuring Systems

5.1 General Information on the Operation of Motors with IndraDrive

Basics on the Motors to be Controlled

Brief Description

With the controllers of the IndraDrive range it is possible to control both synchronous motors and asynchronous motors.

Types

The following motor types are possible:

- rotary motors
- linear motors

Both types can be used in housing design (motor with a driven 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 also possible to evaluate temperature sensors not listed above, but their specific characteristics have to be entered manually!

Motor Holding Brakes

IndraDrive allows controlling and monitoring holding brakes that are mechanically connected to the motor:

- electrically releasing brakes (self-holding)
- electrically holding brakes (self-releasing)

Adjusting Motor/Controller

The IndraDrive controllers are adjusted to the motor to be controlled by providing or inputting the motor-specific data.

- In the case of Rexroth motors this can be done without any problem because the manufacturer provides a specific data set for adjusting each motor type. The data are documented by the manufacturer as parameter values, stored and made available in motor-specific parameters.
- In the case of third-party motors it is necessary to check, by means of the motor data and the data of the possibly available motor encoder, whether they are basically suited for operation with IndraDrive. The parameter values for adjusting the controller have to be specifically determined for each motor and input by the user.

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> **Note:** 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!

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-0-4047, Motor inductance**
- **P-0-4048, Stator resistance**

Asynchronous Motor Parameters:

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

Field-Weakening Range Parameters:

- **P-0-0533, Flux loop proportional gain**
- **P-0-0534, Flux loop integral action time**
- **P-0-0535, Motor voltage at no load**
- **P-0-0536, Motor voltage max.**

Other Motor-Relevant Parameters

In connection with the motor there are other important parameters:

- measuring system parameter
- motor holding brake parameter
- temperature sensor parameter
- default control loop parameter

Hardware Data

For the electrical connection of the motors to the controller please 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.

Motor Temperature Monitoring

Brief Description

See above "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
- **E2051 Motor overtemp. prewarning**

- **F2019 Motor overtemperature shutdown**

- **F2021 Motor temperature monitor defective**

Functional Description

Motors with incorporated temperature sensor can be monitored by the controller and protected against damage by thermal overload.

The controller is informed on the temperature sensor type via parameter **P-0-0512, Temperature sensor**. Standard sensor types are characterized by a characteristic number. A characteristic stored in the firmware is assigned to this number.

The measured motor temperature is monitored for the following threshold values:

- motor warning temperature (S-0-0201)

- motor shutdown temperature (S-0-0204)

The threshold values have to be entered in the respective parameters, depending on the thermally restricting material properties and constructional features. Thermally restricting properties can be:

- insulation class of the motor

- type and construction of the bearing

- allowed thermal effect on the machine design, etc.

If the temperature sensor was not connected this is detected by the motor temperature monitor, too.

The thermal motor monitor has the following states:

Thermal status	Motor temperature...	Message or reaction
Thermal range not allowed, temperature sensor possibly not connected.	... for 30 s ≤ -20°C	Error: **F2021 Motor temperature monitor defective**, → motor is immediately shut down (error reaction) and switched off!
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** → no specific reaction
Upper limit of allowed thermal range reached!	... ≥ value of S-0-0204	Error: **F2019 Motor overtemperature shutdown**, → motor is immediately shut down (error reaction) and switched off!

Fig. 5-1:   States of the thermal motor monitor

The current motor temperature can be queried via the value of parameter **S-0-0383, Motor temperature**.

Rexroth Motors
Rexroth motors are equipped with standard type sensors. The respective parameter value for the temperature sensor as well as for the motor shutdown temperature are automatically set correctly when loading the motor parameters!

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Note:	In the case of MHD, MKD, LSF, MBS and MKE motors, the motor temperature, due to the sensor characteristics, can only be determined very inexactly. Shutdown is caused by abrupt resistance increase of the sensor at maximum temperature! The warning and shutdown thresholds (S-0-0201 and S-0-0204) to be set cannot be used!

Third-Party Motors   Third-party motors may include temperature sensors that do not correspond to the standard type sensors. This information is given to the controller via the **P-0-0512, Temperature sensor** parameter. The respective resistance temperature characteristic then has to be input manually as a table of values in the **P-0-0513, Temperature sensor characteristic** parameter.

Third-party motors without installed temperature sensor can also be operated with IndraDrive controllers, but in the case of overload they are **not** protected on the controller side against thermal damage! 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" in the same chapter

Notes on Commissioning

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

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

→   No temperature sensor relevant parameter setting required!

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

- **S-0-0201, Motor warning temperature**

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

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

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

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

Note:	The value in parameter S-0-0201 has to be smaller than the value of S-0-0204!

Activating the Function   It is not necessary to separately activate the temperature monitor of the motor. You only have to enter the appropriate values in the respective parameters.

When this function is activated, the following diagnostic messages are possible:

- **E2051 Motor overtemp. prewarning**
- **F2019 Motor overtemperature shutdown**
- **F2021 Motor temperature monitor defective**

Querying the current motor temperature (not in the case of the characteristic temperature sensor number "1" or "4"):

- **S-0-0383, Motor temperature**

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.

Note: Holding brakes at Rexroth motors normally aren't designed for decelerating when in operation. Increased wear caused by deceleration in operation can destroy the holding brake at an early stage!

The following motor holding brake types are possible:

- electrically releasing brakes (self-holding)
- electrically holding brakes (self-releasing)

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 holding brake controls in order to minimize wear of the brake in the case of error:

- holding brake control for servo drives
- holding brake control for main drives

If the braking torque of holding brakes is too low due to wear and corrosion, this can cause interruption of service in machines and installations. IndraDrive controllers provide the advantage of monitoring the effectiveness of the holding brake and, in the case of corrosion, re-establishing the braking effect:

- automatically each time the drive enable is set and reset
- depending on the situation at a command of the control unit.

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!

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**

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- **P-0-0539, Holding brake status word**
- **P-0-0540, Torque of motor holding brake**
- **P-0-0541, C2100 Brake check command**
- **P-0-0542, C2000 Command Release motor holding brake**
- **P-0-0543, C3800 Command Apply motor holding brake**
- **P-0-0544, C3900 Command Abrasion of brake**
- **P-0-0545, Test torque for releasing motor holding brake**
- **P-0-0546, Starting torque for releasing motor holding brake**
- **P-0-0547, Test torque with holding brake applied**

Pertinent Diagnostic Messages
- **C2001 Command not enabled**
- **C2101 Brake check only possible with drive enable**
- **C2103 Brake torque too low**
- **C2104 Command execution not possible**
- **C3800 Command Apply motor holding brake**
- **C3900 Command Abrasion of brake**
- **C3901 Abrasion of brake only possible with drive enable**
- **C3902 Error during abrasion of brake**
- **C3903 Command execution impossible**
- **E2069 Brake torque too low**
- **F2069 Error when releasing the motor holding brake**
- **F6024 Maximum braking time exceeded**

Hardware Requirements

The motor holding brake is controlled via a controller-internal relay contact. Voltage supply is realized by the controller via the 24V control voltage. The holding brake must be suited for the voltage that is output, the holding brake current mustn't exceed the allowed maximum value of the respective device (see documentation "Project Planning Manual of controllers"), if necessary the holding brake has to be controlled separately.

Note: The optionally available holding brakes of Rexroth motors can be directly controlled via the controller!

Functional Description

With IndraDrive it is possible to control both self-releasing (electrically holding) and self-holding (electrically releasing) motor holding brakes. The controller is informed of the brake type via the respective bit in parameter **P-0-0525, Holding brake control word**.

Releasing the Holding Brake   When drive enable (AF) is set by the control unit the releasing of the holding brake is activated. The brake is released with a delay, due to the inductance of the brake winding. The controller is informed on this delay via **S-0-0206, Drive on delay time**.

In order to avoid wear of the brake the command value acceptance is blocked within this delay. Only then does the controller signalize 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 " in chapter "Master Communication"
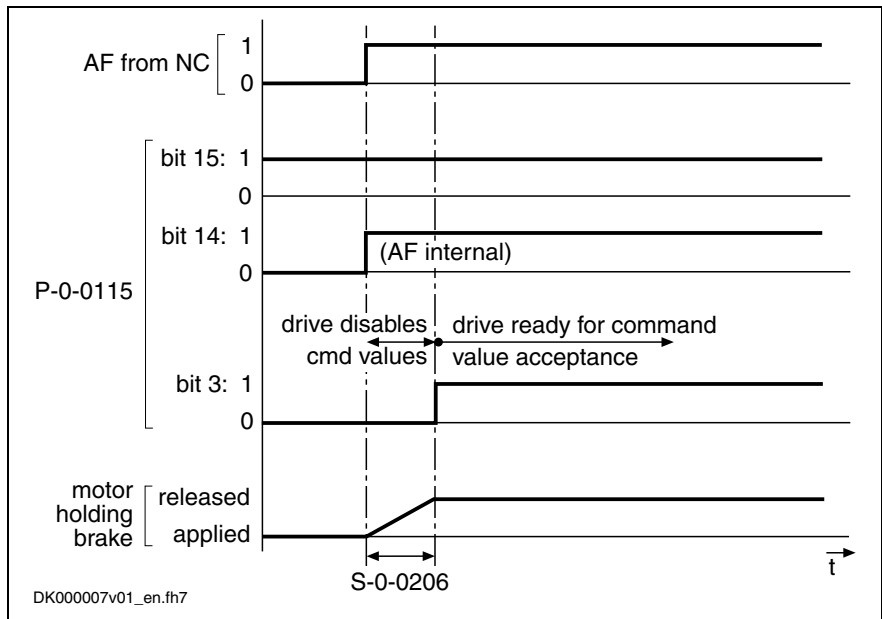
Fig. 5-2:   Time response when releasing the holding brake

Applying the Holding Brake   When "AF" (drive enable) is reset by the control unit the applying of the brake is activated. The brake is applied with a delay, due to the inductance of the brake winding. The controller is informed on this delay via **S-0-0207, Drive off delay time**.

In order to avoid, for example, that a non-equilibrated vertical axis in standstill does not move down due to weight force, "AF" (drive enable) is internally reset by this delay later. During this delay the velocity command value is internally set to zero.

Behavior of the Holding Brake Control in the Case of Error   In the case of interruptions and errors that can suddenly occur for different causes during normal operation, in most of the cases there is a demand to quickly shut down the mechanical system for reasons of personnel and installation safety. This is done, if possible, by actively braking the drive.

In the case of error it is decisive whether the drive is able by itself to decelerate. This is the case when the drive comes to a standstill within an axis-specific maximum braking time. The controller is informed on this time via parameter **S-0-0273, Maximum drive off delay time**.

Note: The "maximum drive off delay time" is the time that the drive needs in order to stop the axis out of maximum velocity at maximum inertia or mass with maximum allowed braking torque or braking force.

If the drive is unable to shut down the mechanical system within the maximum braking time the drive at least reacts with the most convenient control of the holding brake. What is decisive for the control in this case is whether the customer determined the application type to be "servo drive" or "main drive".

You have to distinguish the following situations in the case of error:

Error Situation 1
- Drive remains fully operational; "velocity command value reset with or without ramp and filter" or "return motion" was set as the error reaction (F2xxx, F4xxx, F6xxx error or NC-side drive enable reset in the case of axis motion).

Error Situation 2
- Drive defect (F8xxx error) or "torque or force disable of the motor ("coasting")" was set as the error reaction (F2xxx, F4xxx, F6xxx error or NC-side drive enable reset in the case of axis motion).

Note:	The error reaction is set in parameter **P-0-0119, Best possible deceleration**.

Errors can possibly cause damage to machines or drive components. Depending on the application the following strategies are used for minimizing damage:

Holding Brake Control for Servo Drives
In the case of servo drives that mostly drive linear axes with limited travel distances, the protection of the machine is preferred to the drive in the case of error situation 2. The controller, when set by the customer (**P-0-0525, Holding brake control word**), therefore tries to realize the shortest possible braking distances, even if this damages the holding brake.

Holding Brake Control for Main Drives
Main drives are rotary axes with "unlimited" travel distance, such as spindle motors of milling and turning machines. Due to high speed and high inertia most of these axes produce kinetic energies in operation that often exceed the allowed energy absorption capacity of holding brakes integrated in the motor. In the case of error situation 2, shutdown realized by the holding brake only could destroy the brake very easily. Due to the unlimited travel distance there normally isn't any danger of damaging the machine. The controller therefore, when determined by the customer (P-0-0525), prevents the holding brake from applying and gives priority to friction braking.

P-0-0525, Holding brake control word
The required functionality of the holding brake, depending on the application type of the drive (servo or main drive), is determined by the respective bit in parameter P-0-0525.

Holding Brake Control with Error Situation 1
If the drive cannot shut down the mechanical system within the time after occurrence of the error entered in parameter S-0-0273, the motor holding brake is applied after motor standstill, independent of the application (servo or main drive).

Depending on the error reaction, motor standstill means:

- falling below a velocity threshold (in the case of "velocity command value reset" error reaction, with or without ramp)

- target position reached and actual velocity value lower than the value of **S-0-0124, Standstill window** (in the case of "return motion" error reaction)

See also "Error Reactions" in chapter "Drive Functions"
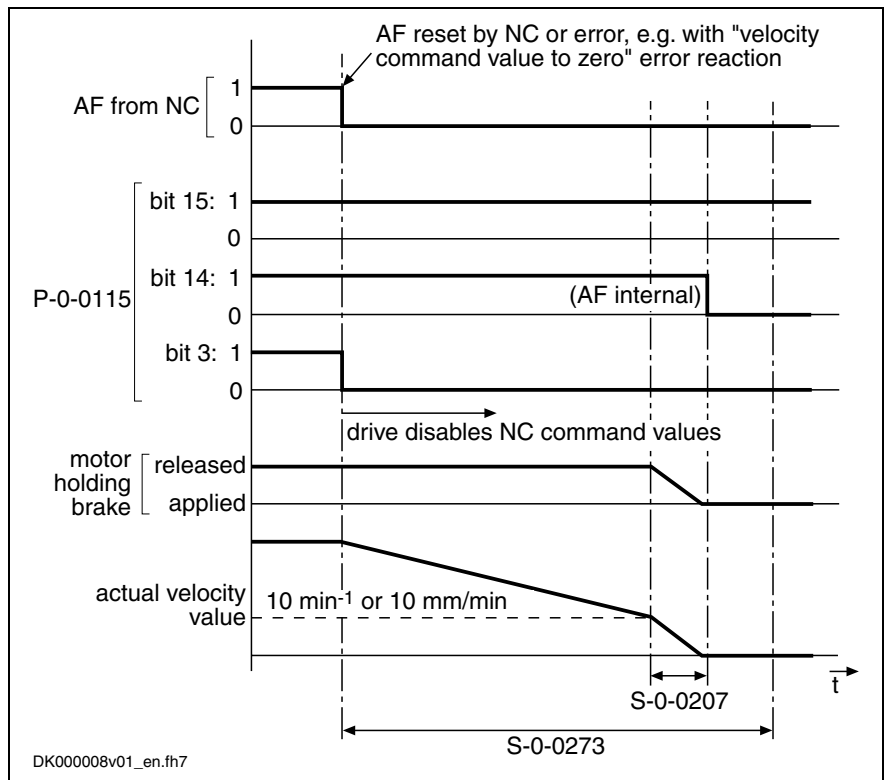
Fig. 5-3:   Holding brake control with error situation 1 and braking
                time < S-0-0273 ("velocity command value reset" error reaction)
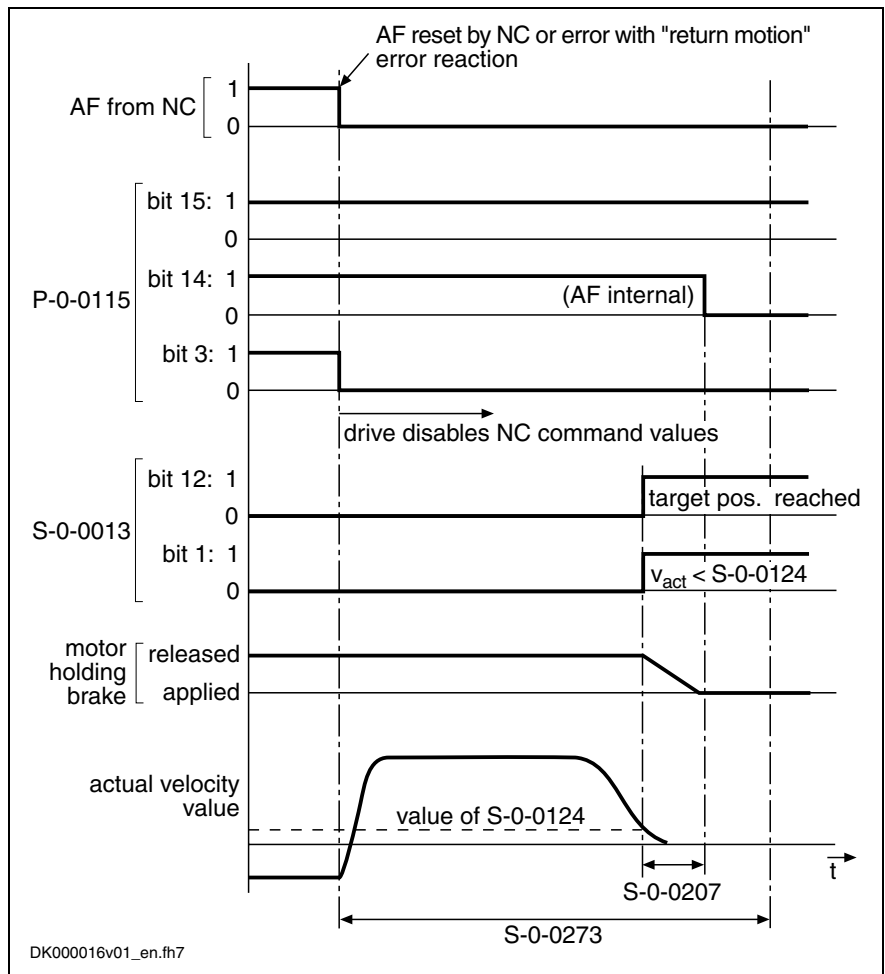
Fig. 5-4:   Holding   brake   control   with   error   situation 1   and   braking time < S-0-0273 ("return motion" error reaction)

If the drive cannot shut down the mechanical system within the time after occurrence of the error entered in parameter S-0-0273, the motor holding brake is controlled depending on the application (servo or main drive):
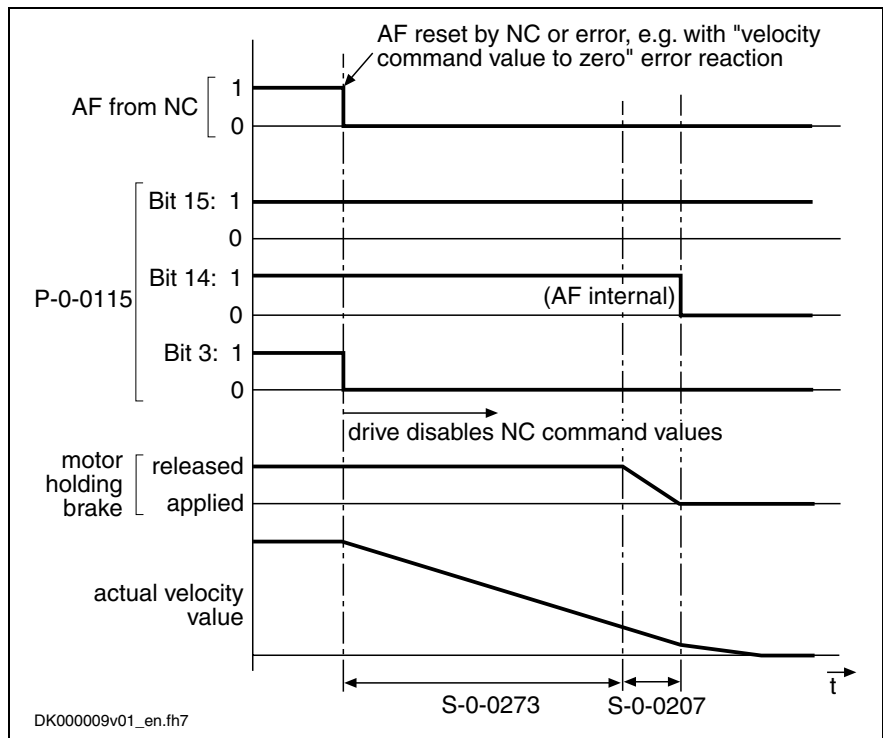
Fig. 5-5:   Holding brake control with error situation 1 and braking time > S-0-0273 for servo drives
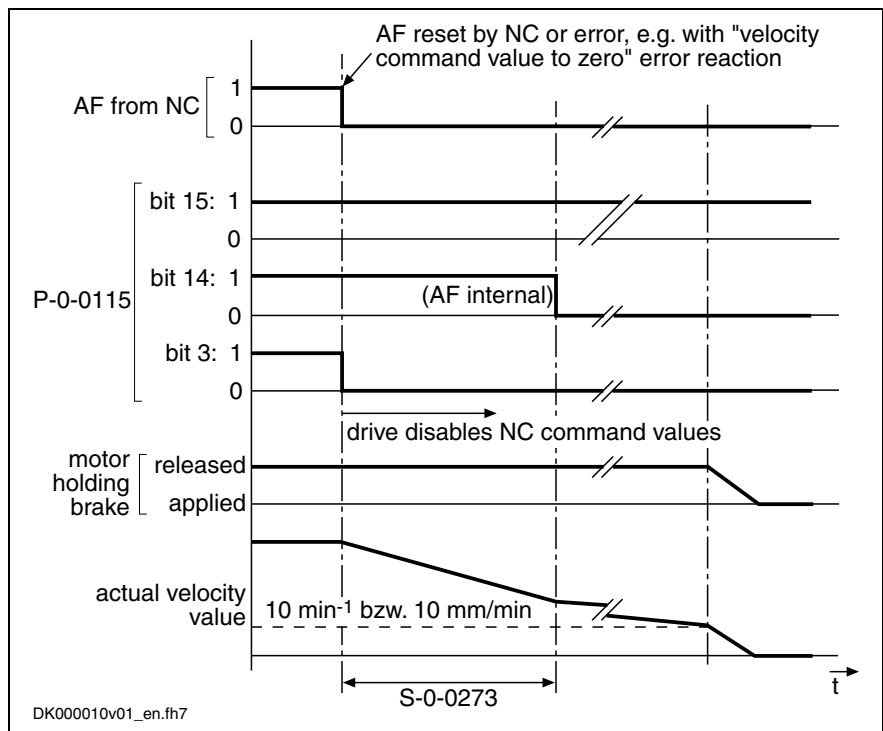
Fig. 5-6:   Holding brake control with error situation 1 and braking time > S-0-0273 for main drives

Note: If the "return motion" error reaction has not yet been completed after the time set in S-0-0273, it is aborted:

- In the case of servo drives, the holding brake is applied. The internal drive enable is switched off with the delay of "drive off delay time".

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- In the case of main drives, the internal drive enable is switched off immediately. The drive coasts to stop. After the velocity has fallen below the minimum value, the holding brake is applied.

Holding Brake Control with Error Situation 2

In the case of error situation 2, the drive becomes torque- or force-free after the error event. The braking effect, in addition to the axis friction, can only be achieved by means of the holding brake. To limit the damage the holding brake is controlled depending on the application (servo or main drive).
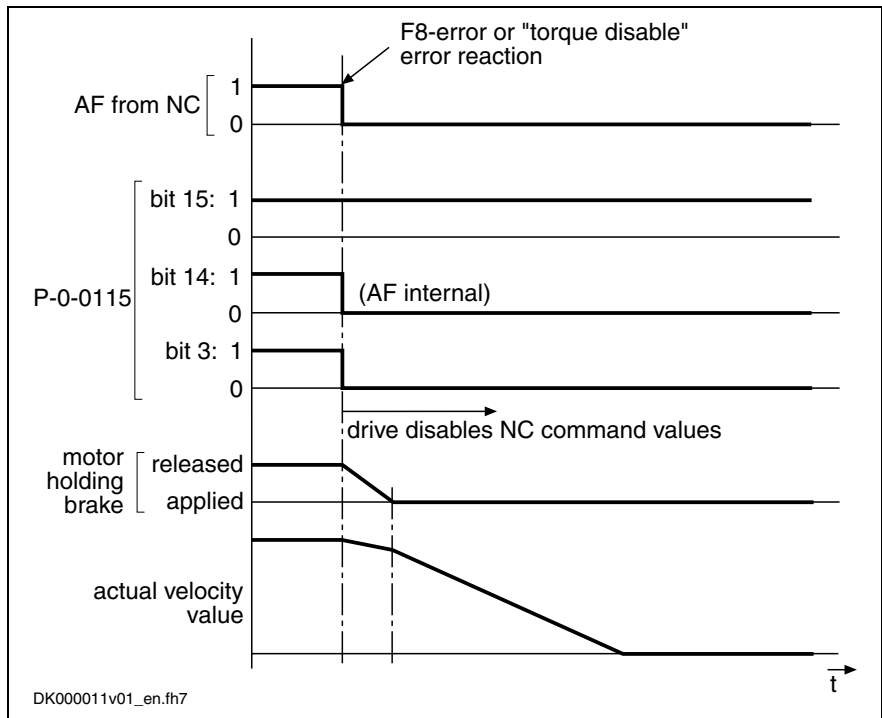
Fig. 5-7:   Holding brake control with error situation 2 for servo drives
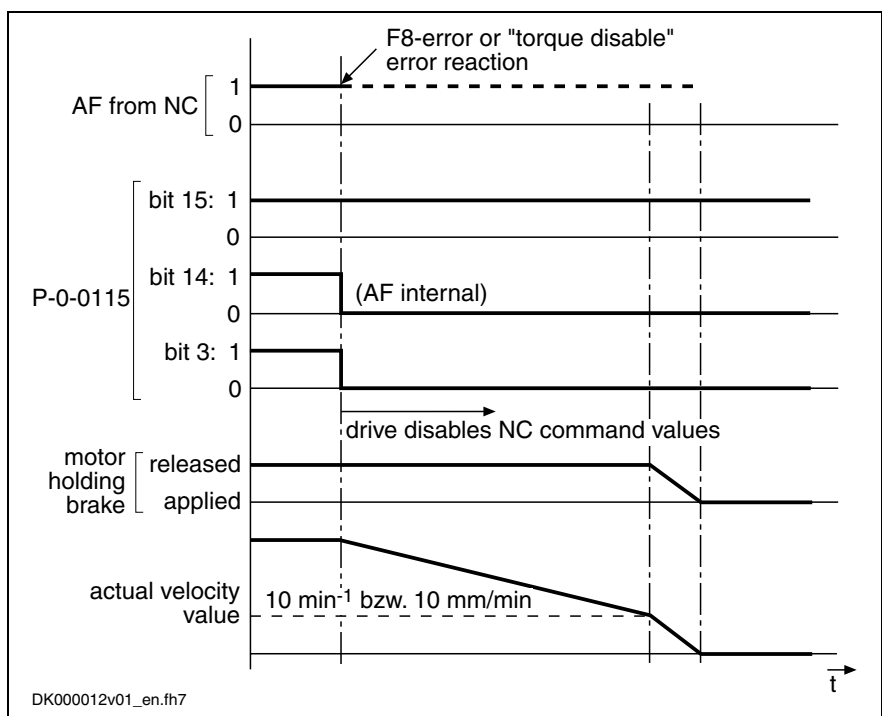
Fig. 5-8:   Holding brake control with error situation 2 for main drives

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 the drive enable is set and reset

- or -

- depending on the situation by **P-0-0541, C2100 Brake check command**

If the holding brake is all right the drive is operational after the routine is over. If the braking 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 (see "Notes on Commissioning") and entered in parameter **P-0-0545, Test torque for releasing motor holding brake**.

If the check was successful, the drive starts operations.

If the motor does not move during this check, the error message **F2069 Error when releasing the motor holding brake** is output; the drive switches off.

When "AF" (drive enable) is reset by the control unit the holding torque of the brake is checked. After the holding brake was applied, a torque or force is generated that mustn't yet set the motor in motion if the status of the holding brake is correct. The value of this torque or force can be entered in **parameter P-0-0547, Test torque with holding brake applied**. This value, too, is determined during initial commissioning (see "Notes on Commissioning").

If the motor does not move during this check, the brake has the specified or required holding torque.

If the motor moves during this check, the diagnostic message **E2069 Brake torque too low** is output and drive enable is reset internally.

The warning E2069 is triggered by the following motor movement:

- rotary motors: > 2 degr
- linear motors: pole pair distance (in mm) / 180 $\rightarrow$ P-0-0018 / 180

⚠ **CAUTION**

Possible property damage caused by vertical axis moving down!

$\Rightarrow$ Take constructional precautions!

"Brake Check" Command	At the start of the **P-0-0541, C2100 Brake check command** the drive must be in "AF" (drive enable).
	The routine corresponds to that of automatic monitoring (see above).
Reestablishing the Holding Brake Torque	For reestablishing the brake torque parameter **P-0-0544, C3900 Command Abrasion of brake** 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 and 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".

Command C3900 does not check whether the abrasion of the brake was successful! It is therefore recommended to execute command C2100 (brake check) after command C3900!

<table>
<tr><td>⚠
CAUTION</td><td>**Property damage caused by drive-controlled axis motion when executing the commands for brake check and for abrasion of the brake!**
⇒ Before starting the command, move the axis to a noncritical position!</td></tr>
</table>

Diagnosing the Brake Check   The result of the brake check and the operating status of the holding brake is displayed in the respective bits of **P-0-0539, Holding brake status word**.

Command "Release Holding Brake"   In special cases it can be convenient to release the holding brake even if the drive is not in "AF" (drive enable). This is possible by activating **P-0-0542, C2000 Command Release motor holding brake**. This command, however, first has to be enabled by the respective bit in **P-0-0525, Holding brake control word**!

<table>
<tr><td>⚠
CAUTION</td><td>**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!</td></tr>
</table>

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)!

Command "Apply Holding Brake"   In special cases it can be convenient to apply the holding brake if the drive is in an active state ("AF", drive enable). This is possible by activating **P-0-0543, C2000 Command Apply motor holding brake**!

<table>
<tr><td>⚠
CAUTION</td><td>**Damage to the holding brake!**
If the axis is moved with the holding brake applied, the brake can become prematurely worn!
⇒ In case of doubt start **P-0-0541, C2100 Brake check command**!</td></tr>
</table>

Influence of Drive Enable on Command "Apply Motor Holding Brake"   If drive enable ("AF") is reset and set again when the command is active, the brake releases when drive enable is set although the command is still active!

When the command is completed, the brake releases again if the drive is still active ("AF").

When the command is completed, the brake remains applied if drive enable was reset during the execution of the command!

Notes on Commissioning

Relevant Parameters   Enter application-dependent parameter values:

* **S-0-0273, Maximum drive off delay time**

In this parameter enter the determined time that the drive needs in order to stop the axis out of maximum velocity at maximum inertia or mass with maximum allowed brake torque or brake force. If necessary, increase the determined time to make sure the axis really stops!

<div style="border: 1px solid; padding: 10px;">

⚠️

CAUTION

Danger of damaging the motor brake when value in S-0-0273 is too low!

⇒ The value for **S-0-0273, Maximum drive off delay time** must always be set higher than the time needed to decelerate the axis by velocity command value reset (if necessary with ramp), taking the maximum possible velocity into account.

</div>

Enter holding brake data:

- **S-0-0206, Drive on delay time**
- **S-0-0207, Drive off delay time**
- **P-0-0540, Torque of motor holding brake**

Note: The holding brake data are ...

- entered automatically when switching the drive on, in the case of Rexroth motors **with** encoder data memory!

- entered automatically only when loading the motor-specific parameter values from the data base of the "DriveTop" commissioning tool, in the case of Rexroth motors **without** encoder data memory!

Configure holding brake control in:

- **P-0-0525, Holding brake control word**

Activating the Holding Brake Function   The holding brake control is linked with drive enable and does not have to be separately activated.

Command "Brake Check"   The control unit can activate the brake check by means of a command:

- **P-0-0541, C2100 Brake check command**

<div style="border: 1px solid; padding: 10px;">

⚠️

CAUTION

Property damage caused by drive-controlled axis movements during brake check!

⇒ Before starting the command, move the axis to a noncritical position!

</div>

Automatic Brake Check   The "brake check" function can also take place automatically, every time drive enable is set and reset. The function is activated via the respective bit in parameter

- **P-0-0525, Holding brake control word**

Presetting the Brake Check   Check for brake released:

The status "holding brake released" is checked by the motor generating a torque or force that sets the motor slightly in motion. The maximum value can be preset in

- **P-0-0545, Test torque for releasing motor holding brake**.

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The appropriate value for P-0-0545 can be determined on the basis of the value displayed in

- **P-0-0546, Starting torque for releasing motor holding brake**.

Note:	The value of P-0-0546 should be provided with a safety factor if used for P-0-0545!
	See also respective Parameter Description.

Check for sufficient holding torque of the brake:

The holding torque of the brake is checked by the motor generating a torque or force with the brake having been applied. The maximum value can be preset in parameter

- **P-0-0547, Test torque with holding brake applied**.

The criterion for which the check is to be carried out is decisive for determining an appropriate value for P-0-0547:

- nominal torque or force of the holding brake
- holding torque or force for fixing the axis
- increased holding torque or force.

Criterion "Nominal Torque or Force"
The nominal torque or force of the holding brake from **P-0-0540, Torque of motor holding brake** can be activated for the check.

i   See Parameter Description "P-0-0547, Test torque with holding brake applied"

Criterion "Fixing the Axis"
The torque or force required for fixing the axis can be determined on the basis of P-0-0546. In this case P-0-0547 could also be written with the value of P-0-0545 (safety factor >1 * P-0-0546).

Note:	Due to dimensioning, the required torque or force with the criterion "fixing the axis" is lower than the nominal torque or force of the holding brake. This expands the tolerance range for detection of holding brake wear and therefore increases the service life of the holding brake.

Criterion "Increased Holding Torque or Force"
With safety-relevant dimensioning of the drive it is sometimes necessary to make increased demands on the holding brake. In this case enter the respective test torque or force in parameter P-0-0547!

Note:	With the criterion "increased holding torque or force", the tolerance range for detection of holding brake wear is reduced which can shorten the service life of the holding brake.

Command "Abrasion of Brake"
By starting a command it is possible to reestablish, by removing the oxide film (abrasion 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 Abrasion of brake**

Command "Release Holding Brake"
The control unit can release the holding brake by means of the following command:

- **P-0-0542, C2000 Command Release motor holding brake**

> ⚠ **CAUTION**
>
> **Property damage caused by movement of non-equilibrated axes when releasing the holding brake!**
>
> ⇒ Before starting the command, move the axis to a noncritical position!

Command "Apply Holding Brake"

The control unit can apply the holding brake by means of the following command when the drive is active:

- **P-0-0543, C2000 Command Apply motor holding brake**

> ⚠ **CAUTION**
>
> **Damage to the holding brake!**
>
> **If the axis is moved with the holding brake applied, the brake can become prematurely worn!**
>
> ⇒ In case of doubt start **P-0-0541, C2100 Brake check command**!

Operating Status

Displaying the operating status and the monitoring function:

- **P-0-0539, Holding brake status word**

Signaling the readiness to accept command values:

- **S-0-0135, Drive status word**

Warnings

- **E2069 Brake torque too low**

Errors

- **F2069 Error when releasing the motor holding brake**
- **F6024 Maximum braking time exceeded**

Command Errors

- **C2001 Command not enabled**
- **C2101 Brake check only possible with drive enable**
- **C2103 Brake torque too low**
- **C2104 Command execution impossible**
- **C3901 Abrasion of brake only possible with drive enable**
- **C3902 Error during abrasion of brake**
- **C3903 Command execution impossible**

5.2   Rexroth Motors

Basics on Rexroth Motors

Brief Description

Bosch Rexroth's "Electric Drives and Controls" technology field offers a wide range of motors for equipping machines and installations with drives.

With regard to their type of construction the Rexroth electric motors can be divided into:

- housing motors with drive shaft and flange or mounting supports

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- kit motors to be installed in machines and installations; consisting of individual components that are mounted to a moving and as 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 "DriveTop" commissioning tool.

The motor parameter values determined by the manufacturer guarantee that the motor can be loaded in accordance with its operational characteristic, if the required current and the corresponding power are provided by controller and supply unit.

Thermal Motor Monitoring

Rexroth motors are thermally monitored by the controller and protected against overheating. To do this the current motor temperature is determined by thermo sensors installed in the motor winding. Depending on temperature thresholds that can be set, the controller generates a warning or switches the motor off.

Note: Rexroth motors, by motor parameters made available and temperature evaluation adjusted in an optimum way, guarantee easy commissioning, full drive performance and a high degree of operational safety!

Measuring System

As a standard, Rexroth housing motors are equipped with a position measuring system. The individual motor series have different measuring systems which allows offering cost-efficient motors depending on the application.

The following measuring systems are used:

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

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

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

Rexroth Housing Motors with Encoder Data Memory

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

- MHD, MKE, MKD
- in preparation: MSK, MSH, MAD, MAF, MAL

Note: The Bosch motor with the type designation "SF..." that can be operated 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 contains the following parameters.

Motor parameters:

- **P-0-2141, Motor type, encoder memory**
- **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-0-3002, 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-0-3006, Kind of motor, 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**

Parameters for motor holding brake (if available):

- **P-0-3010, Torque of motor holding brake, encoder memory**

Default control loop parameters:

- **P-0-2100, Velocity controller proportional gain, encoder memory**
- **P-0-2101, Velocity controller integral-action time, encoder memory**
- **P-0-2104, Position controller Kv-factor, encoder memory**
- **P-0-2106, Current controller proportional gain 1, encoder memory**
- **P-0-2107, Current controller integral-action time 1, encoder memory**

- **P-0-3004, Speed controller smoothing time constant, encoder memory**

At a command, default control loop parameters can be loaded to the controller. They are useful starting values for further control loop optimization.

Pertinent Diagnostic Messages

- **C07_0 Load defaults procedure com. (load controller param.)**
- **C0702 Default parameters not available**
- **C0703 Default parameters invalid**
- **C0704 Parameters not copyable**
- **C0706 Error when reading the controller parameters**
- **F2008 RL The motor type has changed.**
- **F2104 Commutation offset invalid**

Notes on Commissioning

Initial Commissioning

In the case of Rexroth housing motors with encoder data memory, the values for the motor parameters stored in the encoder, the measuring system parameters and, where required, the motor holding brake parameters are automatically loaded to the controller when the drive is switched on.

At the initial commissioning of a drive the **F2008 RL The motor type has changed.** error message will appear. This message only means that this motor has not yet been connected to the controller.

By clearing this error message (reset via control panel or 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.

Note: Depending on the setting in **P-0-4090, Index for C07 Load defaults procedure**, the following parameter values are loaded with the "load defaults procedure" command (S-0-0262):

- default control loop parameter values (default setting)
- basic parameter values (default parameter set) of the firmware.

In the case of motors with integrated holding brake, the type of motor holding brake and the activation of the brake control is automatically set in **P-0-0525, Holding brake control word**.

In the case of motors with several cooling type variants (MHD, MKD), the load data can be referred to the cooling type realized by entering the corresponding value in **P-0-0640, Cooling type**.

Recommissioning

When the machine is repaired the motor can be replaced by a motor of the same type without any problem. The adjustment to the controller does not need to be repeated. In the case of an absolute motor encoder, it is only necessary to make an adjustment to the machine axis by establishing the position data reference.

If the motor type connected to the controller has changed, the controller signals this with **F2008 RL The motor type has changed** and requests the default control loop parameter values and the motor type parameter to be loaded. In the case of a desired motor change, initial commissioning of the new axis motor is necessary. Otherwise there is an assembly error that has to be corrected!

Diagnostic Messages

- While the default control loop parameter values and the motor type parameter is loaded the controller signals:
C07_0 Load defaults procedure com. (load controller param.)

- If the parameter values in the encoder data memory cannot be read:
C0706 Error when reading the controller parameters

- If the motor type connected to the controller has changed:
F2008 RL The motor type has changed.

- If an invalid value for the commutation offset is contained in the encoder memory, the controller signals:
F2104 Commutation offset invalid

Rexroth Housing Motors without Encoder Data Memory

The following Rexroth housing motors do not have an encoder data memory:

- 2AD, ADF

Brief Description

See section "Basics on Rexroth Motors"

Pertinent Parameters

The parameters mentioned under "Basics on the Motors to be Controlled" are used for these motors.

Functional Description

Application-Dependent Motor Parameters for Asynchronous Motors

The Rexroth motors without encoder data memory, 2AD, ADF, MAD and MAF series, are asynchronous motors. Therefore, a value adjusted to the application has to be written to the **P-0-0532, Premagnetization factor** parameter.

The premagnetization factor influences the "magnetizing current" motor parameter:

effective magnetizing current = P-0-0532 / 100% * P-0-4004

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

Fig. 5-9:   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.
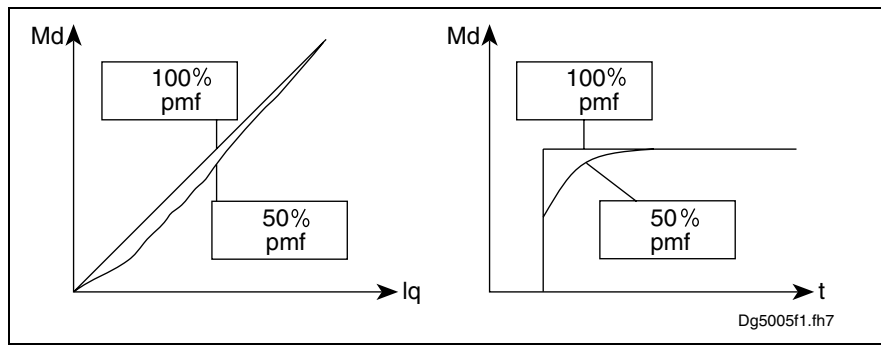
Md: torque at the motor shaft
Iq: torque-generating content of the motor current
t: time

Fig. 5-10:   Influence of the premagnetization factor on the torque

Notes on Commissioning

Parameter Values Made Available

In the case of Rexroth motors without encoder data memory, the motor-specific parameter values made available, such as

- motor parameters
- parameters of the measuring system
- parameters of the motor holding brake
- temperature sensor parameters

can either be input manually by means of a list (e.g. via the control terminal) or loaded via the "DriveTop" commissioning tool from a data base.

Setting the Premagnetization Factor

Setting of P-0-0532 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. 5-11:   Recommended setting for parameter P-0-0532

With values between 50% and 100% it is possible to obtain a compromise between the mentioned effects!

It is therefore necessary to make sure you obtain the desired results for processing or acceleration/deceleration procedures after the premagnetization factor has been reduced!

Note: The selection lists for motor/controller combinations with Rexroth asynchronous motors (2AD, ADF, 1MB, MAD, MAF), published by Rexroth, refer to a premagnetization of 100%.

With lower values you have to expect deviation from these data!

Rexroth Kit Motors

General Information

Kit motors consist of individual components that are mounted to a moving and as static part of the machine's mechanical system and functionally put together to form a motor.

A kit motor consists of the following components:

- electrically active part with thermo sensor
- electrically passive part
- measuring system
- bearing

The electrical parts of the kit motor are supplied by Rexroth, the measuring system and the bearing are provided on the machine side.

Rexroth kit motors are manufactured according to the "asynchronous motor" or "synchronous motor" functional principles. With regard to control the functional principles have different requirements:

- In the case of synchronous motors, the current in the windings of the stator must have a fixed allocation to the permanent magnetic field of the rotor so that the maximum torque or the maximum force is generated.

- In the case of asynchronous motors there is no fixed allocation between stator and rotor required in order to generate the maximum torque or the maximum force.

Rexroth Kit Motors, Synchronous

Brief Description

The following Rexroth kit motors are manufactured according to the "synchronous motor" functional principle:

- LSF linear motors
- MBS and MBT rotary motors

As the motor is assembled in the machine, stator, rotor and measuring system can only be put together on site. The electric-magnetic-mechanical allocation of the synchronous motor is therefore only to be made on site. This is done by determining and setting the commutation offset.

Note: The measuring system should be realized with high resolution and as a motor encoder that can 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 success of the respective method depending on the mechanical axis system:

- measuring method for relative motor encoder and Hall sensor box (distance measurement, currentless → only possible with Rexroth linear kit motors, see documentation "Hall Sensor Box SHL01.1")

- measuring method for motor encoder that can be evaluated in absolute form (distance measurement, currentless → only possible with linear kit motors)

- saturation method (with current → possible with all types of construction in combination with motor encoders that can be evaluated in absolute form and with relative motor encoders)

Note: 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!

See "Motor Control: Commutation Setting" in chapter "Drive Control"

Pertinent Parameters   Apart from the motor parameters (see parameter overview in section "Basics on the Motors to be Controlled"), there are further parameters available for the commutation setting of synchronous kit motors:

- **P-0-0506, Voltage amplitude for angle acquisition**
- **P-0-0507, Test frequency for angle acquisition**
- **P-0-0508, Commutation offset**
- **P-0-0521, Effective commutation offset**
- **P-0-0522, Control word for commutation setting**
- **P-0-0523, Commutation setting measured value**
- **P-0-0524, C1200 Commutation offset setting command**
- **P-0-3008, Commutation offset, encoder memory**

Pertinent Diagnostic Messages
- **C1200 Commutation offset setting command**
- **C1204 Error in offset calculation**
- **C1208 No adjustment with asynchronous motor**
- **C1209 Proceed to phase 4**
- **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**
- **F2032 Plausibility error during commutation fine adjust**
- **F8013 Automatic commutation: current too low**
- **F8014 Automatic commutation: overcurrent**
- **F8015 Automatic commutation: timeout**
- **F8016 Automatic commutation: iteration without result**

Rexroth Kit Motors, Asynchronous

Brief Description

The following Rexroth kit motors are manufactured according to the "asynchronous motor" functional principle:

- 1MB and MBA rotary motors

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.

Note:	The measuring system should be realized with high resolution and as an absolute encoder! Avoid using encoders with square-wave signals!

Pertinent Parameters The parameters mentioned under "Basics on the Motors to be Controlled" are used for these motors.

Notes on Commissioning

Parameter Values Made Available For commissioning the motor-specific parameter values made available by Rexroth, such as

- motor parameters and

- temperature sensor parameters

can either be input manually by means of a list (e.g. via the control terminal) or loaded via the "DriveTop" commissioning tool from a data base.

Premagnetization Factor A value adjusted to the application only has to be written to the **P-0-0532, Premagnetization factor** parameter.

See section"Rexroth Housing Motors without Encoder Data Memory"

5.3   Third-Party Motors at IndraDrive Controllers

General Information on Third-Party Motors

Why Third-Party Motor Control?

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 motor constructions diverging from the standard.

Undeliverable Motor Design For these cases there is the demand on the drive supplier to realize, apart from the deliverable standard drive consisting of (standard) motor, controller, cable and, if required, machine control unit, drives with motors that are not included in his own product range due to the special design.

With Rexroth controllers of the IndraDrive range it is also possible to control third-party motors.

Checking Whether Third-Party Motors Can be Controlled

For successfully controlling a third-party motor it is first of all necessary to check

- whether the third-party motor to be controlled meets the requirements of the controller,

- whether the mounted position measuring system can be evaluated by the controller or which position measuring system can be selected for kit motors,

- which controller, including supply, is suitable due to the motor power to be delivered.

How to do Project Planning?

This section contains the requirements on third-party motors and information on the measuring systems that can be evaluated as motor encoders. The collection of the required data of motor, temperature sensor and motor encoder is supported by forms (see section "Required Manufacturer-Side Output Data for Third-Party Motors").

The controller required for the respective motor and the supply unit are determined by comparing the motor data to the data of these devices (see documentation for HMS/HMD and HMV or HCS).

Note:	The continuous current of the controller should be greater than that of the motor, the continuous power of the supply must be greater than the sum of all average powers of the axes of the drive system!

How to Commission?

First it is necessary to determine the motor parameter values (see section "Determining the Motor Parameter Values"). In addition, the commissioning tool "DriveTop" supports the determination of motor parameter values of third-party motors!

It is advisable to document the determined values in the forms contained in section "Forms for Parameter Values".

The section "Notes on Commissioning" explains the proceeding for commissioning third-party motors.

Which are the Important Directives?

According to the legal requirements

- of the EU directives EMV89/336/EWG and

- the German EMC laws

installations and machines have to be designed and built according to the present state of standardization. In order to comply with the machine directives regarding "electromagnetic compatibility (EMC)", a conformity test of the drive system (motor with controller and connection design) has to be carried out. The test of the drive system and compliance with the directives has to be guaranteed by the machine manufacturer.

Requirements on Third-Party Motors

Dielectric Strength of the Winding

The dielectric strength of third-party motor windings has to be checked. Depending on the controller that is used there are different loads:

Controller type	Max. voltage amplitude û$_{max}$ between motor terminals and motor terminals against housing (ground)	Rate of rise of voltage du/dt
HMS, HMD at HVE, HMV (3x400VAC) HCS (3x400VAC)	1200 V$_{pp/2}$	8kV/µs
HMS, HMD at HVR HMS, HMD at HVE (3x480VAC) HCS (3x480VAC)	1500 V$_{pp/2}$	10kV/µs

Fig. 5-12: Voltage load of motors depending on the controllers

Motor Inductance

Depending on the controller used, the motor has to have a minimum value for inductance. The actually available inductance of a motor can be measured directly between two motor terminals by means of an inductance measuring bridge. The measurement has to be made for a complete motor wired for normal operation but not yet connected. During the measurement one motor terminal remains open!

For asynchronous motors the measured value can only be used if the rotor doesn't have closed slots!

Controller	Minimum required motor inductance
HMS, HMD at HVE, HMV (3x400VAC) HCS (3x400VAC)	$L_{U-V} = 80* 4/(\sqrt{2} * I_{Type} * PWM)$ (in mH)
HMS, HMD at HVR HMS, HMD at HVE, HMV (3x480VAC) HCS (3x480VAC)	$L_{U-V} = 116* 4/(\sqrt{2} * I_{Type} * PWM)$ (in mH)

I$_{Type}$ type current of selected controller (rms value)
PWM: desired pulse width modulation frequency in kHz

Fig. 5-13:   Minimum inductance depending on controller data, supplies and supply voltage

If the inductance of the third-party motor is lower than indicated in the above table, a three-phase choke has to be connected in the motor feed wire. This choke has to increase the inductance that can be measured between two motor terminals to the minimum value.

Note: When the inductance is measured, different inductance values can be determined at different rotor positions within one pole pair distance of the motor. The average value is relevant for the check of the minimum value.
     Attention: Correct values can only be determined when the motor is in standstill!

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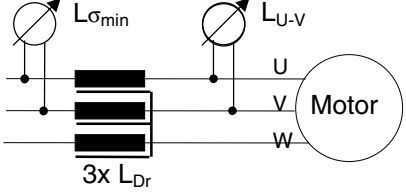
Available third-party motor	Planned third-party motor
$L_{Dr} = 0.5 * (L_{min} - L_{U-V})$ (inductance measurement with 1 kHz) mounting of 3x L_{Dr} (three-phase choke)	Calculating the leakage inductance (asynchronous motor) or inductance (synchronous motor) of the third-party motor by means of the single-phase substitute connection diagram (manufacturer's specification!). Determine choke by means of calculation, if necessary. It is recommended to contact Rexroth!

Requirements on the choke:

- $I_{n\_Dr} \geq I_{n\_Mot}$
  The rated current of the choke has to be greater than or equal to the rated motor current.

- $f_I = f_{Ausgang, max.}; f_{PWM}$
  Depending on the maximum speed, the choke is loaded with the respective output frequency and the PWM frequency of the controller.

- Insulation class
  The insulation class has to correspond at least to that of the motor or has to be dimensioned for higher temperatures.

- The voltage load of the choke depends on the controller used.

Fig. 5-14:   Data for possibly required choke

Temperature Evaluation

Only such motors with incorporated temperature sensor should be operated together with IndraDrive controllers, because only then can the motor be thermally monitored by the controller and protected against destruction by too high temperature rise.

The controller is informed on the temperature sensor type via parameter **P-0-0512, Temperature sensor**. Standard sensor types are characterized by a characteristic number. A characteristic stored in the firmware is assigned to this number.

See "Motor Temperature Monitoring" in section "General Information on the Operation of Motors with IndraDrive"

[i]   See Parameter Description "P-0-0512, Temperature sensor"

General Information on Controlling Third-Party Motors

Pertinent Parameters

Motor Parameters for Synchronous and Asynchronous Motors

- **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**
- **P-0-0018, Number of pole pairs/pole pair distance**
- **P-0-0045, Control word of current controller**
- **P-0-0051, Torque/force constant**

- **P0-0510, Moment of inertia of the rotor**
- **P-0-4014, Type of construction of motor**
- **P-0-4048, Stator resistance**

Motor Parameters for Field Weakening Range for Synchronous and Asynchronous Motors

- **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, Motor voltage max.**

Other Motor Parameters 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**
- **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-0-4036, 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**

Other Motor Parameters for Synchronous Motors

- **P-0-4016, Direct-axis inductance of motor**
- **P-0-4017, Quadrature-axis inductance of motor**

Only for field weakening range:

- **P-0-4005, Flux-generating current, limit value**

Other Motor-Relevant Parameters

Measuring system parameters (motor encoder):

- **S-0-0116, Feedback 1 resolution**
- **S-0-0277, Position feedback 1 type**
- **P-0-0074, Encoder type 1 (motor encoder)**

Motor holding brake 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**

Temperature sensor parameters:

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

Default control loop parameters:

- **S-0-0100, Velocity loop proportional gain**
- **S-0-0101, Velocity loop integral action time**

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Note:	For more details on motor measuring system, motor holding brake, motor temperature evaluation and default control loop parameters see respective subchapter of this documentation!

Pertinent Diagnostic Messages

Diagnostic messages with regard to command "C3200 Calculate data for asynchronous motor":

- **C3201 Incorrect input for current**
- **C3203 Incorrect input for voltage**
- **C3202 Incorrect input for frequency**
- **C3204 Incorrect input for speed**
- **C3205 Incorrect input for power factor**
- **C3206 Incorrect input for power**
- **C3207 Type plate list incomplete**
- **C3208 Error when writing parameters**

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.

Third-Party Motors to be Controlled

Motor Types The following motor types can be controlled:

- asynchronous motors, rotary
- asynchronous motors, linear
- synchronous motors, rotary
- synchronous motors, linear

These motors can be operated within the scope of the technical data of the IndraDrive controller selected for motor control, if these motors have been equipped with holding brakes.

Note:	For third-party motors Bosch Rexroth, as a matter of principle, does not assume the guarantee for the power data at the motor shaft!

In the case of synchronous motors, the commutation offset has to be set first during commissioning. For synchronous third-party motors at IndraDrive devices this offset is determined with the "saturation method".

Note:	For application-specific limitations for synchronous motors in conjunction with the saturation method see "Motor Control: Commutation Setting" in chapter "Drive Control"!

Motor Encoder The control section integrated in the controller can evaluate the measuring systems as a motor encoder that are contained in **P-0-0074, Encoder type 1 (motor encoder)** (see also product documentation of the IndraDrive control sections).

Motor Encoder for Asynchronous Third-Party Motors	Asynchronous motors can also be controlled by IndraDrive controllers in "open-loop" operation. This does not require any motor encoder! "Closed-loop" operation does require a motor encoder, for asynchronous motors a relative measuring system is sufficient.
Motor Encoder for Synchronous Third-Party Motors	For operationally reliable drives with synchronous third-party motors at IndraDrive controllers the following possible combinations or restrictions have to be taken into account when selecting the measuring system:

Drive range	Motor measuring system	Synchronous third-party motor
IndraDrive	absolute	+
	relative	o

+ …   Advantageous combination
o …   Combination is possible, commissioning may be more complicated!

Fig. 5-15:   Possible combinations of synchronous third-party motors and measuring system

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Note: For information on absolute and relative measuring systems see section "Measuring Systems"!

Determining the Motor Parameter Values

Before the commissioning procedure it is necessary to determine the motor parameter values for the respective third-party motor. For this purpose the motor manufacturer has to make available specific motor data (see below "Required Manufacturer-Side Output Data for Third-Party Motors").

The motor parameter values can be determined in different ways:

- For motors that had already been used with Diax/EcoDrive, the existing motor parameter values can be converted to IndraDrive.

- For rotary asynchronous motors, the motor parameter values can be determined controller-internally on the basis of the type plate data.

- By means of the manufacturer-side, specific motor data the motor parameters can be calculated via DriveTop or using formulas.

Note: For project planning and commissioning of a third-party motor the required, manufacturer-specific motor data must always be available!

Converting the Parameter values from Diax/EcoDrive to IndraDrive

Parameters for Synchronous and Asynchronous Motors

P-0-4014, Type of construction of motor;
P-0-0512, Temperature sensor

P-0-4014 (Diax/EcoDrive)	P-0-4014 (IndraDrive)	P-0-0512 (IndraDrive)
1	00000100.00000000	1
2	00000001.00000000	2
3	00000010.00000000	1
4	00000011.00000000	1
5	00000100.00000000	1
6	00000001.00000000	1
7	00000000.00000000	1
8	00000001.00000000	3
9	00000010.00000000	3
10	00000011.00000000	3
11	00000000.00000000	3

Fig. 5-16:   Converting P-0-4014(Diax/EcoDrive) to P-0-4014 (IndraDrive) and P-0-0512 (IndraDrive)

P-0-0051, Torque/force constant

$$P\text{-}0\text{-}0051_{(IndraDrive)} = P\text{-}0\text{-}0051_{(Diax/EcoDrive)} * \sqrt{2}$$

Fig. 5-17:   Conversion to IndraDrive parameter values

S-0-0109, Motor peak current
S-0-0111, Motor current at standstill

$$\text{parameter value}_{(IndraDrive)} = \text{parameter value}_{(Diax/EcoDrive)} / \sqrt{2}$$

Fig. 5-18:   Conversion to IndraDrive parameter values

S-0-0100, Velocity loop proportional gain

$$S\text{-}0\text{-}0100_{(IndraDrive)} = S\text{-}0\text{-}0100_{(Diax/EcoDrive)} * P\text{-}0\text{-}0051_{(Diax/EcoDrive)}$$

P-0-0051, Torque/force constant

Fig. 5-19:   Conversion to IndraDrive parameter values

P-0-0045, Control word of current controller

P-0-0538 (Diax/EcoDrive)	P-0-0045 (IndraDrive)
0	00000000.00000000
2	00000000.00000001

Fig. 5-20:   Conversion to IndraDrive parameter values

S-0-0106, Current loop proportional gain 1

$$S\text{-}0\text{-}0106_{(IndraDrive)} = S\text{-}0\text{-}0106_{(Diax/EcoDrive)} * 0{,}66$$

Fig. 5-21:   Conversion to IndraDrive parameter values

Parameters for Asynchronous Motors

P-0-4004, Magnetizing current

$$\text{parameter value}_{(IndraDrive)} = \text{parameter value}_{(Diax/EcoDrive)} / \sqrt{2}$$

Fig. 5-22:   Conversion to IndraDrive parameter values

P-0-4041, Motor magnetizing inductance

$$P-0-4041(\text{IndraDrive}) = \frac{P-0-0051 + \sqrt{(P-0-0051)^2 + \frac{3}{2}(P-0-4047)/1000 * P-0-0018 * P-0-4004 * P-0-0051}}{3 * P-0-0018 * P-0-4004} * 1000$$

P-0-0051, Torque/force constant (Diax/EcoDrive)
P-0-4047, Motor inductance (Diax/EcoDrive)
P-0-0018, Number of pole pairs/pole pair distance (Diax/EcoDrive)
P-0-4004, Magnetizing current (Diax/EcoDrive)

Fig. 5-23:   Conversion to IndraDrive parameter values (in mH)

P-0-4042, Characteristic of motor magnetizing inductance

list parameter P-0-4042 (IndraDrive)
→ enter the value "1,0" in each of the five lines!

P-0-4039, Stator leakage inductance

$$P-0-4039(\text{IndraDrive}) = \frac{P-0-4047(\text{Diax/EcoDrive})}{4}$$

P-0-4047, Motor inductance (Diax/EcoDrive)

Fig. 5-24:   Conversion to IndraDrive parameter values (in mH)

P-0-0529, Scaling of stall current limit

$$P-0-0529(\text{IndraDrive}) = \frac{10 * \sqrt{3} * \pi * P-0-0531 * P-0-0018 \cdot [P-0-4041(P-0-4039 + P-0-4040) + P-0-4039 * P-0-4040]}{30 * P-0-0535 * (P-0-4041 + P-0-4040)}$$

P-0-0531, Stall current factor (Diax/EcoDrive)
P-0-0018, Number of pole pairs/pole pair distance (Diax/EcoDrive)
P...4039: P-0-4039, Stator leakage inductance (IndraDrive)
P...4040: P-0-4040, Rotor leakage inductance
P...4041: P-0-4041, Motor magnetizing inductance (IndraDrive)
P-0-0535, Motor voltage at no load (Diax/EcoDrive); in %

Fig. 5-25:   Conversion to IndraDrive parameter values (in %)

P-0-4040, Rotor leakage inductance

$$P-0-4040(\text{IndraDrive}) = \frac{P-0-4047(\text{Diax/EcoDrive})}{4}$$

P-0-4047, Motor inductance (Diax/EcoDrive)

Fig. 5-26:   Conversion to IndraDrive parameter values (in mH)

P-0-0528, Flux control loop proportional gain

$$P-0-0528(\text{IndraDrive}) = 0{,}4 * \left[\frac{(P-0-4041 + P-0-4039) * (P-0-4041 + P-0-4040)}{P-0-4041 * (P-0-4039 + P-0-4040) + P-0-4039 * P-0-4040} - 2 \right]$$

P-0-4041, Motor magnetizing inductance; see above (IndraDrive)
P-0-4040, Rotor leakage inductance; see above (IndraDrive)
P-0-4039, Stator leakage inductance; see above (IndraDrive)

Fig. 5-27:   Calculation from IndraDrive parameter values calculated above

P-0-4043, Rotor time constant

$$P-0-4043(\text{IndraDrive}) = \frac{100000}{2 * \pi * (P-0-4004(\text{Diax/EcoDrive})) * (P-0-4012(\text{Diax/EcoDrive}))}$$

P-0-4004, Magnetizing current
P-0-4012, Slip factor

Fig. 5-28:   Conversion to IndraDrive parameter values (in ms)

P-0-4036, Rated motor speed   The rated speed of the motor is only required for rotary asynchronous motors in "open-loop" operation!

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Parameters for Synchronous Motors

P-0-4005, Flux-generating current, limit value

$$P\text{-}0\text{-}4005_{(IndraDrive)} = S\text{-}0\text{-}0109_{(Diax/EcoDrive)}/\sqrt{2}$$

or

$$P\text{-}0\text{-}4005_{(IndraDrive)} = 2{,}0 * S\text{-}0\text{-}0111_{(Diax/EcoDrive)}/\sqrt{2}$$

S-0-0109, Motor peak current
S-0-0111, Motor current at standstill

Fig. 5-29:   Conversion to IndraDrive parameter value (the value with the lower absolute value has to be entered with negative sign!)

P-0-4016, Direct-axis inductance of motor

$$P\text{-}0\text{-}4016_{(IndraDrive)} = P\text{-}0\text{-}4047_{(Diax/EcoDrive)} * 0{,}5$$

P-0-4047, Motor inductance (Diax/EcoDrive)

Fig. 5-30:   Conversion to IndraDrive parameter value

P-0-4017, Quadrature-axis inductance of motor

$$P\text{-}0\text{-}4017_{(IndraDrive)} = P\text{-}0\text{-}4047_{(Diax/EcoDrive)} * 0{,}5$$

P-0-4047, Motor inductance (Diax/EcoDrive)

Fig. 5-31:   Conversion to IndraDrive parameter value

P-0-4002, Charact. of quadrature-axis induct. of motor, inductances

list parameter P-0-4002 (IndraDrive)
→ enter the value "1,0" in each of the four lines!

P-0-4003, Charact. of quadrature-axis inductance of motor, currents

list parameter P-0-4003 (IndraDrive)
→ enter the value "1,0" in each of the four lines!

Note: The other relevant Diax/EcoDrive motor parameter values can be directly used for IndraDrive!

Determining the Motor Parameter Values by Entering the Type Plate Data

For asynchronous motors it is possible to have the motor parameters calculated internally by means of the type plate data. The calculation is carried out successfully when all required data with regard to an operating point, in the ideal case at rated load, are correctly entered.

Required Type Plate Data of Rotary Asynchronous Motors

Element	Text	Default value	Unit	Notes
1	rated current	4.000	A_{eff}	
2	rated voltage	380.000	V_{eff}	phase-to-phase voltage
3	rated frequency	50.000	Hz	electric frequency
4	rated speed	925.000	1/min	
5	power factor cos φ	0.760	1	
6	rated power	1.500	kW	mechan. power

Fig. 5-32: Lines of list parameter **P-0-4032, Type plate list asynchronous motor**

Required type plate data:

1. Rated current
   → rms value of the electric current in the motor feed wire (motor phase) at rated load

2. Rated voltage
   → rms value of the voltage between the motor terminal connectors at rated load

3. Rated frequency
   → frequency of the feeding, sinusoidal electric voltage

4. Rated speed
   → speed of motor output shaft at rated load

5. Power factor cos φ
   → power factor at rated load

6. Rated power
   → power that can be continuously delivered at rated load

Note: "Rated load" means load of the motor output shaft with rated torque when feeding the motor with rated voltage and rated frequency.
The power at the output shaft is the rated power.

Condition:
The rated load point mustn't be in the field weakening range!

Internally Calculated Motor Parameter Values

With the command **P-0-4033, C3200 Command Calculate data for asynchronous motor** the parameter values listed below are calculated from the type plate data of the asynchronous motor entered in list parameter P-0-4032.

Internally calculated motor parameters for asynchronous motors with "open-loop" operation and "closed-loop" operation:

- **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**
- **P-0-0051, Torque/force constant**
- **P-0-0528, Flux control loop proportional gain**
- **P-0-0529, Scaling of stall current limit**
- **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, Motor voltage max.**
- **P-0-4004, Magnetizing current**
- **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**

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Other internally calculated motor parameters for asynchronous motors only with "open-loop" operation:

- **P-0-0569, Maximum stator frequency change**
- **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**

Note: The input in P-0-4032 is irrelevant unless the command C3200 has been started!

When the command has been processed without error, the motor parameter values are operational.

Apart from these parameters, other parameters are relevant in conjunction with the motor (see above).

Note: When the type plate data are used, the output data of the motor made available by the manufacturer must be indicated, too, for checking the usability!

Determining the Motor Parameter Values by Calculation by Means of Motor Output Data

Initial State   Based on the required motor-specific data made available by the manufacturer, the motor parameter values can also be manually determined.

Note: The PC-based commissioning tool "DriveTop" support the determination of the motor parameter values as of version FWA-DTOP-16V**. DriveTop calculates the parameter values by means of the output data of the motor (completed form has to be available!).

Determining the Parameter Values Relevant for Synchronous and Asynchronous Motors

S-0-0141, Motor type   The type designation of the third-party motor has to be entered in parameter **S-0-0141, Motor type**.

P-0-4014, 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**.

Note: 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!

P-0-0051, Torque/force constant

Calculating the torque/force constant with motor at operating temperature and rated current or continuous current at standstill:

$$\text{rotary synchronous motors} : P-0-0051 = M_N/I_N$$
$$\text{linear synchronous motors} : P-0-0051 = F_N/I_d$$

M_N: rated torque (acc. to motor output data)
I_N: rated current (rms value, acc. to motor output data)
F_N: rated force (acc. to motor output data)
I_d: continuous current at standstill (rms value, acc. to motor output data)

Fig. 5-33: Value for P-0-0051 in Nm/A$_{(rms\ value)}$ with rotary synchronous motors, in N/A$_{(rms\ value)}$ with linear synchronous motors

$$\text{rotary asynchronous motors} : P-0-0051 = M_N/(I_N * \cos\varphi)$$
$$\text{linear asynchronous motors} : P-0-0051 = F_N/\sqrt{I_d{}^2 - I_{Mag}{}^2}$$

M_N: rated torque (acc. to motor output data)
I_N: rated current (rms value, acc. to motor output data)
$\cos\varphi$:   power factor
F_N: rated force (acc. to motor output data)
I_d: continuous current at standstill (rms value, acc. to motor output data)
I_{Mag}:   magnetizing current (rms value, acc. to motor output data)

Fig. 5-34: Value for P-0-0051 in Nm/A$_{(rms\ value)}$ with rotary asynchronous motors, in N/A$_{(rms\ value)}$ with linear asynchronous motors

P-0-0018, Number of pole pairs/pole pair distance

The value for parameter **P-0-0018, Number of pole pairs/pole pair distance** has to be taken from the completed form "Output Data for Asynchronous or Synchronous Motors".

S-0-0113, Maximum motor speed

The velocity command value that is output by the controller is limited to this value of parameter **S-0-0113, Maximum motor speed**. The value mustn't be higher than the maximum allowed velocity (speed)!

S-0-0111, Motor current at standstill

The motor current at standstill is the rms value of the torque-generating component of the continuous motor current.

The value entered in parameter **S-0-0111, Motor current at standstill** is the 100% reference value for the torque/force limit parameters S-0-0092 and P-0-0109 with percentage-based scaling (see below).

$$\text{rotary synchronous motors} : S-0-0111 = I_N$$
$$\text{linear synchronous motors} : S-0-0111 = I_d$$

I_N: rated current (rms value, acc. to motor output data)
I_d: continuous current at standstill (rms value, acc. to motor output data)

Fig. 5-35: Value for S-0-0111 in Nm/A$_{(rms\ value)}$ with rotary synchronous motors, in N/A$_{(rms\ value)}$ with linear synchronous motors

$$\text{rotary asynchronous motors} : S-0-0111 = I_N * \cos\varphi$$
$$\text{linear asynchronous motors} : S-0-0111 = \sqrt{I_d{}^2 - I_{Mag}{}^2}$$

I_N: rated current (rms value, acc. to motor output data)
$\cos\varphi$:   power factor
I_d: continuous current at standstill (rms value, acc. to motor output data)
I_{Mag}:   magnetizing current (rms value, acc. to motor output data)

Fig. 5-36: Value for S-0-0111 in Nm/A$_{(rms\ value)}$ with rotary asynchronous motors, in N/A$_{(rms\ value)}$ with linear asynchronous motors

S-0-0109, Motor peak current

The rms value of the maximum allowed total motor current (magnetic-field-generating and torque-generating current) is indicated in parameter **S-0-0109, Motor peak current**.

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For asynchronous motors there usually isn't any value indicated for the maximum allowed peak current.

For thermal reasons we recommend limitation according to the following relationships:

$$S-0-0109 = 2,5 * I_{Nenn}$$

S-0-0109:   rms value of maximum total motor current (in A)
I_{Nenn}:   nominal current, rms value (in A)

Fig. 5-37: Recommendation for rotary motors

$$S-0-0109 = 2,5 * I_d$$

S-0-0109:   rms value of maximum total motor current (in A)
I_d: continuous current at standstill, rms value (in A)

Fig. 5-38: Recommendation for linear motors

S-0-0106, Current loop proportional gain 1

The value of the parameter **S-0-0106, Current loop proportional gain 1** depends on the inductance of the motor (including possibly required additional motor chokes) between the motor terminals.

$$S-0-0106 = K * (L_{U-V} + 2 {}^*L_{Dr})$$

S-0-0106:   current loop proportional gain 1 (in V/A)
L_{U-V}:   inductance of motor between terminals (minimum value in mH), third terminal is not connected
L_{Dr}:   phase inductance (in mH) of a possibly required choke (3x L_{Dr})
K: factor for current loop gain, see table

Fig. 5-39: Calculating the value for S-0-0106

The factor K depends on the switching frequency that was set (P-0-0001) and the control performance (P-0-0556, bit 2; basic/advanced performance). The factor K can be taken from the following table:

Control performance P-0-0556; bit 2	Switching frequency (in Hz) P-0-0001	Factor K for determining current loop gain
x	4000	1,4
0 (basic)	8000	2,2
1 (advanced)	8000	2,8
x	12000	3,3
x	16000	4,4

P-0-0001:   switching frequency of the power output stage
P-0-0556:   control word of axis controller ("x" = 0 or 1)

Fig. 5-40:   K-factor for determining the current loop gain

Attention: The measured value of the inductance between the motor terminals can only be used for asynchronous motors, if the rotor doesn't have closed slots (observe manufacturer's specification!).

S-0-0107, Current loop integral action time 1

$$S-0-0107 = \frac{(L_{U-V} + 2 {}^*L_{Dr})}{R_{U-V}}$$

S-0-0107:   current loop integral action time 1 (in ms)
L_{U-V}:   inductance of motor between terminals (in mH), third terminal is not connected
L_{Dr}:   phase inductance (in mH) of a possibly required choke (3x L_{Dr})
R_{U-V}:   resistance of the motor between the terminals (in mΩ)

Fig. 5-41: Calculating the value for S-0-0106

P-0-4048, Stator resistance

$$P - 0 - 4048 = (R_{U\text{-}V} + 2 * R_{Dr})$$

P-0-4048: total resistance of the connected motor (in Ω)
$R_{U\text{-}V}$:   resistance of the motor between the terminals at 20°C (in Ω)
R_{Dr}:   phase resistance of a possibly required choke at 20°C (in Ω)

Fig. 5-42: Value for P-0-4048 (in Ω)

P-0-0510, Rotor inertia

For the parameterization of **P-0-0510, Rotor inertia** use the values from the completed form "Output data for Asynchronous or Synchronous Motors".

P-0-0512, Temperature sensor

The controller can directly evaluate frequently used temperature sensors because the resistance characteristics of the sensors are stored in the firmware. For **P-0-0512, Temperature sensor** the value for the temperature sensor installed in the third-party motor has to be entered. If the resistance characteristic has not been stored, it can be stored in parameter **P-0-0513, Temperature sensor characteristic**.

S-0-0204, Motor shutdown temperature, S-0-0201, Motor warning temperature

The motor shutdown temperature depends on the insulation class of the motor. The motor warning temperature should be at least 10 K below the motor shutdown temperature. These threshold values have to be set according to the insulation class of the third-party motor in the parameters **S-0-0204, Motor shutdown temperature** or **S-0-0201, Motor warning temperature**.

P-0-0533, Voltage loop proportional gain

The voltage loop is used to control the motor voltage in the field-weakening range. For synchronous motors the value for **P-0-0533, Voltage loop proportional gain** is determined by:

$$P - 0 - 0533 = 1 / S - 0 - 0106$$

P-0-0533:   voltage loop proportional gain (in V/A)
S-0-0106:   current loop proportional gain 1 (in V/A)

Fig. 5-43: Calculating the value for P-0-0533 for synchronous motors

For asynchronous motors the value for P-0-0533 is determined by

$$P - 0 - 0533 = \frac{8,5}{P - 0 - 0018 * P - 0 - 4036 * (P - 0 - 4039 + P - 0 - 4041)}$$

P-0-0533:   voltage loop proportional gain (in V/A)
P-0-0018:   number of pole pairs/pole pair distance (without unit/in mm)
P-0-4036:   rated motor speed
P-0-4039:   stator leakage inductance
P-0-4041:   motor magnetizing inductance

Fig. 5-44: Calculating the value for P-0-0533 for asynchronous motors

P-0-0534, Voltage loop integral action time

The voltage loop is used to control the motor voltage in the field-weakening range. For synchronous motors the value for **P-0-0534, Voltage loop integral action time** is determined by:

$$P - 0 - 0534 = 3 * S - 0 - 0107$$

P-0-0534:   voltage loop integral action time (in ms)
S-0-0107:   current loop integral action time 1 (in ms)

Fig. 5-45: Calculating the value for P-0-0534 for synchronous motors

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For asynchronous motors the value for P-0-0534 is determined by:

$$P-0-0534 = P-0-4043$$

P-0-0534:   voltage loop integral action time (in ms)
P-0-4043:   rotor time constant (in ms), see p.5-40

Fig. 5-46: Calculating the value for P-0-0534 for asynchronous motors

P-0-0535, Motor voltage at no load

The parameter **P-0-0535, Motor voltage at no load** takes effect in field weakening operation.
→ value to be set is "80" (in %)

Note:	For linear motors this parameter is irrelevant. Its default value mustn't be changed!

P-0-0536, Motor voltage max.

The parameter **P-0-0536, Motor voltage max.** takes effect in field weakening operation.
→ value to be set is "90" (in %)

Note:	For linear motors this parameter is irrelevant. Its default value mustn't be changed!

Determining Other Parameter Values only Relevant for Asynchronous Motors

P-0-4004, Magnetizing current

The value for parameter **P-0-4004, Magnetizing current** is the rms value of the motor magnetizing current.

$$P-0-4004 = I_{Mag}$$

P-0-4004:   magnetizing current (rms value in A)
I_{Mag}:   indicated magnetizing current (rms value in A)

Fig. 5-47: Calculating the value for P-0-4004

If there hasn't any value been indicated in the output data of the asynchronous motor, the following approximation can be used for calculation:

$$P-0-4004 = \sqrt{1-(\cos\varphi)^2} \ast I_{Nenn}$$

P-0-4004:   magnetizing current (rms value in A)
I_{Nenn}:   rated current of the motor (rms value in A)
cos φ: power factor at rated load

Fig. 5-48: Calculating the value for P-0-4004 by means of approximation

P-0-0532, Premagnetization factor

The parameter **P-0-0532, Premagnetization factor** influences the value of the no-load current (magnetizing current). This value indicates how many percent of the magnetizing current are flowing when the motor has no load.

The following values are recommended:

Drive application	Value for P-0-0532
servo application	100
spindle application	50

Fig. 5-49:   Recommended values for the premagnetization factor

P-0-0530, Slip increase

This parameter determines to which degree the slip in the motor is increased depending on the temperature rise of the motor windings. The

slip increase only takes effect when temperature sensor that can be evaluated was installed in the end winding of the motor.

The following values are depending on the cooling type of the motor:

Cooling type of the motor	Value for P-0-0530
non-ventilated	1,4
ventilated	1,5
liquid-cooled	1,8
motor without temperature sensor	1,0

Fig. 5-50:   Values for P-0-0530

P-0-0529, Scaling of stall current limit

With the value to be set in **P-0-0529, Scaling of stall current limit** it is possible to change the stall current limit relatively.
→ value to be set is "100" (in %)

P-0-4036, Rated motor speed

The value for parameter **P-0-4036, Rated motor speed** has to be taken from the completed form "Output Data for Asynchronous Motors".

Data of the Single-Phase Substitute Connection Diagram

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. The desired data are referring to the single-phase substitute connection diagram of asynchronous motors with star connection reference.
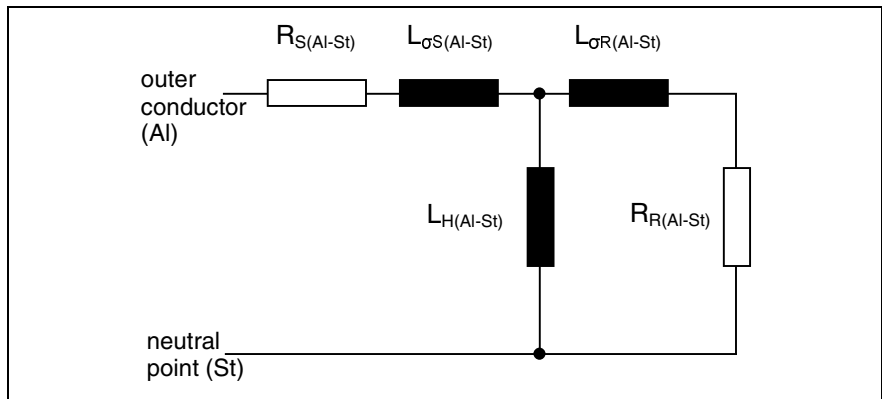
$R_{S(Al-St)}$: ohmic resistance of stator at 20°C
$R_{R(Al-St)}$: ohmic resistance of rotor at 20°C
$L_{\sigma S(Al-St)}$: leakage inductance of stator
$L_{\sigma R(Al-St)}$: leakage inductance of rotor
$L_{H(Al-St)}$: motor magnetizing inductance

Fig. 5-51:   Substitute connection diagram of asynchronous machine, single-phase, with star connection reference

P-0-4039, P-0-4040, P-0-4041

The values for the parameters P-0-4039, P-0-4040, P-0-4041 have to be taken from the form "Output Data for Asynchronous Motors".

$$P - 0 - 4039 = L_{\sigma S(Al-St)}$$
$$P - 0 - 4040 = L_{\sigma R(Al-St)}$$
$$P - 0 - 4041 = L_{H(Al-St)}$$

P-0-4039:   stator leakage inductance (in mH)
P-0-4040:   rotor leakage inductance (in mH)
P-0-4041:   motor magnetizing inductance (in mH)

Fig. 5-52:   Values for P-0-4039, P-0-4040 and P-0-4041 according to manufacturer's specification

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If the values of the manufacturer's specification are not available, they can be determined by measurement by means of approximation:

$$P-0-4039 = \frac{L_{U-V}}{4}$$

L_{U-V}:   inductance of motor between terminals (in mH), third terminal is not connected

Fig. 5-53:   Approximate calculation for P-0-4039 (in mH)

$$P-0-4040 = \frac{L_{U-V}}{4}$$

L_{U-V}:   inductance of motor between terminals (in mH), third terminal is not connected

Fig. 5-54:   Approximate calculation for P-0-4040 (in mH)

If a rated voltage and rated frequency have been indicated for the motor, the magnetizing inductance can be calculated by means of approximation:

$$P-0-4041 = \frac{U_{Nenn}}{2 * \pi * \sqrt{3} * I_{Leer} * f_{Nenn}} - L_{U-V}/4$$

U_{Nenn}:   rms value of the rated voltage (outer conductor voltage)
I_{leer}:   rms value of the no-load current in the rated point, alternatively the magnetization current P-0-4004 (see above)
f_{Nenn} rated frequency
L_{U-V}:   inductance of motor between terminals (in mH), third terminal is not connected

Fig. 5-55:   Calculating the value for P-0-4041 (in mH) by means of approximation

Note: If the required rated data of the motor are not available, the magnetizing inductance can also be determined by a no-load test. With this test the voltage, current and frequency have to be determined and used for the above formula!

P-0-0528, Flux control loop proportional gain   The value of the parameter P-0-0528, Flux control loop proportional gain is used for controlling the magnetic flux in the asynchronous motor.

$$P-0-0528 = 0.4 * \left[\frac{(P-0-4041 + P-0-4039) * (P-0-4041 + P-0-4040)}{P-0-4041 * (P-0-4039 + P-0-4040) + P-0-4039 * P-0-4040} - 2 \right]$$

P-0-4041, Motor magnetizing inductance, see previous calculations
P-0-4040, Rotor leakage inductance, see previous calculations
P-0-4039, Stator leakage inductance, see previous calculations

Fig. 5-56:   Value for P-0-0528

P-0-4042, Characteristic of motor magnetizing inductance   list parameter P-0-4042
$\rightarrow$ enter the value "1,0" in each of the five lines!

P-0-4043, Rotor time constant   The value for parameter **P-0-4043, Rotor time constant** has to be taken from the completed form "Output Data for Asynchronous Motors".

If the value is not available, it can be calculated by means of approximation:

$$P\text{-}0\text{-}4043 = \frac{L_{\sigma R(Al\text{-}St)} + L_{H(Al\text{-}St)}}{R_{R(Al\text{-}St)}} = \frac{(P-0-4040+P-0-4041)}{RR_{(Al\text{-}St)}}$$

$R_{R(Al\text{-}St)}$:   ohmic resistance of rotor at 20°C
$L_{\sigma R(Al\text{-}St)}$:   leakage inductance of rotor
$L_{H(Al\text{-}St)}$:   motor magnetizing inductance
Fig. 5-57:   Value for P-0-4043 (in ms)

Determining Other Parameter Values only Relevant for Synchronous Motors

P-0-4005, Flux-generating current, limit value

$$P\text{-}0\text{-}4005 = -(S\text{-}0\text{-}0109)$$

or

$$P\text{-}0\text{-}4005 = -(2,0 * S\text{-}0\text{-}0111)$$

S-0-0109, Motor peak current
S-0-0111, Motor current at standstill
Fig. 5-58:   Values for P-0-4005; the value with the lower absolute value has to be entered with negative sign in P-0-4005!

Direct-Axis Inductance of Motor and Quadrature-Axis Inductance of Motor

Depending on the position of the primary part of the motor with regard to the secondary part of the motor, different inductance values can be observed when the leakage inductance is measured. The values are fluctuating between a minimum and a maximum value.

- The minimum value is relevant for the direct-axis inductance of the motor ($L_{L(U\text{-}V)}$).

- The maximum value is relevant for the quadrature-axis inductance of the motor ($L_{Q(U\text{-}V)}$).

Note: Correct values can only be determined when the motor is in standstill!

P-0-4016, Direct-axis inductance of motor

The value for the direct-axis inductance of motor contained in the completed form "Output Data for Synchronous Motors" has to be used for calculation as follows:

$$P\text{-}0\text{-}4016 = L_{L(U\text{-}V)} * 0,5$$

$L_{L(U\text{-}V)}$:   value according to motor output data
Fig. 5-59:   Value for P-0-4016

P-0-4017, Quadrature-axis inductance of motor

The value for the quadrature-axis inductance of motor contained in the completed form "Output Data for Synchronous Motors" has to be used for calculation as follows:

$$P\text{-}0\text{-}4017 = L_{Q(U\text{-}V)} * 0,5$$

$L_{Q(U\text{-}V)}$:   value according to motor output data
Fig. 5-60:   Value for P-0-4017

P-0-4002, Charact. of quadrature-axis induct. of motor, inductances

list parameter P-0-4002
→ enter the value "1,0" in each of the five lines!

P-0-4003, Charact. of quadrature-axis inductance of motor, currents

list parameter P-0-4003
→ enter the value "1,0" in each of the five lines!

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Forms for Required Manufacturer-Side Output Data

Form for Output Data of Asynchronous Motors

Manufacturer,
motor type:_____

Customer, installation,
axis designation:_____

Designation	Symbol/short form	Unit	Value	see ...
rated power [1]	P_N	kW		p. 5-34
rated torque [1]	M_N	Nm		
rated current [1]	I_N	A_{eff}		p. 5-34
power factor [1]	$\cos \varphi$	--		p. 5-34
magnetizing current [2]	I_{Mag}	A_{eff}		p. 5-42
rated speed [1]	n_N	min^{-1}		p. 5-36
rated frequency [1]	f_N	Hz		p. 5-36
rated voltage [1]	U_N	V_{eff}		p. 5-36
contin. current at standstill [2]	I_d	A_{eff}		
rated force [2]	F_N	N		
inertia/mass	J/m	_		pp. 5-39
frequency for I_d [2]	f_{Id}	Hz		
maximum speed [1] or	n_{max}	min^{-1}		
maximum velocity [2]	v_{max}	m/min		
no. of pole pairs (rotary) or	PPZ	--		
pole pair distance (linear)	PWT (N-N-pol)	mm		
insulation class	Isol.Kl.	--		
motor inductance, min. value	$L_{U-V, min}$	mH		p. 5-28
motor inductance, max. value	$L_{U-V, max}$	mH		p. 5-28
motor induct., average value	L_{U-V}	mH		p. 5-28
stator leakage inductance [*]	$L_{\sigma S(Al-St)}$	mH		p. 5-41
rotor leakage inductance [*]	$L_{\sigma R (Al-St)}$	mH		p. 5-41
motor magnetizing inductance [*]	$L_{H(Al-St)}$	mH		p. 5-41
stator resistance (20°C) [*]	$R_{S(Al-St)}$	ohm		p. 5-41
rotor resistance (20°C) [*]	$R_{R(Al-St)}$	ohm		p. 5-41
rotor time constant [*]	T_R	ms		p. 5-41
winding resistance (20°C)	R_{U-V}	ohm		p. 5-39
allowed periodic peak voltage	$\hat{u}_{max\_zul.}$	$V_{pp/2}$		p. 5-28
allowed rate of rise of voltage	$du/dt_{zul.}$	kV/µs		p. 5-28
cooling type	(without/with blower, liquid cooling)	--		
tpye of motor	rotary/linear	--		
Does rotor/secondary part have closed slots?		Y/N		

Fig. 5-61: Motor data

([1]…type plate data with rotary motor; [2]…only with linear motors;
[*]…helpful, but not obligatory data)

Note: Also take form for output data of motor temperature sensor and motor encoder into account (see below)!

_____

Name   Date   Signature

Form for Output Data of Synchronous Motors

Manufacturer,
motor type:_____

Customer, installation,
axis designation:_____

Designation	Symbol/short form	Unit	Value	see ...
rated power [1]	P_N	kW		
rated torque [1] rated force [2]	M_N F_N	Nm N		
rated current [1]	I_N	A_{eff}		
rated speed [1] rated velocity [2]	n_N v_N	min^{-1} m/ min		
rated voltage [1]	U_N	V_{eff}		
continuous current at standstill [2]	I_d	A_{eff}		
inertia/mass	J/m	_		p. 5-39
rated force [2]	F_N	N		
allowed maximum current (magn. saturation effects?)	I_{max}	A_{eff} (yes/no)	____ ____	
maximum torque [1] or	M_{max}	Nm		
maximum force [2]	F_{max}	N		
maximum speed [1] or	n_{max}	min^{-1}		
maximum velocity [2]	v_{max}	m/min		
no. of pole pairs (rotary) or	PPZ	--		
pole pair distance (linear)	PWT (N-N-pol)	mm		
insulation class	Isol.Kl.	--		
direct-axis inductance of motor [*]	$L_{L(U-V)}$	mH		p. 5-43
quadrature-axis inductance of motor [*]	$L_{Q(U-V)}$	mH		p. 5-43
motor inductance, min. value	$L_{U-V, min}$	mH		p. 5-28
motor inductance, max. value	$L_{U-V, max}$	mH		p. 5-28
motor induct., average value	L_{U-V}	mH		p. 5-28
winding resistance (20°C)	R_{U-V}	ohm		p. 5-39
allowed periodic peak voltage	$\hat{u}_{max\_zul.}$	$V_{pp/2}$		p. 5-28
allowed rate of rise of voltage	du/dt $_{zul.}$	kV/μs		p. 5-28
cooling type	(without/with blower, liquid cooling)	--		
type of motor	rotary/linear	--		

Fig. 5-62: Motor data

([1]…type plate data with rotary motor; [2]…only with linear motors;
[*]…helpful, but not obligatory data)

Note: Also take form for output data of motor temperature sensor and motor encoder into account (see below)!

_____
Name   Date   Signature

Form for Output Data of Motor Temperature Sensor and Motor Encoder

Temperature Sensor Data

PTC? NTC? switch contact?	
Type designation?	
How many and where installed?	
Characteristics available?	

Fig. 5-63:   Data of temperature sensor

Motor Encoder (if Available)

Kind/standard?	
Signal amplitude?	
Signal shape?	
Cycles/revolution? Division period/µm?	
Manufacturer? type of construction?	

Fig. 5-64:   Data of motor encoder

_____

Name   Date   Signature

Forms for Parameter Values

Form "Parameters for Asynchronous Motors"

Manufacturer,   Customer, installation,
Motor type:_____   Axis designation:_____

Parameter no.	Parameter name	Value determined	Value set	Unit	see ...
Motor parameters					
S-0-0141	Motor type				p. 5-36
P-0-4014	Type of construction of motor		░░░░		p. 5-36
P-0-0051	Torque/force constant			_____	p. 5-37
P-0-0018	Number of pole pairs/pole pair distance		░░░░	PPZ/mm	p. 5-37
S-0-0113	Maximum motor speed			_____	p. 5-37
P-0-4004	magnetizing current			A	p. 5-40
P-0-0532	premagnetization factor	100		%	p. 5-40
S-0-0111	motor current at standstill			A	p. 5-37
S-0-0109	Motor peak current			A	p. 5-37
P-0-0528	Flux control loop proportional gain				p. 5-42
Current loop parameters					
S-0-0106	Current loop proportional gain 1			V/A	p. 5-38
S-0-0107	Current loop integral action time 1			ms	p. 5-38
Field weakening range parameters					
P-0-0530	Slip increase			1/100K	p. 5-40
P-0-0529	Scaling of stall current limit			%	p. 5-41
P-0-0533	Voltage loop proportional gain			A/V	p. 5-39
P-0-0534	Voltage loop integral action time			ms	p. 5-39
P-0-0535	Motor voltage at no load	80.0		%	p. 5-40
P-0-0536	Motor voltage max.	90.0		%	p. 5-40
P-0-4036	Rated motor speed			1/min	p. 5-41
Motor data					
P-0-4039	Stator leakage inductance			mH	p. 5-41
P-0-4040	Rotor leakage inductance			mH	p. 5-41
P-0-4041	Motor magnetizing inductance			mH	p. 5-41
P-0-4042	Characteristic of motor magnetizing inductance			mH	p. 5-42
P-0-4048	Stator resistance			ohm	p. 5-39
P-0-0510	Rotor inertia			_____	p. 5-39
P-0-4043	Rotor time constant			ms	p. 5-42
Temperature monitoring parameters					
P-0-0512	Temperature sensor			--	p. 5-39
S-0-0201	Motor warning temperature			°C	p. 5-39
S-0-0204	Motor shutdown temperature			°C	p. 5-39
Position encoder parameters					
P-0-0074	Encoder type 1 (motor encoder)	░░░░			p. 5-30
S-0-0116	Feedback 1 resolution	░░░░			
S-0-0277	Position feedback 1 type	░░░░			

Fig. 5-65: Parameter protocol for asynchronous motors

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Form "Parameters for Synchronous Motors"

Manufacturer,
Motor type:_____

Customer, installation,
Axis
designation:_____

Parameter no.	Parameter name	Value determined	Value set	Unit	see ...
Motor Parameters					
S-0-0141	Motor type				p. 5-36
P-0-4014	Type of construction of motor		▨		p. 5-36
P-0-0051	Torque/force constant			_____	p. 5-37
P-0-0018	Number of pole pairs/pole pair distance		▨	PPZ/mm	p. 5-37
S-0-0113	Maximum motor speed			_____	p. 5-37
S-0-0111	Motor current at standstill			A	p. 5-37
S-0-0109	Motor peak current			A	p. 5-37
Current loop parameters					
S-0-0106	Current loop proportional gain 1			V/A	p. 5-38
S-0-0107	Current loop integral action time 1			ms	p. 5-38
Field weakening range parameters					
P-0-4005	Flux-generating current, limit value			A	p. 5-43
P-0-0533	Voltage loop proportional gain			A/V	p. 5-39
P-0-0534	Voltage loop integral action time			ms	p. 5-39
P-0-0535	Motor voltage at no load	80.0		%	p. 5-40
P-0-0536	Motor voltage max.	90.0		%	p. 5-40
Motor data					
P-0-4016	Direct-axis inductance of motor			mH	p. 5-43
P-0-4017	Quadrature-axis inductance of motor			mH	p. 5-43
P-0-4002	Charact. of quadrature-axis induct. of motor, inductances				p. 5-43
P-0-4003	Charact. of quadrature-axis inductance of motor, currents				p. 5-43
P-0-4048	Stator resistance			ohm	p. 5-39
P-0-0510	Rotor inertia			_____	p. 5-39
Temperature monitoring parameters					
P-0-0512	Temperature sensor			--	p. 5-39
S-0-0201	Motor warning temperature			°C	p. 5-39
S-0-0204	Motor shutdown temperature			°C	p. 5-39
Position encoder parameters					
P-0-0074	Encoder type 1 (motor encoder)	▨			p. 5-30
S-0-0116	Feedback 1 Resolution	▨			

Fig. 5-66: Parameter protocol for synchronous motors

Notes on Commissioning

First check whether the third-party motor has been connected according to manufacturer's specification.

Note:	Third-party motors at IndraDrive controllers should only be commissioned if the form with the motor output data completed by the motor manufacturer is available and the requirements (see "Requirements on Third-Party Motors") were found to have been fulfilled!

For the commissioning of a third-party motor it is basically the same procedure as for the commissioning of a Rexroth kit motor that is applying. The difference is that the motor parameters cannot be loaded from the motor parameter data base of DriveTop, but have to be determined by means of one of the mentioned procedures (see "Determining the Motor Parameter Values").

Converting the Motor Parameter values from Diax/EcoDrive to IndraDrive

This is only possible for third-party motors, if motors of the same type were already operated with controllers of the "Rexroth Diax" or "Rexroth EcoDrive 03" ranges and therefore the respective motor parameter values are already existing.

The values are converted with the above formulas, the units, unless indicated differently, have to be used according to the respective scaling. The parameter values converted to IndraDrive are input in the drive, e.g. with the commissioning tool "DriveTop".

Determining the Motor Parameter Values by Entering the Type Plate Data

For standard asynchronous motors only the type plate data may be known. In this case it is possible to determine the motor parameter values on the basis of the data on the type plate. To do this the type plate data of the rotary asynchronous motor are entered in

- **P-0-4032, Type plate list asynchronous motor**.

The motor parameter values are calculated by the firmware in phase 2 by starting

- **P-0-4033, C3200 Command Calculate data for asynchronous motor**.

Note:	The list of parameters the values of which are calculated can be found above under "Determining the Motor Parameter Values by Calculation by Means of Motor Output Data".
	Without execution of the command C3200 the values entered in P-0-4032 are irrelevant!

Note:	As a matter of principle it is not allowed to do without the manufacturer-side output data of a motor! By means of the detailed output data it is possible to determine the motor parameter values more exactly.
	In addition it is necessary to check whether the motor has the required dielectric strength!

If the entered type plate data are incorrect, this is displayed by the respective error messages:

- **C3201 Incorrect input for current**
- **C3203 Incorrect input for voltage**
- **C3202 Incorrect input for frequency**
- **C3204 Incorrect input for speed**

- **C3205 Incorrect input for power factor**
- **C3206 Incorrect input for power**
- **C3207 Type plate list incomplete**
- **C3208 Error when writing parameters**

"Third-Party Motor Dialog" in DriveTop
With the commissioning tool "DriveTop" the output data of the third-party motor can be entered via a so-called "third-party motor dialog". In the dialog the requirements are checked and finally the values of the motor parameters are calculated.

The motor parameter values are stored in a file. During commissioning they can be loaded to the controller.

Further Notes on Commissioning
See chapter "Commissioning"

5.4   Measuring Systems

Basics on Measuring Systems, Resolution

Brief Description

Control Loops and Measuring Systems
Operating drives in the closed control loop requires measuring systems in order to metrologically acquire the current status of the physical value to be controlled, the so-called actual value.

The following drive control loops are distinguished:

- torque/force control loop: actual value by evaluating the current measuring system and converting the value
- velocity control loop: actual value by evaluating the position measuring system and time-derivation
- position control loop: actual value by evaluating the position measuring system

The actual value of the torque/force control loop is generated by means of the internal current measurement. The measuring system is inaccessible for the user and has a fixed configuration.

Possibilities of Position Measuring
For acquiring the actual values of the velocity and position control loop there are position measuring systems available that provide the user possibilities of configuration. Position measurement can be carried out

- at the motor only (measurement via motor encoder)

- or -

- both at the motor and at the mechanical axis system (measurement via motor encoder and "external" or "optional" encoder).

Note: Position measurement via motor encoder is always required, measurement at the mechanical axis system is optional, the encoder at the mechanical axis system is therefore called "optional" encoder. It is also called "external" encoder because this encoder is not installed internally at the motor, but externally at the axis.

Types of Position Measuring Systems

Position measuring systems are available for the different kinds of motion in adapted types of construction:

- rotary encoders

- linear encoders

With the appropriate signal specification, encoders in both types of construction can be evaluated by IndraDrive controllers.

Evaluating Position Measurement

Depending on their design and the mechanical arrangement at the axis, the position encoders can be evaluated as

- relative encoders (incremental encoders)

- or -

- absolute encoders (absolute value encoders).

Relative Position Measurement

In the case of relative position measurement, only position differences can be evaluated by means of the measuring system. The actual position values signaled by the measuring system refer to the (mostly undefined) position at the time the drive is switched on. To operate the drive within a limited travel range a position reference must be established ("homing") after each time the drive is switched on again.

Absolute Position Measurement

In the case of absolute position measurement, the encoder signals actual position values with a fixed encoder-dependent reference point to the controller. After each time the drive is switched on the correct actual position value is immediately available with each axis position. Due to the mostly undefined mounting situation of the encoder to motor or mechanical axis system, it is necessary to determine the position offset ("setting the absolute value") once at the initial commissioning.

Precision, Resolution

The precision of the position measurement depends on:

- the resolution of the measuring system (division periods = DP)

- the absolute encoder precision

- the digitalization quality of the analog encoder signals

- the dimension of the travel range of the axis

Monitoring Functions

Correct position information is of fundamental importance for reliable drive behavior and motion according to contour. The encoder signals are therefore monitored for plausibility 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 section "Monitoring the Measuring Systems"

Hardware Requirements

For connecting the measuring systems to the controller there are 3 optional interfaces available. The parameters **P-0-0077, Assignment motor encoder->optional slot** and **P-0-0078, Assignment optional encoder ->optional slot** define the interface to which the respective encoder is connected. It must be equipped with the encoder input appropriate for the encoder.

ℹ See also separate documentation "Project Planning Manual for Control Sections

Note: The following applies to these parameters:

- In the case of motors with encoder data memory (MHD, MKD, MKE), P-0-0077 is automatically set correctly!

- In the case of motors without encoder data memory (2AD, ADF, rotary and linear kit motors), P-0-0077 must be set manually!

- In the case of optional encoders, P-0-0078 must be set manually, too.

Pertinent Parameters
- **S-0-0051, Position feedback 1 value**
- **S-0-0053, Position feedback 2 value**
- **S-0-0115, Position feedback 2 type**
- **S-0-0116, Feedback 1 Resolution**
- **S-0-0117, Feedback 2 Resolution**
- **S-0-0256, Multiplication 1**
- **S-0-0257, Multiplication 2**
- **S-0-0277, Position feedback 1 type**
- **S-0-0278, Maximum travel range**
- **P-0-0074, Encoder type 1 (motor encoder)**
- **P-0-0075, Encoder type 2 (optional encoder)**
- **P-0-0129, Internal position data format**

Functional Description

Absolute Encoder Precision   The absolute precision is a feature of the encoder and is determined by its construction and the quality of its components. The data for the absolute precision are indicated by the manufacturer of the encoder.

Resolution (Division Periods)   The resolution of the measuring system (division periods) is entered in the following parameters:

- **S-0-0116, Feedback 1 Resolution**
- **S-0-0117, Feedback 2 Resolution**

Note: Generally, the following applies:

- feedback 1 means "motor encoder"
- feedback 2 means "external or optional encoder"

The value of S-0-0116 or S-0-0117 can mean:

- in the case of rotary motor encoders or external rotary encoders, the number of division periods or cycles per encoder revolution (DP/rev)

- in the case of linear motor encoders (used for linear motors) or external linear encoders, the length of the division period in mm (mm/line count)

- in the case of resolvers as motor encoders or external resolver encoders, the number of pole pairs of the resolver

The significance of the value of S-0-0116 is determined in parameter **P-0-4014, Type of construction of motor** (rotary or linear motor).

> **Note:** In the case of Rexroth housing motors (MHD, MKD, MKE, 2AD, ADF, MAD, MAF) and linear motors with EnDat encoder, the correct value is automatically written to S-0-0116!

Maximum Encoder Resolution After Digitalization

The analog encoder signals are converted to digital position data via A/D converter. Thereby encoder resolution available at the axis is increased compared with resolution of the measuring system (see above!).

motor encoder, rotary:	S-0-0116 * 2^{15}
external encoder, rotary:	S-0-0117 * 2^{15}

S-0-0116:   Feedback 1 resolution
S-0-0117:   Feedback 2 resolution

Fig. 5-67:   Maximum possible encoder resolution of rotary encoder

motor encoder, linear:	S-0-0116 / 2^{15}
external encoder, linear:	S-0-0117 / 2^{15}

S-0-0116:   Feedback 1 resolution
S-0-0117:   Feedback 2 resolution

Fig. 5-68:   Maximum possible encoder resolution of linear encoder

> **Note:** Depending on the type of motion of the encoder, the "maximum encoder resolution after digitalization" is output in different units:
> - rotary encoders: position information/encoder revolution
> - linear encoders: mm (length of the shortest measurable distance)

Internally the value range of the encoder position data is $\pm 2^{31}$, i.e. the encoder position range can be resolved to 2^{32} data. By digitalization, a multitude of position data results from one division period. By means of adjusted multiplication, the range of encoder position data of $\pm 2^{31}$ values, referring to the travel range of the axis (S-0-0278), is complied with.

The resulting drive-internal encoder resolution is as follows:

Internal Encoder Resolution, Rotary Encoders

motor encoder: internal encoder resolution = S-0-0116 * S-0-0256
ext. encoder: internal encoder resolution = S-0-0117 * S-0-0257

auxiliary calculation and drive-internal limitation:

$$S\text{-}0\text{-}0256 = 2^{30} * c_{achs\_G1} / (S\text{-}0\text{-}0116 * S\text{-}0\text{-}0278) <= 2^n, \ n<=15 \text{ (integral!)}$$
$$S\text{-}0\text{-}0257 = 2^{30} * c_{achs\_G2} / (S\text{-}0\text{-}0117 * S\text{-}0\text{-}0278) <= 2^n, \ n<=15 \text{ (integral!)}$$

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 ($\pm$ travel range)
c_{achs_G1}:   axis motion range / motor encoder revolution
c_{achs_G2}:   axis motion range / revolution of the external encoder

Fig. 5-69:   Internal encoder resolution for rotary encoders

Internal Encoder Resolution, Linear Encoders

motor encoder: internal encoder resolution = S-0-0116/S-0-0256
ext. encoder: internal encoder resolution = S-0-0117/S-0-0257

                 auxiliary calculation and drive-internal limitation:

$S\text{-}0\text{-}0256 = 2^{30} * S\text{-}0\text{-}0116 / S\text{-}0\text{-}0278 <= 2^{n}$, $n <= 15$ (integral!)
$S\text{-}0\text{-}0257 = 2^{30} * S\text{-}0\text{-}0117 / S\text{-}0\text{-}0278 <= 2^{n}$; (load reference) $n <= 15$ (integral!)
$S\text{-}0\text{-}0257 = 2^{30} * S\text{-}0\text{-}0117 / (S\text{-}0\text{-}0278 * c_{vor\_M}) <= 2^{n}$; (motor reference) $n <= 15$
                                          (integral!)

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 ($\pm$ travel range)
c_{vor_M}:   infeed length/motor revolution

Fig. 5-70:   Internal encoder resolution for linear encoders

Note: Internally the multiplication (S-0-0256 and S-0-0257) is automatically determined taking S-0-0278 into consideration.

Encoder Dimensioning

The value of the multiplication (S-0-0256 and S-0-0257) calculated according to the formulas in "Internal encoder resolution for rotary encoders" or "Internal encoder resolution for linear encoders" characterizes the encoder dimensioning:
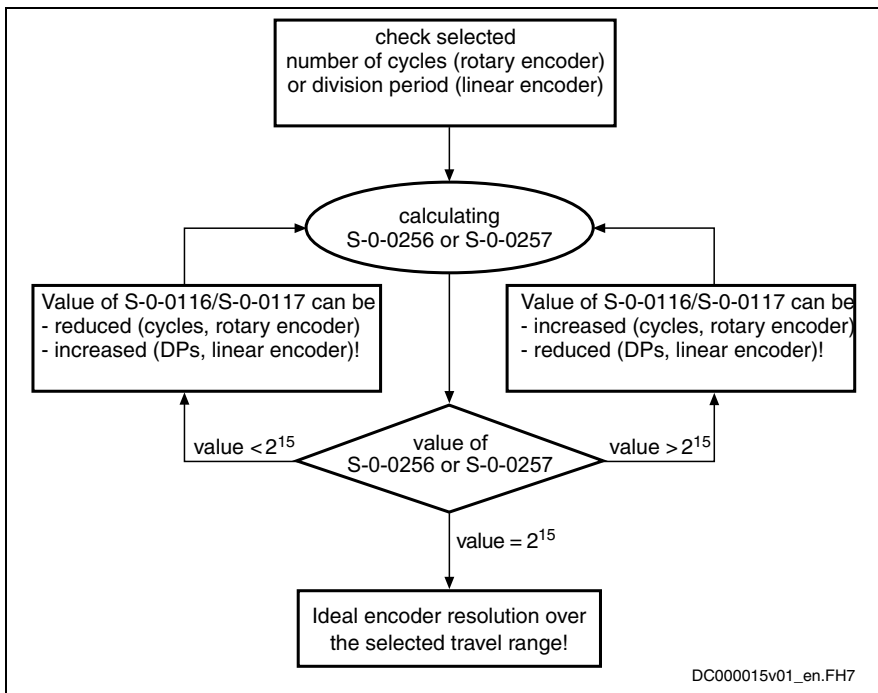
S-0-0116:   Feedback 1 resolution
S-0-0117:   Feedback 2 resolution

Fig. 5-71:   Checking the selected and determining the ideal resolution for encoder 1 (or encoder 2)

Note: The calculated value of S-0-0256 or S-0-0257 normally will never exactly correspond to 2^{15} (= 32768). With result values $\geq 2^{15}$ 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 parameter **S-0-0278, Maximum travel range**:

$$P-0-0129 = \frac{\pm 2^{30}}{number\_of\_motor\,revolutions\,for\_S-0-0278} \leq 2^{28}$$

P-0-0129:   Internal position data format
S-0-0278:   Maximum travel range ($\pm$ travel range!)
Fig. 5-72:   Drive-internal resolution of the position data for rotary motors

$$P-0-0129 = \frac{\pm 2^{30} * P-0-0018}{S-0-0278} \leq 2^{28}$$

P-0-0129:   Internal position data format
S-0-0278:   Maximum travel range ($\pm$ travel range!)
P-0-0018:   pole pair distance of linear motors
Fig. 5-73:   Drive-internal resolution of the position data for linear motors

Real Resolution of Rotary Encoders	The lower value from drive-internal encoder resolution and "maximum encoder resolution after digitalization" is the real resolution of the position data of a rotary encoder.
Real Resolution of Linear Encoders	The higher value from drive-internal encoder resolution and "maximum encoder resolution after digitalization" is the real resolution of the position data of a linear encoder.

Note:	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:

- **P-0-0077, Assignment motor encoder->optional slot**
- **P-0-0078, Assignment optional encoder ->optional slot**

Note:	In the case of motors with encoder data memory (MHD, MKD, MKE), P-0-0077 is automatically set correctly!

Configuring the Encoder	Set the motor encoder type:

- **P-0-0074, Encoder type 1 (motor encoder)**

Set the encoder type of the optional encoder:

P-0-0075, Encoder type 2 (optional encoder)

Set the resolution (number of lines, division period) of the motor encoder:

- **S-0-0116, Feedback 1 Resolution**

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Set the resolution (number of lines, division period) of the optional encoder:

S-0-0117, Feedback 2 Resolution

Set the kind of encoder and the rotational direction of the motor encoder:

S-0-0277, Position feedback 1 type

Set the kind of encoder and the rotational direction of the optional encoder:

S-0-0115, Position feedback 2 type

Note:	In the case of Rexroth housing motors (MHD, MKD, MKE, 2AD, ADF, MAD, MAF), P-0-0074, S-0-0116 and S-0-0277 are automatically written with the correct value; in the case of linear motors, P-0-0074 and S-0-0116 are automatically written with the correct value.

Setting the Travel Range

Enter the travel range of the axis:

- **S-0-0278, Maximum travel range**

Information on Position Evaluation

Current actual position value of the motor encoder:

- **S-0-0051, Position feedback 1 value**

Current actual position value of the optional encoder:

S-0-0053, Position feedback 2 value

Position status of the connected encoders:

S-0-0403, Position feedback value status

Multiplication of the motor encoder:

S-0-0256, Multiplication 1

Multiplication of the optional encoder:

S-0-0257, Multiplication 2

Resolution of the position data in the drive:

P-0-0129, Internal position data format

Note:	When S-0-0256 and, if available, S-0-0257 have the value 32768, the encoder evaluation is ideal. When the value is lower, S-0-0278 has to be checked for correct travel range input!

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 plausibility and compliance with the allowed tolerances.

Monitoring the encoder signals allows detecting faulty states, such as:

- encoder is dirty
- noise injection in the case of inappropriate wire routing or wire design
- exceeding the max. allowed encoder velocity (limit frequency of the encoder signals)
- wire break or short circuit on wire

Monitoring the Axis Position when Switching On

In addition it is possible to monitor drives with an encoder that can be evaluated in absolute form for compliance with the position when switching on compared to the last time the drive was switched off. This allows detecting, for example, whether a vertical axis moved down after the machine was switched off or whether an axis was moved away from the position it had when the machine stopped.

Monitoring Mechanical Transfer Elements

It is also possible to monitor the difference between the actual position values of motor encoder and external encoder. This allows, for example, detecting slip due to wear in mechanical transfer elements between motor and axis at an early stage.

Monitoring the Position Data Reference

If the loss of the position data reference of absolute encoders (motor encoder or optional encoder) is detected due to changes in parameter values, e.g. of the mechanical drive system, the drive will signal this faulty status.

Pertinent Parameters

- **S-0-0391, Monitoring window feedback 2**
- **P-0-0095, Absolute encoder monitoring window for motor encoder**
- **P-0-0096, Absolute encoder monitoring window for opt. encoder**
- **P-0-0177, Absolute encoder buffer 1 (motor encoder)**
- **P-0-0178, Absolute encoder buffer 2 (optional encoder)**
- **P-0-0185, Function of encoder 2 (optional encoder)**
- **P-0-0391, Actual position value difference encoder1 - encoder2**

Pertinent Diagnostic Messages

- **E2074 Encoder 1: encoder signals disturbed**
- **E2075 Encoder 2: encoder signals disturbed**
- **F2036 Excessive position feedback difference**
- **F2042 Encoder 2: encoder signals incorrect**
- **F2046 Max. signal frequency of encoder 2 exceeded**
- **F2048 Low battery voltage**
- **F2074 Actual pos. value 1 outside absolute encoder window**
- **F2075 Actual pos. value 2 outside absolute encoder window**
- **F2174 Loss of motor encoder reference**
- **F2175 Loss of optional encoder reference**
- **F8022 Enc. 1: enc. signals incorr. (can be cleared in ph. 2)**

Functional Description

IndraDrive controllers can evaluate signals of the following encoder types:

- sine encoder 1 Vpp (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:

$$0{,}2 * U_{A,B\_nom} \leq \sqrt{U_A^2 + U_B^2} \leq 1{,}5 * U_{A,B\_nom}$$

U_A: amplitude of encoder track A
U_B: amplitude of encoder track B
U_{A,B_nom}: nominal amplitude value of the encoder tracks, in this case 1.0 V_{pp}

Fig. 5-74:   Allowed voltage range for the signal amplitudes of sine encoders

The quadrant allocation is checked by counting the zero crossings of the sine or cosine signal. In the case of trouble-free operation, the count is changed by the value ± 1 at every zero crossing of a track.

When the encoder signals temporarily leave (e.g. due to interference injection or local accumulation of dirt on the code disk) the allowed voltage range that is monitored in the hardware side, the controller outputs the respective warning:

- **E2074 Encoder 1: encoder signals disturbed**
- **E2075 Encoder 2: encoder signals disturbed**

The warning remains active until the drive is switched off or switched to communication phase P2!

Incorrect counts caused by injected noise and permanently reduced signal amplitudes caused by dirty code disks can be the reason why an error message for the motor encoder or the external encoder is generated:

- **F8022 Enc. 1: enc. signals incorr. (can be cleared in ph. 2)**
- **F2042 Encoder 2: encoder signals incorrect**

The drive then reacts with the error reaction that has been set.

Signal Monitoring for Resolver Encoders

Monitoring the analog resolver encoder signals with carrier frequency is only possible by the calculated analysis of digitized values:

$$0{,}5 * U_{A,B\_nom} \leq \sqrt{U_A^2 + U_B^2} \leq 1{,}2 * U_{A,B\_nom}$$

$$U_{A,B\_nom} = U_{out\_Resolver} * \ddot{u}_{Resolver}$$

U_A: amplitude of resolver track A
U_B: amplitude of resolver track B
U_{A,B_nom}: nominal amplitude value of the resolver tracks
$U_{out\_Resolver}$:   controller output voltage for resolver supply
$\ddot{u}_{Resolver}$: gear ratio of the resolver

Fig. 5-75:   Allowed voltage range for the signal amplitudes of resolvers

Note: The resolver data and resolver voltage supply data are contained in the Project Planning Manuals for motors and controllers!

Signal Monitoring for Square-Wave Encoders

Monitoring the signals of square-wave encoders with regard to amplitude and quadrant allocation is not possible with IndraDrive controllers!

Monitoring the Axis Position when Switching On

When the drive is switched off the current encoder data of the absolute motor encoder and/or of the absolute external encoder are stored:

- **P-0-0177, Absolute encoder buffer 1 (motor encoder)**
- **P-0-0178, Absolute encoder buffer 2 (optional encoder)**

When switching on a drive with an absolute motor encoder and/or an absolute external encoder, a check is run to determine in how far the current actual position value differs from the actual position value at the time of the last switch off. The maximum allowed difference is fixed in the following parameters:

- **P-0-0095, Absolute encoder monitoring window for motor encoder**
- **P-0-0096, Absolute encoder monitoring window for opt. encoder**

When the difference exceeds the determined value the respective error message is output:

- **F2074 Actual pos. value 1 outside absolute encoder window**
- **F2075 Actual pos. value 2 outside absolute encoder window**

This monitoring function can be deactivated!

Monitoring Mechanical Transfer Elements

For axis drives that are equipped with an external encoder, the controller provides the possibility of monitoring the difference of the actual position values of motor encoder and external encoder with regard to a maximum value that can be set. The monitor is only active when both encoders were homed.

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 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. The drive then switches off with the **F2046 Max. signal frequency of encoder 2 exceeded** error message.

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 the **P-0-0185, Control word of encoder 2 (optional encoder)** parameter.

Determining the maximum frequency of the encoder (encoder output frequency):

$$f_{encoder,out} = \frac{DP/rev * n_{max}}{60000s/\min}$$

$f_{encoder, out}$: encoder output frequency in kHz
DP/rev: number of lines of the encoder
n_{max}: maximum speed of the spindle in min^{-1}

Fig. 5-76: Calculating the output frequency of the encoder

In the firmware there are, for the different encoder types, maximum frequencies stored up to the values of which troublefree signal evaluation is guaranteed:

Value of P-0-0075	External encoder used	Maximum frequency stored in firmware
1	GDS/GDM encoder (Rexroth standard)	70 kHz
2	incremental encoder with sine signals (signal specification of Heidenhain)	200 kHz
3	resolver encoder with encoder data memory	2 kHz
4	encoder with HIPERFACE interface from Stegmann	200kHz
5	incremental encoder with square-wave signals (signal specification of Heidenhain)	500 kHz
8	encoder with EnDat interface from Heidenhain	200 kHz

Fig. 5-77: Maximum frequency for troublefree encoder evaluation

When the maximum encoder output frequency reaches or exceeds the maximum frequency stored in the firmware it makes sense to deactivate the spindle encoder monitor.

Note: The maximum frequency stored in the firmware has a "safety distance" to the maximum input frequency of the respective optional input module (see documentation "Project Planning Manual for control sections").

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:

7. 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.

8. 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**.

9. Multiply this value with a safety factor (recommended: 2-fold value) and enter it in the **S-0-0391, Monitoring window feedback 2** parameter. The unit is that of the actual position value.

If this monitoring function is not desired you have to enter the value "0".

Configuring the Spindle Encoder Monitor

When using an optional encoder at a spindle you should first determine, during the initial commissioning procedure, whether the maximum input frequency of the respective encoder input is exceeded at maximum speed. To do this, accelerate the spindle to maximum speed.

To prevent the drive from switching off, while in operation, with the

- **F2046 Max. signal frequency of encoder 2 exceeded**

error message, the spindle encoder monitor should be deactivated. Therefor enter the respective value in the parameter

- **P-0-0185, Control word of encoder 2 (optional encoder)**

Diagnostic Messages

If the position deviation of a motor encoder or external encoder with absolute position data reference exceeds the value in P-0-0095 or P-0-0096 between the points of time the control voltage is switched off and on again, the drive generates the error message

- **F2074 Actual pos. value 1 outside absolute encoder window**

- or -

- **F2075 Actual pos. value 2 outside absolute encoder window**

Note: The value in P-0-0095 or P-0-0096 has to be unequal zero; value "0" deactivates the monitor!

When the actual position value difference of motor encoder and external encoder (P-0-0391) exceeds the value of S-0-0391, the drive generates the error message

- **F2036 Excessive position feedback difference**.

If, when switching the drive on, the loss of the position data reference of absolute encoders (motor encoder or optional encoder) is detected due to changes in the mechanical parameters, for example, the drive signals

- **F2174 Loss of motor encoder reference**

- or -

- **F2175 Loss of optional encoder reference**

When the encoder signal frequency of the external encoder exceeds the maximum value stored in the firmware (see above) the drive generates the error message

- **F2046 Max. signal frequency of encoder 2 exceeded**.

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When temporarily incorrect encoder signals are detected the drive generates the warning

- **E2074 Encoder 1: encoder signals disturbed**

- or -

- **E2075 Encoder 2: encoder signals disturbed**

The warning remains active until the drive is switched off or switched to communication phase P2!

When incorrect encoder signals are detected the drive generates the error message

- **F8022 Enc. 1: enc. signals incorr. (can be cleared in ph. 2)**

- or -

- **F2042 Encoder 2: encoder signals incorrect**

When the voltage of the battery of the encoder data memory has fallen below the determined limit value, the drive generates the following error message:

- **F2048 Low battery voltage**.

See also "Error Reactions" in chapter "Drive Functions"

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 as

- single-turn encoders (absolute actual position values over one encoder shaft revolution)

- or -

- multi-turn encoders (absolute actual position values over 4096 encoder shaft revolutions).

These encoders can be evaluated as absolute encoders if the travel range of the axis can be represented within the absolute actual position value range of the encoder:

- in the case of single-turn encoders within one encoder shaft revolution

- in the case of multi-turn encoders within 4096 encoder shaft revolutions

Encoders of Rexroth Housing Motors

As a standard, Rexroth housing motors are equipped with a position measuring system. The individual motor series have different measuring systems which allows offering cost-efficient motors depending on the application.

The following measuring systems are used:

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

- resolver, single- or multi-turn type

Absolute Encoders for Kit Motors and External Encoders

For kit motors or directly at the mechanical axis system, the following measuring systems, that can be evaluated in absolute form, can be used:

- EnDat linear encoders (Heidenhain) for linear motors or linear axes
- rotary EnDat encoders (Heidenhain) or Rexroth single-turn or Rexroth multi-turn encoders for rotary kit motors or rotary axes

Establishing Axis-Related Absolute Distance

The actual position values of an absolute encoder first only relate to the encoder itself. Due to the mostly undefined mounting situation of the encoder to motor or mechanical axis system, it is necessary to determine the position offset between encoder and axis zero point once at the initial commissioning (see also "Establishing the Position Data Reference: Establishing Position Data Reference for Absolute Measuring Systems" in chapter "Drive Functions").

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**

Hardware Requirements

Signal Specification for Position and Homing Signals

For the signal specification for the position signals of third-party encoders with regard to amplitude and phase angle, please see the Project Planning Manual for the control sections.

Note: Rexroth encoders correspond to the required signal specification!

Functional Description

Absolute Encoder Range and Absolute Encoder Evaluation

Absolute encoders can only display a limited position range in absolute values. For encoders that can be evaluated in absolute form, the drive, depending on the connection of the encoder or the encoders to the axis and on the position data scaling, calculates the travel range of the axis that can be displayed in absolute actual position values.

The following parameters indicate the maximum extent of the travel range that can be selected so that an absolute motor encoder can be evaluated in absolute form:

- **S-0-0378, Absolute encoder range of motor encoder**
- **S-0-0379, Absolute encoder range of optional encoder**

On the user side, the travel range of the axis is fixed:

- **S-0-0278, Maximum travel range**

When the travel range is smaller than the absolute encoder range determined by the drive, the respective control encoder (motor encoder or external encoder; according to the selected operating mode) can be evaluated as an absolute encoder.

This is displayed in the respective bits of the following parameters:

- **S-0-0277, Position feedback 1 type**
- **S-0-0115, Position feedback 2 type**

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Note:	If absolute evaluation of an encoder is possible but not desired, the absolute evaluation can be switched off by setting the respective bit in the S-0-0277 or S-0-0115 parameters! The encoder can then only be evaluated in relative form!

Controlling the Dimensioning Regarding Absolute Encoder Evaluation

To dimension absolute encoders it is necessary to check by the way of calculation whether the intended travel range of the axis, considering all mechanical transfer elements, can be displayed within the absolute encoder range.

The following condition must be fulfilled:

- rotary encoders: Travel range of the axis requires less encoder revolutions than preset in the absolute encoder range!

- linear encoders: Travel range of the axis is smaller than preset in the 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.

Note:	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 Command Set absolute measuring**). Thereby the offset between the actual position value that first is encoder-related and the required axis-related actual position value is internally determined and permanently stored! The respective encoder then is "in reference".

At first the actual position value is only encoder-related. If the drive, for example, is only equipped with one measuring system (motor encoder to be evaluated in absolute form) the controller sets the actual position value to

- **P-0-0019, Initial position value**

The initial position value can be determined by the user!

If the drive, apart from the motor encoder, is equipped with an external encoder and at least one encoder can be evaluated in absolute form, the following actual position values, depending on the reference status of the encoder, are resulting after switching on:

Absolute evaluation 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 commissioning status	(S-0-0403, bit ..2,1,0)
yes	yes	P-0-0019	P-0-0019	Initial commissioning not yet carried out, none of the encoders has "reference".	0b … 000
		absolute value motor encoder	absolute value motor encoder	During the initial commissioning only the motor encoder was set "in reference".	0b … 01x
		absolute value ext. encoder	absolute value ext. encoder	During the initial commissioning only the external encoder was set "in reference".	0b … 10x
		absolute value motor encoder	absolute value ext. encoder	During the initial commissioning both encoders were set "in reference".	0b … 111

yes	no	P-0-0019	P-0-0019	Initial commissioning not yet carried out, motor encoder not "in reference".	0b … 000
		absolute value motor encoder	absolute value motor encoder	Initial commissioning was carried out, the motor encoder was set "in reference".	0b … 01x
no	yes	P-0-0019	P-0-0019	Initial commissioning not yet carried out, external encoder not "in reference".	0b … 000
		absolute value ext. encoder	absolute value ext. encoder	Initial commissioning was carried out, the external encoder was set "in reference".	0b … 10x

Fig. 5-78:   Actual position values when switching on a drive with encoders to be evaluated in absolute form

Note: The **S-0-0403, Position feedback value status** parameter displays whether the encoders connected to the drive and the reference encoder selected via **S-0-0147, Homing parameter** are in reference.

[i]   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

[i]   The commissioning guidelines with regard to "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems" have to be observed, too!

Setting the Travel Range   Enter the travel range of the axis:

- **S-0-0278, Maximum travel range**

Check the absolute encoder range of the respective control encoder:

S-0-0378, Absolute encoder range of motor encoder

S-0-0379, Absolute encoder range of optional encoder

Note: 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!

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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 in **P-0-0019, Initial position value** parameter a defined initial position value for the actual position value of the encoder or the encoders. 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!

Relative Measuring Systems

Brief Description

Evaluating Position Measurement

IndraDrive controllers can evaluate the signals of both absolute and relative measuring systems, if the encoder signals correspond to the specification.

The disadvantages of relative encoders as opposed to encoders that can be evaluated in absolute form are as follows:

- Axes with relative position encoder must go through a homing procedure after switching on so that they can be operated in position control.

- Relative encoders are unsuitable as motor encoders for synchronous motors because each time the drive is restarted it has to go through a procedure for setting the commutation offset. Therefore, the immediate readiness for operation is not guaranteed for synchronous motors!

There are, however, advantages of relative encoders as opposed to encoders that can be evaluated in absolute form:

- Longer travel distances are possible for linear encoders!

- The costs of the encoder are mostly lower given equal absolute precision and number of lines or division period length!

Aspects of Use

Due to the above disadvantages, relative measuring systems are not used as motor encoders for synchronous Rexroth housing motors. For asynchronous motors there aren't any disadvantages when using relative motor encoders.

For kit motors it can be necessary, however, to use relative encoders as motor encoders if absolute encoders of the required design are not available:

- great encoder lengths for long travel distances in the case of linear motors

- hollow-shaft encoders with special bore diameters or encoders for high maximum speeds in the case of rotary kit motors

Establishing Axis-Related Absolute Distance

The actual position values of relative encoders first do not have any position reference. In any axis position the actual position value of the respective relative encoder, when switching the drive on, is written with the so-called initial position value, if no other encoder being in reference has been connected.

There are two ways to establish the axis-related absolute distance:

- move to a defined axis position with reproducible precision

- or -

- detecting a defined axis position by "passing" two distance-coded reference marks of the encoder.

At a defined position the actual position value of the encoder to be homed is written with the corresponding absolute value of the axis (see also "Establishing the Position Data Reference: Establishing Position Data Reference for Relative Measuring Systems" in chapter "Drive Functions").

Pertinent Parameters

- **S-0-0165, Distance-coded reference offset A**
- **S-0-0166, Distance-coded reference offset B**
- **S-0-0277, Position feedback 1 type**
- **S-0-0115, Position feedback 2 type**
- **P-0-0019, Initial position value**

Hardware Requirements

Signal Specification for Position and Homing Signals

For the signal specification for position and homing signals with regard to amplitude and phase position, please see the Project Planning Manual for the control section.

Functional Description

Initial position value

When the drive is switched on the actual position values of relative encoders are written with the initial position value (P-0-0019), if none of the encoders is an absolute value encoder that has already been set in reference.

Absolute evaluation possible?		Actual position values when switching on		Notes on the operating status	Current position status
Motor encoder	External encoder	Motor encoder (S-0-0051)	External encoder (S-0-0053)		(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 motor encoder	absolute value motor encoder	Axis was homed via motor encoder; at the home point, S-0-0053 is set to the value of S-0-0051.	0b … 01x
		absolute value ext. encoder	absolute value ext. encoder	Axis was homed via external encoder; at the home point, S-0-0051 is set to the value of S-0-0053.	0b … 10x
		absolute value motor encoder	absolute value ext. encoder	Axis was homed via motor encoder and external encoder.	0b … 111

Fig. 5-79:   Actual position values after switching on resp. after homing (drive with exclusively relative encoders)

Note: The **S-0-0403, Position feedback value status** parameter displays whether the encoders connected to the drive and the reference encoder selected via **S-0-0147, Homing parameter** are in reference.

Reference Marks

In order to establish the axis-related absolute distance ("reference") the controller monitors the signals of the relative encoder or of the axis sensors that contain absolute position information regarding the axis:

- reference marks of the encoder, if necessary in combination with home point switch of the axis
- distance-coded reference marks of the encoder
- home point switch of the axis

The controller is told via **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" in chapter "Drive Functions").

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 (see "Establishing the Position Data Reference: Establishing Position Data Reference for Relative Measuring Systems" in chapter "Drive Functions").

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 controller is informed of these two distances via **S-0-0165 Distance-coded reference offset A** and **S-0-0166 Distance-coded reference offset B**.
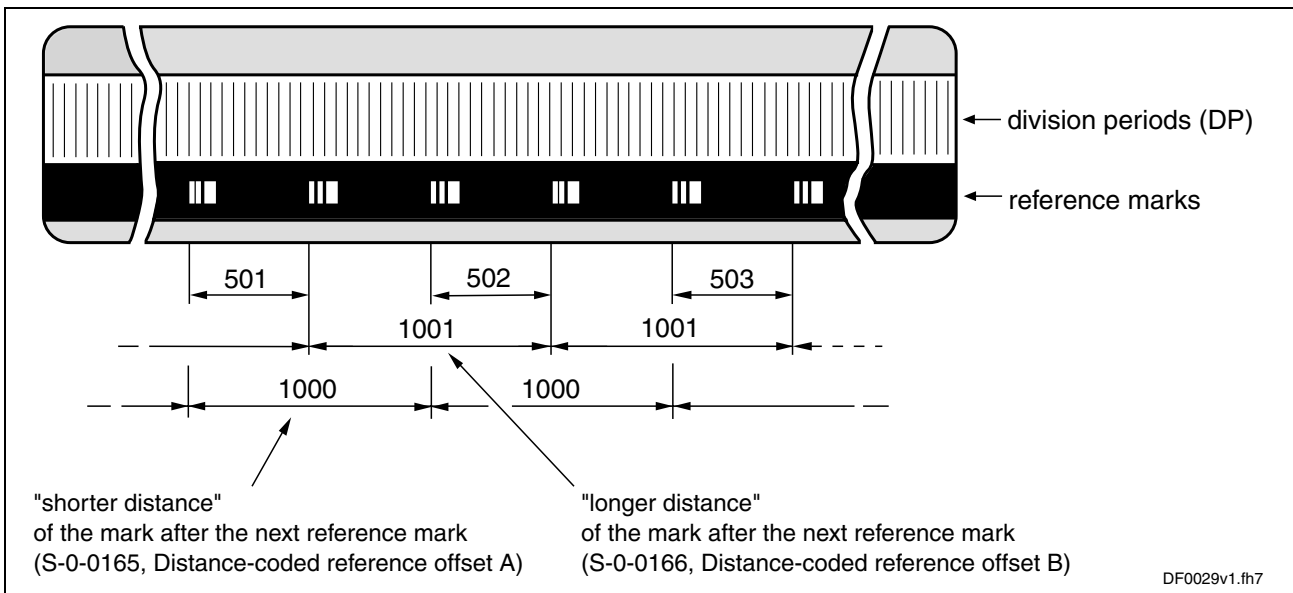
Fig. 5-80:   Reference mark distances in the case of a distance-coded linear encoder with a distance difference of 1 DP

Note: The values for "distance-coded reference offset A" and "distance-coded reference offset B" have to be indicated by the manufacturer!

Determining the "Distance-Coded Reference Offset A"

If the value of "distance-coded reference offset A" is not directly indicated in the data sheet of the distance-coded encoder, the value can also be determined by means of calculation if the travel distance for establishing the absolute reference point is indicated in the data sheet of the encoder:

Linear Encoders

$$\text{general}: \qquad S-0-0165 = \frac{Xref}{DP}$$

$$\text{motor encoder}: \quad S-0-0165 = \frac{Xref}{S-0-0116}$$

$$\text{ext. encoder}: \qquad S-0-0165 = \frac{Xref}{S-0-0117}$$

S-0-0165:   distance-coded reference offset A in number of DP
Xref: travel distance for establishing the absolute reference point in mm
DP, S-0-0116, S-0-0117: division period of the relative linear encoder in mm

Fig. 5-81:   Determining the value for the "shorter distance" of the distance-coded reference marks with a relative linear encoder

Rotary Encoders

$$\text{general}: \qquad S-0-0165 = \frac{Nzyk * PHIref}{360^o}$$

$$\text{motor encoder}: \quad S-0-0165 = \frac{S-0-0116 * PHIref}{360^o}$$

$$\text{ext. encoder}: \qquad S-0-0165 = \frac{S-0-0117 * PHIref}{360^o}$$

S-0-0165:   distance-coded reference offset A in number of cycles
PHIref: travel angle for establishing the absolute reference point in degrees
Nzyk, S-0-0116, S-0-0117: number of cycles of the rotary encoder per 360°

Fig. 5-82:   Determining the value for the "shorter distance" of the distance-coded reference marks with a rotary encoder

Determining the "Distance-Coded Reference Offset B"

If the value of "distance-coded reference offset B" is not directly indicated in the data sheet of the distance-coded encoder, the value can only be determined by means of calculation if the distance difference (longer distance – shorter distance) is indicated in the data sheet of the encoder:

Linear Encoders

$$\text{general}: \qquad S-0-0166 = \frac{Xref + n * DP}{DP}$$

$$\text{motor encoder}: \quad S-0-0166 = \frac{Xref + n * S-0-0116}{S-0-0116}$$

$$\text{ext. encoder}: \qquad S-0-0166 = \frac{Xref + n * S-0-0117}{S-0-0117}$$

S-0-0166:   distance-coded reference offset B in number of DP
Xref: travel distance for establishing the absolute reference point in mm
n: number of DP of the distance difference (big-small distance)
DP, S-0-0116, S-0-0117: division period of the relative linear encoder in mm

Fig. 5-83:   Determining the value for the "longer distance" of the distance-coded reference marks with a relative linear encoder

Rotary Encoders

$$\text{general}: \qquad S-0-0166 = \frac{Nzyk * PHIref}{360^o} + z$$

$$\text{motor encoder}: \quad S-0-0166 = \frac{S-0-0116 * PHIref}{360^o} + z$$

$$\text{ext. encoder}: \qquad S-0-0166 = \frac{S-0-0117 * PHIref}{360^o} + z$$

S-0-0166:   distance-coded reference offset B in number of cycles
PHIref: travel angle for establishing the absolute reference point in degrees
z: number of cycles of the distance difference (big-small distance)
Nzyk, S-0-0116, S-0-0117: number of cycles of the rotary encoder per 360°

Fig. 5-84:   Determining the value for the "longer distance" of the distance-coded reference marks with a relative rotary encoder

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Notes on Commissioning

i   The commissioning guidelines in the sections "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems" have to be observed, too!

Setting the Initial Position Value

If the actual position value of relative encoders is not to be written with the default value "0" when the drive is switched on, **P-0-0019, Initial position value** has to be changed to have the desired value.

In the Case of Distance-Coded Measuring System

If the relative encoder possesses distance-coded reference marks the controller is informed on this by the respective bit in the following parameters:

- **S-0-0277, Position feedback 1 type**
- **S-0-0115, Position feedback 2 type**

The value for the "shorter distance" of the distance-coded reference marks has to be entered in the **S-0-0165, Distance-coded reference offset A** parameter.

The value for the "longer distance" of the distance-coded reference marks has to be entered in the **S-0-0166, Distance-coded reference offset B** parameter.

5.5 Mechanical Axis System and Measuring Systems

Measuring Systems for Motor and Axis Control, Arrangement

Brief Description

Motor Encoder

Controlled motor activation requires a position measuring system that measures the current rotor position or the position of the moving part as opposed to the static part of the motor.

This position measurement is required for the:

- current control loop,
- velocity control loop and, if required,
- position control loop.

The precision and resolution of the position measurement is decisive for the quality of the actual values, especially in the velocity and position control loop.

External Encoders

Depending on the mechanical properties of the mechanical system between driven motor shaft and machine axis it can be required to carry out the position control by means of an external position encoder (not integrated in the motor) directly at the moving part of the axis, e.g. in the case of

- mechanical system with slip,
- gear play or a low degree of stiffness of the mechanical system, etc.

The external (optional) encoder can also be used as a measuring wheel encoder (frictionally engaged on transported material).

See "Measuring Wheel Mode" in chapter "Drive Functions"

For information on encoder evaluation and monitoring see also "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems" in section "Measuring Systems"

Motor Encoders of Rexroth Housing Motors

Rexroth housing motors have integrated position measuring systems:

- HSF encoders for MHD, 2AD and ADF motors of high precision requirements
- resolver encoders for MKD and MKE motors for lower precision requirements

They are optionally available as

- relative measuring system ("single-turn motor encoder")

- or -

- absolute measuring system ("multi-turn motor encoders", range of values ± 4096 motor revolutions).

The measuring systems of Rexroth housing motors support the commissioning because the data for encoder type and resolution are stored in the encoder. They are loaded to the controller when the controller is switched on.

Motor Encoders for Rexroth Kit Motors and Third-Party Encoders

Rexroth kit motors are delivered as individual components and assembled in the machine to form the motor. It consists of a moving and a static part, the bearing and the motor encoder.

The following measuring systems can be used as a motor encoder:

- GDS/GDM encoders from Rexroth (rotary single-turn or multi-turn encoders with housing and shaft)
- incremental encoder with sine signals (compatible with signal specification of Heidenhain)
- combined encoder of incremental encoder with sine signals (compatible with signal specification of Heidenhain) and "Hall sensor box SHL01.1" (Rexroth-compatible signal specification)
- encoder with EnDat interface from Heidenhain
- incremental encoder with square-wave signals (compatible with signal specification of Heidenhain)
- combined encoder of incremental encoder with square-wave signals (compatible with signal specification of Heidenhain) and "Hall sensor box SHL01.1" (Rexroth-compatible signal specification)

Note: Don´t use incremental encoder with square-wave signals as motor encoder! Bad drive properties 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")!

Note: For synchronous kit resp. synchronous third-party motors it is advantageous to use a measuring system, that can be evaluated in absolute form, as a motor encoder (see also "Absolute Measuring Systems").

Motor Encoder with Gear

Especially with rotary kit motors it is sometimes impossible to connect the motor encoder directly to the motor shaft. IndraDrive provides the possibility to evaluate a motor encoder connected via a gear.

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External Encoders at Machine Axes

IndraDrive controllers can evaluate the following measuring systems as external encoders:

- GDS/GDM encoders from Rexroth (rotary single-turn or multi-turn encoders with housing and shaft)
- incremental encoder with sine signals (compatible with signal specification of Heidenhain)
- encoder with EnDat interface from Heidenhain
- incremental encoder with square-wave signals (compatible with signal specification of Heidenhain)

Possibilities of Arranging Measuring Systems:

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-0-0115:   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. 5-85:   Overview of arrangement possibilities of mechanical drive system and measuring systems

Pertinent Parameters

- **S-0-0115, Position feedback 2 type**
- **S-0-0277, Position feedback 1 type**
- **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-0-0123, 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)**

Hardware Requirements

For connecting the measuring systems to the controller there are 3 optional interfaces available. By writing the parameters **P-0-0077, Assignment motor encoder->optional slot** and **P-0-0078, Assignment optional encoder ->optional slot** the interface is defined to which the respective encoder is connected. The interface must be equipped with the appropriate encoder input for the encoder (see also documentation "Project Planning Manual for Control Sections")!

Functional Description

Motor Encoder

The motion type of the motor encoder can either be rotary or linear. The controller is told this via parameter **S-0-0277, Position feedback 1 type**.

When "linear motor encoder" is set in 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 "with respect to the motor" and "linear". As the actual position values are determined directly at the moving part of the axis it does not make sense to use another external encoder!
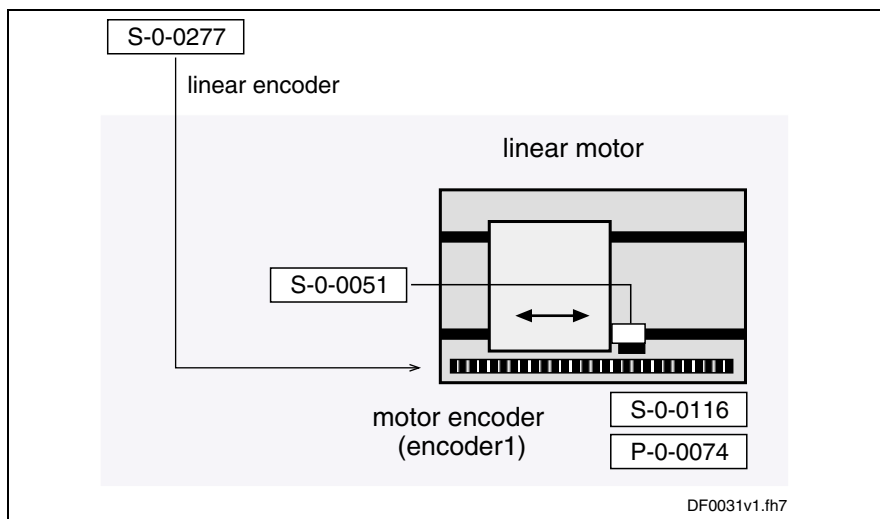
S-0-0051:   Position feedback 1 value
S-0-0116:   Feedback 1 Resolution
S-0-0277:   Position feedback 1 type
P-0-0074:   Encoder type 1 (motor encoder)

Fig. 5-86:   Motor encoder arrangement for drive with linear motor

When "rotary motor encoder" is set the controller assumes an application with a rotary motor. This means:

- In the case of rotary kit motors, the motor encoder can be connected via a gear; Rexroth housing motors have a direct motor connection.

- The load side of the drive can be rotary or linear (S-0-0076).
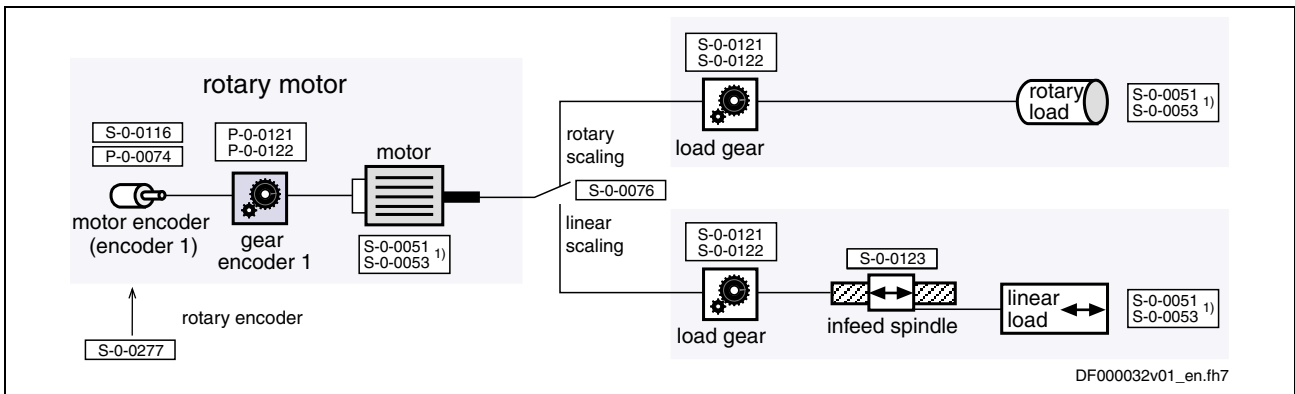

```
1) …         S-0-0051/S-0-0053 depending on scaling (S-0-0076)
S-0-0051:    position feedback 1 value
S-0-0053:    position feedback 2 value
S-0-0076:    position data scaling type
S-0-0116:    feedback 1 resolution
S-0-0121:    input revolutions of load gear
S-0-0122:    output revolutions of load 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. 5-87:   Possible drive arrangements with rotary motor (without external encoder)

External Encoder   In the case of drives with rotary motor a rotary or linear load-side (external) encoder can be necessary, depending on the application:

- A rotary external encoder can be connected to the load via an encoder gear.

- A linear external encoder determines the actual position value directly at the linear load.

```
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-0-0115:               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. 5-88:   Possible drive arrangements with rotary motor and external encoder

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Notes on Commissioning

ℹ️   The commissioning guidelines in the sections "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems" have to be observed, too!

Basic Settings   Set encoder type "linear" or "rotary":

- **S-0-0277, Position feedback 1 type**

Enter encoder type, hardware assignment and resolution:

- **S-0-0116, Feedback 1 Resolution**
- **P-0-0074, Encoder type 1 (motor encoder)**
- **P-0-0077, Assignment motor encoder->optional slot**

Settings for Rotary Motor   Enter motor encoder gear ratio:

- **P-0-0121, Gear 1 motor-side (motor encoder)**
- **P-0-0122, Gear 1 encoder-side (motor encoder)**

Enter load gear ratio:

- **S-0-0121, Input revolutions of load gear**
- **S-0-0122, Output revolutions of load gear**

For linear axes enter the feed constant:

- **S-0-0123, Feed constant**

Settings for External Encoder   Set encoder type "linear" or "rotary":

- **S-0-0115, Position feedback 2 type**

Enter encoder type, hardware assignment and resolution:

- **P-0-0075, Encoder type 2 (optional encoder)**
- **P-0-0078, Assignment optional encoder ->optional slot**
- **S-0-0117, Feedback 2 Resolution**

Enter gear ratio for the external (optional) encoder:

- **P-0-0124, Gear 2 load-side (optional encoder)**
- **P-0-0125, Gear 2 encoder-side (optional encoder)**

Settings for Measuring Wheel Encoder   Activate feed constant for measuring wheel:

- **P-0-0185, Control word of encoder 2 (optional encoder)**

Enter feed constant for measuring wheel:

- **P-0-0123, Feed constant 2 (optional encoder)**

Scaling of Physical Data

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:

- position measurement,
- current measurement and
- temperature measurement.

The measured values collected in this way are converted into phys. data:

- position, velocity, acceleration and jerk data
- current data, torque and force data
- temperature data and load data

The master transmits command values to the drive that are used by the controller for transforming them at the motor output shaft or mechanical axis system. The drive in return registers and transmits actual values, signals operating and command states and, if necessary, generates error messages and warnings.

Communication between drive and master also takes place by exchanging data.

Scaling An operating data (numeric value) can only be evaluated as a physical value, when the numeric value is connected to a physical unit and the position of the decimal point (decimal places). The data thereby is "scaled" in a qualitative and quantitative way.

Parameters All data are stored in parameters and transmitted as parameter values (for explanations on parameters see chapter "Parameters, Basics" in chapter "Handling, Diagnostic and Service Functions"). The scaling of the parameters containing data of the following physical values can be defined by the customer:

- position
- velocity
- acceleration
- torque/force
- temperature

Preferred Scaling/ Parameter Scaling To simplify the scaling definition so-called "preferred scalings" were predefined. But physical data can also be exchanged in the control-internal format, i.e. without concrete reference to physical units. To do this, the scaling for certain data can be freely set ("parameter scaling").

Linear and Rotary Data Depending on the kind of motion of motor or load, the data can be displayed

- 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).

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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 "Measuring Systems: "Basics on Measuring Systems, Resolution" in chapter "Motor, Mechanical Axis System, Measuring Systems").

In the case of axes with unlimited travel range (e.g. rotary axes) it is useful to limit the infinite value range of the position data to a finite value. With continuous motion the value range is recurrently run from minimum to maximum value ("modulo" evaluation of the actual position value).

Pertinent Parameters
- **S-0-0043, Velocity polarity parameter**
- **S-0-0044, Velocity data scaling type**
- **S-0-0045, Velocity data scaling factor**
- **S-0-0046, Velocity data scaling exponent**
- **S-0-0055, Position polarities**
- **S-0-0076, Position data scaling type**
- **S-0-0077, Linear position data scaling factor position data**
- **S-0-0078, Linear position data scaling exponent**
- **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**

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		rotary
	with unit "m"	with unit "inch"	unit "degree"
position data	0.0001 mm	0.000001 inch	0.0001 dgr
velocity data	0.001 mm/min	0.00001 inch/min	0.0001 min^{-1} or 0.000001 s^{-1}

Fig. 5-89:   Overview: preferred scalings for position data and velocity data

Physical data	Preferred scaling			
	linear		rotary	ramp time
	with unit "m"	with unit "inch"	with unit "rad"	with unit "s"
acceleration data	0.001 mm/s^2	0.00001 inch/s^2	0.001 rad/s^2	1.000 ms
jerk data	0.000001 mm/s^3	0.00001 inch/s^3	0.001 rad/s^3	1.000 ms^2

Fig. 5-90:   Overview: preferred scalings for acceleration data and jerk data

---

Note: The jerk data scaling is derived from the acceleration data scaling.

To be Noticed: Ramp Time Scaling Type

The acceleration data can also be scaled with reference to a velocity ramp:

$$\text{reference vel. ramp } = \frac{S-0-0446}{\text{ramp reference time}}$$

$$= \frac{S-0-0446}{1.000 \text{ ms}} \text{ (with preferred scaling)}$$

S-0-0446:   ramp reference velocity for acceleration data

Fig. 5-91:   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 table contains an overview.

Physical data	Scaling type	Unit	S-0-0076	S-0-0077 (scal. factor)	S-0-0078 (scal. exp.)	Attribute number of decimal places
position data	linear	mm	..xx00.0001	1	-7	4
	linear	inch	..xx01.0001	1	-6	6
	rotary	degree	..xx00.0010	1	-4	4
Physical data	**Scaling type**	**Unit**	**S-0-0044**	**S-0-0045 (scal. factor)**	**S-0-0046 (scal. exp.)**	**Attribute number of decimal places**
velocity data	linear	mm/min	..0x00.0001	1	-6	3
	linear	inch/min	..0x01.0001	1	-5	5
	rotary	min^{-1}	..0x00.0010	1	-4	4
	rotary	s^{-1}	..0x10.0010	1	-6	6
Physical data	**Scaling type**	**Unit**	**S-0-0160**	**S-0-0161 (scal. factor)**	**S-0-0162 (scal. exp.)**	**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

Fig. 5-92:   Overview of values of scaling parameters determined by preferred scaling and decimal places of the data

Note: For practical reasons, the metric measures of length in the case of preferred scaling are scaled in "mm". This when reading the respective parameter can also be seen from the corresponding "unit" data element. The decimal places are adjusted to the current unit.

Parameter Scaling (Individually Defined)   As an alternative to preferred scaling it is also possible to activate parameter scaling. For parameter scaling the least significant bit (LSB) of the respective operating data can be individually defined.

$$position\ data, linear : \quad LSB = unit^{1)} * scaling\ factor^{1)} * 10^{scaling\ exponent}$$

$$position\ data, rotary : \quad LSB = \frac{360}{rotational\ position\ resolution^{2)}} * unit^{2)}$$

$$velocita\ data : \quad LSB = \frac{unit(position\ data)}{time\ unit} * scaling\ factor * 10^{scaling\ exponent}$$

$$acceleration\ data\ (lin.; rot.) : \quad LSB = \frac{unit(position\ data)}{time\ unit^2} * scaling\ factor * 10^{scaling\ exponent}$$

$$acceleration\ data\ (ramp\ time\ -\ scaling) : \quad LSB = \frac{S - 0 - 0446}{scaling\ factor * 10^{scaling\ exponent}}$$

$$jerk\ data : \quad LSB = \frac{unit(position\ data)}{time\ unit^3} * scaling\ factor * 10^{scaling\ exponent}$$

1) …   With scaling factor unequal 1 the unit is no longer indicated as in S-0-0076, but only "incrementally" (control-dependent unit reference).

2) …   With rotational resolutions (S-0-0079) the results of which are not powers of 10 of 360, the units are no longer "angular degrees" (acc. to S-0-0076) but only "incremental" (control-dependent unit reference).

Fig. 5-93:   Defining the least significant bit (LSB) for parameter scaling

Note: The jerk data scaling is derived from the acceleration data scaling.

Respective units of measurement and time defined in the parameters:

• **S-0-0076, Position data scaling type**

• **S-0-0044, Velocity data scaling type**

• **S-0-0160, Acceleration data scaling type**

Respective scaling factor and scaling exponent defined in the following parameters:

• **S-0-0077, Linear position data scaling factor position data**
  S-0-0078, Linear position data scaling exponent

• **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, in the case of parameter scaling, for the

• **S-0-0079, Rotational position resolution**

has to be determined for defining the LSB.

Torque/Force Data   For torque/force data there are the following basic scaling types:

• linear

• rotary

• percentage-based

Note:	It is only possible to select preferred scaling (predefined scaling)!

Physical value	Preferred scaling		
	linear	**rotary**	**percentage-based**
torque force	1 N or 0.1 lbf	0.01 Nm or 0.1 inlbf	0.1% 0.1%

Fig. 5-94:   Overview: preferred scalings for torque/force data

The scaling types and units can be determined in the respective bits of parameter

- **S-0-0086, Torque/force data scaling type**.

As individually defined scaling is impossible for torque/force data, the parameters

- **S-0-0093, Torque/force data scaling factor** and
- **S-0-0094, Torque/force data scaling exponent**

have fixed values corresponding to preferred scaling.

Temperature Data   For temperature data only the following units can be selected:

- degree Celsius (°C)
- Fahrenheit (F)

Note:	For temperature data is it only possible to select preferred scaling (predefined scaling)!

Physical value	Preferred scaling	
	Celsius	**Fahrenheit**
temperature	0.1 °C	0.1 F

Fig. 5-95:   Overview: 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:

- **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)**
- **S-0-0115, Position feedback 2 type**
- **S-0-0277, Position feedback 1 type**
- **S-0-0121, Input revolutions of load gear**
- **S-0-0122, Output revolutions of load gear**
- **S-0-0123, Feed constant**
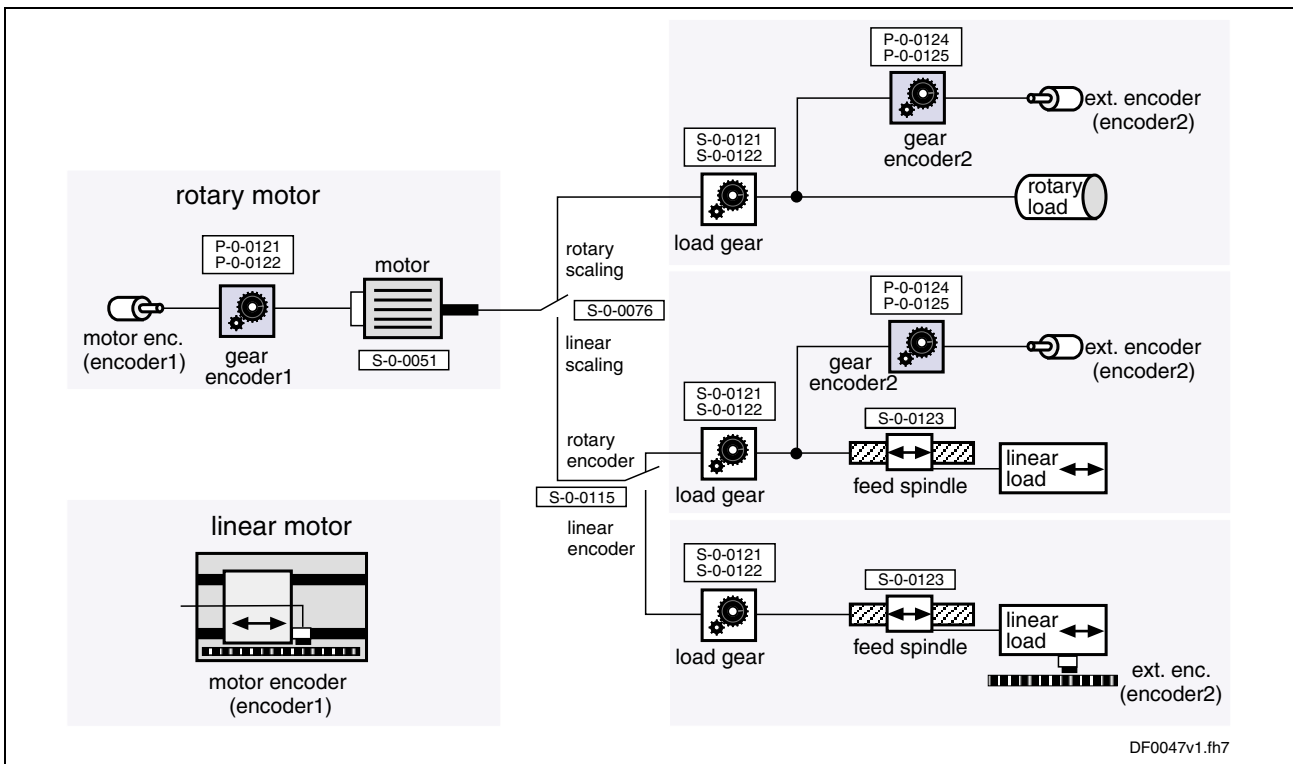
Fig. 5-96:   Mechanical transfer elements between motor, encoders and load

Note: For linear motors the motor reference is the same as the load reference because the point where the force is input and point where the load takes effect are identical. There aren't any mechanical transfer elements!

Polarity   The polarity of the position, velocity and torque/force data can be changed from positive to negative polarity in the following parameters:

- **S-0-0055, Position polarities**
- **S-0-0043, Velocity polarity parameter**
- **S-0-0085, Torque/force polarity parameter**

Depending on the mounting situation (especially of kit motors and their respective motor encoder or external encoder), this allows determining the appropriate polarity of the respective data for the machine axis.

Modulo Scaling   Via the respective bit of parameter **S-0-0076, Position data scaling type** it is possible to select, for the position data format, between

- absolute format and
- modulo format.

If the position data of an axis with infinite travel range (e.g. rotary axis, spindle etc.) were processed in absolute format, the axis would risk to move beyond the value range of the position data. This would lead to invalid position data; operating modes with position control would not be safe to operate.

The value range for modulo format is limited, only position data between the value 0.00... and a maximum value to be determined in parameter **S-0-0103, Modulo value** are possible.

When the measured actual position value exceeds the value range or falls below it, the actual position value displayed in S-0-0051/S-0-0053 behaves unsteadily, i.e. it changes by the absolute value of the modulo value range in such a way that the actual position value displayed always remains within the modulo value range.

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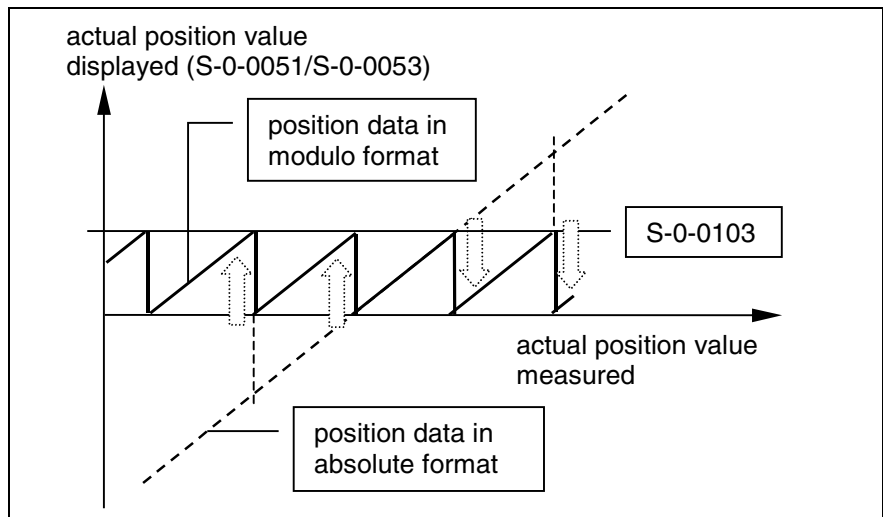
S-0-0051:   position feedback 1 value
S-0-0053:   position feedback 2 value
S-0-0103:   Modulo value

Fig. 5-97:   Actual position value for axis motion with constant velocity for absolute and modulo format

Modulo Format - Requirements

The "modulo format" selection for actual position values is only appropriate for rotary motors, because e 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!

Note: The condition "rotary motor" for selecting "modulo format" is checked when the drive progresses to the ready-for-operation status. If the condition has not been fulfilled, an error is signaled!

Restrictions/Conditions for "Modulo Format"

When using the modulo format, the following restrictions and conditions have to be observed and complied with:

• Due to the firmware-internal conversion of absolute format to modulo format, the allowed maximum velocity is as follows:

$$v_{\max} = \frac{S-0-0103}{2ms}$$

$v_{\max}$:   maximum velocity or maximum angular velocity
S-0-0103:   Modulo value

Fig. 5-98:   Allowed maximum velocity for modulo format

WARNING

Possible property damage caused by errors when controlling motors and moving parts!

⇒   The value in **S-0-0091, Bipolar velocity limit value** mustn't be higher than the allowed maximum velocity for modulo format!

• In the case of encoders evaluated in absolute form, the mechanical drive system, with the drive switched off, may as a maximum be moved by a distance or angle corresponding to half the absolute encoder range (**S-0-0378/S-0-0379, Absolute encoder range of motor encoder/optional encoder**)! The actual position value after switching on can otherwise be incorrect! This, however, cannot be diagnosed on the controller side!

> ⚠ **WARNING**
>
> **Possible property damage caused by errors when controlling motors and moving parts!**
> ⇒ Block the mechanical system with drive switched off by self-holding holding brake or self-locking gear!

See also "Measuring Systems: Absolute Measuring Systems" in chapter "Motor, Mechanical Axis System, Measuring Systems"

- The following conditions have to be complied with in the case of rotary modulo scaling:

Scaling type of position data:	Modulo scaling, rotary position reference		
External encoder:	external encoder available		no external encoder available
Type of motion of external encoder:	rotary	linear (not possible!)	
Conditions (no.) to be complied with:	1 2 3 4 5 6	---	1 2 4 5
Conditions:	No. 1: S-0-0079 * S-0-0122 $\leq 2^{64}$ No. 2: S-0-0079 * P-0-0121 * S-0-0122 $\leq 2^{64}$ No. 3: S-0-0079 * P-0-0124 * S-0-0121 $\leq 2^{64}$ No. 4: S-0-0103 * P-0-0129 * S-0-0121 $\leq 2^{64}$ No. 5: S-0-0103 * S-0-0116 * P-0-0122 * S-0-0121 $\leq 2^{64}$ No. 6: S-0-0103 * S-0-0117 * P-0-0125 * S-0-0122 $\leq 2^{64}$		

S-0-0079:   rotational position resolution
S-0-0103:   modulo value
P-0-0129:   internal position data format
S-0-0116:   feedback 1 Resolution
S-0-0117:   feedback 2 Resolution
P-0-0121:   gear 1 motor-side (motor encoder)
P-0-0122:   gear 1 encoder-side (motor encoder)
S-0-0121:   input revolutions of load gear
S-0-0122:   output revolutions of load gear
P-0-0124:   gear 2 load-side (optional encoder)
P-0-0125:   gear 2 encoder-side (optional encoder)

Fig. 5-99:   Conditions for modulo scaling and rotary position reference

Note: Rotary modulo scaling is impossible for linear external encoder!

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- Only load reference is possible for linear modulo scaling. Depending on the use of an external encoder the following conditions have to be complied with:

Scaling type of position data:	Modulo scaling, linear position reference			
Reference:	motor reference (not possible!)	Load Reference		
External encoder:	---	external encoder available		no external encoder available
Type of motion of external encoder:	---	rotary	linear	---
Conditions (no.) to be complied with:	---	1 2 3 4 5 6	1 2 3 4 5 7	1 2 3 4
Conditions:	No. 1: $\quad$ S-0-0103 * S-0-0121 * P-0-0129 $\leq 2^{64}$ No. 2: $\quad$ S-0-0123 * S-0-0122 $\leq 2^{64}$ No. 3: $\quad$ S-0-0103 * S-0-0121 * P-0-0122 * S-0-0116 $\leq 2^{64}$ No. 4: $\quad$ S-0-0123 * S-0-0122 * P-0-0121 $\leq 2^{64}$ No. 5: $\quad$ S-0-0103 * P-0-0125 * S-0-0117 $\leq 2^{64}$ No. 6: $\quad$ S-0-0123 * P-0-0124 $\leq 2^{64}$ No. 7: $\quad$ S-0-0103 * S-0-0077 * $10^{\text{S-0-0078}} \leq 2^{64}$			

S-0-0103:   modulo value
P-0-0129:   internal position data format
S-0-0116:   feedback 1 Resolution
S-0-0117:   feedback 2 Resolution
S-0-0077:   linear position data scaling position data
S-0-0078:   linear position data scaling position data
S-0-0123:   feed constant
P-0-0121:   gear 1 motor-side (motor encoder)
P-0-0122:   gear 1 encoder-side (motor encoder)
S-0-0121:   input revolutions of load gear
S-0-0122:   output revolutions of load gear
P-0-0124:   gear 2 load-side (optional encoder)
P-0-0125:   gear 2 encoder-side (optional encoder)

Fig. 5-100: Conditions for modulo scaling and linear position reference

Note: Linear modulo scaling is impossible for motor reference!

Notes on Commissioning

Basic Scaling Settings   First make the basic scaling settings for position, velocity, acceleration and torque/force data. This is only possible in the parameter mode (communication phase 2).

You have to determine:

- scaling type (rotary/linear/without scaling/percentage-based, if necessary)

- unit of measurement and unit of time, if necessary

- data reference (motor/load)

- absolute/modulo format for position data

- preferred scaling (predefined) or parameter scaling (can be individually defined)

To do this, set the respective bits in the following parameters:

- **S-0-0076, Position data scaling type**
- **S-0-0044, Velocity data scaling type**
- **S-0-0160, Acceleration data scaling type**
- **S-0-0086, Torque/force data scaling type**

Settings and Tips for Modulo Scaling

When selecting "modulo format" the value range limit has to be set in parameter **S-0-0103, Modulo value**.

Note:	For "modulo format" enter a value greater than or equal to the value of parameter S-0-0103 in parameter **S-0-0278, Maximum travel range**!

⚠️ **WARNING**

Danger of incorrect actual position value of encoders evaluated in absolute form after switching the drive on, when the mechanical drive system, with the drive switched off, was moved in the case of modulo scaling!

⇒ Make sure that the mechanical drive system, with the drive switched off, is as a maximum moved by a distance or angle corresponding to half the absolute encoder range (**S-0-0378/S-0-0379, Absolute encoder range of motor encoder/optional encoder**)!

Temperature Scaling

In addition, make the scaling setting for temperature data in parameter **S-0-0208, Temperature data scaling type**.

Individual Settings for Parameter Scaling

Further Settings for Parameter Scaling

position data:

- **S-0-0077, Linear position data scaling factor position data**
- **S-0-0078, Linear position data scaling exponent**

- 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**

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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:

- **C0122 Incorr. parameteriz. of motor enc. (mechanical system)**
- **C0123 Modulo value for motor encoder cannot be displayed**
- **C0127 Incorr. parameteriz. of opt. enc. (mechanical system)**
- **C0128 Modulo value for optional encoder cannot be displayed**
- **C0140 Rotary scaling not allowed**
- **C0101 Invalid parameters (see S-0-0021)**
- **C0102 Limit error in parameter (-> S-0-0021)**
- **C0103 Parameter conversion error (->S-0-0021)**

Example of Scaling Settings

There are many possibilities to make settings for the scaling type. The table below shows useful settings for which there aren't any command errors to be expected:

Mechanical system			Encoder		Useful scaling type settings		
Motor	**Load gear**	**Feed spindle**	**Motor encoder**	**External encoder**	**Motor reference**	**Load reference**	**Modulo**
rotary	available	not available	rotary	no	rotary	rotary	possible
	available/ not avail.	available	rotary	no	rotary	---	possible
					---	linear	possible
	available	not available	rotary	rotary	rotary	rotary	possible
	available/ not avail.	available	rotary	rotary	rotary	---	possible
					---	linear	possible
			rotary	linear	rotary	---	possible
					---	linear	possible
linear	not available	not available	linear	---	---	linear	not possible

Fig. 5-101: Useful scaling type settings depending on mechanical drive system and measuring systems

6   Drive Control

6.1   Overview of Drive Control

The IndraDrive firmware supports the following two basic principles of drive control:

- **open-loop axis control** or **open-loop operation** (open-loop U/f control)
  → open-loop-controlled operation without encoder information

- **closed-loop axis control** or **closed-loop operation**
  → closed-loop-controlled operation with encoder feedback

Note: Using the closed-loop operation makes higher demands to the hardware design of a drive, as it always requires a motor encoder.

Open-Loop Axis Control (Open-Loop Operation)

In the case of open-loop axis control ("open-loop operation"), controlling the drive is only possible without encoder. Consequently there are restrictions in the selection of operating modes (no position control modes).

Motor control in this case takes place as open-loop U/f control (see "Voltage-Controlled Operation (Open-Loop U/f Control)" in section "Motor Control").

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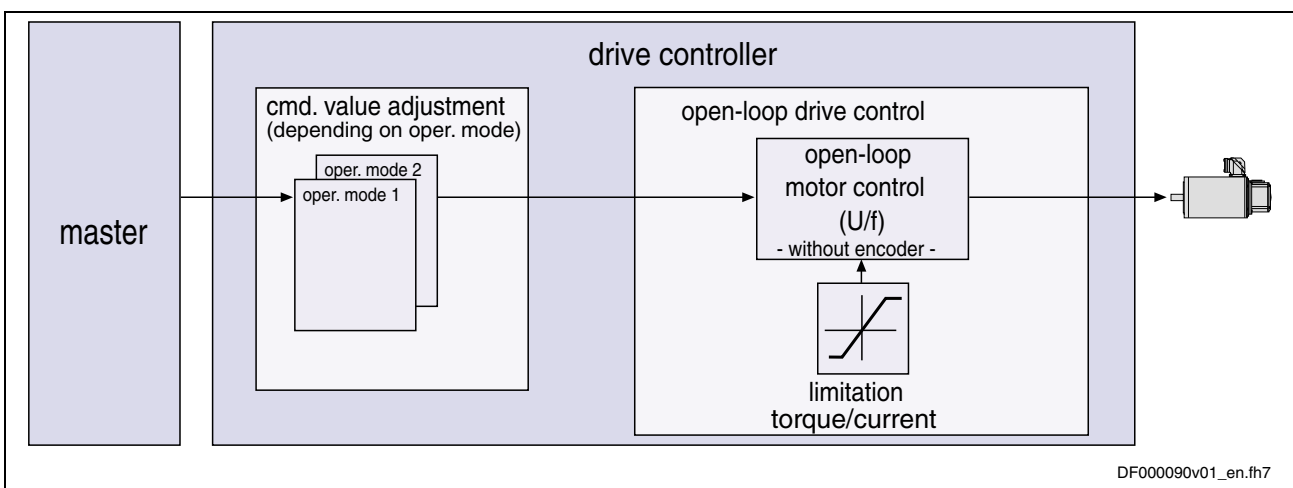
Fig. 6-1:   Principle of drive control of open-loop operation

See also section "Open-Loop Axis Control (Open-Loop Operation)" in the same chapter

See also section "Functional Packages" in chapter "System Overview"

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Closed Loop Axis Control (Closed-Loop Operation)

In the case of closed-loop axis control ("closed-loop operation"), closed-loop drive control with encoder is carried out with position or velocity feedback. The velocity and position control loops are closed by means of the encoder feedback.

Motor control in this case takes place as field-oriented closed-loop current control (see "Field-Oriented Closed-Loop Current Control" in section "Motor Control").
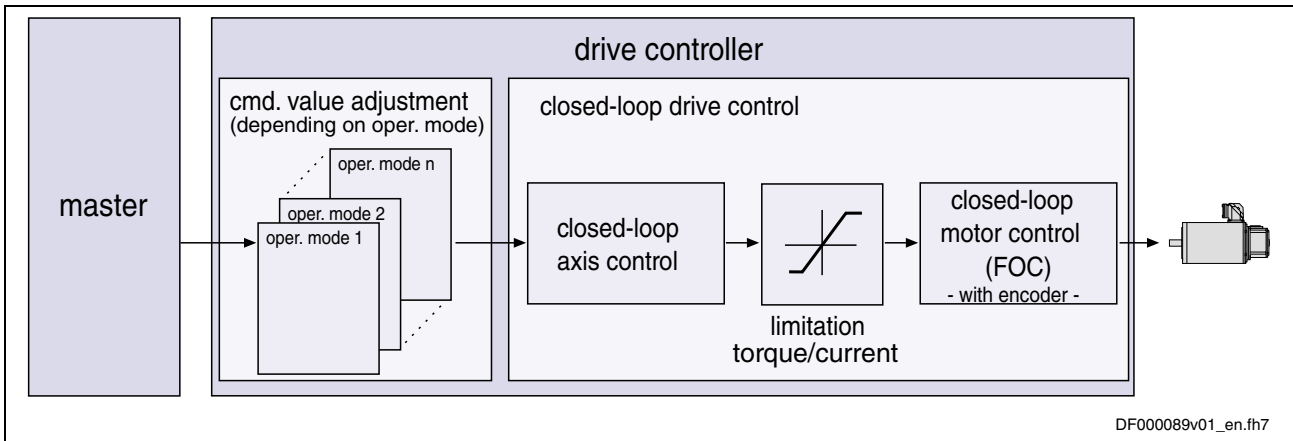
Fig. 6-2:   Principle of drive control of closed-loop operation

See also section "Closed-Loop Axis Control (Closed-Loop Operation)" in the same chapter

See also section "Functional Packages" in chapter "System Overview"

6.2   Motor Control

General Information on Motor Control

Open-Loop/Closed-Loop Operation

Apart from operation with encoder and field-oriented closed-loop current control, the IndraDrive firmware supports operation without encoder and open-loop U/f control.

The motor control method is selected by means of parameter **P-0-0045, Control word of current controller**.

P-0-0045; bit 14:

- bit 14 = 1   → open-loop U/f control

- bit 14 = 0   → field-oriented closed-loop current control

See also section "Overview of Drive Control" in the same chapter

Cycle Times and PWM Frequencies

Depending on the firmware type (MPH, MPD or MPB) and the respective control section (CSH01.1, CDB01.1, CSB01.1), there are the following possible cycle times and PWM frequencies:

TA_current	P-0-0001	FWA type	P-0-0556, bit 2	Performance
62.5 µs	16000	MPH02	0	Basic
83.3 µs	12000	MPH02	0	Basic
125 µs	8000	MPH02 MPB02 MPD02	0	Basic
125 µs	4000	MPH02 MPB02 MPD02	0	Basic
62.5 µs	16000	MPH02	1	Advanced
62.5 µs	8000	MPH02	1	Advanced
125 µs	4000	MPH02	1	Advanced

TA_current: sampling time of current loop
P-0-0001:   switching frequency of power output stage (in Hz)
P-0-0556:   control word of axis controller

Fig. 6-3:   Cycle times and switching frequencies that can be set

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Note: As regards the MPH firmware for advanced control sections (CSH01.1), you can either select basic or advanced performance via bit 2 of parameter **P-0-0556, Control word of axis controller**.

Voltage-Controlled Operation (Open-Loop 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 operating mode "velocity synchronization with real/virtual master axis" is additionally available.

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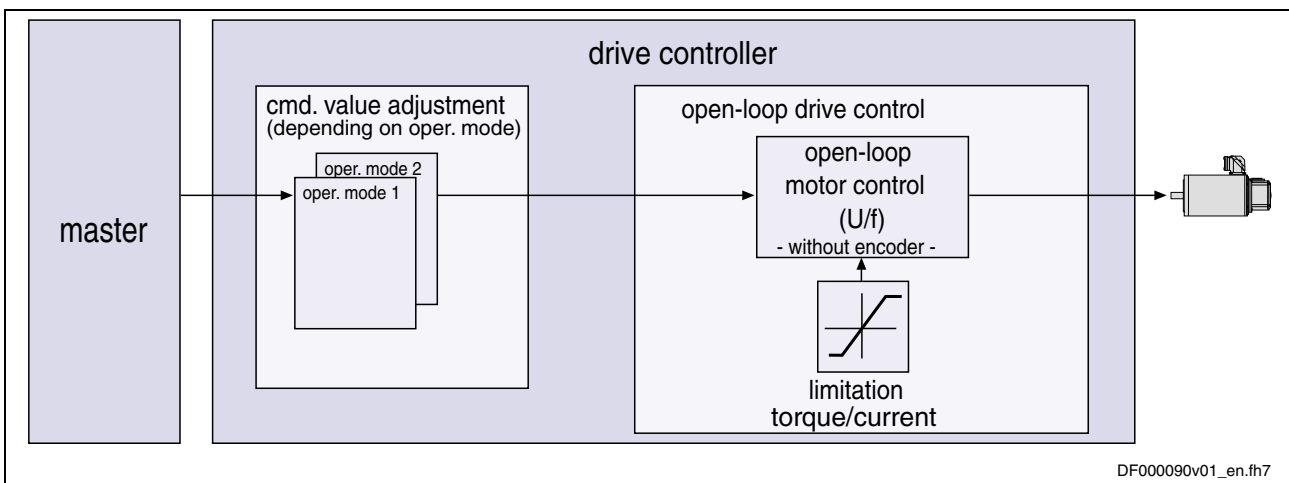
Fig. 6-4:   Principle of open-loop U/f control

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Open-loop U/f motor control is characterized by the following features or core functions:

Features

- monitoring and **limitation** of the maximum **stator frequency change** that results from the command velocity change
- **stall protection loop** (PI loop that can be optionally activated to prevent breakdown of the machine when the torque limits are attained)
- **slip compensation** (feedforward of estimated slip of the machine by means of slip compensation factor)
- calculation of output voltage by means of a **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
- **velocity search mode** of a coasting machine after switching drive enable on (can be set for the preset rotational direction or both rotational directions)
- acceptance of the limitation of the available peak current by **current limitation loop**
- user-side **torque/force limitation** via 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-0-0568, Voltage boost factor**
- **P-0-0569, Maximum stator frequency change**
- **P-0-0570, Stall protection loop proportional gain**
- **P-0-0571, Stall protection loop integral action time**
- **P-0-0572, Slip compensation factor**
- **P-0-0573, IxR boost factor**
- **P-0-0574, Oscillation damping factor**
- **P-0-0575, Search mode: search current factor**

- **P-0-0576, Search mode: finding point slip factor**
- **P-0-0577, Square characteristic: lowering factor**
- **P-0-4036, Rated motor speed**
- **P-0-4040, Rotor leakage inductance**
- **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

The figure below illustrates the core functions of open-loop U/f control:
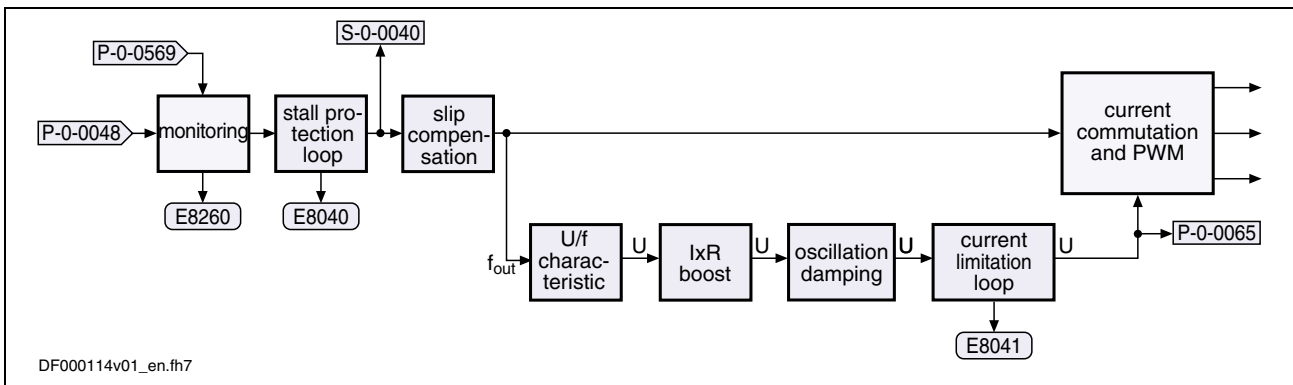
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S-0-0040:   velocity feedback value
P-0-0048:   effective velocity command value
P-0-0065:   absolute voltage value, actual value
P-0-0569:   maximum stator frequency change

Fig. 6-5:   Overview of open-loop U/f control

Maximum Stator Frequency Change

The maximum change of velocity with which the drive can follow the command values is determined by the motor and the sampling time of the stall protection loop. The limit value can be set in parameter **P-0-0569, Maximum stator frequency change**.

Stall Protection Loop

When the torque limits in the case of motive and generating load have been reached, the "breakdown" of the asynchronous machine is prevented by the so-called stall protection loop.

The stall protection loop is enabled via bit 12 of parameter **P-0-0045, Control word of current controller**:

- bit 12 = 1 $\rightarrow$ stall protection loop enabled
- bit 12 = 0 $\rightarrow$ stall protection loop switched off

Note: The default setting in bit 12 of P-0-0045 is "0" (stall protection loop deactivated).

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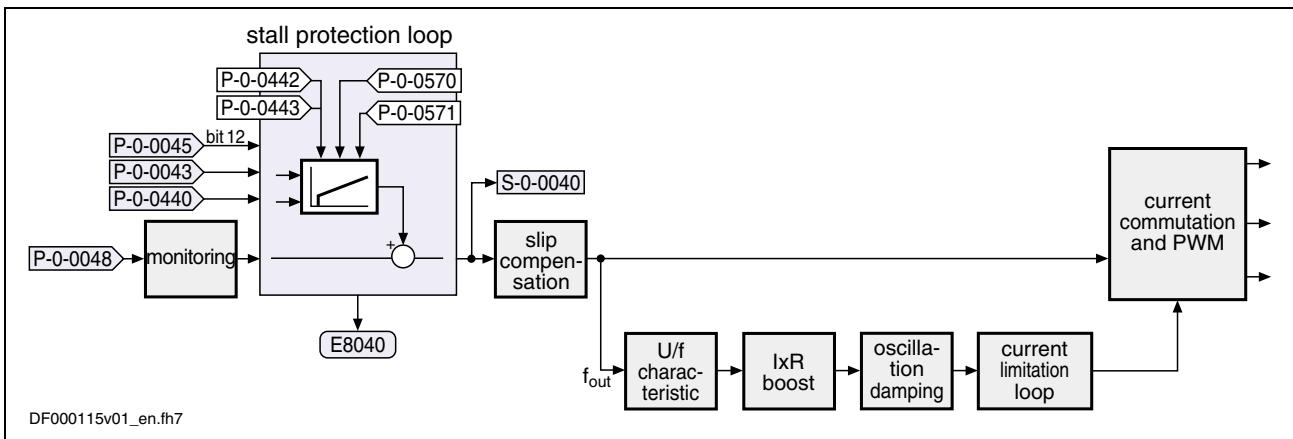
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S-0-0040:   velocity feedback value
P-0-0043:   torque-generating current, actual value
P-0-0045:   control word of current controller
P-0-0048:   effective velocity command value
P-0-0440:   actual output current value (absolute value)
P-0-0442:   actual value torque limit positive (stationary)
P-0-0443:   actual value torque limit positive (stationary)
P-0-0570:   stall protection loop proportional gain
P-0-0571:   stall protection loop integral action time

Fig. 6-6:   Core function "stall protection loop"

The input value is the result of the command value adjustment **P-0-0048, Effective velocity command value**, as well as the current values in the parameters **P-0-0043, Torque-generating current, actual value** and **P-0-0440, Actual output current value (absolute value)**.

The controller is set via the parameters:

- **P-0-0570, Stall protection loop proportional gain**

- **P-0-0571, Stall protection loop integral action time**

The values of the parameters **P-0-0442, Actual value torque limit positive (stationary)** and **P-0-0443, Actual value torque limit negative (stationary)** are the torque limits to which the stall protection loop is to limit the values.

Slip Compensation   With the slip compensation the estimated slip of the machine is precontrolled by means of the motor model data.
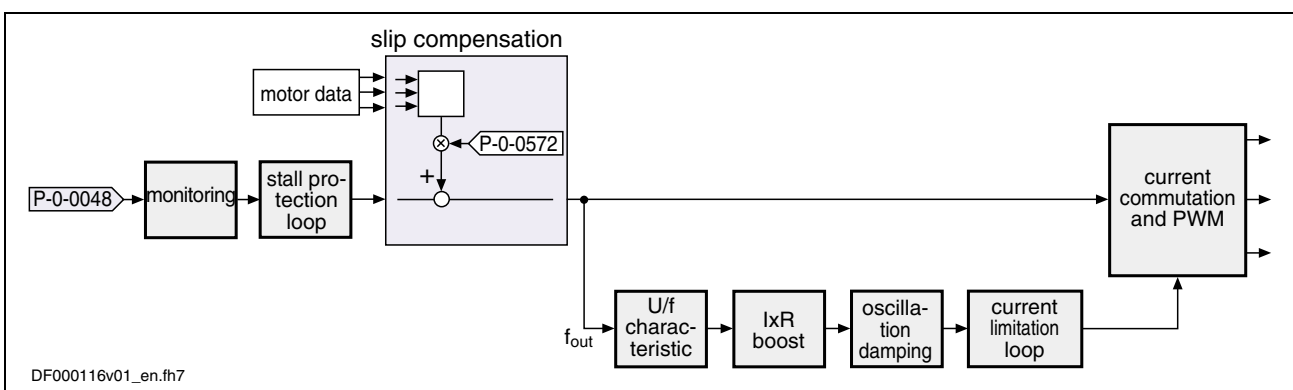
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P-0-0048:   effective velocity command value
P-0-0572:   slip compensation factor

Fig. 6-7:   Core function "slip compensation"

The output signal of the stall protection loop is used as the input value.

The precontrol can be set via parameter **P-0-0572, Slip compensation factor**.

	Note: With a value of "0.00%" in parameter P-0-0572 the slip compensation is switched off.

U/f Characteristic   In the "U/f characteristic" function the respective voltage for the effective output frequency is calculated from the motor model data.

The form of the characteristic in the basic range of setting, i.e. up to **P-0-4036, Rated motor speed**, is selected with bit 13 in **P-0-0045, Control word of current controller**:

- bit 13 = 1   → square characteristic
- bit 13 = 0   → linear characteristic

	Note: The default setting in bit 13 of P-0-0045 is "0" (linear characteristic).
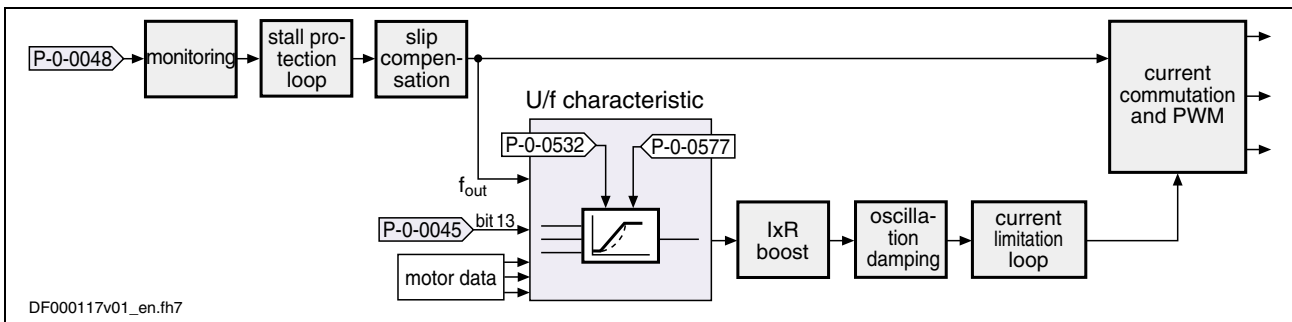
P-0-0045:   control word of current controller
P-0-0048:   effective velocity command value
P-0-0532:   premagnetization factor
P-0-0577:   square characteristic: lowering factor
Fig. 6-8:   Core function "U/f characteristic"

The output signal of the slip compensation is used as the input value for the U/f characteristic.

With a square characteristic the degree of lowering can be adjusted in the basic range of setting with the value in parameter **P-0-0577, Square characteristic: lowering factor**. The value of 100% corresponds to the original square curve. This lowering factor is reduced as the percentage value decreases.

	Note: The value "0.00%" in parameter P-0-0577 corresponds to the linear characteristic.

By means of parameter **P-0-0532, Premagnetization factor** it is possible to make a subsequent trimming of the machine's magnetization. This parameter can be configured in the MDT. If the premagnetization factor is cyclically transmitted by a higher-level master, it can precontrol the machine's magnetization in an appropriate way in the case of an expected change of load.

IxR Boost   By means of parameter **P-0-0573, IxR boost factor** it is possible to influence the precontrol of the output voltage in a load-depending way.

	Note: With a value of "0.00%" in parameter P-0-0573 the precontrol is switched off.

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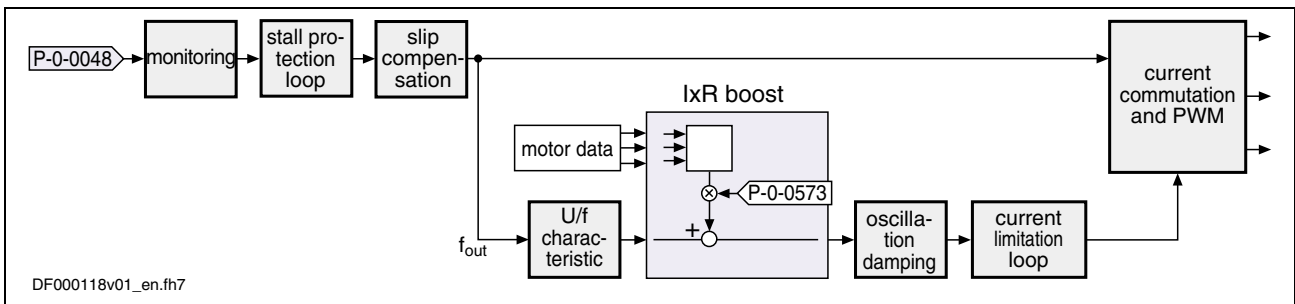
P-0-0048:   effective velocity command value
P-0-0573:   IxR boost factor

Fig. 6-9:   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 precontrol can be influenced with parameter **P-0-0574, Oscillation damping factor**.

Note: With a value of "0.00%" in parameter P-0-0574 the precontrol is switched off.
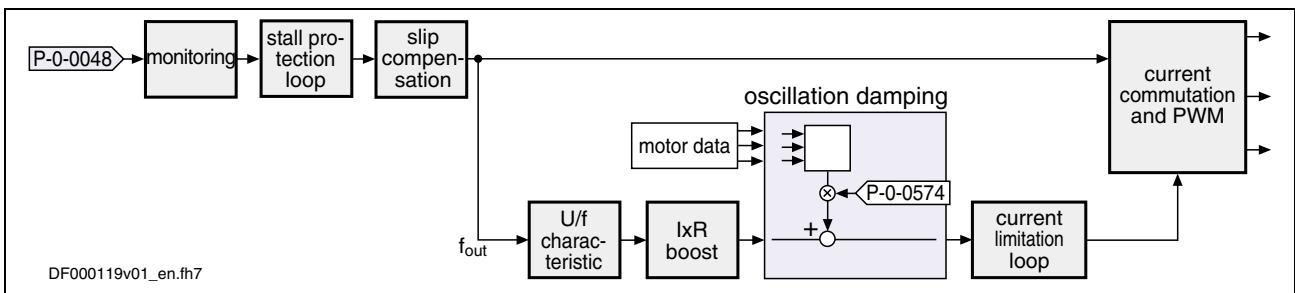
P-0-0048:   effective velocity command value
P-0-0574:   oscillation damping factor

Fig. 6-10:   Core function "oscillation damping"

Current Limitation Loop   It is the task of the current limitation loop to limit the maximum output current by reducing the output voltage. This normally causes breakdown of the motor. In this case, however, this has to be accepted because the protection of motor and devices has the higher priority.

The current limitation loop only becomes active if the enabled stall protection loop by changing the working point cannot reduce the drive load.

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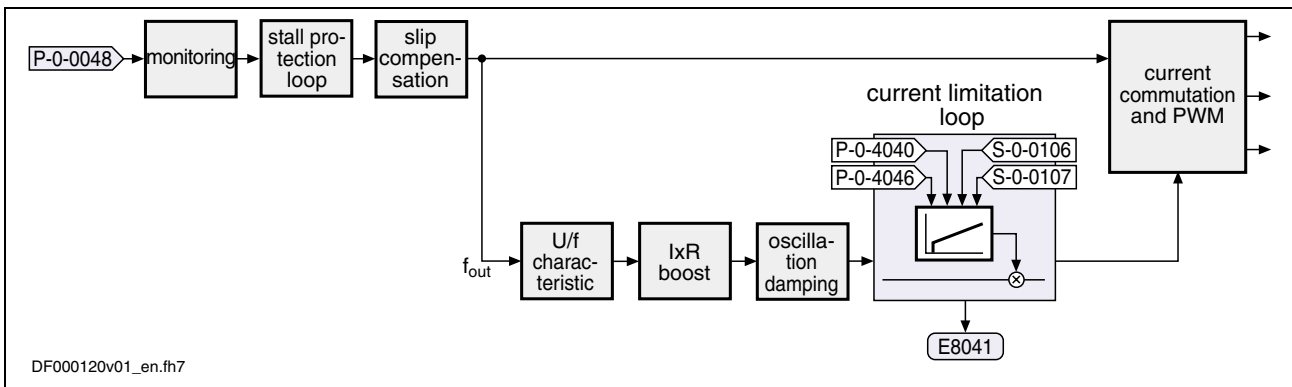
S-0-0106:   current loop proportional gain 1
S-0-0107:   current loop integral action time 1
P-0-0048:   effective velocity command value
P-0-4040:   rotor leakage inductance
P-0-4046:   effective peak current

Fig. 6-11:   Core function "current limitation loop"

Velocity Search Mode

The velocity search mode is selected and activated in parameter **P-0-0045, Control word of current controller** (bits 8, 9).

The following modes are distinguished for velocity search:

- **Velocity search after drive enable**
  After the start the search is run up to a speed equal zero with **S-0-0091, Bipolar velocity limit value** in the rotational direction given by **S-0-0036, Velocity command value**. At the current speed of the coasting machine, but at the latest at speed = 0, the search mode function is completed and the normal command value processing starts. In normal command value processing the drive moves to the provided command value with the initialization encoder.

- **Velocity search after drive enable, bidirectional**
  After the start the search is run up to a speed equal zero with **S-0-0091, Bipolar velocity limit value** in the rotational direction given by **S-0-0036, Velocity command value**. If the speed of the machine has not been found up to speed = 0, there is another search with the rotational direction changed. At the current speed of the coasting machine or at the latest at speed = 0, the search mode function is completed and the normal command value processing starts. In normal command value processing the drive moves to the provided command value with the initialization encoder.

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% are corresponding to the rated slip of the machine. This added value is subsequently trimmed with **P-0-0576, Search mode: finding point slip factor**.

Diagnostic and Status Messages

Monitoring the Stator Frequency

The limit value for the maximum change of velocity with which the drive can follow the command values is set in parameter **P-0-0569, Maximum stator frequency change**.

When the limitation of the maximum stator frequency change takes effect, the diagnostic message **E8260 Torque/force command value limit active**. As soon as the stator can follow the required frequency change again, the message is reset.

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Status of Stall Protection Loop	The activation of the stall protection loop is displayed in parameter **P-0-0046, Status word of current controller** (bit 12: stall protection loop):

- bit 12 = 1 → stall protection loop active

  In addition, the diagnostic message **E8040 Torque/force actual value limit active** is generated.

- bit 12 = 0 → stall protection loop not active

Status of Current Limitation Loop	The activation of the current limitation loop is displayed in parameter **P-0-0046, Status word of current controller** (bit 13: current limitation loop):

- bit 13 = 1 → current limitation loop active

  In addition, the diagnostic message **E8041 Current limit active** is generated.

- bit 13 = 0 → current limitation loop not active

Status of Velocity Search Mode	The status of the velocity search mode can be read in parameter **P-0-0046, Status word of current controller** (bit 14: search mode):

- bit 14 = 1 → search mode active
- bit 14 = 0 → search mode not active

Field-Oriented Closed-Loop Current Control

> **Base package** of all variants in **closed-loop** characteristic

Brief Description

The drive function "field-oriented current control" is made available in the base package "closed-loop".

Note: The current loop was preset for all Rexroth motors and normally does not have to be adjusted.

For notes on how to commission the current loop for third-party motors see "Third-Party Motors" in chapter "Motor, Mechanical Axis System, Measuring Systems"!

In the case of field-oriented closed-loop current control, the internal control task consists in generating the transformed currents I_d and I_q in closed-loop-controlled form:

- I_d (field-generating current)   → PI loop for I_d
- I_q (torque-generating current)   → PI loop for I_q

Working Ranges With the firmware, you can operate asynchronous and synchronous motors in the entire speed range, including field weakening.

As a basic principle, we distinguish the following three working ranges:

- base speed range (1)   → **constant torque**
- field weakening range (2)   → **constant power**
- field weakening range (3)   → **power limit range**

General Features   The field-oriented closed-loop current control has the following general features:

- closed-loop control of the motor current according to the principle of field orientation, i.e. separate closed-loop control of the torque-generating current and the flux-generating current
- compensation of the cross coupling of the d and q axes to increase dynamics
- voltage loop for operation in the field weakening range
- activation of the optimum current loop proportional amplification value depending on the current PWM frequency during the load defaults procedure

Features of Synchronous Motor Control   In the case of synchronous motors, the field-oriented closed-loop current control additionally has the following features:

- limitation of the I_q command value at the voltage limit for protection against too little control margin
- utilization of the reluctance effect to increase the available torque in the basic speed range
- support of synchronous motors with reluctance torque, i.e. motors with significantly different inductances in the d and q axes

Features of Asynchronous Motor Control   In the case of asynchronous motors, the field-oriented closed-loop current control additionally has the following 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**

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**

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Power monitoring:

- **S-0-0158, Power threshold Px**
- **S-0-0337, Message 'P >= Px'**
- **S-0-0382, DC bus power**

Encoder monitoring:

- **P-0-0520, Error threshold for encoder monitoring**

Display parameters:

- **S-0-0380, DC bus voltage**
- **P-0-0043, Torque-generating current, actual value**
- **P-0-0044, Flux-generating current, actual value**
- **P-0-0046, Status word of current controller**
- **P-0-0063, Torque-generating voltage, actual value**
- **P-0-0064, Flux-generating voltage, actual value**
- **P-0-0065, Absolute voltage value, actual value**

Pertinent Diagnostic Messages

- **E8025 Overvoltage in power section**
- **E8028 Overcurrent in power section**
- **F2077 Current measurement trim wrong**
- **F8023 Error mechanical link of encoder 1**
- **F8060 Overcurrent in power section**

General Function of Field-Oriented Closed-Loop Current Control

Torque/Force Control In contrast to the functional principle used in the "torque/force control" mode, this is actually is current control, as the actual current value is measured and not the force or the motor torque. This means that open-loop control of torque/force takes place, the torque or the force being directly connected with the torque-/force-generating current via the torque/force constant.

In the case of asynchronous motors, the torque constant is corrected according to the active rotor flux.

$$M_i = K_M \cdot I_q$$

Field Weakening Operation With the firmware, it is possible to operate asynchronous and synchronous motors in the entire speed range (including field weakening range).

As a basic principle, we distinguish three working ranges that are illustrated and described below:
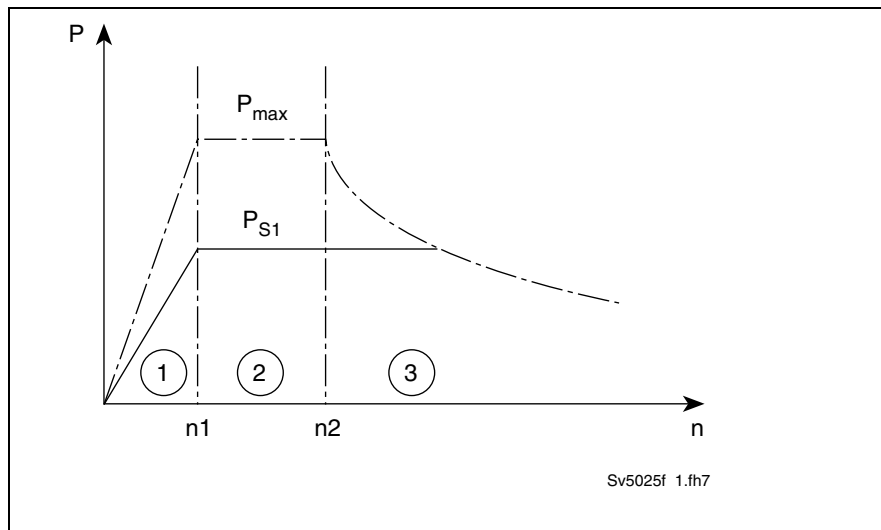
Fig. 6-12:   Working ranges

Base Speed Range (1) The base speed range is characterized by constant torque and fixed torque/force constant (P-0-0051).

In the case of asynchronous motors, the programmed, effective magnetizing current flows in no-load operation. The motor voltage is less than the maximum controller output voltage. The corner speed n1 is directly proportional to the DC bus voltage.

Field Weakening Range (2)
(Constant Power) This field weakening range 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 (3)
(Power Limit Range) The field weakening range 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.

Note: Due to this causal connection, it is clear that the power in range 3 cannot be increased by using a more powerful controller.

Field-Oriented Closed-Loop Current Control of a Synchronous Machine

Synchronous motors with a motor encoder in field-oriented closed-loop 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.

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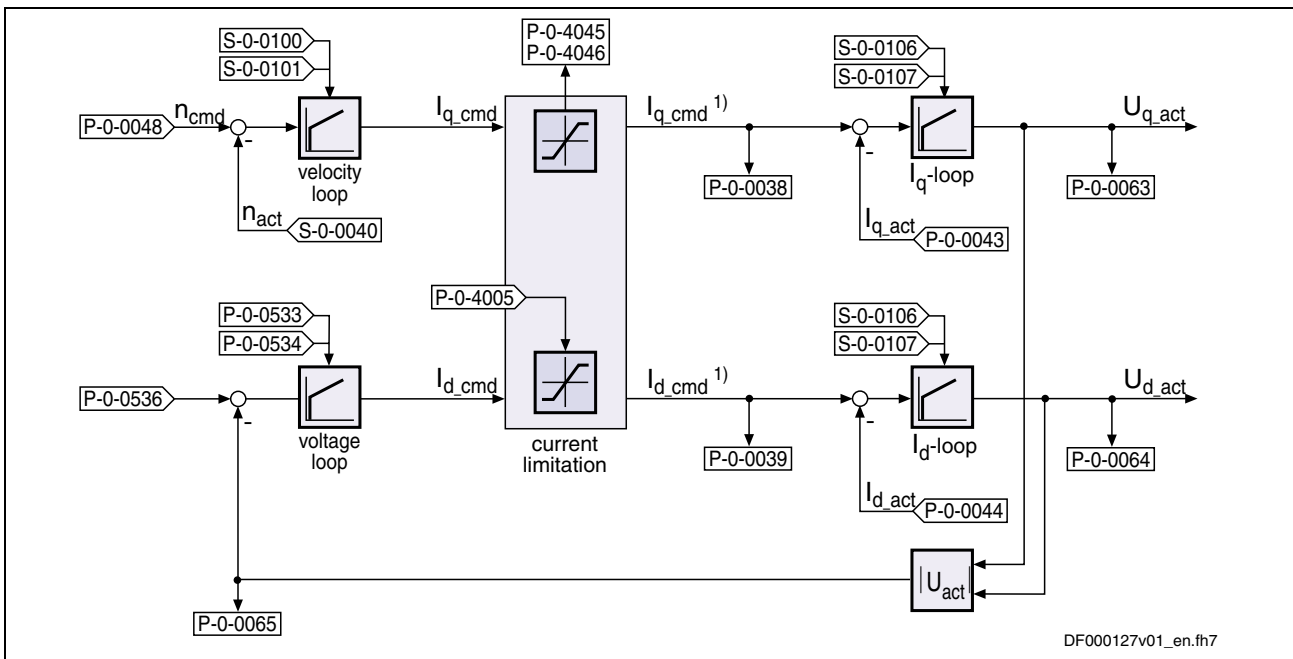
1): current command value after limitation

Fig. 6-13: Simplified schematic diagram of the current control loop for a synchronous machine (incl. voltage loop)

Voltage Loop for Synchronous Motors

For field (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**

Note: 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) a reduction of the output voltage can be obtained.

Note: The output value of the voltage loop is the command value for the field-generating component of the subsequent current loop (see figure above).

Field Weakening of Synchronous Motors

In the case of synchronous motors with field weakening, a command value of $I_{d\_cmd} = 0$ is run in the base speed range, as in the case of synchronous motors without field weakening.

When entering the field weakening, I_{d_cmd} is increased towards negative values and therefore allows higher motor velocities.

Closed-Loop Control of Synchronous Motors with Distinctive Reluctance Torque

Closed-loop control of synchronous motors with reluctance torque, i.e. motors with significantly different inductances in the d and q axes, requires the separate input of L_d and L_q in the respective parameters:

- **P-0-4016, Direct-axis inductance of motor** (L_d)
- **P-0-4017, Quadrature-axis inductance of motor** (L_q)

Note:	Utilization of the reluctance effect allows increasing the available torque in the base speed range.

Field-Oriented Closed-Loop Current Control of an Asynchronous Machine

Field-oriented closed-loop control of the asynchronous machine differs from closed-loop control of the synchronous machine in the additional function blocks "flux feedforward" and "flux loop incl. flux model". The figure below illustrates the control loop structure and the points at which the individual parameters take effect.
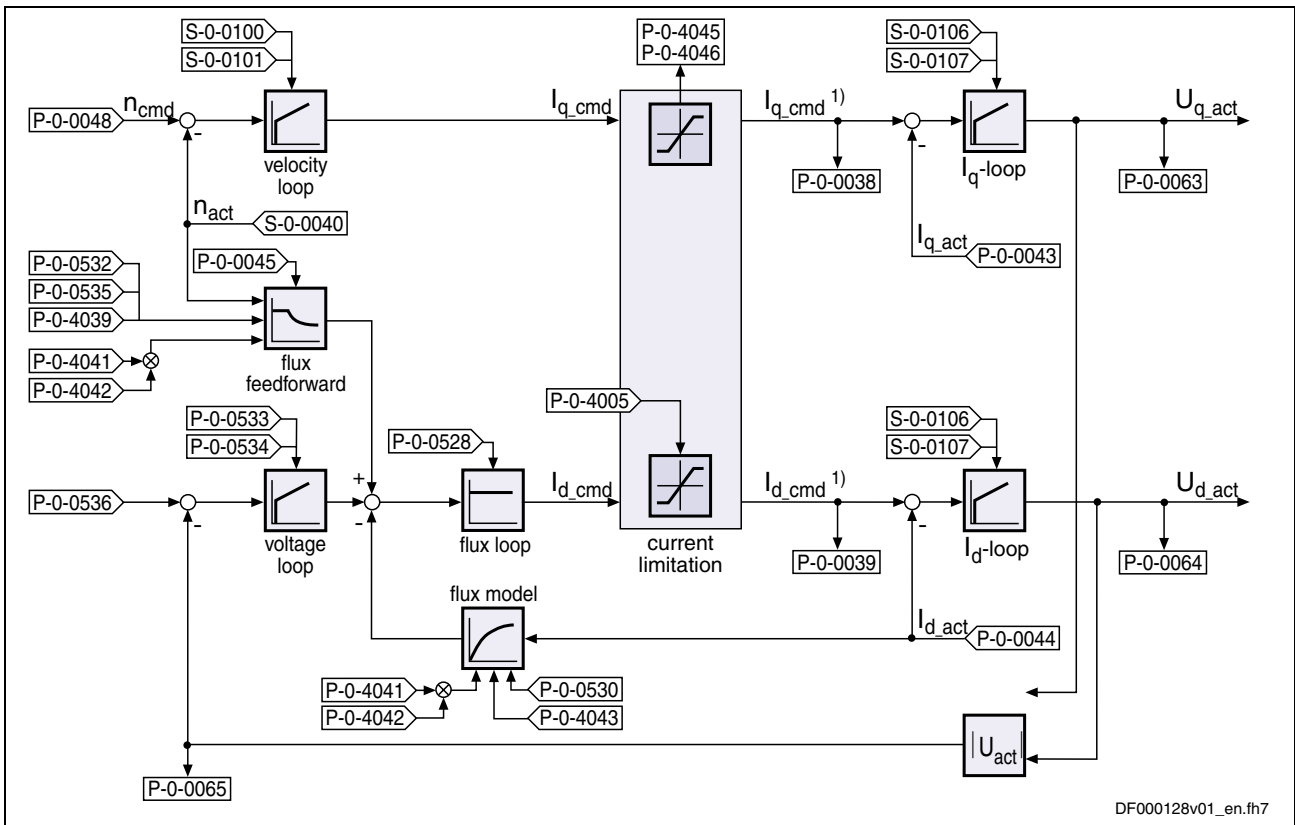
1):   current command value after limitation

Fig. 6-14:   Simplified schematic diagram of the current control loop for an asynchronous machine (incl. voltage loop and flux loop)

Note:	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.

Flux Feedforward   Due to high magnetization (rotor flux) the motor produces a higher torque. In no-load operation the magnetization, however, produces loss which is the reason why it is useful to reduce magnetization for less dynamic applications.

Note:	For reducing magnetization a value between 50% and 100% can be set in parameter **P-0-0532, Premagnetization factor**.

In addition, magnetization can be influenced via bit 2 of **P-0-0045, Control word of current controller**:

- With **bit 2 = 0** in P-0-0045 (default) magnetization is increased up to the nominal value according to the required torque; 100% are reached at nominal motor torque.

- With **bit 2 = 1** in P-0-0045 magnetization remains at the value set in P-0-0532 independent of the load.

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. As limit value the flux feedforward uses the value in parameter **P-0-0535, Motor voltage at no load**. 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.

> **Note:** A **setting of 80%** in parameter P-0-0535 is advisable.

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**

Flux Model On the basis of the above motor data and the active value of the flux-generating current I_d, the flux model calculates the actual value of the rotor flux. This value is used as actual value for the flux loop (see below) and additionally determines the torque constants and the behavior of the slip frequency of the asynchronous machine required for generating the torque.

The slip frequency changes with the temperature of the motor. This is compensated by measuring the motor temperature (S-0-0383) and evaluation with the factor in parameter

- **P-0-0530, Slip increase**.

This factor is to set depending on the motor cooling type.

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 feed forward.

The maximum motor voltage is specified in a percentage-based way and refers to the maximum possible output voltage of the inverter that is determined by the active DC bus voltage (cf. S-0-0380).

> **Note:** A **setting of 90%** in parameter P-0-0536 is advisable.

Flux Loop	The flux loop works as a P-loop with command value feedforward. It compares the actual value from the rotor flux model to the command value from flux feedforward and voltage loop and by the corresponding input of the flux-generating current component $I_{d\text{-}cmd}$ provides for rapid rotor flux generation. This is of importance for applications with dynamic speed response (field weakening range). The gain can be set in parameter **P-0-0528, Flux control loop proportional gain**.

Note: For Rexroth motors the corresponding value is stored in the "DriveBase" data base.

Stall Current Limit	The stall current limit only takes effect in the power limit range of the field weakening range (3). The maximum allowed torque-generating current is calculated by means of the active rotor flux and the motor data. This absolute limit value can be relatively changed via the setting in parameter **P-0-0529, Scaling of stall current limit** (in percent).

Note: When operating a motor without field weakening (generally in the case of linear asynchronous motors) it is only the effective magnetizing current that is accepted as command value for the field-generating current component.

Notes on Commissioning

Note: The current loop was preset for all Rexroth motors and normally does not have to be adjusted.

For notes on how to commission the current loop for third-party motors see "Third-Party Motors" in chapter "Motor, Mechanical Axis System, Measuring Systems"!

Current Loop (Torque-Generating Current)	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 data memory they are stored in this memory.
- For Rexroth motors without motor data memory they can be taken from a motor data base during commissioning via "DriveTop".
- For third-party motors they have to be calculated by means of the data sheet (see "Third-Party Motors" in chapter "Motor, Mechanical Axis System, Measuring Systems").

See also "Commissioning the Motor" in chapter "Commissioning"

Voltage Loop (Flux Loop)	The voltage loop designed as a PI loop can be set via the following parameters:

- **P-0-0533, Voltage loop proportional gain**
- **P-0-0534, Voltage loop integral action time**

> **Note:** 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 defined by means of parameter **P-0-0536, Maximum motor voltage**.

The input in P-0-0536 is made in percent and refers to the maximum possible output voltage of the inverter that is determined by the active DC bus voltage (cf. S-0-0380).

> **Note:** A **setting of 90%** in parameter P-0-0536 is advisable.

In addition to the parameterization of the field loop, the following settings can be made or changed, if required:

- The field weakening can be activated via **P-0-0045, Control word of current controller** (bit 0).

- According to the motor cooling type, a different factor can be set in parameter **P-0-0530, Slip increase**.

Diagnostic and Status Messages

Status Messages

- **S-0-0158, Power threshold Px**
  This parameter determines the power threshold above which the drive outputs the status message "power > = Px" in parameter S-0-0337, Message 'P >= Px'.

- **S-0-0337, Message 'P >= Px'**
  Only bit 0 of this parameter is used. It is set when:
  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 (advanced: T = 62.5 µs; basic: T = 125 µs) and displayed in parameter **S-0-0380, DC bus voltage**.

- The effective electric power produced by the controller (taking the inverter losses into account) is displayed in parameter **S-0-0382, DC bus power**.

  Calculation according to formula below:

$$P_{eff} = (U_d * I_d + U_q * I_q) * 1.5$$

  The calculated value is displayed in filtered form (T = 8ms). When the parameterized threshold value in **S-0-0158, Power threshold Px** is exceeded, bit 0 is set in **S-0-0337, Message 'P >= Px'** and bit 7 in class 3 diagnostics.

- The measured value of the torque-generating current (I_q) detected in the current loop clock (advanced: T = 62.5 µs; basic: T = 125 µs) is displayed in parameter **P-0-0043, Torque-generating current, actual value**.

- The measured value of the field-generating current (I_d) detected in the current loop clock (advanced: T = 62.5 µs; basic: T = 125 µs) is displayed in parameter **P-0-0044, Flux-generating current, actual value**.

- Parameter **P-0-0046, Status word of current controller** displays the status of the current loop.

- **C0132 Invalid settings for controller cycle times**
  An error in the parameterization of the controller cycle times and pulse width modulation frequency was detected.

- **C0251 Error during synchronization to master communication**
  The synchronization of drive control to the bus interface (SERCOS, PROFIBUS, Interbus …) failed during progression to the operating mode.

- **E8025 Overvoltage in power section**
  This warning is generated when the DC bus voltage exceeds a value of 870.0 V. In this case, the current loop is temporarily switched off to protect the motor.

- **E8028 Overcurrent in power section**
  This warning is generated when the total current > 1.2 * minimum (**S-0-0109, Motor peak current**; **S-0-0110, Amplifier peak current**). In this case, the current loop is temporarily switched off to protect the motor (avoiding demagnetization).

- **F2067 Synchronization to master communication incorrect**
  The synchronization of drive control to the bus interface (SERCOS, PROFIBUS, Interbus …) failed during operating.

- **F2077 Current measurement trim wrong**
  During zero adjust of the current measurement a deviation outside the tolerance range occurred (hardware defect).

Commutation Setting

Brief Description

The following Rexroth kit motors are manufactured according to the "synchronous motor" functional principle:

- LSF, MLF linear motors

- MBS and MBT rotary motors

As the motor is assembled in the machine, stator, rotor and measuring system can only be put together on site. The electric-magnetic-mechanical allocation of the synchronous motor is therefore only to be made on site. This is done by determining and setting the commutation offset.

Measuring Systems for Synchronous Rexroth Motors

Absolute measuring systems should ideally be used for synchronous Rexroth kit motors. The advantage in this case is the absolute position detection of the rotor position which immediately ensures, when drive enable is set, the correct assignment of current in the primary part to the magnetic field in the secondary part. This is realized by the commutation offset stored at initial commissioning.

For some applications it is necessary to use incremental measuring systems because the available length of absolute measuring systems is limited, for example. The disadvantage in this case is that absolute detection of the rotor position is impossible. It is therefore necessary, after each time the drive is switched on again or after having changed the communication phase from "P2" to "P4" ("bb" or "Ab"), to set the commutation offset again. This disadvantage can be removed by using the Hall sensor box SHL01.1, because with regard to commutation setting the relative motor encoder then behaves like an absolute measuring system.

Note: If you use an incremental motor encoder, using the Hall sensor box SHL01.1 is absolutely recommended! This realizes highest safety with regard to correct motor function and compliance with the power data!

Measuring Systems for Synchronous Third-Party Motors

For operationally reliable drives with synchronous third-party motors and IndraDrive controllers there are, with regard to the selected measuring system, the same principles applying as for synchronous Rexroth kit motors (see above); the Hall sensor box SHL, however, cannot be used for third-party motors!

Overview of the Synchronous Motors to be Used for Motor Measuring Systems

Motor measuring system	Synchronous Rexroth Kit Motors	Synchronous Rexroth Kit Motor with SHL01.1	Synchronous third-party motor
absolute	+	-	+
relative	o	+	o

+ : advantageous combination
o : combination possible, initial commissioning might possible require especially trained staff
- : combination not useful

Fig. 6-15: Possible combinations of motor measuring system and synchronous motors for which commutation setting is required

Note: The measuring system should be realized with high resolution and as a motor encoder to be evaluated in absolute form. If it is necessary to use an incremental measuring system the use of encoders with square-wave signals should be avoided!

See also "Absolute Measuring Systems" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Note: In the case of absolute measuring systems, the commutation offset only has to be determined once (at initial commissioning), manually via command start; in the case of incremental measuring systems (without SHL01.1), it is automatically determined again each time the drive is switched on! Differences in the values can occur when commutation offset is determined again, this can cause different drive behavior!

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 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, see documentation "Hall Sensor Box SHL01.1")

- measuring method for motor encoders that can be evaluated in absolute form
  (distance measurement, currentless → only possible for Rexroth linear kit motors)

- saturation method (without constraint of motion)
  (with current → possible with all types of construction in combination with motor encoders that can be evaluated in absolute form and with relative motor encoders; but see below "Restrictions for Saturation Method")

- sine-wave method (with constraint of motion)
  (with current → possible with all types of construction with motor encoders that can be evaluated in absolute form and with relative motor encoders; but see below "Restrictions for Sine-Wave Method")

Note:	The sine-wave method (generally with constraint of motion) 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 that without or with only little saturation effects	Saturation method cannot be used for determining commutation offset!
applications with relative measuring system (without using the optimum commutation offset value with regard to the reference point)	Max. torque/force can be reduced by approx. 15% compared to the optimum value (automatic detection of commutation offset with "AF")!
applications with relative measuring system that are using the optimum commutation offset value with regard to the reference point	Max. torque/force until reference mark is passed can be reduced by approx. 15%!
drives that can be in motion during the determination of the commutation offset, e.g. coasting spindles, printing roller drives etc.	Saturation method only possible for motors in standstill!
drives with low inertia and little friction	Axis might move when current is supplied, saturation method only successful for motors in standstill!
drives with a low degree of overload capacity	Saturation method only successful if amplifier current is sufficiently high (2...4-fold continuous motor current required)!

Fig. 6-16:   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 mustn't be active at the other drive!
rotary axes with single drive	Only balanced axes with little friction; high inertia can cause problems!
rotary axes, mechanically connected	see above "linear axes in Gantry arrangement"

Fig. 6-17:   Typical applications and restrictions for sine-wave method

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Pertinent Parameters

Apart from the motor parameters (see parameter overview in "Basics on the Motors to be Controlled" in chapter "Motor, Mechanical Axis System, Measuring Systems"), there are further parameters available for commutation setting:

- **P-0-0506, Voltage amplitude for angle acquisition**
- **P-0-0507, Test frequency for angle acquisition**
- **P-0-0508, Commutation offset**
- **P-0-0517, Commutation: required harmonics component**
- **P-0-0521, Effective commutation offset**
- **P-0-0522, Control word for commutation setting**
- **P-0-0523, Commutation setting measured value**
- **P-0-0524, C1200 Commutation offset setting command**
- **P-0-3008, Commutation offset, encoder memory**

Pertinent Diagnostic Messages

- **C1200 Commutation offset setting command**
- **C1204 Error in offset calculation**
- **C1208 No adjustment with asynchronous motor**
- **C1209 Proceed to phase 4**
- **C1211 Commutation offset could not be determined.**
- **C1214 Command only possible with linear synchronous motor**
- **C1215 Command only possible in 'bb'**
- **C1216 Commutation determination not selected**
- **C1217 Setting only possible in 'Ab'**
- **C1218 Automatic commutation: current too low**
- **C1219 Automatic commutation: overcurrent**
- **C1220 Automatic commutation: timeout**
- **C1221 Automatic commutation: iteration without result**
- **C1222 Error when writing offset parameters**
- **F2032 Plausibility error during commutation fine adjust**
- **F8010 Autom. commutation: max. motion range when moving back**
- **F8011 Commutation offset could not be determined**
- **F8012 Autom. commutation: max. motion range**
- **F8013 Automatic commutation: current too low**
- **F8014 Automatic commutation: overcurrent**
- **F8015 Automatic commutation: timeout**
- **F8016 Automatic commutation: iteration without result**

Determining the Commutation Offset, Calculation Method when Using the Hall Sensor Box SHL01.1

The Hall sensor box SHL01.1 is an absolute measuring system within one pole pair distance of a Rexroth linear motor. Via the signals of the Hall sensors the controller detects the position of the motor windings compared to the magnetic field of the motor.

The value for the commutation offset depends on the motor data and the mounting distance of the box compared to the primary part. This value is independent of the axis position and is determined once during initial commissioning (data for mounting, connection and determination of commutation offset see documentation on Hall sensor box SHL01.1).

Determining the Commutation Offset, Measuring Method

Application-Related Aspect

The measuring method for determining the commutation offset described below can only be used for Rexroth linear motors with motor encoder that can be evaluated in absolute form (EnDat encoder). The method is currentless, i.e. the motor does not generate any force. At drive enable (AF = **A**ntriebs**f**reigabe) it is then immediately fully operational.

Note:	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). The distances to be measured are depending on the axis position, the measurements described below have to be carried out once during initial commissioning.

Measuring the Relative Position Between Primary and Secondary Part

Depending on the possibility of accessing the primary and secondary part in the machine or installation, the relative position of the primary and secondary part can be measured in different ways:
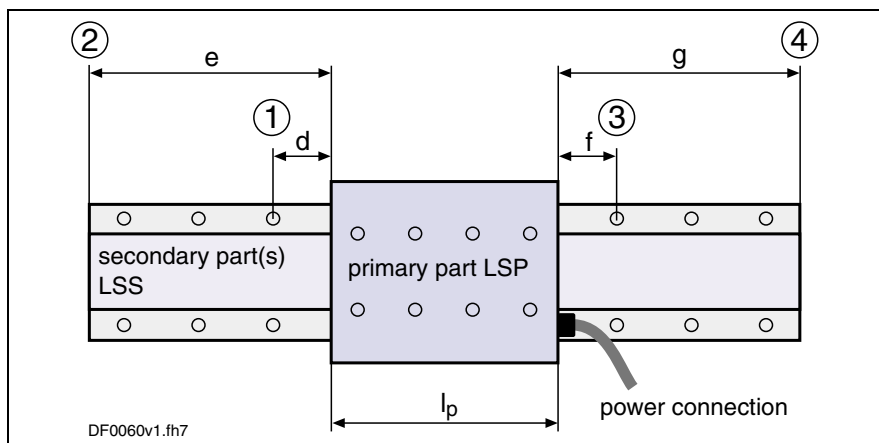
Fig. 6-18: Measuring the relative position between primary and secondary part

Note:	After the distance has been measured the position of the primary part mustn't be changed any more until the determination of the commutation offset is completed!

Calculating P-0-0523, Commutation setting measured value

The input value in P-0-0523 required for determining the commutation offset must be calculated from the measured relative position of primary part with regard to secondary part (see fig. "Measuring the relative position between primary and secondary part", distance d, e, f or g, according to possibility of access), as well as a motor-dependent constant k_{mx} (see "Calculation formulas for P-0-0523" and table "Motor constant k_{mx} for commutation setting").

$$reference\ point\ 1: \qquad P-0-0523 = d - k_{mx}$$

$$reference\ point\ 2: \qquad P-0-0523 = e - k_{mx} - 37.5\,mm$$

$$reference\ point\ 3: \qquad P-0-0523 = -f - l_p - k_{mx}$$

$$reference\ point\ 4: \qquad P-0-0523 = 37.5\,mm - g - l_p - k_{mx}$$

P-0-0523:   commutation setting measured value in mm
d: distance reference point 1 – front side of primary part in mm [1]
e: distance reference point 2 – front side of primary part in mm [1]
f: distance reference point 3 – front side of primary part in mm [1]
g: distance reference point 4 – front side of primary part in mm [1]
k_{mx}:   motor constant for commutation setting in mm
l_p: length of primary part in mm
[1]:   see fig. above "Measuring the relative position between primary and secondary part"

Fig. 6-19: Calculation formulas for P-0-0523

Note: When determining **P-0-0523, Commutation setting measured value** you have to make sure the preceding sign is correct.
If P-0-0523 is determined with a negative sign, this has to be entered!

Motor Constant k_{mx} for Commutation Setting   The motor constant k_{mx} for setting the commutation offset depends on the arrangement of the primary and secondary part:
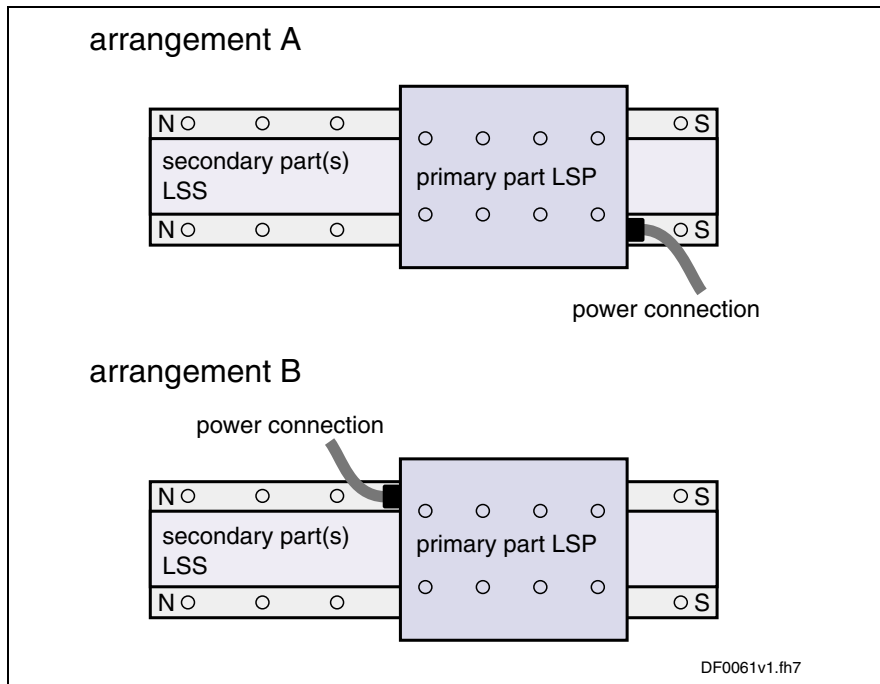
Fig. 6-20: Possibilities of arrangement of primary and secondary part

	Arrangement A k_{mx} in mm	Arrangement B k_{mx} in mm
encapsulated standard construction sizes 080, 120, 160, 200, 240	38.0 mm	75.5 mm
encapsulated standard construction size 040	66.0 mm	104.0 mm
encapsulated standard construction size 140	38.0 mm	75.5 mm
encapsulated thermo construction sizes 080, 120, 160, 200, 240	38.0 mm	75.5 mm

Fig. 6-21:   Motor constant k_{mx} for commutation setting

Example 1, reference point ① (fig. "Measuring the relative position between primary and secondary part"):

d = 100.0 mm, k_{mx} = 38.0 mm

P-0-0523 = d - k_{mx} = 100.0 mm – 38.0 mm = 62.0 mm

Example 2, reference point ① (fig. "Measuring the relative position between primary and secondary part"):

d = 0.0 mm, k_{mx} = 38.0 mm

P-0-0523 = d - k_{mx} = 0.0 mm – 38.0 mm = – 38.0 mm

Example 3, reference point ④ (fig. "Measuring the relative position between primary and secondary part"):

$g = 180.0$ mm , $k_{mx} = 38.0$ mm , $l_p = 540.0$ mm

P-0-0523 = 37.5 mm - g - l_p - k_{mx} = 37.5 mm – 180.0 mm – 540.0 mm – 38.0 mm

P-0-0523 = – 720.5 mm

Carrying Out the Measuring Method (Commissioning)

Requirements
- The determination of the commutation offset can only be used for synchronous linear motors with absolute encoder (e.g. encoder with EnDat interface).
- During the setting procedure below the drive must be in the **A0013 Ready for power on** status.
- The position of the primary part or the slide mustn't have changed since the relative position of primary and secondary part was measured.
- The correct value must have been entered in **P-0-0018, Number of pole pairs/pole pair distance**.

How to Proceed
1. Measure the reference between primary and secondary part.
2. Calculate the value for P-0-0523 with the appropriate formula for the arrangement; enter the determined value in **P-0-0523, Commutation setting measured value**.
3. Select the method by setting the respective bit in **P-0-0522, Control word for commutation setting**.
4. Start the **P-0-0524, C1200 Commutation offset setting command** in order to carry out the calculation of the commutation offset.
5. The controller enters the determined value in **P-0-0521, Effective commutation offset**. If the commissioning mode was activated in **P-0-0522, Commutation setting control word** the value from P-0-0521 is accepted in **P-0-0508, Commutation offset** and **P-0-3008, Commutation offset, encoder memory**, too.
6. The command then has to be reset again!

Relevant Parameters Parameters for input data:
- **P-0-0523, Commutation setting measured value**
- **P-0-0522, Control word for commutation setting**

Command parameters:
- **P-0-0524, C1200 Commutation offset setting command**

Parameters for output data:
- **P-0-0508, Commutation offset**
- **P-0-0521, Effective commutation offset**
- **P-0-3008, Commutation offset, encoder memory**

Relevant Diagnostic Messages Diagnostic messages for command errors:
- **C1204 Error in offset calculation**
- **C1208 No adjustment with asynchronous motor**
- **C1209 Proceed to phase 4**
- **C1214 Command only possible with linear synchronous motor**

- **C1215 Command only possible in 'bb'**
- **C1216 Commutation determination not selected**
- **C1222 Error when writing offset parameters**

Determining the Commutation Offset, Saturation Method

Application-Related Aspect   The saturation method for determining the commutation offset can be used for all types of synchronous motors. Compared to the measuring method, it provides the advantage that distance measurement is not required. Stator and rotor of the motor in this case can be inaccessibly installed in the machine. The commutation offset is determined by a current flow procedure. The controller sets drive enable automatically for the duration of the measurement.

Note: Observe the restrictions for the saturation method (see table above "Restrictions for saturation method")!

Method   By a sinusoidal 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 therefor 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.

Note: 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 in order to cause magnetic saturation in the motor (e.g. in the case of command error C1218), use controller with higher type current!

→ If the generated test current is too low in spite of sufficient controller type current (e.g. in the case of command error C1218), measures as described for C1218 in the Troubleshooting Guide can be carried out!

Should it be impossible to determine a commutation angle in spite of these measures (e.g. command error C1221), the saturation method cannot be used for commutation setting!

Carrying Out the Saturation Method (Commissioning)

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 optimized during the initial commissioning.

Sequence of the Saturation Method for Synchronous Motors with Absolute Measuring System   1. In **P-0-0522, Commutation setting control word** activate:

initial commissioning mode and

saturation method

2. Make presettings for automatic determination of motor-specific parameter values (P-0-0506, P-0-0507) of the test signal required for determining the commutation offset:

- enter value "0" in **P-0-0506, Amplitude for angle acquisition**

3. Switch drive to operating mode ("AB"); start 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, due to the initial commissioning mode, is simultaneously stored in the following parameters in the case of absolute measuring systems:

- **P-0-0508, Commutation offset**
- **P-0-0521, Effective commutation offset**,
- **P-0-3008, Commutation offset, encoder memory** (if available)

The execution of the command is now completed, it can be reset. The drive now is operational.

Note: It is recommended to execute the command C1200 several times over a pole pair or a distance between pole centers, to generate and enter the average value of P-0-0521. Checking and optimizing P-0-0521 by force or torque measurement at the axis is recommended!

See also below "Manually Optimizing the Commutation Offset Value"

---

5. In **P-0-0522, Commutation setting control word** deactivate the initial commissioning mode by the 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 resp. P-0-3008 is accepted in P-0-0521 and becomes effective as the commutation offset value.

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!

Note: 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 at initial commissioning becomes effective!

Initial Commissioning of a Synchronous Motor with Incremental Measuring System by Saturation Method

1. In **P-0-0522, Commutation setting control word** activate:

- initial commissioning mode and
- saturation method

2. Make presettings for automatic determination of motor-specific parameter values (P-0-0506, P-0-0507) of the test signal required for determining the commutation offset:

- enter value "0" in **P-0-0506, Amplitude for angle acquisition**

3. Switch drive to operating mode ("AB"); start saturation method by **P-0-0524, C1200 Commutation offset setting command**

4. After the current was supplied and the commutation offset value has been successfully determined this value is contained in **P-0-0521, Effective commutation offset**. The drive now is operational. In addition, the motor-specific values for P-0-0506 and P-0-0507 were stored.

Note: The motor-specific values for P-0-0506 and P-0-0507 should be checked for their safe function, independent of the position. To do this, set axis to several different positions within one pole pair or pole pair distance, execute command C1200 each time and write down value of P-0-0521. If P-0-0521 shows great deviations (> approx. +/-30) or error messages are generated, the values of P-0-0506 and P-0-0507 have to be automatically generated again (see above) or subsequently manually optimized.

− With error message "F8013" (current too low):
→ increase voltage (P-0-0506), reduce frequency (P-0-0507)

− With error message "F8014" (overcurrent):
→ reduce voltage (P-0-0506), increase frequency (P-0-0507)

If error message "F8013" occurs, but the deviation of P-0-0521 is within the allowed range of values (< approx. +/-30), further measures can be taken as described for F8013 in the Troubleshooting Guide!

Note: It is recommended to execute the command C1200 several times over a pole pair or a distance between pole centers, to generate and enter the average value of P-0-0521. Checking and optimizing P-0-0521 by force or torque measurement at the axis is recommended!

See also below "Manually Optimizing Commut. Offset Value"

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5. Now switch drive to parameter mode (P2). After switching back to operating mode, set "AF" and test function of drive. This automatically start the determination of the commutation offset with the stored parameters (P-0-0506, P-0-0507, P-0-0517). The motor is supplied with current and the commutation offset determined again.

Test commutation behavior of the drive at several different positions. If it is not satisfactory, repeat manual optimization of P-0-0506, P-0-0507, P-0-0517 as described below.

Note: If inadmissible values are generated for **P-0-0521, Effective commutation offset** and therefore the message **F8078 Speed loop error** appears although there wasn't any error signaled during commutation determination, the value of parameter **P-0-0517, Commutation: required harmonics component** has to be increased!

---

6. 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 home point and stored in **P-0-0508, Commutation offset** and **P-0-3008, Commutation offset, encoder memory** (if available).

7. In **P-0-0522, Commutation setting control word** deactivate the initial commissioning mode via the respective bit! The value in P-0-0508 resp. P-0-3008 is now write-protected.

Recommissioning of Synchronous Motors with Incremental Measuring System

At the first drive enable after switching on or after the measuring system has been reinitialized, the drive automatically determines the commutation offset. The value is stored in P-0-0521 and refers to the current position of the axis.

If due to the incremental measuring system the drive-controlled homing procedure is now started, the value of P-0-0521 is converted to the position of the home point when the home point is passed. This converted value now is compared to the optimum commutation offset value stored in P-0-0508 at the initial commissioning.

If the comparison results in "plausibility", the value of P-0-0508 is accepted as effective commutation offset value in P-0-0521 ("fine adjustment" of the commutation offset). If there is no plausibility the value in P-0-0508 is probably incorrect (e.g. inverted value in the case of several axes etc.). The **F2032 Plausibility error during commutation fine adjust** error message is output, the drive switches off.

Note: If the fine adjustment of the commutation offset is not desired, it can be deactivated via P-0-0508 = 0 or P-0-3008 = 0 (can be written in communication phase "P2"). This causes the automatically determined value to remain effective!

Relevant Parameters

Parameters for input data:

- **P-0-0522, Control word for commutation setting**

Parameters for the saturation method:

- **P-0-0506, Voltage amplitude for angle acquisition**
- **P-0-0507, Test frequency for angle acquisition**
- **P-0-0517, Commutation: required harmonics component**

Command parameters:

- **P-0-0524, C1200 Commutation offset setting command**

Parameters for output data:

- **P-0-0508, Commutation offset**
- **P-0-0521, Effective commutation offset**
- **P-0-3008, Commutation offset, encoder memory**

Relevant Diagnostic Messages

Diagnostic messages for command errors:

- **C1216 Commutation determination not selected**
- **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**

Diagnostic messages for errors:

- **F8013 Automatic commutation: current too low**
- **F8014 Automatic commutation: overcurrent**
- **F8015 Automatic commutation: timeout**
- **F8016 Automatic commutation: iteration without result**
- **F2032 Plausibility error during commutation fine adjust**

Determining the Commutation Offset, Sine-Wave Method

Application-Related Aspect

The sine-wave method for determining the commutation offset can be used for all types of synchronous motors. 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!

Note: Observe the restrictions for the sine-wave method (see table above "Restrictions for sine-wave method")!

Method

By a sinusoidal 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 therefor necessary that the generated test current puts the motor into motion.

Note: The maximum motion range for the sine-wave method is +/- $45°_{(mech)}$/PPN 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 parameter P-0-0506 at the start of **P-0-0524, C1200 Commutation offset setting command**. The detected motor-specific values for P-0-0506 and P-0-0507 are stored and used for commutation setting for further operations.

Carrying Out the Sine-Wave Method (Commissioning)

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 optimized during the initial commissioning.

Sequence of the Sine-Wave Method for Synchronous Motors with Absolute Measuring System

1. In **P-0-0522, Commutation setting control word** activate:
   - initial commissioning mode and
   - sine-wave method
2. Make presettings for automatic determination of motor-specific parameter values (P-0-0506, P-0-0507) of the test signal required for determining the commutation offset:
   - enter value "0" in **P-0-0506, Amplitude for angle acquisition**
3. Switch drive to operating mode ("AB"); start sine-wave method 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, due to the initial commissioning mode, is simultaneously stored in the following parameters in the case of absolute measuring systems:
   - **P-0-0508, Commutation offset**
   - **P-0-0521, Effective commutation offset**,
   - **P-0-3008, Commutation offset, encoder memory** (if available)

The execution of the command is now completed, it can be reset. The drive now is operational.

Note: It is recommended to execute the command C1200 several times over a pole pair or a distance between pole centers, to generate and enter the average value of P-0-0521. Checking and optimizing P-0-0521 by force or torque measurement at the axis is recommended!

See also below "Manually Optimizing Commut. Offset Value"

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5. In **P-0-0522, Commutation setting control word** deactivate the initial commissioning mode by the 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 resp. P-0-3008 is accepted in P-0-0521 and becomes effective as the commutation offset value.

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!

Note: 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 reference to the home point becomes effective as commutation offset!

Initial Commissioning of a Synchronous Motor with Incremental Measuring System by Sine-Wave Method

1. In **P-0-0522, Control word for commutation setting** activate in communication phase "P2" (parameter mode):
   - initial commissioning mode and
   - sine-wave method

2. Make presettings for automatic determination of motor-specific parameter values (P-0-0506, P-0-0507) of the test signal required for determining the commutation offset:
   - enter value "0" in **P-0-0506, Amplitude for angle acquisition**

3. Switch drive to operating mode ("AB"); start sine-wave method 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:

- 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".

Note:	It is recommended to execute the command C1200 several times over a pole pair or a distance between pole centers, to generate and enter the average value of P-0-0521. Checking and optimizing P-0-0521 by force or torque measurement at the axis is recommended!
	See also below "Manually Optimizing the Commutation Offset Value"

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 first referring to an arbitrary position is converted to the position of the home point and stored in **P-0-0508, Commutation offset** and **P-0-3008, Commutation offset, encoder memory** (if available).

6. In **P-0-0522, Commutation setting control word** deactivate the initial commissioning mode via the respective bit! The value in P-0-0508 resp. P-0-3008 is now write-protected.

Relevant Parameters   Parameters for input data:

- **P-0-0522, Control word for commutation setting**

Parameters for the sine-wave method:

- **P-0-0506, Amplitude for angle acquisition**
- **P-0-0507, Test frequency for angle acquisition**

Command parameters:

- **P-0-0524, C1200 Commutation offset setting command**

Parameters for output data:

- **P-0-0508, Commutation offset**
- **P-0-0521, Effective commutation offset**
- **P-0-3008, Commutation offset, encoder memory**

Relevant Diagnostic Messages   Diagnostic messages for command errors:

- **C1211 Commutation offset could not be determined**
- **C1216 Commutation determination not selected**
- **C1222 Error when writing offset parameters**

Diagnostic messages for errors:

- **F8010 Autom. commutation: max. motion range when moving back**
- **F8011 Commutation offset could not be determined**
- **F8012 Autom. commutation: max. motion range**
- **F8015 Automatic commutation: timeout**
- **F2032 Plausibility error during commutation fine adjust**

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Recommissioning of Synchronous Motors with Incremental Measuring System

At the first drive enable after switching on or after the measuring system has been reinitialized, the drive automatically determines the commutation offset. The value is stored in P-0-0521 and refers to the current position of the axis.

If an incremental measuring system now requires the function "drive-controlled homing procedure" to be started, the value of P-0-0521 is converted to the position of the home point when the home point is passed. This converted value now is compared to the optimum commutation offset value stored in P-0-0508 at the initial commissioning.

If the comparison results in "plausibility", the value of P-0-0508 is accepted as effective commutation offset value in P-0-0521 ("fine adjustment" of the commutation offset). If there is no plausibility the value in P-0-0508 is probably incorrect (e.g. inverted value in the case of several axes etc.). The **F2032 Plausibility error during commutation fine adjust** error message is output, the drive switches off.

Note:	If the fine adjustment of the commutation offset is not desired, it can be deactivated via P-0-0508 = 0 or P-0-3008 = 0 (can be written in communication phase "P2"). This causes the automatically determined value to remain effective!

Manually Optimizing the Commutation 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. The optimization should be carried out using a force measurement device!

$$P\text{-}0\text{-}0521(\text{manually}) = P\text{-}0\text{-}0521(\text{automatically determined}) \pm 256$$

Fig. 6-22: Range of values for optimizing the commutation offset

⚠ **CAUTION**	**Property damage caused by errors when controlling motors and moving parts!**
	⇒ Before optimizing the commutation offset, move the axis to a noncritical position!

6.3 Axis Control (Open-Loop Operation)

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.

Note:	The method of open-loop/closed-loop motor control can be selected via bit 14 of parameter **P-0-0045, Control word of current controller**.

See also section "Motor Control" in the same chapter
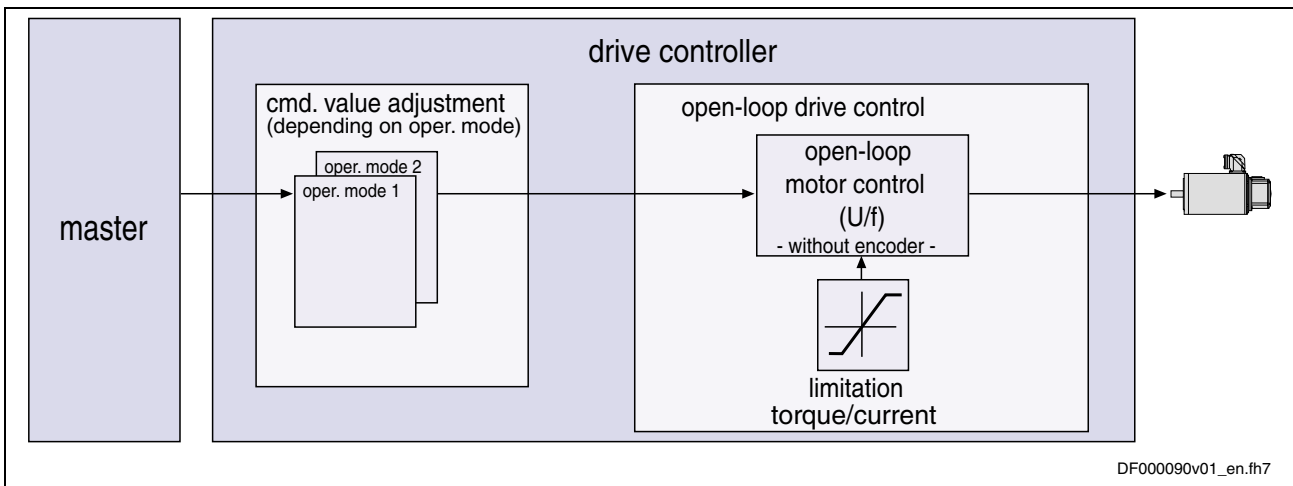
Fig. 6-23:   Principle of drive control in open-loop operation

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 (can be switched off via P-0-0556, bit 1)
- filtering of actual velocity value to be parameterized
- additive velocity command value (S-0-0037)
- display of resulting command value (in P-0-0048)
- monitoring and **limitation** of the maximum stator frequency change 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 a **U/f characteristic** based on motor model data
- subsequent trimming of magnetization via premagnetization factor (linear or square characteristic to be selected)
- **IxR boost** (adjustable load-dependent feedforward of the output voltage due to the voltage drop on the motor winding resistance)
- **oscillation damping** (adjustable load-dependent feedforward to prevent velocity oscillations in the partial load and idling ranges)
- **current limitation loop** to protect the output stage
- **velocity search mode** of a coasting machine after switching drive enable on (can be set for one or both rotational directions)

Pertinent Parameters

- **S-0-0037, Additive velocity command value**
- **S-0-0040, Velocity feedback value**
- **S-0-0091, Bipolar velocity limit value**
- **P-0-0048, Effective velocity command value**
- **P-0-0049, Effective torque/force command value**
- **P-0-0555, Status word of axis controller**
- **P-0-0556, Control word of axis controller**

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Pertinent Diagnostic Messages

- **F8079 Velocity limit S-0-0091 exceeded**

Functional Description

Fine Interpolator When the drive is running in open-loop operation (open-loop U/f control), the preset velocity command value can be smoothed by a fine interpolator via 2 steps.
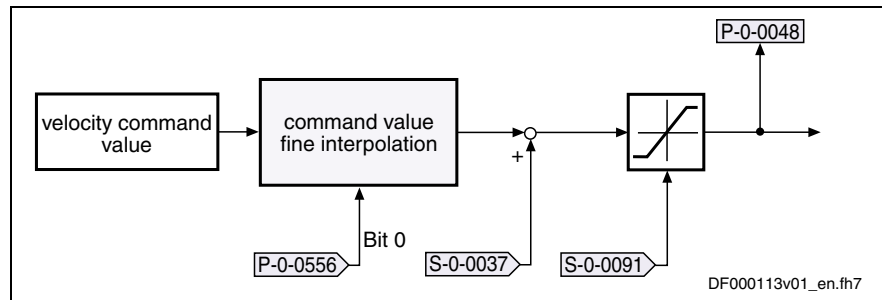
S-0-0037:   additive velocity command value
P-0-0048:   effective velocity command value
P-0-0556:   control word of axis controller

Fig. 6-24:   Fine interpolation of the velocity command value

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Note: The fine interpolator can be activated via bit 0 in parameter **P-0-0556, Control word of axis controller**.

Units of the Processed Data   The physical data for velocity control have the following units:

- velocity data: rpm or mm/min
- acceleration data: (rpm)/controller clock or (mm/min)/contr. clock
- torque data: Nm or N

Note: The fine interpolator can be activated via bit 0 in parameter **P-0-0556, Control word of axis controller**.

Open-Loop U/f Control   The output variable of the fine interpolator (P-0-0048) is used as the input variable for the subsequent open-loop U/f control which is described in the section "Motor Control: Voltage-Controlled Operation".

Diagnostic and Status Messages

Monitoring the Velocity Limit Value   The actual velocity value generated internally via the stall protection loop is monitored with regard to the limit value of 1.125 * S-0-0091 (bipolar velocity limit value). When the limit value is exceeded, the following error message is generated:

- **F8079 Velocity limit S-0-0091 exceeded**

6.4   Axis Control (Closed-Loop Operation)

Overview

Control Loop Structure

The drive controller has a cascade structure, i.e. the individual loops (position, velocity and current) are connected into one another. 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 operating mode it is only possible to close the torque control loop, the torque and velocity control loop or additionally the position control loop in the drive. The overall structure of the control loops is illustrated below.

current control loop

current controller

S-0-0106 S-0-0107   PWM   P-0-0001 S-0-0380

act. current   P-0-0043

velocity control loop

1/P-0-0051   ↓9,t   P-0-0001 P-0-0640 S-0-0111   S-0-0109 S-0-0110

P-0-0180   P-0-0109 S-0-0092

S-0-0082 S-0-0083

S-0-0124 S-0-0155   velocity controller   S-0-0100 S-0-0101

filter cascade (N = 8)   P-0-1120 P-0-1121 P-0-1122 P-0-1123

P-0-1126

P-0-1125 P-0-0004

V_{act_motor} $V_{act\_ext.encoder}$ P-0-1119

actual velocity

position control loop

S-0-0348

P-0-0040

S-0-0032, bit 3   posit. controller   S-0-0104

F8079   S-0-0091

IPO

actual position   S-0-0051   S-0-0053

S-0-0037   S-0-0081

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-0-0109, Torque/force peak limit
P-0-0180, Acceleration feedforward smoothing time constant
P-0-0640, Cooling type
P-0-1119, Velocity mix factor feedback 1 & 2
P-0-1120, Velocity control loop filter: filter type
P-0-1121, Velocity control loop filter: limit frequency low pass
P-0-1122, Velocity control loop filter: band-stop filter of band width
P-0-1123, Vel. cont. loop filter: band-stop filter of center frequen
P-0-1125, Velocity control loop: average value filter clock
P-0-1126, Velocity control loop: acceleration feedforward

S-0-0032, Primary mode of operation
S-0-0037, Additive velocity command value
S-0-0051, Position feedback 1 value
S-0-0053, Position feedback 2 value
S-0-0081, Additive Torque/Force command
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-0-0124, Standstill window
S-0-0155, Friction compensation
S-0-0348, Acceleration feedforward gain
S-0-0380, Intermediate DC bus voltage

DF0001v2.fh7

sampling times (TA) see Fig. 6-26
Fig. 6-25:   Overall structure of control loop

Features of the Control Loops

For simplifying parameterization of the control loops and increasing the capacity, some standardizations and structural modifications were made.

Performance (Controller Cycle Times)   The internal controller cycle times (current, velocity and position) depend on the contents of the following parameters:

- **P-0-0001, Switching frequency of the power output stage**
- **P-0-0556, Control word of axis controller**

The following cycle times and PWM frequencies can be set:

P-0-0556 (bit 2)	P-0-0001	TA_position loop	TA_velocity loop	TA_current loop
0 (Basic)	16 kHz	500 µs	250 µs	62.5 µs
0	12 kHz	500 µs	250 µs	83.3 µs
0	8 kHz	500 µs	250 µs	125.0 µs
0	4 kHz	500 µs	250 µs	125.0 µs
1 (Advanced)	**16 kHz**	**250 µs**	**125 µs**	**62.5 µs**
1	**8 kHz**	**250 µs**	**125 µs**	**62.5 µs**
1	4 kHz	250 µs	125 µs	125.0 µs

TA: sampling time

Fig. 6-26:   Possible control cycle times in accordance with controller performance and switching frequency that have been set

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Note: We distinguish between basic and advanced control. Advanced control could take place, for example, with 8 kHz/16 kHz switching frequency, 62.5 µs current loop clock, 125 µs velocity loop clock and 250 µs position loop clock.

Position Loop

- Jerk limitation in the "cyclic position control" mode by introducing the **S-0-0349, Jerk limit bipolar** parameter. The filter degree of the smoothing filter (moving average) can be set in parameter **P-0-0042, Current position command average value filter order**.

- velocity feedforward to be set, i.e. the feedforward degree can be set via parameter **P-0-0040, Velocity feedforward evaluation** (0 % … 100 %)

- input value for parameter **S-0-0348, Acceleration feedforward gain** can directly be the respective inertia in kg*m^2 (for rotary motor) or the mass in kg (for linear motor)

Velocity Loop

- Standardization of the output value at the velocity loop to Newton (N) or Newton meter (Nm). According to the motor type, there are the following units for parameter S-0-0100 for IndraDrive:
  - rotary motor $\rightarrow$ Nm * s / rad
  - linear motor $\rightarrow$ N * min / mm

- Extending the possibilities for filtering resonance frequencies. There are 4 filters of 2nd degree available that can be set via the parameters P-0-1120, P-0-1121, P-0-1122 and P-0-1123.

- limiting the acceleration in velocity control by setting in parameter **S-0-0138, Bipolar acceleration limit value**

Possibilities of Accessing Outer Control Loops

It is possible to access the outer control loops when operating in a higher-level mode. Depending on the basic operating mode, the following parameters are available to do this.

In position control:

- **S-0-0037, Additive velocity command value**

- **S-0-0048, Additive position command value**

- **S-0-0081, Additive torque/force command value**

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In velocity control:

- **S-0-0037, Additive velocity command value**
- **S-0-0081, Additive torque/force command value**

In current control:

- **S-0-0081, Additive torque/force command value**
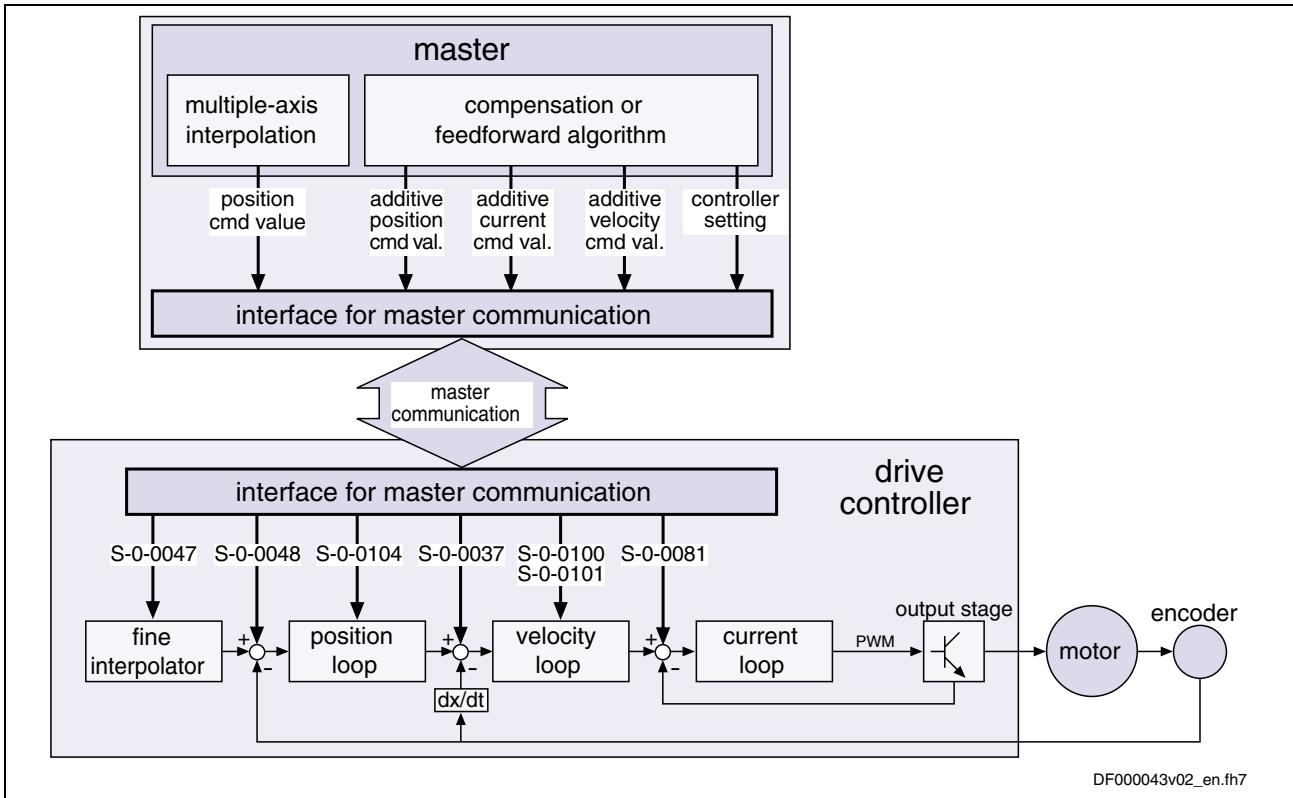
S-0-0037:	additive velocity command value
S-0-0047:	position command value
S-0-0048:	position command value additional
S-0-0081:	additive torque/force command value
S-0-0100:	velocity loop proportional gain
S-0-0101:	velocity loop integral action time
S-0-0104:	position loop Kv-factor

Fig. 6-27: Structural overview (incl. possibilities of access)

Command Value Processing Depending on Operating Mode

Position Control

In the case of the following operating modes, the position control loop, apart from the velocity and current control loop, is closed internally (in the drive), too:

- position control with cyclic command value input
- drive-internal interpolation
- drive-controlled positioning

See also description of the respective operating mode in chapter "Operating Modes"

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" in chapter "Operating Modes"

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" in chapter "Operating Modes"

Notes on Commissioning for Control Loop Setting

The control loop settings in a digital drive controller are very important for the features of the servo axis.

To optimize the control loop setting, application-specific controller parameters are available for all digital Rexroth drives.

Order of Manual Control Loop Setting   Due to the cascade structure of the control loops it is necessary to parameterize them "from the inside to the outside". The resulting order for setting the control loops is as follows:

1. **Current control loop**
    For **Rexroth motors with motor encoder data memory** (MHD, MKD and MKE series), optimizing the current loop is not required because the corresponding parameter values (S-0-0106 and S-0-0107) are read from the motor encoder data memory.

    For all **Rexroth motors without motor encoder data memory** (e.g. linear motors), the parameter settings can be taken from a central motor data base via the "DriveTop" commissioning tool.

    The commissioning of **third-party motors** (incl. control loop setting) is described in the respective sections on third-party motors in this documentation (see "Third-Party Motors at IndraDrive Controllers" in chapter "Motor, Mechanical Axis System, Measuring Systems").

2. **Velocity control loop**
    The settings of the velocity loop (S-0-0100 and S-0-0101) with the respective filters (P-0-0004 and P-0-1120, P-0-1121, P-0-1122, P-0-1123) on the one hand depend on the motor parameters (inertia and torque/force constant), on the other hand they strongly depend on the mechanical properties (load inertia/mass, friction, stiffness of the connection, ...). Therefore, manual or automatic optimization is often required (see section "Control Loop Setting").

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

S-0-0262, C07_x Load defaults procedure command   For all Rexroth motors of the series 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** parameter:

*   Automatically when running up the drive by recognizing that the motor type (cf. parameter S-0-0141) has changed. The display then reads "RL" and the "load defaults procedure" command is internally started by pressing the "Esc" button on the control panel, unless this was deactivated in **P-0-0556, Control word of axis controller**.

*   Starting the command by writing "11b" to parameter S-0-0262.

See also "Loading, Storing and Saving Parameters" in chapter "Handling, Diagnostic and Service Functions"

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Note:	In order to start the "load defaults procedure" command the value "0" (default setting) must have been set in parameter **P-0-4090, Index for C07 Load defaults procedure**.

During the load defaults procedure, the following control loop parameters are set to their default values optimized for the respective motor:

- **S-0-0100, Velocity loop proportional gain**
- **S-0-0101, Velocity loop integral action time**
- **S-0-0104, Position loop Kv-factor**
- **S-0-0106, Current loop proportional gain 1**
- **S-0-0107, Current loop integral action time 1**
- **P-0-0004, Velocity loop smoothing time constant**

Note:	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 parameters are set to their firmware-side default values although there haven't been any default values stored for them in the motor data memory:

- **S-0-0348, Acceleration feedforward gain**
- **P-0-1125, Velocity control loop: average value filter clock**

Note:	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.

Automatic Setting of Axis Control

Brief Description

To facilitate drive parameterization, the IndraDrive firmware provides automatic control loop setting in closed-loop operation. Parameters **P-0-0163, Damping factor for autom. controller adjust** and **P-0-0164, Application for autom. controller adjust** can be used to influence the result of the control loop setting (obtained control loop dynamics).

Note:	To carry out the automatic control loop setting it is necessary to move the drive. The velocity and position control loops are optimized.

Features

- definition of a travel range for movement control for the automatic control loop setting by
    - absolute travel limits
    - or -
    - entering a travel distance based on the current actual position
- use of drive-internal interpolation and its parameters

- possible settings in **P-0-0165, Selection for autom. controller adjust** for:

  - velocity loop

  - position loop

  - acceleration feedforward

  - determination of load inertia

  - determination of maximum acceleration

  - oscillation movement/unipolar movement

  - absolute travel limits/relative movement around the starting position

Pertinent Parameters
- **P-0-0162, C1800 Command Automatic control loop adjust**
- **P-0-0163, Damping factor for autom. controller adjust**
- **P-0-0164, Application for autom. controller adjust**
- **P-0-0165, Selection for autom. controller adjust**
- **P-0-0166, Lower limit for autom. control loop adjust**
- **P-0-0167, Upper limit for autom. control loop adjust**
- **P-0-0168, Maximum acceleration to be parameterized**
- **P-0-0169, Travel distance for autom. controller adjust**

Pertinent Diagnostic Messages
- **C1800 Command automatic control loop setting**
- **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**
- **E2047 Interpolation velocity = 0**
- **E2048 Interpolation acceleration = 0**
- **E2049 Positioning velocity >= S-0-0091**
- **E2055 Feedrate override S-0-0108 = 0**
- **F2039 Maximum acceleration exceeded**

Prerequisites for Starting the Automatic Control Loop Setting

⚠ CAUTION

Property damage and/or personal injury caused by drive motion!

During the execution of command **C1800 Command automatic control loop setting**, the drive moves automatically, i. e. without external command values.

⇒ Check and make sure that the E-Stop circuit and the travel range limit switches are working.

See also chapter: "Safety Instructions for Electric Drives and Controls"

Defining the Travel Range

Since the axis must be moved in order to identify and set the control loop, it is necessary to define an allowed travel range. There are basically two possibilities for defining the range within which the axis may move during the automatic control loop setting:

- definition of a travel range by entering limit values in the parameters P-0-0166 and P-0-0167

- or -

- definition of a travel range by parameterizing **P-0-0169, Travel distance for autom. control loop adjust** (required for modulo axes)

Note:	The mode for travel range definition is selected in parameter **P-0-0165, Selection for autom. control loop adjust** (bit 15).

Determining Travel Range Limits

If bit 15 of P-0-0165 has not been set (value "0"), the allowed travel range is defined by means of

- the lower limit position (P-0-0166) and

- the upper limit position (P-0-0167).

The value of **P-0-0169, Travel distance for autom. control loop adjust** results from these two limit values.

Entering a Travel Range

If bit 15 of P-0-0165 has set (value "1"), the allowed travel range is defined by means of

- **P-0-0169, Travel distance for autom. controller adjust** and

- **start position** (actual position) at the start of the command.

The resulting limit values for the travel distance are:

- lower limit: P-0-0166 = start position – 0.5*travel distance (P-0-0169)

- upper limit: P-0-0167 = start position +0.5*travel distance (P-0-0169)
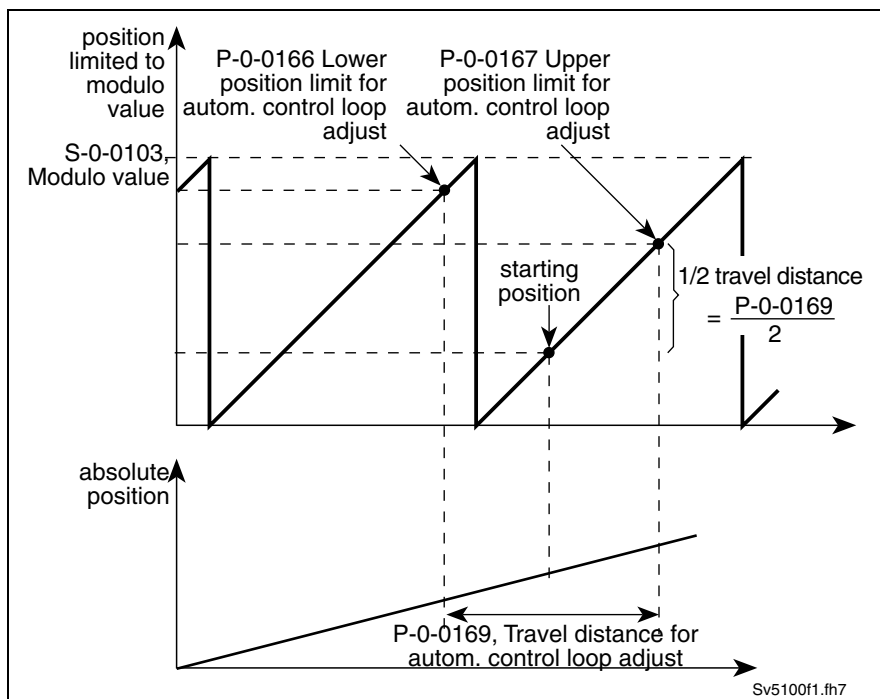
Fig. 6-28:   Travel range for automatic control loop setting with modulo scaling

Note:	The travel range defined is only monitored during the execution of the command "automatic control loop setting".

Loading the Default Controller Parameters

Before starting the command "automatic control loop setting", the default controller parameters stored in the motor encoder data memory should be loaded or the data of the motor data sheet should be entered in the respective parameters.

Drive Enable and Drive Start

An oscillation for automatic control loop setting is only carried out when the following requirements have been fulfilled:

- **drive enable** is present
- **drive start** has been set

Parameter Settings

All parameters used for the command "automatic control loop setting" must be determined before command start so that they take effect for the automatic control loop setting.

- **P-0-0163, Damping factor for autom. controller adjust**
  $\rightarrow$ to select the desired control loop dynamics
- **P-0-0164, Application for autom. controller adjust**
  $\rightarrow$ to take the mechanical properties into account for controller optimization
- **P-0-0165, Selection for autom. controller adjust**
  $\rightarrow$ to select the functionality (modes) of the automatic control loop setting

Chronological Sequence of Automatic Control Loop Setting

Steps of Automatic Control Loop Setting

The automatic control loop setting is carried out in the following steps:

8. start command and make check for possible command errors

9. determine total and extrinsic inertia by evaluating acceleration and deceleration processes

10. calculate and activate controller parameters in drive taking **P-0-0163, Damping factor for autom. controller adjust** and **P-0-0164, Application for autom. controller adjust** into account

11. check velocity control loop and correct controller parameters, if need be, until desired behavior occurs (depends on dynamics programmed)

12. check position control loop and correct controller parameters, if need be, until aperiodic behavior in position control loop occurs

13. wait for possible restart or end of command

    During this step the drive is idle (velocity = 0) and the display reads "C1800".

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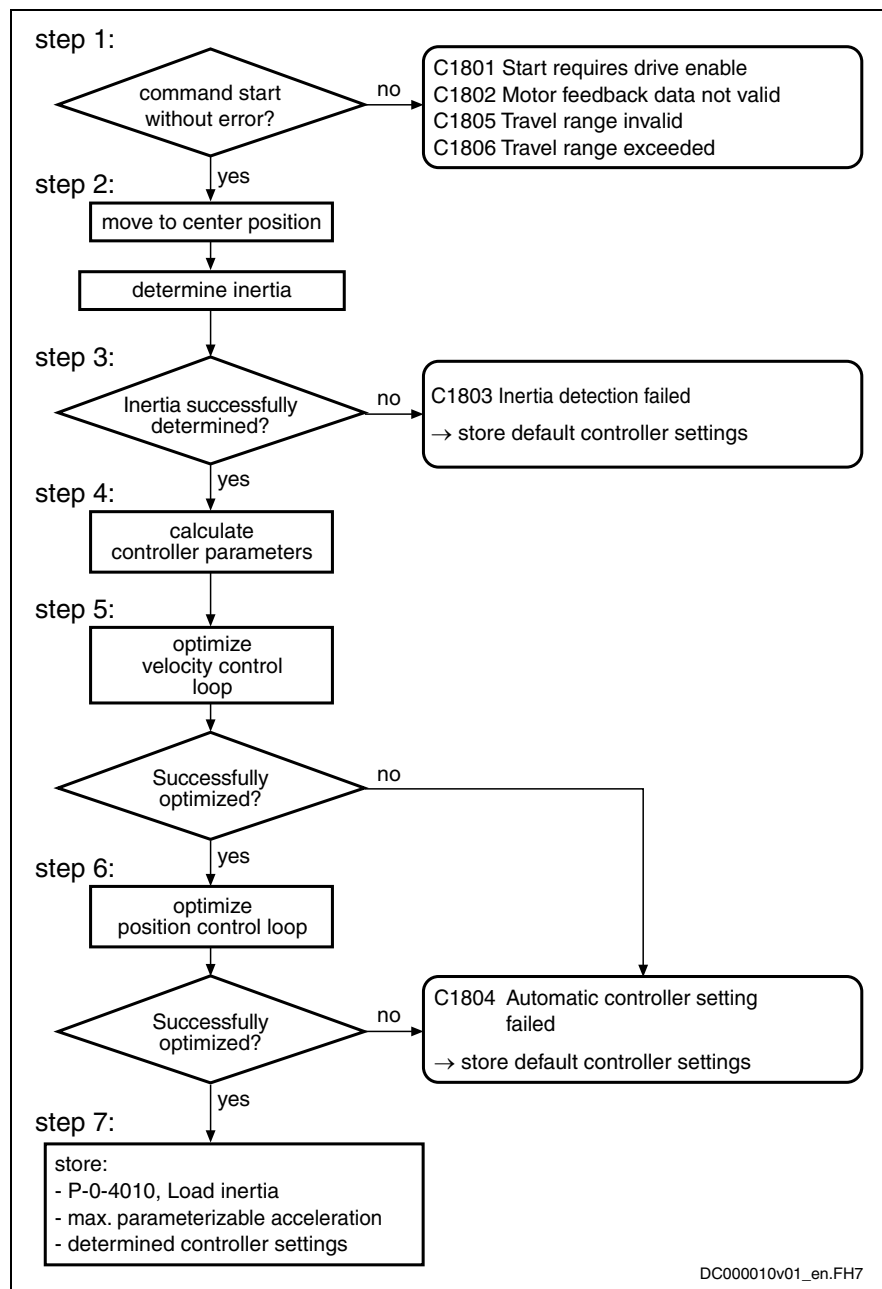
Fig. 6-29:   Steps of automatic control loop setting

Result of Automatic Control Loop Setting

Note: 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 "Notes on Commissioning for Control Loop Setting (Load Defaults Procedure)" in chapter "Drive Control"

Selection Parameter for Automatic Control Loop Setting   Via **P-0-0165, Selection for autom. controller adjust** it is possible, by selecting the corresponding bit, to activate (bit = 1) or deactivate (bit = 0) the respective function of the automatic control loop setting. The result of automatic control loop setting depends on the selection made in P-0-0165.

See Parameter Description "P-0-0165, Selection for autom. controller adjust"

Possible results of automatic control loop setting (with respective bit set in P-0-0165):

- **bit 1** → setting of velocity control loop
  (cf. S-0-0100, S-0-0101, P-0-0004, P-0-1120 ...)

- **bit 2** → setting of position control loop (cf. S-0-0104)

- **bit 4** → determination of load inertia (reduced to motor shaft) and input in parameter P-0-4010

- **bit 6** → determination of maximum drive acceleration and input in parameter P-0-0168

- **bit 3** → determination of acceleration feedforward

  As the result of the automatic control loop setting, the value for acceleration feedforward is calculated according to the formula below and entered in parameter P-0-0348.

$$S-0-0348 = \frac{(P-0-4010) + (P-0-0051)}{S-0-0051}$$

Fig. 6-30:   Calculating the acceleration feedforward

Notes on Commissioning

⚠️ **CAUTION**

Carrying out the automatic control loop setting is connected with a drive motion!

⇒ Select the travel range defined with the parameters P-0-0166 and P-0-0167 or P-0-0169 such that danger to man and machine resulting from drive motion is excluded.

Note: The parameter settings required to execute the command "automatic control loop setting" must be made prior to command start.

Starting the Automatic Control Loop Setting

The automatic control loop setting is started by writing the binary numeric value "3" (11b) to parameter **P-0-0162, C1800 Command Automatic control loop adjust** (command start).

Triggering a Motion

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 the **C1800 Command Automatic control loop adjust**, but the axis won't move.

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Triggering the Motion by Starting Command C1800
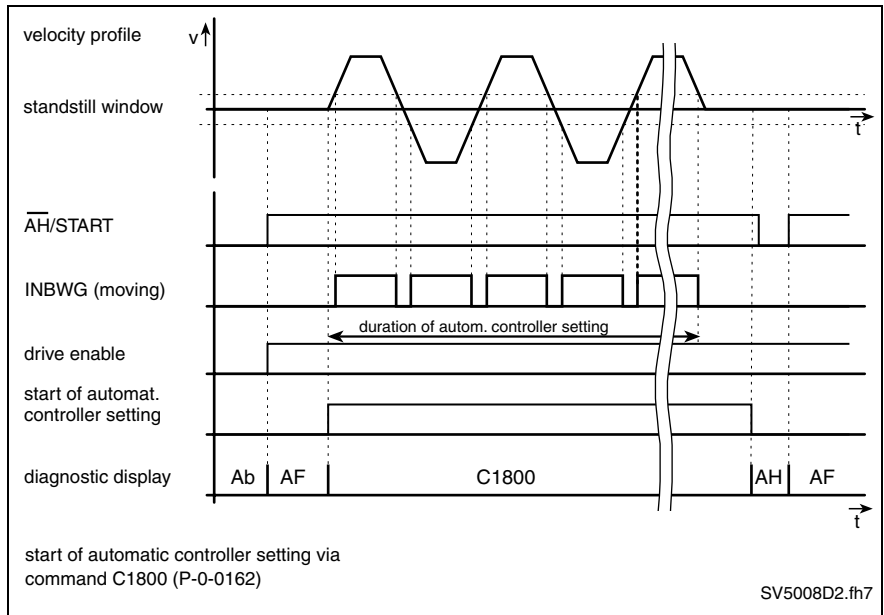
Fig. 6-31:   Signal flow chart for motion by command start

Triggering the Motion by "Drive Start"
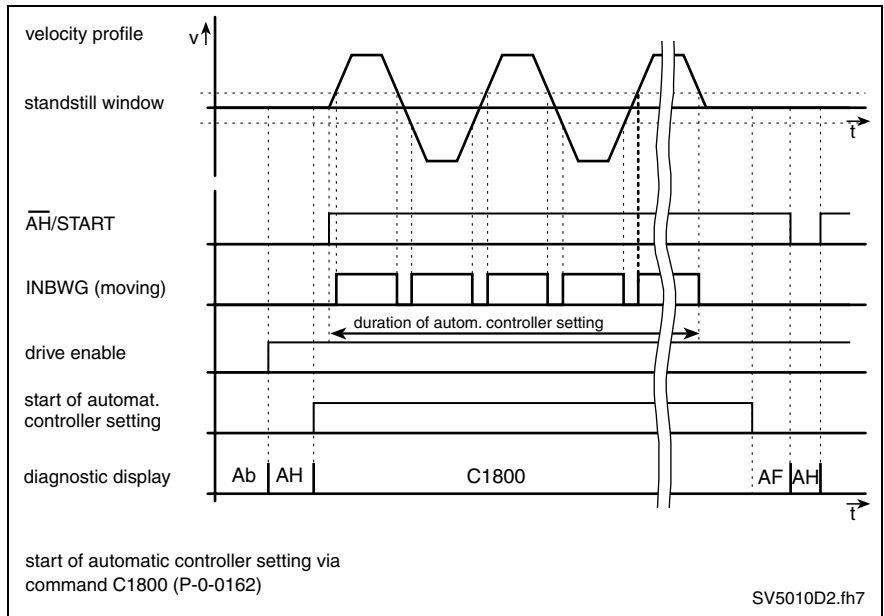
Fig. 6-32:   Signal flow chart for motion by "drive start"

Interrupting the Command with "Drive Halt"
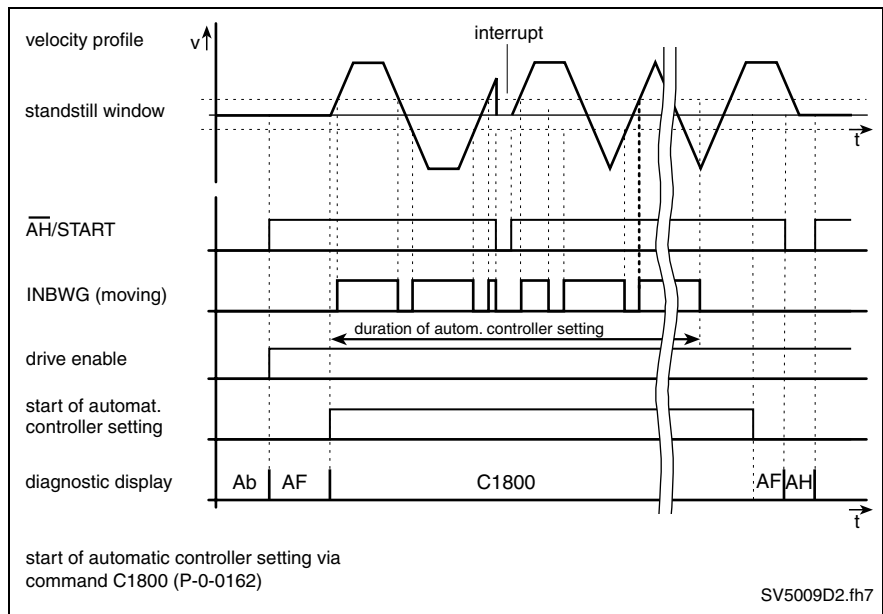
Fig. 6-33:   Signal flow chart for interruption by "Drive Halt"

Note: A repeated run with possibly changed settings can be carried out in two ways:

- by removing and then applying drive enable or start signal ("drive start")

- by completing and then restarting command C1800

Diagnostic Messages and Monitoring Functions

Checking the Defined Travel Range

When the travel range is defined, it is checked with regard to useful values. In the case of error the following command error messages can be generated:

- If the defined travel range is less than 2 motor revolutions, the command error **C1805 Travel range invalid** is displayed because the correct execution of the command requires a minimum travel range.

- If the axis is not within the defined travel range at command start, the command error **C1805 Travel range invalid** is displayed.

Drive Enable Missing

If drive enable is missing at command start, the command error **C1801 Start requires drive enable** is generated.

Monitoring of Inertia Detection

In order to ensure correct setting of the controller parameters the inertia detection required to do this is monitored. Incorrect detection of the inertia would cause incorrect controller settings and therefore is signaled by the error message **C1803 Inertia detection failed**. This error message is generated when the values set in the following parameters are too low:

- **S-0-0092, Bipolar torque/force limit value**
  The maximum motor torque effective during the automatic control loop setting can be influenced via parameter S-0-0092. It is thereby possible to limit the torque to prevent wear of the mechanical system.

- **S-0-0108, Feedrate override**
  By means of the feedrate override the velocity can be influenced via the analog channel (potentiometer) during the automatic control loop setting.

- **S-0-0259, Positioning Velocity**
  This parameter defines the velocity effective during the automatic control loop setting.

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- **S-0-0260, Positioning Acceleration**
  In this parameter you have to set the acceleration effective during the automatic control loop setting.

Note: The command error C1803 can occur due to the above-mentioned points but also due to a too high degree of inertia. In this case the entire drive dimensioning has to be checked, if necessary.

Velocity Loop (with Respective Filters)

Brief Description

In operation with encoder (closed-loop) the drive firmware, apart from the field-oriented current loop, also closes the velocity control loop in the drive (PI cascade structure).

Note: The kind of motor control can be selected via **P-0-0045, Control word of current controller** (bit 14).

The use of this function requires the firmware package for closed-loop operation (see "Functional Packages" in chapter "System Overview").
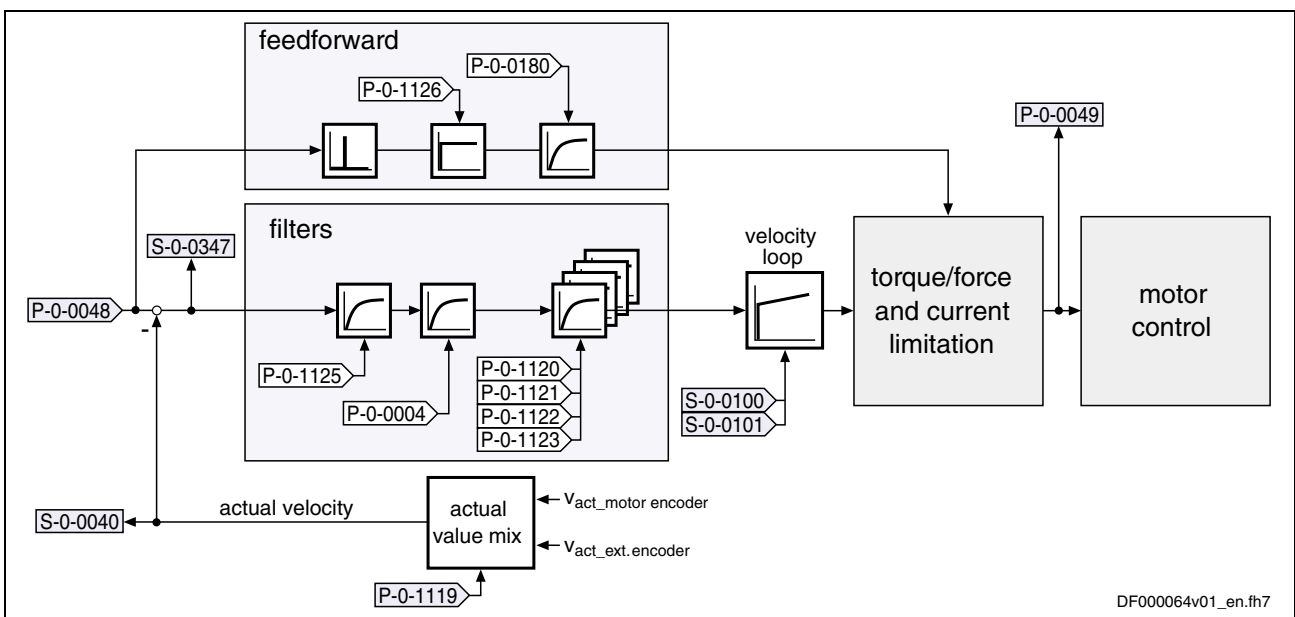
Fig. 6-34: Overview of velocity loop

Note: The following description only refers to the velocity loop with the respective possibilities of filtering and feedforward.

For the description of velocity command value processing see section "Velocity Control" in chapter "Operating Modes".

Features   The velocity loop is a PI loop that can be parameterized via **S-0-0100, Velocity loop proportional gain** and **S-0-0101, Velocity loop integral action time**.

- The setting can be made by
  - executing the "Load defaults procedure" function once or
  - manual optimization (see description below).
- Depending on the control performance that was set, a cycle time of 125 µs (advanced) or 250 µs (basic) is used for the velocity loop (cf. P-0-0556, bit 2).
- velocity mix of motor encoder velocity
- 4 freely configurable 2nd order filters (e.g. band-stop filters) for filtering resonance frequencies
- moving average filter of the control loop deviation for a maximum of 16 controller clocks (as a feedback filter, in the case of low-resolution motor measuring systems)
- low-pass filter via P-0-0004 (VZ1)
- fine interpolation of the command values of the position controller (can be switched off)
- velocity control loop monitor (can be switched off via P-0-0556, bit 1)
- optional acceleration feedforward from the speed command value (with filter possibility)

Pertinent Parameters
- **S-0-0037, Additive velocity command value**
- **S-0-0040, Velocity feedback value**
- **S-0-0081, Additive torque/force command value**
- **S-0-0091, Bipolar velocity limit value**
- **S-0-0100, Velocity loop proportional gain**
- **S-0-0101, Velocity loop integral action time**
- **S-0-0149, C1300 Positive stop drive procedure command**
- **S-0-0155, Friction compensation**
- **S-0-0347, Velocity error**
- **P-0-0451, Actual acceleration torque/force value**
- **P-0-0452, Actual process torque/force value**
- **P-0-0004, Velocity loop smoothing time constant**
- **P-0-0048, Effective velocity command value**
- **P-0-0049, Effective torque/force command value**
- **P-0-0180, Acceleration feedforward smoothing time constant**
- **P-0-0555, Controller status word**
- **P-0-0556, Control 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-0-1125, Velocity control loop: average value filter clock**
- **P-0-1126, Velocity control loop: acceleration feed forward**

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- **P-0-2100, Velocity controller proportional gain, encoder memory**
- **P-0-2101, Velocity controller integral-action time, encoder memory**
- **P-0-3004, Speed controller smoothing time constant, encoder memory**

Pertinent Diagnostic Messages
- **E2059 Velocity command value limit active**
- **F8078 Speed loop error**
- **E8260 Torque/force command value limit active**

Functional Description

Fine Interpolator
The velocity command value can be smoothed by means of a fine interpolator via 2 steps. This is useful, for example, for cyclic position control with particularly great position command value jumps (long cycle times, cf. S-0-0001 and S-0-0002).
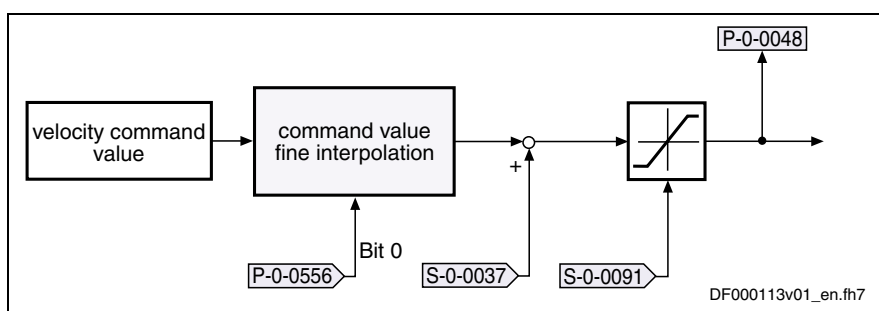
S-0-0037:	additive velocity command value
S-0-0091:	bipolar velocity limit value
P-0-0048:	effective velocity command value
P-0-0556:	control word of axis controller

Fig. 6-35: Fine interpolation of the velocity command value

Note: The fine interpolator can be activated via bit 0 in parameter **P-0-0556, Control word of axis controller**.

Units of the Processed Data
The physical data in the velocity control loop have the following units:

- velocity data: rpm or mm/min
- acceleration data: (rpm)/controller clock or (mm/min)/controller clock
- torque data: Nm or N

Velocity Loop
The velocity loop designed as a PI loop can be set via the following parameters:

- **S-0-0100, Velocity loop proportional gain**
- **S-0-0101, Velocity loop integral action time**

The respective parameter settings depend on the mechanical properties (mass inertia, stiffness, ...) of the motors and the connected mechanical system.

- In the case of Rexroth motors with motor data memory, a default controller setting that is appropriate for most of the standard applications is stored in this memory.
- For Rexroth motors without motor data memory and third-party motors the controller settings have to be determined during commissioning.

See also section "Notes on Commissioning" for velocity loop

Velocity Mix Factor   When using a load-side encoder the velocity control loop includes the possibility to generate the actual velocity value used for control via a "mix factor" (see Parameter Description of P-0-1119) from the actual velocity values of the motor encoder and the load-side encoder (see also figure "Velocity loop").

Note: Combining the actual values of motor encoder and load-side encoder via a mix factor can be very advantageous for controlling systems with a low degree of stiffness in the case of connected load.

Acceleration Feedforward   In the velocity control loop there is the additional possibility of making the control performance of the velocity loop more dynamic by using the so-called acceleration feedforward. The command value for the current controller then, to the greatest possible extent, is directly derived from the velocity command value. The velocity loop will then only be required for correcting disturbances. The figure below illustrates controller feedforward:
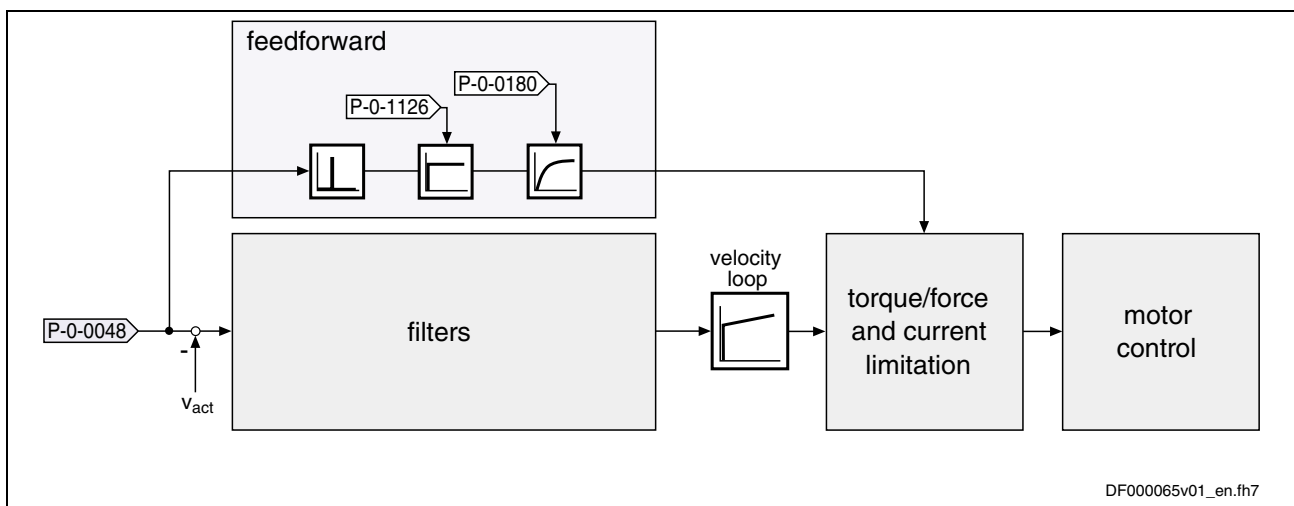
P-0-0048:   effective velocity command value
P-0-0180:   acceleration feedforward smoothing time constant
P-0-1126:   velocity control loop: acceleration feedforward

Fig. 6-36:   Acceleration feedforward in velocity control loop

Note: This kind of feedforward can be advantageously used for a very high degree of inertia and/or low encoder resolution.

Possibilities of Filtering   The following filters are available in the velocity control loop:

- four freely configurable 2nd order filters (low pass, band-stop, ...)
- one 1st order low pass (PT1 element)
- one moving average filter

The illustration below shows the position of the filters in the overall control loop:
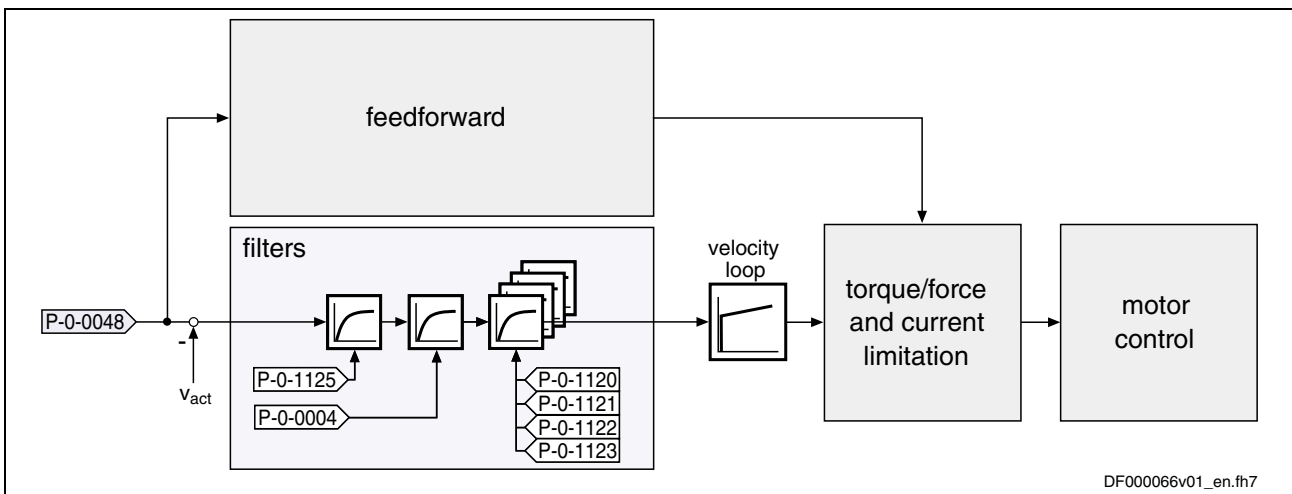
P-0-0004:   velocity loop smoothing time constant
P-0-0048:   effective velocity command value
P-0-1120:   velocity control loop filter: filter type
P-0-1121:   velocity control loop filter: limit frequency of low pass
P-0-1122:   velocity control loop filter: bandwidth of band-stop filter
P-0-1123:   vel. cont. loop filter: center frequency of band-stop filter
P-0-1125:   velocity control loop: average value filter clock

Fig. 6-37:   Possibilities of filtering in the velocity control loop

In practical application there often occur resonant oscillations that mostly result from deficiencies or restrictions of the mechanical system:

- limited stiffness of connection between mechanical system and motor shaft
  $\rightarrow$ possible resonances within the range of 20 Hz … 1000 Hz (according to stiffness of connection and mass relations)

- gear play

- bad arrangement of the load-side encoder
  $\rightarrow$ possible resonances within the range of 1 kHz … 2 kHz (according to arrangement of encoder)

This "two-mass oscillation" (or multiple-mass oscillation) mostly has one (or several) distinctive resonance frequency/frequencies that can be selectively suppressed by the rejection filters integrated in the drive. With the implemented filter cascade ($N = 8$) it is possible to selectively suppress up to 4 different resonance frequencies.

Note:	The implemented band-stop filters allow suppressing resonance frequencies within the **frequency range of 100 Hz to a max. of 4000 Hz**.
	The upper limit depends on the velocity loop cycle time TA_n (sampling theorem).

When suppressing the mechanical resonance frequencies it is possible to considerably increase the dynamic response of the speed control loop and of the position control loop, compared to closed-loop control without using rejection filters. This results in a higher degree of contour precision and shorter cycle times for positioning processes with sufficient distance to the stability limit.

Description of Filter Function   For each filter it is possible to set center frequency and bandwidth. The attenuation of the rejection frequency is the strongest; the bandwidth determines the frequency range in which the attenuation is smaller than –3 dB.

Note: Due to the filter structure, greater bandwidth results in lower attenuation of the rejection frequency!
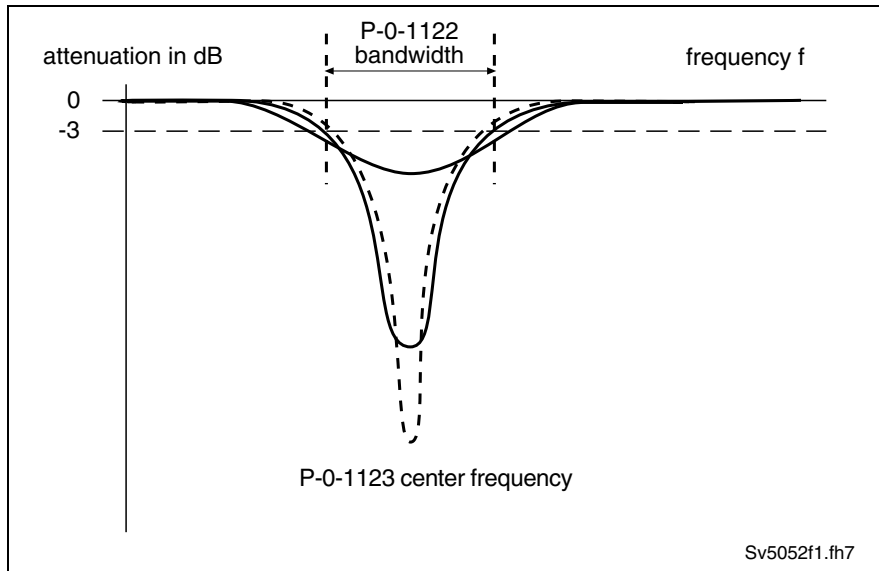
Fig. 6-38:   Amplitude characteristic of a band-stop filter depending on the bandwidth (qualitative)

Filtering by Means of Multiple Smoothing Filter   Optimizing the control loop by means of a rejection 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).

To do this, each of the 4 elements in parameter **P-0-1120, Velocity control loop filter: filter type** is set to the value "1" or "0" (see Parameter Description of P-0-1120).

Instead of the rejection filter there are smoothing filters activated in the control loop the smoothing time constants (T_{gl}) of which are contained in parameter **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 a filter characteristics with PT_N-behavior. Frequencies higher than the limit frequency ($f_g = 1/2\pi T_{gl}$) 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**
  $\rightarrow$ attenuation of 20 dB/decade

- **P-0-1121, Velocity control loop filter: limit frequency of low pass**
  $\rightarrow$ attenuation of 40 dB/decade

When activating all low-pass filters the maximum attenuation is 180 dB/decade. This is a very high filter degree.

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Note:	When using the smoothing filters, take into account that each filter causes phase displacement in the control loop and therefore has a negative effect on the phase margin in the control loop ($\rightarrow$ control loop stability).
	Therefore, the following applies:
	"As little filtering as possible, but as much filtering as necessary!"
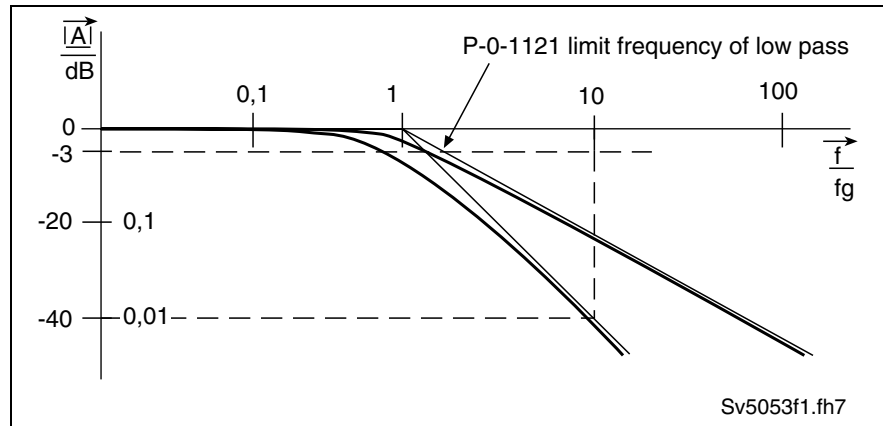
Fig. 6-39: Frequency response of a PT1- and PT2-filter

Notes on Commissioning

Preparing the Setting of the Velocity Loop

In order to be able to carry out the setting of the velocity loop it is necessary to make some preparations:

- The mechanical system of the machine must have been set up in its definite assembly in order to have original conditions for parameter setting.

- The drive controller must have been correctly connected.

- The operatability of the safety limit switches (if available) must have been checked.

- The "velocity control" mode must have been selected in the drive.

Start Settings

For parameterizing the controller make the start setting as follows:

- **S-0-0100, Velocity loop proportional gain**
  = standard value of the connected motor

- **S-0-0101, Velocity loop integral action time** = 0 ms
  $\rightarrow$ no I-component

- **P-0-0004, Velocity loop smoothing time constant** = minimum value
  $\rightarrow$ filter is switched off

  - P-0-0004 = 125 □s (advanced: P-0-0556, bit 2 = 1)

  - P-0-0004 = 250 □s (basic: P-0-0556, bit 2 = 0)

- **P-0-1120, Velocity control loop filter: filter type** = [0 0 0 0]
  $\rightarrow$ deactivated

Note:	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.

Determining the Critical Proportional Gain

To determine the "critical proportional gain" proceed as follows:

1. Let the drive move with low velocity after switching drive enable on:

   - linear motor   →   1000 … 2000 mm/min
   - rotary motor   →   10 … 20 rpm

2. Increase value in parameter **S-0-0100, Velocity loop proportional gain** until instable behavior (continuous oscillation) occurs.

3. Determine frequency of oscillation by oscilloscoping the actual velocity (see also "Analog Outputs" or "Oscilloscope Feature"). When frequency of oscillation is considerably higher than 500 Hz, increase value in parameter **P-0-0004, Velocity loop smoothing time constant** until oscillation diminishes. Then continue increasing the value in parameter **S-0-0100, Velocity loop proportional gain** until oscillation (instability) occurs again.

4. Reduce parameter **S-0-0100, Velocity loop proportional gain** until permanent oscillation decreases automatically.
   The value thus determined is the so-called "critical velocity loop proportional gain".

Note: By using the filter cascade (P-0-1120, P-0-1121, P-0-1122, P-0-1123) it is possible to activate a PT4-filter.

Determining the Critical Integral Action Time

To determine the "critical integral action time" proceed as follows:

1. Set parameter **S-0-0100, Velocity loop proportional gain** = 0.5 * "critical proportional gain"

2. Reduce value in parameter **S-0-0101, Velocity loop integral action time**, beginning with maximum value, until instable behavior (continuous oscillation) occurs.

3. Increase value in parameter **S-0-0101, Velocity loop integral action time** until continuous oscillation decreases automatically.
   The value thus determined is the "critical integral action time". Usual values are within the range from 5 to 20 ms!

Characteristics of Controller Setting

From the determined critical values (see above) it is possible to derive a controller setting with the following characteristics:

- independent of changes at the axis because sufficient distance to stability limit
- properties can be reliably reproduced in series machines

The following table contains some of the most common types of application and the corresponding characteristics of the control loop setting.

Application type	Speed controller proportional gain	Speed controller integral action time	Notes
feed axis at standard machine tool	$K_p = 0.5 \times K_{pkrit}$	$T_n = 2 \times T_{nkrit}$	good load stiffness and good control performance
feed axis at perforating machine or nibbling machine	$K_p = 0.8 \times K_{pkrit}$	$T_n = 0$	high proportional gain; no I-component in order to obtain short response times
feed drive at following-on cutting devices	$K_p = 0.5 \times K_{pkrit}$	$T_n = 0$	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. 6-40: Characteristics of controller setting

Parameterizing the Band-Stop Filters
The band-stop filters are parameterized via the following parameters:

- **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**

Each of these parameters has 4 elements which results in the following assignment of the relevant filter settings:

- **band-stop filter1:** P-0-1120 [**0**], P-0-1122 [**0**], P-0-1123 [**0**]
- **band-stop filter2:** P-0-1120 [**1**], P-0-1122 [**1**], P-0-1123 [**1**]
- **band-stop filter3:** P-0-1120 [**2**], P-0-1122 [**2**], P-0-1123 [**2**]
- **band-stop filter4:** P-0-1120 [**3**], P-0-1122 [**3**], P-0-1123 [**3**]

Presetting
The following procedure is recommended for setting the band filter:

1. First deactivate rejection filters.

2. Enter the following values in parameter **P-0-1120, Velocity control loop filter: filter type**:
    - P-0-1120 [**0**] = 0 →filter 1 switched off
    - P-0-1120 [**1**] = 0 →filter 2 switched off
    - P-0-1120 [**2**] = 0 →filter 3 switched off
    - P-0-1120 [**3**] = 0 →filter 4 switched off

Determine Resonance Frequency
The following procedure is recommended for determining the resonance frequency:

1. Use the oscilloscope feature of the drive to display the actual velocity value. This value can be directly read by fast-Fourier transformation (FFT) of the frequency response. This requires the use of the "DriveTop" commissioning tool.

2. In reversing duty increase the value in parameter **S-0-0100, Velocity loop proportional gain** until distinctive oscillation is noticed (resonant oscillation).

3. Record the time behavior of the oscillation with the oscilloscope feature (alternatively with external oscilloscope) and analyze it with regard to clearly distinctive frequencies. When using the internal oscilloscope feature, the resonance frequency can be directly read via the "DriveTop" commissioning tool by means of the frequency display.

Determining Initial State of Control Behavior
4. Set drive enable and optimize the velocity control loop with inactive rejection filter (see section "Setting the Velocity Loop").

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 limit!

Activate Rejection Filter and Check Its Effect
6. Enter the most distinctive frequency in Hz in parameter **P-0-1123, Vel. cont. loop filter: center frequency of band-stop filter**. Enter a minimum bandwidth (e.g. 25 Hz) in parameter **P-0-1122, Velocity control loop filter: bandwidth of band-stop filter**.
    → Record previous step response again.

If the step response shows <u>less overshooting</u> and shorter period of oscillation:

7. Check whether there is further improvement when increasing the value in parameter **P-0-1122, Velocity control loop filter: bandwidth of band-stop filter** or when changing the value in parameter **P-0-1123, Vel. cont. loop filter: center frequency of band-stop filter**.

If the step response shows the <u>same behavior</u>:

8. Check the determined resonance frequency; if necessary, significantly increase the value in parameter **P-0-1122, Velocity control loop filter: bandwidth of band-stop filter**.

Optimizing Rejection Filter or Velocity Loop

9. With the previously optimized values in the parameters **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** optimize the velocity loop again.

10. If necessary, carry out another optimization procedure for parameters P-0-1122 and P-0-1123 due to the high-frequency or less attenuated resonance points that are now possibly occurring.

Diagnostic and Status Messages

Velocity Error

The velocity error (S-0-0347) is generated from the effective velocity command value (P-0-0048) and the current actual velocity value (S-0-0040) by means of subtraction.

Acceleration Torque/Force

The acceleration torque is determined from the total inertia (determined using the automatic control loop setting) and the value in parameter **S-0-0164, Acceleration feedback value 1**. It is displayed in parameter **P-0-0451, Actual acceleration torque/force value**.

Process Torque/Force

The current process torque is determined from the current total torque in parameter **S-0-0084, Torque/force feedback value** and the determined **P-0-0451, Actual acceleration torque/force value**. It is displayed in **P-0-0452, Actual process torque/force value**.

Current Command Value Limit (E8260)

The output signal of the velocity loop is limited to a maximum and a minimum torque. This is a torque/force command value that already includes the additive component for the friction torque compensation.

This torque command value is limited with the parameters S-0-0082, S-0-0083 and S-0-0092. The effective torque/force command value (P-0-0049) can be read at the output of the limitation.

Note:	When the limit is active, the corresponding warning **E8260 Torque/force command value limit active** is generated and the respective bit (positive/negative limitation) is set in parameter **P-0-0555, Controller status word**.

Speed Loop Error (F8078)

The correct function of the velocity loop is monitored in the drive to avoid the so-called "runaway effect". Possible error causes 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.

ℹ️ See also Troubleshooting Guide for "F8078 Speed loop error"

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Position Loop (with Respective Feedforward Functions)

Brief Description

The following section only describes the position loop with the respective feedforward possibilities (velocity and acceleration feedforward).

Note:	For the description of position command value processing see section "Velocity Control with Cyclic Command Value Input" in chapter "Operating Modes".

Features

The position loop merely is a proportional loop. The P-amplification can be set via the **S-0-0104, Position loop Kv-factor** parameter.

- The lag error is minimized by:
  - variable velocity feedforward (cf. P-0-0040) and
  - variable acceleration feedforward (cf. S-0-0348) incl. smoothing filter.
- Depending on the control performance that was set, a cycle time of 250 µs (advanced) or 500 µs (basic) is used for the position loop (cf. P-0-0556, bit 2).
- with lag distance or lagless, i.e. with velocity feedforward
- model monitor for the lag error (see also F2028)

Pertinent Parameters

- **S-0-0032, Primary mode of operation** (bit 3 = 1 → activation of lagless operation)
- **S-0-0104, Position loop Kv-factor**
- **S-0-0189, Following distance**
- **S-0-0348, Acceleration feedforward gain**
- **P-0-0040, Velocity feedforward evaluation**
- **P-0-0556, Control word of axis controller**

Parameters for command value processing/filtering:

- **P-0-0042, Current position command average value filter order**
- **P-0-0099, Position command smoothing time constant**
- **P-0-0187, Position command processing mode**

Pertinent Diagnostic Messages

- **F2028 Excessive deviation**
- **F2036 Excessive position feedback difference**
- **F2037 Excessive position command difference**

Functional Description

Note:	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.

Acceleration Feedforward

In order to achieve a reduction of the lag error during the acceleration process, the acceleration feedforward (cf. S-0-0348) has to be activated.

For optimum parameterization of the acceleration feedforward the following values have to be entered in parameter S-0-0348:

- linear motor   → total mass (motor + load) in kg
- rotary motor   → total mass inertia (motor + load) in kgm^2

Note: The input value of parameter S-0-0348 has to be adjusted on site, depending on the respective mechanical system!

The illustration below exemplifies the operating principle of the respective feedforward procedure.
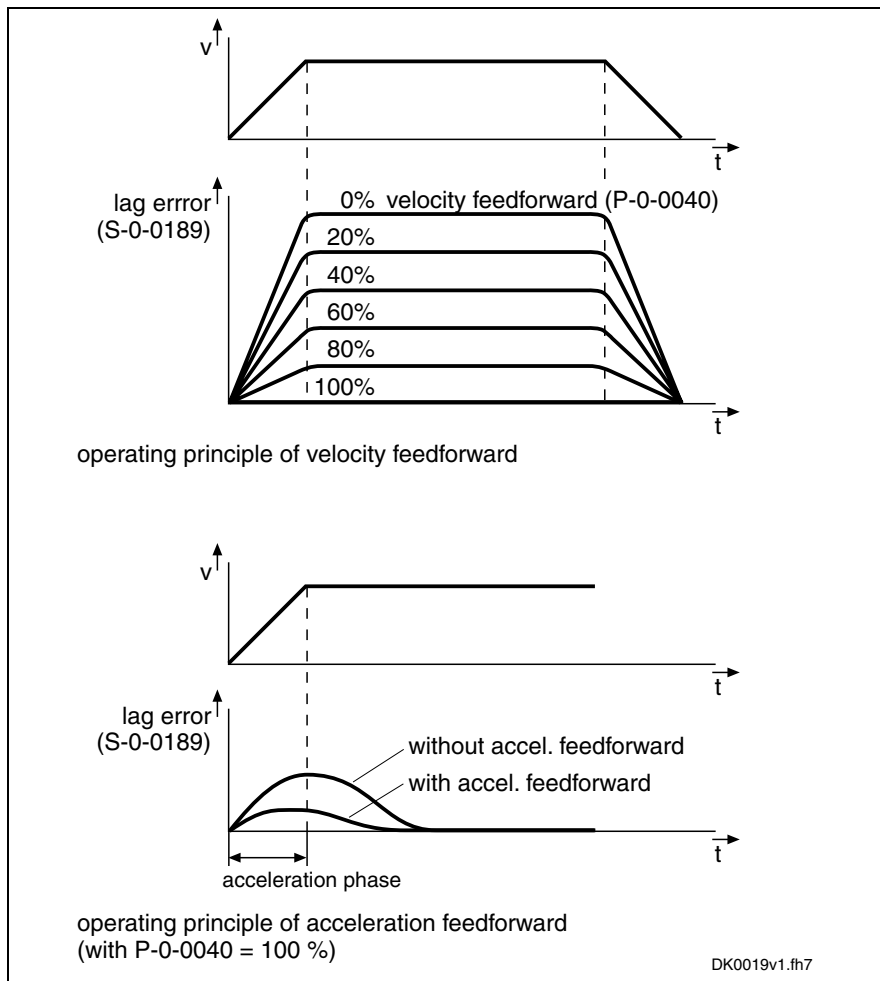
Fig. 6-41:   Operating principle of the velocity and acceleration feedforward

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 drive enable on:

   - linear motor   →   1000 … 2000 mm/min
   - rotary motor   →   10 … 20 rpm

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2. Increase parameter **S-0-0104, Position loop Kv-factor** until instable behavior (continuous oscillation) occurs.

3. Reduce parameter **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 Controller Setting

From the determined critical Kv-factor (see above) it is possible to derive a controller setting with the following characteristics:

• independent of changes at the axis because sufficient distance to stability limit

• properties can be reliably reproduced in series machines

The position loop normally is checked by optimizing the lag error. To do this, the following machine and application types have to be distinguished:

• **high-end machine tools** (e.g. grinding machines)
   $\rightarrow$ optimization with regard to a minimum lag error characteristic by the highest possible Kv-factors

• **standard positioning axes** (e.g. press transfer)
   $\rightarrow$ Optimization with regard to a minimum lag error characteristic is not required, the important thing is smoothest possible, jerk-free positioning. This is achieved, among other things, by relatively low Kv-factors resulting in very stable controller settings.

Diagnostic and Status Messages

Position command value (S-0-0047) and additive position command value (S-0-0048) form the position command value that is first smoothed via the subsequent position command value filter and then fine interpolated. If necessary, the value is reduced to the bipolar velocity limit value (S-0-0091). The result of the limitation is the effective velocity command value (P-0-0048).

The position command values preset by the master are monitored in the drive with regard to the following limit values:

F2037 Excessive position command difference

• The **position command value difference** of the incoming position command values within a SERCOS cycle must be smaller than the bipolar velocity limit value (S-0-0091). If this position command value difference between two successive position command values is greater than the value in parameter S-0-0091, the **F2037 Excessive position command difference** error message is generated and the excessive position command value is stored in parameter **P-0-0010, Excessive position command value**. The last valid position command value is stored in parameter **P-0-0011, Last valid position command value**. When modulo processing of the position data was set the interpretation of the command values additionally depends on the value in parameter **S-0-0393, Command value mode**. The parameter should be set to "shortest distance" (value "0").

F2028 Excessive deviation

• 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 theoretical and real actual position value permanently exceeds the value of parameter **S-0-0159, Monitoring window** it is obvious that the drive cannot follow the preset command value and the **F2028 Excessive deviation** error message is generated.

F2036 Excessive position feedback difference

• When 2 measuring systems (1 motor encoder and possibly external length measuring system) are used simultaneously, the actual position

value 1 and the actual position value 2, in cyclic operation (phase 4), are monitored for a maximum allowed actual position value difference indicated in parameter **S-0-0391, Monitoring window feedback 2**. If the absolute value of the difference is greater than the value of the monitoring window, the **F2036 Excessive position feedback difference** error message is generated.

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.

6.5 Limitations

Overview

Limitations in Open-Loop Operation (U/f Operation)

To protect the device or motor the following parameterizable limitations have been implemented in open-loop operation:

• current and torque limitation

    • current limitation

    • torque/force limitation

    • stall protection loop for current limitation

    • current limitation loop

• position limitation

    • travel range limit switch

    • software limit switch

Limitations in Closed-Loop Operation

To protect the device or motor the following parameterizable limitations have been implemented in closed-loop operation:

• current and torque limitation

    • current limitation

    • torque/force limitation

• velocity limitation

• position limitation

    • travel range limit switch

    • software limit switch

Current and Torque Limitation (Open-Loop)

Brief Description

In open-loop operation there is a current limitation and a torque/force limitation available in the drive. Both limitations take effect independently of each other.

See section "Current and Torque Limitation (Closed-Loop)"

Other possibilities of current and torque limitation in open-loop operation:

- limitation of the available peak current or torque by dynamic controller and motor protection equipment with current limitation loops

- user-side limitation of the available torque or force via stall protection loop
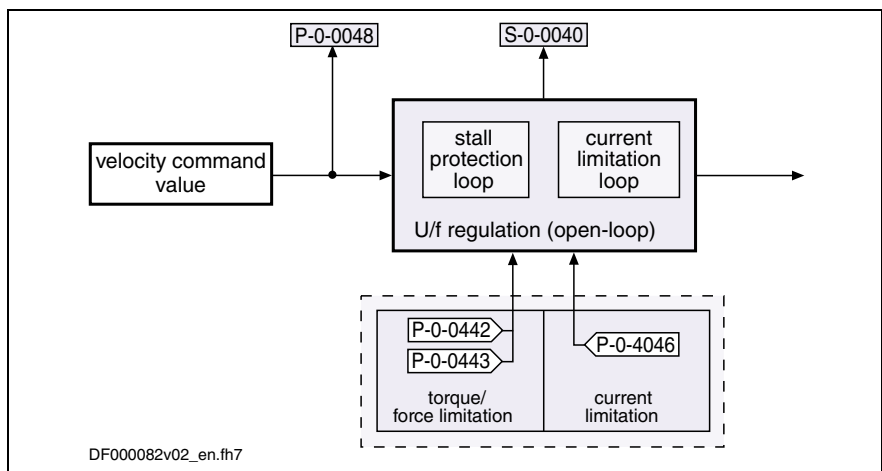
S-0-0040:   velocity feedback value
P-0-0048:   effective velocity command value
P-0-0442:   actual value torque limit positive (stationary)
P-0-0443:   actual value torque limit negative (stationary)
P-0-4046:   effective peak current

Fig. 6-42:   Principle of current and torque limitation (open-loop)

Operating Principle of Stall Current Loop and Current Limitation Loop

See also "Functional Description: Stall Protection Loop" in section "Motor Control: Voltage-Controlled Operation (Open-Loop)"

See also "Functional Description: Current Limitation Loop" in section "Motor Control: Voltage-Controlled Operation (Open-Loop)"

Current and Torque Limitation (Closed-Loop)

Brief Description

In closed-loop operation there is a current limitation and a torque/force limitation available in the drive. Both limitations take effect independently of each other.
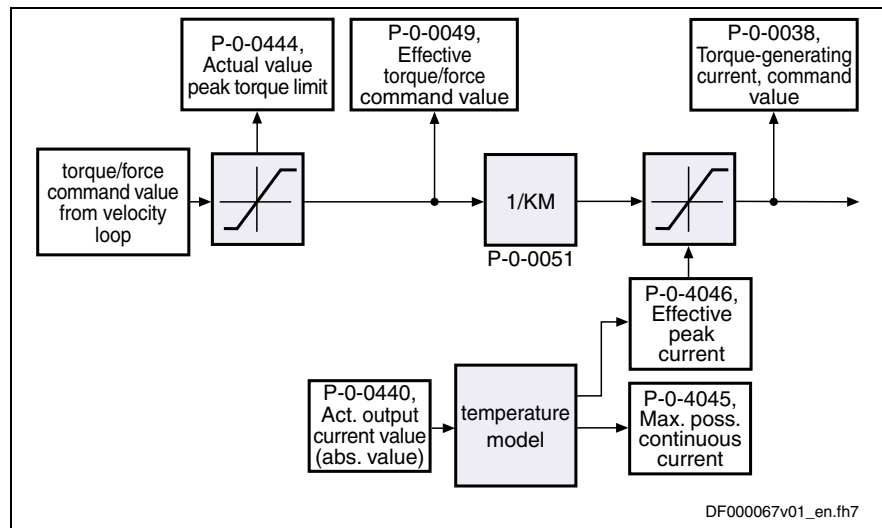
P-0-0051:   Torque/force constant

Fig. 6-43:   Principle of current and torque limitations (closed-loop)

Features   • separate limitation of current and torque/force (separated via **P-0-0051, Torque/force constant**)

• unipolar limits for torque/force (S-0-0082, S-0-0083)

• absolute current limitation by minimum value of **S-0-0110, Amplifier peak current** and **S-0-0109, Motor peak current**

• dynamic current limitation:

   • for currents above the 1.15.-fold motor current at standstill

   • based on the amplifier temperature model (E8057/E2061)

   • stall current protection for asynchronous motors

• display parameter **P-0-0440, Actual output current value (absolute value)**

• separate status word for torque/force limit (P-0-0445)

• resulting limitations displayed in:

   • **P-0-0444, Actual value peak torque limit**

   • **P-0-4046, Effective peak current**

   • **P-0-4045, Maximum possible continuous current** (depending on pulse width modulation frequency and amplifier type)

• current command values displayed in:

   • **P-0-0049, Effective torque/force command value**

   • **P-0-0038, Torque-generating current, command value**

• "total actual current value" as a parameter

• process torque displayed

Pertinent Parameters   • **S-0-0082, Torque/force limit value positive**

• **S-0-0083, Torque/force limit value negative**

• **S-0-0092, Bipolar torque/force limit value**

• **S-0-0109, Motor peak current**

• **S-0-0110, Amplifier peak current**

• **S-0-0111, Motor current at standstill**

• **S-0-0112, Amplifier nominal current**

• **S-0-0384, Amplifier temperature**

- **P-0-0001, Switching frequency of the power output stage**
- **P-0-0038, Torque-generating current, command value**
- **P-0-0049, Effective torque/force command value**
- **P-0-0051, Torque/force constant**
- **P-0-0109, Torque/force peak limit**
- **P-0-0141, Thermal drive load**
- **P-0-0440, Actual output current value (absolute value)**
- **P-0-0441, Overload warning**
- **P-0-0442, Actual value torque limit positive (stationary)**
- **P-0-0443, Actual value torque limit negative (stationary)**
- **P-0-0444, Actual value peak torque limit**
- **P-0-0445, Status word torque/current limit**
- **P-0-0640, Cooling type**
- **P-0-4034, Thermal time constant winding**
- **P-0-4035, Thermal time constant motor**
- **P-0-4037, Thermal short time overload of winding**
- **P-0-4045, Maximum possible continuous current**
- **P-0-4046, Effective peak current**
- **P-0-4058, Amplifier type data**
- **P-0-4059, Electric type data of power section**

Pertinent Diagnostic Messages

- **E2050 Device overtemp. Prewarning**
- **E2051 Motor overtemp. prewarning**
- **E2056 Torque limit = 0**
- **E2061 Device overload prewarning**
- **E8055 Motor overload, current limit active**
- **8057 Device overload, current limit active**
- **F2018 Device overtemperature shutdown**
- **F2019 Motor overtemperature shutdown**
- **F2021 Motor temperature monitor defective**
- **F2022 Device temperature monitor defective**

Torque/Force Limitation

The torque/force limit can be freely parameterized by the user and provides bipolar and unipolar limits.

Parameters for bipolar limits:

- **S-0-0092, Bipolar torque/force limit value**
- **P-0-0109, Torque/force peak limit**

Parameters for unipolar limits:

- **S-0-0082, Torque/force limit value positive**
- **S-0-0083, Torque/force limit value negative**

The figure below illustrates the functional principle:
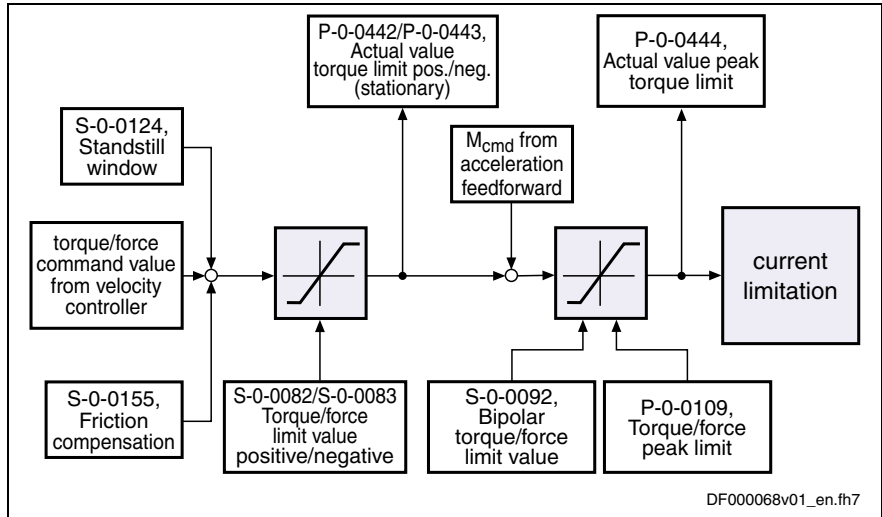
Fig. 6-44:   Principle of torque/force limitation

Features   The basic features of torque/force limitation:

- It is always the lowest value of the torque/force limit values entered in S-0-0082, S-0-0083, S-0-0092 or P-0-0109 that takes effect.

- The torque/force limit value effective at the output of the limitation is displayed in parameter **P-0-0444, Actual value peak torque limit**.

Current Limitation

Note: The current limitation cannot be parameterized by the user, but is automatically configured by the drive to protect the motor and the amplifier.

We basically distinguish the following principles of current limitation:

- **absolute current limitation** (depending on maximum possible peak currents and continuous currents of motor and drive controller)

- **dynamic peak current limitation** (depending on work load, realized by motor and amplifier temperature model)

Absolute Current Limitation   Calculating the maximum values for continuous current and peak current:
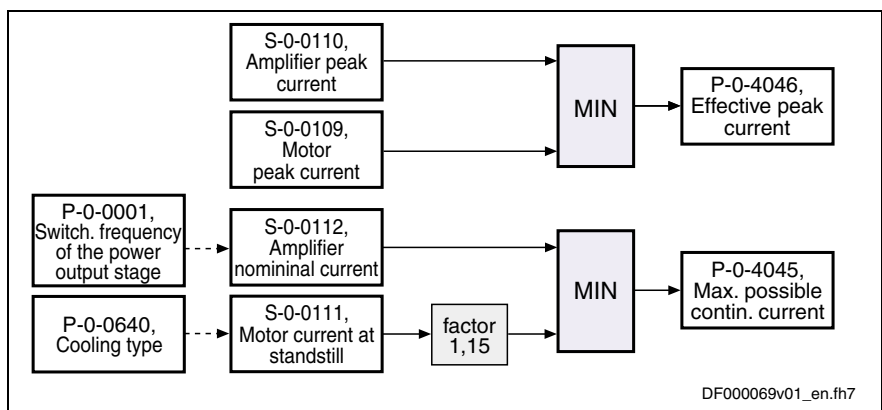
Fig. 6-45:   Generating the maximum values for continuous current and peak current

P-0-4045, Maximum possible continuous current

The maximum possible continuous current (P-0-4045) can be the 1.15-fold value of the motor current at standstill. As a result, the motors theoretically can be continuously operated with the 1.15-fold current at standstill if the continuous current of the controller (power section) allows it.

Note:	Overload protection in peak load and short-time operation (KB = "Kurzzeitbetrieb") is realized by the temperature model of the motor and additionally by the temperature sensor included in the motor.

P-0-4046, Effective peak current

According to the thermal load of the motor or drive controller, the effective peak current (P-0-4046) is subject to a dynamic current limitation. The theoretical maximum value for P-0-4046 results from the minimum of S-0-0109 and S-0-0110 (see fig. "Generating the maximum values for continuous current and peak current").

Dynamic Peak Current Limitation

In the case of dynamic peak current limitation, we distinguish 2 types due to the influencing factors:

- **Amplifier current limitation**
  Used to protect the drive controller. An amplifier temperature model based on the amplifier type data is therefor stored in the controller.

Note:	The amplifier type data are determined at the factory and stored in parameter P-0-4058 on the power section.

- **Motor current limitation**
  Used to protect the motor in the case of peak load and short-time overload operation. A motor temperature model based on the motor current data is therefor stored in the controller.
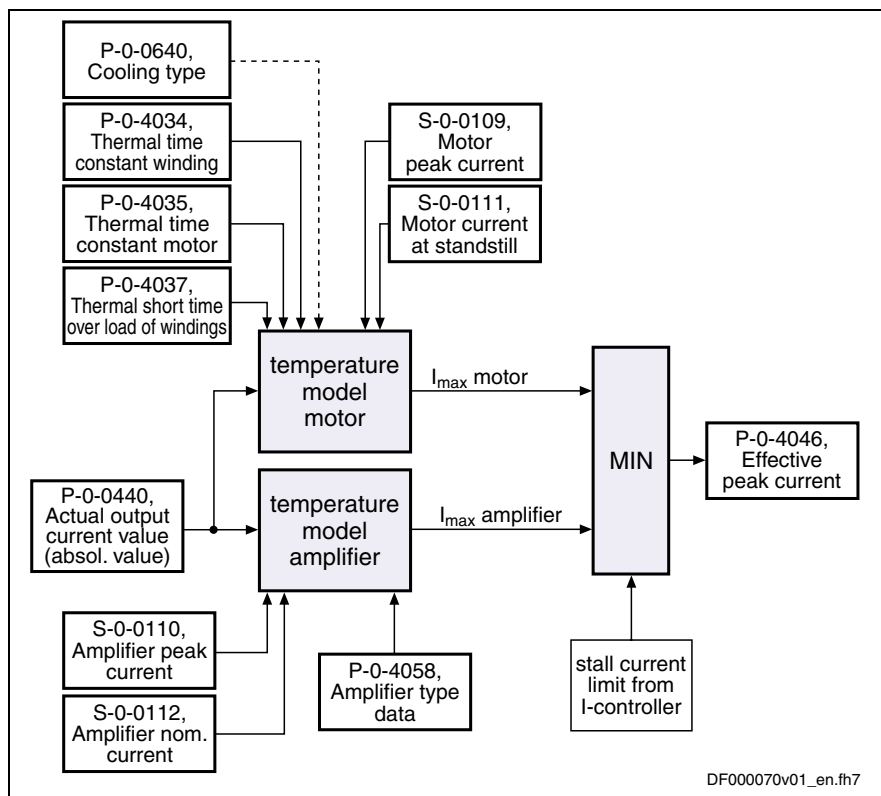
Fig. 6-46:   Generating the dynamic peak current limit value (temperature model)

Features	The basic features of dynamic current limitation:

- The value taking effect is always the lowest value resulting from motor current or amplifier current limitation.
- The maximum possible continuous current is displayed in P-0-4045, the effective peak current in P-0-4046.
- The current command value after limitation is displayed in parameter P-0-0038.

Maximum Peak Current If the drive controller was sufficiently dimensioned, the effective peak current (P-0-4046) can as a maximum reach the peak current of the motor (S-0-0109) because its value is the upper limit for the motor temperature model.

Maximum Duration for the Peak Current The maximum possible peak current can be made available for the time t_1 (see fig. "Time response of the effective peak current") [e.g. a maximum of 400 ms with switching frequency 4 kHz].

Note:	According to load cycle or with higher switching frequency and the thermal load involved, the time t_1 is reduced.

Time Dependency of Effective Peak Current If the peak current is required for a longer period than t_1, the value of **P-0-4046, Effective peak current** is reduced accordingly, at the very most to the value preset in **P-0-4045, Maximum possible continuous current**.
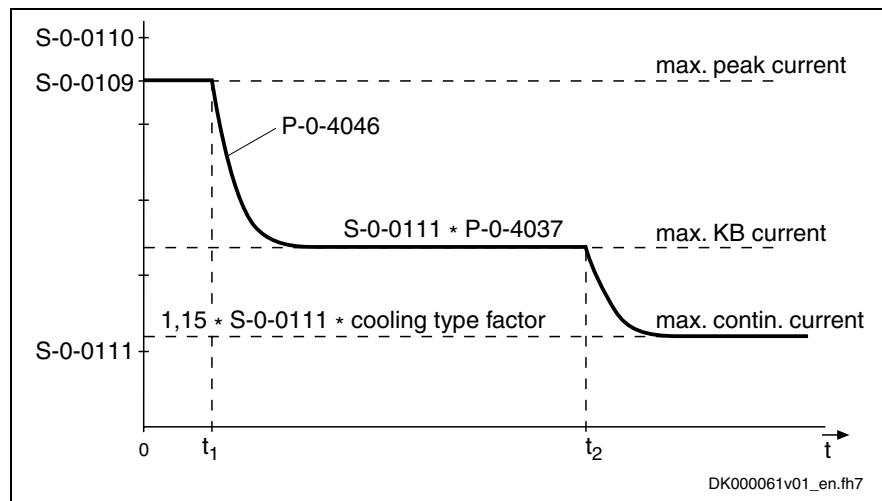
S-0-0109:	motor peak current
S-0-0110:	amplifier peak current
S-0-0111:	motor current at standstill
P-0-4045:	maximum possible continuous current
P-0-4046:	effective peak current
t_1:	max. duration after which the motor temperature model reduces to the max. KB current
t_2:	max. duration after which the motor temperature model reduces to the max. continuous current
KB:	short-time operation (KB = "<u>K</u>urzzeit<u>b</u>etrieb")
c. type factor:	depending on the cooling type and the resulting setting of **P-0-0640, Cooling type** (see also Parameter Description):
	1.0…for standard cooling (2AD, ADF, MAD, MAF, MBT, MBS, LSF, MLF, non-ventilated MHD, MSK, MKD, MKE)
	1.5…for ventilation (only MHD, MSK, MKD, MKE)
	1.9…for liquid cooling (only MHD, MSK, MKD, MKE)

Fig. 6-47: Time response of the effective peak current

(at full motor load, if the motor temperature model is the effective limitation)

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$$t_1 = -\ln\left[1 - \left(\frac{(P-0-4037)*(S-0-0111)}{I_{Last1}}1\right)^2\right]*(P-0-4034)$$

$$t_2 = -\ln\left[1 - \left(\frac{1{,}15*cooling\ type\ factor*(S-0-0111)}{I_{Last2}}\right)^2\right]*\frac{(P-0-4035)}{cooling\ type\ factor}$$

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_{Last1}:   assumed load current (> max. KB current)

I_{Last2}:   assumed load current (max. continuous current < I_{Last2} < 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

c. type factor: depending on the cooling type and the resulting setting of **P-0-0640, Cooling type** (see also Parameter Description):
                1.0…for standard cooling (2AD, ADF, MAD, MAF, MBT, MBS, LSF, MLF, non-ventilated MHD, MSK, MKD, MKE)
                1.5…for ventilation (only MHD, MSK, MKD, MKE)
                1.9…for liquid cooling (only MHD, MSK, MKD, MKE)

Fig. 6-48:   Calculating the duration for the effective peak current (see above)

The duration t_1 depends on:

- the motor-controller combination

- the thermal preloading of the drive

- the load cycle

Note: The physical data of motor-controller combinations can be retrieved via the selection list program "DriveSelect" (Intranet).

Notes on Commissioning

Current Limitation   The user cannot parameterize the current limitation because the limit values are resulting from the amplifier and motor data taken as a basis or the application-specific load cycle.

Unipolar Torque Limitation   Bipolar torque/force limits are generally determined to protect the mechanical system because this allows defining the allowed stress of the mechanical components (e.g. gear, coupling). The limit values to be entered therefore depend on the mechanical axis system.

Bipolar Torque Limitation   In certain cases of application, however, the process can require realizing a variable torque limit. This can be done via **S-0-0092, Bipolar torque/force limit value**, because this parameter can be cyclically transmitted via the bus or assigned to an analog input.

Note: Parameter **P-0-0109, Torque/force peak limit** is used to determine the absolute limit and therefore always has to be defined by means of the mechanical limits.

Diagnostic and Status Messages

For diagnostic purposes, the status of all partial limits is mapped to a status word for torque/force limitation and current limitation (see P-0-0445). As soon as a limit value is 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 there have been monitoring functions implemented that can activate, in conjunction with the current and torque limitation, the warnings and error messages listed below:

Warnings

Device-specific warnings:

- **E2050 Device overtemp. Prewarning**
- **E2061 Device overload prewarning**
- **8057 Device overload, current limit active**

Motor-specific warnings:

- **E2051 Motor overtemp. prewarning**
- **E2056 Torque limit = 0**
- **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**

Velocity Limitation

Brief Description

A velocity limitation was implemented in the drive that limits the velocity command value to a freely definable threshold.

Features

- bipolar velocity limit value
- cyclically configurable velocity limit value

Pertinent Parameters

- **S-0-0036, Velocity command value**
- **S-0-0037, Additive velocity command value**
- **S-0-0091, Bipolar velocity limit value**

Pertinent Diagnostic Messages

- **E2059 Velocity command value limit active**
- **E2063 Velocity command value > limit S-0-0091**
- **F8079 Velocity limit S-0-0091 exceeded**

Functional Description
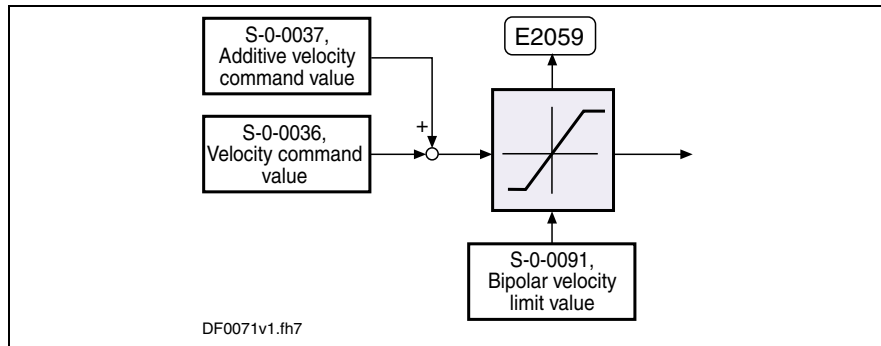
Fig. 6-49: Functional principle of velocity limitation

Notes on Commissioning

The content of **S-0-0091, Bipolar velocity limit value** is the limit for the maximum allowed velocity and has to be adjusted to the mechanical properties. When defining this parameter 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.

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 S-0-0091**
  Parameter **S-0-0036, Velocity command value** is limited to the value of parameter **S-0-0091, Bipolar velocity limit value**, if the value in S-0-0036 is higher than the value in S-0-0091. In this case the warning E2063 is generated.

- **F8079 Velocity limit S-0-0091 exceeded**
  The value of parameter **S-0-0040, Velocity feedback value** is monitored. If it exceeds the 1.125-fold value parameterized in **S-0-0091, Bipolar velocity limit value**, the F8079 error message is generated.

Position Limitation/Travel Range Limit Switch

Brief Description

To avoid accidents and damages to the machine, many 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 monitor (travel range limit switch or software limit switch) 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 **position limit values (software limit switch)**

  Monitoring 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 **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.

Note:	The functionality of the travel range limit switches is only guaranteed if the respective digital inputs have been configured for this purpose!
	See "Digital Inputs/Outputs" in chapter "Extended Drive Functions"

Features of Travel Range Limit Switch

- 2 travel range limit switches (Limit+, Limit-) monitored at the drive
- signal behavior of travel range limit switches (N/C and N/O) can be set
- travel range limit switches activated via parameter
- reaction (error/warning) when exceeding travel range can be set
- status display of travel range limit switches
- command values monitored for validity when limit switch activated
- travel range limit switches evaluated and position limit value monitor activated in 2 ms clock

Features of Position Limit Values

- 2 position limit values ("software limit switch") that can be parameterized; only operational when axis has been homed
- reaction (error/warning) when exceeding position limit values can be set
- position limit values activated via parameter
- automatic reference to measuring system that has been homed
- command values monitored for validity when position limit values exceeded

Pertinent Parameters

- **S-0-0012, Class 2 diagnostics**
- **S-0-0049, Positive position limit value**
- **S-0-0050, Negative position limit value**
- **S-0-0055, Position polarities**
- **S-0-0147, Homing parameter**
- **S-0-0403, Position feedback value status**
- **P-0-0090, Travel range limit parameter**
- **P-0-0222, Travel range limit 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 travel limit exceeded**
- **F6030 Negative travel limit exceeded**
- **F6042 Both travel range limit switches activated**
- **F6043 Positive travel range limit switch activated**
- **F6044 Negative travel range limit switch activated**

Travel Range Limit Switches

At the drive it is possible to connect and monitor 2 travel range limit switches (Limit+, Limit-) that can be connected to the digital inputs on the control section.

Note: 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 Monitor

Monitoring for exceeding the travel range limit switches is only carried out when the monitor was activated via bit 1 of **P-0-0090, Travel range limit parameter**.

Reaction when Exceeding Travel Range

The drive reaction to exceeding the travel range can be determined via bit 2 of **P-0-0090, Travel range limit parameter**.

Exceeding Travel Range as an Error

When "0" is entered in bit 2 of P-0-0090, exceeding the travel range is handled as an error with the reaction "velocity command value reset".

Drive behavior:

- After the velocity command value has been reset, the drive switches off the internal drive enable and thus is torque-free.
- The "ready-for-operation" contact opens.

See also "Velocity Command Value Reset" in section "Error Reactions: Best Possible Deceleration" in chapter "Drive Functions"

Exceeding Travel Range as a Warning

When "1" is entered in bit 2 of P-0-0090, exceeding the travel range is handled as a warning with the reaction "velocity command value reset".

Drive behavior:

- The drive does not switch off the internal drive enable.
- As long as the warning condition is present, i.e. the limit switch is activated, only such command values are accepted that lead back to the allowed range. Checking the command values is dependent on the active operating mode (see "Notes on Commissioning").

See also "Velocity Command Value Reset" in section "Error Reactions: Best Possible Deceleration" in chapter "Drive Functions"

Note: Shutting down the axis using a velocity command value ramp is not possible! Shutdown is always carried out as quickly as possible with maximum allowed torque/force.

Position Limit Values (Software Limit Switch)

Parameters for Position Limit Values

To define the travel range via position limit values the following parameters are available:

- **S-0-0049, Positive position limit value**
- **S-0-0050, Negative position limit value**

Note: The position limit values are polled every 2 ms so that the assigned error reaction is started at the earliest approx. 3 ms after the position limit has been exceeded.

Requirements for Activating the Function

Requirements for using (activating) the position limit value monitor:

- The position data reference of the drive must have been established (i.e. the encoder system of the active operating mode must be in reference). The status bit in **S-0-0403, Position feedback value status** then is "1".

- The monitor of the position limit values was activated in the **S-0-0055, Position polarities** parameter (bit 4 = 1).

Reference Point for Position Limit Value Monitoring

When 2 measuring systems are used the drive, for position limit value monitoring, automatically refers to the measuring system that has been homed.

Note: When 2 measuring systems are used and both systems 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 operating mode is outside the travel range defined by the position limit values.

Reaction when Exceeding Position Limit Values

The drive reaction to exceeding the position limit values can be determined via bit 2 of **P-0-0090, Travel range limit parameter**.

Exceeding Position Limit Values as an Error

When "0" is entered in bit 2 of P-0-0090, exceeding the position limit value is handled as an error with the reaction "velocity command value reset" (see also "Speed Command Value Reset").

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" in chapter "Drive Functions"

Exceeding Position Limit Values as a Warning

When "1" is entered in bit 2 of P-0-0090, exceeding the position limit values is handled as a warning with the reaction "velocity command value reset".

Drive behavior:

- The drive does not switch off the internal drive enable.

- As long as the warning condition is present, i.e. the limit switch is activated, only such command values are accepted that lead back to the allowed range. Checking the command values is dependent on the active operating mode (see "Notes on Commissioning").

See also "Velocity Command Value Reset" in section "Error Reactions: Best Possible Deceleration" in chapter "Drive Functions"

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Note:	Shutting down the axis using a velocity command value ramp is not possible! Shutdown is always carried out as quickly as possible with maximum allowed torque/force.

Leaving the Inadmissible Travel Range

After the allowed travel range has been exceeded, the command values are checked for validity and only such command values are accepted that lead back to the allowed travel range.

Note:	Moving to the allowed travel range is also possible in the case of error!

Notes on Commissioning

When parameterizing the position limit values, the position of the travel range limit switches has to taken into consideration. The working range defined with the two position limit values (S-0-0049, S-0-0050) should be within the working range defined with the travel range limit switches. As long as the position data reference hasn't been established yet (axis not homed), the function of the software limit switches (position limit values) isn't guaranteed yet. 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).
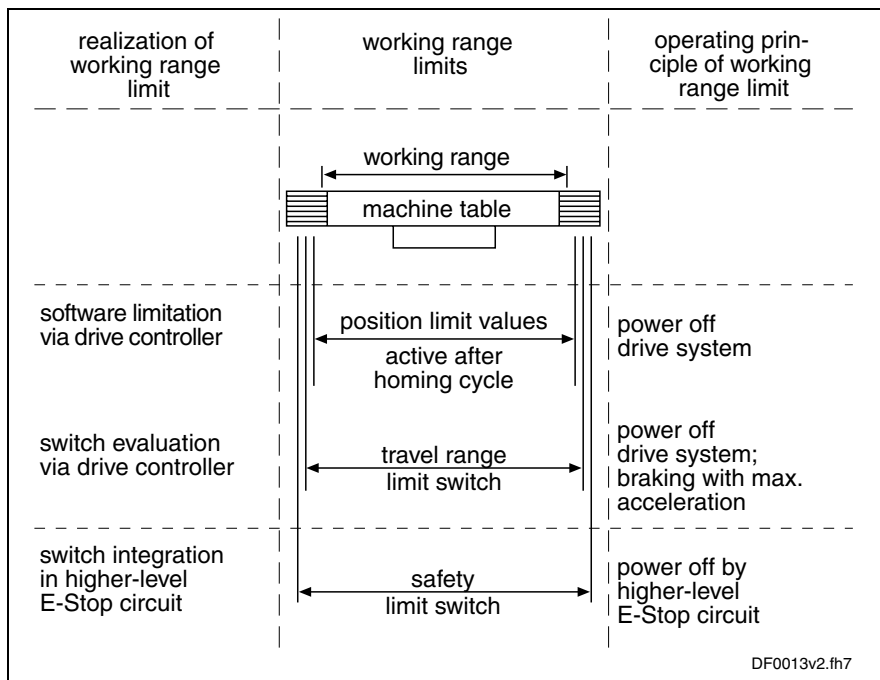
Fig. 6-50: Realizations and operating principles of working range limitations

Note:	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, position limit values can also be monitored by the control master.

Activating the Position Limit Value Monitor	The monitor of the position limit values is activated by setting bit 4 in parameter **S-0-0055, Position polarities**.

Note:	Before activating the position limit value monitor 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**.

Note:	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" in chapter "Extended Drive Functions"

Signal Behavior of Travel Range Limit Switches (N/O and N/C)	Via bit 0 of **P-0-0090, Travel range limit parameter** it is possible to set whether the connected travel range limit switches are evaluated as N/O or N/C. This allows activating an inversion of the signal.
Recommissioning in Case of Error	After a limit switch or limit value error occurred (diagnostic messages F6043/F6044 or F6029/F6030), the following steps are required for recommissioning:

- Clear the error message via the **S-0-0099, C0500 Reset class 1 diagnostics** command or by pressing the "Esc" button on the standard control panel.

- Activate the drive with a positive edge of the drive enable signal.

If the error condition is still present, i.e. if the limit switch is still activated or if the position limit values are still exceeded, only such command values are accepted that lead back to the allowed range. Checking the command values is dependent on the active operating mode.

The following applies:

Operating mode	Command value check
torque control	polarity of S-0-0080, Torque/force command value
all operating modes with drive-internal velocity control	polarity of the internal velocity command value
all operating modes with drive-internal position control	polarity of the velocity resulting from the preset position command value

Fig. 6-51:   Checking the command values in the case of error

Note:	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 occur again!

Diagnostic and Status Messages

Diagnostic Messages when Travel Range Limit Value Exceeded

In case the position limit value is 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 error (bit 2 = 0)	F6029	F6029 Positive travel limit exceeded
	F6030	F6030 Negative travel limit exceeded
as warning (bit 2 = 1)	E8029	E8029 Positive position limit exceeded
	E8030	E8030 Negative position limit exceeded

Fig. 6-52:   Diagnostic messages when position limit values exceeded

E2053 Target position out of travel range

When "drive-internal interpolation" is used as active operating mode, the drive checks whether the target position is outside the position limit values (S-0-0049 or S-0-0050). If this is the case, the drive does not move. It generates the **E2053 Target position out of travel range** warning and additionally sets bit 13 in parameter **S-0-0012, Class 2 diagnostics**.

Diagnostic Messages when Activating Travel Range Limit Switch

Exceeding the travel range limit switches is detected when these 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 error (bit 2 = 0)	F6042	F6042 Both travel range limit switches activated
	F6043	F6043 Positive travel range limit switch activated
	F6044	F6044 Negative travel range limit switch activated
as warning (bit 2 = 1)	E8042	E8042 Both travel range limit switches activated
	E8043	E8043 Positive travel range limit switch activated
	E8044	E8044 Negative travel range limit switch activated

Fig. 6-53:   Diagnostic messages when travel range limit switches exceeded

Status of Travel Range Limit Switches

The status of the connected travel range limit switches is displayed in parameter **P-0-0222, Travel range limit inputs**.

- bit 0:   → status of positive limit switch (Limit+)
- bit 1   → status of negative limit switch (Limit-)

i   See also Parameter Description "P-0-0222, Travel range limit inputs"

Connecting the Travel Range Limit Switches

See "Digital Inputs/Outputs" in chapter "Extended Drive Functions"

i   See documentation "Project Planning Manual for Control Sections"

6.6   Power Supply

Possibilities of Power Supply for IndraDrive

Brief Description

For IndraDrive devices we basically distinguish two lines:

- modular line, consisting of supply unit and modular inverter (IndraDrive M)
- non-modular line, so-called converter devices, including power supply and inverter (IndraDrive C)

The power supply of the motors controlled via inverter is realized by a direct voltage power bus (DC bus). In the case of the modular line, this bus is supplied by the supply unit connected to the mains. Converters are supplied by the mains connection via the integrated supply unit.

Pertinent Parameters
- **S-0-0380, DC bus voltage**
- **P-0-0114, Undervoltage threshold**
- **P-0-0118, Power supply, configuration**
- **P-0-0460, Module group, control word**
- **P-0-0461, Module group, status word**
- **P-0-0806, Current mains voltage crest value**
- **P-0-0809, Properties of charging circuit**
- **P-0-0810, Minimum mains crest value**
- **P-0-0815, Nominal mains voltage crest value**
- **P-0-0833, Braking resistor threshold**
- **P-0-0844, Braking resistor load**
- **P-0-0858, Data of external braking resistor**
- **P-0-0859, Data of internal braking resistor**
- **P-0-0860, Control word of power section**
- **P-0-0861, Status word of power section**

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**
- **E2026 Undervoltage in power section**
- **E2818 Phase failure**
- **E2819 Mains failure**
- **E2820 Braking resistor overload prewarning**
- **E2829 Not ready for power on**
- **E8025 Overvoltage in power section**
- **E8028 Overcurrent in power section**
- **8057 Device overload, current limit active**

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- **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**
- **F2828 DC bus voltage, no mains**
- **F2833 Ground fault in motor line**
- **F2834 Contactor control error**
- **F2836 DC bus balancing monitor error**
- **F2838 Overcurrent external braking resistor**
- **F2840 Error supply shutdown**
- **F2860 Overcurrent in mains-side power section**
- **F8838 Overcurrent external braking resistor**

Possible Device Combinations and Mains Connection

Note:	The possible device combinations are only described in principle for the purpose of explanation. As regards combinations of device types actually possible and specific facts to be observed, see the hardware documentation (Project Planning Manual) of the respective device!

Central Supply   The figures below illustrates the principle of central supply:
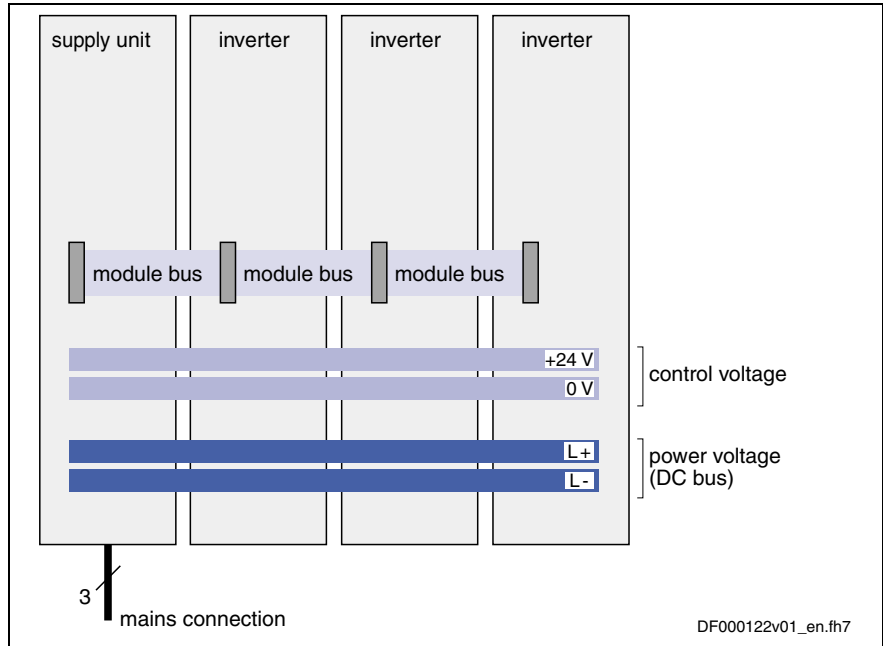
Fig. 6-54:   Mains supply via supply unit
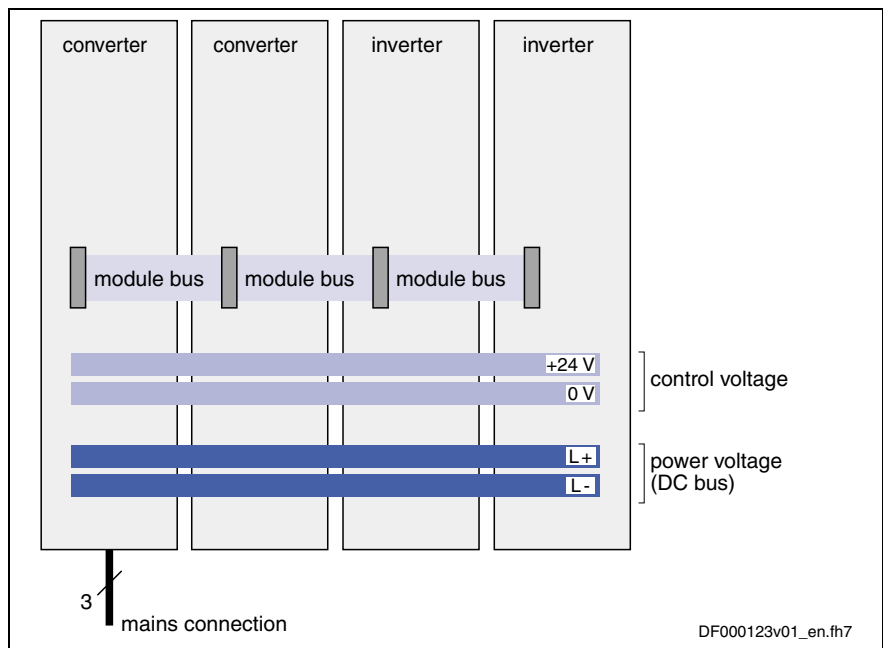
Fig. 6-55:   Mains supply via converter

Note: The following possibilities and restrictions have to be observed:

- IndraDrive M inverters can be connected to IndraDrive C converters! Take DC bus power into account!

- Further HCS02.1 converters that are operated as inverters may be connected to IndraDrive C devices (converter HCS02.1).
  Exception: There mustn't be any further HCS03.1 devices be connected to HCS03.1 devices (inverter operation)!

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Group Supply   The figure below illustrates the principle of group supply:
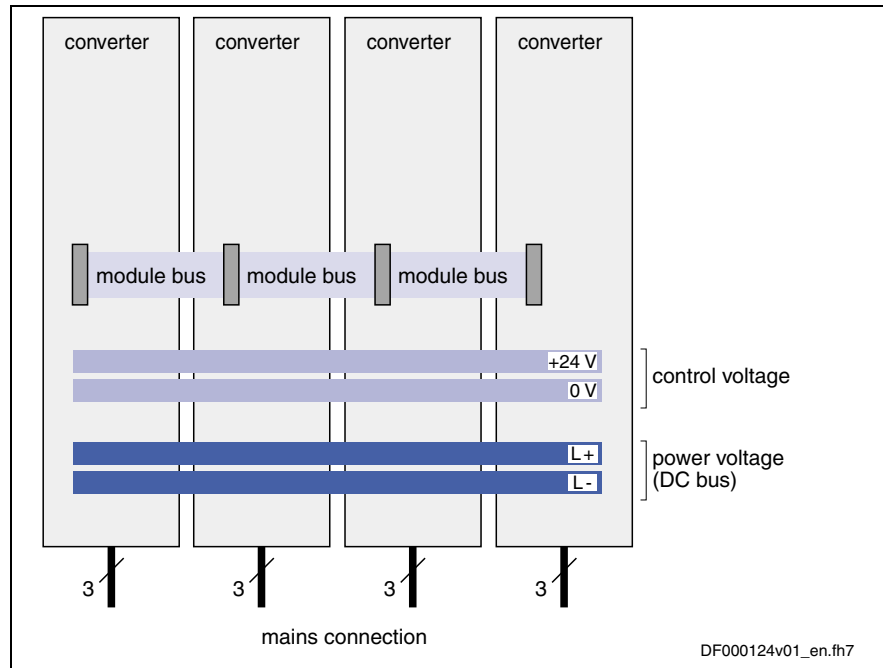
Fig. 6-56:   Mains supply via all devices

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. braking operation) 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).

Note: Recommendations on mains connection and control of the power supply, including external braking resistor and DC bus short circuit, are contained in the documentation of the supply units (HMV type) and converters (HCS type).

Functional Description

Information on the Module Bus

Function of the Module Bus
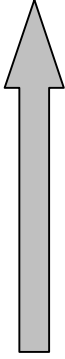
The module bus establishes the exchange of signals between the inverters or converters or from the inverters to the supply unit. Independent of the master communication, this allows the devices to exchange information on internal status variables of the drive system and error situations without delay. 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 (IV), supply unit (SU) or converter (CV) to the module bus has a hierarchical order.

Status information	generated by			Priority in hierarchy
	SU	**CV**	**IV**	
resetting of supply errors		X	X	high
supply units or converters not ready for operation ("supply error")	X	X	X[1]	
inverters or converters not ready for operation ("inverter error")		X[2]	X[2]	
failure of DC bus supply ("DC bus not ok", in operation)	X	X		
prewarning "supply overload"	X	X		
DC bus ready for power output ("DC bus ok", after switching power voltage on)	X	X		
all module bus nodes error-free	X	X	X	low

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. 6-57:   Module bus status information and hierarchy

If several parts of status information from one or several module bus nodes are present at the same time, the status information highest in hierarchy determines the signal status of the module bus.

Resetting Error Messages of the Supply Unit

Error messages of supply unit output via:

- display of supply unit
    - and -
- inverter or converter connected at module bus (collective error message **F2086 Error supply module**)

Error messages of supply unit cleared via:

- "Esc" button at display of supply unit

  - and -

- module bus, triggered by command **S-0-0099, C0500 Reset class 1 diagnostics** for an inverter of the mould group

Note:	Inverters can reset error messages of the supply unit via the module bus as they 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 regarding 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 to 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.

Voltage Messages of the Supply

The supply unit or the supply section of the converter signals the following states to 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.

Note:	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".

Overload Warning of the Supply

The supply unit or the supply section of the converter signals "supply overload prewarning" to the module bus if the power supply risks to automatically switch 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 "supply overload prewarning" is output via the inverters or converters connected to the module bus (**E2086 Prewarning supply module overload**). The control master can thereby detect imminent supply overload and react in an appropriate way.

Note:	The exact causes of this warning are shown on the display of the supply unit or converter by detailed diagnostic message texts.

Diagnosis of Module Bus Status

The control information currently transmitted by an inverter or converter to 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.

Note:	For this reason the status information "supply ready for operation" (respective bit in **P-0-0861, Status word of power section**) has to be assigned to the "Rel1" contact of the control section for converters; no other signal may be assigned to this contact. **Otherwise it is possible to switch power on although an error condition is present!**

Note:	Recommendations on the hardware-side control of supply units or converters are contained in the documentation of the respective device.

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, the following error is signaled:

- **F2816 Softstart fault power supply unit**
  (displayed for supply unit and converter)

The soft start error is transmitted as a supply error to the other devices via the module bus

- **F2086 Error supply module**
  (displayed for inverter or further converters)

If the soft start process has been successfully completed, the supply signals via the module bus that the DC bus is ready for power output ("ZK ok" = "DC bus ok").

Minimum Voltage for Power Output

In the case of power output of the DC bus and correct mains voltage, the minimum value of the DC bus voltage for signaling the readiness for power output ...

- in the case of supply units, 75% of the crest value of the mains voltage detected when switching on (cannot be set),

- in the case of converters, 75% of the crest value of the mains voltage detected when switching on, unless a higher minimum value has bee 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.

Note:	The crest value of the mains voltage is detected when the mains contactor is activated. It is displayed in parameter **P-0-0815, Nominal mains voltage crest value** (only for converters, not for supply units).

Power Off

In the case of error power is switched off automatically,

- in the case of supply units, by switching the integrated mains contactor off,

- in the case of converters, by opening the "Rel1" contact that has to be available in the switch-off path of the mains contactor.

Note:	Therefor the status information "supply ready for operation" (respective bit in **P-0-0861, Status word of power section**) has to be assigned to the "Rel1" contact of the control section for converters; no other signal may be assigned to this contact. **Otherwise power is not switched off automatically!**

Depending on the hardware-side design and control of the supply unit or converter, "DC bus short circuit" (for decelerating synchronous motors) can be activated, too.

Note:	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 "Supply Error Messages" in section "Diagnostic and Status Messages")

- fatal error in inverter or converter (F8xxx), is signaled at supply unit by corresponding configuration of the inverter or converter as regards power supply (P-0-0118)

- charged DC bus has fallen below "minimum voltage for power output" (see above)

Note:	When an inverter signals missing readiness for operation to the module bus, power is not switched off when DC bus is ready for power output (exception see above "fatal error... (F8xxx), ...")!

Mains Failure Detection	Due to hardware differences there are different requirements for mains failure detection in supply units and converters:

- The supply unit has an integrated mains contactor, the mains voltage must have been provided at the mains input terminals of the supply unit before power is switched on.

- The converter doesn't have an integrated mains contactor, the mains voltage is only provided at the mains input terminals of the converter by switching power on.

The mains voltage is therefore monitored when

- the mains contactor has been switched on in the case of supply units,

- the mains contactor has been switched on and drive enable has been set in the case of converters.

Note: For converters the mains failure monitor is only convenient when the drive is active ("AF"). The disconnection of power (mains contactor disconnection) would otherwise always cause the error message **F2819 Mains failure** although the mains voltage is available without error at the mains contactor. For this reason error reset would be required even if the device status is correct!

Immediate Measure at Mains Failure	When the failure of mains voltage is detected, the following immediate measures are taken:

- The warning **E2818 Phase failure/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 case the mains voltage fails permanently, the DC bus voltage is continuously decreasing, the voltage value falls below the "minimum voltage for power output" (see above). The following reactions are then triggered:

- In the case of supply units, the integrated mains contactor is switched off. The converter opens the "Rel1" contact via which the external mains contactor has to be switched off.

- The error message **F2819 Mains failure** appears on the display of the supply unit or converter.

- The message "readiness for operation of supply unit missing" is signaled via the module bus.

Temporary Mains Failure	If the voltage value, in the case of temporary mains voltage failure, does **not** fall below the "minimum voltage for power output" (see above), there are the following reactions:

- The warning **E2818 Phase failure** or **E2819 Mains failure** (for supply units) or **E2819 Mains failure** (for converters) automatically disappears from the display.

- The message "DC bus ready for power output" is generated via the module bus again.

The behavior of the drives connected via the module bus in the case of temporary mains failure depends on the reaction to undervoltage in the DC bus that was set (configuration of power supply in parameter P-0-0118).

There are the following possibilities:

- error reaction triggered according to setting in **P-0-0119, Best possible deceleration**

- No error reaction, i.e. the message is handled as "non-fatal warning".

Configuration of Power Supply

For each of the drives connected by the module bus it is possible to make basic settings for power supply in parameter **P-0-0118, Power supply, configuration**:

- reaction to drive errors signaled via module bus
- individual drive errors signaled via the module bus
- drive-side handling of undervoltage (voltage value of DC bus falling below a minimum) defined as error or warning
- fatal drive errors (F8xxx) signaled to supply unit because of power off and possibly DC bus short circuit for shutting down synchronous motors

Information on Inverters

The motors are controlled via inverters. Inverters can be designed as modular devices or together with a supply unit be integrated in converters. For motor control the inverter converts the DC bus voltage into alternating voltage (AC).

DC Bus Voltage Monitor

By means of the DC bus voltage level the inverter evaluates whether the connected motor can be supplied with sufficient power or not. The inverter can do this with the following procedures:

- evaluation of the message "failure DC bus supply" signaled by the supply unit via the module bus

- or -

- monitoring of the internally measured DC bus voltage with regard to an individual minimum threshold value

The desired procedure is determined in parameter **P-0-0114, Undervoltage threshold**:

- P-0-0114 = 0   → drive detects undervoltage when the supply unit signals "DC bus not ok" via the module bus
- P-0-0114 ≠ 0   → determination and activation of undervoltage threshold active in the drive greater 75% of nominal mains voltage crest value

Depending on the configuration of the power supply (P-0-0118), undervoltage is handle as an error (error reaction according to 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, Control word of power section**.

Note: Converters of the HCS03.1 type cannot be operated as inverters on a DC bus!

Mains Voltage Data

When a converter is directly connected to the supply mains (converter operation), the following mains voltage data are made available:

- **P-0-0806, Current mains voltage crest value**
- **P-0-0810, Minimum mains crest value**
- **P-0-0815, Nominal mains voltage crest value**

In parameter P-0-0810 it is possible to set a threshold value, for triggering the warning **E2814 Undervoltage in mains**, higher than the minimum value of the mains connection voltage range; this possibly enables the control master to react to the situation in the mains. The tolerance limit can be influenced via the level of the threshold value.

Identifying the Charging Circuit for DC Bus

The control section of the converter receives data on the properties of the charging circuit hardware for the soft start via parameter **P-0-0809, Properties of charging circuit**. The content of this list parameter is stored in write-protected form on the hardware of the converter power section and can be displayed for test purposes.

Status of Power Supply

The converter signals the status of power supply, mains voltage, DC bus charging status and the readiness for operation of the supply unit via parameter **P-0-0861, Status word of power section**. This allows diagnosing the converter in the case of error.

Supply Section Ready for Operation

The readiness for operation of the supply section of a converter is displayed via a bit in P-0-0861. This status information has to be assigned to the "Rel1" contact of the control section; the "Rel1" contact has to be integrated in the mains contactor control circuit. There mustn't be any other information assigned to the "Rel1" contact because otherwise the power of the converter cannot be switched off automatically!

See also "Digital Inputs/Outputs" in chapter "Extended Drive Functions"

Note:	Data on the hardware-side control of converters are contained in the documentation of the device.

Information on the Braking Resistor

External/Internal Braking Resistor

Converters of the HSC02.1 type are equipped with an integrated braking resistor. For the devices with higher maximum current it is possible to connect an external braking resistor as an alternative to the internal braking resistor (device option). The presetting for whether an internal or external braking resistor becomes active is made in parameter **P-0-0860, Control word of power section**.

Converters of the HCS03.1 type do not have an internal braking resistor. Depending on the device option it is possible, however, to connect an external braking resistor.

When an external braking resistor is used, its technical data have to be entered in parameter **P-0-0858, Data of external braking resistor**. If an internal braking resistor is available, its data are contained on the manufacturer side in parameter **P-0-0859, Data of internal braking resistor** and stored in write-protected form in a parameter memory on the power section.

The external braking resistor has to be activated in parameter **P-0-0860, Control word of power section**!

Note:	When an external braking resistor is connected, the minimum resistor value that can be connected has to be taken into consideration. See documentation for the respective device!

Switch-On/Switch-Off Threshold of Braking Resistor

For the switch-on/switch-off threshold of the braking resistor in the case of converters of the HCS type there are

- reference values that can be selected and
- dynamic adjustment to the current load of the braking resistor.

The reference values for the switch-on/switch-off threshold can be set to fixed standard values or variable values in parameter **P-0-0860, Control word of power section**.

ℹ️   See also Parameter Description "P-0-0860, Control word of power section"

For the switch-on or switch-off threshold of the braking resistor in the case of supply units of the HMV type 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-... a fixed reference value for the switch-on threshold of DC820V

  - and -

- dynamic adjustment to the current load of the braking resistor.

Note: Explanations on the reference values for the switch-on/switch-off thresholds of the braking resistor and on the control of X32 are contained in the documentation of the supply units of type HMV (DOK-INDRV*-HMV-*******-AW01-...).

As parameterization is impossible for the supply modules, the customer in this case only has a limited choice.

Regenerative supply unit HMV01.1R: The basic switch-on threshold of the braking resistor is 820 V. There always is dynamic adjustment to the active load.

Infeeding supply unit HMV01.1E: Via an interface input the customer can choose between mains-oriented threshold and fixed threshold. Default (open-circuited interface) is mains-oriented. The basic switch-on threshold then is 80 V above the mains voltage crest value measured at the first power on. In the "fixed threshold" mode the basic switch-on threshold is 820 V. In both operating modes there always is dynamic adjustment to the active load.

The dynamic adjustment to the current load is advantageous for:

- protecting the braking resistor from overload and
- equal load of all braking resistors active in a common DC bus.

The current load of the braking resistor is displayed in parameter **P-0-0844, Braking resistor load**.

Depending on the load the switch-on threshold of the braking resistor is increased:

- with load 0% ... 80% → linear increase, starting from reference value, to reference value +15 V
- with load 80% ... 100% → linear increase, starting from reference value +15 V, to reference value +30 V

The currently effective switch-on threshold is displayed in parameter **P-0-0833, Braking resistor threshold**.

Note: 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!

Notes on Commissioning

Settings, Configuration

Configuration of Power Supply

The required or desired axis-specific settings of the power supply of the device connected by the module bus have to be made in parameter **P-0-0118, Power supply, configuration**.

The following settings or definitions can be made:

- signaling of drive errors inside the drive system and reaction to signaled errors

- handling of undervoltage as error or warning

- signaling of fatal drive errors to the supply for switching power off (if necessary with DC bus short circuit)

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, Control word of power section**.

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, Status word of power section**

has to be assigned to the "Rel1" contact of the control section.

The wiring of the "Rel1" contact has to correspond to the data contained in the documentation of the converter devices!

Setting Threshold Value for Message "Mains Undervoltage"

In the case of converters, the threshold value for the message "mains undervoltage" can be set in parameter

- **P-0-0810, Minimum mains crest value**.

If there isn't any value entered, the default setting remains active (see Parameter Description for P-0-0810)!

Selecting Braking Resistor

For certain converters of the HCS02.1 type it is possible to determine whether the internal braking resistor is to be switched off and an externally connected braking resistor is to be activated. The selection is made in parameter

- **P-0-0860, Control word of power section**.

If an external braking resistor is to be used, the data required for control by the converter have to be entered in parameter

- **P-0-0858, Data of external braking resistor**.

Switch-On/Switch-Off Threshold for Braking Resistor

In the case of converters, the reference values for the switch-on/switch-off thresholds of the braking resistor can be selected. This is done in parameter

- **P-0-0860, Control word of power section**.

In accordance with the setting in parameter P-0-0860, the switch-on threshold can be dynamically increased depending on the load. The switch-on threshold currently effective is displayed in

- **P-0-0833, Braking resistor threshold**.

The current load of the braking resistor is displayed in

- **P-0-0844, Braking resistor load**.

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⚠ **CAUTION**

Property damage caused by inadmissibly high voltage on the motor terminals!

⇒ For third-party motors the maximum allowed terminal voltage has to be observed!

Diagnostic and Status Messages

Module Bus   Displaying module bus status:

- **P-0-0461, Module group, status word**

Displaying device-side module bus control information:

- **P-0-0460, Module group, control word**

Displaying interrupted module bus communication:

- **F2087 Module group communication error**

Mains Voltage   Mains voltage diagnoses:

- **P-0-0806, Current mains voltage crest value**
- **P-0-0815, Nominal mains voltage crest value**

Mains voltage warnings:

- **E2814 Undervoltage in mains**
- **E2818 Phase failure**
- **E2819 Mains failure**

Mains voltage error messages:

F2814 Undervoltage in mains

F2816 Softstart fault power supply unit

F2818 Phase failure

- **F2819 Mains failure**

F2834 Contactor control error

F2840 Error supply shutdown

F2860 Overcurrent in mains-side power section

DC Bus   DC bus diagnosis:

S-0-0380, DC bus voltage

DC bus warnings:

- **E2026 Undervoltage in power section**
- **E2026 Undervoltage in power section**
- **E8025 Overvoltage in power section**

DC bus error messages:

- **F2026 Undervoltage in power section**

F2817 Overvoltage in power section

F2833 Ground fault in motor line

F2836 DC bus balancing monitor error

Braking Resistor	Braking resistor diagnoses:

- **P-0-0844, Braking resistor load**
- **P-0-0833, Braking resistor threshold**

Braking resistor warnings:

- **E2820 Braking resistor overload prewarning**
- **E2802 HW control of braking resistor**
- **E2829 Not ready for power on**

Braking resistor error messages:

- **F2820 Braking resistor overload**
- **F2821 Error in control of braking resistor**
- **F2825 Switch-on threshold braking resistor too low**
- **F8838 Overcurrent external braking resistor**

Power Section Supply	Power section warnings:

- **E8028 Overcurrent in power section**
- **8057 Device overload, current limit active**

Power section error message:

- **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**

Notes

7   Operating Modes

7.1   Overview of Operating Modes

Supported Operating Modes

The drive firmware MPX-02 supports the following operating modes:

- torque/force control
- velocity control
- position control with cyclic command value input
- drive-internal interpolation
- drive-controlled positioning
- positioning block mode
- synchronization modes:
    - velocity synchronization with real/virtual master axis
    - phase synchronization with real/virtual master axis
    - electronic cam shaft with real/virtual master axis

Note: The operating modes supported by the firmware are depending on the hardware and firmware and are contained in parameter **S-0-0292, List of all operating modes**.

Operating Mode Handling

Selecting the Operating Mode

It is possible to configure up to 4 different operating modes (see also S-0-0292) in the drive. Assignment and configuration are made via the following parameters:

- **S-0-0032, Primary mode of operation**
- **S-0-0033, Secondary operation mode 1**
- **S-0-0034, Secondary operation mode 2**
- **S-0-0035, Secondary operation mode 3**

Note: If the value "0" was entered in one of these parameters, the **F2007 Switching to non-initialized operating mode** error message is generated when this operating mode is activated.

Activating the Operating Mode   The operating mode is activated and controlled via bits 8 and 9 in parameter **P-0-0116, Device control: control word**:

- bit 8/9 = 00:   primary mode of operation activated
- bit 8/9 = 01:   secondary operating mode 1 activated
- bit 8/9 = 10:   secondary operating mode 2 activated
- bit 8/9 = 11:   secondary operating mode 3 activated

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Note:	The control bits (8 and 9) contained in parameter P-0-0116 are also contained in the control words depending on the master communication (cf. S-0-0134, P-0-4077, P-0-4068 and P-0-4028) and can therefore be written via the control words.

One of the operating modes defined in the parameters S-0-0032 to S-0-0035 is active when:

- the drive (control section and power section) is ready for operation

  - and -

- the drive enable signal sees a positive edge.

Acknowledging the Active Operating Mode

As regards the activation of an operating mode, there are the following kinds of feedback:

- With active operating mode the display of the control panel reads "AF".

- In parameter **S-0-0390, Diagnostic message number** the respective diagnostic message number of the active operating mode is displayed (e.g. "A0101" in "velocity control" mode).

- In parameter **S-0-0095, Diagnostic message** the active operating mode is displayed in text form (e.g. "A0101 velocity control").

- In parameter **P-0-0115, Device control: status word** bit 3 ("drive follows command values") is used to acknowledge whether the drive is running in the preset operating mode or not.

- In parameter **P-0-0115, Device control: status word** bits 8 and 9 ("acknowledgment of operating mode") are used to signal the operating mode presently active.

Note:	The status bits contained in P-0-0115 (3, 8 and 9) 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.

See also "Basic Functions of Master Communication: Device Control" in chapter "Master Communication"

Changing the Operating Mode

When drive enable is activated, the drive, after having gone through the initialization routines, changes to the operating mode that was selected via bits 8 and 9 of the specific control word of the respective master communication (S-0-0134, P-0-4077, P-0-4068, P-0-4028 or P-0-0116).

Note:	The change of operating modes is carried out within one position loop clock (advanced: 250µs; basic: 500µs). Another position loop clock passes until the command values of the activated operating mode become effective, because the initialization of the operating mode is carried out first.

| Special Cases | With the following exceptional circumstances, the desired operating mode is not carried out in spite of the operating mode having been correctly selected: |

- **Drive error** is present
  → The corresponding error reaction is carried out.

- **Fatal warning** was triggered
  → The corresponding reaction is carried out.

- A "**drive command**" (e.g. homing procedure, set absolute measuring etc.) is executed
  → The command started is carried out.

- **Drive Halt**
  → This drive function is carried out.

See also "Basic Functions of Master Communication: Device Control" in chapter "Master Communication"

| Drive-Controlled Change of Operating Mode | In order to achieve a quick and smooth change of operating mode in running operation, it is possible to make a "drive-controlled change of operating mode". Drive-internally this procedure ensures that when the operating mode is changed the transition is carried out in a synchronized way, even if the command value changes abruptly. |

Command Value Acceptance and Acknowledgment

| Command Value Acceptance | Each preset command value is accepted immediately when the respective command value parameter (e.g. S-0-0036, S-0-0080, S-0-0258, …) is written in the case of the operating modes: |

- torque/force control
- velocity control
- position control with cyclic command value input
- drive-internal interpolation
- synchronization modes:
  - velocity synchronization with real/virtual master axis
  - phase synchronization with real/virtual master axis
  - electronic cam shaft with real/virtual master axis

In the positioning modes (drive-controlled positioning, positioning block mode), however, the command value (target position, velocity, positioning block, ...) is only accepted when the master explicitly requests this by a "command value acceptance".

The command value acceptance is carried out in a different way, according to the positioning mode or profile type:

- operating mode "drive-controlled positioning"
  acceptance of preset command value (position, velocity) by toggling bit 0 in **S-0-0346, Positioning control word**
  → **toggle mechanism**

- operating mode "positioning block mode"
  acceptance of the positioning block selected via **P-0-4026, Positioning block selection** by a 0-1 edge of bit 0 in **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**

Note:	When the positioning block mode is used for field buses in the freely configurable operating mode (P-0-4084 = 0xFFFE) or with SERCOS interface, the toggle mechanism is used **in spite of the above rule**.

Command Value Acknowledgment

The explicit acknowledgment of the command value acceptance only takes place for the positioning modes (drive-controlled positioning, positioning block mode).

It is possible to check in the master whether and when the preset command value was accepted in the drive (command value acceptance handshake).

The command value acknowledgment is carried out in a different way, according to the positioning mode:

- operating mode "drive-controlled positioning"
  The drive acknowledges the command value acceptance by toggling bit 0 in **S-0-0419, Positioning command acknowledge**.

- operating mode "positioning block mode"
  The drive acknowledges the command value acceptance by displaying the effective positioning block in **P-0-4051, Positioning block acknowledgment**.

Note:	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

Base package of all variants with **closed-loop** characteristic

Brief Description

In the "torque/force control" mode a torque/force command value is preset for the drive. If required this command value can be filtered. When the operating mode is activated the diagnostic message is **A0100 Drive in TORQUE control**.
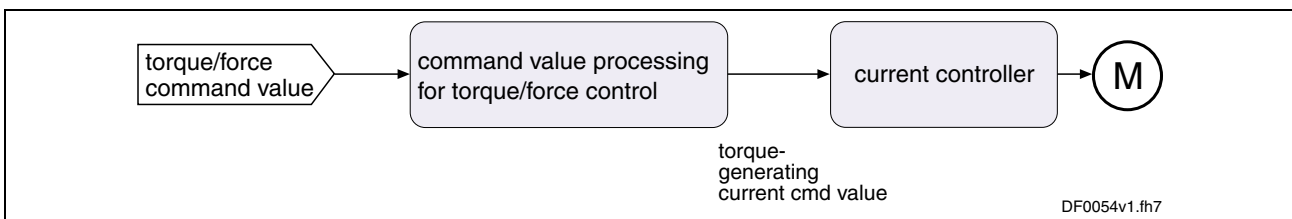
Fig. 7-1:   "Torque/force control" block diagram

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**

- The torque/force command value is generated internally by the velocity loop. The value of parameter S-0-0081 can be added to this command value as an additive component.

- limitation of the preset command value to limit value that can be parameterized

- filtering the command value by means of parameter **P-0-0176, Torque/force command smoothing time constant**

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**
- **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-0-0176, Torque/force command smoothing time constant**
- **P-0-4046, Effective peak current**

Pertinent Diagnostic Messages

- **A0100 Drive in TORQUE control**
- **F8079 Velocity limit S-0-0091 exceeded**

See also below "Command Value Processing in Torque/Force Control"

See also below "Current Loop"

Command Value Processing in Torque/Force Control

Filtering the Command Value

The command value preset by **S-0-0080, Torque/force command value** is filtered by a PT1 filter. The time constant of the filter can be changed by means of **P-0-0176, Torque/force command smoothing time constant**.

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   The following command value limitations are distinguished:

- torque/force limit
- current limit

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 processing for torque/force control is the torque-generating component of the current command value Iqcmd (P-0-0038).
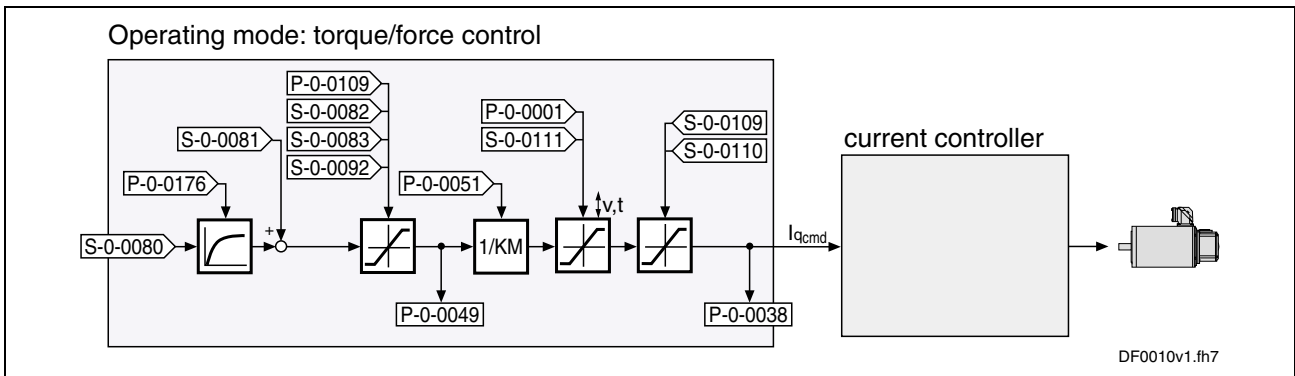
Fig. 7-2:   Command value processing in torque/force control

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 processing in torque/force control, the torque-generating component of the current command value (P-0-0038).
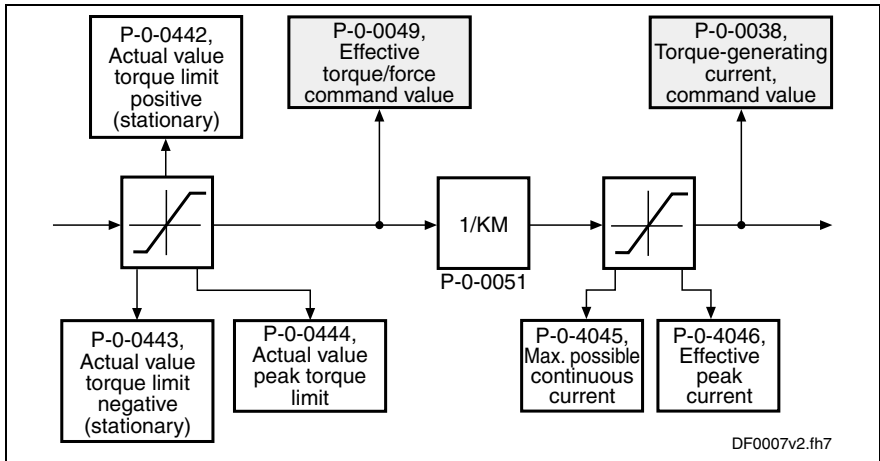
Fig. 7-3:   Display of the active limit values and the current torque/force and current command value

Velocity Monitor   In torque/force control the velocity of the drive is reached depending on the component of the drive torque or the drive force acting on the acceleration. As the velocity of a motor or an axis has to stay within the allowed range in order to avoid damage, the actual velocity value is monitored.

If the value of **S-0-0040, Velocity feedback value** exceeds the 1.125-fold value of **S-0-0091, Bipolar velocity limit value**, the drive generates the **F8079 Velocity limit S-0-0091 exceeded** error message and switches off with the error reaction that was set.

Notes on Commissioning

On the user side the following limitations are available:

- maximum allowed torque/force (S-0-0092, P-0-0109)

- motive and generating load with stationary velocity (S-0-0082, S-0-0083)

$\boxed{\mathbf{i}}$ See also separate documentation "Parameter Description for IndraDrive Drive Controllers"

Note: 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.

Note: The content of **P-0-4046, Effective peak current** results from the current and torque limits.

See also below "Current Loop"

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 figure "Overall structure of control loop" in chapter "Drive Control"

Note: In fact, the torque is not closed-loop controlled but open-loop controlled. Given the linear relation between torque and current (cf. P-0-0051) it is possible, however, to assume closed-loop torque/force control. Just the absolute torque precision is limited due to manufacturing tolerances of the motor (max. ± 10%).

Controller Performance and Cycle Times   According to the available hardware (basic or advanced design), the current control loop is closed every 62.5 µs (advanced) or 125 µs (basic). (see also **P-0-0556, Control word of axis controller**, bit 2)

Notes on Commissioning

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 "DriveTop" commissioning tool.

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Diagnostic Messages and Monitoring Functions

Diagnostic Status Message

The activated "torque/force control" mode is displayed by the following diagnostic message:

- **A0100 Drive in TORQUE control**

Monitoring Functions

Monitoring functions in torque/force control:

E2063 Velocity command value > limit S-0-0091

- The value of parameter **S-0-0036, Velocity command value** is limited to **S-0-0091, Bipolar velocity limit value**. If the value in S-0-0036 is higher than the value in S-0-0091, the **E2063 Velocity command value > limit S-0-0091** warning is generated.

7.3   Velocity Control

Base package of all variants

Brief Description

In the "velocity control" mode a velocity command value is preset for the drive. The velocity command value is limited by ramps and filters.
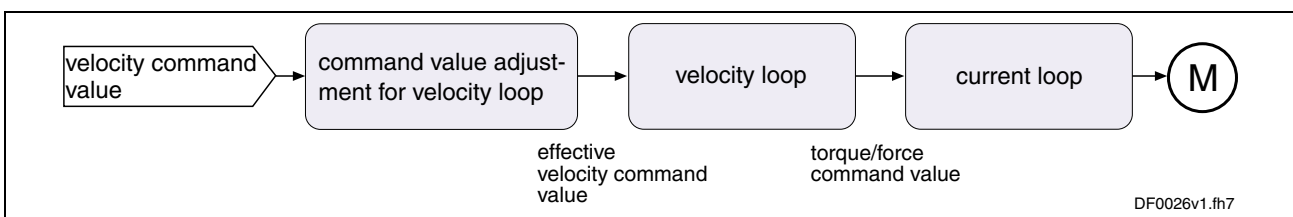
Fig. 7-4:   "Velocity control" block diagram

Features
- an external velocity command value (sum of **S-0-0036, Velocity command value** and **S-0-0037, Additive velocity command value**) is preset via analog inputs or master communication interface (SERCOS, field bus, ...)

- selection of predefined and internally stored velocity command value steps (fixed values) via digital inputs (e.g. jogging forward/backward, feeding, setting up, ...)

- window comparator for masking critical velocity ranges in the command value channel (e.g. machine resonances) with corresponding acceleration adjustment (cf. P-0-1209)

- ramp generator with separately adjustable two-stage acceleration and deceleration limits of the preset velocity command value; switching from ramp 1 to ramp 2 is done with selectable velocity and run-up stop that can be parameterized

- velocity control via a digital PI loop with extensive filter measures

- monitoring the command velocity and actual velocity for exceeding parameter **S-0-0091, Bipolar velocity limit value**

- smoothing of velocity control loop difference via filter that can be parameterized

- smoothing of preset command value by means of average filter (jerk limitation by means of moving average filter)

- fine interpolation of the velocity command values; transmission of these command values in the position loop clock
  fine interpolator is switched on by default (P-0-0556, bit 0 1)

- Velocity control loop monitoring (cannot be parameterized) to prevent the drive from running away.
  This monitor can be switched off (P-0-0556, bit 1); the default setting is "On".

- velocity loop internally generates the torque/force command value to which the value of parameter **S-0-0081, Additive torque/force command value** can be added as an additive component.

- control word and status word especially for "velocity control" mode (cf. P-0-1200 and P-0-1210)

Pertinent Parameters

- **S-0-0036, Velocity command value**
- **S-0-0037, Additive velocity command value**
- **S-0-0091, Bipolar velocity limit value**
- **S-0-0100, Velocity loop proportional gain**
- **S-0-0101, Velocity loop integral action time**
- **P-0-0004, Velocity loop smoothing time constant**
- **P-0-0048, Effective velocity command value**
- **P-0-0556, Control word of axis controller**
- **P-0-1119, Velocity mix factor feedback 1 & 2**
- **P-0-1120, Velocity control loop filter: filter type**
- **P-0-1125, Velocity control loop: average value filter clock**
- **P-0-1126, Velocity control loop: acceleration feed forward**
- **P-0-1200, Control word of velocity control mode**
- **P-0-1201, Ramp 1 pitch**
- **P-0-1202, Final speed ramp 1**
- **P-0-1203, Ramp 2 pitch**
- **P-0-1206, Memory of velocity command values**
- **P-0-1207, Lower limit of velocity masking window**
- **P-0-1208, Upper limit of velocity masking window**
- **P-0-1209, Acceleration factors for velocity masking window**
- **P-0-1210, Status word of velocity control mode**
- **P-0-1211, Deceleration ramp 1**
- **P-0-1213, Deceleration ramp 2**
- **P-0-1222, Velocity command filter**

Pertinent Diagnostic Messages

- **A0101 Drive in velocity control**
- **E2059 Velocity command value limit active**
- **E2063 Velocity command value > limit S-0-0091**
- **F8078 Speed loop error**
- **F8079 Velocity limit S-0-0091 exceeded**

Command Value Adjustment in Velocity Control

The figure below illustrates command value processing in the "velocity control" mode as a block diagram.
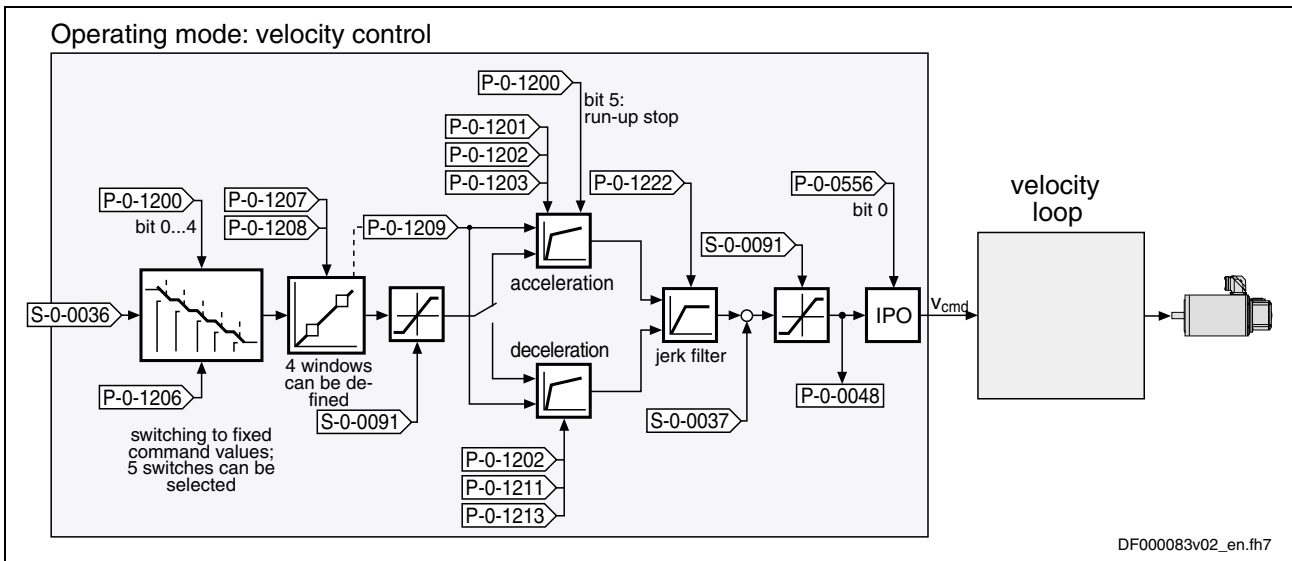
Fig. 7-5: Command value adjustment in velocity control

The velocity command value is processed by the so-called ramp generator

Note:	Information on the status of the ramp generator is contained in parameter P-0-1210.
	See Parameter Description "P-0-1210, Status word of velocity control mode"

Command Value Input

In the "velocity control" mode velocity command values can be input in the following ways:

- cyclic command value input by means of parameter **S-0-0036, Velocity command value** via the master communication (analog interface, SERCOS, field bus) or IndraMotion MLD

- using velocity command values internally stored in the drive in parameter **P-0-1206, Memory of velocity command values** (list parameter with 5 elements); selection via digital inputs, master communication interface (SERCOS, field bus) or IndraMotion MLD, for example

Note:	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.

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.
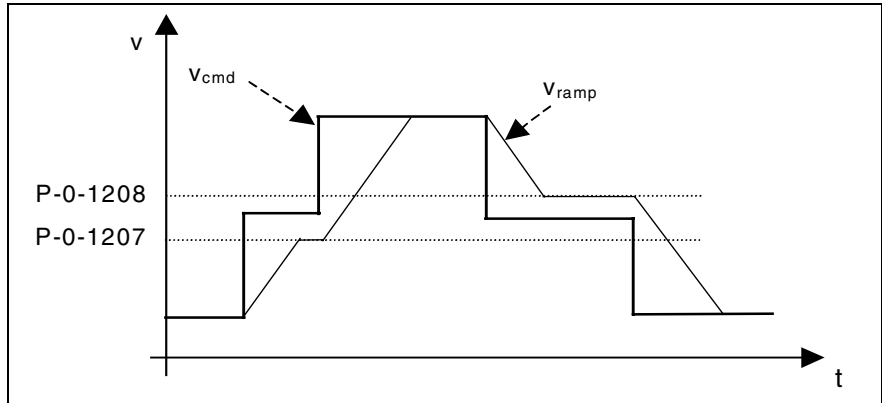
P-0-1207:   lower limit of velocity masking window

P-0-1208:   upper limit of velocity masking window

Fig. 7-6:   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 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 generator (P-0-1201, P-0-1203, P-0-1211 and P-0-1213).
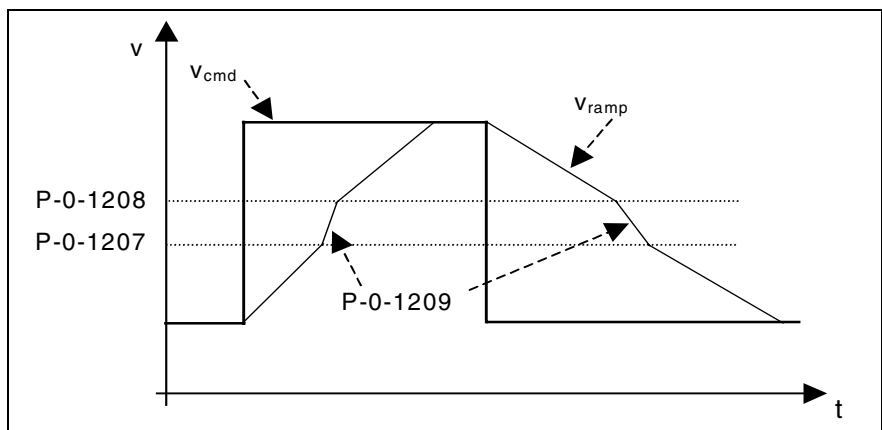
P-0-1207:   lower limit of velocity masking window

P-0-1208:   upper limit of velocity masking window

Fig. 7-7:   Operating principle of the acceleration factors from P-0-1209

ℹ️   See also Parameter Description "P-0-1209, Acceleration factors for velocity masking window"

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Ramp Generator

The increase (acceleration) and deceleration of the velocity command value can be limited in steps via 2 ramps.

- Acceleration process:
  In the first step, the increase of the command value is limited via **P-0-1201, Ramp 1 pitch** (acceleration ramp 1).
  If the command velocity exceeds the threshold entered in parameter **P-0-1202, Final speed of ramp 1**, the increase of the command value is limited with the value **P-0-1203, Ramp 2 pitch** (acceleration ramp 2).

- Deceleration or braking process:
  Parameters **P-0-1211, Deceleration ramp 1** or **P-0-1213, Deceleration ramp 2** are used accordingly for deceleration.

Note: This allows parameterizing different ramps for the acceleration and braking process.

Run-Up Stop   When there is acceleration-dependent torque limitation occurring or due to installation-dependent failures/irregularities it is necessary to interrupt the acceleration ramp. For this purpose the function "run-up stop" was introduced that is controlled via **P-0-1200, Control word of velocity control mode**.

Possibilities of setting for activating the function "run-up stop" via the respective bits of P-0-1200:

- activation of the function without additional condition

- triggering of torque limitation E2060

- triggering of command value limitation (cf. S-0-0091)

- triggering of command value or torque limitation

Note: While a speed masking window is passed, the function "run-up stop" is deactivated.

Jerk Limitation

The velocity command value, the increase and maximum of which are limited, is jerk-limited by means of a moving average filter (**P-0-1222, Velocity command filter**).

Command Value Limitation

The effective velocity command value (sum of S-0-0036 and S-0-0037) is limited to the value indicated in **S-0-0091, Bipolar velocity limit value**.

Note: 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 **P-0-0556, Control word of axis controller**.

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 "Axis Control: Control Loop Structure" in chapter "Drive Control"

Controller Performance and Cycle Times

The minimum possible controller cycle time of the velocity loop depends

- on the available control section (CSH, CSB, CDB),
- on the respective firmware variant (MPH, MPB or MPD)
  - and -
- in the case of variant MPH, on the parameterized performance (Basic or Advanced; cf. **P-0-0556, Control word of axis controller**, bit 2).

The following list shows the maximum available performance:

- CSH (Advanced single-axis) → TA = 125 µs
- CSB (Basic single-axis)   → TA = 250 µs
- CDB (Basic double-axis)   → TA = 250 µs

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 "Current Loop" in section "Torque/Force Control"

Possibilities of Filtering

To filter noise components possibly present in the actual velocity value or to attenuate resonance frequencies, the following filter settings can be made:

- Via parameter **P-0-0004, Velocity loop smoothing time constant** the low-pass filter that filters the control difference for the velocity loop can be set.
- Parameter **P-0-1125, Velocity control loop: average value filter clock** allows filtering the velocity control loop deviation with a moving average filter.
- To filter the control deviation it is possible to configure four filters connected in series as low-pass filters or band-stop filters with parameter **P-0-1120, Velocity control loop filter: filter type**.

Note: The **S-0-0081, Additive torque/force command value** parameter is added to the output signal of the velocity loop and the resulting value is transmitted to the current and torque/force limitation (see also "Limitations: Current and Torque Limitation" in chapter "Drive Control").

Notes on Commissioning

Inputting or Selecting the Velocity Command Value

Apart from the cyclic velocity command value (S-0-0036), the drive can be moved with fixed constant velocity command values stored in the drive.

Example of Application   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.

The velocity steps (max. 5 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. The figure below illustrates the interaction of the parameters:
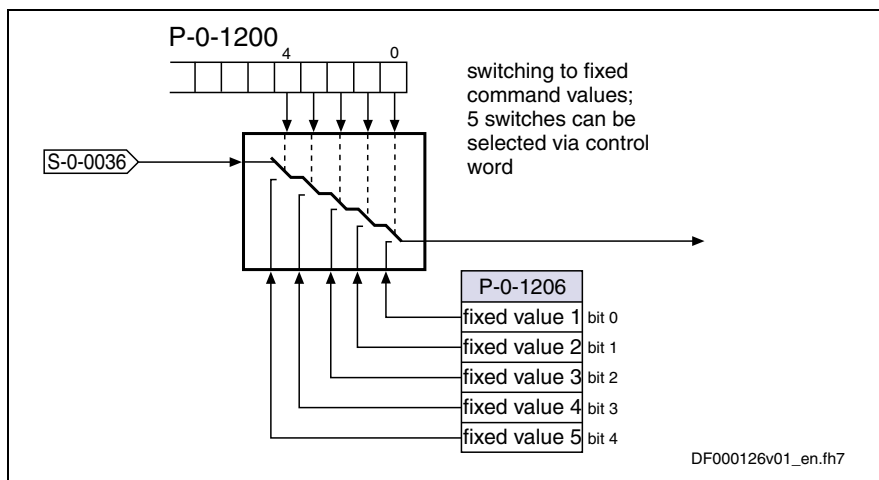
S-0-0036:   velocity command value

P-0-1200:   control word of velocity control mode

P-0-1206:   memory of velocity command values

Fig. 7-8:   Selecting the internally stored velocity command values

Note: If one of the bits 0...4 has been set in P-0-1200, the cyclically preset velocity command value (S-0-0036) is no longer transmitted, but the fixed command value activated via the bit takes effect.

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.

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 "Axis Control: Control Loop Structure" in chapter "Drive Control"

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, as well for acceleration as 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.

Note: The default value of the parameters P-0-1207 and P-0-1208 is zero which means that the speed window hasn't been defined.

Diagnostic Messages and Monitoring Functions

Diagnostic Status Message

Active Operating Mode   The activated "velocity control" mode is displayed by the following diagnostic message:

- **A0101 Drive in velocity control**

Status of Ramp Generator

Effective Velocity Command Value   The currently effective velocity command value at the output of command value adjustment that is preset for the velocity loop via the fine interpolation, is mapped to parameter **P-0-0048, Effective velocity command value**.

Status of Ramp Generator (Run-Up Encoder)   "Frequency converter" applications require several status messages that are contained in parameter **P-0-1210, Status word of velocity control mode**:

- Bit 0 = 1 $\rightarrow$ command value reached
  The output of the ramp 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 $\rightarrow$ run-up stop active
  The command "run-up stop" prevents the acceleration ramp from being integrated. The jerk filter is not stopped, the current command value for the time set in the jerk filter can change.

- Bit 2 = 1 $\rightarrow$ 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 $\rightarrow$ 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 generator goes through the range of a masking window, the increased acceleration/deceleration according to P-0-1209 is active. In addition to this message bit, either the bit "acceleration active" or "deceleration active" is set.

Monitoring Functions

Monitoring functions specific to operating mode:

E2059 Velocity command value limit active

- The effective velocity command value (sum of 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**.

E2063 Velocity command value > limit S-0-0091

- The value of parameter **S-0-0036, Velocity command value** is limited to **S-0-0091, Bipolar velocity limit value**. If the value in S-0-0036 is higher than the value in S-0-0091, the **E2063 Velocity command value > limit S-0-0091** warning is generated.

F8078 Speed loop error

- The drive monitors the correct function of the velocity loop and in the case of fatal errors disables the drive torque with the error message **F8078 Speed loop error**.

F8079 Velocity limit S-0-0091 exceeded

- The value of parameter **S-0-0040, Velocity feedback value** is monitored. If it exceeds the 1.125-fold value parameterized in **S-0-0091, Bipolar velocity limit value**, the **F8079 Velocity limit S-0-0091 exceeded** error message is generated.

7.4   Position Control with Cyclic Command Value Input

Base package of all variants in **closed-loop** characteristic

Brief Description

In the "position control" mode, a cyclic position command value is preset for the drive in NC cycle time. This command value is fine interpolated in the drive and jerk-limited via filters, if necessary, before being transmitted to the position controller.

To minimize the lag error, variable acceleration feedforward is available in addition to variable velocity feedforward.

There are different forms of the "position control" mode which result in the corresponding diagnostic messages when the operating mode was activated (see "Pertinent Diagnostic Messages").
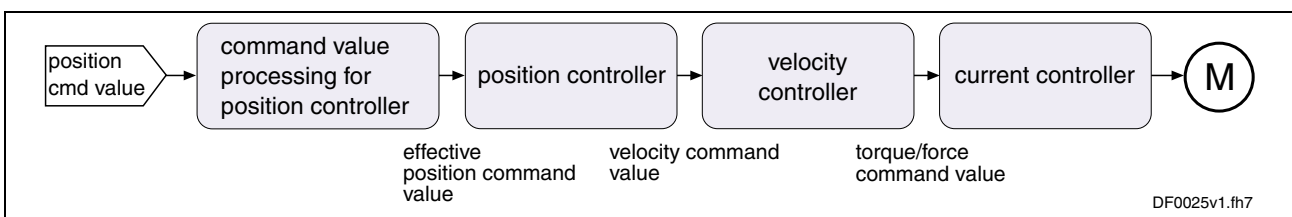
Fig. 7-9:   "Position control with cyclic command value input" block diagram

Features
- position control with regard to the command value preset in parameter **S-0-0047, Position command value**

- timebase for cyclic command value input defined by **S-0-0001, NC cycle time (TNcyc)**

- monitoring 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 shape 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 controller clock; can be switched by means of parameter **P-0-0187, Position command processing mode**

- position control with regard to actual position value encoder 1 (motor encoder) or actual position value encoder 2 [external (load-side) encoder], can be dynamically switched

- velocity feedforward through adjustable factor of 0...150 % (default = 100 %)

- acceleration monitor for position command value can be switched on (P-0-0556, bit 15)

Note: The condition for this operating mode is synchronous communication between the control unit and the drive as it is the case with SERCOS interface, for example.

Pertinent Parameters
- **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-0-0099, Position command smoothing time constant**
- **P-0-0187, Position command processing mode**
- **P-0-0434, Position command value controller**
- **P-0-0556, Control word of axis controller**
- **S-0-0047, Position command value**
- **S-0-0091, Bipolar velocity limit value**
- **S-0-0138, Bipolar acceleration limit value**

Pertinent Diagnostic Messages
- **A0102 Position mode with encoder 1**,
- **A0103 Position mode with encoder 2**,
- **A0104 Position mode lagless, encoder 1**,
- **A0105 Position control lagless, encoder 2**
- **F2037 Excessive position command difference**
- **F2039 Maximum acceleration exceeded**

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Command Value Processing in Position Control

Note:	The command value cyclically transmitted by the control unit is displayed in parameter **P-0-0047, Position command value control**.
	The internal position command value at the position controller is displayed in parameter **P-0-0434, Position command value controller**.

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.

Note:	The PT1 filter for jerk limitation that can be parameterized via **P-0-0099, Position command smoothing time constant** only takes effect for linear fine interpolation.

Fine Interpolation of the Position Command Value

The position command value cyclically transmitted in the NC cycle time by the control unit can be fine interpolated in the drive, if necessary.

Via **P-0-0187, Position command processing mode** it is possible to switch between

- cubic fine interpolator (according to contour),
- linear fine interpolator or
- cubic approximator.

🛈 See also Parameter Description "P-0-0187, Position command processing mode"

Note:	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.
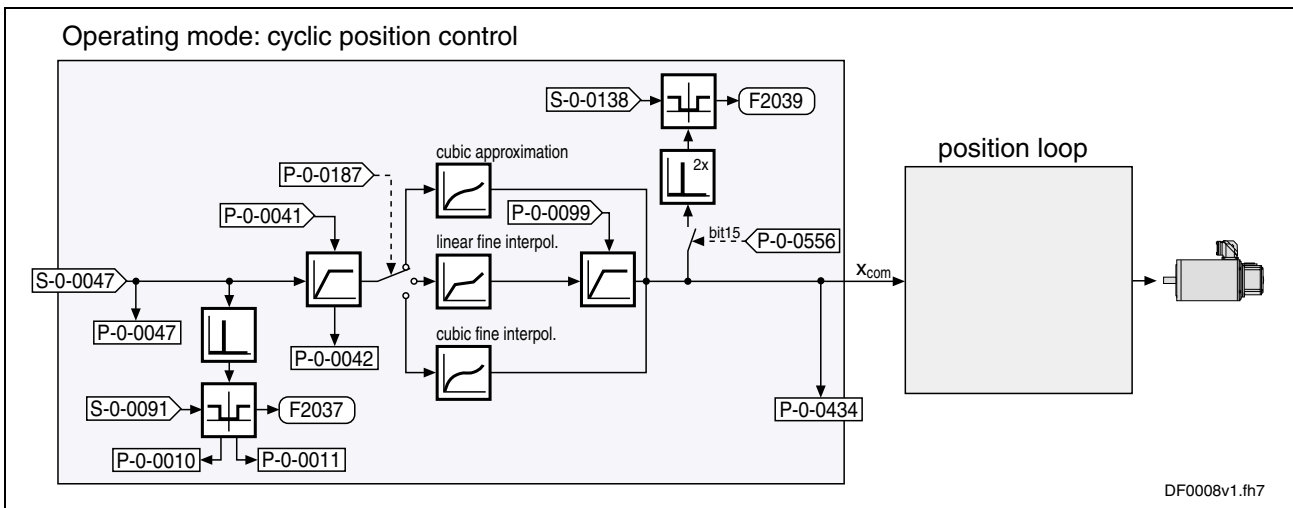
Fig. 7-10:   Command value processing in position control

See also below "Position Controller"

See also below "Velocity Controller" in section "Velocity Control"

See also below "Current Controller" in section "Torque/Force Control"

Position Controller

The position controller is a simple P-controller, its proportional gain can be set with the value of **S-0-0104, Position loop Kv-factor**.

See also figure "Overall structure of control loops" in chapter "Drive Control"

Controller Performance and Cycle Times

According to the available performance design, the position control loop is closed every **250 μs** (advanced) or **500 μs** (basic) (see P-0-0556, bit 2).

According to the application it is possible to set via bit 3 of the operating mode parameters (S-0-0032 to S-0-0035):

- lagless operation
  (<u>with</u> velocity feedforward)

- operation with lag error
  (<u>without</u> velocity feedforward)

The lag error is the difference between position command value and actual position value. The current value is stored in parameter **S-0-0189, Following distance**.

Note: If the mechanical system and the application permit it, lagless operation should always be selected.

Possibilities of Feedforward

In lagless operation variable acceleration feedforward can be activated in addition to variable velocity feedforward (**P-0-0040, Velocity feedforward evaluation**).

To do this, the acceleration-proportional feedforward component (additive current command value) is set via parameter **S-0-0348, Acceleration feedforward gain** and the velocity-proportional feedforward component

(additive velocity command value) is set via **P-0-0040, Velocity feedforward evaluation**.

This allows setting the lag error to a desired percentage value at constant velocity.

Note:	In lagless operation and with P-0-0040 = 100%, there is a minimum lag error of "0" at constant velocity.

See also "Axis Control (Closed-Loop Operation)" in chapter "Drive Control"

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 with encoder 1**,
- **A0103 Position mode with encoder 2**,
- **A0104 Position mode lagless, encoder 1**,
- **A0105 Position control lagless, encoder 2**

Monitoring Functions

Operating mode-specific monitoring functions/diagnostic messages are:

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 checked for plausibility.

Reasons why the monitoring function triggers:

- incorrect command values by control unit
- command value transmission error

Note:	In the case of single command value failure, the position command value is extrapolated.

Excessive Position Command Difference

F2037 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 **F2037 Excessive position command difference** error message is generated. In addition, the tow 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.
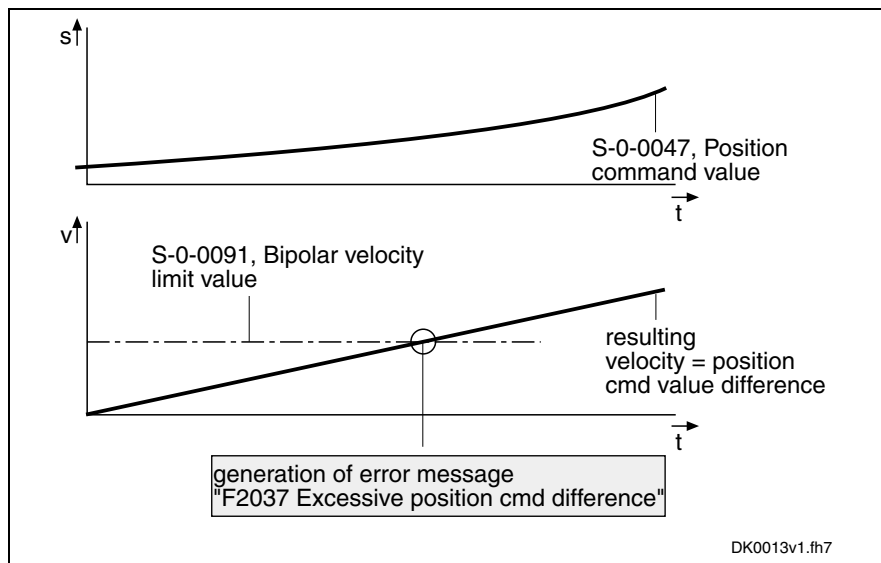
Fig. 7-11:   Monitoring for error **F2037 Excessive position command difference**

Note: The value entered in parameter **S-0-0091, Bipolar velocity limit value** should be approximately 5 to 10 % above the intended maximum velocity of the axis.

Maximum Acceleration Exceeded

F2039 Maximum acceleration exceeded

In parameter **P-0-0556, Control word of axis controller** (bit 15) it is possible to set that the command acceleration is monitored for compliance with **S-0-0138, Bipolar acceleration limit value**. When the value of S-0-0138 is exceeded, the **F2039 Maximum acceleration exceeded** error message is generated.

7.5   Drive-Internal Interpolation

Base package of all variants in **closed-loop** characteristic

Brief Description

The operating modes "drive-internal interpolation" and "drive-controlled positioning" allow time-optimized positioning of a single axis. The "drive-internal interpolation" mode is the basis for the more comprehensive functionality of the "drive-controlled positioning" mode.

In the "drive-internal interpolation" mode, a target position is directly preset for the drive. In the internal positioning generator a position command value characteristic is generated (interpolated), from the preset value for the target position considering preset positioning data (velocity, acceleration and jerk), as the input value for the position loop.

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There are different forms of the "drive-internal interpolation" mode which result in the corresponding diagnostic messages when the operating mode was activated (see "Pertinent Diagnostic Messages").
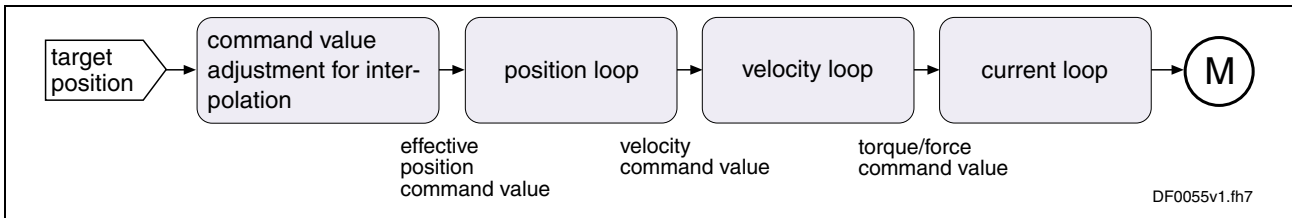
Fig. 7-12:   "Drive-internal interpolation" block diagram

Features

- drive-internal generation of a position command value profile for moving to the target position (S-0-0258) complying with the adjustable positioning velocity (S-0-0259) and positioning acceleration (S-0-0260) or positioning deceleration (S-0-0359); can be set separately

- jerk limitation of the generated position command value via **S-0-0193, Positioning Jerk**

- evaluation of the positioning velocity with **S-0-0108, Feedrate override**

- monitoring the positioning velocity for exceeding **S-0-0091, Bipolar velocity limit value**

- monitoring the target position for maintaining position limit values

- command value mode in modulo format (shortest distance, only positive or only negative direction) can be set in **S-0-0393, Command value mode**

- position control with regard to **S-0-0051, Position feedback 1 value** (motor encoder) or **S-0-0053, Position feedback 2 value** [external (load-side) encoder]

- acceleration and deceleration ramps can be set separately

- no change in direction of movement when command value mode in modulo format equal "shortest distance", if v_{act} > S-0-0417

- shortest distance when "command value mode in modulo format" equal "only positive/negative direction of movement" and target position within **S-0-0418, Target position window in modulo format**

Note: In this operating mode it is possible to separately parameterize the acceleration and deceleration processes. This allows optimum adjustment to the respective application-specific requirements.

Pertinent Parameters

- **S-0-0108, Feedrate override**
- **S-0-0193, Positioning jerk**
- **S-0-0258, Target position**
- **S-0-0259, Positioning Velocity**
- **S-0-0260, Positioning Acceleration**
- **S-0-0342, Target position reached**
- **S-0-0343, Status "Interpolator halted"**
- **S-0-0359, Positioning Deceleration**

- S-0-0393, **Command value mode**
- S-0-0417, **Velocity threshold for positioning in modulo format**
- S-0-0418, **Target position window in modulo format**
- S-0-0430, **Effective target position**
- S-0-0437, **Positioning status word**
- P-0-0434, **Position command value controller**

Pertinent Diagnostic Messages

- **A0106 Drive controlled interpolation, encoder 1**
- **A0107 Drive controlled interpolation, encoder 2**
- **A0108 Drive controlled interpolation, lagless, encoder 1**
- **A0109 Drive controlled interpolation, lagless, encoder 2**
- **E2047 Interpolation velocity = 0**
- **E2048 Interpolation acceleration = 0**
- **E2049 Positioning velocity >= S-0-0091**
- **E2053 Target position out of travel range**
- **E2055 Feedrate-override S-0-0108 = 0**

Command Value Processing with Drive-Internal Interpolation

The target position can be cyclically preset via parameter **S-0-0258, Target position**.

The drive generates the position command value profile necessary to move to the target position, considering the requirements defined in the following parameters:

- **S-0-0259, Positioning Velocity**
- **S-0-0260, Positioning Acceleration**
- **S-0-0359, Positioning Deceleration**
- **S-0-0193, Positioning Jerk**
- **S-0-0108, Feedrate override**

Note: The target position preset by the master is displayed in parameter P-0-0050.
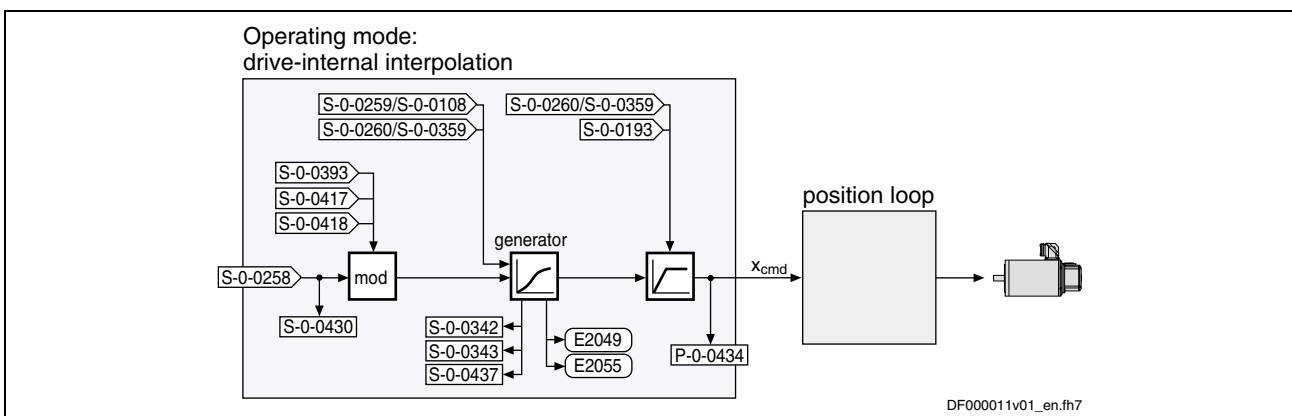
Fig. 7-13:   Command value processing with "drive-internal interpolation"

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Position Loop with Drive-Internal Interpolation

The position command value generated at the output of the command value generator is displayed in parameter **P-0-0434, Position command value controller** and can be output at the analog output.

In this operating mode, the same information as relevant in the "position control with cyclic command value input" mode applies to the position control loop.

See also figure "Overall structure of control loop" in chapter "Drive Control"

See also "Position Loop" in section "Position Control with Cyclic Command Value Input"

Notes on Commissioning

Effective Positioning Velocity

The drive reaches its maximum velocity after an acceleration phase with the value set in parameter **S-0-0260, Positioning Acceleration**.

The maximum velocity during a positioning procedure is the result of:

$$V_{max} = S-0-0259, \text{Positioning Velocity} * \frac{S-0-0108, \text{Feedrate override}}{100\%}$$

Effective Acceleration and Deceleration

The maximum deceleration is defined in parameter **S-0-0359, Positioning Deceleration**.

If the value in parameter **S-0-0359, Positioning Deceleration** equals zero, the drive uses the parameter value of **S-0-0260, Positioning Acceleration** for deceleration as well.

⚠ **CAUTION**

Property damage caused by incorrect parameterization!

If the values for positioning deceleration and acceleration are zero, the drive cannot brake. The preset target is never reached or is overrun.

⇒ Always enter a value > 0 for positioning acceleration!

Smoothing Filter (or Jerk Filter)

In the "drive-internal interpolation" mode the position command value can be filtered at the output of the positioning generator. The filter order of the (moving) average filter available to do this (cf. P-0-0041 and P-0-0042) is calculated on the basis of the preset positioning acceleration or the positioning jerk.

This means that the parameterized acceleration or deceleration only become effective after t = P-0-0042 * $T_{A,position}$.

Note: 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).

$$P-0-0042 = \frac{S-0-0260, \text{Positioning Acceleration}}{S-0-0193, \text{Positioning Jerk}}$$

- or -

$$P-0-0042 = \frac{S-0-0359, \text{Positioning Deceleration}}{S-0-0193, \text{Positioning Jerk}}$$

Note: S-0-0193 = 0 switches the smoothing filter off; i.e. the desired acceleration or deceleration is immediately reached.

Modulo Processing

The **S-0-0393, Command value mode** parameter controls the drive behavior in the case of **position processing in modulo format**. For S-0-0393 the following definition applies:

- bit 1/0 = 00: positive direction of rotation

- bit 1/0 = 01: negative direction of rotation

- bit 1/0 = 10: shortest path

$\boxed{\mathbf{i}}$ See also Parameter Description "S-0-0393, Command value mode"

Special Cases   The following special cases apply for evaluating the settings for parameter S-0-0393:

- If the absolute value of the current actual velocity is greater than the velocity threshold for positioning (**S-0-0417, Velocity threshold for positioning in modulo format**), the drive always moves in the last active direction of rotation.

- If the target position is within the target position window (S-0-0418), positioning is always carried out according to the "shortest path" mode.

Note: 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.

$\boxed{\mathbf{i}}$ See also Parameter Description "S-0-0417, Velocity threshold for positioning in modulo format", "S-0-0418, Target position window in modulo format" and "P-0-0050, Effective target position"

Diagnostic Messages and Monitoring Functions

Diagnostic Status Messages

The activated "drive-internal interpolation" mode is displayed by one of the following diagnostic messages:

- **A0106 Drive controlled interpolation, encoder 1**
- **A0107 Drive controlled interpolation, encoder 2**
- **A0108 Drive controlled interpolation, lagless, encoder 1**
- **A0109 Drive controlled interpolation, lagless, encoder 2**

Monitoring Functions

Operating mode-specific monitoring functions are:

E2053 Target position out of travel range

- If position limit value monitoring is activated (bit 4 of **S-0-0055, Position polarities** is set) and the measurement system used for the operating mode has been homed, the parameter **S-0-0258, Target position** is monitored for complying with the position limit values (S-0-0049 or S-0-0050). If these values are exceeded, the **E2053 Target position out of travel range** warning is generated.

  The preset target position will not be accepted.

E2047 Interpolation velocity = 0

- If the positioning velocity preset in **S-0-0259, Positioning Velocity** equals zero, the **E2047 Interpolation velocity = 0** warning is generated.

E2048 Interpolation acceleration = 0

- If the positioning velocity preset in **S-0-0260, Positioning Acceleration** equals zero, the **E2048 Interpolation acceleration = 0** warning is generated.

E2049 Positioning velocity >= S-0-0091

- If the preset positioning velocity (**S-0-0259, Positioning Velocity**) exceeds the maximum allowed limit value (**S-0-0091, Bipolar velocity limit value**), the **E2049 Positioning velocity >= S-0-0091** warning is generated.

  The drive will move to the new target position with the velocity from parameter **S-0-0091, Bipolar velocity limit value**.

E2055 Feedrate override S-0-0108 = 0

- If the factor of the positioning velocity **S-0-0108, Feedrate override** equals zero, the **E2055 Feedrate override S-0-0108 = 0** warning is generated.

Status Messages

The **S-0-0437, Positioning status word** parameter contains all important status information for this "drive-internal interpolation" mode.

![i] See Parameter Description "S-0-0437, Positioning status word"

The figures below illustrate the operating principle of the status messages:
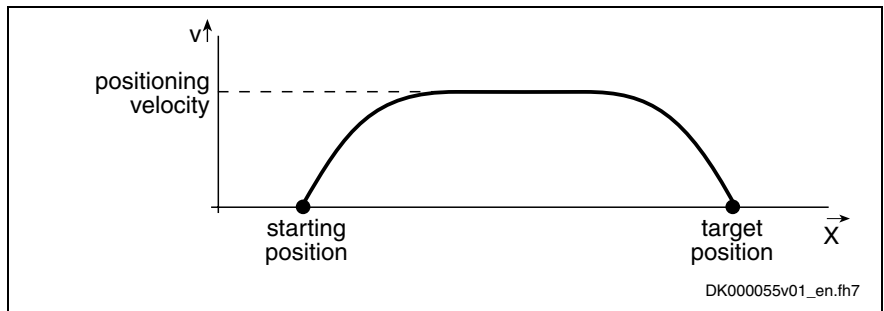
Fig. 7-14:   Travel profile to explain how the interpolation status messages work

In this example, the drive is at the starting position when the new target position is preset.

The result is the following time diagram:
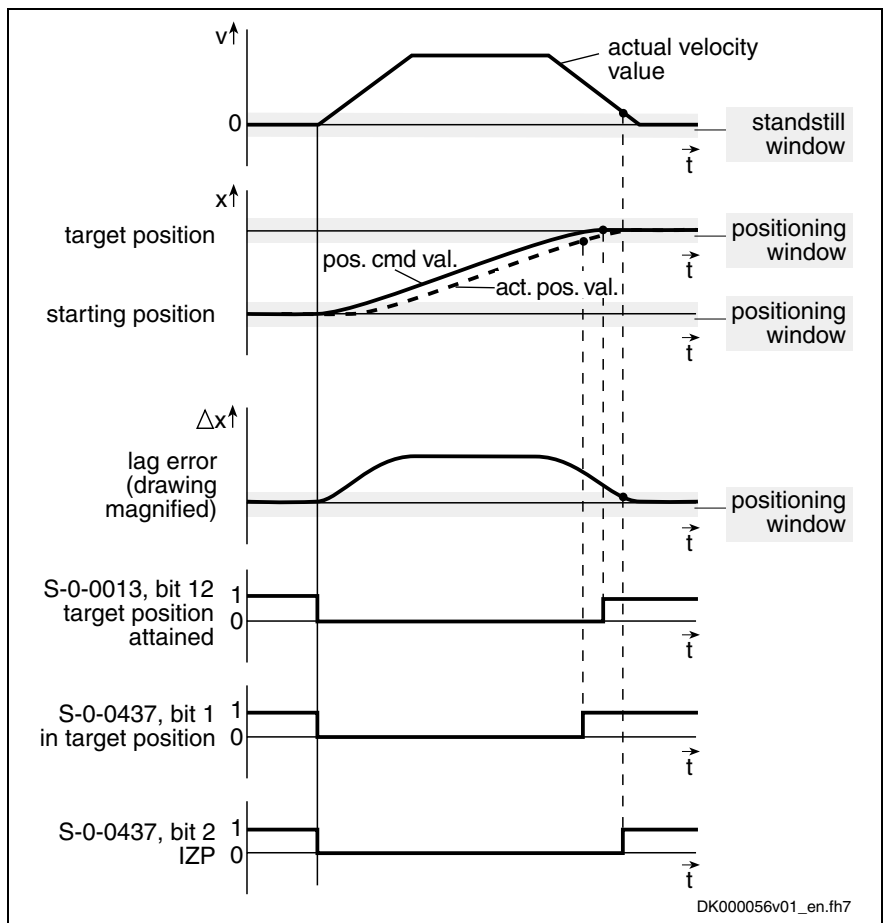
Fig. 7-15:   Generating the status bits of the operating modes with drive-internal interpolation

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7.6 Drive-Controlled Positioning

Base package of all variants in **closed-loop** characteristic

Brief Description

The operating modes "drive-internal interpolation" and "drive-controlled positioning" allow time-optimized positioning of a single axis. The "drive-internal interpolation" mode is the basis for the more comprehensive functionality of the "drive-controlled positioning" mode.

In the "drive-controlled positioning" mode a positioning command value is preset for the drive. The drive can continue processing this value internally in absolute (position target) or relative (travel distance) form. In the internal interpolator, a position command value characteristic is generated as the input value for the position loop from the preset positioning data (effective target position, velocity, acceleration and jerk).

There are different forms of the "drive-controlled positioning" mode which result in the corresponding diagnostic messages when the operating mode was activated (see "Pertinent Diagnostic Messages").
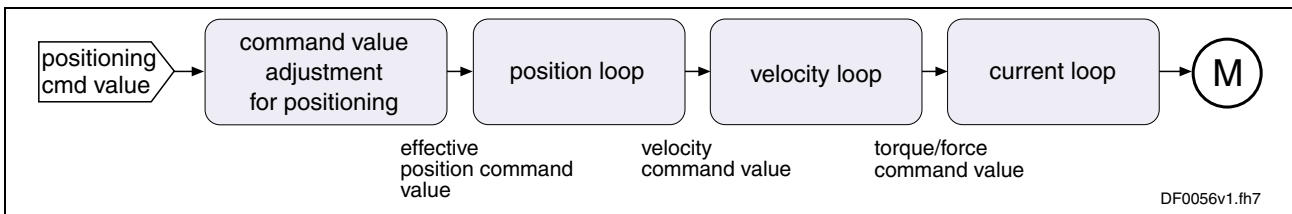
Fig. 7-16: "Drive-controlled positioning" block diagram

Features
- processing of an absolute target position or a relative travel distance
- drive-internal generation of a position command value profile for moving to the target position (S-0-0258) specified by parameter **S-0-0282, Positioning command value**, complying with the adjustable positioning velocity (S-0-0259) and positioning acceleration (S-0-0260) or positioning deceleration (S-0-0359); can be set separately
- edge-controlled acceptance of the positioning command value via toggle bit (S-0-0346, bit 0)
- jerk limitation of the generated position command value with parameter **S-0-0193, Positioning Jerk**
- evaluation of the positioning velocity with parameter **S-0-0108, Feedrate override**
- monitoring the positioning velocity for exceeding parameter **S-0-0091, Bipolar velocity limit value**
- monitoring the target position for observing the position limit values (cf. **S-0-0049, Positive position limit value**, **S-0-0050, Negative position limit value**)
- command value mode can be set in modulo format in parameter **S-0-0393, Command value mode** (shortest distance, positive only or negative only direction, no reversal of direction of rotation)
- position control with regard to **S-0-0051, Position feedback 1 value** (motor encoder) or **S-0-0053, Position feedback 2 value** [external (load-side) encoder]

- acceleration and deceleration ramps can be set separately (**S-0-0260, Positioning acceleration** or **S-0-0359, Positioning deceleration**)
- considering position limit values when accepting target position, positioning velocity and positioning acceleration
- infinite travel positive or negative
- residual path processing can be activated
- "on-the-fly acceptance" of the new target position or intermediate stop

---

Note: In this operating mode it is possible to separately parameterize the acceleration and deceleration processes in order to achieve optimum adjustment to the respective application-specific requirements.

Pertinent Parameters

- **S-0-0108, Feedrate override**
- **S-0-0193, Positioning Jerk**
- **S-0-0258, Target position**
- **S-0-0259, Positioning Velocity**
- **S-0-0260, Positioning Acceleration**
- **S-0-0282, Positioning command value**
- **S-0-0342, Target position reached**
- **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, Velocity threshold for positioning in modulo format**
- **S-0-0418, Target position window in modulo format**
- **S-0-0419, Positioning command acknowledge**
- **S-0-0430, Effective target position**
- **S-0-0437, Positioning status word**
- **P-0-0434, Position command value controller**

Pertinent Diagnostic Messages

- **A0150 Drive controlled positioning, encoder 1**
- **A0151 Drive controlled positioning, encoder 1, lagless**
- **A0152 Drive controlled positioning, encoder 2**
- **A0153 Drive controlled positioning, encoder 2, lagless**
- **E2047 Interpolation velocity = 0**
- **E2048 Interpolation acceleration = 0**
- **E2049 Positioning velocity >= S-0-0091**
- **F2050 Overflow of target position preset memory**
- **E2053 Target position out of travel range**
- **E2055 Feedrate-override S-0-0108 = 0**
- **E2064 Target position out of num. range**

Command Value Processing with Drive-Controlled Positioning

Overview
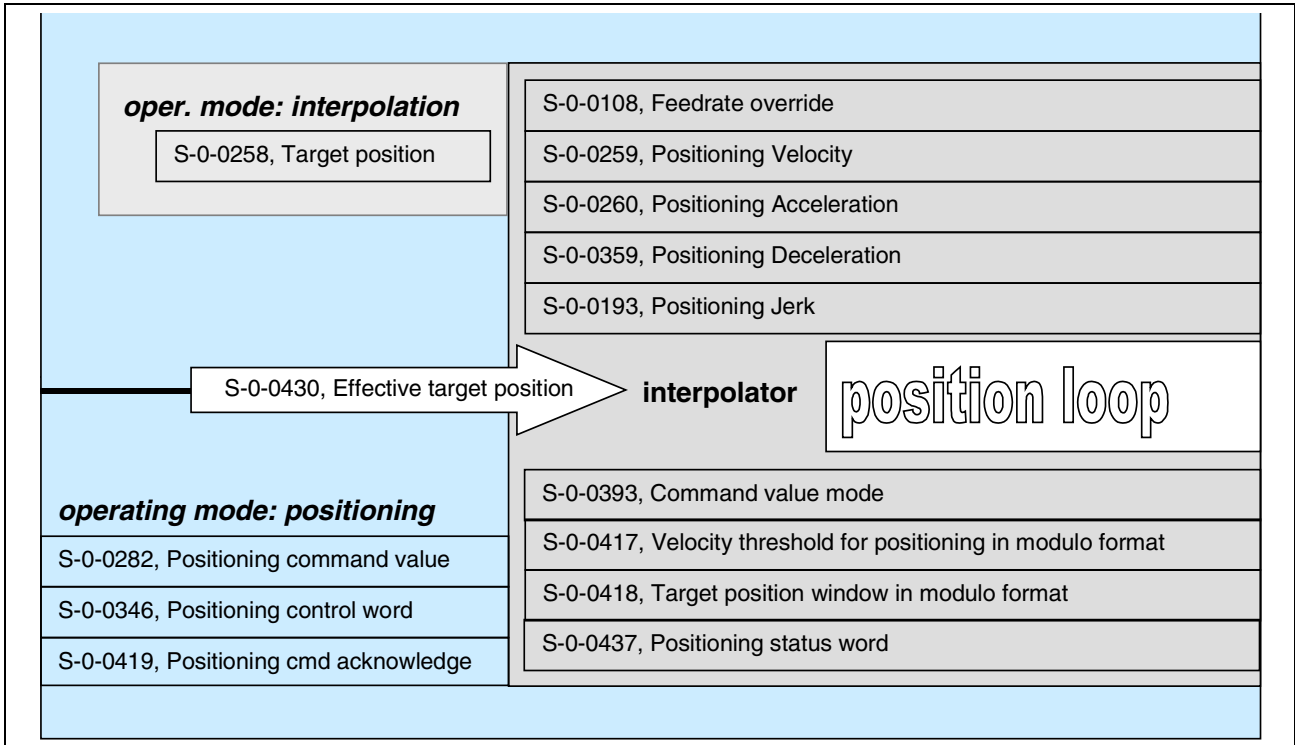
Fig. 7-17:   Parameters of command value adjustment with drive-controlled positioning
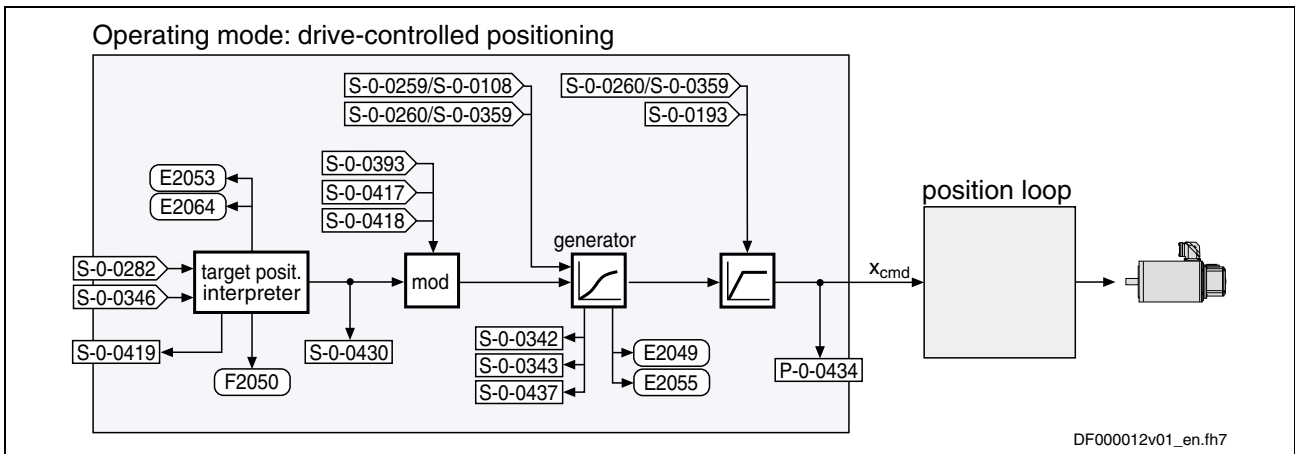
Fig. 7-18:   Command value processing with drive-controlled positioning

Position Target Interpreter

Accepting and Acknowledging the Command Value

The acceptance and internal processing of **S-0-0282, Positioning command value** to a value entered in parameter **S-0-0430, Effective target position** is controlled via **S-0-0346, Positioning control word**.

At each edge of bit 0 (toggle bit) of S-0-0346 the content of **S-0-0282, Positioning command value**, depending on bit 3 of S-0-0346, is

- **copied to** parameter S-0-0430
  (when bit 3 = 0 → absolute **target position**)

- or -

- **added** to the value of S-0-0430
  (when bit 3 = 1 → **travel distance**).

Note: If a positioning process is aborted by switching bits 1 and 2 of S-0-0346 from status "00" to "01", "10" or "11", a 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.

The drive acknowledges the acceptance of the positioning command value via **S-0-0419, Positioning command acknowledge** (bit 0). This allows realizing a data handshake for monitoring the command value acceptance between master and drive.

Note: The active target position is displayed in parameter **S-0-0430, Effective target position**.
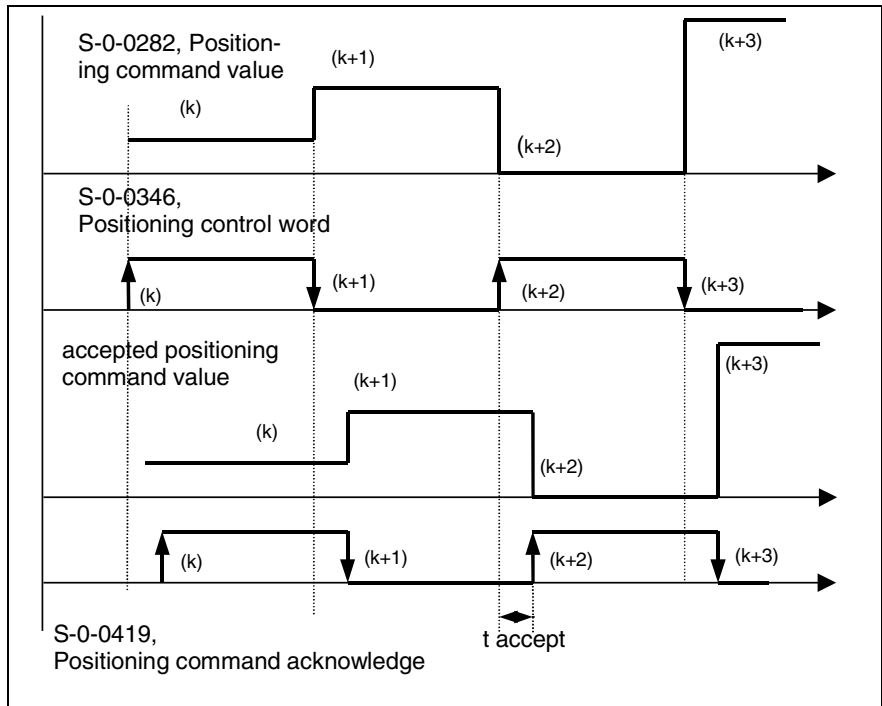
Fig. 7-19:   Positioning command value acceptance and acknowledgment

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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 and actual values and thus depends on the configuration of the interface to the master (e.g. SERCOS/field bus timing parameter).

Note: If the "drive-controlled positioning" mode is not yet active, the acknowledgment of acceptance of the new positioning command value does not take place.

If bit 0 of S-0-0346 is unequal bit 0 of S-0-0419 while the operating mode is active, the positioning command value from S-0-0282 is immediately accepted and the drive immediately moves to this command value.

The acknowledgment of acceptance takes place when the new positioning command value is accepted from the intermediate memory into parameter **S-0-0430, Effective target position** and thus into the position command value generator.
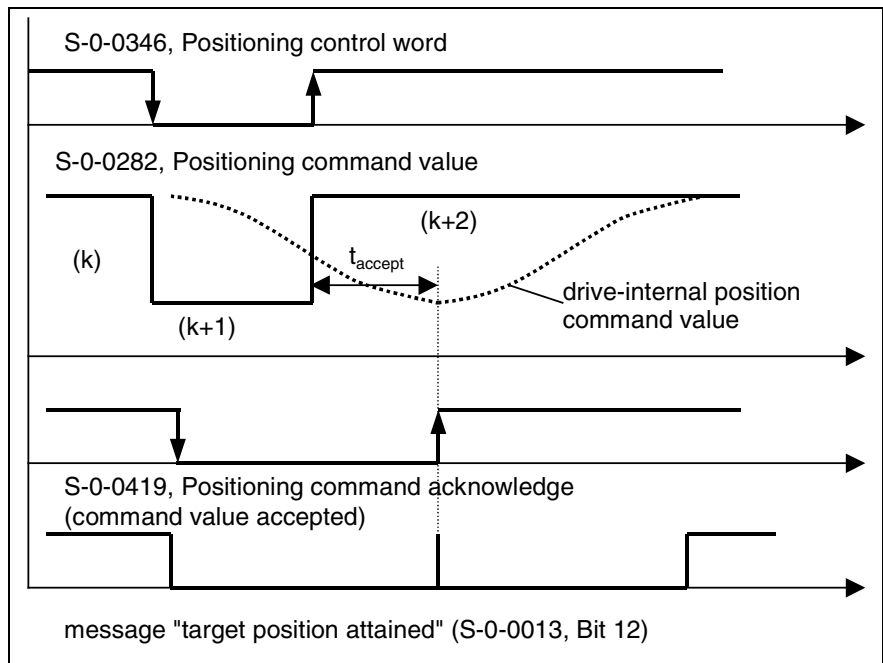
Fig. 7-20: Acknowledgment of positioning command value acceptance in mode "complete move to positioning command value (k+2)"

Acknowledgment with Error "Overflow of target position preset memory"

When trying, in the "complete move to positioning command value" mode, to preset a new positioning command value by toggling parameter **S-0-0346, Positioning control word** although the previous positioning command value (k+1) was not accepted (because the drive had not yet moved to the previous positioning command value (k)), the **F2050 Overflow of target position preset memory** error message is generated.
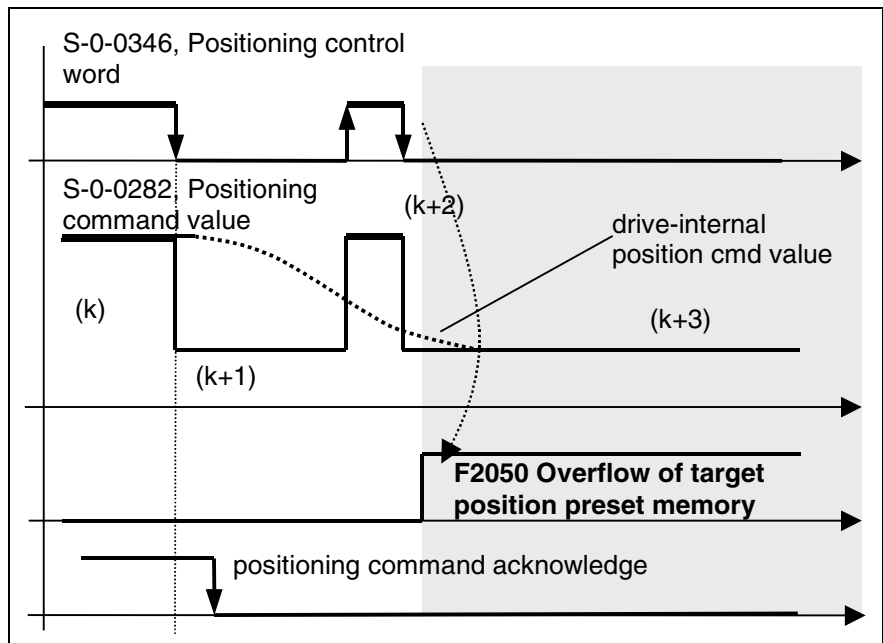
Fig. 7-21: Acknowledgment with error "Overflow of target position preset memory"

Apart from bit 0 for mere block acceptance, the **S-0-0346, Positioning control word** parameter contains further control bits which are explained below.

Positioning Modes to be Selected

Different positioning modes can be defined via bit 1 and bit 2 of S-0-0346:

- **"infinite travel"** (jogging 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

Note: Bit 4 takes effect with every new travel job (edge on bit 0). Residual path processing is only carried out, during the first positioning process after the operating mode was activated, when the position status has been set and bit 2 = 1 in parameter P-0-4060. In this case the residual path, after the operating mode was activated, is traveled without start edge.

Reaction to New Target Position Preset

Via bit 5 of S-0-0346 it is possible to determine the time of the reaction to a new target position preset:

- **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

$\boxed{\mathbf{i}}$ See also Parameter Description "S-0-0346, Positioning control word"

Processing in Modulo Format

The **S-0-0393, Command value mode** parameter controls the drive behavior in the case of **position processing in modulo format**. For S-0-0393 the following definition applies:

- bit 1/0 = 00: positive direction of rotation
- bit 1/0 = 01: negative direction of rotation
- bit 1/0 = 10: shortest distance

$\boxed{\mathbf{i}}$ See also Parameter Description "S-0-0393, Command value mode"

Special Cases

The following special cases apply for evaluating 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, Velocity threshold for positioning in modulo format**), the drive always moves in the last active direction of rotation.

- If the target position is within the target position window (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

Note: 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.

$\boxed{\mathbf{i}}$ See also Parameter Description "S-0-0417, Velocity threshold for positioning in modulo format" and "S-0-0418, Target position window in modulo format" 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**

Position Loop with Drive-Controlled Positioning

The position command value generated at the output of the command value generator is displayed in parameter **P-0-0434, Position command value controller** and can be output at the analog output.

In this operating mode, the same information as relevant in the "position control with cyclic command value input" mode applies to the position control loop.

See also figure "Overall structure of control loop" in chapter "Drive Control"

See also "Position Loop" in section "Position Control with Cyclic Command Value Input"

Notes on Commissioning

Effective Positioning Velocity

The drive reaches its maximum velocity after an acceleration phase with the value set in parameter **S-0-0260, Positioning Acceleration**.

The maximum velocity during a positioning procedure is the result of:

$$V_{max} = S-0-0259, \text{Positioning Velocity} * \frac{S-0-0108, \text{Feedrate override}}{100\%}$$

Effective Acceleration and Deceleration

The maximum deceleration is defined in parameter **S-0-0359, Positioning Deceleration**.

If the value in parameter **S-0-0359, Positioning Deceleration** equals zero, the drive uses the parameter value of **S-0-0260, Positioning Acceleration** for deceleration as well.

⚠ **CAUTION**

Property damage caused by incorrect parameterization!

If the values for positioning deceleration and acceleration are zero, the drive cannot brake. The preset target is never reached or is overrun.

⇒ Always enter a value > 0 for positioning acceleration!

Smoothing Filter (or Jerk Filter)

In the "drive-controlled positioning" mode the position command value can be filtered at the output of the positioning generator. The filter order of the (moving) average filter available to do this (cf. P-0-0041 and P-0-0042) is calculated on the basis of the preset positioning acceleration or the positioning jerk.

This means that the parameterized acceleration or deceleration only become effective after $t = P-0-0042 * T_{A,position}$.

> **Note:** 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).

$$P-0-0042 = \frac{S-0-0260, \text{Positioning Acceleration}}{S-0-0193, \text{Positioning Jerk}}$$

or

$$P-0-0042 = \frac{S-0-0359, \text{Positioning Deceleration}}{S-0-0193, \text{Positioning Jerk}}$$

> **Note:** S-0-0193 = 0 switches the smoothing filter off; i.e. the desired acceleration or deceleration is immediately reached.

Command Value Mode in Modulo Format

Positive/Negative Direction of Movement

If modulo format was selected for displaying position data (infinitely turning axes) and "positive/negative direction of movement" was set in **S-0-0393, Command value mode**, the drive moves to the preset target position in the programmed direction.

Via parameter **S-0-0418, Target position window in modulo format** it is possible to set the distance from which on it is the "shortest distance" that is traveled from actual position value to target position.

"Positive Direction" and Target Position Outside S-0-0418, 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 the target position window (S-0-0418).

- **Case 1:**
  current velocity positive and braking distance greater than the distance between starting position and next target position
  → drive moves to next possible target position

- **Case 2:**
  current velocity positive and braking distance smaller than the distance between starting position and next target position
  → drive moves to next possible target position

- **Case 3:**
  current velocity negative
  → drive brakes to velocity = 0 and positions at next target in positive direction

"Positive Direction" and Target Position Within S-0-0418, 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 within the target position window (S-0-0418).

- **Case 4:**
  current velocity positive and braking distance greater than the distance between starting point and next target point
  → drive moves to next possible target position in positive direction
  Braking and moving back would lead to a movement in negative

direction greater than the programmed target position window!
The following applies to the braking procedure:
starting position + braking distance – target position **> S-0-0418**
→ positioning in negative direction not allowed; i.e. drive must move to target in positive direction

- **Case 5:**
  current velocity = 0
  → drive moves to target position in negative direction
  The following applies to the braking procedure:
  starting position + braking distance – target position **< S-0-0418**
  → positioning in negative direction allowed; i.e. drive must move to target in negative direction

- **Case 6:**
  current velocity negative and braking distance smaller than the difference between starting position and next target position
  → drive directly moves to target position in negative direction
  The following applies to the braking procedure:
  starting pos. + braking distance (negative) – target position **< S-0-0418**
  → positioning in negative direction directly at target position

- **Case 7:**
  current velocity negative and braking distance greater than the difference between starting position and next target position
  → drive brakes to zero and positions at next target position in positive direction
  The following applies to the braking procedure:
  starting pos. + braking distance (negative) – target position **> S-0-0418**
  → drive brakes to zero and positions positively at next target position

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Note: 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.

Note: Depending on **S-0-0417, Velocity threshold for positioning in modulo format**, the drive moves with or without reversal of direction.

"Shortest Distance" with Different Velocities   The following examples show the behavior of the drive in the "shortest distance" mode with different velocities.

- **Case 8:**
  current velocity positive and **> S-0-0417**; braking distance greater than the distance between starting position and next target position
  → drive moves to target position, that can be reached <u>without reversal of direction</u>, 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 the distance between starting position and next target position
  → drive moves to next target position
  The following applies to the braking procedure:
  starting position + braking distance – target position **< S-0-0418**
  → positioning in negative direction allowed; i.e. drive must move to target in negative direction

- **Case 10:**
  current velocity (negative) **< S-0-0417**
  braking distance smaller than distance between starting position and next target position
  → drive moves to next target position
  The following applies to the braking procedure:
  starting pos. + 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 pos. + braking distance (now negative) – target position
  > S-0-0418
  → drive positions negatively at next target position

Note: 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 the 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 the distance between starting position and next target position
  → drive brakes to zero and changes direction in order to move to the next target position

Diagnostic Messages and Monitoring Functions

Diagnostic Status Messages

The activated "drive-controlled positioning" mode is displayed by one of the following diagnostic messages:

- **A0150 Drive controlled positioning, encoder 1**
- **A0151 Drive controlled positioning, encoder 1, lagless**
- **A0152 Drive controlled positioning, encoder 2**
- **A0153 Drive controlled positioning, encoder 2, lagless**

Monitoring Functions

Operating mode-specific monitoring functions are:

E2053 Target position out of travel range

- If position limit value monitoring is activated (bit 4 of **S-0-0055, Position polarities** is set) and the measurement system used for the operating mode has been homed, the parameter **S-0-0258, Target position** is monitored for complying with the position limit values (S-0-0049 or S-0-0050). If these values are exceeded, the **E0253 Target position out of travel range** warning is generated.

  The preset target position will not be accepted.

E2047 Interpolation velocity = 0

- If the positioning velocity preset in **S-0-0259, Positioning Velocity** equals zero, the **E2047 Interpolation velocity = 0** warning is generated.

E2048 Interpolation acceleration = 0

- If the positioning velocity preset in **S-0-0260, Positioning Acceleration** equals zero, the **E2048 Interpolation acceleration = 0** warning is generated.

E2049 Positionier-Geschwindigkeit >= S-0-0091

- If the preset positioning velocity (**S-0-0259, Positioning Velocity**) exceeds the maximum allowed limit value (**S-0-0091, Bipolar velocity limit value**), the **E2049 Positioning velocity >= S-0-0091** warning is generated.

  The drive will move to the new target position with the velocity from parameter **S-0-0091, Bipolar velocity limit value**.

E2055 Feedrate-override S-0-0108 = 0

- If the factor of the positioning velocity **S-0-0108, Feedrate override** equals zero, the **E2055 Feedrate-override S-0-0108 = 0** warning is generated.

E2064 Target position out of num. range

- If the internal numeric range of the position data is exceeded due to continuous relative positioning, the warning **E2064 Target position out of num. range** is generated.

Status Messages

The **S-0-0437, Positioning status word** parameter contains all important status information for this operating mode.

ℹ️ See Parameter Description "S-0-0437, Positioning status word"

The figures below illustrate the operating principle of the status messages:
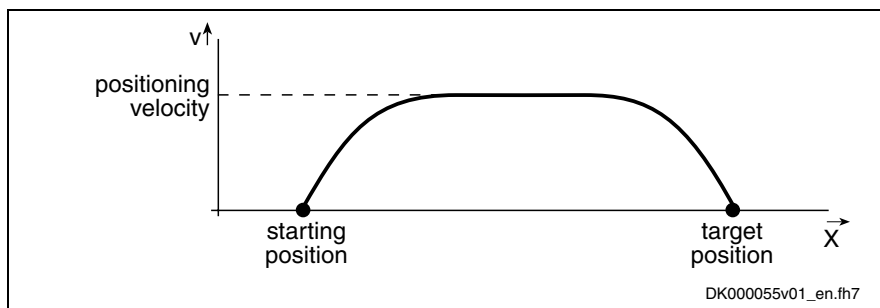
Fig. 7-22:   Travel profile to explain how the interpolation status messages work

In this example, the drive is at the starting position when the new target position is preset.

The result is the following time diagram:
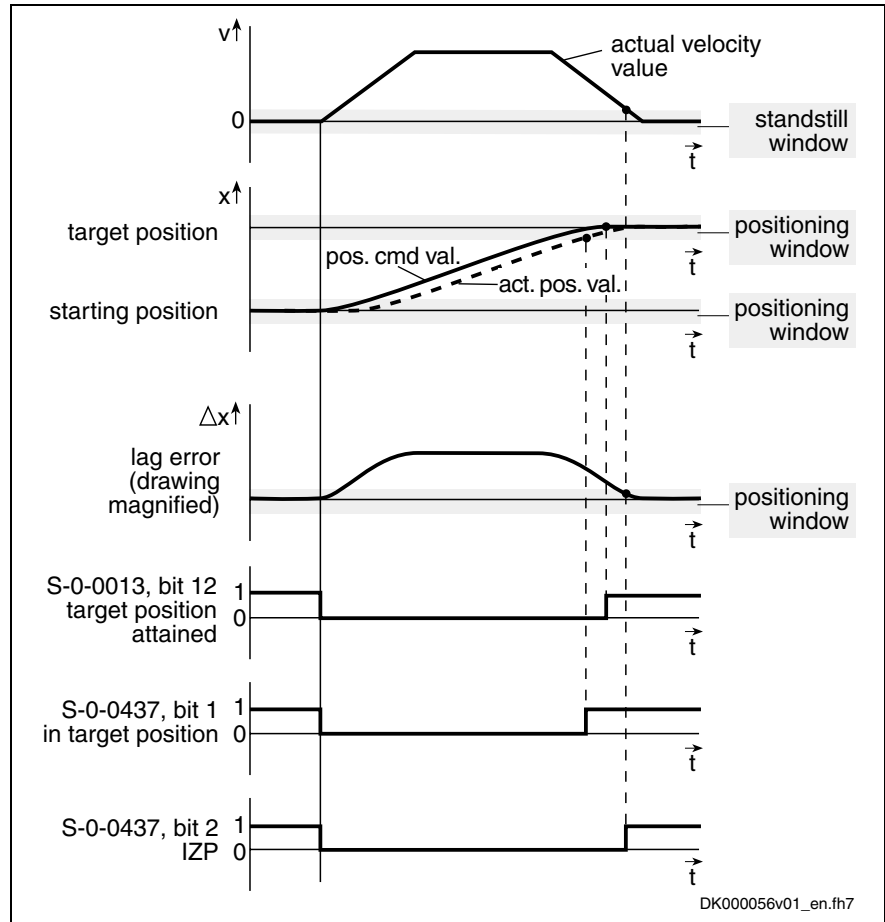
Fig. 7-23:   Generating the status bits of the operating modes with drive-internal interpolation

7.7   Positioning Block Mode

Base package of all variants in **closed-loop** characteristic

Brief Description

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.
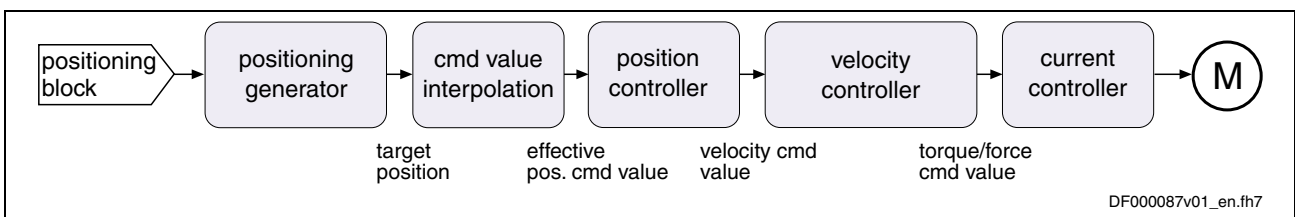
Fig. 7-24:   "Positioning block mode" block diagram

Features

- parameterization of up to 64 positioning blocks; each with target position/travel distance, velocity, acceleration, deceleration and jerk
- defined block acceptance by toggling bit 0 in S-0-0346 with reaction time $t_{R\_Strobe} = t_{position}$

  Note: With field bus drives, the I/O mode and control via the parallel interface are exceptions. In these cases acceptance takes place by a 0-1 edge of bit 0 in P-0-4060.

  - block selection and acknowledgment via separate parameters ($\rightarrow$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 while taking command value mode into account (shortest distance, positive direction, ...)
- residual path processing can be activated ($\rightarrow$ 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 processed in direct sequence without having to give a new start signal each time. Typical fields of application are:

- There is none or only a very simple higher-level control unit available and control is realized via digital I/Os only or a field bus control word (I/O mode with field bus interface).
- There are quick reaction times or block advances required. The required motion profiles can be represented in the drive by the maximum possible 64 positioning blocks.
- There are positioning processes required which cover long distances at high speeds (rapid traverse) and then position at the end position at low speed without any intermediate stops; for example:
  - taking up or putting down transport goods in handling robots
  - execution of joining processes in assembly facilities

Pertinent Parameters

- **S-0-0138, Bipolar acceleration limit value**
- **S-0-0259, Positioning Velocity**
- **S-0-0346, Positioning control word**
- **S-0-0393, Command value mode**
- **S-0-0419, Positioning command acknowledge**
- **S-0-0430, Effective target position**
- **S-0-0437, Positioning status word**

- **P-0-4006, Process block target position**
- **P-0-4007, Positioning block velocity**
- **P-0-4008, Positioning block acceleration**
- **P-0-4009, Positioning block jerk**
- **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**

Note: Parameter S-0-0259 is used in positioning block mode to reduce positioning velocity (see also **P-0-4060, Positioning block control word**).

Pertinent Diagnostic Messages

- **A0206 Positioning block mode, encoder 1**
- **A0207 Positioning block mode lagless, encoder 1**
- **A0210 Positioning block mode, encoder 2**
- **A0211 Positioning block mode lagless, encoder 2**
- **E2047 Interpolation velocity = 0**
- **E2048 Interpolation acceleration = 0**
- **E2049 Positioning velocity >= S-0-0091**
- **E2053 Target position out of travel range**
- **E2054 Not homed**
- **E2055 Feedrate override S-0-0108 = 0**
- **E2058 Selected process block is not programmed.**
- **E2064 Target position out of num. range**

Command Value Processing in Positioning Block Mode
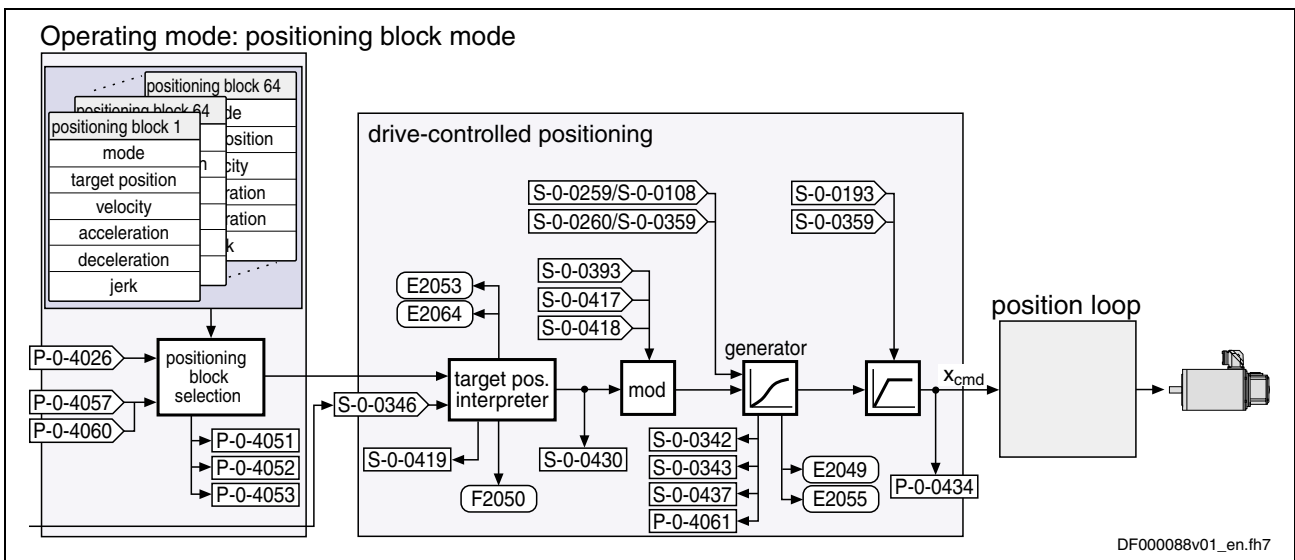
Fig. 7-25:   Command value processing in positioning block mode

Single-Block Processing

Description of Basic Function

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-0-4019, Positioning block mode**
- **P-0-4063, Positioning block deceleration**

Note:	Each parameter contains 64 elements, elements of the same number generate the travel profile of the respective positioning block.

The drive reaches the relevant positioning block velocity after an acceleration phase with the respective positioning block acceleration (P-0-4008).

Effective Positioning Velocity   The effective velocity during a positioning process is calculated as follows:

$$v_{max} = P\text{-}0\text{-}4007 * S\text{-}0\text{-}0108 / 100\%$$

v_{max}:   velocity

P-0-4007:   positioning block velocity

S-0-0108:   feedrate override

Fig. 7-26:   Effective velocity during a positioning process

Effective Acceleration and Deceleration

The maximum deceleration is specified by parameter **P-0-4063, Positioning block deceleration**.

Note:	When P-0-4063 was parameterized with value "0", the warning **E2048 Interpolation acceleration = 0** is generated.

⚠ **CAUTION**	**Property damage!** If the acceleration or deceleration values are equal to zero, the drive can no longer brake. The specified target is never reached or overrun. ⇒ Set acceleration value > 0

Note:	Further limitation takes place by the value of parameter **S-0-0138, Bipolar acceleration limit value** because this limit value takes effect in all operating modes with position control.

Jerk Limitation by Jerk Filter

In the "positioning block" mode the position command value can be filtered at the output of the positioning generator. The filter order of the (moving) average filter available to do this (cf. P-0-0041 and P-0-0042) is calculated on the basis of the preset positioning acceleration or the positioning jerk.

This means that the parameterized acceleration or deceleration only become effective after $t = \text{P-0-0042} * T_{A,position}$.

Note:	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).

$$P - 0 - 0042 = \frac{P\text{-}0\text{-}4008}{P - 0 - 4009}$$

- or -

$$P - 0 - 0042 = \frac{P\text{-}0\text{-}4063}{P - 0 - 4009}$$

Note:	With value equal zero in parameter P-0-4009 the smoothing filter is switched off, i.e. the desired acceleration or deceleration is immediately reached.

Positioning Block Control Word	With parameter **P-0-4060, Positioning block control word** (bit 1) the positioning velocity can be limited to the value defined in parameter **S-0-0259, Positioning Velocity**.
Position Feedback	When a positioning block is completed, bit 4 (end position reached) is set in parameter **P-0-4061, Positioning block status word**.

→ |S-0-0430 – S-0-0051/53| < S-0-0057 && no sequential block

Interrupting a Positioning Block

The positioning block mode can be interrupted by:

*   removing drive enable
*   activating "Drive Halt"
*   changing the operating mode
*   jogging
*   positioning stop or operational stop (S-0-0346, bit 1 and bit 2 = 1)
*   a drive error occurring

Positioning Block Modes

Parameter **P-0-4019, Positioning block mode** is used to define the way in which the target position is processed in parameter **P-0-4006, Positioning block target position**. There are the following options:

*   absolute Positioning
*   relative positioning
*   relative positioning with residual path storage
*   infinite travel in positive/negative direction
*   sequential block processing

ℹ️ See Parameter Description "P-0-4019, Positioning block mode"

Note: It is possible to define an individual positioning mode for each positioning block.

Command Value Mode (S-0-0393)

The parameter **S-0-0393, Command value mode** controls the drive behavior in case "modulo format" was determined 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 is within the target position window in modulo format (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

	Note:	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.

$\boxed{\mathbf{i}}$ See also Parameter Description "S-0-0417, Velocity threshold for positioning in modulo format"

$\boxed{\mathbf{i}}$ See also Parameter Description "S-0-0418, Target position window in modulo format"

Activating Positioning Blocks

Requirements "Positioning block mode" must have been entered as the primary mode of operation.

	Note:	This is done by the respective selection of the active operating mode in the status word, by activating drive enable and by setting "Drive Halt" = 1.

Command Value Acceptance Depending on the master communication, a positioning block is started by:

- toggling bit 0 in parameter **S-0-0346, Positioning control word**

- or -

- 0-1 edge of bit 0 in parameter **P-0-4060, Positioning block control word** with **parallel interface or 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).

	Note:	The block acceptance is confirmed by updating **P-0-4051, Positioning block acknowledgment** and **S-0-0419, Positioning command acknowledge**. In addition, bit 0 of parameter S-0-0346 is toggled internally, too, in the case of a 0-1 edge of bit 0 of parameter P-0-4060.

According to master communication and profile type, the block acceptance requires different configurations in the cyclic command value channel:

- **SERCOS interface**
  - **S-0-0346** 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 freely expandable I/O mode (profile type P-0-4084 = 0xFF82) bit 3 of P-0-4068 is mapped to bit 0 of **P-0-4060**.
    As an alternative, the start in the I/O mode can also take place by setting the start signal (P-0-4068, bit 1).

- **Parallel interface**

  - Bit 0 of **P-0-4060** has to be configured on a digital input (see also "Digital Inputs/Outputs" in chapter "Extended Drive Functions").

See also "Command Value Acceptance" in section "Overview of Operating Modes"

Note: If bit 0 is different in S-0-0346 and in S-0-0419 when the operating mode is activated, the selected positioning block is immediately accepted and executed.

Block Selection

In the positioning block mode, block selection is always carried out via the content of parameter **P-0-4026, Positioning block selection**.

Depending on the master communication, P-0-4026 can be written in different ways:

Configuration of P-0-4026	Master communication		
	SERCOS interface	**Field bus**	**Parallel interface**
via cyclic data channel	X	X	
via digital inputs	X	X	X
via serial interface	X	X	X
via field bus control word		X	

Fig. 7-27:   Possibilities of writing parameter P-0-4026 depending on the master communication

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Note: The assignment of P-0-4026 to digital inputs requires, among other things, the parameters **S-0-0144, Signal status word** and **S-0-0145, Signal control word**.

Absolute Positioning

Parameter Setting
- **P-0-4019, Positioning block mode** = 1h

Definition
In an absolute positioning block, the target position is a fixed (absolute) position within the machine co-ordinate system.

For absolute positioning the drive must have been homed.

Requirements
Requirements for carrying out absolute positioning blocks are:

- The drive must have been homed.

- The travel range can be limited with position limit values. Absolute positioning blocks are only carried out if the target position is within the allowed travel range.

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Example:

Absolute positioning with target position = 700 (current position = 200).
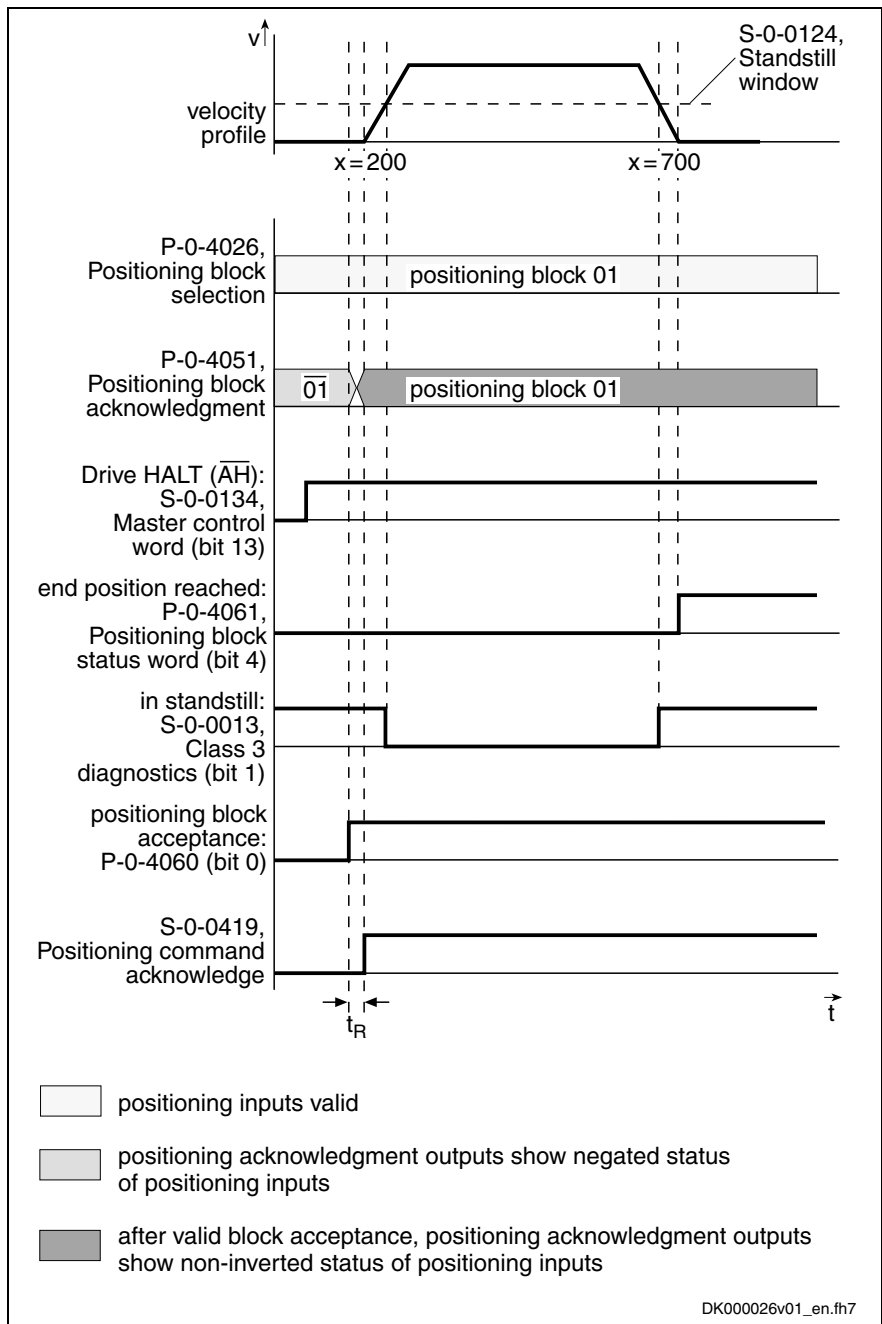
Fig. 7-28: Absolute positioning block

Note: According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Relative Positioning without Residual Path Storage

Parameter Setting

- **P-0-4019, Positioning block mode** = 2h

Reference position

In the case of relative positioning blocks without residual path storage, the target position contained in the positioning block is added to the current position.

Relative positioning blocks are also executed, if the drive has not been homed.

Incremental Dimension Reference

By sequencing relative positioning blocks it is possible to position with incremental dimension. If a relative positioning block without residual path storage is interrupted, the incremental dimension reference gets lost.

If the positioning block is completed (i.e. the drive reaches target position and message "end position reached" is active), positioning is possible without losing the incremental dimension reference.

Note: 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).

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Example:

Relative positioning without residual path storage with travel distance = 700 (current position = 200; target position = 900).
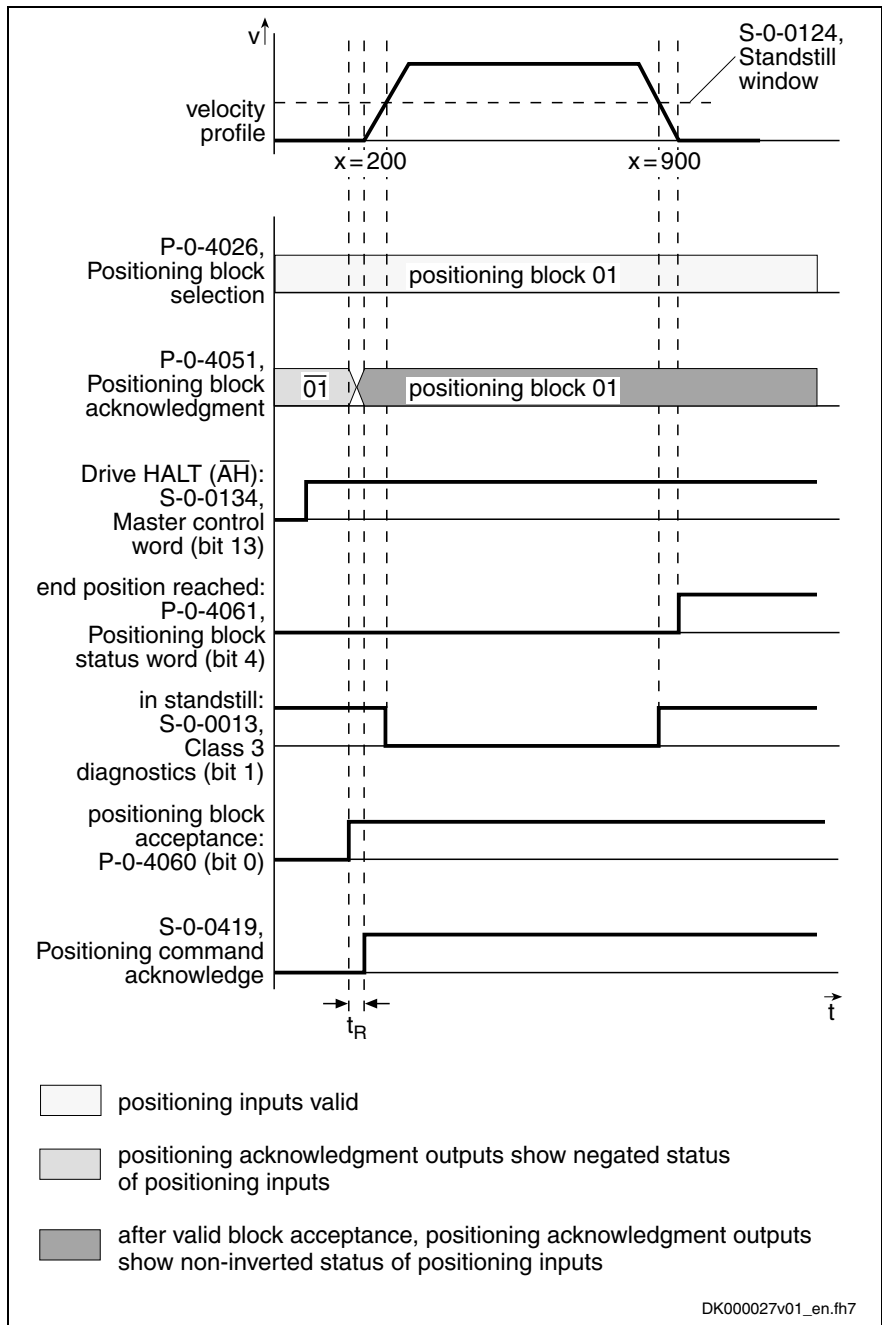
Fig. 7-29:   Relative positioning block without residual path storage

Note: According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Example:

Relative positioning without residual path storage with target position = 700 (current position = 200); interrupting and restarting a relative positioning block without residual path storage
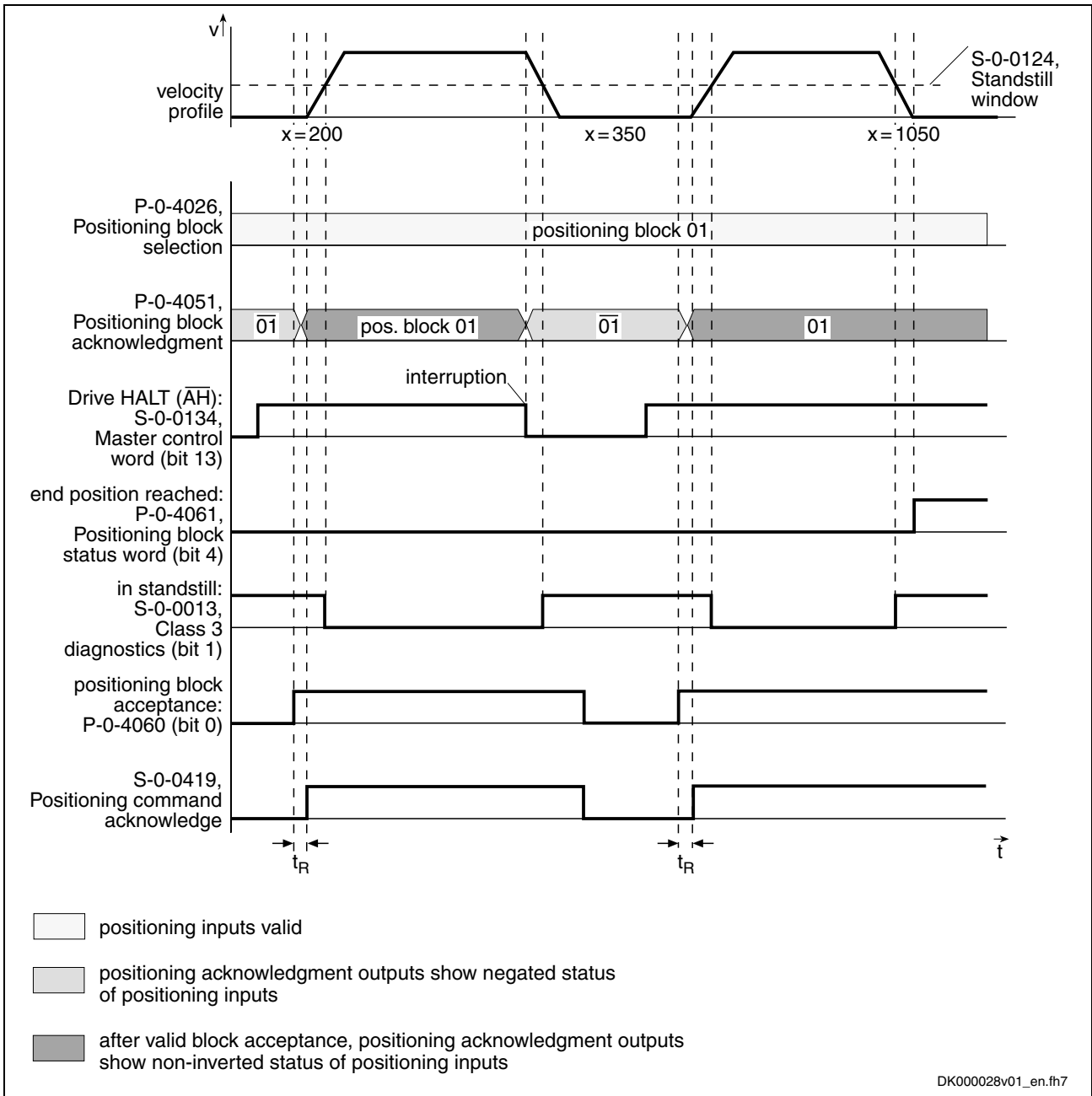
Fig. 7-30:   Interrupting a relative positioning block without residual path storage

Note: 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

Parameter Setting
- **P-0-4019, Positioning block mode** = 102h

Residual Path
If positioning blocks are interrupted, a distance still to be traveled up to the target position remains. This remaining distance is the residual path.

In a relative positioning block with residual path storage, the target position is a relative distance that relates to the target position at which the message "end position reached" was last active.

Relative positioning blocks with residual path storage are also carried out, 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.

Note: If another positioning block is started while such a positioning block is being carried out, the residual path is rejected. If this new block is also a relative positioning block with residual path storage, the target position is related **to the current actual position** as a relative distance.

Example:

- relative positioning with residual path storage with travel distance = 700 (plus residual path = 20 of positioning block n-1)
- without interruption
- current position = 180; new target position = 900

Reference Position   The last valid target position is used as reference position (in the example position = 200 of positioning block n-1).
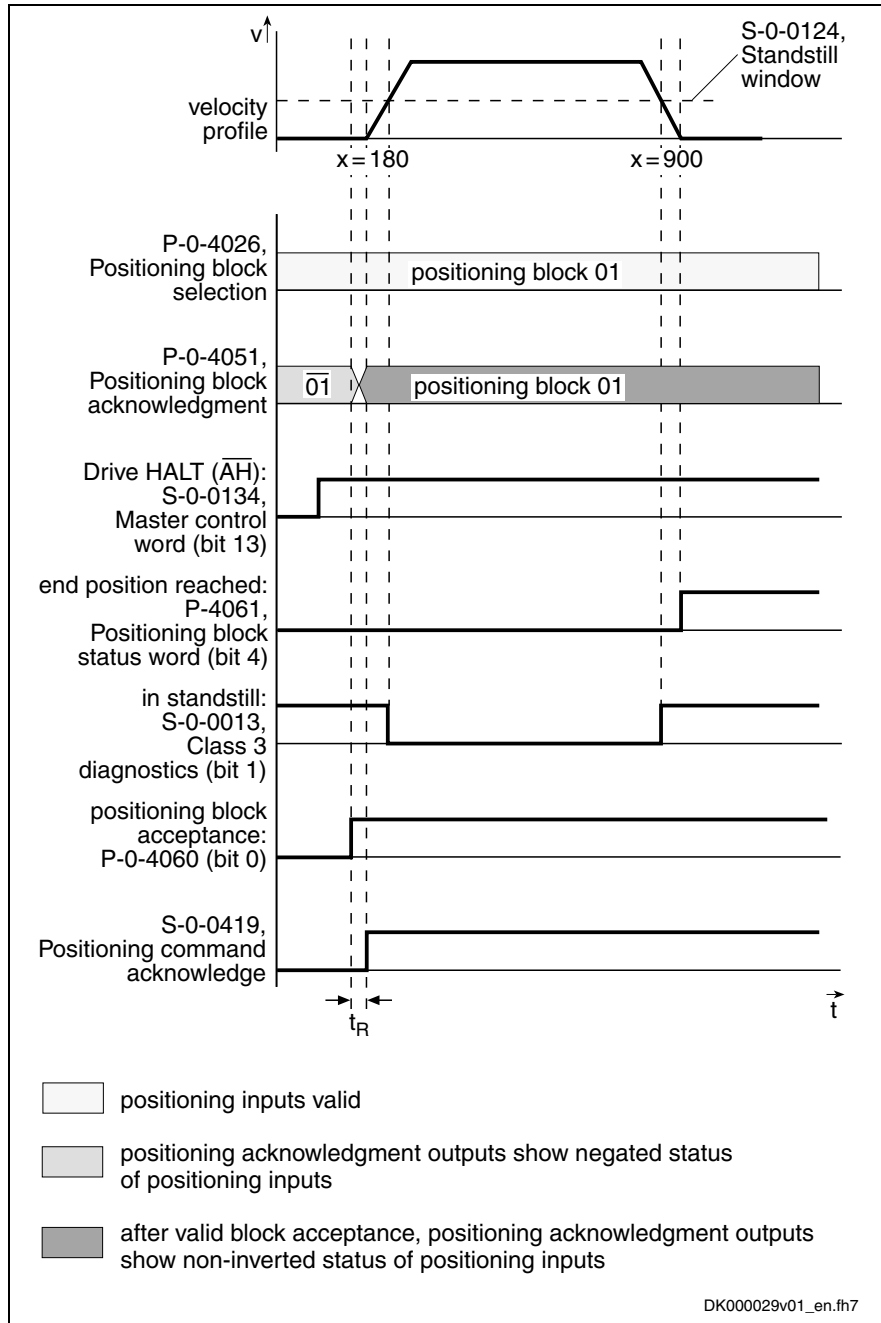
Fig. 7-31:   Relative positioning block with residual path storage

Note: According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Relative Positioning Block with Residual Path Storage after Activating Drive Enable

Example:

Interrupted relative positioning block with residual path storage after activation of drive enable with travel distance = 400 (current position = 200; target position = 800).

Reference Position   The position command value at the last "end position reached" (position = 200) message is used as the reference position.

Note: The incremental dimension reference is guaranteed.
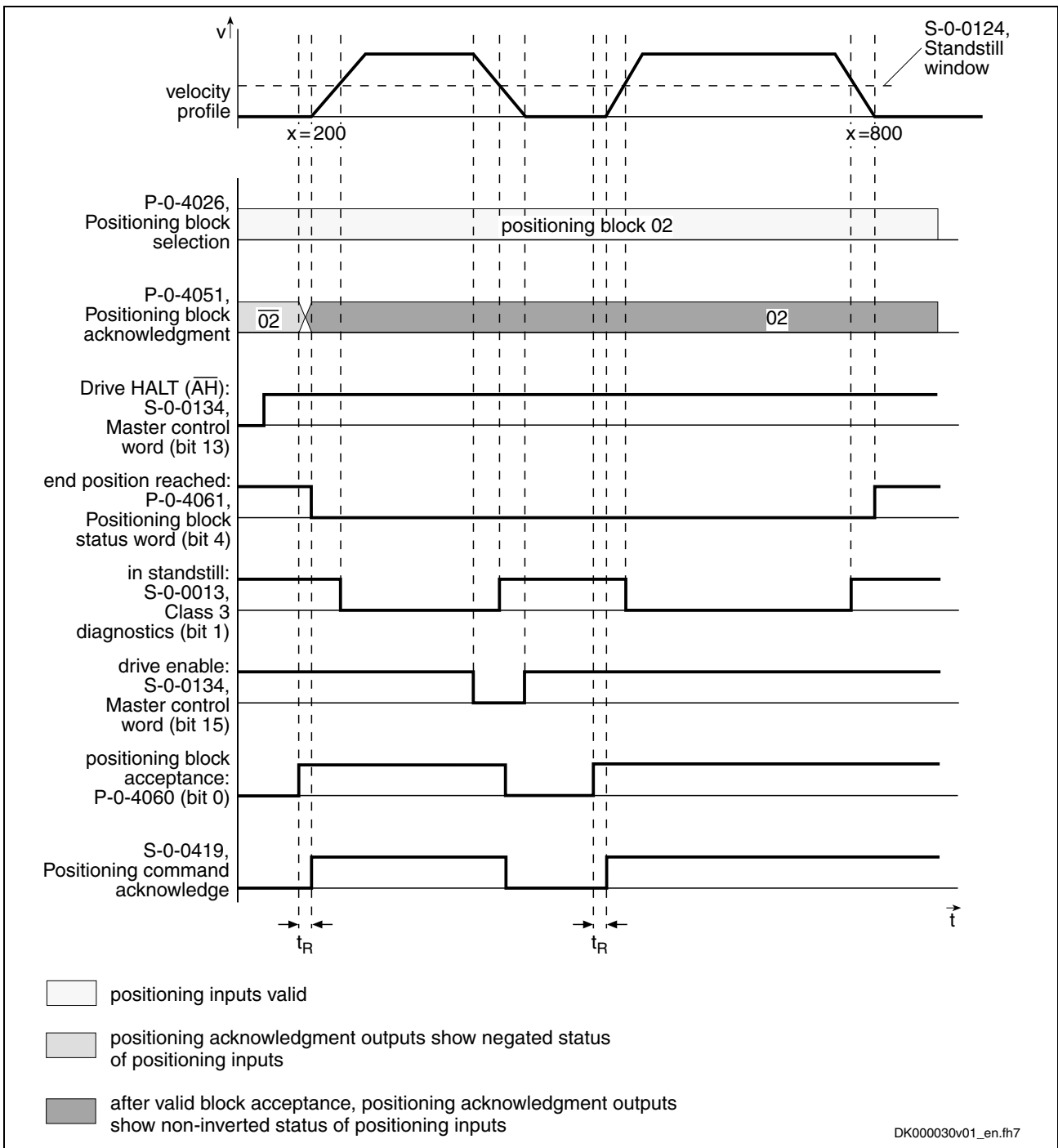
Fig. 7-32:   Relative positioning block with residual path storage after activating drive enable

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Note: According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Relative Positioning Block with Residual Path Storage after Interrupting with Jog mode

Example   Interrupted relative positioning block **with residual path storage** after jog mode with target position = 600 **without overrunning the target position** while jogging

Reference Position   Positioning is always continued at the current actual position value.

Behavior   An interruption by means of jogging or positioning stop clears the residual path memory.

Note: The incremental dimension reference is no longer ensured!
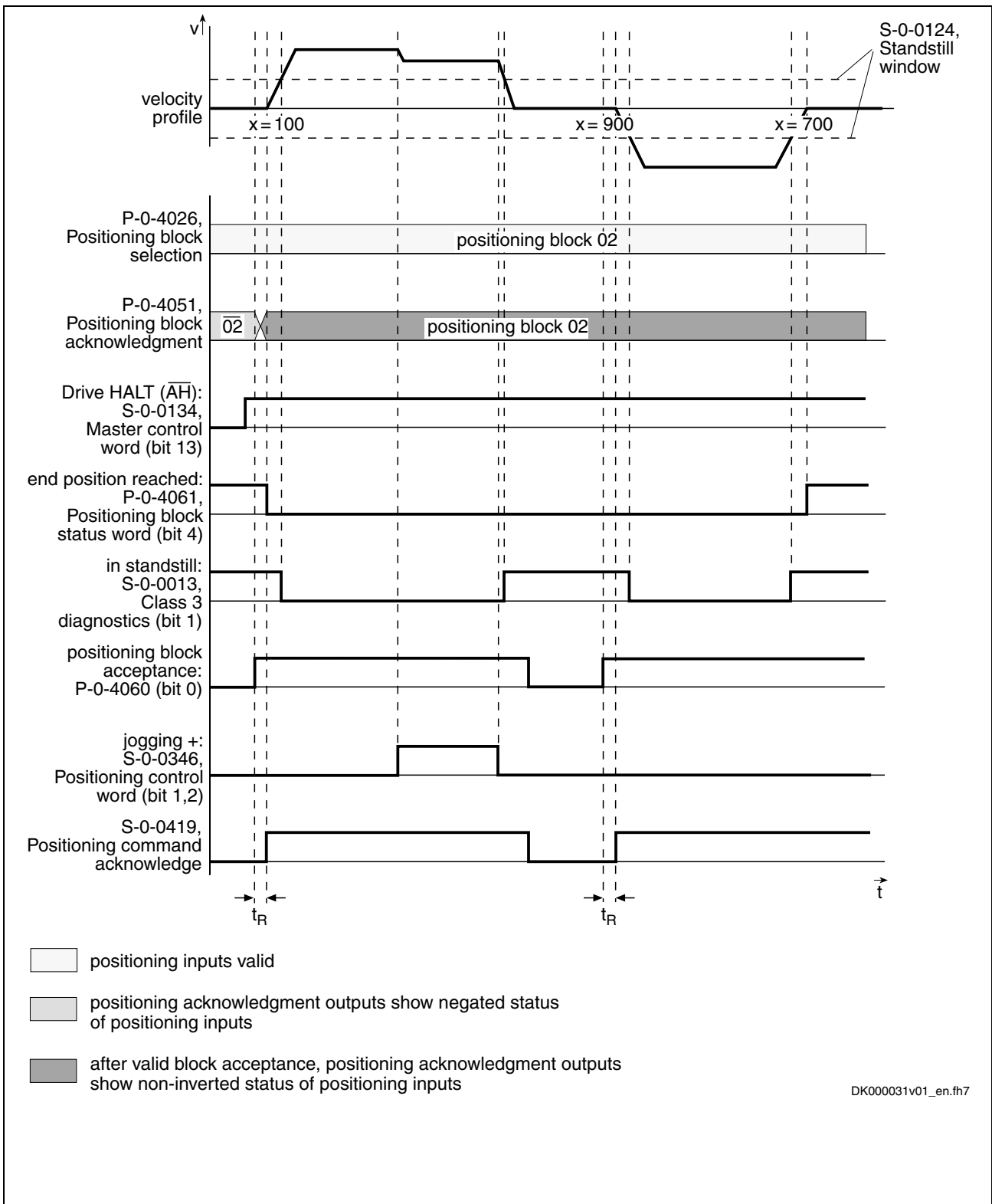
Fig. 7-33:   Relative positioning block with residual path storage after jog mode

Note: According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Relative Positioning Block with Residual Path Storage After Switching Drive Controller Control Voltage Off and On

If an absolute encoder is used the incremental dimension reference can be retained after switching control voltage off and on. The previously calculated target position is stored at power shutdown. The rest of the distance is traveled after the interrupted relative positioning block with residual path storage is activated.

If a single-turn encoder is used, the residual path is rejected and positioning continues at the actual position.

Reference Position   The position command value at the last "end position reached" (position = 100) message is used as the reference position.

Note: 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 set is irrelevant in this positioning mode.

Parameter Setting
- **P-0-4019, Positioning block mode** = 04h
  $\rightarrow$ travel in positive direction
- **P-0-4019, Positioning block mode** = 08h
  $\rightarrow$ travel in negative direction
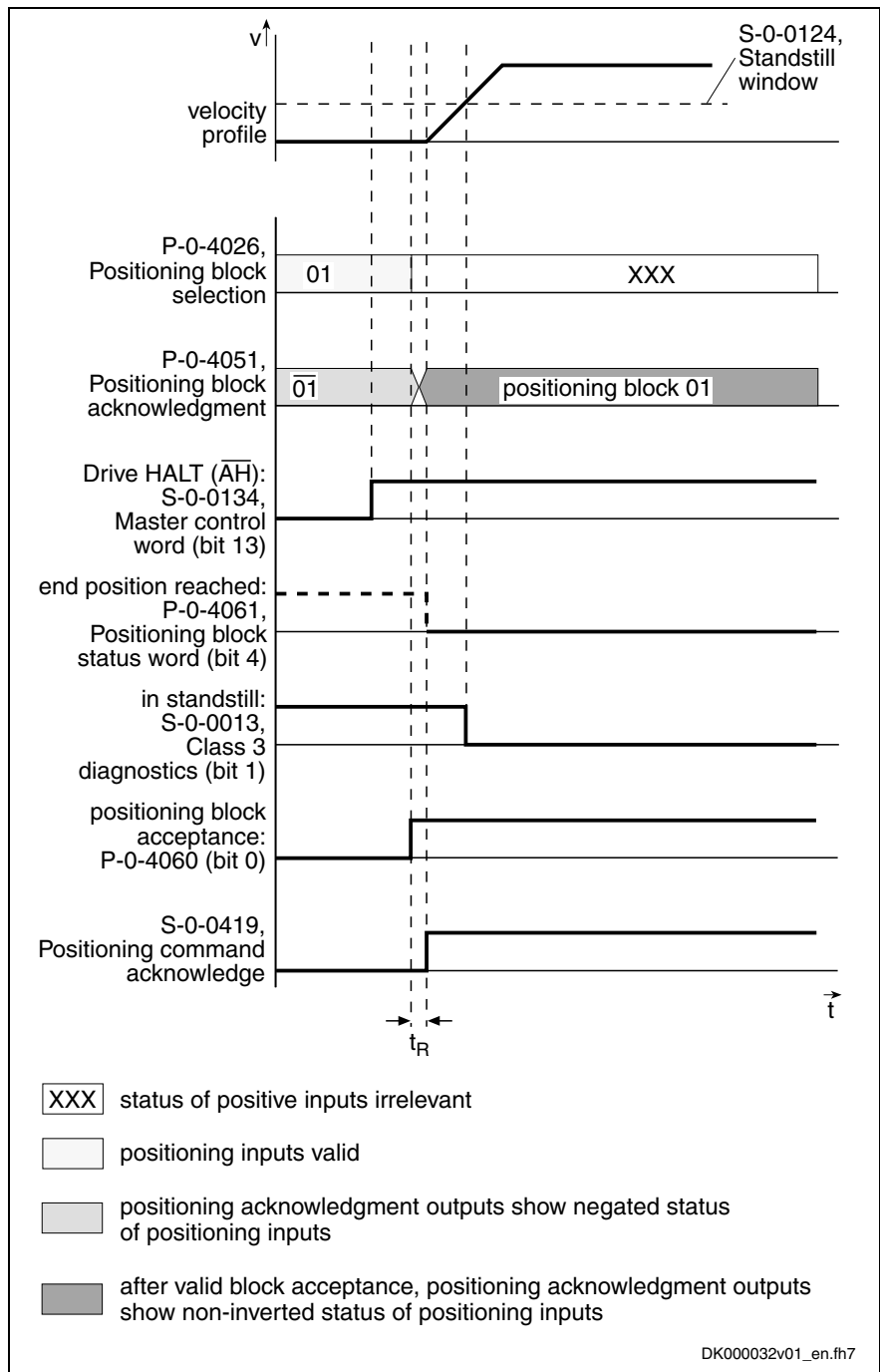
Fig. 7-34:   Example: infinite travel in positive/negative direction

Note: 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.

Sequential Block Processing

Description of Basic Function

Note:	First of all the same basic rules as to single block processing (see that section) apply to sequential 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.

Note:	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 that can be subdivided:

1. Mode: **position-dependent block advance**

   - block transition with old positioning velocity
   - block transition with new positioning velocity
   - block transition with intermediate stop

2. Mode: **switch-signal-dependent block advance**

Position-Dependent Block Advance

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:

a) Block transition with old positioning velocity (mode 1)

Parameter Setting

- **P-0-4019, Positioning block mode** = 11h
  $\rightarrow$ absolute block with sequential block

- **P-0-4019, Positioning block mode** = 12h
  $\rightarrow$ relative block with sequential block

- **P-0-4019, Positioning block mode** = 14h
  $\rightarrow$ infinite block in positive direction with sequential block

- **P-0-4019, Positioning block mode** = 18h
  $\rightarrow$ infinite block in negative direction with sequential block

Definition

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.

Note: 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.
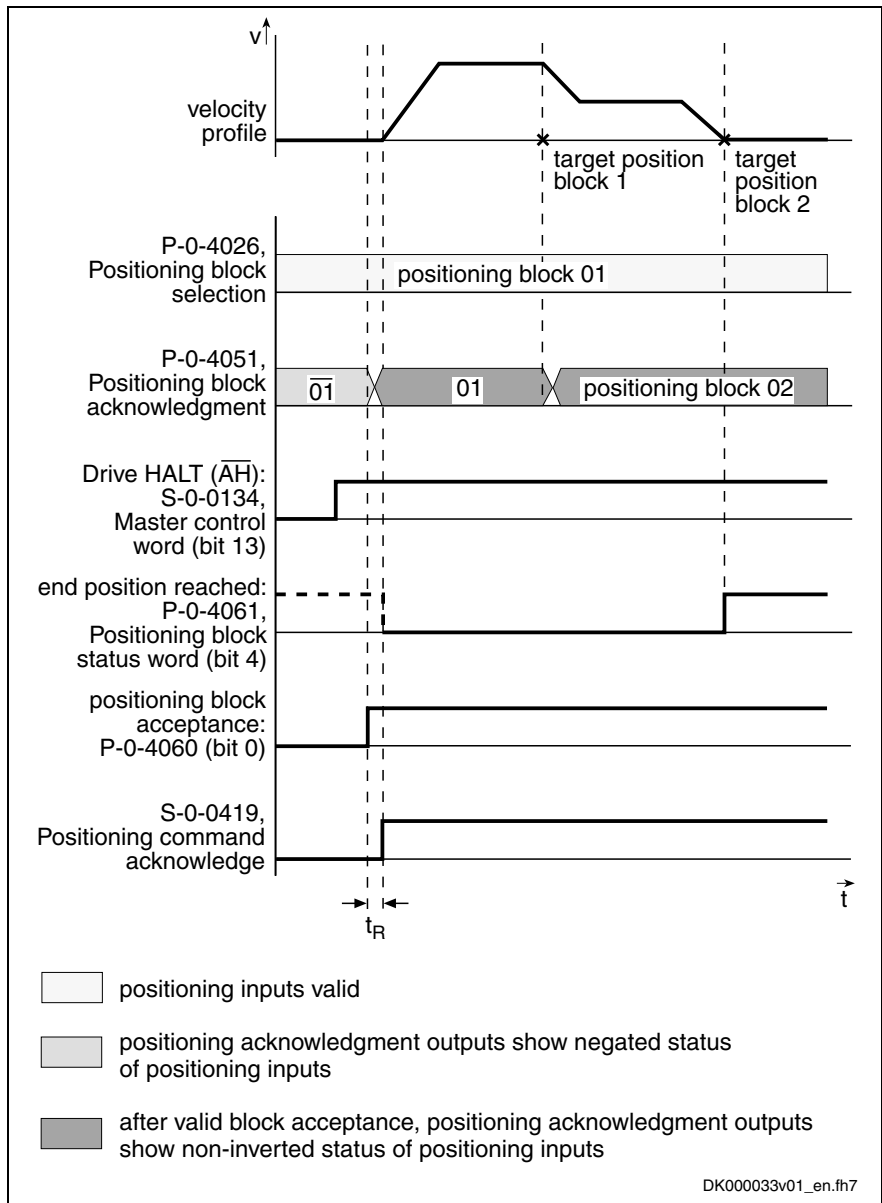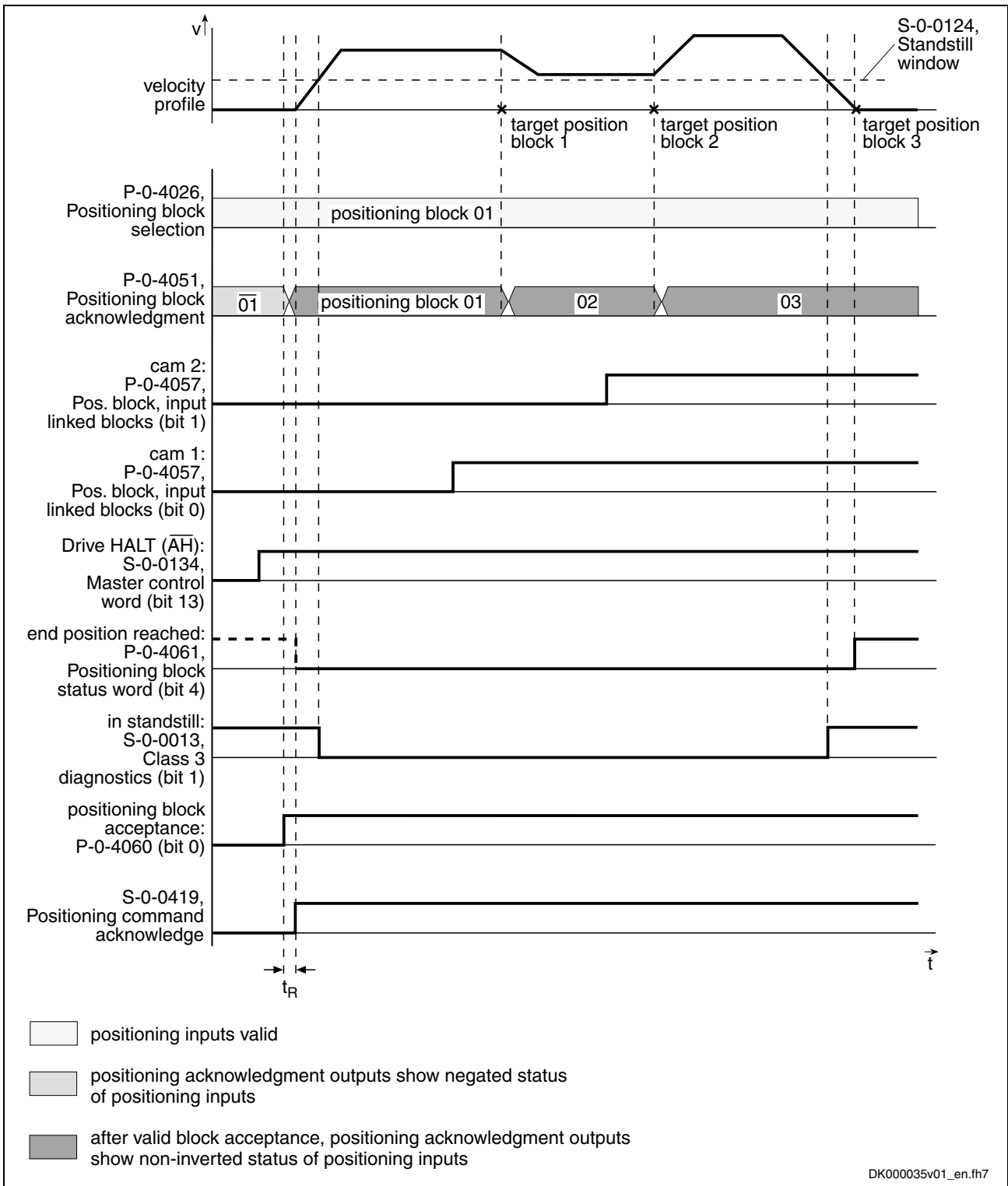

Fig. 7-35: Example: position-dependent block advance (mode 1)

Note: 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.

b) Block transition with new positioning velocity (mode 2)

Parameter Setting

- **P-0-4019, Positioning block mode** = 21h
  $\rightarrow$ absolute block with sequential block

- **P-0-4019, Positioning block mode** = 22h
  $\rightarrow$ relative block with sequential block

- **P-0-4019, Positioning block mode** = 24h
  $\rightarrow$ infinite block in positive direction with sequential block

- **P-0-4019, Positioning block mode** = 28h
  $\rightarrow$ infinite block in negative direction with sequential block

Definition

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.
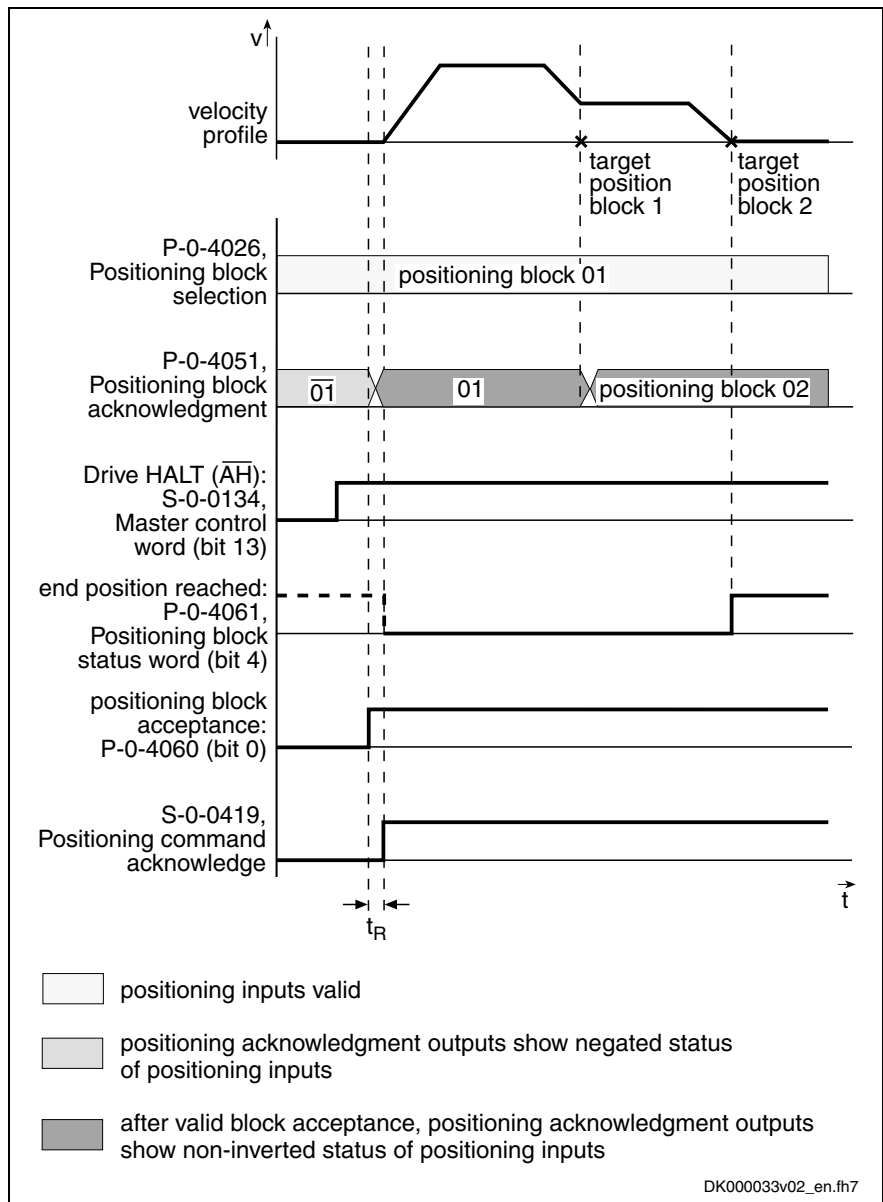
Fig. 7-36:   Example: position-dependent block advance (mode 2)

Note: 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.

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c) Block transition with intermediate stop

Parameter Setting
- **P-0-4019, Positioning block mode** = 41h
  → absolute block with sequential block

- **P-0-4019, Positioning block mode** = 42h
  → relative block with sequential block

Definition   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.

Another operating mode is switching when overrunning the target position with intermediate stop.

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In this case, the drive is decelerated to speed "0" at the target position and then accelerated to the new positioning velocity.

Note: Advance takes place when the internal command value generator has reached the target position. With very low jerk values the resulting dwell time is relatively long.
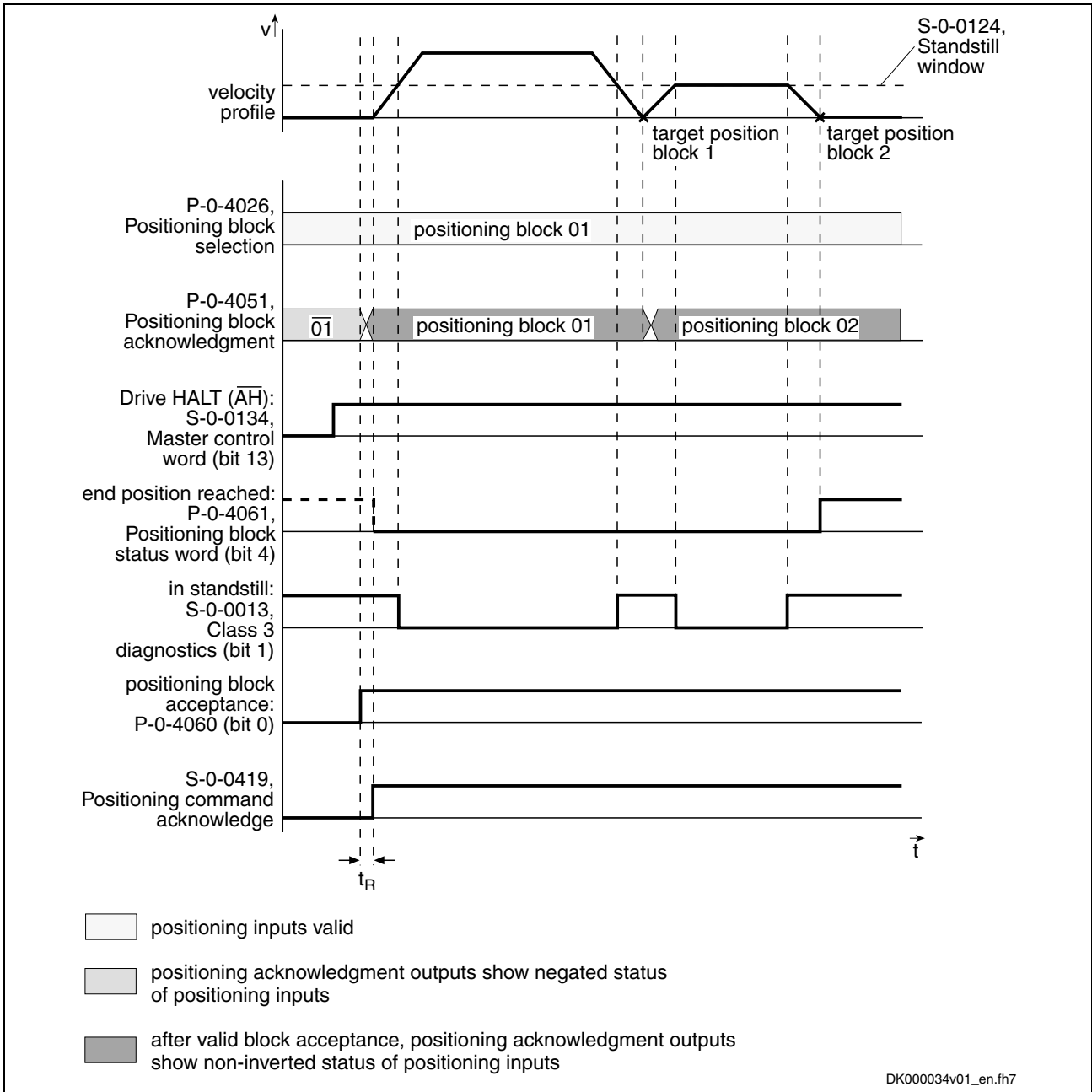
Fig. 7-37:   Example: sequential block advance for target position with intermediate stop

Note: 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.

Note:	This mode should be used if there is a change in direction in the case of two consecutive sequential blocks within one sequential block chain. Otherwise, the position at which the direction is changed will be inevitably overrun.

Switch-Signal-Dependent Block Advance

For switch-signal-dependent block advance there are the following positioning modes:

- **P-0-4019, Positioning block mode** = 81h
  → absolute block with sequential block

- **P-0-4019, Positioning block mode** = 82h
  → relative block with sequential block

- **P-0-4019, Positioning block mode** = 84h
  → infinite block in positive direction with sequential block

- **P-0-4019, Positioning block mode** = 88h
  → infinite block in negative direction with sequential block

Note:	Advance to the block with the next higher block number is triggered by an externally applied switch signal.

Switching with Cams   The switch-signal-dependent block advance allows transition to a sequential block, triggered by an external switch signal. As input for this switch signal there are two sequential block inputs/probe inputs available.

The status of the hardware signals is displayed in parameter **P-0-4057, Positioning block, input linked blocks**.

Definition   The drive switches to the **next travel block n+1** as soon as the input for the **sequential block cam 1** changes from "0" to "1". If the target position is not reached, switching to the new positioning block is carried out while traveling.

The drive switches to the **travel block after the next one n+2** as soon as the input for the **sequential block cam 2** changes from "0" to "1". If a sequential block cam is activated during this travel, the drive switches to the positioning block after the next.

Reference Position   A following relative positioning block refers to the position at which the sequential block cam was switched.

Note:	The sequential block cams are sampled in the position loop clock (Advanced: T = 250μs, Basic: T = 500μs). The precision of position detection therefore strongly depends on the velocity during overrun.

Assignment Table for Cams

Cam 2	Cam 1	drive reaction
0	0	drive moves to target position of block n
X	0 → 1	block n+1 is started
0 → 1	X	block n+2 is started

X: not relevant

n: Positioning block selected via the parallel inputs or parameter **P-0-4026, Positioning block selection**.

Fig. 7-38:   Drive reaction with different switch signal sequences

Fig. 7-39: Example: switch-signal-dependent block advance

Note:	According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Failure of Switch Signal for Block Advance If the start block of a switch-signal-dependent sequential block is an absolute or relative positioning block, the drive positions at target position if the switch signal for block advance is not received. The drive thus only generates the message "end position reached" after the sequential block chain is completed. If a switch signal is then applied, the drive will carry out the sequential block.
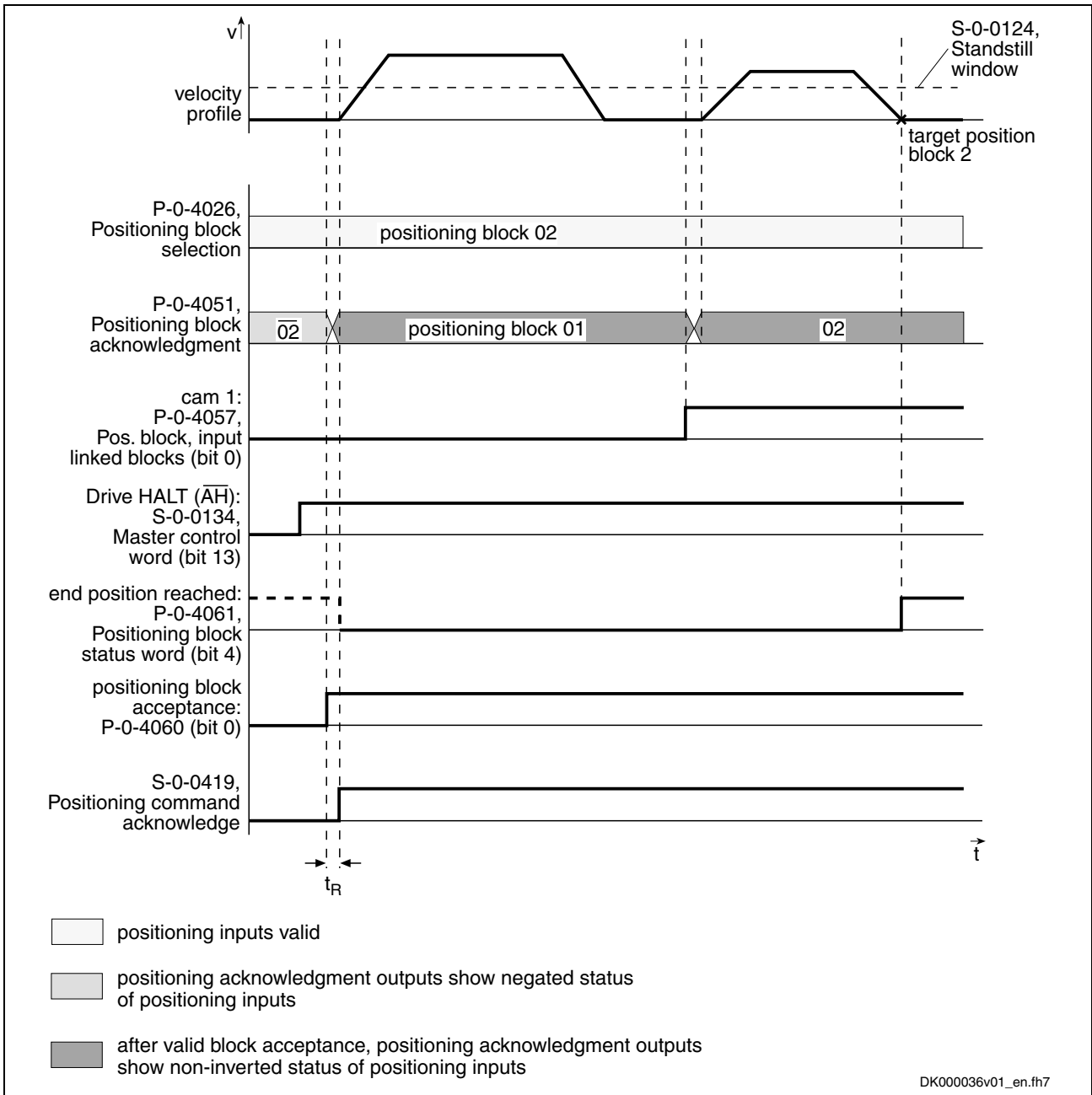
Fig. 7-40: Example: switch-signal-dependent block advance (behavior with failure of switch signal)

Note: 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.

Note:	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:

1. **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 carried out. Thereby the incremental dimension reference gets lost!

2. **residual path is maintained** when interruption by:
   - removing drive enable
   - removing the "drive start" signal
   - changing the operating mode

Depending on the block type of the sequential block chain that was interrupted and the events occurring during this interruption, the sequential block chain is processed differently after a restart.

Note:	In sequential block mode relative positioning blocks **without residual path storage** are **not allowed** as otherwise the incremental dimension reference would get lost in the case of interruption.

Given an interruption, a restart will end the sequential block chain.

Reference Position

The reference position is the original start position of the sequential block chain.

Note:	The incremental dimension reference is retained as only absolute and relative positioning blocks with residual path storage are used in sequential block mode!
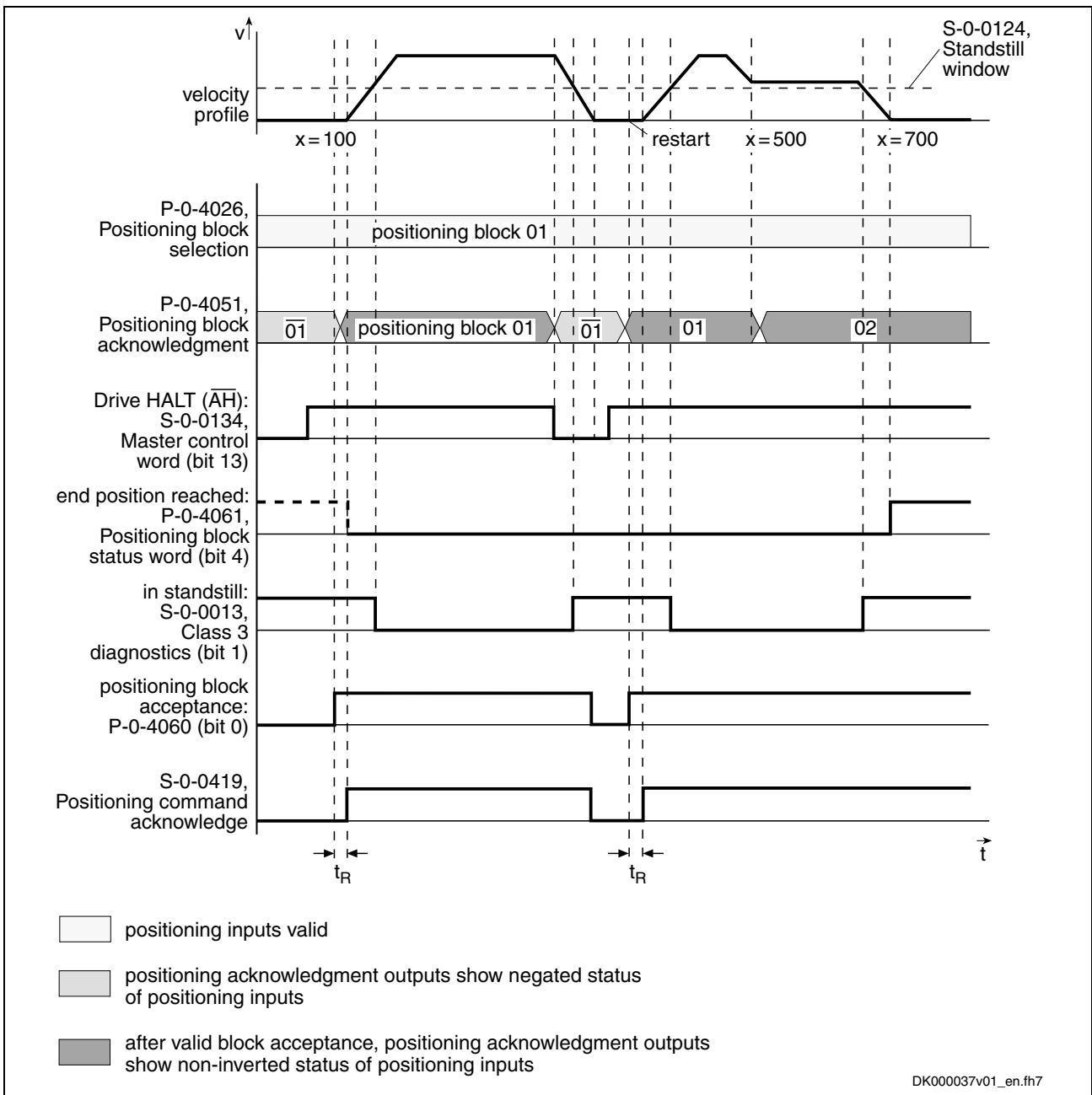
Fig. 7-41:   Example: sequential block interruption with same block selected

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Note: According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Changing to Different Operating Mode

When changing the operating mode during an interruption, the sequential block chain interrupted before is completed at the restart if there hadn't been any new block selected.

Given a sequential block with advance due to target position, only the overrun of the target position of the current positioning block will be detected. The processing of the sequential block is completed from this position.

> **Note:** The advance condition due to switch signals is always detected.

Interrupting a Sequential Block Chain with Selection of New Positioning Block

If a new positioning block is selected during an interruption (e.g. with Drive Halt), the previously interrupted sequential block chain is not completed after a restart, but the currently selected block is executed.

Reference Position

Reference position is the current actual position value.

> **Note:** The incremental dimension reference gets lost if the sequential block is interrupted.

The conditions for the interruption of sequential blocks also apply after the control voltage is switched off, if an absolute encoder is used.

Interrupting a Sequential Block Chain with Absolute Sequential Blocks

An interruption with absolute positioning blocks represents no 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 in carried out.

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**.

Notes on Commissioning/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 comply with 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:

Minimum acceleration value

$$acceleration > \frac{velocity\ difference^2}{2 * target\ position\ difference} = \frac{(v_{n+1} - v_n)^2}{2 * (x_{n+1} - x_n)}$$

x_n:	target position of block n
x_{n+1}:	target position of block n+1
v_n:	velocity of block n
v_{n+1}:	velocity of block n+1

Fig. 7-42:   Minimum acceleration value with sequential block mode (linear)

Note: 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

Note: 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.
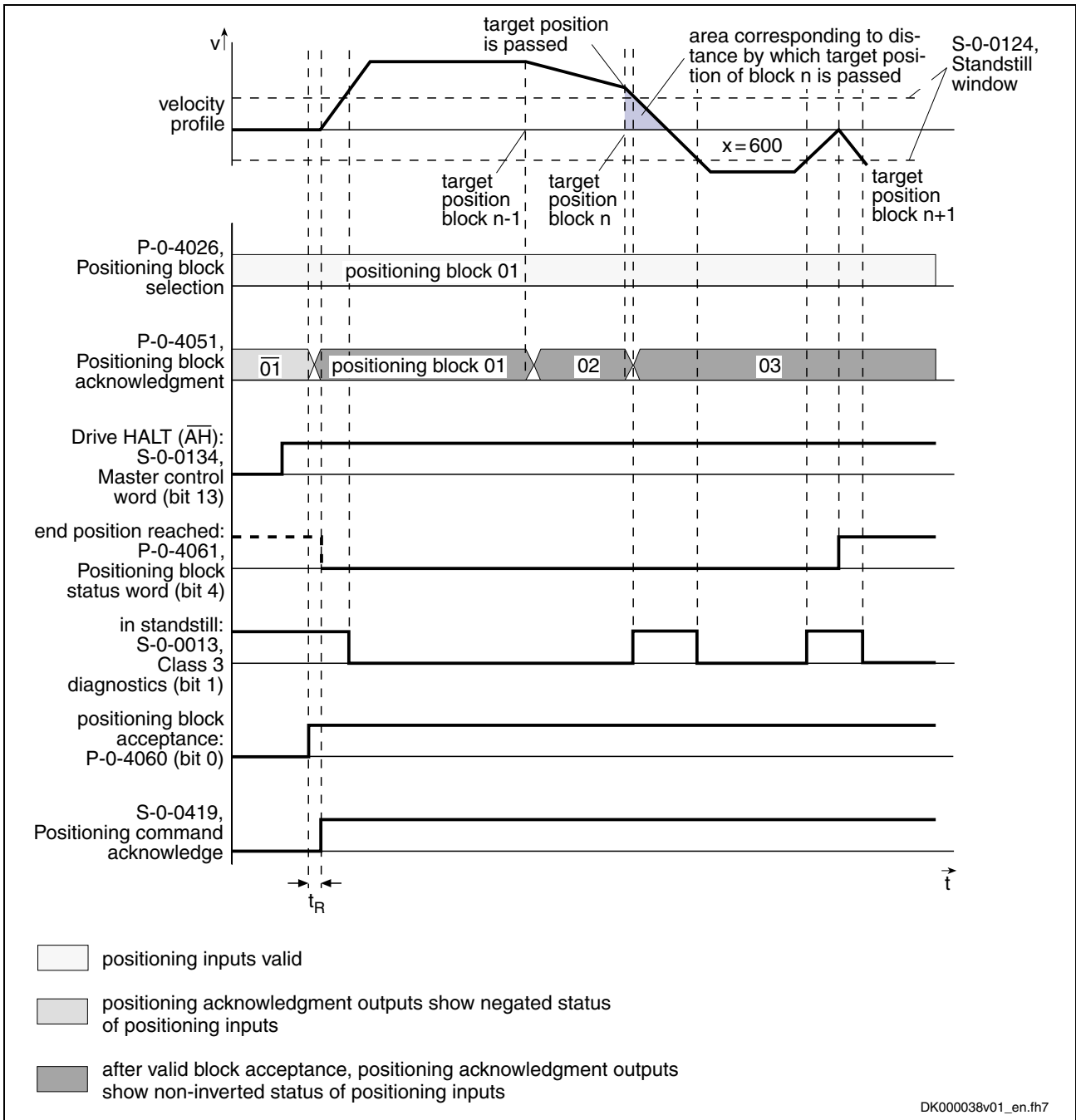
Fig. 7-43:   Parameterizing a sequential block with directional change

Note: 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.

Note:	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!

Diagnostic and Status Messages, Acknowledgment

Positioning Block Acknowledgment

The positioning block acknowledgment is used for feedback of the execution of the active positioning block.

Acknowledgment with Active Operating Mode

After the positioning block mode has been activated, the complement of the block number of the selected positioning block is acknowledged until a start signal (toggling of bit 0 in **S-0-0346, Positioning control word** or 0-1 edge of bit 0 in **P-0-4060, Positioning block control word**) is set. As of the first start signal and if operation is trouble-free, the block number of the positioning block that was started is output. If an error is detected at the start of a positioning block, the faulty positioning block is acknowledged with the complement of the block number. The drive generates a warning and stops.

Acknowledgment at "Drive Halt"

If "Drive Halt" is active, the complement of the block number of the selected positioning block is output in parameter **P-0-4051, Positioning block acknowledgment**.

Acknowledgment with Secondary Operating Modes

The acknowledgment is not affected by secondary operating modes, error reaction and command inputs, i.e. parameter **P-0-4051, Positioning block acknowledgment** retains the value.

Acknowledgment with Drive Enable Switched Off

After switching off drive enable the last accepted positioning block is output at the acknowledge outputs. If the drive is at the target position of the last accepted positioning block, the message "end position reached" is additionally output.

The example below shows the same absolute positioning block being started once again.
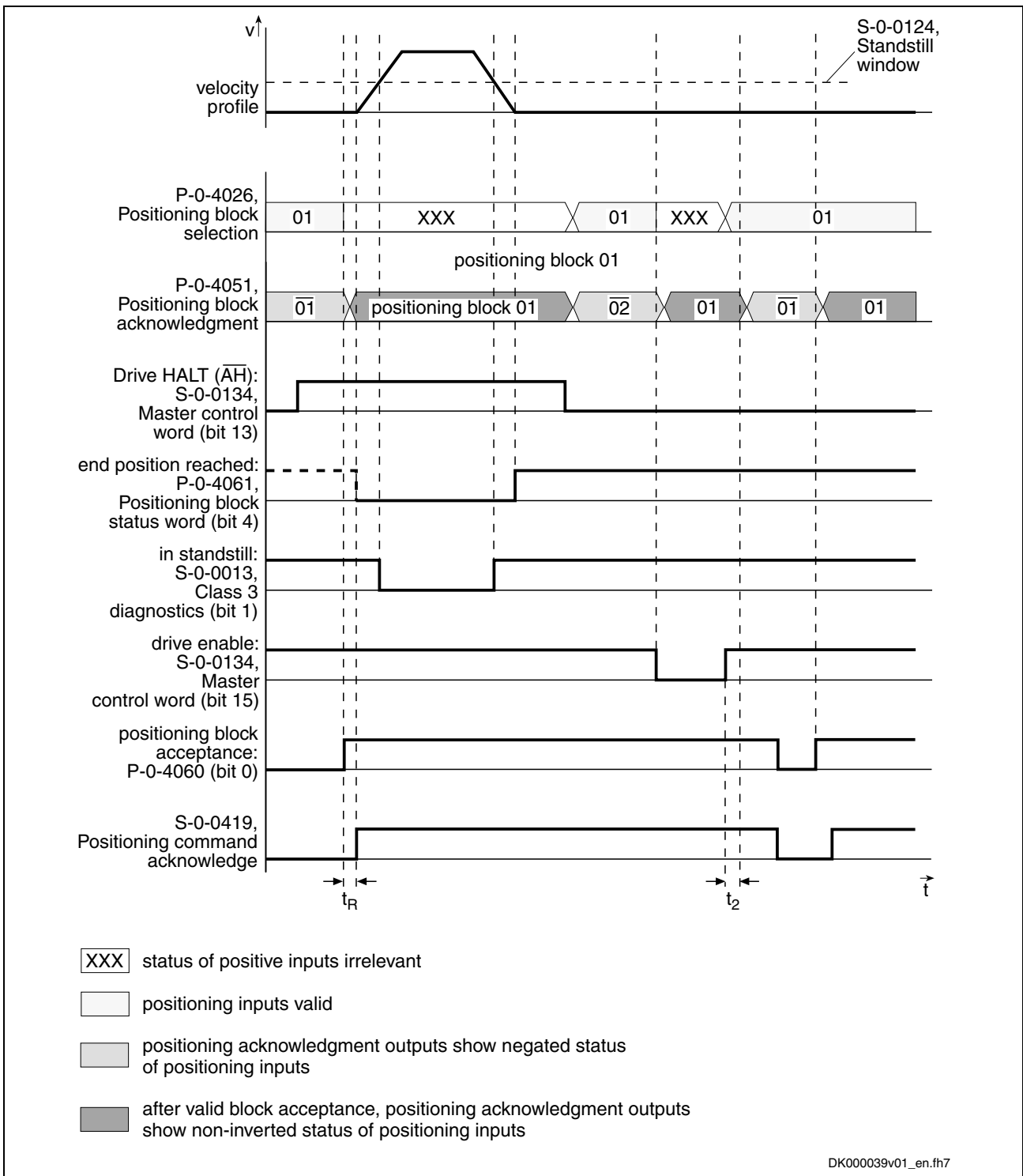
Fig. 7-44:   Acknowledge and message "end position reached" after drive enable
            switched off

Note:	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.

**Acknowledge with Control
Voltage Interrupted**

If the control voltage is switched off, the last accepted positioning block is stored in parameter **P-0-4052, Positioning block, last accepted** so that after switching control voltage on, it is always the last accepted positioning block that is output.

With Absolute Value Encoder	If an **absolute encoder** is used, it is possible to decide, after the control voltage is switched off and on, whether the drive still is at the target position of the last accepted positioning block (end position reached).

The "end position reached" message is generated as soon as the drive is ready for operation again ("bb" contact closed).

With Single-Turn Encoder	If a **single-turn encoder** is used, the "end position reached" message is not clearly defined after a voltage interrupt until the first target position has been run to or homed.

Note: 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 "Status Messages" in section "Drive-Internal Interpolation"

i	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**
  $\rightarrow$ acknowledgment of the currently accepted and active positioning block

---

Note: At "Drive Halt" the selected positioning block is returned in negated form (complementary to positioning block mode).

- **P-0-4052, Positioning block, last accepted**
  $\rightarrow$ 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**
  $\rightarrow$ contains the last active positioning block (stored in non-volatile form)

> **Note:** For sequential block chains this is the last active block of the sequential block chain. For single blocks (no sequential block processing) the contents of parameters **P-0-4052** and **P-0-4053** are always equal!

- **P-0-4057, Positioning block, input linked blocks**
  → contains an image of the digital sequential block inputs (switch cam inputs)

Diagnostic Messages

In positioning block mode the following diagnostic messages can be generated:

- **E0248 Interpolation acceleration = 0**
- **E0249 Positioning velocity >= S-0-0091**
- **E0253 Target position out of travel range**
- **E0254 Not homed**
- **E2055 Feedrate override S-0-0108 = 0**
- **E2058 Selected process block is not programmed.**
- **E2064 Target position out of num. range**
- **F2028 Excessive deviation**

7.8   Synchronization Modes

Basic Functions of the Synchronization Modes

Brief Description

The synchronization modes allow the drive to run synchronously with regard to a real or virtual master axis. The synchronization modes are divided into the following two groups:

- **velocity synchronization** with real/virtual master axis
- **synchronous position control modes**
  - phase synchronization with real/virtual master axis
  - electronic cam shaft with real/virtual master axis

The figure below illustrates how the synchronization modes are integrated in the control loop structure.
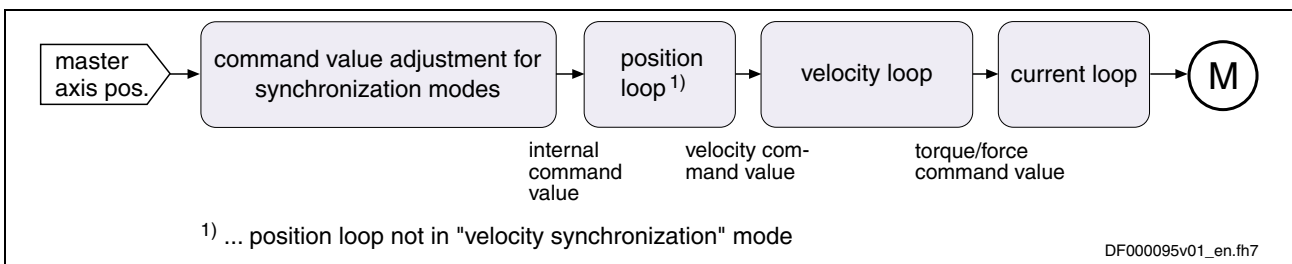
Fig. 7-45:   "Synchronization modes" block diagram

The synchronization modes basically consist of identical or similar basic functions:

- master axis evaluation for virtual and real master axis
- electronic gear function with fine adjust
- command value processing specific to operating mode
- drive-controlled dynamic synchronization

The figure below illustrates the interaction of the individual basic functions (function blocks) of the synchronization modes.
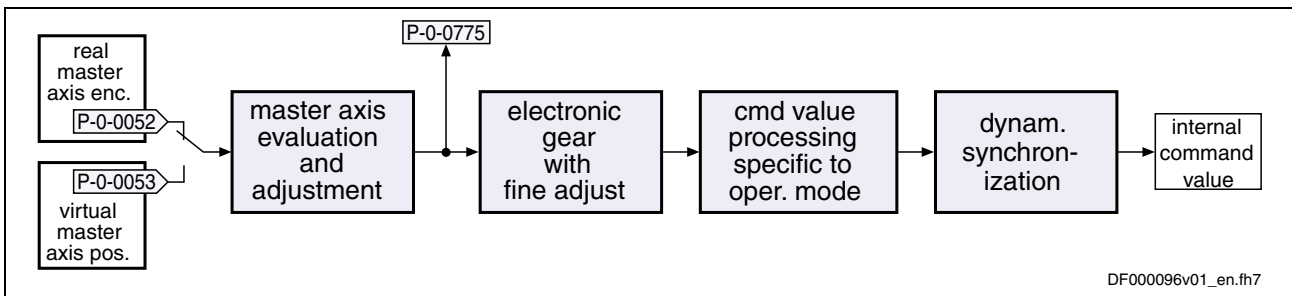
P-0-0052:   actual position value of measuring encoder

P-0-0053:   master axis position

P-0-0775:   resulting master axis position

Fig. 7-46:   Function blocks of the synchronization modes

Pertinent Parameters (Synchronization Parameters)

General:

- **S-0-0037, Additive velocity command value**
- **P-0-0048, Effective velocity command value**
- **P-0-0088, Control word for synchronous operation modes**
- **P-0-0089, Status word for synchronous operating modes**
- **P-0-0434, Position command value of controller**

Master Axis Evaluation:

- **P-0-0052, Actual position value of measuring encoder**
- **P-0-0053, Master axis position**
- **P-0-0054, Additive master axis position**
- **P-0-0750, Master axis revolutions per master axis cycle**
- **P-0-0764, Master axis velocity**
- **P-0-0775, Resulting master axis position**

Electronic Gear with Fine Adjust:

- **P-0-0083, Gear ratio fine adjust**
- **P-0-0108, Master drive polarity**
- **P-0-0156, Master drive gear input revolutions**
- **P-0-0157, Master drive gear output revolutions**
- **P-0-0753, Position actual value in actual value cycle**
- **P-0-0776, Effective master axis position**
- **P-0-0777, Effective master axis velocity**

Command Value Processing:

- **P-0-0071, C3100 Recalculate actual value cycle**
- **P-0-0072, Cam shaft profile 1**

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- **P-0-0073, Cam shaft distance 2**
- **P-0-0092, Cam shaft profile 2**
- **P-0-0093, Cam shaft distance**
- **P-0-0094, Cam shaft switch angle**
- **P-0-0144, Cam shaft distance switch angle**
- **P-0-0155, Synchronization mode**
- **P-0-0752, Load revolutions per actual value cycle slave axis**
- **P-0-0754, Command value cycle**
- **P-0-0778, Synchronous position command value**
- **P-0-0779, Synchronous velocity**
- **P-0-0780, Cam shaft profile 3**
- **P-0-0781, Cam shaft profile 4**

Dynamic Synchronization:

- **S-0-0040, Velocity feedback value**
- **S-0-0048, Additive position command value**
- **P-0-0034, Position command additional actual value**
- **P-0-0142, Synchronization acceleration**
- **P-0-0143, Synchronization velocity**
- **P-0-0151, Synchronization init window for modulo format**
- **P-0-0152, Synchronization completed**
- **P-0-0154, Synchronization direction**
- **P-0-0155, Synchronization mode**
- **P-0-0751, Synchronization divisions per command cycle slave axis**
- **P-0-0753, Position actual value in actual value cycle**

Pertinent Diagnostic Messages   General:

- **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**
- **E2049 Positioning velocity >= S-0-0091**
- **E2063 Velocity command value > limit S-0-0091**
- **F2005 Cam shaft invalid**
- **F2039 Maximum acceleration exceeded**

Dynamic Synchronization:

- **E2047 Interpolation velocity = 0**
- **E2048 Interpolation acceleration = 0**
- **F2037 Excessive position command difference**

Master Axis Evaluation for Real/Virtual Master Axis

The synchronization modes allow the drive to run synchronously with regard to a real or virtual master axis.

- In the case of a real master axis, the master axis position is preset by evaluating a master axis encoder (measuring encoder).

- In the case of a virtual master axis, command values are cyclically preset by the master via the master communication.

See also "Measuring Encoder" in chapter "Extended Drive Functions"

Note:	The master axis position can only be processed in a binary format (1 master axis revolution = 2^{20} increments). This has to be taken into consideration when using a real master axis encoder and the encoder has to be selected accordingly.

Note:	The minimum/maximum value of **P-0-0054, Additive master axis position** at maximum corresponds to the master axis cycle (P-0-0750 * 2^{20}). Exception: When **P-0-0750, Master axis revolutions per master axis cycle** equals zero, the resulting maximum value for parameter P-0-0054 is (231 – 1) increments and the minimum value is –231 increments.
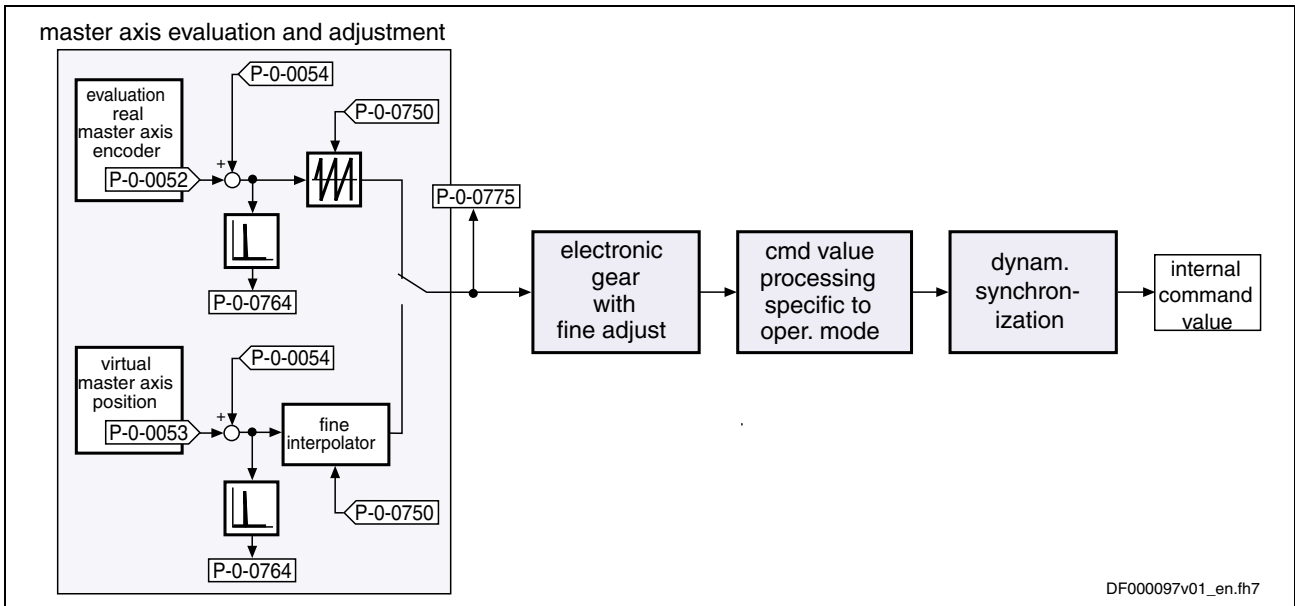
Fig. 7-47:   Function block "master axis evaluation" for real/virtual master axis

Command Value Input with Real/Virtual Master Axis

The command value input in the synchronization modes with real or virtual master axis is carried out depending on the kind of master axis:

- **real master axis:**
  A measuring encoder is cyclically evaluated in the position loop clock, the master axis position is displayed in parameter **P-0-0052, Actual position value of measuring encoder**.

- **virtual master axis:**
  A virtual master axis position is cyclically preset in the NC clock via parameter **P-0-0053, Master axis position**. This master axis position is preset by the master in equidistant intervals.

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Fine Interpolation and Master Axis Range

For both master axes it is possible to change, via parameter **P-0-0054, Additive master axis position**, the master axis position by an additive component (= offset) in the NC cycle clock:

- **real master axis:**
  The resulting master axis position (P-0-0052 + P-0-0054) is not fine interpolated, but limited in modulo form to the master axis range (modulo value master axis = P-0-0750 * 2^{20}) via **P-0-0750, Master axis revolutions per master axis cycle**.

- **virtual master axis:**
  The resulting master axis position (P-0-0052 + P-0-0054) is linearly fine interpolated in the position loop clock and limited in modulo form to the master axis range (modulo value master axis = P-0-0750 * 2^{20}) via **P-0-0750, Master axis revolutions per master axis cycle**.

Note: The master axis range is set as an integral multiple of a master axis revolution (= 2^{20} increments) with parameter **P-0-0750, Master axis revolutions per master axis cycle**.

Display of results of master axis processing:

- The master axis speed is generated by differentiating the master axis position in the NC clock and displayed in parameter **P-0-0764, Master axis velocity**.

- The modulo-limited (and fine interpolated, with virtual master axis) master axis position is displayed in parameter **P-0-0775, Resulting master axis position**.

Electronic Gear Function with Fine Adjust

The input value for the electronic gear is the resulting master axis position (P-0-0775).
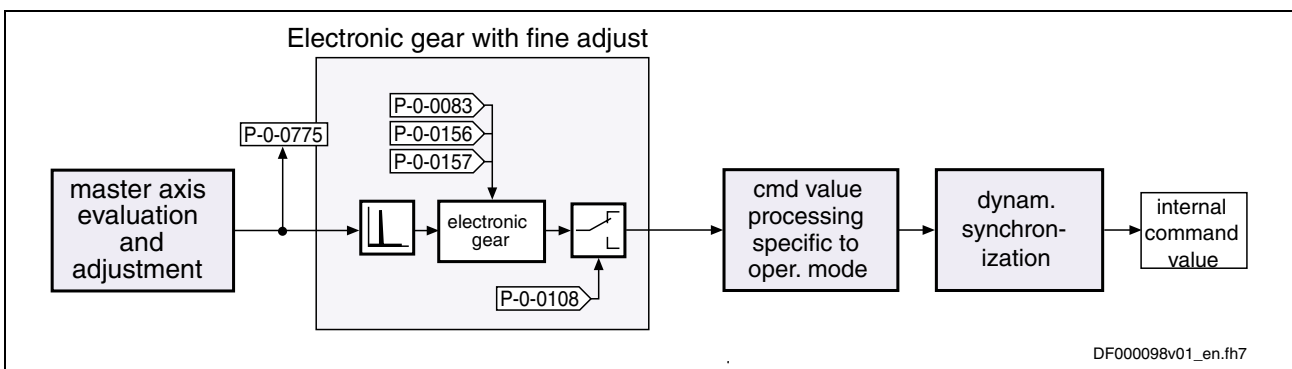
Fig. 7-48:   Function block "electronic gear with fine adjust"

The function block "electronic gear with fine adjust" is divided into the following subfunctions:

- **electronic master axis gear with fine adjust**
  The master axis position or master axis velocity is first multiplied with the factor from P-0-0157/P-0-0156 (output revolutions/inputs revolutions).
  By multiplying the resulting master axis position or master axis velocity with the value 1 + P-0-0083 (gear ratio fine adjust) the fine adjust is carried out.

- **polarity reversal of master axis position**
  Via parameter **P-0-0108, Master drive polarity** it is possible to invert the polarity of the master axis position or master axis velocity.

Note:	For the operating modes "phase synchronization" and "electronic cam shaft", the conversion of the master axis position to a position of the slave axis depends on the scaling. For the operating mode "velocity synchronization", the master axis velocity is converted to a slave axis velocity.

Currently Effective Master Axis Position and Master Axis Velocity

The currently effective master axis position and master axis velocity after the function block "electronic gear with fine adjust" is generated in the position loop clock (advanced: $T = 250\mu s$, basic: $T = 500\mu s$) and displayed in the following parameters:

- **P-0-0776, Effective master axis position**
- **P-0-0777, Effective master axis velocity**

Command Value Cycle and Actual Value Cycle in the Position Control Modes

With modulo position scaling, the actual value cycle determines the maximum range of actual position values at the slave axis. The drive generates an actual position value that is within this range and that can be read from parameter **P-0-0753, Position actual value in actual value cycle**.
The actual value cycle is required if, in the case of phase synchronization, synchronization is to be carried out in a range greater than the modulo value (command value cycle or division of command value cycle).

For synchronization, the actual position value in the command value cycle or a division of it is deduced from the actual position value in the actual value cycle by means of modulo division. In order to always have unequivocal values, the actual value cycle has to be an integer multiple of the command value cycle. This has to be taken into account when determining the actual value cycle.

Note:	In order to fulfill this requirement by parameterizing the actual value cycle (P-0-0752), the value of parameter **P-0-0156, Master drive gear input revolutions** should be taken into account as a factor for determining the master axis cycle (P-0-0750). 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 in analogy to the command value cycle by setting bit 4 in parameter **P-0-0155, Synchronization mode**.

If several electronic gear ratios are to be set at an axis (e.g. because of different formats), there are several command value cycles resulting at this axis. The actual value cycle then has to be set in such a way that it complies with the least common multiple (LCM) of these command value cycles (P-0-0155; bit 4 = 0).

If the electronic gear is not to be changed, the actual value cycle is set in such a way that it complies with the command value cycle or a multiple of it.

If synchronization is to be carried out only within the modulo range, the number of load revolutions per actual value cycle of the slave axis can be set to "1".

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Establishing the Position Data Reference

This actual position value is set by the command "set absolute measuring" or by "drive-controlled homing procedure" for the actual position value that has been selected in the synchronization mode that was set. If, for example, the operating mode "phase synchronization with virtual master axis, encoder 1" has been set, **P-0-0753, Position actual value in actual value cycle** will change by analogy with **S-0-0051, Position feedback 1 value**. The range of feedback 1 value, however, is limited to **S-0-0103, Modulo value**. The homing of **S-0-0051, Position feedback 1 value** will cause **P-0-0753, Position actual value in actual value cycle** to be set to the same value as **S-0-0051, Position feedback 1 value**. The position status of the actual position value in the actual value cycle can be taken from bit 4 of parameter **P-0-0089, Status word for synchronous operating modes**.

Calculating Actual Value Cycle

The actual value cycle is calculated

- when progressing to operating mode in the transition command from phase 3 to 4

- or -

- by starting the command **P-0-0071, C3100 Recalculate actual value cycle** for recalculating the actual value cycle in phase 4 when a parameter, that was used for calculating the actual value cycle, was changed in phase 4.

Note: At the start of command C3100 the status bits in **S-0-0403, Position feedback value status** and the status bit in **P-0-0089, Status word for synchronous operating modes** (bit 4) are cleared. After the position data reference has been successfully established, the bits are set again.

The actual value cycle is calculated in dependence of bit 4 of parameter **P-0-0155, Synchronization mode**.

P-0-0155 bit 4 = 0

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**.

$$actual\ value\ cycle = P-0-0752 * S-0-0103$$

Fig. 7-49: Actual value cycle with rotary modulo scaling and P-0-0155, bit 4 = 0

$$actual\ value\ cycle = P-0-0752 * P-0-0159$$

Fig. 7-50: Actual value cycle with linear modulo scaling and P-0-0155, bit 4 = 0

P-0-0155 bit 4 = 1

With bit 4 = 1 in P-0-0155 the actual value cycle is determined according to the formulas below:

- operating mode: phase synchronization and cam shaft with P-0-0755 = 0

$$actual\ value\ cycle = P-0-0750 * \frac{P-0-0157}{P-0-0156} * S-0-0103$$

Fig. 7-51: Actual value cycle with rotary modulo scaling and P-0-0155, bit 4 = 1

- operating mode: cam shaft with P-0-0755 ≠ 0

$$\text{actual value cycle} = P-0-0750 * \frac{P-0-0157}{P-0-0156} * \frac{S-0-0103}{P-0-0755}$$

Fig. 7-52: Actual value cycle with rotary modulo scaling and P-0-0155, bit 4 = 1

- operating mode: phase synchronization and
  cam shaft with P-0-0755 = 0

$$\text{actual value cycle} = P-0-0750 * \frac{P-0-0157}{P-0-0156} * P-0-0159$$

Fig. 7-53: Actual value cycle with linear modulo scaling and P-0-0155, bit 4 = 1

- operating mode: cam shaft with P-0-0755 ≠ 0

$$\text{actual value cycle} = P-0-0750 * \frac{P-0-0157}{P-0-0156} * \frac{P-0-0159}{P-0-0755}$$

Fig. 7-54: Actual value cycle with linear modulo scaling and P-0-0155, bit 4 = 1

Synchronization Ranges

With modulo scaling the range for synchronization can be set in parameter **P-0-0155, Synchronization mode**.

- modulo range (S-0-0103)
- command value cycle
- division of the command value cycle

The distance to be traveled is then limited to this range.

Note:	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 (P-0-0752) from which the actual position value is derived must therefore be determined in such a way that is a multiple of the synchronization range.

By setting **P-0-0750, Master axis revolutions per master axis cycle** = 0 it is possible to select absolute handling of the master axis within a range of ± 2048 revolutions.

Synchronization in the Command Value Cycle

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ **S-0-0048, Position command value additional**) and the actual position value. The synchronization distance is limited to the modulo command value cycle.

$$\text{distance} = \%\text{command value cycle}\,(x_{sync} + S-0-0048 - \text{actual pos. value})$$

Fig. 7-55: Synchronization distance during synchronization in command value cycle

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The range for the command value cycle at the slave axis is defined by the master axis cycle and the electronic gear:

- operating mode: phase synchronization and
  cam shaft with P-0-0755 = 0

$$\text{command value cycle} = P - 0 - 0750 * \frac{P - 0 - 0157}{P - 0 - 0156} * S - 0 - 0103$$

Fig. 7-56:   Command value cycle with rotary modulo scaling

- operating mode: cam shaft with P-0-0755 ≠ 0

$$\text{command value cycle} = P - 0 - 0750 * \frac{P - 0 - 0157 * S - 0 - 0103}{P - 0 - 0156 * P - 0 - 0755}$$

Fig. 7-57:   Command value cycle with rotary modulo scaling

- operating mode: phase synchronization and
  cam shaft with P-0-0755 = 0

$$\text{command value cycle} = P - 0 - 0750 * \frac{P - 0 - 0157}{P - 0 - 0156} * P - 0 - 0159$$

Fig. 7-58:   Command value cycle with linear modulo scaling

- operating mode: cam shaft with P-0-0755 ≠ 0

$$\text{command value cycle} = P - 0 - 0750 * \frac{P - 0 - 0157 * P - 0 - 0159}{P - 0 - 0156 * P - 0 - 0755}$$

Fig. 7-59:   Command value cycle with linear modulo scaling

The active value is displayed in parameter **P-0-0754, Command value cycle**. The command value cycle describes the range containing the calculated synchronous position command values.

For modulo division the number of command value cycles per actual value cycle is used. The number is calculated with the following formula:

$$\text{number of command value cycles} = \frac{\text{actual value cycle}}{\text{command value cycle}}$$

Fig. 7-60:   Number of command value cycles per actual value cycle

Synchronization in a Division of the Command Value Cycle   The distance traveled during synchronization is the result of the difference between synchronous position command value (+ **S-0-0048, Position command value additional**) and the actual position value. The synchronization distance is limited to a division of the modulo command value cycle.

$$\text{distance} = \% \text{ part of cmd value cycle } (X_{\text{sync}} + S - 0 - 0048 - \text{actual pos. value})$$

Fig. 7-61:   Synchronization distance for synchronization in a division of the command value cycle

The actual position value in the division of the command value cycle is derived from **P-0-0753, Position actual value in actual value cycle**. For modulo division the number of divisions per actual value cycle is used. The number is calculated with the following formula:

$$\text{number of divisions} = P - 0 - 0751 * \frac{\text{actual value cylce}}{\text{command value cycle}}$$

Fig. 7-62:   Number of synchronization divisions per actual value cycle

Synchronization in the Modulo Range

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ **S-0-0048, Position command value additional**) and the actual position value. The synchronization distance is limited to the modulo value.

$$\text{distance} = \% \text{ modulo value } (X_{sync} + S - 0 - 0048 - \text{actual position value})$$

Fig. 7-63:   Synchronization distance for synchronization in modulo range

Synchronization Direction

With P-0-0155 = 1 it is always the calculated synchronization distance that is traveled. The setting in parameters **P-0-0154, Synchronization direction** and **P-0-0151, Synchronization window for modulo format** is not taken into account.

For modulo axes the distance is limited to +/-0.5 * synchronization range. In addition, the setting in parameters **P-0-0154, Synchronization direction** and **P-0-0151, Synchronization window for modulo format** is taken into account.

Note: The setting in parameter **P-0-0154, Synchronization direction** will only take effect, if the shortest distance (absolute value $\leq$ 0.5 * synchronization range) is greater than the synchronization window. In this case the synchronization direction according to parameter P-0-0154 (positive or negative or shortest distance) is used. 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, therefore there isn't any command value cycle and actual value cycle calculated.

Absolute synchronization is only possible up to $\pm$ 2048 revolutions because the max. master axis encoder range is only 2^{32} increments.

Note: 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 following settings have to be made:

- The parameter **P-0-0750, Master axis revolutions per master axis cycle** has to be initialized with zero.

- The position resulting from the addition of the values of **P-0-0053, Master axis position** (positive and negative values) or **P-0-0052,**

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Actual position value of measuring encoder with **P-0-0054, Additive master axis position** and **S-0-0048, Position command value additional** must be within the max. travel range after conversion to the internal format.

Note: Incorrect parameterization can cause unwanted jumps in position.

Recommendation: activate position limit value monitor!

See "Limitations: Position Limitation" in chapter "Drive Control"

The synchronization distance is calculated according to the following formula:

$$distance = XSynch + S - 0 - 0048 - actual\ position\ value$$

Fig. 7-64:   Synchronization distance with absolute scaling

The synchronization range corresponds to the max. travel range.

Dynamic Synchronization with Velocity Synchronization

Drive-controlled dynamic synchronization in the "velocity synchronization" mode is carried out depending on bit 5 of parameter P-0-0155.

P-0-0155, Synchronization mode:

- bit 5 = 0   → synchronization only takes place when the operating mode is activated
- bit 5 = 1   → synchronization is always active

By generating velocity command values, the drive accelerates or decelerates during synchronization until the synchronous velocity has been reached. The velocity command values are generated in consideration of **P-0-0142, Synchronization acceleration**.
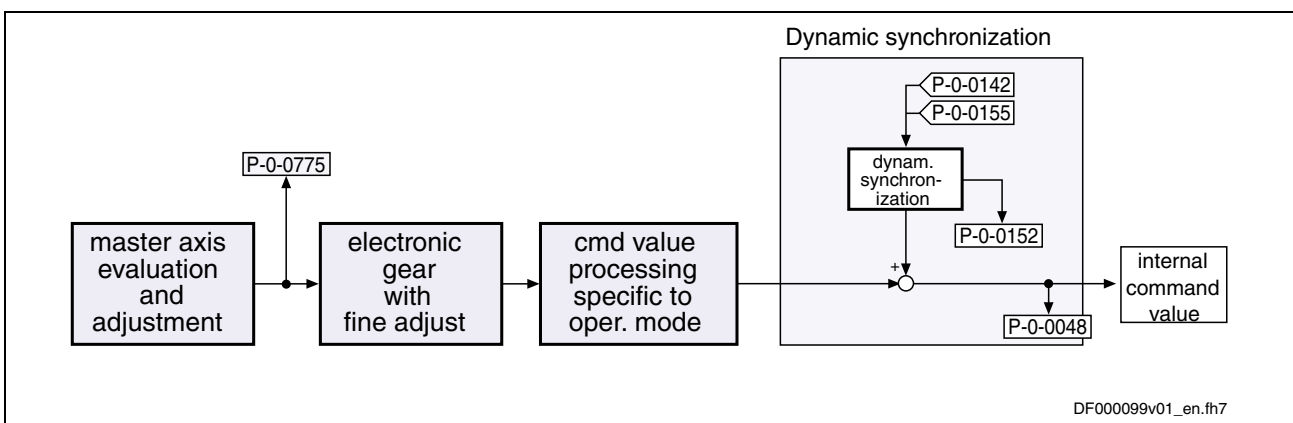
Fig. 7-65:   Function block "dynamic synchronization" for velocity synchronization

Features
- synchronization takes place as velocity adjustment
- generation of status message "synchronization completed" (P-0-0152; bit 0)
- generation of status message "synchronization mode in synchronization" (P-0-0089; bit 8)

Dynamic Synchronization with Synchronous Position Control Modes

Drive-controlled dynamic synchronization in the synchronous position control modes is carried out when

- a synchronous position control mode is activated

  - and -

- the value in parameter **S-0-0048, Position command value additional** is changed.

The values of parameters **P-0-0142, Synchronization acceleration** and **P-0-0143, Synchronization velocity** are used for generating an additive command value for compensation of the salve axis which is not velocity- and position-synchronous.
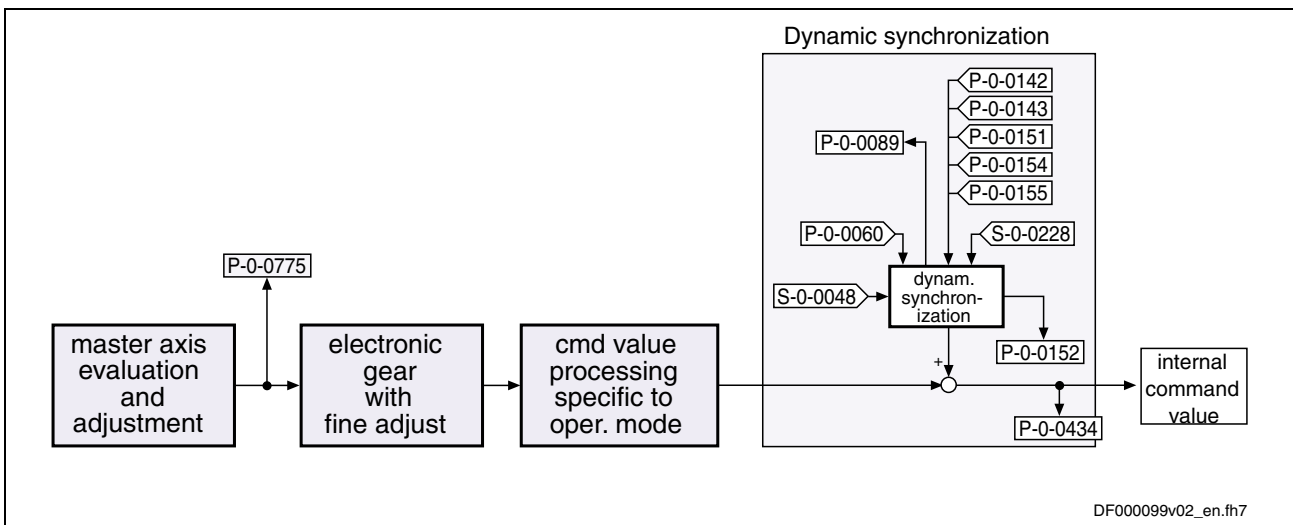
Fig. 7-66:   Function block "dynamic synchronization" for synchronous position control modes

Features
- synchronization takes place in 2 steps (velocity and position adjustment)
- absolute (position and velocity adjustment) or relative (only velocity adjustment) synchronization
- ranges to be set for synchronization:
  - modulo range (S-0-0103)
  - command value cycle for slave axis
  - division for command value cycle; can be set in parameter **P-0-0751, Synchronization divisions per command cycle slave axis**
- direction for synchronization to be set for position adjustment of modulo axes, shortest distance, positive or negative direction in parameter **P-0-0154, Synchronization direction**; setting the tolerance window with only positive or negative direction via **P-0-0151, Synchronization init window for modulo format**
- synchronization mode "standard" or "register controller" can be set in parameter P-0-0155
- display of the difference between actual position value 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)

- generation of status message "synchronization mode in synchronization" (P-0-0089, Status word for synchronous operating modes; bit 8)

Synchronization Procedure for Synchronous Position Control Modes

The dynamic synchronization described below is a part of the synchronization modes with outer position control loop (phase synchronization and cam shaft mode). The synchronization process is a drive-controlled motion with the objective of absolute or relative synchronization. The drive is absolutely synchronous when the actual position value corresponds to the sum of synchronous position command value (derived from the master axis position) and additive position command value (S-0-0048).

Note:	All settings relevant for synchronization have to be made in parameter **P-0-0155, Synchronization mode**.

For synchronization modes with outer position control loop, synchronization is carried out in two steps:

1st Step of Synchronization

1. Velocity adjustment:

The drive either accelerates or decelerates from the current actual velocity at the time of activation to the synchronous velocity.

The synchronous velocity is generated by differentiating the synchronous position command value. The synchronous position command value x_{sync} is determined from the master axis position (**P-0-0052, Actual position value of measuring encoder** or **P-0-0053, Master axis position**) according to the operating mode.

Velocity adjustment already takes place in position control. When accelerating or decelerating, the drive takes the value in parameter **P-0-0142, Synchronization acceleration** into account.

2nd Step of Synchronization

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_{Synch} and the additive position command value (S-0-0048).

The difference is calculated according to the following equation:

$$\text{difference (distance)} = x_{sync} + (S-0-0048) \ - \ (P-0-0434)$$

x_{sync}:   synchronous position command value

S-0-0048:   position command value additional

P-0-0434:   position command value of controller

Fig. 7-67:   Difference with absolute synchronization (travel distance)

In the second step of synchronization the difference generated during velocity adjustment is compensated by a travel motion taking **P-0-0142, Synchronization acceleration** and **P-0-0143, Synchronization velocity** into account. This position adjustment is added to the synchronous movement.

Relative/Absolute Synchronization

In the synchronous position control modes it is possible to select either relative or absolute synchronization:

- **relative synchronization** (P-0-0155, bit 1 = 1)
  → There is no fixed position reference between master axis and slave axis

- **absolute synchronization** (P-0-0155, bit 1 = 0)
  → There is a fixed position reference between master axis position and position command value that results from the master axis position and the parameterized additive position command value.

Relative Synchronization in Standstill

The figure below illustrates the relative synchronization to a virtual master axis, the master axis being in standstill when the operating mode is activated.
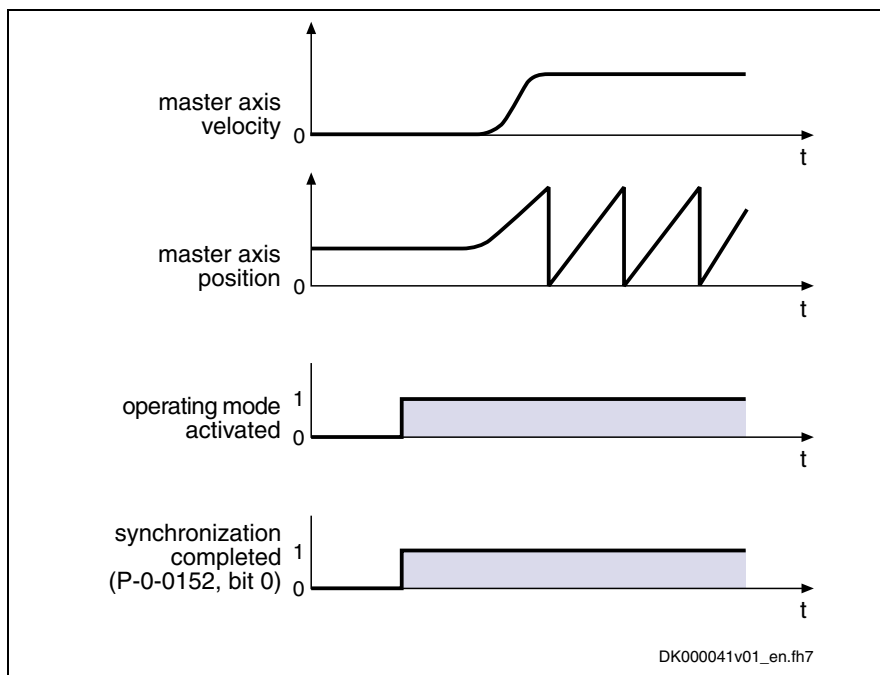
Fig. 7-68:   Example: relative synchronization out of standstill

- When the operating mode is activated, the synchronous velocity = 0.

- Upon activation of the operating mode the bits for "synchronization completed" (P-0-0152, bit 0 = 1) and "slave axis has been synchronized" (P-0-0089, bit 8 = 1) are output.

- When the machine starts, the axis, based on its current position, follows the master axis position with relatively synchronous position.

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Relative Synchronization in Running Operation

The figure below illustrates the relative synchronization to a virtual master axis, the master axis having a velocity ≠ 0 when the operating mode is activated.
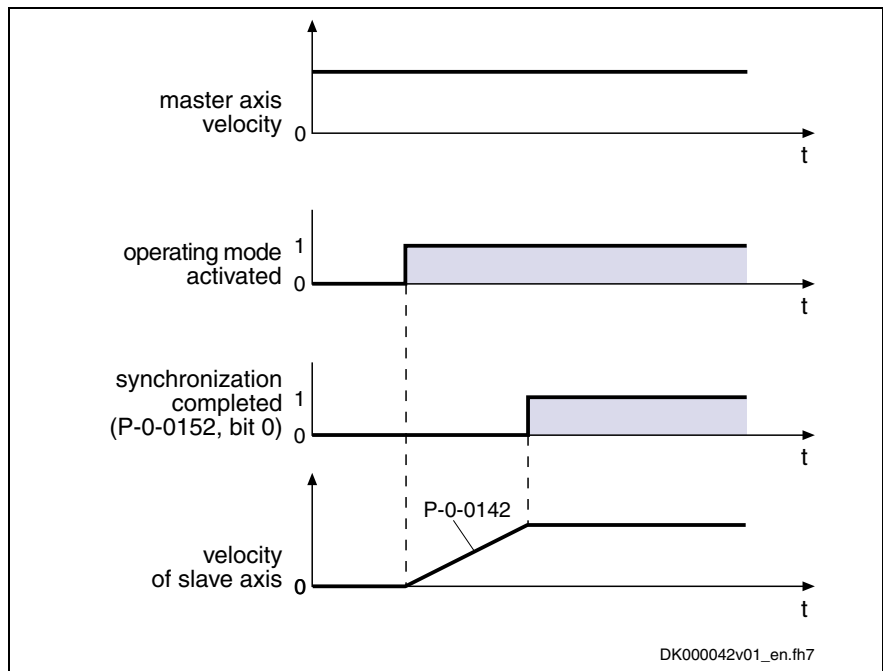
Fig. 7-69:   Example: relative synchronization in running operation

- When the operating mode is activated, the master axis moves at constant velocity.

- Based on its current position the slave axis accelerates to the synchronous velocity. While doing this the synchronization acceleration (P-0-0142) is effective.

- Upon reaching the synchronous velocity the bits for "synchronization completed" (P-0-0152, Bit 0 = 1) and "slave axis has been synchronized" (P-0-0089, bit 8 = 1) are output.

Absolute Synchronization Out of Standstill

The figure below illustrates the absolute synchronization to a virtual master axis, the master axis being in standstill when the operating mode is activated.
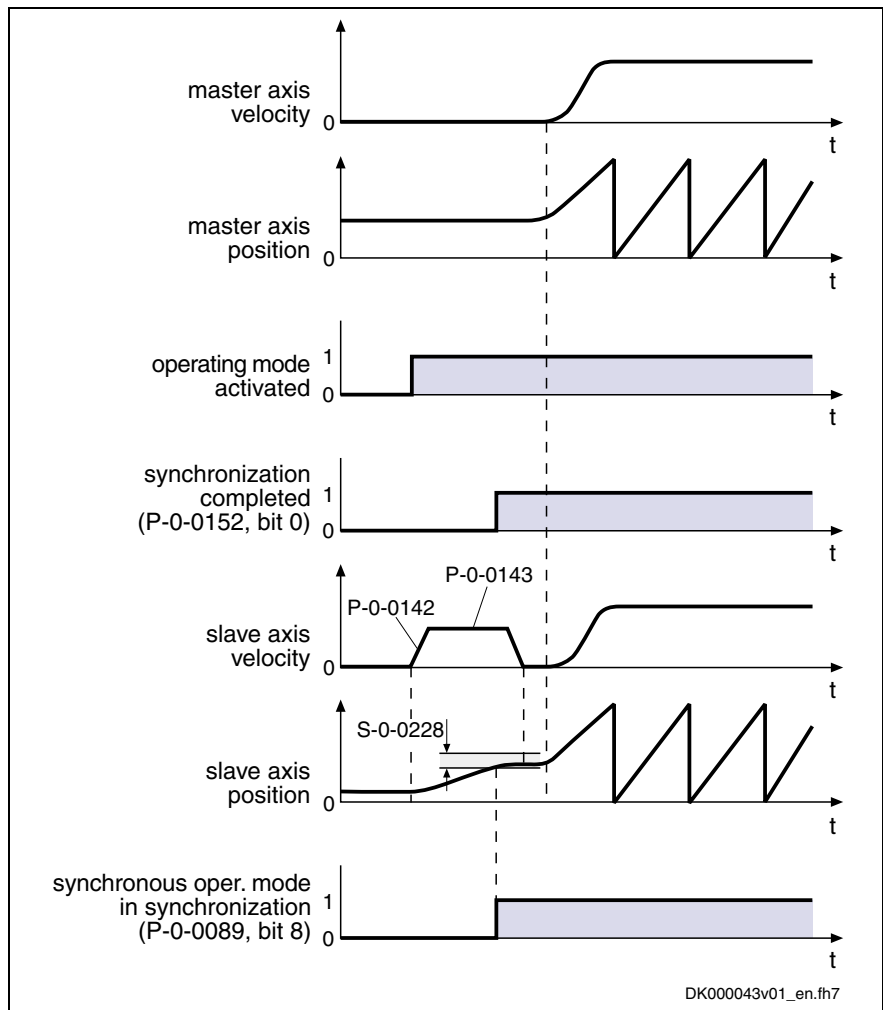
Fig. 7-70:   Example: absolute synchronization out of standstill

- When the operating mode is activated, the synchronous velocity = 0. The current master axis position differs from the synchronous position.

- The synchronization status signals "synchronization running" (P-0-0152, bit 0 = 0).

- The absolute angle reference between slave axis and master axis position is established. The master axis is turning with the parameterized synchronization velocity (P-0-0143). During acceleration and deceleration the synchronization acceleration (P-0-0142) is effective.

- As soon as the position difference between master axis and slave axis is smaller than the "position synchronization window" (S-0-0228), the status bit "slave axis has been synchronized" (P-0-0089, bit 8 = 1) is output.
  Bit 0 is set in parameter P-0-0152 when synchronization has been completed.

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Absolute Synchronization in Running Operation

The figure below illustrates the absolute synchronization to a virtual master axis, the master axis having a velocity $\neq 0$ when the operating mode is activated.

DK000044v01_en.fh7
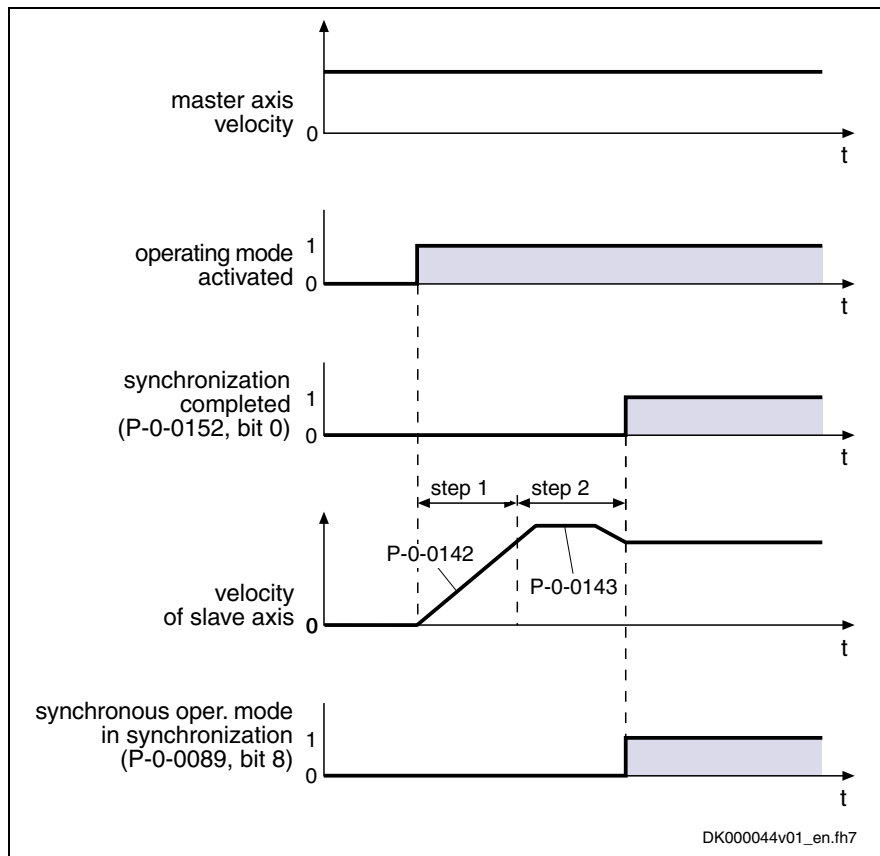
step 1:   velocity adjustment

step 2:   position adjustment

Fig. 7-71:   Example: absolute synchronization in running operation

- When the operating mode is activated, the master axis moves at constant velocity.

- The synchronization status signals "synchronization running" (P-0-0152, bit 0 = 0).

- Based on its current position the slave axis accelerates to the synchronous velocity. While doing this 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.

Standard/Register Controller Synchronization

Synchronization Mode
In the synchronous position control modes it is possible to determine, in parameter **P-0-0155, Synchronization mode**, the synchronization mode for the reaction to further changes in parameter **S-0-0048, Position command value additional** after the absolute synchronization has been reached for the first time.

"Standard" Mode
(P-0-0155, bit 0 = 0)
In the "standard" synchronization mode all further changes in the additive position command value are processed with the values determined in the following parameters:

- **P-0-0142, Synchronization acceleration**
- **P-0-0143, Synchronization velocity**
- **P-0-0151, Synchronization init window for modulo format**
- **P-0-0154, Synchronization direction**

Note: The status bit "synchronization completed" is only set when the condition P-0-0434 = S-0-0048 + x_{sync} has been fulfilled.
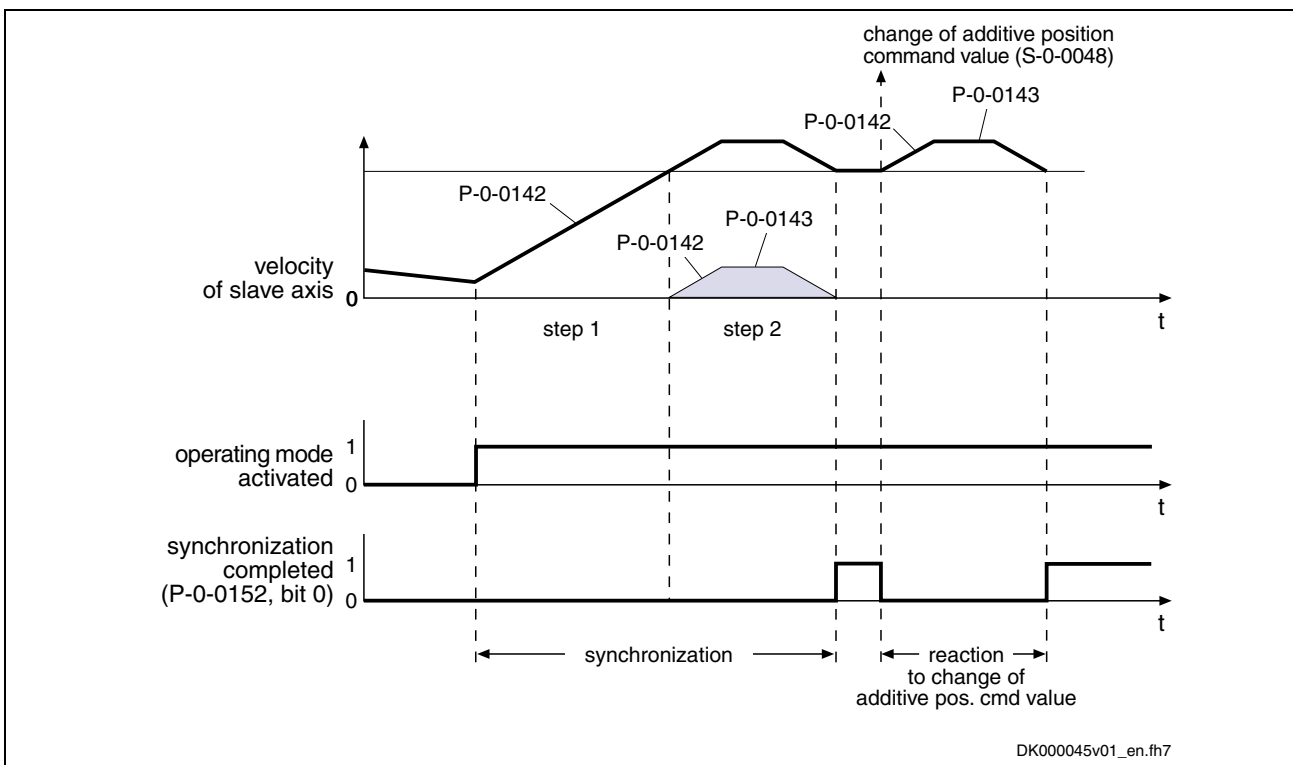
Fig. 7-72:   "Standard" synchronization mode

During synchronization in the "standard" mode the command values are monitored with regard to **S-0-0091, Bipolar velocity limit value** and **S-0-0138, Bipolar acceleration limit value**. If the command values exceed the limit values, the error messages **F2037 Excessive position command difference** or **F2039 Maximum acceleration exceeded** are generated.

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Possible counter measures:

- increasing the filter time constant
- reducing the changes in the additive position command value
- increasing the limit values for velocity and acceleration

"Register Controller" Mode
(P-0-0155, bit 0 = 1)

In the "register controller" synchronization mode all further changes of the additive position command value are smoothed by a 1st order filter. The time constant of the filter is set in parameter **P-0-0060, Filter time constant additional pos. command**.

> **Note:** The status bit "synchronization completed" is set when the absolute synchronization has been reached and won't be cleared even with further changes in **S-0-0048, Position command value additional**.
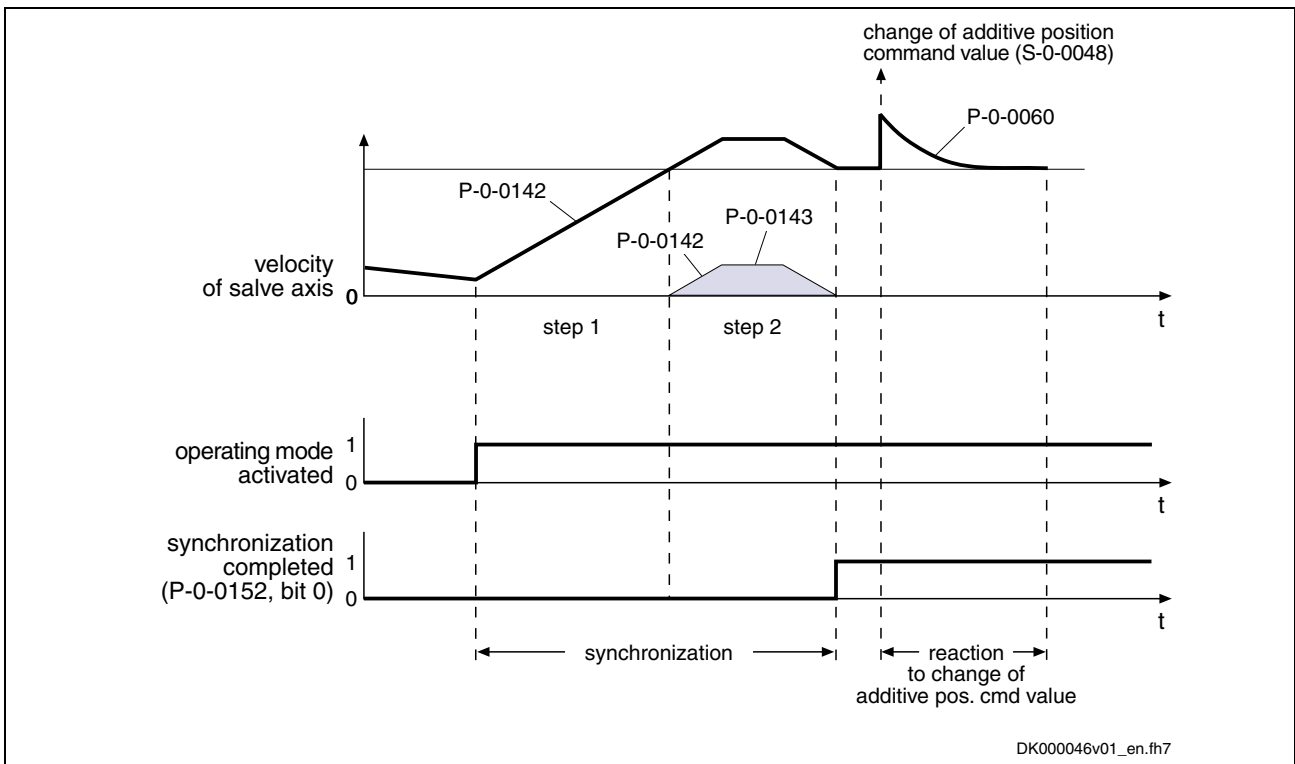
Fig. 7-73:   "Register controller" synchronization mode

During synchronization in the "register controller" mode the command values are monitored with regard to **S-0-0091, Bipolar velocity limit value** and **S-0-0138, Bipolar acceleration limit value**. If the command values exceed the limit values, the error messages **F2037 Excessive position command difference** or **F2039 Maximum acceleration exceeded** are generated.

Possible counter measures:

- 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

Apart from some status and display parameters that are valid for all operating modes, the parameters **P-0-0089, Status word for synchronous operating modes** and **P-0-0152, Synchronization completed** are available for diagnosing the synchronization modes.

P-0-0089, Bit 8 (Synchronization Mode in Synchronization)

The feedback signaling that the slave axis has been synchronized takes place in bit 8 of parameter **P-0-0089, Status word for synchronous operating modes**.

P-0-0089, Status word for synchronous operating modes:

- bit 8 = 0   → slave axis has not been synchronized
- bit 8 = 1   → slave axis has been synchronized

In synchronous position control modes the drive sets bit 8 when the following applies:

$$\left| x_{sync} + (S-0-0048) \ - (P-0-0753) \right| < S-0-0228$$

In the case of velocity synchronization the drive sets bit 8 when the following applies:

$$\left| dx_{sync} + (S-0-0037) \ - (S-0-0040) \right| < S-0-0183$$

P-0-0152, Bit 0 (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**.

P-0-0152, Synchronization completed:

- bit 0 = 0   → synchronization running
- bit 0 = 1   → synchronization completed

As regards the generation of bit 0 in parameter P-0-0152, the following cases have to be distinguished for the operating modes "phase synchronization" and "electronic cam shaft":

- First synchronization process:
  Bit 0 is set when the distance up to the absolute or relative position has been traveled.

- Cyclic normal operation:
  When bit 0 has been set, the fact of whether bit 0 is cleared for the duration of the following travel reaction when the additive position command value (S-0-0048) is changed, depends on the setting of bit 0 in parameter **P-0-0155, Synchronization mode**. If bit 0 = 1 in parameter P-0-0155 ("register controller" mode), bit 0 remains set in parameter P-0-0152.

Velocity Synchronization with Real/Virtual Master Axis

Expansion package **synchronization** (order code **SNC**) in all characteristics

Brief Description

In the case of the operating mode "velocity synchronization with real/virtual master axis" the drive follows a preset master axis velocity in a velocity-synchronous way.

The real master axis velocity is generated by a master axis encoder, the virtual master axis velocity is preset by the master.

See also "Dynamic Synchronization with Velocity Synchronization" 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 master axis position (P-0-0054), multiplied via master axis gear and fine adjustment
- adjustable master axis polarity
- synchronization mode to be selected
  - velocity adjustment always via synchronization acceleration (P-0-0142)
  - velocity adjustment via synchronization acceleration (P-0-0142) only at first synchronization
- display parameter for master axis speed (P-0-0764) and effective master axis velocity (P-0-0777)

Variants of the Operating Mode
There are the following variants of the operating mode to be selected:
- velocity synchronization with real master axis
- velocity synchronization with virtual master axis
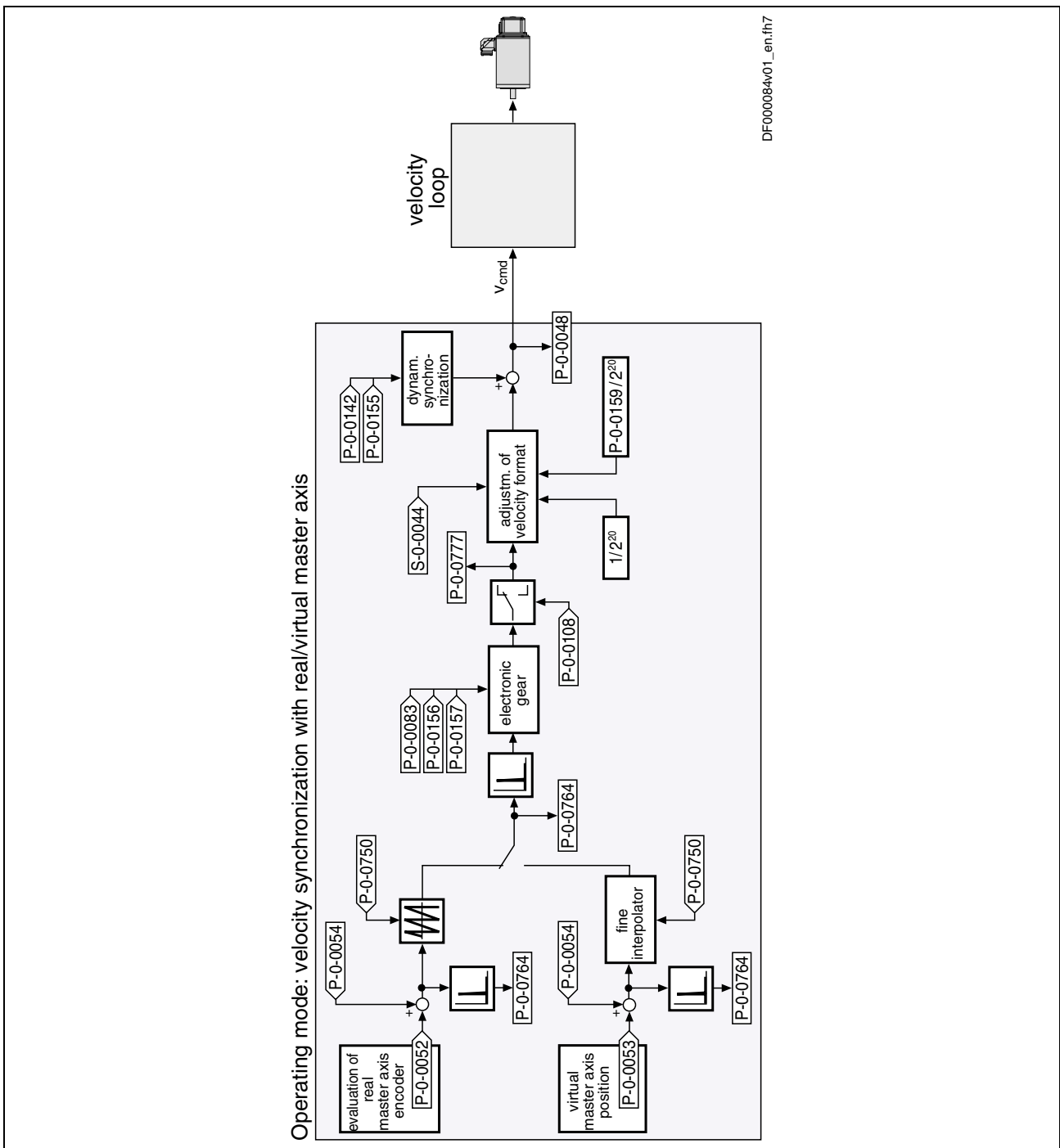
Fig. 7-74:   Block diagram: velocity synchronization with real/virtual master axis

Application "Velocity Synchronization"

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

- **S-0-0037, Additive velocity command value**

- **S-0-0044, Velocity data scaling type**

- **S-0-0048, Additive position command value**

- **S-0-0183, Velocity synchronization window**

- **P-0-0052, Actual position value of measuring encoder**

- **P-0-0053, Master axis position**
- **P-0-0054, Additive master axis position**
- **P-0-0083, Gear ratio fine adjust**
- **P-0-0089, Status word for synchronous operating modes**
- **P-0-0108, Master drive polarity**
- **P-0-0142, Synchronization acceleration**
- **P-0-0155, Synchronization mode**
- **P-0-0156, Master drive gear input revolutions**
- **P-0-0157, Master drive gear output revolutions**
- **P-0-0159, Slave drive feed travel**
- **P-0-0750, Master axis revolutions per master axis cycle**
- **P-0-0764, Master axis velocity**
- **P-0-0775, Resulting master axis position**
- **P-0-0777, Effective master axis velocity**

Pertinent Diagnostic Messages

- **A0110 Velocity synchronization, virtual master axis**
- **A0111 Velocity synchronization, real master axis**
- **E2063 Velocity command value > limit S-0-0091**

Command Value Adjustment

Overview
Command value adjustment in the "velocity synchronization" mode consists of the following basic functions:

- master axis evaluation and adjustment (real or virtual master axis)
- electronic gear with fine adjust
- command value processing specific to operating mode
- dynamic synchronization

See also section "Basic Functions of the Synchronization Modes"
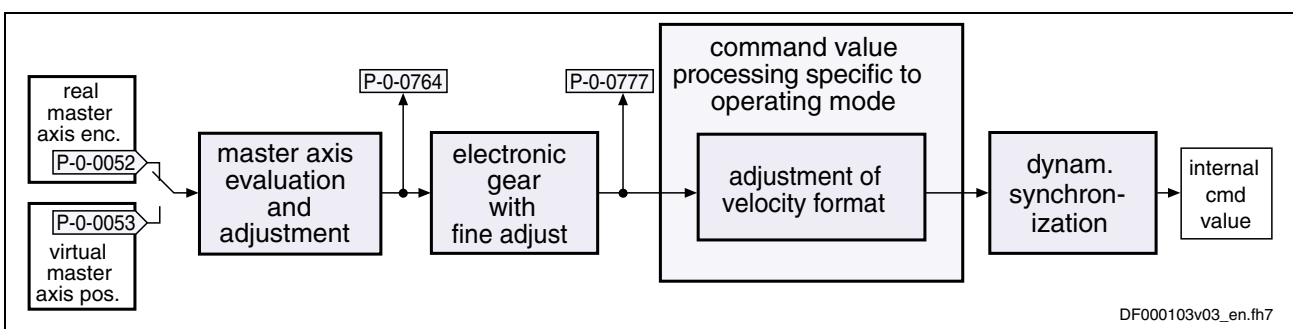
P-0-0052:	actual position value of measuring encoder
P-0-0053:	master axis position
P-0-0764:	master axis velocity
P-0-0777:	effective master axis velocity

Fig. 7-75: Function blocks of command value processing and command value adjustment in operating mode "velocity synchronization with real/virtual master axis"

Note:	Only the function block specific to the velocity synchronization mode is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

Generating the Synchronous Velocity Command Value

The synchronous velocity command value (dx_{sync}) is calculated in terms of the selected master axis polarity (**P-0-0108, Master drive polarity**) and the scaling type that was set (**S-0-0044, Velocity data scaling type**), using the following equations:

$$dXsync = \pm \Delta\,(P\text{-}0\text{-}0053 + P\text{-}0\text{-}0054) * \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} * (1 + P\text{-}0\text{-}0083) * \frac{1}{2^{20}}$$

dx_{sync}:   synchronous velocity command value

Fig. 7-76:   Generating the synchronous velocity command value with rotary scaling

$$dXsync = \pm \Delta\,(P\text{-}0\text{-}0053 + P\text{-}0\text{-}0054) * \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} * (1 + P\text{-}0\text{-}0083) * \frac{P\text{-}0\text{-}0159}{2^{20}}$$

dx_{sync}:   synchronous velocity command value

Fig. 7-77:   Generating the synchronous velocity command value with linear scaling

Note:	As a standard, one master axis revolution is fixed at 2^{20} increments. This means that the LSB of the master axis position corresponds to 2^{-20} master axis revolutions.

Synchronization with Velocity Synchronization

The synchronization process is a drive-controlled motion with the aim of synchronizing the axis to the master axis velocity. The slave axis is velocity-synchronous when the following condition has been fulfilled:

dx_{sync} = P-0-0048 – S-0-0037

Synchronization Process

Upon activating the operating mode, a **velocity adjustment** is first executed.

This means that the drive either accelerates or decelerates from the current actual velocity at the time of activation to the synchronous velocity.

The drive generates the synchronous velocity by differentiating the master axis position:

Δ(P-0-0053 + P-0-0054) or Δ(P-0-0052 + P-0-0054)

After the synchronous velocity has been reached, another change of the synchronous velocity is processed depending on **P-0-0155, Synchronization mode**.

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The following variants are available to do this:

- **P-0-0155 bit 5 = 0**

  $\rightarrow$ velocity adjustment only carried out once, all following changes of velocity are carried out with maximum acceleration

- **P-0-0155 bit 5 = 1**

  $\rightarrow$ each change of velocity is limited by the value of **P-0-0142, Synchronization acceleration**

> **i** See also Parameter Description "P-0-0155, Synchronization mode"
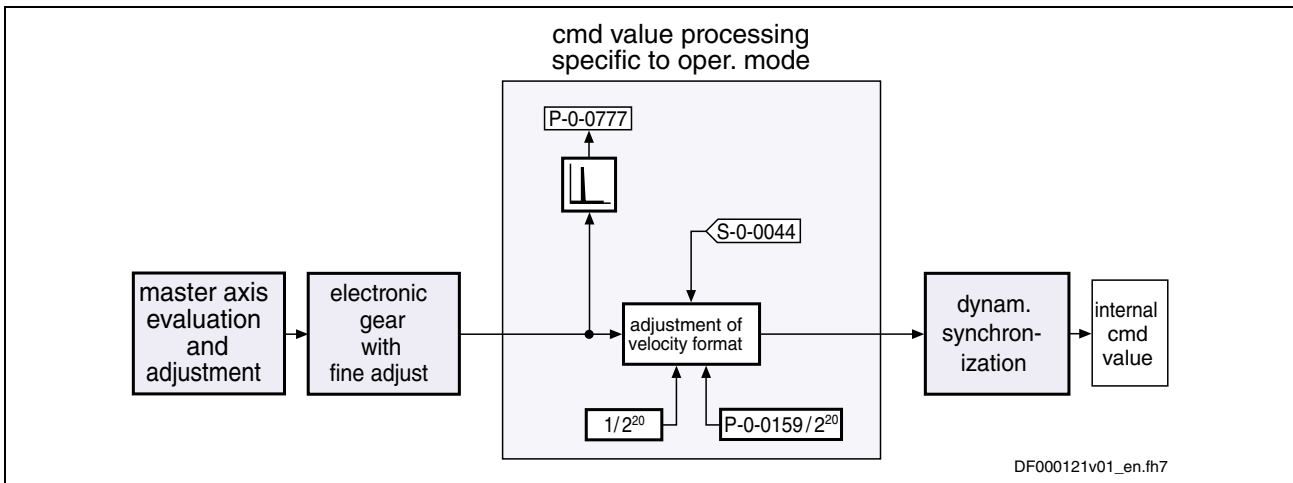
Fig. 7-78:   Command value processing and command value adjustment specific to velocity synchronization

Notes on Commissioning/Parameterization

General Parameterization   For general parameterization it is necessary to make machine-specific presettings:

- scaling of parameter data (linear or rotary)

  - S-0-0076, S-0-0077, S-0-0078 and S-0-0079 for position data

  - S-0-0044, S-0-0045 and S-0-0046 for velocity data

  - S-0-0160, S-0-0161 and S-0-0162 for acceleration data

  See "Mechanical Axis System and Measuring Systems: Scaling of Physical Data" in chapter "Motor, Mechanical Axis System, Measuring Systems"

- 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)

Sequence of parameterization specific to operating mode:

Parameterizing the Operating Mode

1. Depending on parameter **P-0-0750, Master axis revolutions per master axis cycle**, the range of values for the master axis can be between 0 and $2047 * 2^{20}$ increments. In the special case P-0-0750 = 0, the master axis range is from -2^{31} to 2^{31}-1.

2. The distance that the slave axis covers per master axis revolution is determined in parameter **P-0-0159, Slave drive feed travel**.

3. Settings for the electronic gear are made in the following parameters:

    *   **P-0-0083, Gear ratio fine adjust**
    *   **P-0-0108, Master drive polarity**
    *   **P-0-0156, Master drive gear input revolutions**
    *   **P-0-0157, Master drive gear output revolutions**

4. The following settings have to be made for synchronization:

    *   **P-0-0142, Synchronization acceleration**
    *   synchronization mode for velocity synchronization (P-0-0155, bit 5)

Diagnostic and Status Messages

The following diagnostic status messages are displayed in normal operation of the operating mode (drive enabled, "AF"):

Diagnostic Status Messages

*   **A0110 Velocity synchronization, virtual master axis**
*   **A0111 Velocity synchronization, real master axis**

Error Messages and Warnings

Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operating mode:

*   **E2063 Velocity command value > limit S-0-0091**

There are also several status messages specific to operating mode generated in the drive that are mapped to specific status bits (see also **P-0-0089, Status word for synchronous operating modes** and **P-0-0152, Synchronization completed**).

Phase Synchronization with Real/Virtual Master Axis

Expansion package **synchronization** (order code **SNC**) in **closed-loop** characteristic

Brief Description

In the operating mode "phase synchronization with real/virtual master axis" the drive follows a preset master axis position in an absolute or relative phase synchronous way.

The real master axis position is generated by a master axis encoder, the virtual master axis position is preset by the master.

See also "Dynamic Synchronization with Synchronous Position Control Modes" in section "Basic Functions of the Synchronization Modes"

Features
- determination of the position command value from the master axis position using the electronic gear and fine adjust, adjustable master axis polarity
- adjustable master axis cycle and actual value cycle, displayed command value cycle
- synchronization mode to be selected
  - standard (trapezoidal)
  - register controller (PT1 filter)
- additive master axis position
- absolute and modulo processing of the master axis
- absolute or relative phase synchronization
- synchronization range to be selected
  - modulo range
  - command value cycle
  - part of command value cycle
- additive position command value

Variants of the Operating Mode
There are the following variants of the operating mode to be selected:
- 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
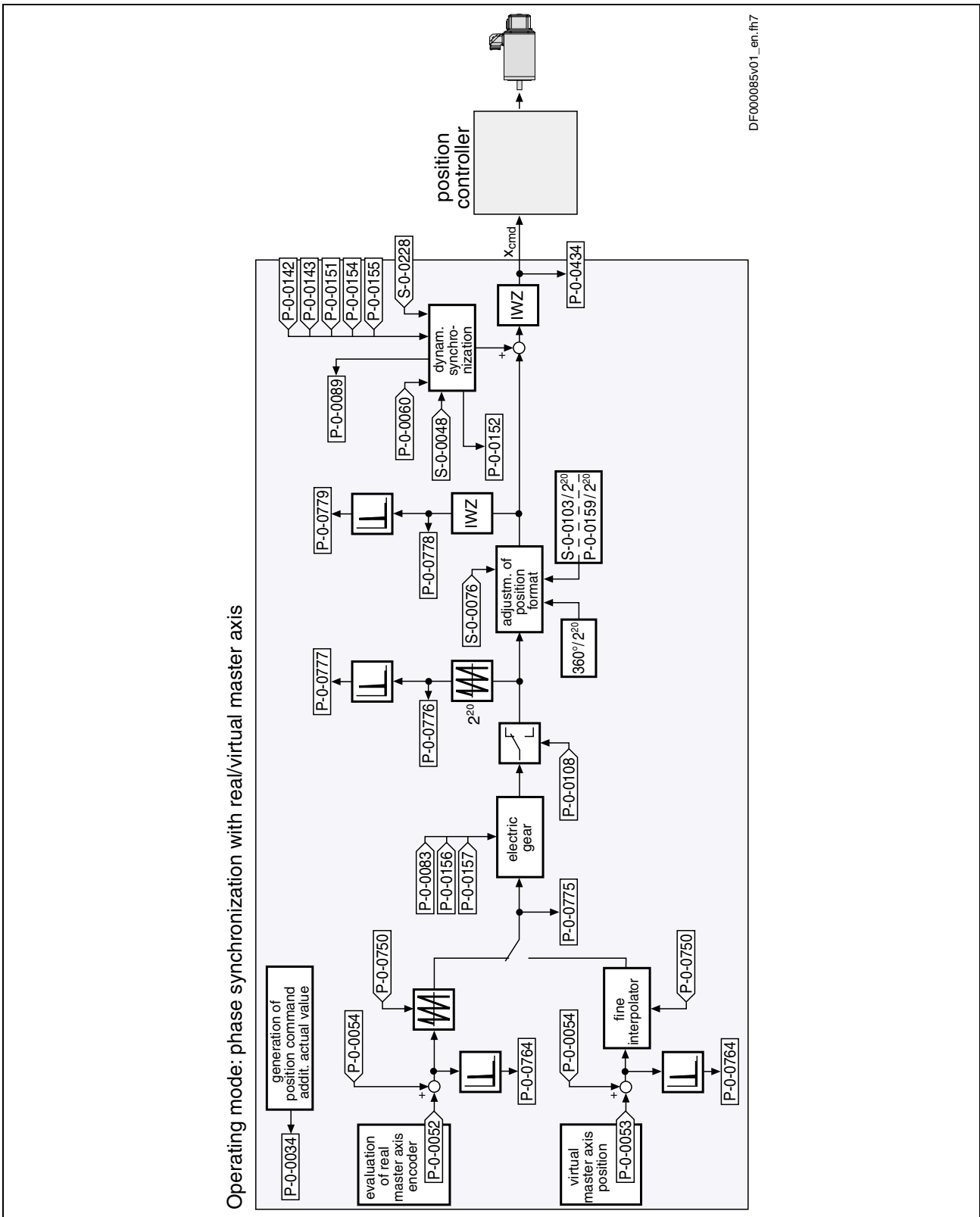
IWZ: modulo actual value cycle

Fig. 7-79:   Block diagram: phase synchronization with real/virtual master axis

Application "Absolute Phase Synchronization"

For 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

- **S-0-0048, Additive position command value**
- **S-0-0076, Position data scaling type**
- **S-0-0103, Modulo value**
- **S-0-0228, Position synchronization window**
- **P-0-0034, Position command additional actual value**
- **P-0-0052, Actual position value of measuring encoder**
- **P-0-0053, Master axis position**
- **P-0-0054, Additive master axis position**
- **P-0-0060, Filter time constant additional pos. Command**
- **P-0-0071, C3100 Recalculate actual value cycle**
- **P-0-0083, Gear ratio fine adjust**
- **P-0-0088, Control word for synchronous operation modes**
- **P-0-0089, Status word for synchronous operating modes**
- **P-0-0108, Master drive polarity**
- **P-0-0142, Synchronization acceleration**
- **P-0-0143, Synchronization velocity**
- **P-0-0151, Synchronization init window for modulo format**
- **P-0-0154, Synchronization direction**
- **P-0-0155, Synchronization mode**
- **P-0-0156, Master drive gear input revolutions**
- **P-0-0157, Master drive gear output revolutions**
- **P-0-0159, Slave drive feed travel**
- **P-0-0750, Master axis revolutions per master axis cycle**
- **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-0-0764, Master axis velocity**
- **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**

Pertinent Diagnostic Messages

- **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**
- **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**
- **E2049 Positioning velocity >= S-0-0091**
- **F2039 Maximum acceleration exceeded**

Command Value Adjustment

Overview   Command value adjustment in the "phase synchronization" mode consists of the following basic functions:

- master axis evaluation and adjustment (real or virtual master axis)
- electronic gear with fine adjust
- command value processing specific to operating mode
- dynamic synchronization

See also section "Basic Functions of the Synchronization Modes"
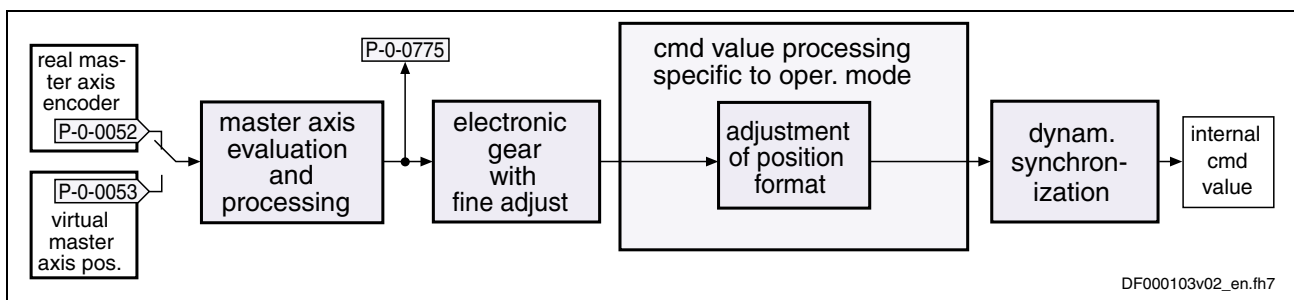
P-0-0052:   actual position value of measuring encoder

P-0-0053:   master axis position

P-0-0775:   resulting master axis position

Fig. 7-80:   Function blocks of command value processing and command value adjustment in operating mode "phase synchronization with real/virtual master axis"

> **Note:** Only the function block specific to the phase synchronization mode is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes"

Generating the Internal Position Command Value

In the operating mode "phase synchronization with real/virtual master axis" the internal position command value (P-0-0434) is generated by addition of the synchronous position command value (x_{sync}) and the position command value from the synchronization process ($x_{sync\_process}$).

$$P - 0 - 0434 = x_{sync} + x_{sync\_process}$$

P-0-0434: position command value of controller

x_{sync}: synchronous position command value

$x_{sync\_process}$: difference to absolute position

Fig. 7-81: Generating the position command value

> **Note:** In the synchronized status (P-0-0089; bit 8 = 1) the following applies:
>
> P-0-0434 = x_{sync} + S-0-0048 (because $x_{sync\_process}$ = S-0-0048)

Generating the Synchronous Position Command Value

The synchronous position command value (x_{sync}) is calculated in terms of the selected master axis polarity (**P-0-0108, Master drive polarity**) and the scaling type that was set (**S-0-0076, Position data scaling type**), using the following equation:

$$Xsync = (P - 0 - 0775 \; * \; \frac{P - 0 - 0157}{P - 0 - 0156} * (1 + P - 0 - 0083) \; * \frac{S - 0 - 0103}{2^{20}}) \; \% \; IWZ$$

x_{sync}: synchronous position command value

IWZ: modulo actual value cycle

Fig. 7-82: Generating the synchronous position command value with rotary modulo scaling

$$Xsync = (P - 0 - 0775 * \frac{P - 0 - 0157}{P - 0 - 0156} * (1 + P - 0 - 0083) * \frac{360 \; degrees}{2^{20}}) \; \% \; IWZ$$

x_{sync}: synchronous position command value

IWZ: modulo actual value cycle

Fig. 7-83: Generating the synchronous position command value with rotary absolute scaling

$$Xsync = (\ P\text{-}0\text{-}0775\ *\ \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156}\ *(1+P-0-0083)\ *\ \frac{P\text{-}0\text{-}0159}{2^{20}})\ \%\ IWZ$$

x_{sync}:   synchronous position command value

IWZ: modulo actual value cycle

Fig. 7-84:   Generating the synchronous position command value with linear scaling

Note: As a standard, one master axis revolution is fixed at 2^{20} increments. This means that the LSB of the master axis position corresponds to 2^{-20} master axis revolutions.
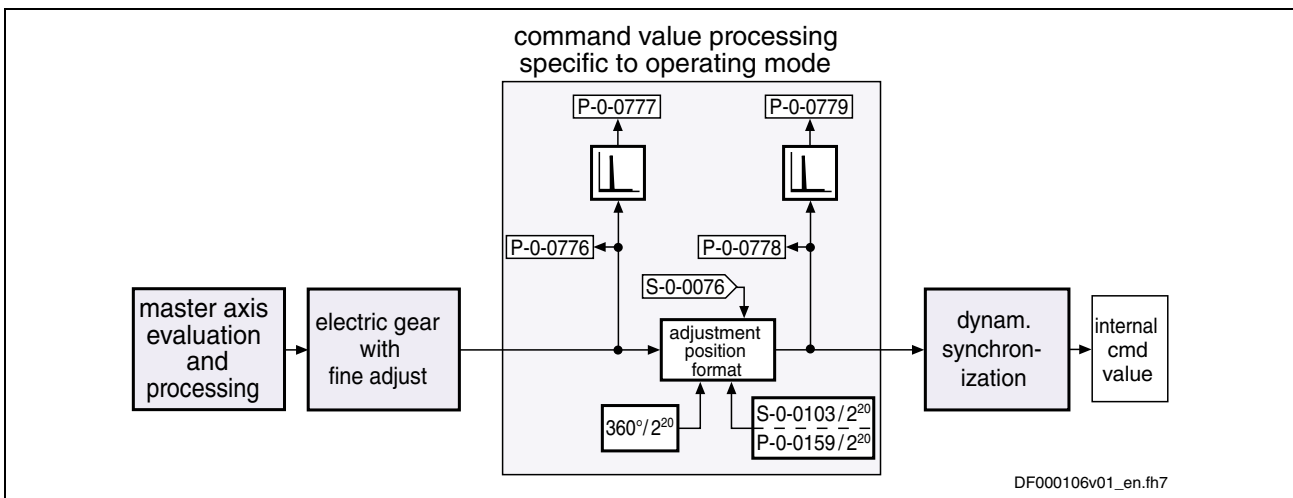
Fig. 7-85:   Command value processing and command value adjustment specific to operating mode with phase synchronization

Notes on Commissioning/Parameterization

General Parameterization

During general parameterization it is necessary to make machine-specific presettings:

- scaling of parameter data (linear or rotary)
  - S-0-0076, S-0-0077, S-0-0078 and S-0-0079 for position data
  - S-0-0044, S-0-0045 and S-0-0046 for velocity data
  - S-0-0160, S-0-0161 and S-0-0162 for acceleration data

  See "Mechanical Axis System and Measuring Systems: Scaling of Physical Data" in chapter "Motor, Mechanical Axis System, Measuring Systems"

- 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)

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"Modulo" Parameterization

For "modulo" parameterization make the following settings:

Modulo Range 1. In parameter **S-0-0103, Modulo value** set the modulo range to that value at which the overflow of the position data (from modulo value to "0") is to take place with infinitely turning axis.

Maximum Travel Range 2. 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).

Master Axis Position Range/ Master Axis Cycle 3. Depending on parameter **P-0-0750, Master axis revolutions per master axis cycle**, the range of values for the master axis can be between 0 and $2047 * 2^{20}$ increments. In the special case of P-0-0750 = 0, the master axis range is from -2^{31} to $2^{31}-1$. This case is used, among other things, for the application flying saw. 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.

"Modulo" Master Axis 4. The "modulo" master axis is a master axis the master axis positions of which are within the master axis cycle determined by parameter **P-0-0750, Master axis revolutions per master axis cycle**. The master axis positions may overflow or underflow (infinitely turning master axis).

Slave Drive Feed Travel 5. The distance that the slave axis covers per master axis revolution is determined in parameter **P-0-0159, Slave drive feed travel**.

Electronic Gear 6. Settings for the electronic gear are made in the following parameters:

- **P-0-0083, Gear ratio fine adjust**
- **P-0-0108, Master drive polarity**
- **P-0-0156, Master drive gear input revolutions**
- **P-0-0157, Master drive gear output revolutions**

"Modulo" Synchronization 7. The following settings have to be made for synchronization:

- synchronization mode for reaction to changes in parameter S-0-0048 after first synchronization (P-0-0155, bit 0)
- relative or absolute synchronization (P-0-0155, bit 1)
- synchronization range (P-0-0155, bits 2 and 3)
- generation of actual value cycle (P-0-0155, bit 4)

Note: The actual value cycle has to be an integral multiple of the synchronization range.

"Absolute" Parameterization

Maximum Travel Range

1. In the case of absolute scaling, the maximum travel range in parameter S-0-0278 has to be selected at least as large as the range in which the synchronous position data are to be contained.

Master Axis Position Range/ Master Axis Cycle

2. Depending on parameter **P-0-0750, Master axis revolutions per master axis cycle**, the range of values for the master axis can be between 0 and $2047 * 2^{20}$ increments. In the special case of P-0-0750 = 0, the master axis range is from -2^{31} to 2^{31}-1. This case is used, among other things, for the application flying saw. 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.

"Absolute" Master Axis

3. The "absolute" master axis is a master axis the master axis positions of which are within the master axis cycle determined by parameter **P-0-0750, Master axis revolutions per master axis cycle**. The master axis positions <u>mustn't</u> overflow or 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 section "Limitations: Position Limit" in chapter "Drive Control"

Slave Drive Feed Travel

4. The distance that the slave axis covers per master axis revolution is determined in parameter **P-0-0159, Slave drive feed travel**.

Electronic Gear

5. Settings for the electronic gear are made in the following parameters:

- **P-0-0083, Gear ratio fine adjust**
- **P-0-0108, Master drive polarity**
- **P-0-0156, Master drive gear input revolutions**
- **P-0-0157, Master drive gear output revolutions**

"Absolute" Synchronization

6. The following settings have to be made for synchronization:

- synchronization mode for reaction to changes in parameter S-0-0048 after first synchronization (P-0-0155, bit 0)
- relative or absolute synchronization (P-0-0155, bit 1)

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The figure below illustrates the basic commissioning steps:

Fig. 7-86:   Overview of commissioning steps for phase synchronization

Diagnostic and Status Messages

The following diagnostic status messages are displayed in normal operation of the operating mode (drive enabled, "AF").

Diagnostic Status Messages

- **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**

Diagnostic Command Messages

- **C0244 Act. modulo value cycle greater than max. travel range**
  This error message is generated when switching from communication phase 3 to 4, if the calculated modulo value for the actual value cycle is greater than the max. travel range (S-0-0278).

- **C3100 Recalculate actual value cycle**
  This command causes the modulo value for the actual value cycle to be recalculated.

- **C3101 Act. modulo value cycle greater than max. travel range**
  This error message is generated when triggering the command **C3100 Recalculate actual value cycle**, if the calculated modulo value for the actual value cycle is greater than the max. travel range (S-0-0278).

- **C3102 Drive is still in drive enable**
  This command error is generated when the command **P-0-0071, C3100 Recalculate actual value cycle** is started with the drive having been enabled.

Error Messages and Warnings

Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operating mode:

- **F2039 Maximum acceleration exceeded**
  The preset acceleration value of two successive command values was greater than the value parameterized in **S-0-0138, Bipolar acceleration limit value**.

- **F2037 Excessive position command difference**
  The velocity preset for the drive by two successive command values, is greater than the value in **S-0-0091, Bipolar velocity limit value**.

There are also several status messages specific to operating mode generated in the drive that are mapped to specific status bits (see also **P-0-0089, Status word for synchronous operating modes** and **P-0-0152, Synchronization completed**).

Position Status of Actual Position Value in Actual Value Cycle

Bit 4 in parameter P-0-0089 indicates the position status of the actual position value in the actual value cycle (P-0-0753).

P-0-0089, Status word for synchronous operating modes:

- bit 4 = 0 → not homed
- bit 4 = 1 → homed (absolute synchronization can take place)

Electronic Cam Shaft with Real/Virtual Master Axis

Expansion package **synchronization** (order code **SNC**) in **closed-loop** characteristic

Brief Description

In the operating mode "Electronic cam shaft with real/virtual master axis" there is a fixed relationship between the master axis position and the slave axis.

The real master axis position is generated by a master axis encoder, the virtual master axis position is preset by the master.

See also "Dynamic Synchronization with Synchronous Position Control Modes" in section "Basic Functions of the Synchronization Modes"

Features
- 4 different cam shaft profiles with 8, 16, 32, 64, 128, 512 or 1024 data points each
  (P-0-0072, P-0-0092, P-0-0780, P-0-0781)
- linear interpolation or cubic spline interpolation of the cam shaft data points can be set
- dynamic angle offset and angle offset at begin of profile
- freely definable switch angle for cam shaft and cam shaft distance
- additive master axis position and additive position command value
- absolute or relative phase synchronization
- synchronization mode to be selected:
  - standard (trapezoidal)
  - register controller (PT1 filter)
- synchronization range to be selected:
  - modulo range
  - command value cycle
  - part of command value cycle
- change of format "on the fly"
- cross cutter function
- clocked pull roll
- adjustable master axis polarity

Variants of the Operating Mode
There are the following variants of the operating mode to be selected:
- cam shaft with real master axis, encoder 1
- cam shaft with real master axis, encoder 2
- cam shaft with real master axis, encoder 1, lagless
- cam shaft with real master axis, encoder 2, lagless
- cam shaft with virtual master axis, encoder 1
- cam shaft with virtual master axis, encoder 2
- cam shaft with virtual master axis, encoder 1, lagless
- cam shaft with virtual master axis, encoder 2, lagless

IWZ: modulo actual value cycle

Fig. 7-87:   Block diagram: electronic cam shaft with real/virtual master axis

Pertinent Parameters
- **S-0-0048, Additive position command value**
- **S-0-0228, Position synchronization window**
- **P-0-0034, Position command additional actual value**
- **P-0-0052, Actual position value of measuring encoder**
- **P-0-0053, Master axis position**
- **P-0-0054, Additive master axis position**
- **P-0-0060, Filter time constant additional pos. Command**
- **P-0-0061, Angle offset begin of profile**
- **P-0-0072, Cam shaft profile 1**
- **P-0-0073, Cam shaft distance 2**
- **P-0-0083, Gear ratio fine adjust**
- **P-0-0085, Dynamic angle offset**
- **P-0-0088, Control word for synchronous operation modes**
- **P-0-0089, Status word for synchronous operating modes**
- **P-0-0092, Cam shaft profile 2**
- **P-0-0093, Cam shaft distance**
- **P-0-0094, Cam shaft switch angle**
- **P-0-0108, Master drive polarity**
- **P-0-0144, Cam shaft distance switch angle**
- **P-0-0151, Synchronization init window for modulo format**
- **P-0-0152, Synchronization completed**
- **P-0-0154, Synchronization direction**
- **P-0-0156, Master drive gear input revolutions**
- **P-0-0157, Master drive gear output revolutions**
- **P-0-0158, Angle offset change rate**
- **P-0-0159, Slave drive feed travel**
- **P-0-0227, Cam shaft profile, access angle**
- **P-0-0750, Master axis revolutions per master axis cycle**
- **P-0-0751, Synchronization divisions per command cycle slave axis**
- **P-0-0752, Load revolutions per actual value cycle slave axis**
- **P-0-0754, Command value cycle**
- **P-0-0755, Gear reduction**
- **P-0-0764, Master axis velocity**
- **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-0-0780, Cam shaft profile 3**
- **P-0-0781, Cam shaft profile 4**

Pertinent Diagnostic Messages
- **A0128 Cam shaft, encoder 1, virtual master axis**
- **A0129 Cam shaft, encoder 2, virtual master axis**
- **A0130 Cam shaft, encoder 1, real master axis**
- **A0131 Cam shaft, encoder 2, real master axis**
- **A0132 Cam shaft, lagless, encoder 1, virt. master axis**
- **A0133 Cam shaft, lagless, encoder 2, virt. master axis**
- **A0134 Cam shaft, lagless, encoder 1, real master axis**
- **A0135 Cam shaft, lagless, encoder 2, real master axis**
- **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**
- **E2049 Positioning velocity >= S-0-0091**
- **F2005 Cam shaft invalid**
- **F2039 Maximum acceleration exceeded**
- **E2047 Interpolation velocity = 0**
- **E2048 Interpolation acceleration = 0**
- **F2037 Excessive position command difference**

Command Value Adjustment

Overview   Command value adjustment in the "electronic cam shaft" mode consists of the following basic functions:

- master axis evaluation and adjustment (real or virtual master axis)
- electronic gear with fine adjust
- command value processing specific to operating mode
  - cam shaft profiles (incl. access)
  - adjustment of position format
- dynamic synchronization
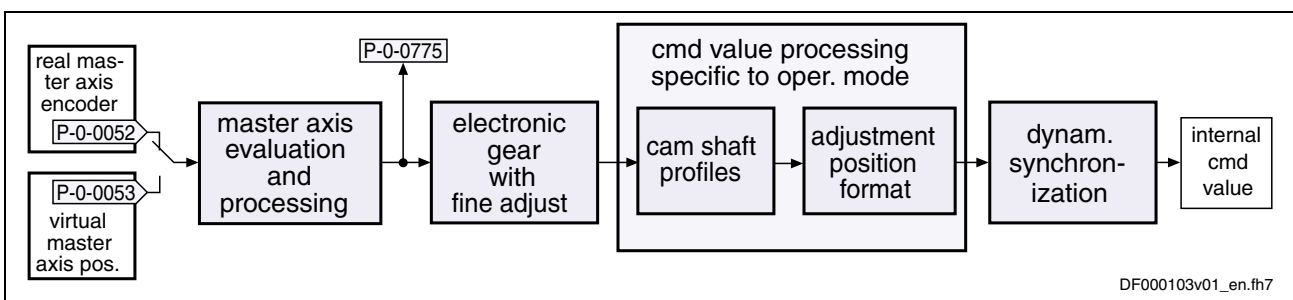
See also section "Basic Functions of the Synchronization Modes"

P-0-0052:   actual position value of measuring encoder
P-0-0053:   master axis position
P-0-0775:   resulting master axis position

Fig. 7-88:   Function blocks of command value processing and command value adjustment in cam shaft mode with real/virtual master axis

Generating the Internal Position Command Value

In the operating mode "electronic cam shaft with real/virtual master axis" the internal position command value (P-0-0434) is generated by addition of the synchronous position command value (x_{sync}) and the position command value from the synchronization process ($x_{sync\_process}$).

$$P - 0 - 0434 = x_{sync} + x_{sync\_process}$$

P-0-0434: position command value of controller

x_{sync}: synchronous position command value

$x_{sync\_process}$: difference to absolute position

Fig. 7-89: Generating the position command value

Fig. 7-90: Command value processing and command value adjustment specific to operating mode with cam shaft mode

In the function block "command value processing specific to operating mode" the calculations specific to the cam shaft mode are carried out for generating the synchronous position command value.

Depending on **P-0-0061, Angle offset begin of profile**, an interpolated profile value is taken from the cam shaft profiles in every control cycle and the difference to the last interpolated profile value is multiplied by the cam shaft distance. The result is added to the position command value.

If **P-0-0755, Gear reduction** is unequal to zero, the master axis position at the output of the electronic gear is additionally divided by the gear reduction and multiplied by a scaling-dependent factor. The result is differentiated and added to the position command value.

Note:	If the profile limit is exceeded in positive direction, the profile continues with its first value, the same happens if the limit is exceeded in negative direction.

Calculating the Internal Position Command Value (Initialization)

Upon activation of the operating mode "Electronic cam shaft with real/virtual master axis", the position command value of the drive is first initialized in terms of the following relation:

$$X_{F(\varphi L)} = (\, h * tab(\pm\varphi_L * \frac{G_a}{G_e} * (1 + F) - \varphi_V) \pm \varphi_L * (\frac{G_a}{G_e} * (1 + F) - \varphi_V)/U + X_V) \, \% \, IWZ$$

X_F:	position command value of slave drive (P-0-0434)
+/-:	master drive polarity (P-0-0108)
φ_L:	resulting master axis position (P-0-0775)
φ_V:	angle offset begin of profile (P-0-0061)
h:	cam shaft distance (P-0-0093 or P-0-0073)
tab(φ):	cam shaft profiles (P-0072, P-0-0092, P-0-0780, P-0-0781)
X_v :	position command value additional (S-0-0048)
G_a:	master drive gear output revolutions (P-0-0157)
G_e:	master drive gear input revolutions (P-0-0156)
F:	fine adjust (P-0-0083)
U:	gear reduction (P-0-0755)
IWZ:	modulo actual value cycle

Fig. 7-91:   Initializing the position command value

Note:	With the operating mode activated, differences, that later on will be added again, are processed in the electronic gear and the cam shaft profiles. Therefore changes in the electronic gear and the cam shaft distance do not cause position command value jumps. Velocity jumps, however, can occur and the absolute position reference established when activating the operating mode is lost.

Accessing the Cam Shaft Profile

In every position loop cycle (advanced: T = 250 µs, basic: T = 500 µs) an interpolated profile value is taken from the activated cam shaft profile, the difference to the last interpolated profile value is generated and a multiplication with the cam shaft distance is carried out. The result is added to the position command value.

In parameter **P-0-0088, Control word for synchronous operation modes** it is possible to set in bits 8 to 11, separately for each cam shaft profile, whether linear fine interpolation or cubic spline interpolation is to take place between the profile values.

> **Note:** With an infinite cam shaft the difference between initial value and final value of the cam shaft profile is 100%.

> **Note:** For constantly fault-free processing of the position data with infinitely turning axes, the values resulting from gear reduction (P-0-0755 ≠ 0) must be used for forward motion. A finite cam shaft profile can be superimposed. When using an infinite cam shaft profile (difference between first and last profile value > 50%), a small error can occur with each profile sequence. Exception: Cam shaft distance corresponds to modulo value (S-0-0103).

Calculating the Internal Position Command Value (in Cyclic Operation)

The position command value is generated as per the following relation:

$$X_{F(n)(\varphi L)} = X_{F(n-1)(\varphi L)} + (h * \Delta tab(\pm\varphi_L * \frac{G_a}{G_e} - \varphi_V + \varphi_d) \pm \Delta\varphi_L * (\frac{G_a}{G_e} * (1+F) - \varphi_V)/U + X_v) \% IWZ$$

X_F :	position command value of slave drive (P-0-0434)
+/- :	Master drive polarity (P-0-0108)
φ_d:	dynamic angle offset (P-0-0085)
φ_L:	resulting master drive position (P-0-0775)
φ_V :	angle offset begin of profile (P-0-0061)
h:	cam shaft distance (P-0-0093 or P-0-0073)
tab(φ):	cam shaft profiles (P-0072, P-0-0092, P-0-0780, P-0-0781)
X_v:	position command value additional (S-0-0048)
G_a:	master drive gear output revolutions (P-0-0157)
G_e:	master drive gear input revolutions (P-0-0156)
F:	fine adjust (P-0-0083)
U:	gear reduction (P-0-0755)
IWZ:	modulo actual value cycle

Fig. 7-92: Cyclically generating the position command value for the slave drive

Notes on Commissioning/Parameterization

General Parameterization

During general parameterization it is necessary to make machine-specific presettings:

Scaling of Data

Scaling of parameter data (linear or rotary):

- S-0-0076, S-0-0077, S-0-0078 and S-0-0079 for position data
- S-0-0044, S-0-0045 and S-0-0046 for velocity data
- S-0-0160, S-0-0161 and S-0-0162 for acceleration data

See "Mechanical Axis System and Measuring Systems: Scaling of Physical Data" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Feed Constant and Load Gear	For linear scaling with rotary motor, parameterize the feed constant per slave axis revolution (S-0-0123).
	If available, also set the load gear of the slave axis accordingly in parameters S-0-0121 and S-0-0122.

Parameterizing the Synchronization Process

Determine synchronization velocity (P-0-0143) and synchronization acceleration (P-0-0142).

Selecting and Acknowledging Active Cam Shaft

Select and acknowledge the active cam shaft profile:

- The active cam shaft profile (P-0-0072, P-0-0092, P-0-0780 or P-0-0781) is selected with parameters **P-0-0088, Control word for synchronous operating modes** and **P-0-0094, Cam shaft switch angle**.

- The active cam shaft is included in parameter **P-0-0089, Status word for synchronous operating modes**. Switching of the cam shaft is started by changing the control word. It is carried out by the drive and acknowledged in the status word, when the master axis position exceeds the angle set in parameter **P-0-0094, Cam shaft switch angle**.

Parameterizing the Cam Shaft Distance

Parameterize the cam shaft distance:

- Parameter **P-0-0144, Cam shaft distance switch angle** defines at which profile access angle and thus profile element a change in value becomes effective for **P-0-0093, Cam shaft distance**. If the profile values in the switch range = 0, an absolute position reference is maintained in the case of a change.

- In parameter **P-0-0088, Control word for synchronous operation modes** select with bits 3 and 4 whether new values for cam shaft distance (P-0-0093) and for the electronic gear (P-0-0156/P-0-0157) take effect immediately or only when the cam shaft distance switch angle is passed or when the cam shaft profile is switched.

  In bit 6 you can determine which reference is to be valid for delayed acceptance of changes (cam shaft distance switch angle or cam shaft profile switching).

  ℹ️   See also Parameter Description "P-0-0088, Control word for synchronous operation modes"

Parameterizing Angle Offset

To avoid great position jumps when changing the profile access angle, a new value for parameter **P-0-0061, Angle offset begin of profile** does not immediately become effective. Starting with the current value, a ramp-like approximation of the new value is carried out. The approximation is carried out over the shortest possible distance. The gradient of the ramp is set in parameter **P-0-0158, Angle offset change rate**.

Note:	With **P-0-0158, Angle offset change rate** equal zero, the angle offset is carried out in one step (immediately effective).

Dynamic Angle Offset   Parameter **P-0-0085, Dynamic angle offset** can be used for compensating a lag error in operation with lag distance, if the mechanical system does not allow lagless operation.

With dynamic angle offset the profile access angle is offset depending on the velocity so that the internal master axis position can be calculated according to the formula below:

$$\varphi_{\substack{effective\_internal \\ master\ axis\ position}} = \varphi_{\substack{internal \\ master\ axis\ position}} + \frac{V_{\substack{internal \\ master\ axis\ vel.}}}{Kv - factor} * dyn.\ angle\ offset$$

internal: after electronic gear (P-0-0156/P-0-0157) and fine adjust (P-0-0083)

Fig. 7-93:   Generating the dynamic angle offset

Note: The master axis velocity used is generated on the timebase T_A = communication cycle time so that a moving average filter results with $T_A = N * T_{position}$.

Clocked Pull Roll   For the special case "clocked pull roll" it is possible, with bit 5 = 1 of parameter **P-0-0088, Control word for synchronous operation modes**, to change between **P-0-0093, Cam shaft distance** and **P-0-0073, Cam shaft distance 2**, depending on the gradient of the cam shaft.

Positive gradient means that **P-0-0093, Cam shaft distance** is active, negative gradient means that **P-0-0073, Cam shaft distance 2** is active.

Cross Cutter Function   By means of the command values of **P-0-0755, Gear reduction** a cross cutter axis can be operated. A cross cutter (rotating knife) is used to cut a defined piece (format) off some material that is transported at constant velocity. The format is set by the electronic gear. With an electronic gear 1:1 the format corresponds to the circumference of the cutting cylinder (with number of knives = 1). Smaller formats are realized by an electronic gear [(output/input) > 1]. The slave axis (cutting cylinder) then turns faster than the master axis. In this case, the cutting cylinder, in the cutting range, has to be decelerated to the transport velocity of the material. After the cutting range the cylinder is accelerated again. This is achieved by superimposing a more or less sinusoidal cam shaft to the constant speed of the axis that is caused by the linear component of the gear reduction. With constant cam shaft profile it is then possible to define, by means of the cam shaft distance, whether the axis decelerates (distance > 0) or accelerates (distance < 0) within the cutting range.

- The number of knives that are distributed at the circumference of the cutting cylinder is entered in parameter **P-0-0755, Gear reduction**. Per cam shaft profile sequence, the cutting cylinder will move by the distance of two knives at the circumference.

- To change the format "on the fly" it is necessary to simultaneously change electronic gear and cam shaft distance in the cutting range. This function is switched on by setting bit 4 in **P-0-0088, Control word for synchronous operating modes**. A change in the electronic gear will only take effect when the new value, after having changed the cam shaft distance, is accepted when passing the angle of **P-0-0144, Cam shaft distance switch angle**.

"Modulo" Parameterization

For "modulo" parameterization make the following settings:

Modulo Range   1.   In parameter **S-0-0103, Modulo value** set the modulo range to that value at which the overflow of the position data (from modulo value to "0") is to take place with infinitely turning axis.

Maximum Travel Range   2.   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).

Master Axis Position Range/
Master Axis Cycle   3.   Depending on parameter **P-0-0750, Master axis revolutions per master axis cycle**, the range of values for the master axis can be between 0 and $2047 * 2^{20}$ increments. In the special case P-0-0750 = 0, the master axis range is from -2^{31} to $2^{31}-1$.

"Modulo" Master Axis   4.   The "modulo" master axis is a master axis the master axis positions of which are within the master axis cycle determined by parameter **P-0-0750, Master axis revolutions per master axis cycle**. The master axis positions may overflow or underflow (infinitely turning master axis).

Slave Drive Feed Travel   5.   The distance that the slave axis covers per master axis revolution is determined in parameter **P-0-0159, Slave drive feed travel**.

Electronic Gear   6.   Settings for the electronic gear are made in the following parameters:

- **P-0-0083, Gear ratio fine adjust**
- **P-0-0108, Master drive polarity**
- **P-0-0156, Master drive gear input revolutions**
- **P-0-0157, Master drive gear output revolutions**

"Modulo" Synchronization   7.   The following settings have to be made for synchronization:

- synchronization mode for reaction to changes in parameter S-0-0048 after first synchronization (P-0-0155, bit 0)
- relative or absolute synchronization (P-0-0155, bit 1)
- synchronization range (P-0-0155, bits 2 and 3)
- generation of actual value cycle (P-0-0155, bit 4)

Note: The actual value cycle has to be an integral multiple of the synchronization range.

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"Absolute" Parameterization

Maximum Travel Range

1. In the case of absolute scaling, the maximum travel range in parameter S-0-0278 has to be selected at least as large as the range in which the synchronous position data are to be contained.

Master Axis Position Range/ Master Axis Cycle

2. Depending on parameter **P-0-0750, Master axis revolutions per master axis cycle**, the range of values for the master axis can be between 0 and $2047 * 2^{20}$ increments. In the special case P-0-0750 = 0, the master axis range is from -2^{31} to $2^{31}-1$.

"Absolute" Master Axis

3. The "absolute" master axis is a master axis the master axis positions of which are within the master axis cycle determined by parameter **P-0-0750, Master axis revolutions per master axis cycle**. The master axis positions in this case do neither overflow nor underflow.
This possibility is not used for practical application. Theoretically, the absolute master axis could be used for infinite cam shafts (e.g. linear cam shafts) and/or when a gear reduction (P-0-0755) unequal zero is selected.

Note:	When a gear reduction (P-0-0755 $\neq$ 0) 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.

"Modulo" Master Axis

The "modulo" master axis is a master axis the master axis positions of which are within the master axis cycle determined by parameter **P-0-0750, Master axis revolutions per master axis cycle**. The master axis positions may overflow or underflow (infinitely turning master axis).

This master axis is used in conjunction with a finite cam shaft (initial value = final value) and when there is no gear reduction (P-0-0755 = 0). If you select a gear reduction, the drive, with infinitely turning master axis, will sometime leave the max. travel range.

Note:	Incorrect parameterization can cause unwanted jumps in position. It is recommended that you activate the position limit value monitor!
	See "Limitations: Position Limit" in chapter "Drive Control"

Slave Drive Feed Travel

4. The distance that the slave axis covers per master axis revolution is determined in parameter **P-0-0159, Slave drive feed travel**.

Electronic Gear

5. Settings for the electronic gear are made in the following parameters:
   - **P-0-0083, Gear ratio fine adjust**
   - **P-0-0108, Master drive polarity**
   - **P-0-0156, Master drive gear input revolutions**
   - **P-0-0157, Master drive gear output revolutions**

"Absolute" Synchronization

6. The following settings have to be made for synchronization:
   - synchronization mode for reaction to changes in parameter S-0-0048 after first synchronization (P-0-0155, bit 0)
   - relative or absolute synchronization (P-0-0155, bit 1)

The figure below illustrates the basic commissioning steps:

```
                        ┌─────────────────┐
                        │      start       │
                        │  commissioning   │
                        └─────────────────┘
                                 │
        ┌────────────────────────────────────────────────┐
        │           general parameterization              │
        │ - linear/rotary scaling                         │
        │ - with linear scaling, parameterize feed constant│
        │ - enter load gear                               │
        │ - synchronization velocity and synchronization acceleration│
        └────────────────────────────────────────────────┘
                                 │
        ┌────────────────────────────────────────────────┐
        │           parameterization of cam shaft         │
        │ - select cam shaft (active cam shaft, switch angle)│
        │ - parameterize cam shaft distance (value, change angle, activation)│
        │ - parameterize angle offset (change angle and change velocity)│
        │ - dynamic angle offset                          │
        │ - parameterize technology functions (cross cutter, clocked pull roll)│
        └────────────────────────────────────────────────┘
```

```
  modulo            scaling            absolute
                    (S-0-0076)
```

```
┌──────────────────────────┐     ┌──────────────────────────┐
│  modulo parameterization │     │ absolute parameterization│
│ - determine modulo range │     │ - determine S-0-0278, Max. travel│
│ - determine S-0-0278, Max. travel│  range (max. +/-2048 revs.)│
│    range (min. S-0-0103) │     │                          │
└──────────────────────────┘     └──────────────────────────┘
```

```
┌──────────────────────────┐     ┌──────────────────────────┐
│    modulo master axis    │     │   absolute master axis   │
│ - parameterize P-0-0750, Master axis│ - parameterize P-0-0750, Master axis│
│    revs. per master axis cycle│     revs. per master axis cycle│
│ - with linear scaling, parameterize│ - with linear scaling, parameterize│
│    feed travel of slave axis│     feed travel of slave axis│
│ - determine electronic gear│   │ - determine electronic gear│
│                          │     │ - only finite cam shaft  │
│                          │     │  (initial value = final value)│
│                          │     │ - no gear reduction (P-0-0757)│
└──────────────────────────┘     └──────────────────────────┘
```

```
┌──────────────────────────┐     ┌──────────────────────────┐
│  modulo synchronization  │     │ absolute synchronization │
│ - select synchronization mode│  │ - select synchronization mode│
│ - relative or absolute synchronization│ - relative or absolute synchronization│
│ - select synchronization range│  └──────────────────────────┘
│ - generation of actual value cycle│
│ - parameterize actual value cycle│
└──────────────────────────┘
```

```
                   ┌──────────────────────┐
                   │  establish position   │
                   │   data reference      │
                   └──────────────────────┘
```

Fig. 7-94:   Overview of commissioning steps for cam shaft mode

Diagnostic and Status Messages

The following diagnostic status messages are displayed in normal operation of the operating mode (drive enabled, "AF").

Diagnostic Status Messages

A0128 Cam shaft, encoder 1, virtual master axis

- **A0129 Cam shaft, encoder 2, virtual master axis**

- **A0130 Cam shaft, encoder 1, real master axis**

- **A0131 Cam shaft, encoder 2, real master axis**

- **A0132 Cam shaft, lagless, encoder 1, virt. master axis**

- **A0133 Cam shaft, lagless, encoder 2, virt. master axis master axis**

- **A0134 Cam shaft, lagless, encoder 1, real master axis**

- **A0135 Cam shaft, lagless, encoder 2, real master axis**

Diagnostic Command Messages

- **C0244 Act. modulo value cycle greater than max. travel range**
  This error message is generated when switching from communication phase 3 to 4, if the calculated modulo value for the actual value cycle is greater than the max. travel range (S-0-0278).

- **C3100 Recalculate actual value cycle**
  This command causes the modulo value for the actual value cycle to be recalculated.

- **C3101 Act. modulo value cycle greater than max. travel range**
  This error message is generated when triggering the command **C3100 Recalculate actual value cycle**, if the calculated modulo value for the actual value cycle is greater than the max. travel range (S-0-0278).

- **C3102 Drive is still in drive enable**
  This command error is generated when the command **P-0-0071, C3100 Recalculate actual value cycle** is started with the drive having been enabled.

Error Messages and Warnings

Different drive errors can occur in operation that cause error messages or warnings to be generated. The error messages listed below are only the messages specific to operating mode:

- **F2005 Cam shaft invalid**
  This message is generated when there is, with the drive having been enabled, an access to a cam shaft profile (P-0-0072, P-0-0092, P-0-0780, P-0-0781) that hasn't been written with 8, 16, 32, 64, 128, 512 or 1024 valid values.

- **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**.

There are also several status messages specific to operating mode generated in the drive that are mapped to specific status bits (see also **P-0-0089, Status word for synchronous operating modes** and **P-0-0152, Synchronization completed**).

Feedback of Active Cam Shaft

Via parameter P-0-0089 (bit 0,1) there is a feedback indicating which cam shaft is presently active.

P-0-0089, Status word for synchronous operating modes:

- bit 0/1 = 00   → cam shaft 1 active (P-0-0072)
- bit 0/1 = 01   → cam shaft 2 active (P-0-0092)
- bit 0/1 = 10   → cam shaft 3 active (P-0-0780)
- bit 0/1 = 11   → cam shaft 4 active (P-0-0781)

Position Status of Actual Position Value in Actual Value Cycle

Bit 4 in parameter P-0-0089 indicates the position status of the actual position value in the actual value cycle (P-0-0753).

P-0-0089, Status word for synchronous operating modes:

- bit 4 = 0   → not homed
- bit 4 = 1   → homed (absolute synchronization can take place)

Status of Cam Shaft Distance Switching

Bit 5 in parameter P-0-0089 indicates the status of the cam shaft distance switching.

P-0-0089, Status word for synchronous operating modes:

- bit 5 = 0   → current distance value not active
- bit 5 = 1   → current distance value active

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Notes

8   Drive Functions

8.1   Drive Halt

Base package of all variants

Brief Description

The "Drive Halt" function is used to shut down an axis with defined acceleration and defined jerk.

The kind of shutdown is determined by the operating mode active before.

Note: Apart from the "Drive Halt" function there is an operational stop for the operating modes "drive-controlled positioning" and "drive-internal interpolation".

Features
- activated via "halt bit" of master communication
- active operating mode interrupted; drive remains in control (after setting the "halt bit" the interrupted operating mode is continued)
- **quick stop**
  → shutdown with acceleration (S-0-0372) and jerk limit values (S-0-0349) when position control mode was active before
- **shutdown with ramp shutdown**
  → shutdown with ramp (S-0-0372) when velocity or torque control was active before
- acknowledgment "Drive Halt" in parameter P-0-0115

Pertinent Parameters

- **S-0-0124, Standstill window**
- **S-0-0134, Master control word**
- **S-0-0135, Drive status word**
- **S-0-0349, Jerk limit bipolar**
- **S-0-0372, Drive Halt acceleration bipolar**
- **P-0-0115, Device control: status word**

Functional Description

When the "Drive Halt" function is activated, the drive no longer follows the command values of the active operating mode, but automatically shuts down while maintaining a parameterized acceleration.

Activating the "Drive Halt" Function   The "Drive Halt" function is activated by:
- disabling the drive halt bit in control word of master communication (e.g. with SERCOS: bit 13 in **S-0-0134, Master control word**)
- interrupting a drive control command (e.g. "drive-controlled homing procedure")

Going Back to the Operating Mode Active Before   The operating mode active before and still selected becomes active again when the drive halt bit is set again in the control word of the master communication.

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The kind of shutdown, in the case of "Drive Halt", depends on the operating mode active before.

Quick Stop in Position Control

In position control shutdown is carried out using the values of the acceleration in **S-0-0372, Drive Halt acceleration bipolar** and of the jerk in **S-0-0349, Jerk limit bipolar**, when a position control mode was active before.

Operating modes with internal position control are:

- position control with cyclic command value input
- drive-internal interpolation
- drive-controlled positioning (incl. jog mode)
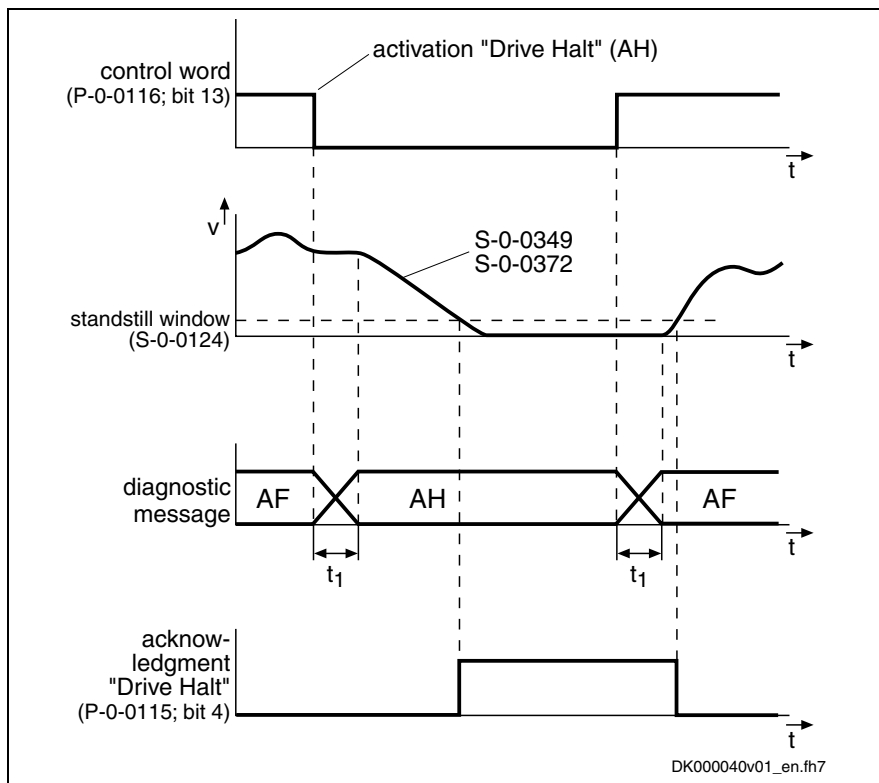
S-0-0349:   jerk limit bipolar
S-0-0372:   Drive Halt acceleration bipolar

Fig. 8-1:   Principle of "Drive Halt" with position control mode active before

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Note: Position-controlled shutdown is carried out with position control with lag error, if an operating mode that also contained position control with lag error was active before. If not, the function is carried out with lagless position control.
If the value in parameter **S-0-0372, Drive Halt acceleration bipolar** equals "0", the axis does not stop.

Shutdown in Velocity Control

When the operating mode "velocity control" or "torque/force control" was active before, shutdown is carried out in velocity control using the value in parameter **S-0-0372, Drive Halt acceleration bipolar**.

Note: If the contents of **S-0-0372, Drive Halt acceleration bipolar** equals "0", deceleration is carried out at the current limit.
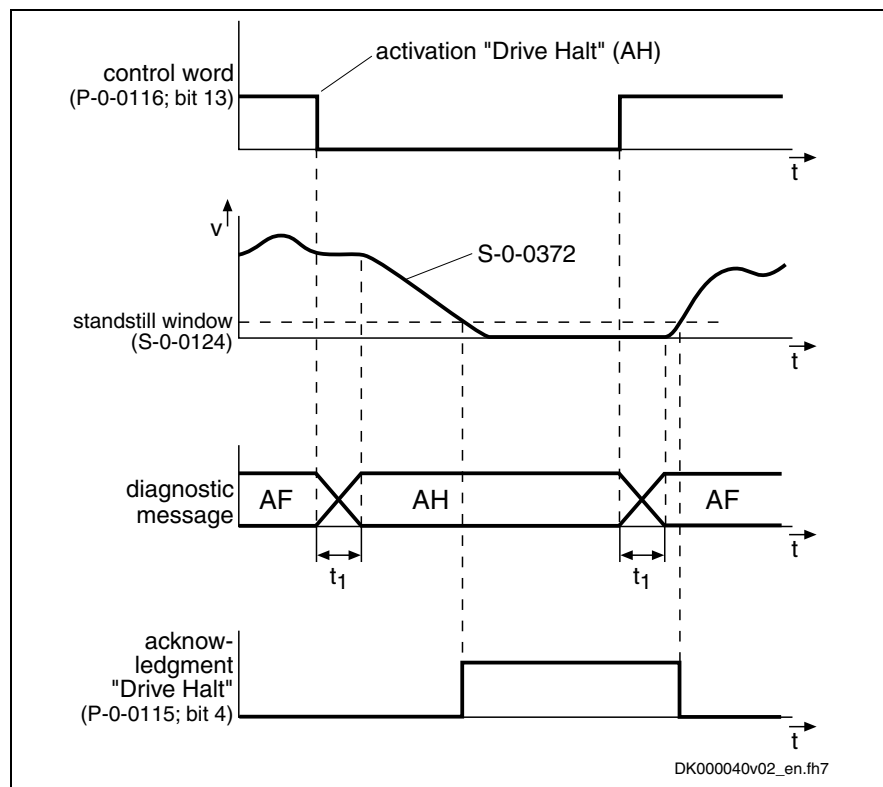
S-0-0372:   Drive Halt acceleration bipolar

Fig. 8-2:   Principle of "Drive Halt" with velocity control active before

Notes on Commissioning

Diagnostic and Status Messages   The activated "Drive Halt" function is displayed as described below:

- "AH" appearing on the control panel display at the front of the device
- "A0010" entered in parameter **S-0-0390, Diagnostic message number**
- "A0010 Drive HALT" entered in parameter **S-0-0095, Diagnostic message**
- in bit "status of command value processing" in status word of master communication (e.g. with SERCOS: bit 3 = 0 in **S-0-0135, Drive status word**)

Acknowledgment "Drive Halt"   An acknowledgment is carried out when the actual velocity falls below the threshold defined in parameter **S-0-0124, Standstill window**. Bit 4 (acknowledgment Drive Halt) is then set in the drive in parameter **P-0-0115, Device control: status word**.

8.2 Establishing the Position Data Reference

Base package of all variants with closed-loop characteristic

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" in chapter "Motor, Mechanical Axis System, 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. To do this, the drive has to move to a defined axis position and the actual position value has to be set to an axis-related value at a defined position (exception: a relative encoder with distance-coded reference marks only requires passing 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
After the master has triggered a command corresponding to the kind of measuring system, the drive automatically establishes the position data reference according to the following sequence:

- In the case of a relative measuring system without distance-coded reference marks, the axis moves to the reference 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.

Displaying the Position Data Reference
A position status parameter shows whether the position data reference of a measuring system evaluated by the controller has been established.

Motor Encoder and External Encoders
In addition to the motor encoder an external (optional) encoder can be available. Both encoders, in any combination of relative and absolute measuring systems, can

- have position data reference to the axis independently of each other (both encoders have different actual position values)   - or -

- have position data reference to the axis dependent of each other (both encoders have the same actual position values).

This is configured via parameters and realized with the commands for establishing the position data reference.

Actual Position Value Offset   The difference of the actual position value before and after establishing the position data reference is displayed, related to the motor encoder or external encoder, in one parameter respectively.

See also the following sections:

- "Establishing Position Data Reference for Relative Measuring Systems"
- "Establishing Position Data Reference for Absolute Measuring Systems"

Pertinent Parameters
- **S-0-0115, Position feedback 2 type**
- **S-0-0175, Offset parameter 1**
- **S-0-0176, Offset parameter 2**
- **S-0-0277, Position feedback 1 type**
- **S-0-0403, Position feedback value status**
- **P-0-0074, Encoder type 1 (motor encoder)**
- **P-0-0075, Encoder type 2 (optional encoder)**

Functional Description

Encoder Types Supported   IndraDrive controllers can evaluate a multitude of standard position encoders. The encoder types that can be evaluated are listed in the descriptions of the following parameters (see documentation "Parameter Description IndraDrive):

- **P-0-0074, Encoder type 1 (motor encoder)**
- **P-0-0075, Encoder type 2 (optional encoder)**

Procedures for Establishing the Position Data Reference   The kind of encoder and the travel range that has been set (S-0-0278) determine whether absolute evaluation is possible for this encoder. This is displayed by the respective bits of the following parameters:

- **S-0-0277, Position feedback 1 type** (motor encoder)
- **S-0-0115, Position feedback 2 type** (external encoder)

Depending on relative or absolute evaluation of the motor encoder or external encoder, the controller makes available different procedures for establishing the position data reference:

- "set absolute measuring" for encoders to be evaluated in absolute form
- "drive-controlled homing procedure" for relative encoders

Note:	After having successfully established the position data reference, the actual position value of the respective encoder refers to the axis. The encoder then is "in reference" or has been "homed".

See also "Absolute Measuring Systems" and "Relative Measuring Systems" in chapter "Motor, Mechanical Axis System, Measuring Systems".

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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!

Note:	The following applies to masters which check the validity of the actual position values via bit 0 of S-0-0403:
	The "encoder selection" in **S-0-0147, Homing parameter** determines the value of the respective position status bit of which encoder is mapped to bit 0 of S-0-0403!

Position Data Reference with Motor Encoder and External Encoder

If an external encoder is connected to the controller in addition to the motor encoder, there are the following possibilities for establishing the position data reference, independent of the evaluation (relative/absolute) of the encoder:

• The position data reference was only established for one of the two encoders. The actual position value of the other, non-homed encoder is set to the value of the homed encoder.

• The position data reference was established for both encoders. The actual position value of each encoder is an individual value that can be identical, but does not need to be identical.

Encoder evaluation		Current position status	Actual position values when switching on		Notes on the commissioning status
Motor encoder	External encoder	(S-0-0403, bits ..2,1,0)	Motor encoder (S-0-0051)	External encoder (S-0-0053)	
relative/ absolute	relative/ absolute	0b … 01x	absolute value motor encoder	absolute value motor encoder	Position data reference only established for motor encoder.
relative/ absolute	relative/ absolute	0b … 10x	absolute value ext. encoder	absolute value ext. encoder	Position data reference only established for external encoder.
relative/ absolute	relative/ absolute	0b … 11x	absolute value motor encoder	absolute value ext. encoder	Position data reference established for motor encoder and external encoder.
relative/ absolute	relative/ absolute	0b … 000	see "Absolute Measuring Systems" or "Relative Measuring Systems"		Position data reference was established neither for motor encoder nor for external encoder.

Fig. 8-3:   Actual position values after establishing the position data reference for motor encoder and external encoder

Actual Position Value Offset Before/After Establishing Position Data Reference

When the position data reference was established for an encoder there mostly is a step change of the actual position value. The difference between the new and the old actual position value is displayed in the following parameters:

• **S-0-0175, Offset parameter 1** (motor encoder)

• **S-0-0176, Offset parameter 2** (external encoder)

The respective values are written to the offset parameters each time the position data reference is established. After the drive was switched on the value, however, is undefined, even if the position data reference has already been established!

Notes on Commissioning

Checking the Absolute Evaluation of Encoders

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**.

Note: 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.

Establishing Position Data Reference for Relative Measuring Systems

Brief Description

See also "General Information on Establishing the Position Data Reference"

Actual Position Value of Relative Measuring Systems when Switching On

After the drive is switched on the actual position values signaled by relative measuring systems do not yet have any reference to the machine axis. Measuring systems can be installed at the motor (motor encoder) and directly at the mechanical axis system (external or optional encoder).

For encoder arrangement and mechanical axis system see also "Measuring Systems for Motor and Axis Control, Arrangement" in chapter "Mechanical Axis System and 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.

Establishing the Position Data Reference

After master-side start of the respective command the drive automatically establishes the position data reference.

In the case of relative measuring systems, it 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.

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 reference point from any axis position (situation when switched on) by moving in a defined direction. Rotary axes do not have an axis end position, the dedicated point is at a defined position within the travel range.

Reference Mark for Relative Measuring Systems
The precision with which this dedicated point is detected considerably influences the absolute precision of the axis. Apart from the signals for position detection, relative measuring systems therefore also provide a signal for exact determination of a dedicated point. This signal is called "reference mark". Depending on their type, relative measuring systems have one or several reference marks over the range of measurement.

Reference Mark and Home Switch
Especially in the case of rotary measuring systems (e.g. motor encoder) at axes moved in a linear way, the reference mark of the encoder can occur several times over the entire travel range. In this case it is required, by axis-side activation of a switch contact at the end of the travel range, to particularly identify **one** reference mark signal. This defines an unequivocal dedicated point that can be found with reproducible precision. This switch contact is called "home switch".

Independent of the number of reference marks over the travel range the home switch, in the case of linear axes, is indispensable 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 with the reference point of the axis. The distance between reference point and zero point normally is determined on the machine side. Especially in the case of serial machines, this distance should be equal for axes of the same kind. The position of the dedicated point, however, is influenced by the kind of encoder arrangement and therefore differs from axis to axis.

Reference Offset
The position difference between dedicated point and reference point of the axis can be compensated by an offset value (reference offset).

See also "General Information on Establishing the Position Data Reference" in this chapter"

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-0-0298, Reference cam shift**
- **S-0-0299, Home switch offset**
- **S-0-0349, Jerk limit bipolar**
- **S-0-0400, Home switch**
- **P-0-0153, Optimum distance home switch - reference mark**

Parameters for relative measuring systems, distance-coded:

- **S-0-0165, Distance-coded reference offset A**
- **S-0-0166, Distance-coded reference offset B**
- **S0-0177, Absolute offset 1**
- **S-0-0178, Absolute offset 2**

Pertinent Diagnostic Messages   Diagnostic messages for relative measuring systems:

- **C0600 Drive controlled homing procedure command**
- **C0601 Homing only possible with drive enable**
- **C0602 Distance home switch - reference mark erroneous**
- **C0604 Homing of absolute encoder not possible**
- **C0606 Reference mark not detected**
- **C0607 Reference cam input not assigned**

Functional Description

General Information

Type and Arrangement of Reference Marks   With regard to the type and arrangement of the reference marks, relative measuring systems can be divided into 4 groups:

- **Group 1:**
  Single-turn measuring systems with absolute range, such as single-turn HSF or resolvers. These measuring systems have an absolute position measuring range of one encoder revolution or parts of one encoder revolution (resolver) and do not have their own reference mark signal. The controller, however, recognizes the zero position (0 dgr) of the actual position value as the reference mark signal.
  These properties apply to:

  - single-turn motor encoders of Rexroth motors of the MHD, MKD, MKE, MSK, MSH, MAD and MAF series
  - GDS measuring system from Rexroth
  - single-turn encoder from Heidenhain (with EnDat interface)

- **Group 2:**
  incremental rotary measuring systems with one reference mark per encoder revolution, such as the ROD or RON types from Heidenhain

- **Group 3:**
  incremental linear measuring systems with one or several reference marks, such as the LS linear scales from Heidenhain

- **Group 4:**
  incremental measuring systems with distance-coded reference marks, such as the LSxxxC linear scales from Heidenhain

For measuring systems with distance-coded reference marks see also "Relative Measuring Systems" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Action of the Axis Drive to Establish Position Data Reference   In order to establish the position data reference of relative measuring systems the drive has to be able to identify an unequivocal dedicated point within the travel range of the axis. To do this, the axis has to carry out the following movement:

- pass the dedicated point (encoders of group 1, 2 or 3)

- or -

- pass two neighboring distance-coded reference marks (encoders of group 4)

Motion Range for Homing   The motion range required for homing depends on the encoder used:

- For encoders of group 1, 2 or 3 motion over the entire travel distance of the axis can be required.

- For encoders of group 4 the axis only has to pass two neighboring distance-coded reference marks (see section "Motion Range for Homing Encoders with Distance-Coded Reference Marks").

Note: With encoders of group 4 the controller can 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

The reference mark signal 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.

The reference mark signal is generally used

- for detecting the end of the travel range in the case of linear axes

  - and -

- for selecting a reference mark signal, when these signals occur several times over the travel range.

Relative encoder of ...	Number of reference mark signals occurring over the travel range			
	one signal		several signals	
	rotary axis	linear axis	rotary axis	linear axis
... group 1,2 (rotary encoder)	HS: no	HS: yes	HS: yes	HS: yes
... group 3 (linear encoder)	------------	HS: yes	------------	HS: yes
... group 4 (rotary/linear encoder)	------------	------------	HS: no	HS: yes

Fig. 8-4:   Recommendation for using a home switch (HS)

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).

Note: If there isn't any reference mark signal available on the encoder-side, the edge reversal of a home switch signal can also be used of detecting the dedicated point. This has to be set in parameter S-0-0147 by deactivating the reference mark evaluation!

Reference Point, Axis Zero Point and Dedicated Point for Encoders of Groups 1, 2, 3   The axis zero point and the reference point are positions determined on the machine side. The position of the dedicated point ideally is identical to the reference point, the position of the dedicated point, however, mostly is influenced by the encoder arrangement. The position difference between reference point and dedicated point is transmitted to the controller via the so-called reference offset.
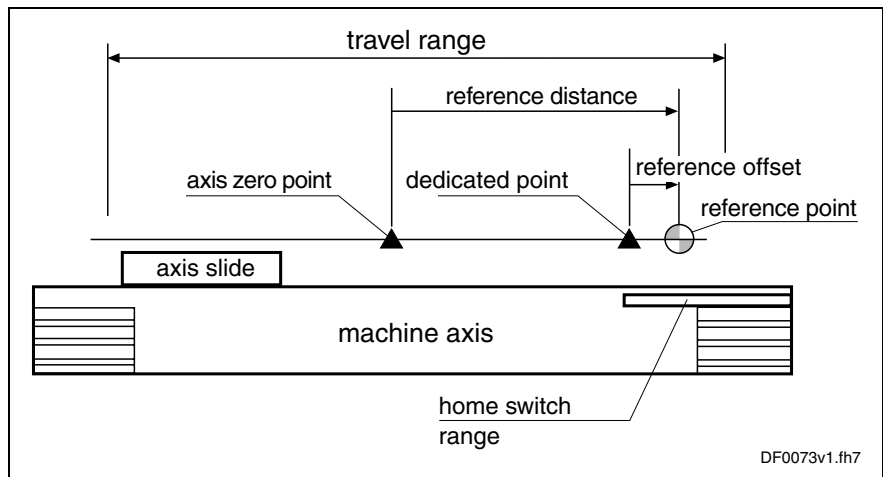
Fig. 8-5:   Example of positions of axis zero point, dedicated point and reference point for encoders of groups 1, 2, 3

As the position data reference can be established both by the motor encoder and by the external encoder possibly available, there are separate parameters for the respective reference offset available for both encoders:

- **S-0-0150, Reference offset 1** (motor encoder)
- **S-0-0151, Reference offset 2** (external encoder)

The reference distance is the distance between the reference point and the axis zero point. There are separate parameters for the respective reference distance available for both encoders:

- **S-0-0052, Reference distance 1** (motor encoder)
- **S-0-0054, Reference distance 2** (external encoder)

Axis Zero Point, Encoder Zero Point and Dedicated Point for Encoders of Group 4

For distance-coded measuring systems (of group 4) the axis-side reference point is not used. The controller can calculate the position of the dedicated point (in this case the encoder zero point) on the basis of the detected position difference of two neighboring distance-coded reference marks. The position difference between axis zero point and encoder zero point is transmitted to the controller via the so-called absolute offset.
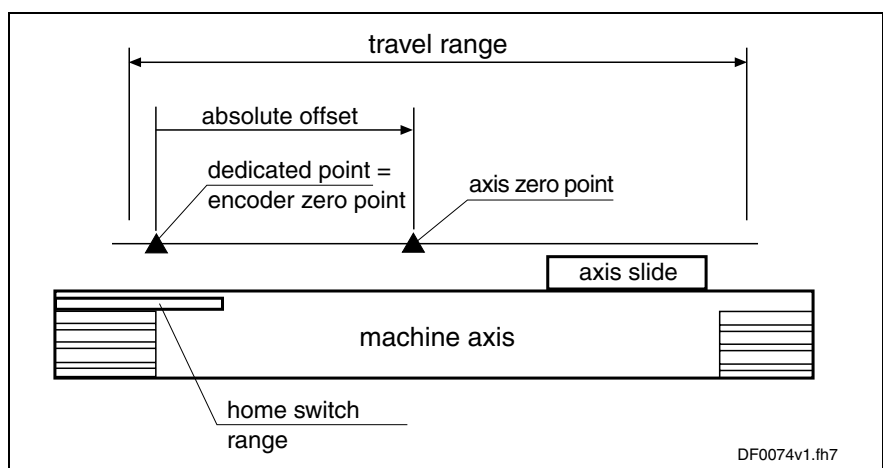
Fig. 8-6:   Exemplary illustration of axis zero point and dedicated point for encoders of group 4

As motor encoder or external encoder can be realized as distance-coded measuring system and the position data reference can be established for both encoders, there are separate parameters for the respective absolute offset available:

- **S-0-0177, Absolute offset 1** (motor encoder)
- **S-0-0178, Absolute offset 2** (external encoder)

Note: Only one distance-coded measuring system can be connected!

Searching the Dedicated Point, Basic Procedure

After starting **C0600 Drive controlled homing procedure command** (S-0-0148) 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 by evaluating the reference mark signals and, if necessary, the home switch signal of the encoder selected in S-0-0147, the position data reference between actual position values and axis can be established.

When the home switch signals that the axis is at the end of the travel range (home switch activated) and the C0600 command is started in this initial position, the controller controls the drive in such a way that the dedicated point is found without the axis exceeding the travel range limit.

For detailed information on the procedure of drive-controlled homing see section "Functional Sequence "Drive-Controlled Homing Procedure""

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" in the same chapter

Information on the Home Switch

Connecting the Home Switch

A home switch possibly required has to be connected to the assigned digital input of the control section of the controller. Observe the allowed signal levels! The signal status of the home switch is displayed in parameter S-**0-0400, Home switch**.

See "Digital Inputs/Outputs" in chapter "Extended Drive Functions"

Activating the Home Switch Evaluation

In the initial status, the evaluation of the home switch signal is activated by the default setting of the respective bit of **S-0-0147, Homing parameter**. If there isn't any home switch required (see fig. "Recommendation for using a home switch") the evaluation has to be deactivated!

Detecting the End of the Travel Range for Encoders Without Distance-Coded Reference Marks

In the case of encoders **without** distance-coded reference marks, it is necessary to determine at which edge reversal of the home switch activation the drive is to react. Status and edge reversal of the home switch signal are monitored by the controller.

Depending on the home switch signal, there are the following drive actions when the C0600 homing command is started:

Determined edge reversal (bit in S-0-0147)	Signal status of the home switch (bit in S-0-0400)	Drive action
positive	0 ("not activated")	motion in reference travel direction, search of positive signal edge
negative	1 ("not activated")	motion in reference travel direction, search of negative signal edge
negative	0 ("activated")	motion against the reference travel direction until signal is "1", then reversal of motion and search of negative signal edge
positive	1 ("activated")	motion against the reference travel direction until signal is "0", then reversal of motion and search of positive signal edge

Fig. 8-7:   Assigning signal status and edge reversal to drive action when starting C0600 command (for non-distance-coded measuring system)

The drive action is completed after detecting the reference position by shutdown and switching the actual position value to axis reference.

Detecting the End of the Travel Range for Encoders With Distance-Coded Reference Marks

In the case of encoders **with** distance-coded reference marks, only the status of the home switch signal is monitored by the controller to detect the end of the travel range. The edge reversal definition doesn't have any influence in this case!

Depending on the home switch signal, there are the following drive actions when the C0600 homing command is started:

Determined edge reversal (bit in S-0-0147)	Signal status of home switch (bit in S-0-0400)	Drive action
positive or negative	0 ("not activated")	motion for search of dedicated point in reference travel direction
positive or negative	1 ("activated")	motion for search of dedicated point against reference travel direction

Fig. 8-8:   Assigning signal status to drive action when starting C0600 command (for distance-coded measuring system)

The drive action is completed after detecting the reference position by shutdown and switching the actual position value to axis reference.

Home Switch for Selecting a Reference Mark

If several reference mark signals can occur over the travel range of an axis and a dedicated point is to be determined by one of the marks, a home switch is required for selecting a reference mark (see fig. "Recommendation for using a home switch").

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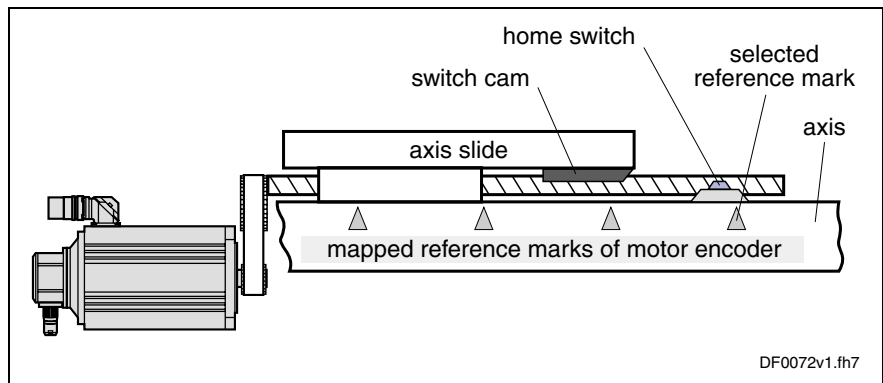
Fig. 8-9:   Selecting a reference mark via home switch

After starting the C0600 command, the dedicated point is detected when the first reference mark signal occurs after the determined edge of the home switch.

Arranging the Home Switch
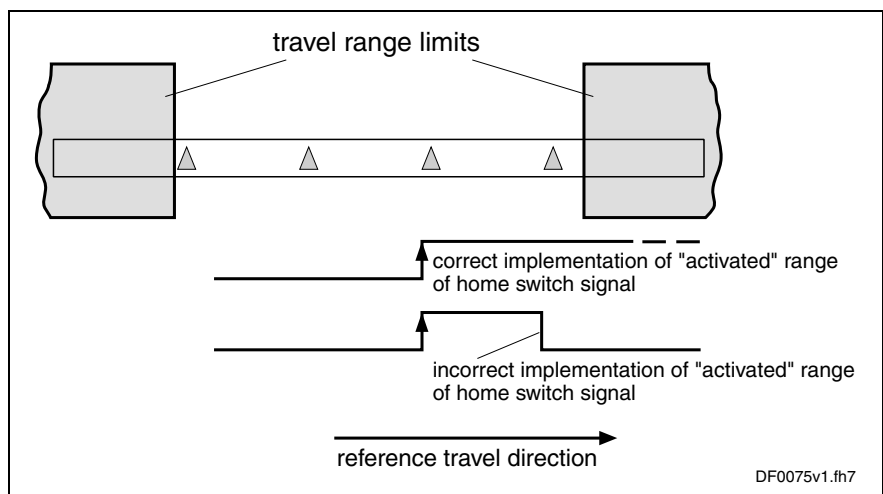
Fig. 8-10:   Arranging the home switch with regard to travel range limits

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!

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) with homing acceleration (S-0-0042), within the travel range. The following applies to the minimum distance home switch-travel range limit:

$$x_{HS\_TrLimit} \geq x_{RefMarks} + \frac{v^2}{2 * a}$$

v:	value in S-0-0041, Homing velocity
a:	value in S-0-0042, Homing acceleration
$x_{RefMarks}$:	distance of the reference marks occurred at the axis - or – value of S-0-0165 for distance-coded measuring system
$x_{HS\_TrLimit}$:	minimum distance to travel range limit

Fig. 8-11:   Minimum distance of home switch signal to travel range limit

Note: Generally, several reference marks can occur in the "activated" range of the home switch signal!

But in the case of encoders with distance-coded reference marks, at least two marks have to occur in the "activated" range of the home switch!

Requirements for Selecting a Reference Mark

If the home switch is to be used for selecting a reference mark signal (in the case of several signals occurring over the travel range), you have to make sure that it is always the same reference mark signal that is evaluated by the controller for detecting the position of the dedicated point!

The controller recognizes the home switch activation with a position inaccuracy inherent in the system. It depends on:

- the input clock of the digital input via which the home switch is evaluated (corresponding to the position controller clock when command C0600 is executed)

    - and -

- the velocity at which the axis moves at the time the home switch is activated.

Within this 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!
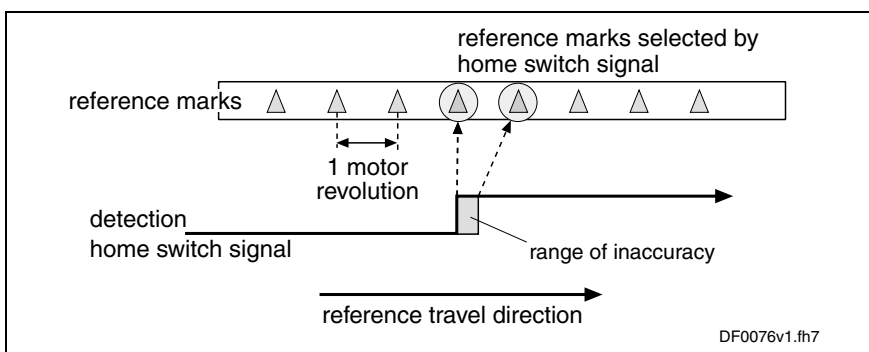
Fig. 8-12:   Ambiguous detection of reference marks in range of inaccuracy of home switch detection

Distance Monitoring Home Switch Edge/ Reference Mark

Due to the range of inaccuracy of home switch evaluation, the distance between the home switch edge and the position of the next reference mark is monitored. If the distance between the home switch edge and the reference mark falls below a certain value, the **C0602 Distance home switch - reference mark erroneous** error message is generated.

Classification of distance	Distance	Drive reaction
critical distance	< 0.25 * reference mark distance	shutdown with C0602
optimum distance	0.5 * reference mark distance	---
allowed distance range	(0.25 ... 0.75) * reference mark distance	---

Fig. 8-13:   Data for distance between home switch signal and reference mark
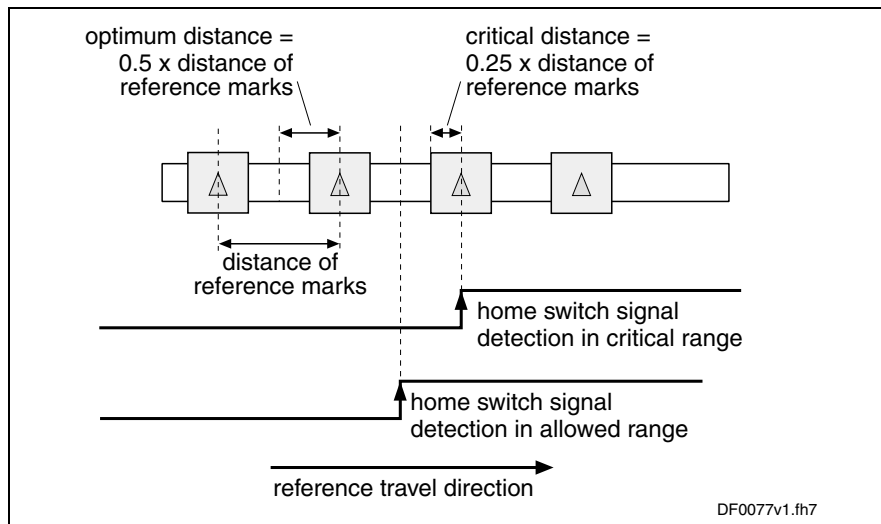
Fig. 8-14: Critical and optimum distance between home switch and reference mark

To monitor the distance home switch-reference mark the optimum distance has to be preset in parameter **P-0-0153, Optimum distance home switch-reference mark**.

Note: When using the motor encoder for Rexroth motors of the MHD, MKD, MKE, MSK, MSH, MAD and MAF series the optimum distance is automatically calculated internally. The value for P-0-0153 has to be left in its default status!

ℹ️ For default values of P-0-0153 for distance monitoring home switch-reference mark see separate documentation "Parameter Description for IndraDrive Drive Controllers"

Distance Correction

During each homing procedure with home switch evaluation the difference between actual distance and optimum distance is monitored by home switch edge and reference mark. The difference is stored in parameter **S-0-0298, Reference cam shift**. For optimum setting of the home switch it can be mechanically shifted by the value of S-0-0298.

The distance between home switch edge and reference mark can also be optimized drive-internally without mechanical shifting. The controller then shifts the activation of the reference mark evaluation after detection of the home switch edge 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.
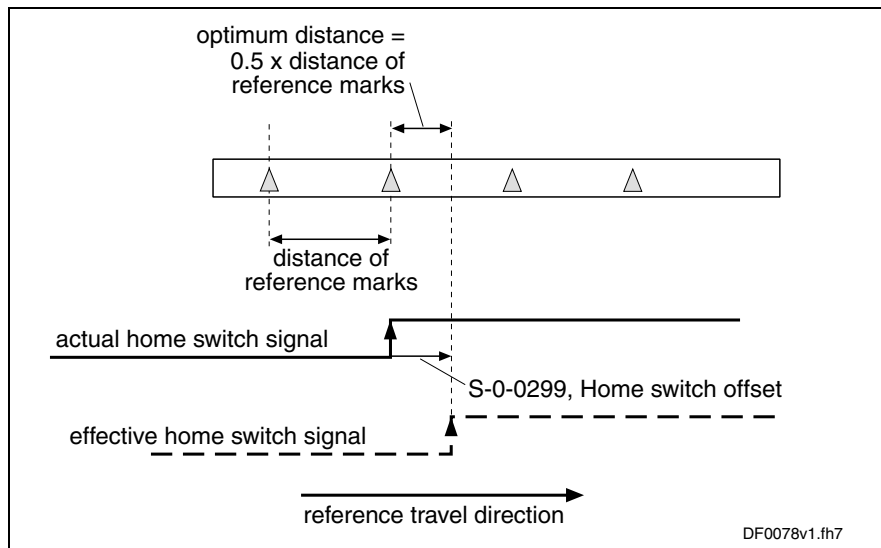
Fig. 8-15:   Operating principle of parameter S-0-0299

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 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 whether

- the parameter values for reference mark evaluation were correctly set

- or -

- the reference mark signals are correctly input.

Note: Parameter P-0-0153 refers to the encoder to be homed according to the setting in **S-0-0147, Homing parameter**. If a second encoder has to be homed that requires different values in P-0-0153, the parameter P-0-0153 has to be adjusted to the respective encoder by the control master before the C0600 command is started!

Motion Range for Homing Encoders with Distance-Coded Reference Marks

For the homing procedure, relative measuring systems with distance-coded reference marks require a motion range corresponding to the distance of two neighboring reference marks.

The distances of neighboring reference marks of encoders with distance-coded reference marks are calculated according to the formula below:

Reference Mark Distance of Linear Encoders

$$\text{motor encoder}: \quad s_{RefMarks} = S\text{-}0\text{-}0165 * S\text{-}0\text{-}0116$$

$$\text{external encoder}: \quad s_{RefMarks} = S\text{-}0\text{-}0165 * S\text{-}0\text{-}0117$$

S-0-0165: value of S-0-0165, Distance-coded reference offset A
S-0-0116: value of S-0-0116, Feedback 1 Resolution
S-0-0117: value of S-0-0117, Feedback 2 Resolution
$s_{RefMarks}$: distance of neighboring reference marks

Fig. 8-16:   Distance of neighboring reference marks of linear encoders with distance-coded reference marks

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Reference Mark Distance of Rotary Encoders

motor encoder : $\quad s_{RefMarks} = \dfrac{360degr * S-0-0165}{S-0-0116}$

external encoder : $\quad s_{RefMarks} = \dfrac{360degr * S-0-0165}{S-0-0117}$

S-0-0165: value of S-0-0165, Distance-coded reference offset A
S-0-0116: value of S-0-0116, Feedback 1 Resolution
S-0-0117: value of S-0-0117, Feedback 2 Resolution
$s_{RefMarks}$: distance of neighboring reference marks
Fig. 8-17: Distance of neighboring reference marks of rotary encoders with distance-coded reference marks

Motion Range for Homing

The actual motion range of homing the axis corresponds either

- to the distance of neighboring reference marks including the distance until detection of the first reference mark and the braking distance at the end of the homing procedure, when "stop" was selected in S-0-0147:

linear scaling : $\quad s_{Refmax} = s_{Ref\_1} + s_{RefMarks} + \dfrac{v^2}{2*a}$

rotary scaling : $\quad s_{Refmax} = s_{Ref\_1} + s_{RefMarks} + \dfrac{\omega^2}{2*\alpha}$

v, ω : value in S-0-0041, Homing velocity
a, α : value in S-0-0042, Homing acceleration
s_{Ref_1}: distance to the first reference mark
$s_{RefMarks}$: distance of neighboring reference marks
s_{Refmax}: maximum motion range
Fig. 8-18: Maximum motion range for homing encoders with distance-coded reference marks in case of "stop" (S-0-0147)

Note: The motion range in the case of "stop" depends on the initial position of the axis at the start of C0600 and 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 S-0-0147:

linear scaling : $\quad s_{Refmax} = 2 * s_{RefMarks} + \dfrac{v^2}{2*a}$

rotary scaling : $\quad s_{Refmax} = 2 * s_{RefMarks} + \dfrac{\omega^2}{2*\alpha}$

v, ω : value in S-0-0041, Homing velocity
a, α : value in S-0-0042, Homing acceleration
$s_{RefMarks}$: distance of neighboring reference marks
s_{Refmax}: maximum motion range
Fig. 8-19: Maximum motion range for homing encoders with distance-coded reference marks in case of "run path" (S-0-0147)

Note: The motion range of the axis in the case of "run path" is always the same! This is advantageous for homing Gantry axes!

Functional Sequence "Drive-Controlled Homing Procedure"

Command Value Profile for Homing Procedure
After starting **C0600 Drive-controlled homing procedure command** (S-0-0148) 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-0-0108, Feedrate override**
- **S-0-0042, Homing acceleration**

The controller ignores command values of the control master during the execution of command C0600!

Note:	If the respective encoder, at the start of command C0600, should have already been homed, the reference is cleared first!
	See also Parameter Description "S-0-0403, Position feedback value status"

Acceleration Process
At the start of 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 has not been activated,

- or -

- near the end of the travel range, the home switch has been activated.

When the home switch has not been activated, the drive accelerates the axis in reference travel direction.

When the home switch has been activated, the drive accelerates 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 when the home switch is detected to be "not activated". In the case of distance-coded encoders, the search of dedicated point is carried out against the reference travel direction.

In the case of rotary axes, a home switch can be required when several encoder reference marks occur over the travel range. The behavior during the homing procedure, regarding the home switch status, corresponds to that of linear axes!

Jerk Limitation
To limit acceleration jumps it is possible to additionally activate a jerk limit. This is done by entering the value parameter **S-0-0349, Jerk limit bipolar**.

Motion Range for Homing
The process for searching the dedicated point requires axis motion. In the case of relative encoders with distance-coded reference marks (of group 4), the axis moves over two neighboring reference marks (see also section "Motion Range for Homing Encoders with Distance-Coded Reference Marks").

Note:	For distance-coded encoders it is possible to set "run path" in parameter S-0-0147. During the homing procedure, it is then always a distance of the same length that is traveled in the case of linear axes. This supports the commissioning of Gantry axes!

In the case of relative encoders without distance-coded reference marks (of groups 1, 2, 3), the motion of the axis, depending on its initial position, can reach over the entire travel range.

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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:

- "positioning"
  → target-oriented motion to the reference point (axis-related value of **S-0-0052, Reference distance 1/S-0-0054, Reference distance 2**)

- or -

- "stopping"
  → non-target-oriented immediate braking motion that possibly is of shorter duration

---

Note: In the case of "run path", the drive stops the axis after the double reference mark distance was covered (only possible for distance-coded encoder)!

The kind of shutdown ("positioning" or "stopping") is set in **S-0-0147, Homing parameter**.
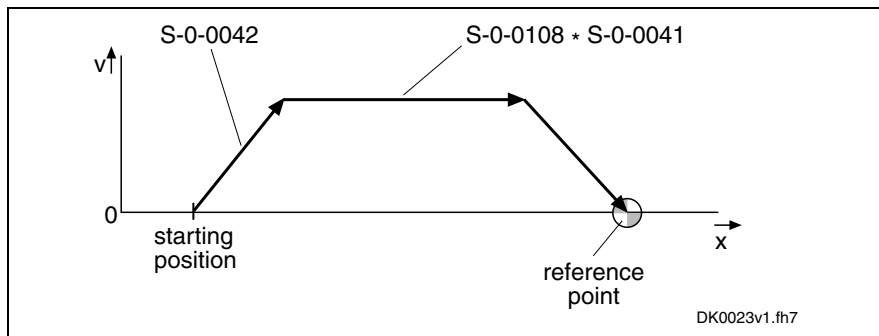
S-0-0041:   homing velocity
S-0-0042:   homing acceleration
S-0-0108:   feedrate override
Abb. 8-20: Command value profile for drive-controlled homing with constant feedrate factor and "positioning" shutdown

---

Note: If parameter **S-0-0108, Feedrate override** starts with zero, the **E2055 Feedrate-override S-0-0108 = 0** warning is output.

Actions of the Control Unit of Drive-Controlled Homing

Starting Command C0600	The control master starts the command by writing data to parameter **S-0-0148, C0600 Drive-controlled homing procedure command**. The command has to be set and enabled. The command acknowledgment has to be taken from the data status of the same parameter. The command execution is completed when the command change bit in **S-0-0135, Drive status word** was 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" in the same chapter

Completing Command C0600　When the control master wants to operate the drive in position control after resetting command C0600, it has to read the drive-internal position command value from **P-0-0047, Position command value control** and preset it as the position command value. By resetting the command the control master takes over the axis without jerk or position offset occurring.

Notes on Commissioning

Notes on Commissioning, General

See also "Notes on Commissioning" in section "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" in chapter "Motor, Mechanical Axis System, Measuring Systems"

For measuring systems with distance-coded reference marks see also Notes on Commissioning for "Relative Measuring Systems" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Settings　Settings regarding encoder and homing procedure have to be made in **S-0-0147, Homing parameter**:

- encoder selection

- reference travel direction

- activation of home switch and setting of edge evaluation of home switch signal

Distance Monitoring of Reference Mark Signals　Encoder-specific values for monitoring the reference mark signals during the homing procedure have to be entered in parameter **P-0-0153, Optimum distance home switch-reference mark** (see parameter description).

> ⚠ **WARNING**
>
> **Property damage at the installation caused by home switch edge incorrectly set!**
>
> ⇒ Make sure the home switch edge was correctly set and is within the travel range!

For home switch evaluation first make the required settings:

Distance Control Home Switch Edge-Travel Range Limit　1. First control whether the minimum distance between home switch edge and travel range limit has been complied with:

- calculate minimum distance on basis of intended values for **S-0-0041, Homing velocity** and **S-0-0042, Homing acceleration** (see section "Information on the Home Switch")

- 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)

If the distance between home switch edge and travel range limit is smaller than the calculated minimum distance, mechanically bring the home switch to the respective distance!

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Distance Correction Home Switch Edge-Reference Mark

2. Check whether distance home switch edge-reference mark is within allowed distance range. To do this, you can proceed as follows:

- If not yet done, first enter encoder-specific value 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 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!

- Carry out homing command C0600 with **S-0-0299, Home switch offset** = 0 with setting "stop after homing" in S-0-0147

- If distance outside range 0.25...0.75 * (2 * P-0-0153), error message **C0602 Distance home switch - reference mark erroneous** is generated. In this case enter value from **S-0-0298, Reference cam shift** in **S-0-0299, Home switch offset**!

- Check: When homing is repeated value "0" should be displayed in S-0-0298.

⚠ **CAUTION**

Property damage at the installation caused by exceeding the allowed travel range!

⇒ The "activated" range of the home switch has to reach beyond the next end of travel range because otherwise axis end position detection is impossible!

Notes on Commissioning for Relative Encoders (Reference Marks not Distance-Coded)

Settings for Axis-Side Position Data Reference of Actual Position Values

To establish the position data reference of an encoder (of groups 1, 2, 3) to the axis, the distance between the dedicated point identified on the drive side and the reference point of the axis, as well as the position of the reference point compared to the axis zero point have to be entered.

To do this the following steps have to be carried out:

1. First set parameters below to value "0":
   - **S-0-0052, Reference distance 1/S-0-0054, Reference distance 2**
   - **S-0-0150, Reference offset 1/S-0-0151, Reference offset 2**

2. If encoder reference marks are not to be evaluated, make corresponding settings in **S-0-0147, Homing parameter** (default setting: encoder reference marks are evaluated!)

3. For initial commissioning set parameters for homing procedure to low values:
   - **S-0-0041, Homing velocity** (e.g. 10 rpm)
   - **S-0-0042, Homing acceleration** (e.g. 10 rad/s²)

4. Execution of command **S-0-0148, C0600 Drive-controlled homing procedure command**

	⚠ **CAUTION**	**Property damage caused by step change of actual position value!**

⇒ By clearing the command the original operating mode becomes active again. When the "drive-internal interpolation" mode was set, for example, the drive immediately moves to the value in **S-0-0258, Target position**. Take change of actual position value into consideration!

Identifying the Dedicated Point

After the command was executed the axis zero point is at the same axis position as the dedicated point, because the reference distance (S-0-0052/S-0-0054) and the reference offset (S-0-0150/S-0-0151) were set to the value "0". The actual position value in parameter **S-0-0051, Position feedback 1 value** or **S-0-0053, Position feedback 2 value** now has absolute reference to this preliminary axis zero point.

Settings for the Reference Point

The reference point normally has an actual position value determined on the axis-side and related to the axis zero point. Ideally the dedicated point identified on the drive-side has the same position as the reference point. As the dedicated point position is considerably influenced by the mounting situation of the encoder, dedicated point and reference point are different. The distance between dedicated point and reference point for the motor encoder or external encoder is entered in the parameter for reference offset 1 or reference offset 2.

To determine the reference offset the following steps have to be carried out, based on the initial status after the proposed identification of the dedicated point:

- Jog axis to determined reference point and enter actual position value displayed at the reference point in parameter **S-0-0150, Reference offset 1** or **S-0-0151, Reference offset 2** with same preceding sign.

In order to establish the position reference to the real axis zero point enter the desired axis-related actual position value of the reference point in parameter **S-0-0052, Reference distance 1** or **S-0-0054, Reference distance 2**. This can be directly done by entering the value defined on the axis-side if this value is known. If not, the axis-related actual position value of the reference point has to be determined:

- Jog axis to desired axis zero point. Enter displayed actual position value in the respective reference distance parameter with inverted sign.

- or -

- Jog axis to actual position value = 0; axis then is at reference point. Axis-related position of reference point can be determined by measuring distance between current position and determined axis zero point. Enter measured distance as axis-related actual position value for reference point in respective reference distance parameter with the correct sign.

After repeated execution of command **S-0-0148, C0600 Drive-controlled homing procedure command** the actual position values refer to the axis zero point.

Settings for 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 execute command C0600 again!

If the axis, after execution of command C0600, is to be at the reference point (S-0-0052/S-0-0054), set the respective bit in **S-0-0147, Homing parameter**.

"Stop" After Detecting the Dedicated Point

When "stop after detecting the dedicated point" (default setting) was set in **S-0-0147, Homing parameter**, the drive stops the axis after the dedicated point was detected.

"Positioning" After Detecting the Dedicated Point

If the axis, after the dedicated point was detected, is to position to the reference point of the encoder selected in S-0-0147, this too has to be determined in parameter S-0-0147. The position can be preset via **S-0-0052, Reference distance 1** or **S-0-0054, Reference distance 2**.

> ⚠️ **CAUTION**
>
> **Possible property damage 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 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 to value "0":
   - **S-0-0177, Absolute offset 1**
   - **S-0-0178, Absolute offset 2**
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. Execution of **C0600 Drive-controlled homing procedure command** (S-0-0148)

> ⚠️ **CAUTION**
>
> **Property damage caused by step change of actual position value!**
>
> ⇒ By clearing the command the original operating mode becomes active again. When the "drive-internal interpolation" mode was set, for example, the drive immediately moves to the value in **S-0-0258, Target position**. Take changed actual position value into consideration!

Identifying the 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 parameter **S-0-0051, Position feedback 1 value** or **S-0-0053, Position feedback 2 value** now has absolute reference to this preliminary axis zero point.

Settings for the Axis Zero Point
An axis-side reference point possibly available is not used for establishing the position data reference for distance-coded measuring systems. In order to establish the position reference to the real axis zero point enter the desired axis-related actual position value of the dedicated point (encoder zero point) in parameter **S-0-0177, Absolute offset 1** or **S-0-0178, Absolute offset 2**. The axis-related actual position value of the dedicated point has to be determined:

- Jog axis to desired axis zero point. Enter displayed actual position value in the respective absolute offset parameter with **inverted** sign.

- or -

- Jog axis to actual position value = 0. Axis then is at dedicated point. Determine axis-related position of dedicated point by measuring distance between current position and determined axis zero point. Enter measured distance as axis-related actual position value for dedicated point in respective absolute offset parameter with the correct sign.

After repeated execution of command **C0600 Drive-controlled homing procedure command** (S-0-0148) the actual position values refer to the axis zero point.

Settings for 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 command C0600 again!

Note: The direction of motion during the homing procedure of distance-coded measuring systems can be against the reference travel direction selected in parameter S-0-0147, if the axis is in the "activated" range of the home switch!

"Stopping" at End of Homing Procedure
If the setting "stop" (default setting) was made in **S-0-0147, Homing parameter**, the drive stops the axis as soon the controller has detected two neighboring reference marks. The motion range of the axis, depending on the initial position, is the single to double reference mark distance (S-0-0165).

"Positioning" at End of Homing Procedure
If the axis, after the dedicated point was detected, is to position to the reference point of the encoder selected in S-0-0147, this too has to be determined in parameter S-0-0147. The position can be preset via **S-0-0052, Reference distance 1** or **S-0-0054, Reference distance 2**.

Note: When homing distance-coded encoders, the value in S-0-0052/S-0-0054 is insignificant for establishing the position data reference! In this case, it can possibly be used for presetting a homing target position.

⚠️ **CAUTION**

Property damage possible at the installation, if the reference point is outside the allowed travel range and the position limit hasn't been activated yet!

⇒ Make sure that reference point is within the travel range and activate the position limit!

"Run Path" for Homing Procedure
If the setting "run path for homing procedure" was made in **S-0-0147, Homing parameter**, the motion range of the axis is always the double reference mark distance (S-0-0165) plus the braking distance for shutting

the axis down. The controller therefore can always detect two neighboring reference marks which is required for establishing the position data reference.

Note:	"Run path" supports homing of Gantry axes when distance-coded encoders are used for both axes!

Checking the Detection of End of Travel Range

For linear axes with distance-coded measuring system a home switch is required for detecting the end of the travel range. If the home switch is activated at the start of command C0600, the axis slide, to establish the position data reference, has to move against the reference travel direction selected in S-0-0147.

The signal status of the home switch is displayed in parameter **S-0-0400, Home switch**.

Procedure for checking the detection of the end of travel range:

- move axis to "activated" range of home switch
- start command C0600
  $\rightarrow$ Axis now must move against reference travel direction until position data reference has been established.

Possible Error Messages during Drive-Controlled Homing

While command C0600 is executed, the following command errors can occur:

- **C0601 Homing only possible with drive enable**
- **C0602 Distance home switch - reference mark erroneous**
- **C0604 Homing of absolute encoder not possible**
- **C0606 Reference mark not detected**
- **C0607 Reference cam input not assigned**

Establishing Position Data Reference for Absolute Measuring Systems

Brief Description

See also "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.

"Set Absolute Measuring" Command

In the case of measuring systems to be evaluated in absolute form, the position data reference is automatically established by the drive by starting the "set absolute measuring" command.

The position data reference once established is maintained until "set absolute measuring" 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 absolute measuring can be separately set for both measuring systems. If the absolute measuring was only set for one of the measuring systems, both actual position values are equal at the position to which the absolute measuring was set.

Note:	If the absolute measuring 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!).

Starting the Command

It is recommended to start the "set absolute measuring" command when the axis is in standstill without drive enable. In the cases in which the drive, for establishing the position data reference, has to move the axis to a defined position and hold it there, "set absolute measuring" can also be executed with active drive.

Note:	"Active drive" means the drive that is in control! Drive enable ("AF") has been set!

Reference of the Axis-Related Actual Position Value

By starting the "set absolute measuring" command the previous actual position value of an encoder at a reference position of the axis is set to a new value. This value then is the current axis position related to the coordinate system of the machine.
The reference position is defined by:

- the current axis position

- or -

- the positioning of the axis at a "striking" axis position
  (e.g. value "0").

The required assignments and configurations for "setting absolute measuring" are realized via parameter settings.

Pertinent Parameters

- **S-0-0052, Reference distance 1**
- **S-0-0054, Reference distance 2**
- **S-0-0269, Parameter buffer mode**
- **P-0-0012, C0300 Command Set absolute measuring**
- **P-0-0177, Absolute encoder buffer 1 (motor encoder)**
- **P-0-0178, Absolute encoder buffer 2 (optional encoder)**
- **P-0-0612, Control word for setting absolute measuring**
- **P-0-1002, Absolute encoder offset 1, encoder memory**
- **P-0-1012, Absolute encoder offset 2, encoder memory**

Pertinent Diagnostic Messages

- **C0300 Command Set absolute measuring**
- **C0301 Measuring system unavailable**
- **C0302 Absolute evaluation of measuring system impossible**
- **C0303 Absolute encoder offset cannot be saved**

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Functional Description

Reference Position

By starting the "set absolute measuring" command the previous actual position value of an encoder at a reference position of the axis is set to a new value. The reference position corresponds to the current axis position at the start of the command.

The new actual position value at the reference position after "set absolute measuring" is the value of parameter

- **S-0-0052, Reference distance 1** (for motor encoder)

- or -

- **S-0-0054, Reference distance 2** (for external encoder).

---

motor encoder: $S\text{-}0\text{-}0051_{new} = S\text{-}0\text{-}0052$

external encoder: $S\text{-}0\text{-}0053_{new} = S\text{-}0\text{-}0054$

S-0-0051:   actual position value 1
S-0-0052:   reference distance 1
S-0-0053:   actual position value 2
S-0-0054:   reference distance 2

Fig. 8-21:   Actual position values after "set absolute measuring"

Selecting the Absolute Encoder to be Homed

If several encoders to be evaluated in absolute form are connected to the controller, it is possible to select, via **P-0-0612, Control word for setting absolute measuring**, the encoder for which the "set absolute measuring" command is to take effect.

Storing the Absolute Encoder Offset

In order that an encoder to be evaluated in absolute form maintains the position data reference to the axis after "set absolute measuring", the absolute encoder offset is stored in the encoder data memory (P-0-1002/P-0-1012) and in the parameter memory (P-0-0177/P-0-0178).

Note: 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!

Parameter Buffer Mode

If the "set absolute measuring" command is cyclically used in the operational sequence (possibly in conjunction with external setting of reference position), 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, Parameter buffer mode** it is possible to select whether parameter values are to be stored permanently or temporarily.

Note: When the absolute encoder offset is stored temporarily the encoder loses the position data reference to the axis when the controller is switched off or when the parameter mode (P2) is activated.

Possible Operating States Before "Set absolute Measuring"

The "set absolute measuring" command can be activated in the following operating states:

- drive is ready for operation, but not active ("AB")

- drive is active in position control ("AF")

- drive is active and in "Drive Halt" ("AH")

Sequence of "Set Absolute Measuring"...

When the "set absolute measuring" command is started, the reference of the selected encoder is cleared first (S-0-0403).

...with Inactive Drive ("AB") or in "Drive Halt (AH)"	After the reference was cleared, the new actual position value (S-0-0051/S-0-0053), with inactive drive ("AB" or "bb") and with drive in "Drive Halt (AH)", is set according to the preselected reference position (see Fig. "Actual position values after "set absolute measuring""). The new position reference takes immediate effect.
...with Drive Enable ("AF")	After the reference was cleared, there are the following possibilities, with active drive, regarding the switching of the actual position value to the new position reference:

- Deactivating drive enable:
  When the drive goes to the inactive state, the new actual position value (S-0-0051/S-0-0053) is set according to the preselected reference position (see Fig. "Actual position values after "set absolute measuring"").

- Starting the "drive-controlled homing procedure" command:
  The drive becomes independent of the preset command values and internally presets the current actual velocity value as the command value. The new position command value (S-0-0051/S-0-0053) is set according to the preselected reference position (see Fig. "Actual position values after "set absolute measuring"") and the "drive-controlled homing procedure" command is reported by the drive to have been executed. The master now has to "synchronize" to the new actual position value of the encoder used in the active operating mode.

  After the master cleared the "drive-controlled homing procedure" command, the drive goes to master-controlled operation again.

Note: "Set absolute measuring" with a moving axis is possible, but makes sense only with master-side presetting of the reference position!

...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 (depending on storage mode; see above). Finally, the "set absolute measuring" command has to be cleared by the master!
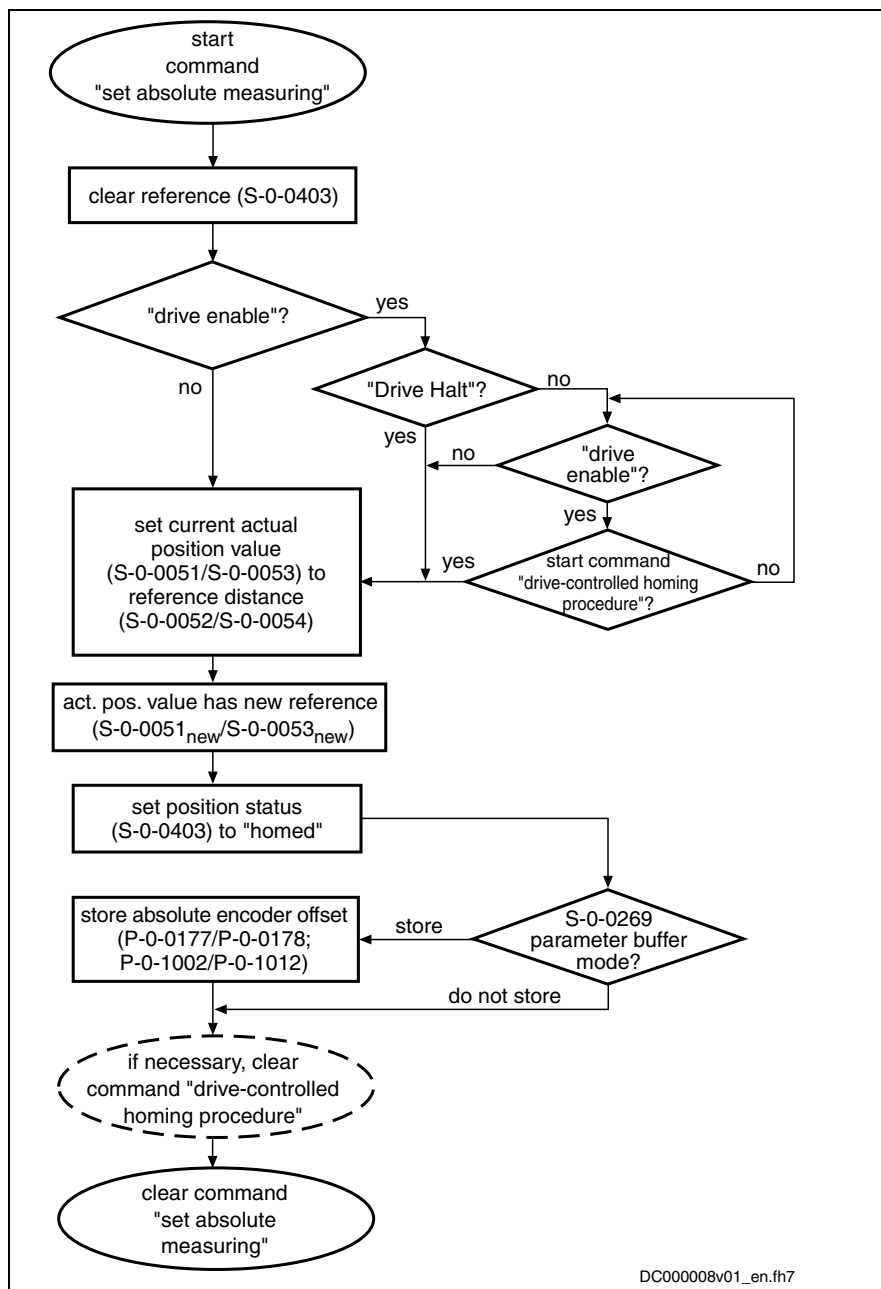
Fig. 8-22:   Sequence of "set absolute measuring" command execution

Notes on Commissioning

See also "Notes on Commissioning" in section "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" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Presetting	Make the presetting for "set absolute measuring" by determining the encoder for "set absolute measuring" in **P-0-0612, Control word for setting absolute measuring**.
Starting "Set Absolute Measuring"	Start the command **P-0-0012, C0300 Command Set absolute measuring**.
	See also "Command Input and Acknowledgment" in chapter "Master Communication"
Starting "Drive-Controlled Homing Procedure" If Necessary	If "set absolute measuring" is to be executed when the drive is active, the command **S-0-0148, C0600 Drive-controlled homing procedure command** has to be started.
	See also "Command Input and Acknowledgment" in chapter "Master Communication"
Checking Whether Position Data Reference was Established	The respective bit of **S-0-0403, Position feedback value status** displays whether the encoder selected via S-0-0612 has been homed.

> **Note:** If the absolute encoder had already been homed, the respective bit only changes for a short time during command execution!

When "set absolute measuring" was executed again for an absolute encoder, a value for the "offset" of the actual position values before and after command execution is entered in:

- **S-0-0175, Offset parameter 1** (motor encoder)
- **S-0-0176, Offset parameter 2** (external encoder)

Clearing the Executed Commands	After the commands (diagnosis possible via **S-0-0403, Position feedback value status**) have been executed, the commands started have to be cleared again in reverse order.
Detecting Encoder Replacement	If an absolute encoder was replaced, the following error message is generated:

- **F2074 Actual pos. value 1 outside absolute encoder window**

- or -

- **F2075 Actual pos. value 2 outside absolute encoder window**

The position data reference has to be established again!

Shifting the Position Data Reference for Relative and Absolute Measuring Systems

All alternative expansion packages with **closed-loop** characteristic

Brief Description

The existing position data reference of the measuring systems to the axis can be shifted if the respective command was activated by the master. It is possible to shift the data reference in standstill or while the axis is moving. This does not affect the position reference of the axis because it is only the actual position values output for the master that are displayed in "shifted" form. Internally the original ("non-shifted") position data reference is maintained.

Shifting the position data reference affects the motor encoder and, if available, the external encoder, independent of which encoder is the active encoder for position control. If different actual position values are valid for the encoders (both encoders possibly have position data reference independent of each other), the actual position values of both measuring systems are shifted by the same difference.

Pertinent Parameters
- **S-0-0197, C3300 Set coordinate system procedure command**
- **S-0-0198, Initial coordinate value**
- **S-0-0199, C3400 Shift coordinate system procedure command**
- **S-0-0275, Coordinates of 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.

Note:	The reference status of the actual position values is not affected by the shifting of the position data reference!

If the position data reference is shifted several times in succession without the drive having been switched to communication phase 2, the shifted values act in an additive way! The total offset with regard to the original actual position value is stored in parameter **S-0-0283, Current coordinate offset**.

Resetting "Shifting Position Data Reference"

The offset of the position data reference is reset by switching the drive to communication phase 2. Therefore, there cannot be any active offset of position data reference when the drive is switched on the first time, because former offsets are cleared when the drive is switched off.

Note:	After resetting the offset by switching to communication phase 2 the position data reference has to be established again for relative measuring systems, if necessary!

Establishing Position Data Reference for "Shifted" Measuring System

If the position data reference of the encoders to the axis is established (**C0300 Command Set absolute measuring** or **C0600 Drive-controlled homing procedure command**) with active offset of the actual position values (S-0-0283 unequal "0"), the new, homed actual position value is already displayed in offset form (in S-0-0051 or S-0-0053). The offset is not cleared by establishing the position data reference!

"Set Coordinate System Procedure" Command

When the control master triggers the **C3300 Set coordinate system procedure command** (S-0-0197), the drive becomes independent of the command values preset by the master and goes to standstill in a drive-controlled way. Deceleration takes place according to the **A0010 Drive HALT** function.

ℹ️   See also Troubleshooting Guide for "A0010 Drive HALT"

In standstill the actual position value is set to **S-0-0198, Initial coordinate value** and the difference between the new and original actual position value is stored in parameter S-0-0283. The command then is acknowledged as having been "executed".

"Shift Coordinate System Procedure" Command

When the control master triggers **C3400 Shift coordinate system procedure command** (S-0-0199), the drive also becomes independent of the command values preset by the master but maintains the current velocity by internal input of the previous velocity command value. The actual position values now are shifted by addition of **S-0-0275, Coordinates of offset value**. The difference between the new and original actual position values is stored in parameter S-0-0283. The command then is acknowledged as having been "executed".

Action of Control Unit After Command Acknowledgment

After the command acknowledgment the control master has to adjust to the shifted actual position values. This can be done by means of the actual position values of the encoder active for position control (S-0-0051 or S-0-0053) or the current offset value (S-0-0283). When the control master has adjusted its command values to the new actual position values, it can clear the command. The master then sets the command values again. In spite of the actual position value having been shifted with the drive active, there is no jerk when controlled!

Change in Position Data by "Shifting Position Data Reference"

Measured position values, generated by probe evaluation, for example, refer to the actual position value system in which they were measured, i.e.:

- When measured after the shifting, they refer to the "shifted" measuring system.

- When measured before the shifting, they refer to the original measuring system.

Command values (cyclic command values, target position, spindle angle position etc.) have to refer to the current actual position value system, i.e. to the possibly shifted position data reference.

Unchanged Position Data After "Shifting Position Data Reference"

Travel range limit values (S-0-0049 or S-0-0050) and **position correction values** (e.g. axis error correction values) are always in their original position data reference, i.e. the control unit, before writing these parameters, has to take the current offset into account and calculate the original position reference again.

Notes on Commissioning

Shifting the position data reference during commissioning can cause incorrect command values after the shifting has been carried out! Commissioning basically makes sense only in conjunction with the control master. Check whether the command value handling of the master is correct!

⚠️ **CAUTION**

Property damage caused by error in command value input after shifting the position data reference!

⇒ Protect the travel range of the axis, activate axis limit switches and make sure they are working!

"Set Coordinate System Procedure"

It is recommended to begin with "set coordinate system procedure". But first the parameter **S-0-0283, Current coordinate offset** should be read. When the shifting of the position data reference has not yet been carried out after the transition from "P2" to "AF", the value has to be "0"!

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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 Input and Acknowledgment" in chapter "Master Communication"

Checking the Offset of Position Data Reference

When the command was acknowledged by the drive, the offset of the position data reference has to be checked:

- The actual position value (S-0-0051 and possibly S-0-0053) has to correspond to **S-0-0198, Initial coordinate value**.

- **S-0-0283, Current coordinate offset** has to be read. With value unequal "0" shifting took place; with value "0" either no shifting has taken place or the actual position value of the axis approximately equaled the value of S-0-0198 when the position data reference was shifted.

Checking the Command Value Input and Clearing the Command

To check the command value input the master has to preset a position command value that corresponds to the value of parameter S-0-0198. Before the master resets the executed command, it is necessary to check whether the master-side command value corresponds to the current actual position value of the encoder used in position control (S-0-0051 or S-0-0053, shifted position data reference). If not, do not clear the command but reset "AF", if necessary, and search for the cause of the incorrect command value!

"Shift Coordinate System Procedure"

With "shift coordinate system procedure" it is recommended to control the axis on the master-side with velocity command value "0" or with very low velocity. But first read **S-0-0283, Current coordinate offset**. When the shifting of the position data reference has not yet been carried out after the transition from "P2" to "AF", the value has to be "0"!

After that start **C3400 Shift coordinate system procedure command** on the master-side.

See also "Command Input and Acknowledgment" in chapter "Master Communication"

Checking the Offset of Position Data Reference

When the command was acknowledged by the drive, the offset of the position data reference has to be checked.

- The values of **S-0-0283, Current coordinate offset** and **S-0-0275, Coordinates of offset value** have to correspond to each other.

Checking the Command Value Input and Clearing the Command

Before the master resets the executed command, it is necessary to check whether the master-side command value corresponds to the current actual position value of the encoder active in position control (S-0-0051 or S-0-0053, shifted position data reference). If not, do not clear the command but reset "AF", if necessary, and search for the cause of the incorrect command value!

8.3 Error Reactions

Base package of all variants (except for error reaction "return motion")

Overview of Error Reactions

Depending on the operating mode that is used and some parameter settings, the drive controller carries out monitoring functions. An error message is generated by the drive controller, if a status is detected that no longer allows correct operation.

Errors can be divided into error classes. The error class is represented by the first two digits of the diagnostic message number.

See also "General Information: Terms, Basic Principles" in chapter "System Overview"

See also "Diagnostic System" in chapter "Handling, Diagnostic and Service Functions"

If the drive controller is in control (drive enable was set) and an error occurs, the drive controller automatically starts a drive error reaction.

This drive error reaction depends on:

- the error class of the error occurred and
- the settings of the following parameters:
    - **P-0-0117, Activation of NC reaction on error**
    - **P-0-0118, Power supply, configuration**
    - **P-0-0119, Best possible deceleration**

Note: At the end of each error reaction, the drive is torque-free. "Power off" depends on setting in parameter P-0-0118!

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Error Classes   There are 8 error classes with different priority:

Diagnostic message number	Error class	Drive reaction
F2xxx	non-fatal error	according to setting in parameter: - P-0-0119, Best possible deceleration - P-0-0117, Activation of NC reaction on error
F3xxx	non-fatal safety technology error	according to setting in parameter: - P-0-0119, Best possible deceleration - P-0-0117, Activation of NC reaction on error
F4xxx	interface error	according to setting in parameter: - P-0-0119, Best possible deceleration
F6xxx	travel range error	velocity command value reset ("emergency halt")
F7xxx	safety technology error	velocity command value reset ("emergency halt")
F8xxx	fatal error	immediate torque disable
F9xxx	fatal system error	immediate torque disable
E-xxxx	fatal system error "processor exception"	immediate torque disable

Fig. 8-23:   Error classes and drive reaction

Note: The error class can be recognized by the diagnostic message number and defines the drive behavior in the case of error.

Best Possible Deceleration

Brief Description

The drive reaction defined in parameter **P-0-0119, Best possible deceleration** is automatically carried out in the case of the following states:

- non-fatal errors (F2xxx)
- non-fatal safety technology errors (F3xxx)
- interface errors (F4xxx)
- change of drive enable signal from "1" to "0" (drive enable switched off)
- switching from operating mode to parameterization mode while the drive is in control (reset of the communication phase)

Note: At the end of each error reaction, the drive goes torque-free!

The setting in parameter **P-0-0119, Best possible deceleration** is ignored in the case of:

- travel range errors (F6xxx)
  → velocity command value reset ("**emergency halt**")
- safety technology errors (F7xxx)
  → velocity command value reset ("**emergency halt**")

- fatal errors (F8xxx)
  → immediate torque disable
- fatal system errors (F9xxx)
  → immediate torque disable

Possible Drive Reactions

One of the following reactions for "best possible deceleration" can be set:

Reaction	Value of P-0-0119
velocity command value reset ("**emergency halt**")	0
torque disable	1
velocity command value reset with ramp and filter ("**quick stop**")	2
return motion [1)]	3

[1)] … Only possible with enabled expansion package "servo function"!

Fig. 8-24:   Parameterization options for "best possible deceleration"

i   See also Parameter Description "P-0-0119, Best possible deceleration"

Velocity Command Value Reset ("Emergency Halt")

P-0-0119 = 0   In the case of error, the closed-loop-controlled servo drive in velocity control is shut down with command value = 0. The drive then brakes with its maximum allowed torque (see also "Limitations: Current and Torque Limitation" in chapter "Drive Control").

Note: In the case of open-loop-controlled U/f operation, the shutdown at the torque limit only takes place, when the stall protection loop has been activated (cf. **P-0-0045, Control word of current controller**)! The maximum deceleration is set by the value entered in **P-0-0569, Maximum stator frequency change**.
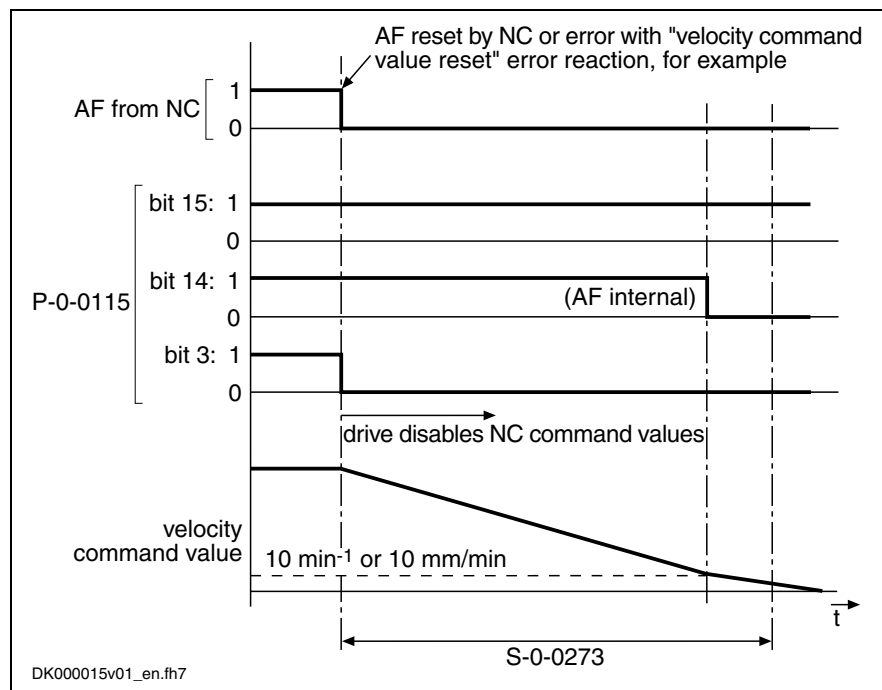
S-0-0273:   maximum drive off delay time
P-0-0115:   device control: status word

Fig. 8-25:   Time flow of velocity command value set to zero

Note: If the value entered for S-0-0273 is too small, the error reaction is sometimes aborted without axis standstill!

Sequence of Error Reaction with Motor Holding Brake Available   The sequence of the error reaction with motor holding brake available and of the output stage release with velocity command value reset is described under "Motor Holding Brake: Error Situation 1 in chapter "Motor, Mechanical Axis System, Measuring Systems".

Note: The activation and function of the motor holding brake depends on the setting in parameter **P-0-0525, Holding brake control word**.

See Parameter Description "P-0-0525, Holding brake control word"

See also "General Information on the Operation of Motors with IndraDrive: Motor Holding Brake" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Velocity Command Value Reset with Filter and Ramp ("Quick Stop")

P-0-0119 = 2   In the case of error

- the closed-loop-controlled servo drive in velocity control

- or -

- the open-loop-controlled drive in U/f operation

is decelerated to the final value "0" with a command value ramp and a jerk-limiting command value smoothing filter.

	Note: In open-loop-controlled U/f operation deceleration takes place taking the delay entered in parameter **P-0-0569, Maximum stator frequency change** into account!

Pertinent Parameters
- **S-0-0349, Jerk limit bipolar**
- **S-0-0372, Drive Halt acceleration bipolar**

The parameters take effect as described under "Drive Halt" in chapter "Drive Functions".

Sequence of Error Reaction with Motor Holding Brake Available

The sequence of the error reaction with motor holding brake available is described in chapter "Motor, Mechanical Axis System, Measuring Systems" in section "General Information on the Operation of Motors with IndraDrive" under "Motor Holding Brake: Error Situation 1".

Note:	The activation and function of the motor holding brake depends on the setting in parameter **P-0-0525, Holding brake control word**.
	See Parameter Description "P-0-0525, Holding brake control word"

See also "General Information on the Operation of Motors with IndraDrive: Motor Holding Brake" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Switch to Torque-Free State

P-0-0119 = 1 or Fatal Error

In the case of error the drive is switched to torque-free state. 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.

Note:	The "torque disable" error reaction is inevitable with fatal errors (F8xxx), because braking, e.g. with a defective output stage, is no longer possible!

⚠ DANGER	**Drive continues to move unbraked in the case of error!** Danger to life from parts in motion when the safety door at the machining cell is opened! ⇒ Check drive for motion (e.g. using **S-0-0040, Velocity feedback value**, if possible) and wait for standstill!

Sequence of Error Reaction with Motor Holding Brake Available

The sequence of the error reaction with motor holding brake available is described in chapter "Motor, Mechanical Axis System, Measuring Systems" in section "General Information on the Operation of Motors with IndraDrive" under "Motor Holding Brake: Error Situation 2".

Note:	The activation and function of the motor holding brake depends on the setting in parameter **P-0-0525, Holding brake control word**.
	See Parameter Description "P-0-0525, Holding brake control word"

See also "General Information on the Operation of Motors with IndraDrive: Motor Holding Brake" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Return Motion

Note:	The error reaction "return motion" can only be used for operation with encoder (closed-loop) and when the expansion package "servo function" has been enabled!

P-0-0119 = 3

If return motion was entered as the "best possible deceleration", the drive generates a **position command value profile** in order to travel the desired distance in the case of error. This means that a relative process block is activated in the case of error.

Generating the Position Command Value Profile

With the "drive-internal interpolation" mode, the position command value profile is generated internally by means of predefined travel block data (velocity, acceleration, jerk).

See also "Drive-Internal Interpolation" in chapter "Operating Modes"

The value of **P-0-0055, Return distance** depends on the preceding sign, i.e. positive return distance causes positive motion referring to the coordinate system selected.

Note:	The value of **P-0-0055, Return distance** can be configured and transmitted in the cyclic telegram (MDT).

The velocity profile is generated with the parameters

- **P-0-0056, Return velocity** and
- **P-0-0057, Return acceleration**.

In addition, the position command values can be smoothed by the position command value average value filter, the order of the average value filter being calculated from **P-0-0057, Return acceleration** and **P-0-0058, Return jerk**.

Calculating **P-0-0042, Current position command average value filter order**:

$$P-0-0042 = \frac{P \text{ - } 0 \text{ - } 0057, Return\ acceleration}{P \text{ - } 0 \text{ - } 0058, Return\ jerk}$$

Status Messages for Acknowledgment

After the drive has traveled the process block, i.e. after it moved to the desired target position, the drive is torque-free. The process block is considered to have been traveled when the following applies:

- target position = active position command value;
  i.e. bit 12 **S-0-0013, Class 3 diagnostics** = 1

  - and -

- $v_{act} = 0$;
  i.e. bit 1 in **S-0-0013, Class 3 diagnostics** = 1 (actual velocity smaller than **S-0-0124, Standstill window**)
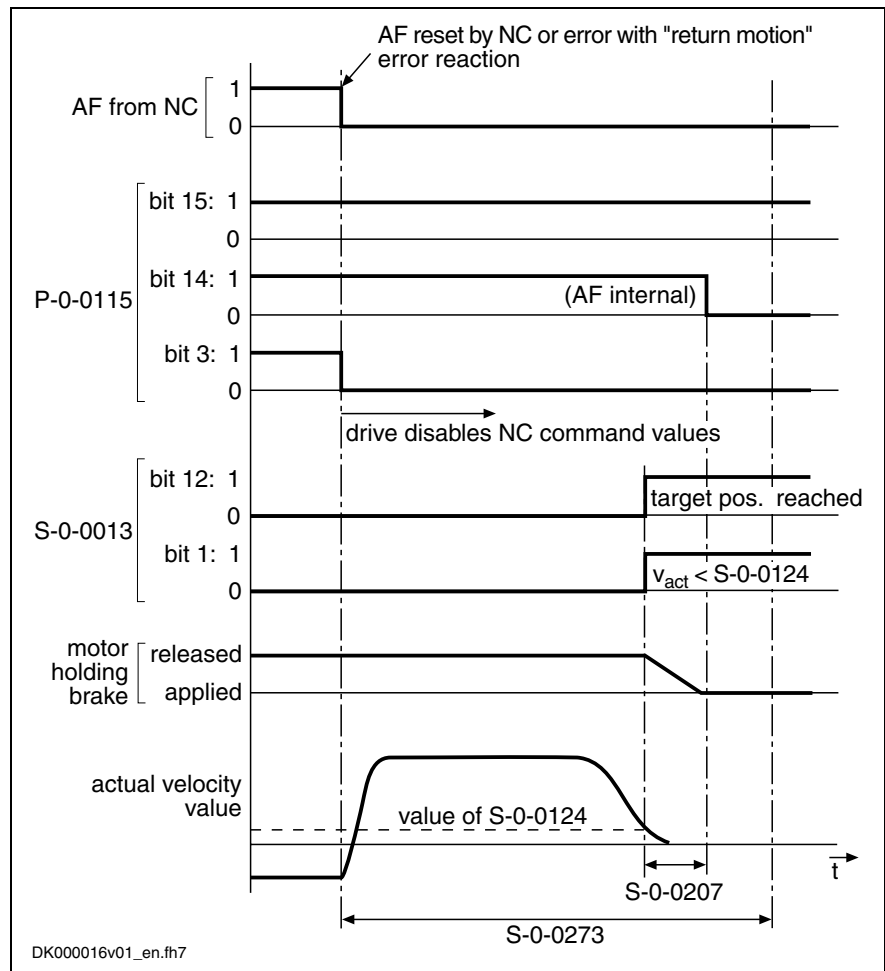
S-0-0013:   class 3 diagnostics
S-0-0207:   drive off delay time
S-0-0124:   standstill window
S-0-0273:   maximum drive off delay time
P-0-0115:   device control: status word

Fig. 8-26:   Sequence of "return motion" error reaction

Error Reaction "Return Motion" with Activated Position Limit Values

When the drive-internal position limit values (**S-0-0049, Positive position limit value** and **S-0-0050, Negative position limit value**) were activated, i.e. when

- bit 4 for "activating the position limit values" was set to "1" in **S-0-0055, Position polarities**

   - and -

- the encoder selected via **S-0-0147, Homing parameter** (bit 3) is in reference (**S-0-0403, Position feedback value status** = 1),

it is ensured that the drive does not leave the defined allowed travel range by executing the "return motion" error reaction.

Note:	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).

Sequence of Error Reaction with Motor Holding Brake Available

The sequence of the error reaction with motor holding brake available is described in chapter "Motor, Mechanical Axis System, Measuring Systems" in section "General Information on the Operation of Motors with IndraDrive" under "Motor Holding Brake: Error Situation 1".

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Note:	The activation and function of the motor holding brake depends on the setting in parameter **P-0-0525, Holding brake control word**.
	See Parameter Description "P-0-0525, Holding brake control word"

See also "General Information on the Operation of Motors with IndraDrive: Motor Holding Brake" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Package Reaction on Error

Brief Description

"Package reaction" is the simultaneous error reaction of all axis drives supplied by a common power bus (DC bus). Drive errors of a drive can be signaled to all other axis drives via the module bus (signal bus) which allows the simultaneous error reaction (according to setting in parameter **P-0-0119, Best possible deceleration**) of all axis drives.

The settings for signaling drive errors and package reaction are made individually for each drive in **P-0-0118, Power supply, configuration**. This allows activating the package reaction only for individual axes. The behavior of the axes for which the package reaction has not been activated has to be taken into account for the case of errors and must be controlled on the master side, if necessary!

Note:	The supply unit switches off power supply only in the case of its own errors and in the case of fatal drive errors (F8...), if the drive signaling errors signals F8 errors to the supply.

Fields of Application

Examples of applications with interactive (interpolating, synchronized) use of drives that are supplied by a common power bus ("drive package"):

- machine tools (e.g. milling, turning, grinding machines)
- gear cutting machines (gear wheel machining)
- printing mechanisms of printing machines, etc.

By setting the error reaction of the drive system devices according to the application, the following damages can be minimized:

- machine damages
- tool/workpiece/material damages

Note:	The package reaction is not suitable for avoiding personal injury!

Reaction to drive errors	Priority of appropriate error reactions for typical drive applications	Setting in P-0-0117	Setting in P-0-0118	Requirements
NC master-side reaction	NC master-side priority of shutdown and power off	NC reaction active	no package reaction, no signaling of drive errors	Drive with F8 error does not decelerate!
drive reaction	shutdown spindle drive (asynchronous motors) shutdown servo drives (synchronous motors) power off	NC reaction not active	package reaction, signaling of drive errors	Drive with F8 error does not decelerate! no DC bus short circuit, power off via NC master
	shutdown servo drives (synchronous motors) power off shutdown spindle drive (asynchronous motors) irrelevant	NC reaction not active	package reaction, signaling of drive errors, signaling of F8 errors to supply	power off only with F8 error, otherwise via NC master with DC bus short circuit
	power off shutdown spindle drive (asynchronous motors) shutdown servo drives (synchronous motors)	NC reaction not active	package reaction, signaling of drive errors, signaling of F8 errors to supply	power off only with F8 error, otherwise via NC master; no DC bus short circuit, drive with F8 error does not decelerate!
	power off shutdown servo drives (synchronous motors) shutdown spindle drive (asynchronous motors)	NC reaction not active	package reaction, signaling of drive errors, signaling of F8 errors to supply	power off only with F8 error, otherwise via NC master with DC bus short circuit

Fig. 8-27:   Examples of settings in P-0-0117 and P-0-0118, depending on the priority of appropriate error reactions, with indication of requirements

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Note: The above examples are not binding and provide basic information on the settings that have to be made according to the axis-specific and application-dependent requirements.

Pertinent Parameters
- **P-0-0118, Power supply, configuration**
- **P-0-0119, Best possible deceleration**

Notes on Commissioning

Basic settings with regard to error handling have to be made in parameter **P-0-0118, Power supply, configuration**:

- reaction to signaled errors of other drives in the drive system ("package reaction")
- signaling of own drive errors in drive system via module bus
- handling of "undervoltage" message for inverters (type HMS or HMD) and converters (type HCS)
- automatic clearing of **F2026 Undervoltage in power section** by switching drive enable off
- signaling of own, fatal drive errors (F8...) to the supply via module bus

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NC Reaction on Error

Brief Description

To avoid damages to the machine some applications require that the master (e.g. NC) retains control of the travel profile of the axes in the case of error, too, and shuts down the machine axes in a coordinated way. For this case, the "NC reaction on error" option was implemented; it can be activated via parameter P-0-0117.

The master is informed of an error in the drive controller via the drive status word (cf. S-0-0135) so that the master can shut down the machine axes in a coordinated way and therefore avoid possible damage.

Note: 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 NC 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 function is activated in parameter **P-0-0117, Activation of NC reaction on error**.

P-0-0117, bit 0:

- **bit 0 = 0** $\rightarrow$ 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** $\rightarrow$ 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: The activation of "NC reaction on error" (P-0-0117, bit 0 = 1) only makes sense for masters that include the respective procedure for the case of error.

8.4   E-Stop Function

Base package of all variants

Brief Description

The E-Stop function is used to shut down the drive with selectable drive reaction (see **P-0-0008, Activation E-Stop function**) via a digital input of the drive controller.

The following options are available:

- E-Stop with reaction to interface error (F4034 Emergency-Stop)

    → **reaction:** best possible deceleration (as set in P-0-0119)

- E-Stop with reaction to travel range error (F6034 Emergency-Stop)

    → **reaction:** velocity command value reset

- E-Stop as fatal warning "E8034 Emergency-Stop"

    → **reaction:** best possible deceleration (as set in P-0-0119)

Note: If E-Stop was parameterized as a warning, it isn't necessary to clear the diagnostic message!

Pertinent Parameters

- **P-0-0008, Activation E-Stop function**
- **P-0-0119, Best possible deceleration**
- **P-0-0223, E-Stop input**

Pertinent Diagnostic Messages

- **E8034 Emergency-Stop**
- **F4034 Emergency-Stop**
- **F6034 Emergency-Stop**

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 P-0-0008, Bit 2   This reaction first of all depends on the setting of bit 2 in parameter P-0-0008.

If the interpretation "fatal warning" was parameterized in P-0-0008 (bit 2 = 1), the drive reacts, as in the case when the external drive enable is switched off, with the reaction set in parameter **P-0-0119, Best possible deceleration**.

- The **E8034 Emergency-Stop** warning appears. Bit 15 is set in **S-0-0012, Class 2 diagnostics** (manufacturer-specific warning).

- Simultaneously, the bit "change bit class 2 diagnostics" is set in the drive status word.

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Note:	This change bit is cleared again by reading **S-0-0012, Class 2 diagnostics**. Using parameter **S-0-0097, Mask class 2 diagnostic** warnings can be adjusted in terms of their effect on the change bit.

Note:	To reactivate the drive, the E-Stop input must be deactivated and **another positive 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 diagnostic error message **F4034 Emergency-Stop** (or **F6034 Emergency-Stop**) appears.

- Bit 15 is set in parameter **S-0-0011, Class 1 diagnostics**.

- Bit 13 (drive interlock, error in class 1 diagnostics) is set in the drive status word of the drive telegram. The error message can be cleared via command **S-0-0099, C0500 Reset class 1 diagnostics** or the "Esc" button of the control panel if the E-Stop input is no longer active.

Note:	The error reaction is carried out without delay, independent of parameter **P-0-0117, Activation of NC reaction on error**.

E-Stop Reaction 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 reads **F4034 Emergency-Stop**.

If bit 1 = 1 was set in parameter P-0-0008, the drive, when the E-Stop triggers, is braked with maximum torque to speed = 0, independent of the error reaction defined in parameter P-0-0119. This setting corresponds to the best possible deceleration "velocity command value reset".

The diagnostic message upon activating the E-Stop input then reads **F6034 Emergency-Stop**.

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: Notes on Commissioning" in chapter "Extended Drive Functions"). A voltage level at the digital input therefore also affects bit 0 of P-0-0223.

Note:	Without this assignment to the digital input the E-Stop reaction fails to occur in spite of the input having been activated!

Activating E-Stop

The activation of the E-Stop input and the selection of a reaction for shutdown of the drive is carried out via bit 0 of parameter **P-0-0008, Activation E-Stop function** (see also Parameter Description P-0-0008).

P-0-0008, bit 0 (activation E-Stop):

- bit 0 = 0 $\rightarrow$ function not activated
- bit 0 = 1 $\rightarrow$ function activated

Selecting the Drive Reaction

Determining Reaction It is possible to determine whether an error message or a warning is generated when 0 V are detected at the E-Stop input. Bit 1 and bit 2 of **P-0-0008, Activation E-Stop function** are relevant for determining this.

P-0-0008, bit 1 (error class when interpreted as error):

- bit 1 = 0   → F4034 → best possible deceleration
- bit 1 = 1   → F6034 → velocity command value reset

P-0-0008, bit 2 (interpretation of the E-Stop input):

- bit 2 = 0   → interpreted as error (see bit 1)
- bit 2 = 1   → interpreted as fatal warning

Note: The error reaction can be determined via **P-0-0119, Best possible deceleration**.

Connecting the E-Stop Input

See documentation "Project Planning Manual for Control Section"

Note: The polarity of the input cannot be selected. It is always "0-active"; i.e. 0 V on the digital input causes the E-Stop to trigger.

Diagnostic and Status Messages

Diagnostic Warning and Error Messages

There are the following diagnostic messages for the E-Stop function:

- **E8034 Emergency-Stop**
  warning: E-Stop with best possible deceleration

- **F4034 Emergency-Stop**
  error: E-Stop with best possible deceleration

- **F6034 Emergency-Stop**
  error: E-Stop with velocity command value reset

Status Messages

The status of the E-Stop input can be read via parameter **P-0-0223, E-Stop input**:

- bit 0 = 0:   0 V on input   → E-Stop triggers
- bit 0 = 1:   24 V on input   → E-Stop does not trigger

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8.5   Compensation Functions/Corrections

Friction Torque Compensation

> Expansion package **servo function** (order code **SRV**) with **closed-loop** characteristic

Brief Description

The behavior of a machine axis is negatively affected by static friction when starting or when reversing the direction. The drive-internal friction torque compensation allows compensating the static friction by adding, depending on the direction of movement, a torque/force command value.
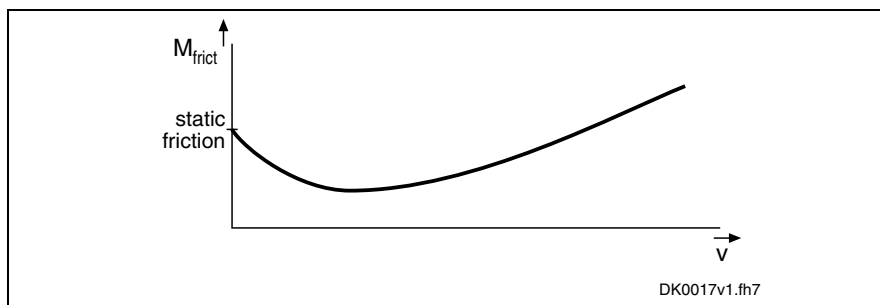
Fig. 8-28:   Friction torque curve with static friction

Note: 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**

Operating Principle

The principle of friction torque compensation is that the known friction component is pre-controlled (compensated) via an added torque/force command value and does not have to be compensated by the controller. This allows, especially when reversing the direction of movement, improving the control behavior (little lag error). Precision of drive control is thereby increased.
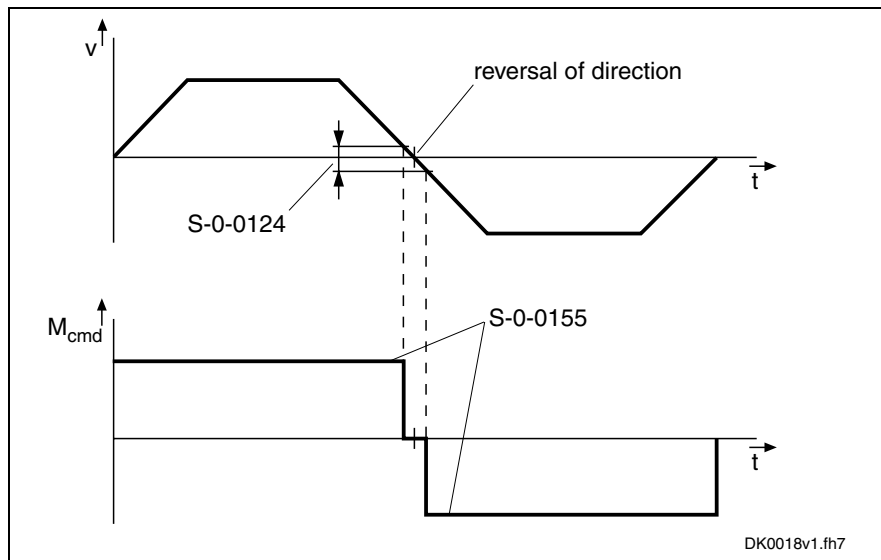
S-0-0124:   standstill window
S-0-0155:   friction compensation

Fig. 8-29:   Functional principle of friction compensation

Note: 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 (cf. S-0-0124).

Notes on Commissioning

The following requirements must have been fulfilled for using this
function:

Requirements
- 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.

Before activating the function the following preparations must be made:

Preparations
- Velocity and position control loops must have been set according to
  the notes on commissioning.

  See "Commissioning and Parameterizing the Control Loops" in
  chapter "Operating Modes"

- The master must have been connected and allow moving the drive
  (e.g. jog function).

- The travel range limits of the axis must have been set and activated
  (cf. P-0-0090, S-0-0049, S-0-0050).

- If the friction characteristic of the axis is highly temperature-
  dependent, the drive has to be brought 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.

Note: If the drive can only be moved in position control, the lag error
              monitor has to be switched off, as otherwise the **F2028
              Excessive deviation** error can occur during determination of
              the compensation value!

Determining the Compensation Value

The compensation value (S-0-0155) is determined in the following steps:

1. Preset a positive command value for the axis and increase **S-0-0092, Bipolar torque/force limit value** until the axis moves. The value then contained in S-0-0092 corresponds to the static friction component for positive direction (friction value_positive).

   Repeat this procedure in the other direction of movement to determine the static friction component for negative direction (friction value_negative).

2. Derive the setting value for friction torque compensation from the determined values (friction value_positive and friction value_negative). As there is no direction-dependent correction value, the average value has to be calculated from these two values and entered in parameter **S-0-0155, Friction compensation**.

Generating the average value for the entry in S-0-0155:

$$S\text{-}0\text{-}0155 = \frac{|\,\text{friction value\_positive}\,| + |\,\text{friction value\_negative}\,|}{2}$$

Encoder Correction

Base package of all variants in **closed loop** characteristic

Brief Description

The quality of machining or the precision with which an axis can follow a given path is determined by several factors. One of the factors of influence is the precision with which a measuring system can identify the position of an axis or shaft.

IndraDrive controllers provide the possibility of improving inaccuracy inherent in position measuring systems with sinusoidal signals. This improves the ability of a drive or an axis to follow the position and velocity command values. The bandwidth of the control loops can also be improved in many cases by the possibility of setting the control loop gain to a higher value.

Pertinent Parameters

- **P-0-0340, C3500 Command Determine encoder correction values**
- **P-0-0341, Control word for encoder correction**
- **P-0-0342, Correction value table for encoder correction**

Pertinent Diagnostic Messages

- **C3500 Command Determine encoder correction**
- **C3501 Acquisition velocity not allowed**
- **C3502 Motor encoder not available**
- **C3503 Optional encoder not available**
- **C3504 Measuring encoder not available**
- **C3505 No encoder selected**
- **C3506 Correction value table cannot be stored**

Functional Description

The precision of the actual position values that the controller determines from the signals of a measuring system depends, in the case of sinusoidal signals, to a high degree on how well the measuring system complies with the sine form.

Inaccuracy of Sinusoidal Encoder Signals

The most important inaccuracies with sinusoidal signals are caused by:

- signal offset
  → the evaluated sine signal is not symmetrical to the zero line

- amplitude error
  → the signal amplitude is either too low (bad resolution) or too high (crest range cannot be displayed)

- signal shape error
  → the curve shape differs from the exact sine shape

Actual position values are calculated from both sinusoidal signals of an encoder that are offset by a quarter of a division period. The mentioned errors cause sine signals differing from the ideal shape and therefore differing actual position values compared to ideal actual position values of exactly sinusoidal signal curves.

The controller automatically compensates the signal offset and the amplitude error for all encoders connected to the controller.

Compensating Signal Shape Errors

Due to the high degree of required calculated capacity, the correction of signal shape errors can only be activated for one of the encoders that can be connected. To do this it is necessary to determine one encoder, for which the correction is to be carried out, in **P-0-0341, Control word for encoder correction**. The controller acquires the signal shape by activation of **P-0-0340, C3500 Command Determine encoder correction values**.

To acquire the signal shape errors of the encoder division periods it is necessary to control the drive in the "velocity control" mode with a constant velocity command value.

The following applies to the maximum velocity for determining the correction values:

$$S-0-0040 \leq \frac{0{,}03125}{T_{Vloop} * DP/rev.} \text{ (rotary encoder)}$$

$$S-0-0040 \leq \frac{0{,}03125 * DP}{T_{Vloop}} \text{ (linear encoder)}$$

S-0-0040:   velocity feedback value
T_{Vloop}:   sampling time of the velocity loop
DP/rev.:   division periods per encoder revolution (number of lines of the rotary encoder)
DP: length of the division period (linear encoder)

Fig. 8-30:   Maximum velocity for acquiring the encoder signals related to the encoder shaft (rotary encoder) or the sensor head (linear encoder)

When all required measured values have been acquired, the correction values calculated and stored in **P-0-0342, Correction value table for encoder correction**, the controller completes the command execution. If with the command C3500 being active the actual velocity value should be lower than 50% or higher than 100% of the maximum value calculated above, the acquisition of the encoder signals is aborted (error message "C3501 Acquisition velocity not allowed"). For trouble-free acquisition of the encoder signals a command value of approx. 75% of the maximum velocity is recommended.

Note:	The values in the correction table P-0-0342 are only suitable for the encoder for which they were determined! In case an encoder is replaced the correction values have to be determined again (command C3500)!

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Activation/Deactivation	The correction values are determined once during initial commissioning. If encoder correction has been activated with the drive in operation (respective bits of P-0-0341), the signal shape errors of the encoder track are compensated by adding a correction value. The correction values are generated from the table values of parameter P-0-0342. If there hasn't been any encoder selected, the encoder correction is deactivated!
Notes on Application	According to experience the encoder correction can be effectively used for encoders with the following characteristics:

- rotary encoders   → up to approx. 1000 cycles/revolution
- linear encoders   → division periods up to approx. 0.1mm

Observe the following basic principles for application:

- If the encoder correction shouldn't cause any improvement, this function has to be deactivated (relieving the processor!).
- If the constant speed of a drive is to be improved, the encoder correction has to be applied to the motor encoder.
- If the positioning precision is to be improved, the encoder correction has to be applied to the position control encoder.

Notes on Commissioning

Preparation	Before starting the command C3500 make the following preparations for the respective drive:

- Determine the encoder to be corrected in **P-0-0341, Control word for encoder correction**.
- Determine the velocity that mustn't be exceeded for acquiring the encoder signals.
- Estimate the travel range of the axis for a motion time of at least 4 s with the maximum acquisition velocity and make sure that the travel range is sufficient (start position, direction of motion).
- Activate the "velocity control" mode.

Carrying Out Encoder Correction	During initial commissioning the encoder correction has to be carried out once:

- activate drive ("AF") and start **P-0-0340, C3500 Command Determine encoder correction values**
- input velocity command values of approx. 75% of calculated maximum value

⚠ **CAUTION**	**Property damage caused by errors when controlling motors and moving parts!**
	⇒ Make sure that the travel range of the axis is sufficient! Activate axis end position switches and set them to collision-safe positions!

- Observe the status of command execution and with the end of the command execution set the velocity command value to zero.
- Check the effectiveness of the encoder correction, e.g. by checking the amplitude of the speed deviation, if, as in the case of the acquisition of the encoder signals with activated and deactivated encoder correction, the same distance is traveled in the same way. With active encoder correction the amplitude has to be distinctly smaller!
  If necessary, repeat the command C3500 with modified acquisition velocity!

Activating Encoder Correction   When the drive is switched on again (after initial commissioning), the correction values stored in parameter **P-0-0342, Correction value table for encoder correction** are automatically activated when the respective bit was set in **P-0-0341, Control word for encoder correction**!

Axis Error Correction

> Expansion package **servo function** (order designation **SRV**) in **closed-loop** characteristic

Brief Description

The actual position value provided by the measuring system can differ from the real actual position value at the axis, e.g. at the point of chip removal in the case of metal-cutting machining, due to...

- inaccuracy of the measuring system
- transmission inaccuracy in mechanical transmission elements such as gear, clutch, feed spindle etc.
- thermal expansion of machine parts of the drive system.

For compensating the mechanically determined position error sources, IndraDrive controllers provide the following correction functions:

- backlash on reversal correction
- precision axis error correction
- control-side axis error correction

Only one of the three above correction functions can be active at a time. If more than one should have been activated, only the correction function of highest priority is active, the order of the above list is according to increasing priority. If several correction functions are activated simultaneously, only the one of highest priority takes effect!

In addition, 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

The two possibilities of temperature error correction can be activated simultaneously and in addition to the other correction functions!

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!

Available correction functions and their dependencies:

- backlash on reversal correction
  (depending on sign of velocity command value)

- precision axis error correction
  (depending on sign of velocity command value and on actual position value)

- position-dependent temperature error compensation
  (depending on current temperature and on actual position value)

- position-independent temperature error compensation
  (depending on current temperature)

- control-side axis error correction
  (current, cyclic position correction value from control unit)

Note: 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" in chapter "Drive Functions").

The sign of the velocity command value always refers to the load side, independent of the selected data reference (motor shaft or load).

Active Correction Value

The sum of active correction values is displayed in parameter **P-0-0401, Axis correction active correction value**. The value refers to the encoder selected in parameter P-0-0413.

Backlash on Reversal Correction

By means of the backlash on reversal correction it is possible to correct play in the mechanical axis system.
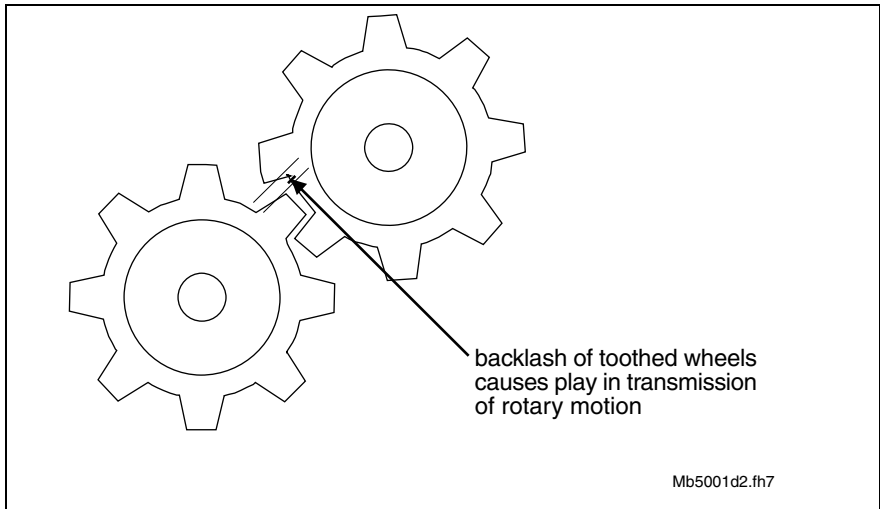
Fig. 8-31:   Illustration of play with toothed wheels

The function is activated by inputting the play 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).

Positive or negative direction of motion is detected, when

- in the case of position control, the time-related change of position command value (corresponding to velocity feedforward value in the case of lagless position control),

- in the case of velocity control, 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!
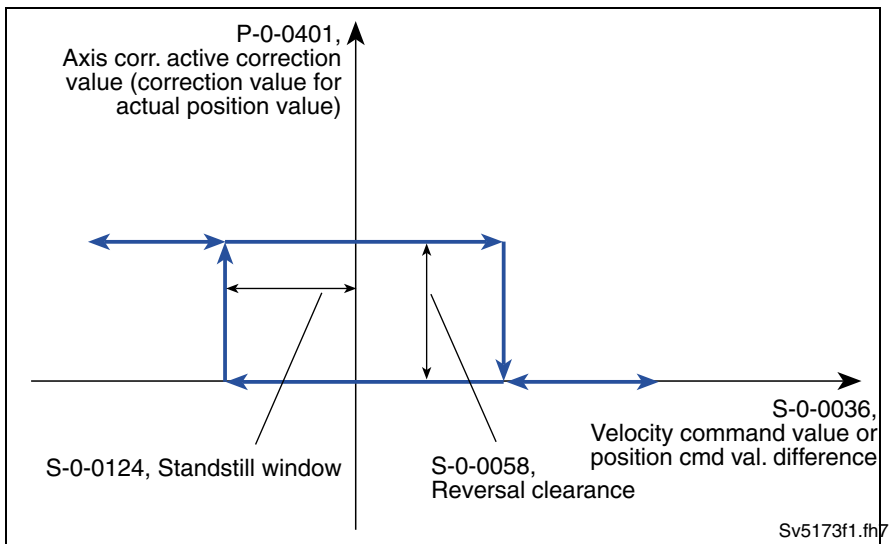
Fig. 8-32: Operating principle of backlash on reversal correction, hysteresis when changing direction of motion

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$$x_{act,\,corr} = x_{act}$$

x_{act}: uncorrected actual position value 1 or 2
$x_{act,corr}$: corrected actual position value 1 or 2
Fig. 8-33: Actual position value for v(cmd) > standstill window (S-0-0124)

$$x_{act,\,corr} = x_{act} + correction\ value$$

x_{act}: uncorrected actual position value 1 or 2
$x_{act,corr}$: corrected actual position value 1 or 2
Fig. 8-34: Actual position value for v(cmd) < (-)standstill window (S-0-0124)
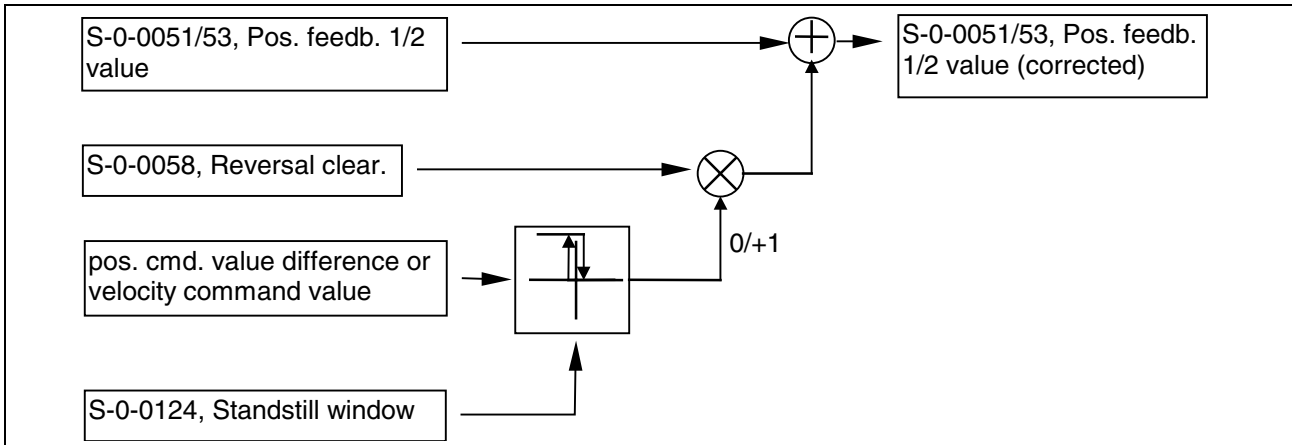
Fig. 8-35: Block diagram for backlash on reversal correction

Determining the Reversal Clearance

The following procedure is recommended for determining the value for parameter **S-0-0058, Reversal clearance**:

- by means of jog mode move axis in positive direction
- place dial gauge at appropriate spot of mechanical axis system and set it to zero
- jog axis in negative direction until change in pointer deflection of dial gauge is visible

The reversal clearance then is determined according to the following calculation:

$$reversal\ clearance = \Delta X_{control} - \Delta X_{dial\ gauge}$$

$\Delta X_{control}$: distance traveled from zero position of dial gauge according to control display
$\Delta X_{dial\ gauge}$: distance traveled according to dial gauge referring to its zero position
Fig. 8-36: Determining the input value for S-0-0058

Precision Axis Error Correction

The precision axis error correction is used for correcting non-linear encoder errors and non-linear errors of the mechanical system. The correction acts on the encoder selected by means of P-0-0413.

Pertinent parameters:

- **P-0-0408, Axis correction start position**
- **P-0-0409, Axis correction end position**
- **P-0-0410, Axis correction support point distance**
- **P-0-0411, Axis correction, correction table positive**
- **P-0-0412, Axis correction, correction table negative**

Correction Values

By means of the tables **P-0-0411, Axis correction, correction table positive** and **P-0-0412, Axis correction, correction table negative** 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 is within the range of values 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 at which the correction support points are registered 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. Positive or negative direction of motion is detected, when

- in the case of position control, the time-related change of position command value (corresponding to velocity feedforward value in the case of lagless position control),
- in the case of velocity control, the velocity command value (S-0-0036)

has exceeded the absolute value of the standstill window (S-0-0124) in positive or negative direction. In this case, the standstill window acts as hysteresis, too!

Activating the Precision Axis Error Correction

The precision axis error correction is active, when a value greater than zero was entered in parameter **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.

Fig. 8-37:   Illustration of correction value generation from the entered correction
            support points

Table index	P-0-0411 (positive direction)	P-0-0412 (negative direction)
0	0 (correction value at start position P-0-0408)	0 (correction value at start position P-0-0408)
1	correction value support point 2	correction value support point 2
2	correction value support point 3	correction value support point 3
3	correction value support point 4	correction value support point 4
....	....	....
498	correction value support point 499	correction value support point 499
499	0	0

Fig. 8-38:   Assignment of support point correction values to table index of
            correction tables P-0-0411 and P-0-0412

Note: It is not necessary to use all 500 table values. 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!

Note: Different correction values for positive and negative directions
            of motion at the same support point are causing 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:
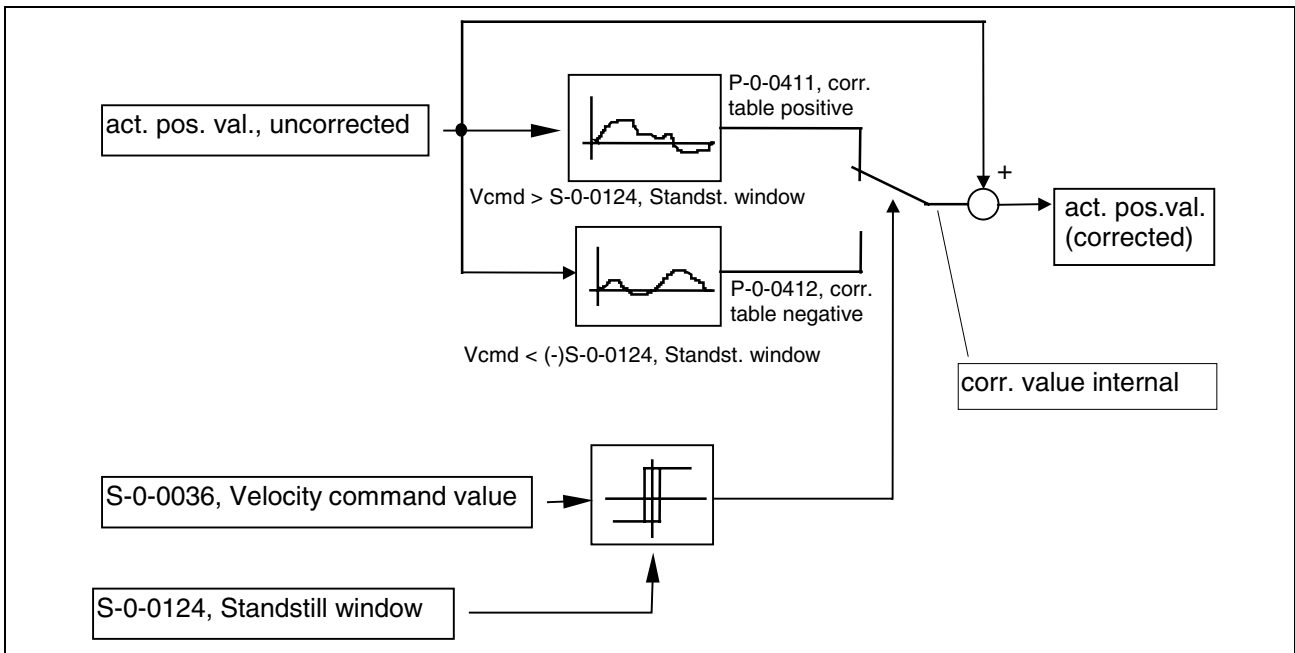
Fig. 8-39:   Block diagram for precision axis error correction

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.

$$xk = x(meas) - x(display)$$

xk: correction value relate to support point
x(meas):   measured position value at support point
x(display):   S-0-0051 or S-0-0053
Fig. 8-40: Determining correction value for precision axis error correction

The correction values relate to support point are entered in the tables 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!

$$P-0-0410 = \frac{length\_of\_correction\,range}{max.\_no.of\ support\ points(P\text{-}0\text{-}0411, P\text{-}0\text{-}0412)}$$

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. 8-41:   Determining the support point distance

Note: With the value zero in parameter P-0-0410 the precision axis error correction is deactivated!

Determining Start Position

The start position for precision axis error compensation determines 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

IndraDrive controllers provide the possibility of cyclically sending control-side correction values for the actual position value to the drive and using it for calculating the actual position value in the position control clock.

The control-side axis error correction is activated when the parameter **P-0-0400, Axis correction external correction value** is available in the master data telegram. The correction values act on the encoder selected in parameter **P-0-0413, Axis correction control word**.

Note: For control-side axis error correction it is not necessary to establish the position data reference drive-internally for the respective encoder!
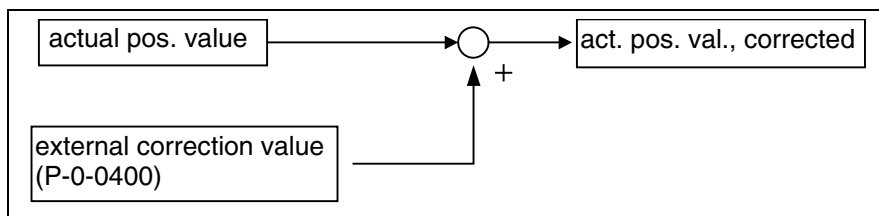
Fig. 8-42: Control-side axis error correction

Temperature Correction

The temperature correction is used to correct actual position value errors that can occur due to temperature-dependent linear expansion at servo axes.

Dependencies of the Actual Position Value Errors of Thermal Cause

According to the mechanical configuration of the axis and the arrangement of the workpiece or tool, the actual position value errors caused by the influence of temperature can

- only depend on temperature

- or -

- depend on temperature and on axis position.

IndraDrive controllers therefore provide two possibilities of temperature 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! For position-dependent and position-independent temperature correction the controller accepts its own measured temperature values!

Reference Temperature

The temperature-dependent correction functions are working relatively to a reference temperature at which there isn't any temperature-dependent actual position value error present. The reference temperature value has to be entered in parameter **P-0-0402, Axis correction reference temperature**.

> **Note:** When actual position reference values are measured, all machine parts have to have reference temperature!

Scaling All temperature data are scaled with the temperature scaling (S-0-0208) set on the drive side. The factors for linear expansion (P-0-0406, P-0-0407) are scaled with the quotient position data scaling/temperature scaling (S-0-0076/S-0-0208).

Position-Independent Temperature Correction

How to Use the Function The position-independent temperature correction is used to compensate the temperature-dependent linear expansion of tools, workpieces and slides. The expansion of these components of a servo axis only depends on the temperature difference compared to a reference temperature, the resulting actual position value error is the same at each position of the axis.

Pertinent parameters:

- **P-0-0402, Axis correction reference temperature**
- **P-0-0405, Axis correction actual temperature pos.-independent**
- **P-0-0407, Axis correction temperature factor pos.-independent**
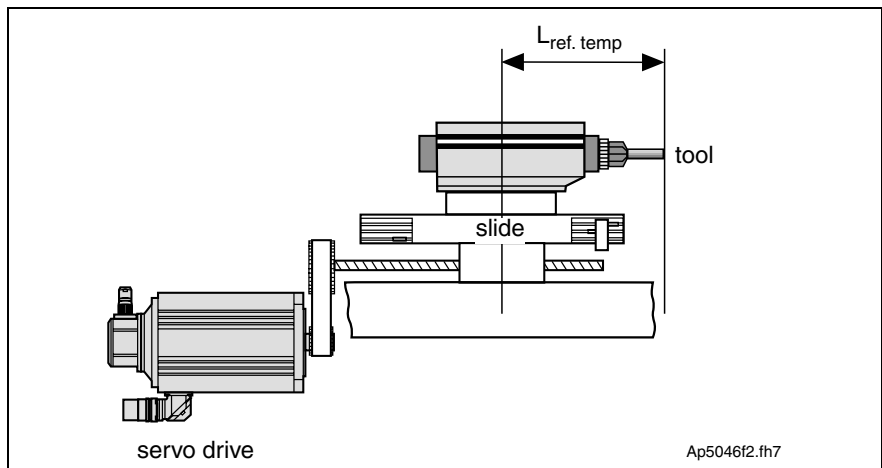
$L_{ref.temp}$: material length the temperature expansion of which has to be compensated (at reference temperature)

Fig. 8-43: Example of application for position-independent temperature correction

> **Note:** The actual position value system to be corrected is selected via the respective bit of **P-0-0413, Axis correction control word**.

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Operating principle of position-independent temperature correction:
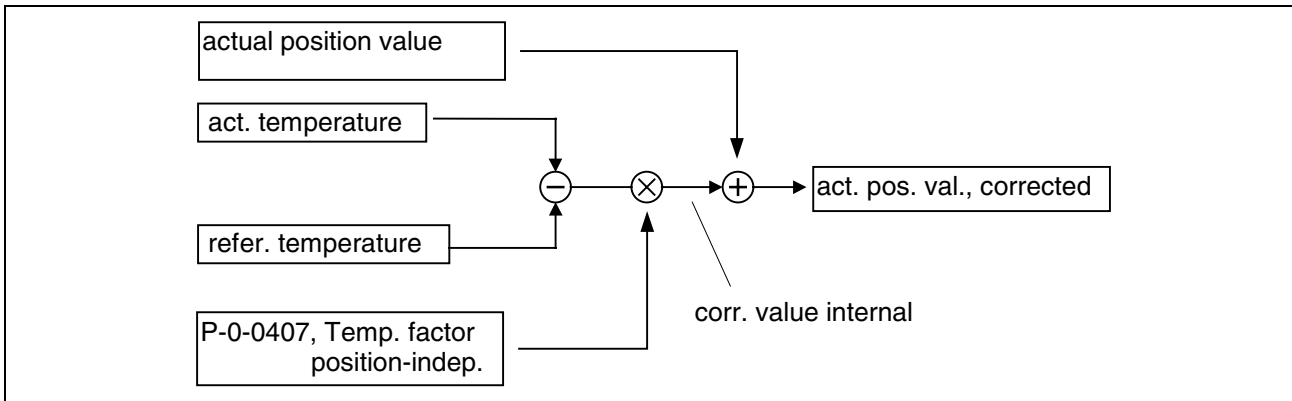
Fig. 8-44: Position-independent temperature correction

Drive-internal determination of the correction value:

$$x_k = P\text{-}0\text{-}0407 * (P\text{-}0\text{-}0405 - P\text{-}0\text{-}0402)$$

Xk:	correction value, temperature-dependent
P-0-0407:	axis correction temperature factor pos.-independent
P-0-0405:	axis correction actual temperature pos.-independent
P-0-0402:	axis correction reference temperature

Fig. 8-45: Determining the correction value

Position-Independent Temperature Factor

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.

$$P\text{-}0\text{-}0407 = \alpha * L_{ref.temp}$$

P-0-0407:	axis correction temperature factor pos.-independent
α:	Linear expansion coefficient of the material
$L_{ref.temp}$:	material length the temperature expansion of which has to be compensated (at reference temperature)

Fig. 8-46: Calculating P-0-0407

$$P\text{-}0\text{-}0407 = \alpha * L_{ref.temp}$$
$$= 0.000018 \ 1/K * \ 100 \ mm$$
$$= 0.00018 \ mm/0.1K$$

α:	e.g. 0.000018 $^1/_K$, if temperature scaling °C (default scaling)
$L_{ref.temp}$:	e.g. 100mm (preferred scaling)

Fig. 8-47: Example for calculating P-0-0407

Measuring the Value

If it is impossible to calculate the value for P-0-0407 (e.g. if the object of correction consists of different materials), it has to be measured. A series of measurements determines the actual position value error of the object of correction at different temperatures. Depending on the temperature difference, a straight line can be approximated by means of the measuring points.
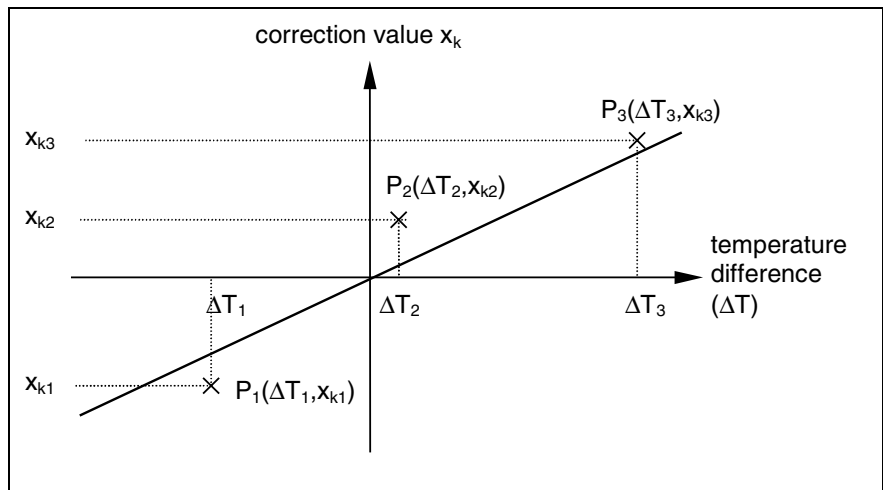
x_{kn}:   correction value (measured position value – actual position value (S-0-0051/S-0-0053))

ΔT_n: temperature difference
          (measured temperature – reference temperature (P-0-0402))

Fig. 8-48:   Approximated straight correction line on the basis of measured correction values at different ΔT

Calculation by Means of Measured Values

The gradient of the approximated straight line is the value of the position-independent temperature factor. By means of the value from the series of measurements it is possible to calculate the position-independent temperature factor:

$$P-0-0407 = \frac{n \times \sum(\Delta T_n \times x_{kn}) - \sum \Delta T_n \times \sum x_{kn}}{n \times \sum \Delta T_n{}^2 - (\sum \Delta T_n)^2}$$

P-0-0407:   axis correction temperature factor pos.-independent

n: number of measured values

ΔT_n: temperature difference at which the correction value x_{kn} was determined

x_{kn}:   correction value at the temperature difference ΔT_n

Fig. 8-49:   Calculating the position-independent temperature factor from the values of the series of measurements

Activating the Function

The position-independent temperature correction is activated when the value of **P-0-0407, Axis correction temperature factor pos.-independent** is greater than zero.

Note: With the value zero in parameter P-0-0407 the function of position-independent temperature correction is deactivated. This correction function does not require position data reference for the measuring system to the corrected!

Position-Dependent Temperature Correction

How to Use the Function

The position-dependent temperature 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 "point of reference" available that is used as the reference position for the position-dependent temperature correction.

Pertinent parameters:

- **P-0-0402, Axis correction reference temperature**
- **P-0-0403, Axis correction reference position for temp. corr.**
- **P-0-0404, Axis correction actual temperature pos.-dependent**
- **P-0-0406, Axis correction temperature factor pos.-dependent**
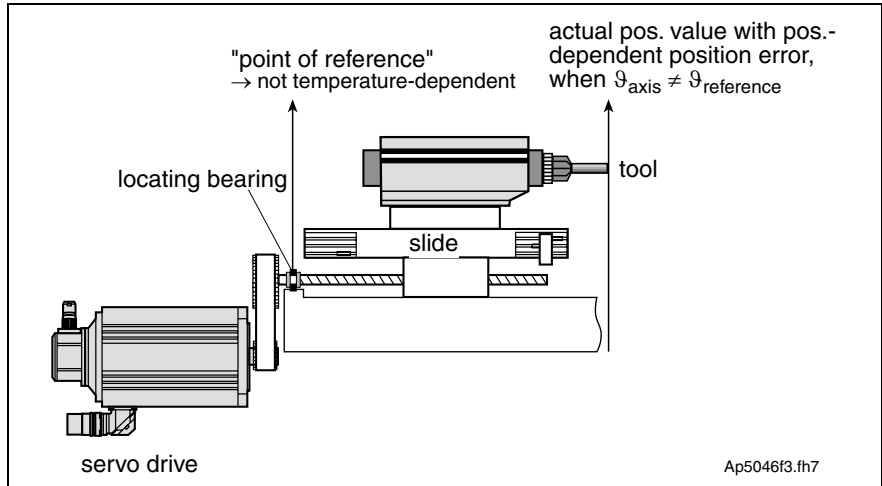
Fig. 8-50: Example of application for position-dependent temperature correction

Note: 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 correction:
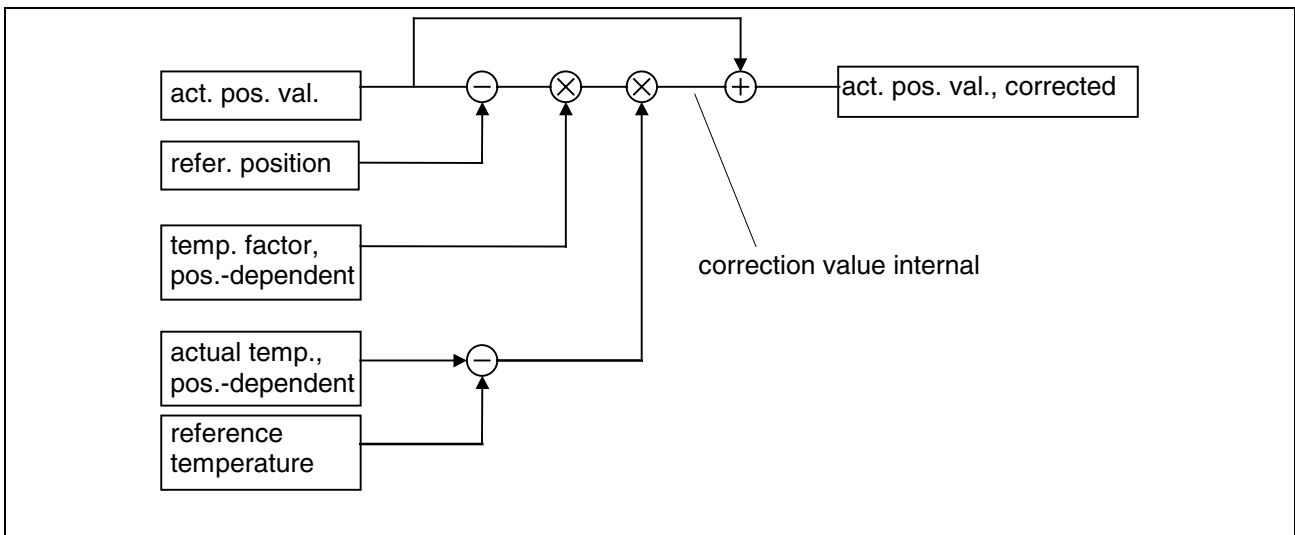
Fig. 8-51: Position-dependent temperature correction

When the position data reference was established for the actual position value system, the correction value related to the current actual position value is drive-internally determined as follows:

$$x_k = (S\text{-}0\text{-}0051/53 - P\text{-}0\text{-}0403) * (P\text{-}0\text{-}0404 - P\text{-}0\text{-}0402) * P\text{-}0\text{-}0406$$

Xk:	correction value, temperature- and position-dependent
S-0-0051/53:	actual position value encoder 1 or encoder 2
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. 8-52: Determining the correction value, temperature- and position-dependent

Determining the Reference Position

For position-dependent temperature correction there is an axis position that is not invalidated by variations of temperature. It is the reference position for position-dependent temperature correction and is entered in parameter **P-0-0403, Axis correction reference position for temp. corr**.

Determining the reference position by:

* direct measurement, if the arrangement of the mechanical transmission elements allows unequivocally recognizing the reference position

- or -

* a series of measurements with which the actual position value error is measured at axis positions clearly different from the reference position (at constant temperature that is clearly different from the reference temperature (P-0-0402))

Reference Position by Series of Measurements

As in the majority of cases it is impossible to determine the reference point by direct measurement, determining the reference point by means of a series of measurements is of great importance.
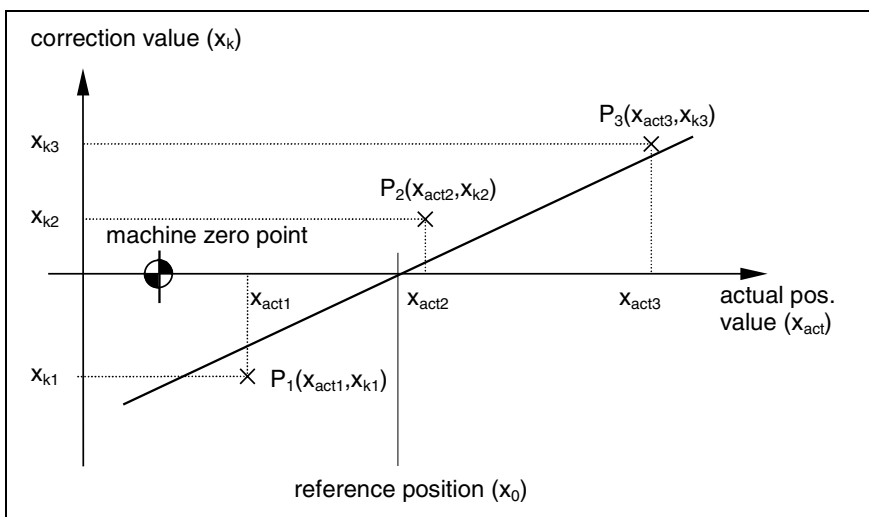
Fig. 8-53:   Illustration of the reference position

By means of the measuring points (P_1, P_2, P_3) it is possible to determine the reference position by the equation of an approximated straight line:

$$x_0 = \frac{-b}{a}$$

x_0:	reference position
b:	intersection point of straight line and correction value axis (x_k)
a:	gradient of the straight line

Fig. 8-54:   Equation for determining the reference position

Gradient of the straight line:

$$a = \frac{n \times \sum (x_{act\_n} \times x_{kn}) - \sum x_{act\_n} \times \sum x_{kn}}{n \times \sum x_{act\_n}{}^2 - (\sum x_{act\_n})^2}$$

n: number of measured values

x_{act_n}: actual position at which a correction value x_{kn} was measured

x_{kn}: correction value at x_{act_n}

Fig. 8-55: Auxiliary equation 1 for determining reference point

Intersection point of straight line and correction value axis (x_k):

$$b = \frac{\sum x_{kn} * \sum x_{act\_n}{}^2 - \sum x_{act\_n} * \sum (x_{act\_n} * x_{kn})}{n * \sum x_{act\_n}{}^2 - (\sum x_{act\_n})^2}$$

n: number of measured values

x_{act_n}: actual position at which a correction value x_{kn} was measured

x_{kn}: correction value at x_{act_n}

Fig. 8-56: Auxiliary equation 2 for determining reference point

Example Measured errors at $T_{act} = 45°C$ (reference temperature $T_0 = 23°C$):

n	X_{act_n} (actual position val. 1) in mm	x_{kn} (error) in mm
1	+10.0000	-0.0300
2	+70.0000	+0.0100
3	+105.0000	+0.0250

Fig. 8-57: Example of a series of measurements for temperature correction

Resulting measuring points: P = [X = X_{act_n} ; X = x_{kn}]

- P1 = [+10.0mm;-0.03mm]
- P2 = [+70.0mm;+0.01mm]
- P3 = [+105.0mm;+0.025mm]
- n = 3

Partial sums for auxiliary equations:

$$\sum x_{kn} = (-0.03 + 0.01 + 0.025)mm = +0.005mm$$

$$\sum x_{act\_n} = (10.0 + 70.0 + 105.0)mm = 185.0mm$$

$$\sum x_{act\_n}{}^2 = (10^2 + 70^2 + 105^2)mm^2 = 16025mm^2$$

$$\sum x_{act\_n} * x_{kn} = (-0.3 + 0.7 + 2.625)mm^2 = 3.025mm^2$$

Fig. 8-58: Partial sums for auxiliary equations

$$a = \frac{3 * 3.025mm^2 - 185.0mm * 0.005mm}{3 * 16025mm^2 - (185.0mm)^2} = \frac{8.15mm^2}{13850mm^2} = 0.0005884$$

Fig. 8-59: Auxiliary equation 1

$$b = \frac{0.005mm * 16025mm^2 - 185.0mm * 3.025mm^2}{3 * 16025mm^2 - (185.0mm)^2} = \frac{-479.5mm^3}{13850mm^2} = -0.034620mm$$

Fig. 8-60:   Auxiliary equation 2

$$x0 = \frac{-(-0.034620mm)}{0.0005884} = 58.83mm$$

Fig. 8-61:   Reference position

In order to be able to determine the reference position as exactly as possible, several series of measurements should be recorded at different temperatures for position-dependent temperature correction.

The resulting reference position is determined by the arithmetical mean of the calculated reference positions.

Position-Dependent Temperature Factor

The value for **P-0-0406, Axis correction temperature factor pos.-dependent** is determined

• by means of the data of the mechanical transmission elements

- or -

• by means of series of measurements for actual position value error at different temperatures at an identical axis position.

Temperature Factor by Means of Series of Measurements

To determine the position-dependent temperature factor it is necessary to record a series of measurements of correction values at different temperatures, at least at one position that clearly differs from the reference position.

Depending on the temperature difference, a straight line can be approximated through the measuring points.
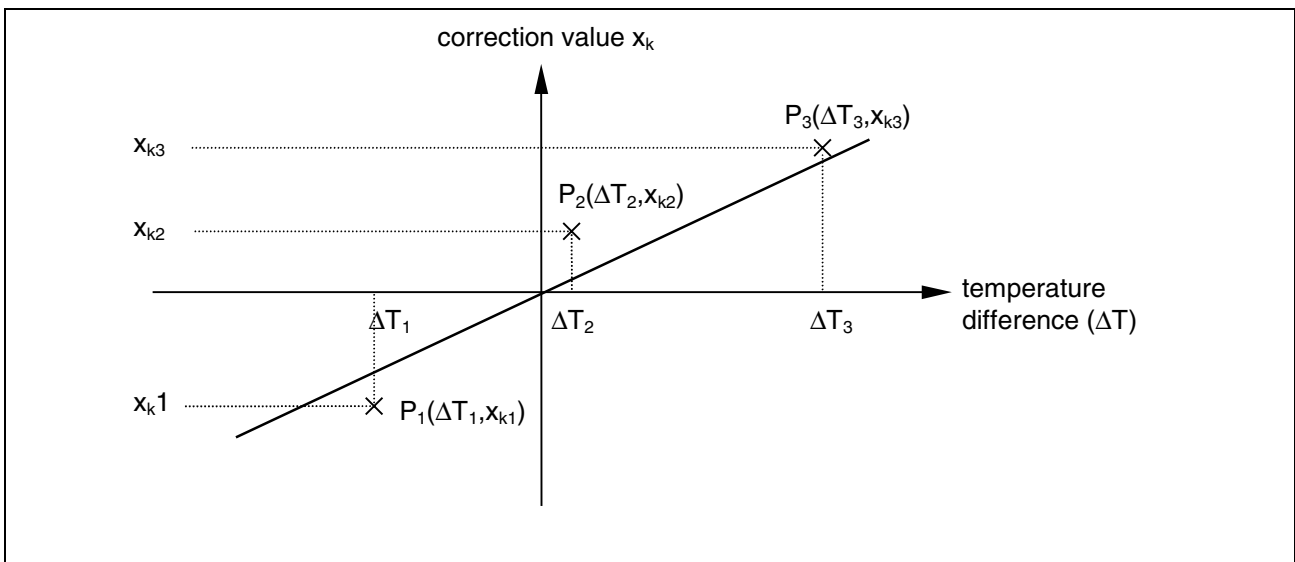
x_{kn}:   correction value (measured position value – actual position value (S-0-0051/S-0-0053))

ΔT_n: temperature difference
(measured temperature – reference temperature (P-0-0402))

Fig. 8-62:   Approximated straight correction line on the basis of measured correction values at different ΔT with identical actual position

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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:

$$P-0-0406 = \frac{n \times \sum (\Delta T_n \times x_{kn}) - \sum \Delta T_n \times \sum x_{kn}}{n \times \sum \Delta T_n{}^2 - (\sum \Delta T_n)^2}$$

P-0-0406: axis correction temperature factor pos.-dependent
n: number of measured values
ΔT_n: temperature difference at which the correction value x_{kn} was determined
x_{kn}:   correction value at the temperature difference ΔT_n

Fig. 8-63: Calculating the position-dependent temperature factor from the values of the series of measurements

In order to determine the factor as precisely as possible, it is useful to record the series of measurements at several positions.

The resulting temperature factor is determined by the arithmetical mean of the calculated temperature factors.

Activating the Function

The position-dependent temperature correction is activated when the value of parameter **P-0-0406, Axis correction temperature factor pos.-dependent** is greater than zero.

Note: With the value zero in parameter P-0-0406 the function of position-dependent temperature correction is deactivated. This correction function requires position data reference for the measuring system to the corrected!

Quadrant Error Correction

Expansion package **servo function** (order designation **SRV**) in **closed-loop**-characteristic (**only MPH**)

Brief Description

In the case of axis drives that are controlled, for example, in circular interpolation, static friction at the reversal points of the direction of motion can cause distortion of the circular contour.

In order to compensate this contour error at the so-called "quadrant transitions" (velocity reversal), IndraDrive controllers provide the "quadrant error correction" function.

This correction function are useful for such cases when drives are operated in circular interpolation by the control master.

Pertinent Parameters

- **P-0-0100, Position command value extension**
- **P-0-0435, Control word of position controller**
- **P-0-0436, Reference radius for quadrant error correction**
- **P-0-0437, Velocity time range for quadrant error correction**
- **P-0-0438, Table of path velocities for quadrant error correction**
- **P-0-0439, Table of velocity pulse for quadrant error correction**

Functional Description

For quadrant error correction, static friction possibly occurring at the reversal points of the direction of motion is compensated by adding an additional, pulse-shaped command value to the velocity command value at the output of the position loop. By means of this velocity feedforward the axis overcomes the static friction faster and with less lag error.

Sinusoidal Position Command Value Profile

Circular interpolation requires two drives that are controlled by the control master in cyclic position control. In this case the drives are controlled 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:
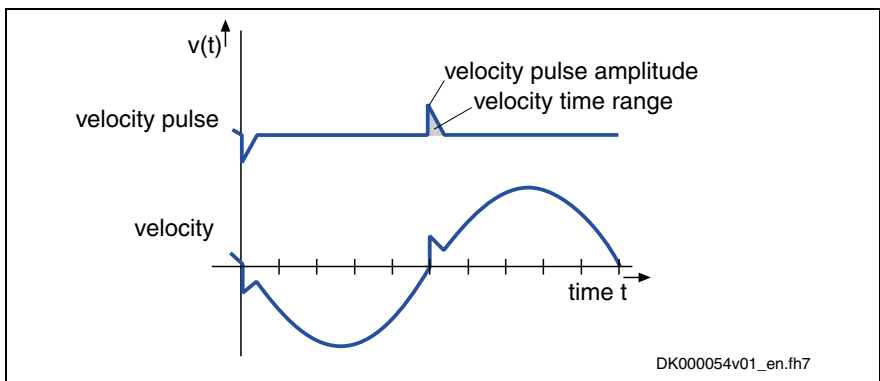
Fig. 8-64: Schematic curves of velocity pulse and velocity command value with quadrant error correction

The controller detects changes in the direction of motion by the time flow of the cyclic position command values.

Reference Circle, Reference Radius

The settings for quadrant error correction are made when a reference circle is processed (radius of reference circle in **P-0-0436, Reference radius for quadrant error correction**), e.g. the circle that is demanded for the reference piece.

The amplitude of the velocity pulse of quadrant error correction is preset depending on the circular velocity. The pulse is added abruptly and decreases in a ramp-like way.

The higher the path velocity the higher the pulse and the steeper it approaches zero, because the velocity time range of the pulse is independent of the velocity. It corresponds to the value input 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 should be done with regard to the path velocity and the duration for processing the reference circle (P-0-0436):

$$P-0-0437 = \frac{1}{2} * \frac{a}{100\%} * v_{path} * \frac{b}{100\%} * T_{circle}$$

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. 8-65: Estimation for value of P-0-0437

By means of list parameters the circular velocities and velocity pulse amplitudes are assigned to one another:

- **P-0-0438, Table of path velocities for quadrant error correction**

- **P-0-0439, Table of velocity pulse for quadrant error correction**

It is possible to store 20 pairs of values for velocity and pulse amplitude in the mentioned parameters, the velocities have to be entered in ascending order.

Determining the Velocity Pulse Amplitude

The velocity pulse amplitude to be assigned to a current circular velocity is determined by means of the list parameter values:

- Between 2 pairs of values the pulse amplitude is interpolated in linear form, depending on the current path velocity.

- Below the lowest path velocity the pulse amplitude is set to zero.

- Above the highest path velocity the pulse amplitude assigned to the highest path velocity continues to take effect.

Determining the Current Circular Velocity

The controller calculates the current circular velocity by means of the current acceleration command value of the drive calculated from the position command values. The reference radius (P-0-0436) is the basis for calculating the path velocity.

If the drive-internal resolution of the calculated acceleration command value is low, quadrant error correction sometimes is without effect. For this case it is recommended to integrate the extended position command value (**P-0-0100, Position command value extension**) in the cyclic master communication. This extends the decimal places of the position command value.

Note:	When using the quadrant error correction it is basically useful to use the extended position command value on the control side and integrate it in the cyclic master communication!

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 should be activated at the earliest one clock after the start of circular interpolation so that the velocity pulse won't be added when the drive is starting. Otherwise high velocity pulses damaging the contour could be added, due to the mostly high starting accelerations, when the drive is starting.

For machining other contours the quadrant error correction should be deactivated. To do this the respective bit of P-0-0435 should be contained in the cyclic master communication and activated depending on the kind of machining.

Note:	The quadrant error correction remains without effect when the value "0" is contained in **P-0-0437, Velocity time range for quadrant error correction**.

Notes on Commissioning

For commissioning it is necessary to move the drive by the control master in cyclic circular interpolation. The quality of the circular form has to be determined, in the ideal case with measuring equipment for circular form testing.

Recommended Steps of Commissioning

The quadrant error correction should be commissioned in the following steps:

1. 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 20% and 40% (list lines 1 and 2), for example, of maximum circular velocity to **P-0-0438, Table of path velocities for quadrant error correction**

    *   in **P-0-0439, Table of velocity pulse for quadrant error correction** write the value "0" to first two list lines

2. Move drive on control side in circular interpolation with 50% of maximum circular velocity, 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 **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.

Note: Observe interpolation data (see above) for the velocity pulse amplitude depending on the current path velocities (P-0-0438 and P-0-0439)!

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8.6 Detecting the Marker Position

Base package of all variants with closed-loop characteristic

Brief Description

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.

Note: 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 Message

- **C1400 Command Get marker position**

Functional Description

After the start of **P-0-0014, C1400 Command Get marker position** the following actions are carried out:

- The diagnostic message **C1400 Command Get marker position** is generated.

- If an incremental measuring system was selected, the search for reference marks is activated and the drive waits for reaching the next reference mark.

- When a reference mark is detected (i.e. the drive passes the position of a reference mark) the actual position value of this mark is stored in parameter **S-0-0173, Marker position A** and then the command execution is signaled to be completed.

Note: The drive does not generate any command value. The operating mode active at the start of the command remains unchanged. In order to pass the reference mark the control master has to preset such command values (e.g. by means of jogging) that lead to a movement in direction of the reference mark to be detected.

Note:	In parameter **S-0-0173, Marker position A** the position of the reference mark is also stored during the execution of the "C0600 Drive-controlled homing procedure command" (S-0-0148). This position, however, refers to the "old" coordinate system (before switching the coordinate system when executing the homing procedure).

8.7 Measuring Wheel Mode/Hybrid Position Control

Expansion package **synchronization** (order code **SNC**) with **closed-loop** characteristic

Brief Description

The measuring wheel mode is used for material feed axes, e.g. in sheet-metal machining. For direct measurement of the infeed of moved material a rotary encoder that is detecting the infeed length is driven via a measuring wheel with frictionally engaged contact to the material surface.

The position control loop is closed via motor encoder and measuring wheel encoder, possible slip between motor and material does not cause incorrect measured values of material length.

Note:	The measuring wheel mode may only be activated when contact has been established between measuring wheel and material surface.

actual position value 2
(optional encoder is
measuring wheel encoder)

actual position value 1
(motor encoder)

Fs5007f1.fh7
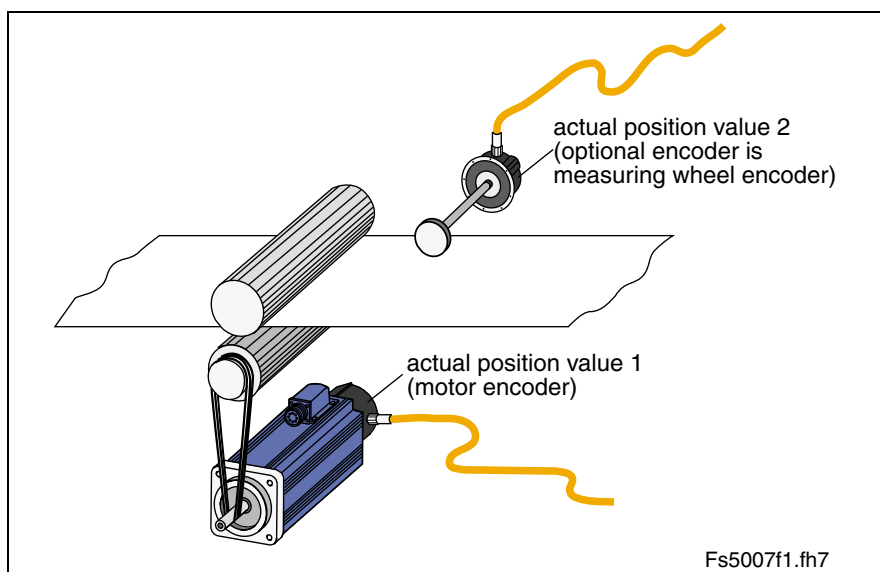
Fig. 8-66:   Typical arrangement of drive for material infeed with measuring wheel encoder

Hardware Requirements

The measuring wheel encoder is an optional (external) encoder that is connected according to the connection diagram contained in the documentation "Project Planning Manual for Control Section".

See also "Measuring Systems" in chapter "Motor, Mechanical Axis System, Measuring Systems"

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Pertinent Parameters

The following parameters are used to parameterize this feature:

- **P-0-0240, C1700 Command measuring wheel mode**
- **P-0-0241, Actual pos. smoothing time constant for hybrid pos. control**
- **P-0-0242, Current actual slip value in %**
- **P-0-0243, Maximum occurred actual slip value in %**
- **P-0-0244, Monitoring window of slip in %**

The following parameters are used to parameterize the measuring wheel encoder:

- **S-0-0115, Position feedback 2 type**
- **S-0-0117, Feedback 2 resolution**
- **P-0-0123, Feed constant 2 (optional encoder)**
- **P-0-0124, Gear 2 load-side (optional encoder)**
- **P-0-0125, Gear 2 encoder-side (optional encoder)**
- **P-0-0185, Control word of encoder 2 (optional encoder)**

Pertinent Diagnostic Messages

- **C1700 Command measuring wheel mode**
- **C1701 Measuring wheel operation not possible**
- **F2036 Excessive position feedback difference**

Functional Description

In the measuring wheel mode, the position control loop is closed via motor encoder and measuring wheel encoder. The measuring wheel mode is activated via **P-0-0240, C1700 Command measuring wheel mod**e and completed when the command is cleared.

For compensating possible slip between drive motor and material the position difference of motor encoder and measuring wheel encoder is included in the actual position value (hybrid position control).

To reduce jerky slip phenomena the added position difference can be attenuated with a filter. The time constant can be set in parameter **P-0-0241, Actual pos. smoothing time constant for hybrid pos. control**.
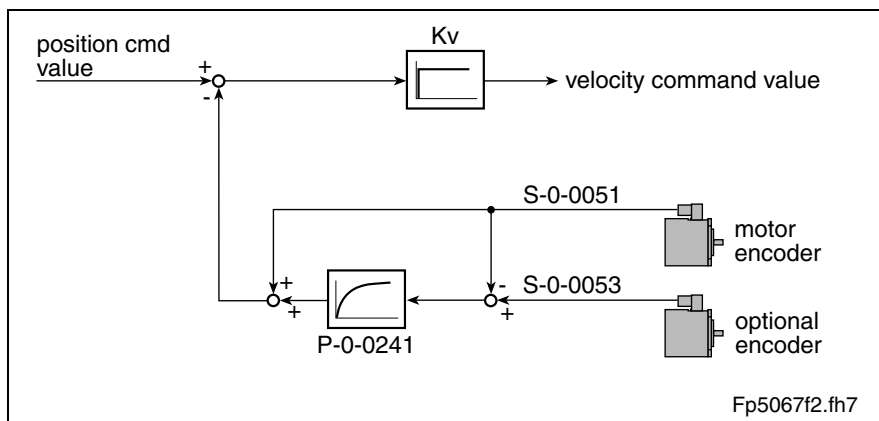
S-0-0051:	position feedback 1 value
S-0-0053:	position feedback 2 value
P-0-0241:	actual pos. smoothing time constant for hybrid pos. control

Fig. 8-67: Generating the actual position value with measuring wheel mode

> **Note:** If the value of parameter **P-0-0241, Actual pos. smoothing time constant for hybrid pos. control** is "0", the actual position value of the motor encoder is ignored and only the actual position value of the measuring wheel encoder is used for position control!

The mechanical arrangement of the measuring wheel encoder in the mechanical drive system is illustrated in the figure below:
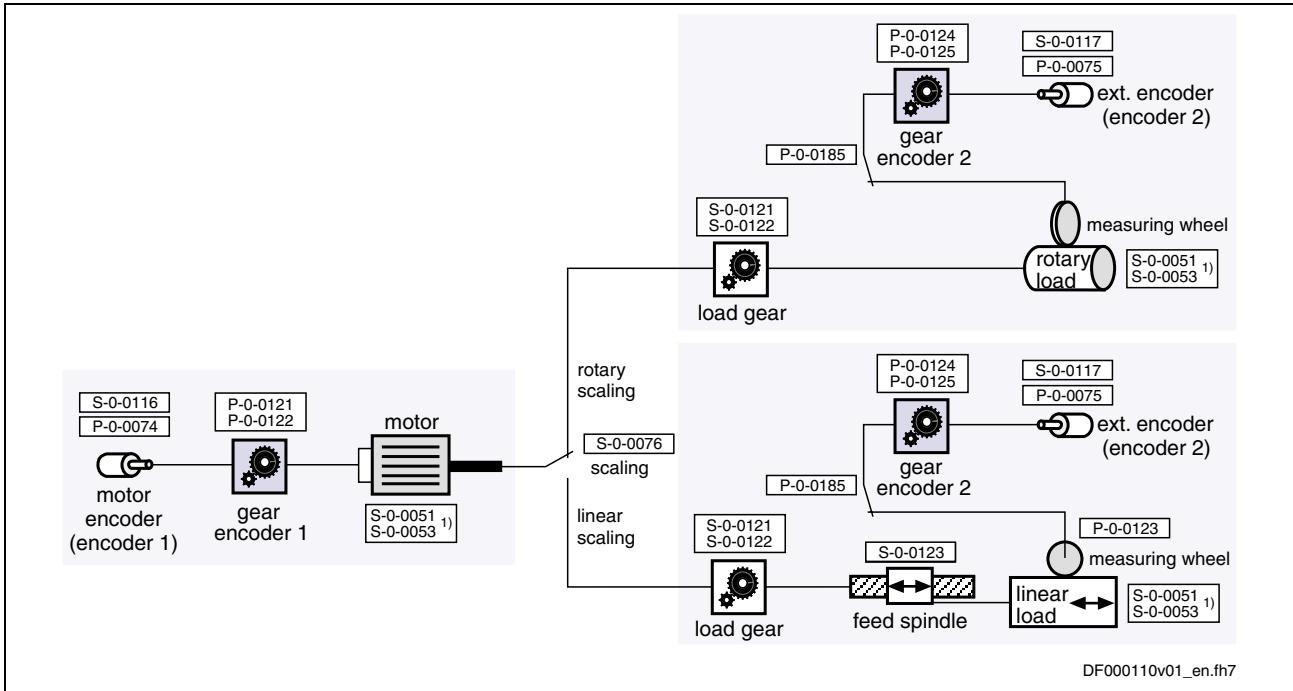
DF000110v01_en.fh7

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-0-0124:	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. 8-68:   Arrangement of the measuring wheel encoder in the mechanical drive system

Operating Modes and Measuring Wheel Mode

The measuring wheel mode can only be used in position-controlled operating modes (position control with cyclic command value input, drive-internal interpolation etc.). But it is possible to switch to non-position-controlled operating modes when the measuring wheel mode has been activated or to activate the measuring wheel mode already in these operating modes.

Activating the measuring wheel mode clears a possibly existing position data reference to the axis for both encoders. In measuring wheel mode the axis can only be moved in a relative way, the control master itself has to establish the position data reference to the material to be infed!

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After the measuring wheel mode has been deactivated, the position data reference to the axis, if necessary, has to be established again for relative and absolute encoders.

Position-Controlled Operating Modes

When activating and completing the measuring wheel mode in position-controlled operating modes, the actual position value of the motor encoder is included in the actual position value of the measuring wheel encoder (**S-0-0051, Position feedback 1 value** -> **S-0-0053, Position feedback 2 value**).

When switching to a non-position-controlled operating mode while the measuring wheel mode has been activated, the actual position value of the measuring wheel encoder is taken to the actual position value of the motor encoder (**S-0-0053, Position feedback 2 value** -> **S-0-0051, Position feedback 1 value**).

Non-Position-Controlled Operating Modes

In non-position-controlled operating modes control, as a basic principle, takes place with regard to the motor encoder. If first the measuring wheel mode is activated and only then the drive is switched to a position-controlled operating mode, the actual position value of the motor encoder is taken to the actual position value of the measuring wheel encoder (**S-0-0051, Position feedback 1 value** -> **S-0-0053, Position feedback 2 value**).

In non-position-controlled operating modes it is possible, with active measuring wheel mode, to lift the feed rolls off the material (discharge the feed rolls), for example.

Monitoring the Slip

Due to the measuring wheel mode, slip that can occur between material and drive motor is compensated via the position control. But slip also implies wear in the mechanical drive system and at the material. The controller supports reducing wear by allowing the monitoring of the occurring slip with regard to a maximum allowed value to be set.

The current actual slip value is displayed in **P-0-0242, Current actual slip value in %**. It is referring to

- one measuring wheel revolution, if "feed constant 2" is active in parameter P-0-0185 (typical case: measuring wheel is measuring linear infeed)

- or -

- one revolution of the external encoder, if "feed constant 2" is not active in parameter P-0-0185 (encoder is measuring rotary infeed).

If the calculated slip exceeds the value in parameter **P-0-0244, Monitoring window of slip in %** (value unequal "0"), the slip monitoring function triggers with the error message **F2036 Excessive position feedback difference** and the drive reacts with the error reaction that has been set.

To determine the monitoring window, the maximum occurring slip, e.g. during a machining cycle, is stored in parameter **P-0-0243, Maximum occurred actual slip value in %**.

Note: The slip monitor is deactivated with the value "0" in P-0-0244!

Notes on Commissioning

Presettings   First set the parameter values relevant to the mechanical arrangement of motor, motor encoder, axis and measuring wheel (see fig. "Arrangement of the measuring wheel encoder in the mechanical drive system").

Activating the Measuring Wheel Mode

> ⚠ **CAUTION**
>
> **Property damage caused by uncontrolled drive motion if measuring wheel encoder or feed motor have no contact to the material!**
>
> ⇒ Only activate measuring wheel mode if the measuring wheel is moved by the material in a frictionally engaged way!

The measuring wheel mode can only be activated when the drive is ready for operation, by

- command C1700 "measuring wheel mode" (P-0-0240)

  - and -

- position-controlled operating mode of the drive.

As the possibly existing position data reference of both encoders to the axis gets lost, the control master can only move the drive with relative (material-related) position command value. The position data reference to the material has to be established on the control side by means of the actual position value of motor encoder or measuring wheel encoder transmitted by the drive and an installation-side signal!

> **Note:**   The measuring wheel mode only takes effect in position-controlled operating modes, but can already be activated in non-position-controlled operating modes. For information on the actual position values in the case of measuring wheel mode and switching of operating modes, see above!

Deactivating the Measuring Wheel Mode   The measuring wheel mode can be deactivated by

- resetting the command C1700 "measuring wheel mode",

- switching to communication phase P2,

- switching the drive off.

If position data reference of the encoders to the axis should be required, it must be established again after the measuring wheel mode has been deactivated!

Setting the Jerk Attenuation   Jerky slip phenomena can be attenuated by entering a value greater than zero in parameter

- **P-0-0241, Actual pos. smoothing time constant for hybrid pos. control**.

> **Note:**   The value "0" in P-0-0241 switches off the attenuation and causes only the actual position value of the measuring wheel encoder to be effective!

Procedure:

1. Enter value "0" in parameter P-0-0241 and move axis at low infeed velocity.

2. Increase infeed velocity up to maximum velocity.

   While increasing the velocity also increase the value of P-0-0241, if necessary, in order to achieve a satisfactory compromise of

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smoothness of running and positioning velocity (e.g. for cutting material into sections) [watch **P-0-0038, Torque-generating current, command value**!].

Slip Monitoring with Measuring Wheel Mode

The slip monitor with active measuring wheel mode is activated by entering a value greater zero in parameter

- **P-0-0244, Monitoring window of slip in %**.

Note:	The value "0" in parameter P-0-0244 causes the slip monitor to be switched off! The value in **P-0-0242, Current actual slip value in %** then is no longer reset after each revolution of measuring wheel or external encoder, but the total slip since the deactivation of the slip monitor is displayed (possibly continuously increasing value).

Procedure:

1. First enter high value in parameter **P-0-0244, Monitoring window of slip in %** so that slip monitor cannot be triggered.

2. Enter value "0" in parameter **P-0-0243, Maximum occurred actual slip value in %** and run complete positioning cycle of axis with maximum infeed velocity several times, if necessary.

3. After having cyclically moved axis read parameter P-0-0243 and enter the value, multiplied by a safety factor (e.g. "2"), in parameter **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

Base package of all variants

Brief Description

For special applications it is required to move machine axes operated in position or velocity control up to a limit stop in order to generate forces of pressure.

When an axis in the standard situation has moved up to a limit stop, the drive should signal a drive error by the monitoring facilities of the position or velocity control loop and react with shutdown.

But if the drive can detect the special case of operation "positive stop drive procedure", it can ignore the messages of the position and motions monitors and generate the required force of pressure, if necessary.

The control master signals this special case to the controller of IndraDrive devices via a command. Upon this command, the drive switches off the respective monitors and acknowledges axis standstill to have been detected and a parameterizable force or torque threshold to have been exceeded.

Pertinent Parameters

- **S-0-0092, 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**

Functional Description

Moving a machine axis to a limit stop in a position-controlled way, e.g. for generating a force of pressure, is a process specifically provoked on the master side. To do this the master inputs a command value for the drive that the axis cannot reach because the mechanical limit stop is situated before it.

In order to avoid error messages and reactions with the drive having been blocked, the execution of **C1300 Positive stop drive procedure command** (S-0-0149) is started before the limit stop is reached. This switches off the following monitors that would cause class 1 diagnostic errors:

- monitor "drive does not follow command value"
  (F2028 Excessive deviation)
- velocity command value monitor
  (F2037 Excessive position command difference)
- acceleration command value monitor
  (F2039 Maximum acceleration exceeded)
- velocity control loop monitor
  (F8078 Speed loop error)

The command is acknowledged on the following conditions:

- The axis has stopped, i.e. the actual velocity value (S-0-0040) has fallen below the velocity threshold in parameter **S-0-0124, Standstill window**.

  - and -

- The generated torque or force has exceeded a threshold value, i.e. the actual torque/force value (S-0-0084) is greater than the value in parameter **S-0-0092, Bipolar torque/force limit value**.

The two criteria for command acknowledgment can be set axis-specifically.

By resetting the command C1300 the monitors are switched on again!

⚠️ **CAUTION**

Property damage can be caused by moving to positive stop too rapidly!

⇒ Reduce moving velocity and torque/force limit value (S-0-0092) to values that are not causing damage to the mechanical system!

Note: 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!

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Notes on Commissioning

For acknowledgment of command C1300 it is necessary to set:

- threshold value for detection of axis standstill
  - **S-0-0124, Standstill window**
- torque/force threshold in
  - **S-0-0092, Bipolar torque/force limit value**

Note: S-0-0124 and S-0-0092 are used for other functions, too. Specific changes of values made for the function "positive stop drive procedure" have to be reset, if necessary!

Before positive stop is reached, start:

- **S-0-0149, C1300 Positive stop drive procedure command**

After drive has moved away from positive stop, reset the command, if necessary!

Diagnostic Message   The command has been executed when the "commands change bit" is set in parameter **S-0-0135, Drive status word** and there isn't any command error present.

If a class 1 diagnostics error is present at the start of command C1300 (e.g. because the axis has already reached positive stop), the command is not executed. The following message is displayed:

- **C1301 Class 1 diagnostics error at command start**

8.9   Spindle Positioning

Expansion package **main spindle** (order code **MSP**) with **closed-loop** characteristic

Brief Description

With the drive function "spindle positioning", the drive, at a command of the master, aligns the spindle independently with regard to the spindle zero position. The command position is transmitted to the drive controller via parameter and can be preset as absolute or relative position.

By means of the "position spindle" command the spindle can be positioned in a position-controlled way (e.g. within the "velocity control" mode) without having to switch the operating mode from velocity to position control.

How to use the drive function "spindle positioning":

- for **milling and drilling spindles**
  - to prepare tool change
    The spindle remains at a defined position in order to allow changing the tool.
- for **turning machine main spindles**
  - to change the workpiece (if required)
  - to place balancing drillings for workpieces to be balanced
  - to index the workpiece for further machining
- for **revolving transfer machines**
  - to advance the turntable in order to bring workpieces to a defined machining position at the different stations

Pertinent Parameters

- **S-0-0152, C0900 Position spindle command**
- **S-0-0153, Spindle angle position**
- **S-0-0154, Spindle position parameter**
- **S-0-0180, Spindle relative offset**
- **S-0-0222, Spindle positioning speed**
- **S-0-0372, Drive Halt acceleration bipolar**
- **S-0-0417, Velocity threshold for positioning in modulo format**
- **S-0-0418, Target position window in modulo mode**
- **S-0-0430, Effective target position**

Pertinent Diagnostic Messages

- **C0900 Position spindle command**
- **C0902 Spindle positioning requires drive enable**
- **C0903 Error during initialization**
- **C0906 Error during search for zero pulse**

Functional Description

The positioning of the spindle is started via **S-0-0152, C0900 Position spindle command**. During the execution of the command the controller ignores the current command value of the active operating mode.

The presetting for the kind of positioning and motion of the spindle towards the target position in made in **S-0-0154, Spindle position parameter**.

Kind of Positioning   The spindle can be positioned at

- the absolute target position or
- the relative target position.

When "absolute target position" was set, the value from parameter **S-0-0153, Spindle angle position** is accepted, at the start of spindle positioning, as the target position effective in the drive (**S-0-0430, Effective target position**).

When "relative target position" was set, the target position (S-0-0430) effective in the drive at the start of spindle positioning is generated by addition of the current actual position value and the value from **S-0-0180, Spindle relative offset**.

Direction of Motion During Positioning   In the case of modulo scaling of position data, it is possible to choose between the following directions of motion for spindle positioning:

- clockwise rotation
- counter-clockwise rotation
- shortest distance

Positioning Velocity   The allowed maximum velocity during the spindle positioning process is entered in parameter **S-0-0222, Spindle positioning speed**.

Acceleration/Deceleration   The maximum acceleration or deceleration during the spindle positioning process is determined by parameter **S-0-0372, Drive Halt acceleration bipolar**.

Control Encoder   For spindle positioning the position control loop can be closed via the motor encoder or the optional encoder.

Note:	In the case of a mechanical system with slip (e.g. V-belt) between motor and spindle, an optional encoder is obligatory!

The encoder used for spindle positioning is defined by the bit for encoder selection in **S-0-0147, Homing parameter**.

Spindle Positioning with Non-Homed Control Encoder

If the encoder selected for spindle positioning doesn't yet have the position data reference to the spindle (see **S-0-0403, Position feedback value status**), the position data reference is automatically established during the execution of spindle positioning!

See also section "Establishing the Position Data Reference"

The figure below illustrates the basic sequence of the drive function "spindle positioning".
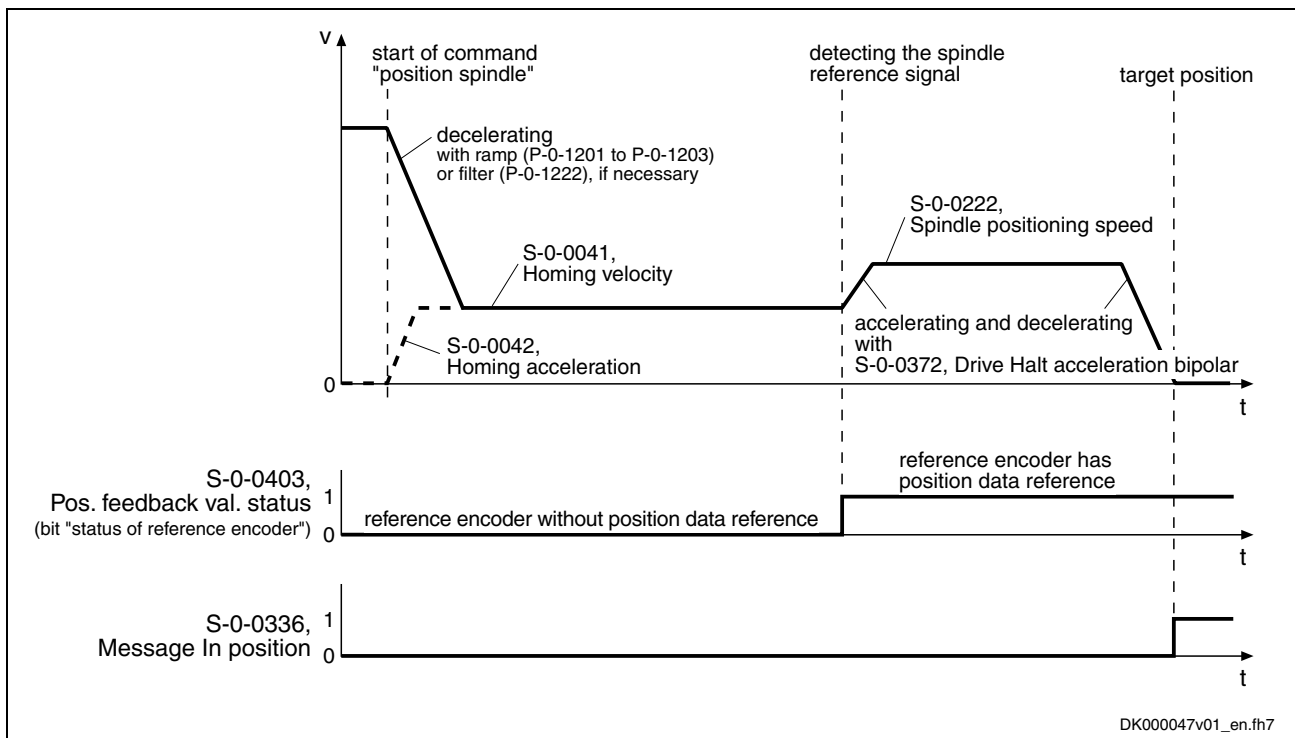
Fig. 8-69:   Basic sequence of spindle positioning (including establishing the position data reference)

Message "Target Position Reached"

The following parameters signal that the target position for spindle positioning has been reached:

- **S-0-0336, Message In position** and
- **S-0-0013, Class 3 diagnostics**

The target position is signaled to have been reached when

- velocity command value and actual velocity value are lower than the threshold value in parameter **S-0-0124, Standstill window**

  - and -

- the distance to target position is smaller than the value in parameter **S-0-0057, Position window**.

ℹ See also Parameter Description "S-0-0013, Class 3 diagnostics"

Specific Features with "Modulo" Position Data Format

Infinitely Turning Axis   Spindles for machine tools or rotary axes mostly are infinitely turning axes, their required position being within one revolution (0…360 dgr). For those axes it is recommended to use the "modulo" position data format because it allows displaying the actual position values with reference to one axis revolution only.

Ambiguity of Target Position   With modulo scaling the target position is ambiguous because it occurs within every spindle revolution. Depending on the direction of motion ("clockwise/counter-clockwise" or "shortest distance") preset for spindle positioning and the velocity at which spindle positioning is started, the positioning distance can be of different length. In addition, one or several additional revolutions can be required until the target position has been reached!

Spindle Positioning Out of Standstill   Out of standstill the spindle or rotary axis positions as determined in **S-0-0154, Spindle position parameter**:

- with the selected direction of motion ("clockwise" or "counter-clockwise")

- or -

- with the direction of motion in which the target position can be reached over the shortest possible distance ("shortest distance")

Spindle Positioning Out of Motion   Apart from the determined direction of motion (in S-0-0154), decelerating and positioning the spindle out of motion depends on

- the absolute value of the current velocity

  - and -

- the distance between current axis position and target position

at the start of spindle positioning.

The actual sequences of the positioning process of a turning axis can differ in spite of the determined direction of positioning motion.

In order to improve the reproduction of the positioning process, further limiting conditions are taken into account for the drive behavior:

- **S-0-0418, Target position window in modulo mode**

- **S-0-0417, Positioning velocity threshold in modulo mode**

Current direction of rotation at start of spindle positioning	Start position of spindle positioning ...	
	… **within** target position window (S-0-0418)	… **outside of** target position window (S-0-0418)
as selected direction of positioning motion ("clockwise" or "counter-clockwise")	Positioning takes place over shortest distance, if values do not leave target position window during deceleration. If values leave target position window during deceleration, drive positions according to selected direction of positioning motion at next target position to be reached.	Positioning takes place at next target position to be reached, while maintaining the velocity direction. If braking distance > distance start position-target position, the positioning process can require one to several revolutions, depending on the velocity at the start of the positioning process.
against selected direction of positioning motion ("clockwise" or "counter-clockwise")	If braking distance < distance start-target position, drive moves to target position over shortest distance. If braking distance > distance start-target position, positioning takes place after deceleration of motor, with reversion of velocity direction, at next target position to be reached.	The motor is decelerated to standstill. The positioning process then takes place at next target position to be reached, according to the determined direction of positioning motion.

Fig. 8-70: Dependence of the positioning process on the start position with determined direction of positioning movement "clockwise" or "counter-clockwise"

Current velocity at start of spindle positioning ...	
… higher than value of **S-0-0417, Positioning velocity threshold in modulo mode**	… lower than value of **S-0-0417, Positioning velocity threshold in modulo mode**
Positioning takes place at next target position to be reached, while maintaining the velocity direction. If braking distance > distance start position-target position, the positioning process can require one to several revolutions, depending on the velocity at the start of the positioning process.	If braking distance < distance start position-target position, positioning takes place at next target position to be reached, while maintaining the velocity direction. If braking distance > distance start position-target position, positioning takes place after deceleration of motor, with reversion of velocity direction, at next target position to be reached.

Fig. 8-71: Dependence of the positioning process on the velocity at the start of spindle positioning with determined direction of positioning motion "shortest distance"

Information on Hardware

The use of a home switch may be required.

See "Establishing Position Data Reference for Relative Measuring Systems" in section "Establishing the Position Data Reference"

Notes on Commissioning

Presettings Determining kind of positioning and direction of positioning motion:

- **S-0-0154, Spindle position parameter**

Determining maximum velocity for spindle positioning:

- **S-0-0222, Spindle positioning speed**

Determining threshold values for "In Position" message:

- **S-0-0057, Position window**
- **S-0-0124, Standstill window**

| **i** | See also Parameter Description "S-0-0013, Class 3 diagnostics"

If the position data are scaled in modulo format, it is possible to specify limiting conditions that improve the reproduction of the positioning process:

- **S-0-0417, Positioning velocity threshold in modulo mode**
- **S-0-0418, Target position window in modulo mode**

Starting Spindle Positioning

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).

Spindle positioning is started by starting the command

- **S-0-0152, C0900 Position spindle command**

Diagnosing Spindle Positioning

The target position effective for the positioning process is displayed in

- **S-0-0430, Effective target position**.

End of Spindle Positioning

When the target position has been reached, this is displayed in

- **S-0-0336, Message In position**

  - and -

- **S-0-0013, Class 3 diagnostics**.

The respective message bit changes from "0" to "1" when the conditions for the message have been fulfilled. The execution of the "position spindle" command is thereby acknowledged as having been "completed without error".

Diagnostic Messages

The execution of spindle positioning required drive enable (AF). Diagnostic message in the case of error:

- **C0902 Spindle positioning requires drive enable**

If an absolute encoder is used as control encoder, the position data reference of the encoder must have been established before the first-time start of spindle positioning. Diagnostic message in the case of error:

- **C0903 Error during initialization**

If a relative encoder is used as control encoder and a home switch is to be evaluated, the position data reference is established with the first-time spindle positioning (unless already done). If the drive does not recognize the home switch signal, the following diagnostic message is generated:

- **C0903 Error during initialization**

If a relative encoder is used as control encoder, the position data reference is established with the first-time spindle positioning (unless already done). If the drive does not recognize any reference mark signal, the following diagnostic message is generated:

- **C0906 Error during search for zero pulse**

8.10   Rexroth IndraMotion MLD-S (Drive-Integrated PLC)

Expansion package **IndraMotion MLD-S** (order designation **ML**)

Brief Description

General Information

The optional expansion package "IndraMotion MLD-S" provides 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)
  - completely conforms to IEC-61131-3
  - Online Change
  - Debugging
  - Offline Simulation
- **integrated single-axis motion control**
  motion function block according to PLC-Open for single-axis positioning and ELS operation (synchronous running, cam shafts, etc.)

  $\rightarrow$ "low-level motion functions"
  - priority programming via SFC combined with ST
  - Single-Action-Steps (non-IEC steps) for "single" steps
  - motion function block per libraries
  - cyclic parameters available as direct variables (system-wide variables)
  - library administration
- **basis for technology functions**
  examples: following-on cutting devices, pick&place, process controller (register controller, winding computation, etc.), preventive maintenance, free function block combination
  - synchronous, consistent data exchange with drive control, configurable cyclical data channel
  - periodic, high-priority user task
  - run-time monitoring

Note: This optional extension of the drive functionality is described in detail in the separate documentation "Rexroth IndraMotion MLD-S" (DOK-INDRV*-MLD-S*VRS**-AW01-EN-P; part no. R911306084).

Hardware Requirements   The function "IndraMotion MLD-S" requires the following control section design:

- single-axis ADVANCED (CSH01.1C)

Note:	The functionality of a drive-integrated PLC according to IEC-61131-3 is only contained in the **FWA-INDR*-MPH02VRS** firmware and requires the enabling of the additive functional package "IndraMotion MLD-S".
	See also sections:
	• "Functional Packages" in chapter "System Overview"
	• "Enabling of Functional Packages" in chapter "Handling, Diagnostic and Service Functions"

Functional Features

The functional package "IndraMotion MLD-S" includes the following general features/characteristic values:

- **up to 4 preemptive user tasks are possible**
- **task types:**
  - periodic (min. 1 ms cycle time)
  - free-running (permanently cyclic)
  - event-controlled (min. 1 ms reaction time)
- **memory resources:**
  - 512 kB program memory (with MMC) or
    64 kB program memory (without MMC)
  - 512 kByte data memory
  - 250 bytes retain or 32 kbytes on MD1
- **digital I/Os:**
  - 7...11 digital inputs, 0...4 digital outputs on X3
    (CSH01.1 control section)
    $\rightarrow$ PLC and drive are sharing the inputs!
  - 12 digital inputs, 8 digital outputs on MD1 (optional)
  - 16 digital inputs, 16 digital outputs on PL
    (as parallel master communication)
  - 1 relay output on X3 (CSH01.1 control section)
    $\rightarrow$ PLC and drive are sharing the inputs!
- **analog I/Os:**
  - 1 analog input (+/-10 V) on X3 (CSH01.1 control section)
  - 2 analog outputs (0-5 V) on X3 (CSH01.1 control section)
  - analog inputs/outputs (+/-10 V) on MA1 (optional)
- **other data:**
  - extensive debug possibilities:
    Single-Step, Watch, Force/Write, Breakpoints, Powerflow
  - performance of the programming system:
    - IEC-61131 programming in IL, ST, SFC, CFC, LD, FBD
    - Source Download, Online Change, Debugging, Offline Simulation
    - libraries
    - Debug Monitor for drive (PLC browser)

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Pertinent Parameters

- **P-0-1350, PLC control word**
- **P-0-1351, PLC status word**
- **P-0-1367, PLC configuration**
- **P-0-1369, PLC internally reserved**
- **P-0-1370, PLC Global Register G0**
- **P-0-1371, PLC Global Register G1**
- **P-0-1372, PLC Global Register G2**
- **P-0-1373, PLC Global Register G3**
- **P-0-1374, PLC Global Register G4**
- **P-0-1375, PLC Global Register G5**
- **P-0-1376, PLC Global Register G6**
- **P-0-1377, PLC Global Register G7**
- **P-0-1378, PLC Global Register G8**
- **P-0-1379, PLC Global Register G9**
- **P-0-1380, PLC Global Register G10**
- **P-0-1381, PLC Global Register G11**
- **P-0-1382, PLC Global Register G12**
- **P-0-1383, PLC Global Register G13**
- **P-0-1384, PLC Global Register G14**
- **P-0-1385, PLC Global Register G15**
- **P-0-1386, PLC display format Global Register**
- **P-0-1389, PLC extra input images**

Further parameters are available for configuring the inputs/outputs (see documentation "Rexroth IndraMotion MLD-S").

Notes on Installation/System Configuration

Installation

For installing "IndraMotion MLD-S" on the PC, it is necessary to install the current version of the **"DriveTop" commissioning tool** on the PC. By doing this the **"SCP" communication platform** that is contained on the DriveTop CD-ROM is installed on the PC, too.

After successful installation the **"IndraLogic" PLC programming system** and "DriveTop" can simultaneously communicate with the drive via SCP.

System Configuration

The system configuration of the function "IndraMotion MLD-S" is carried out via a PC with the "IndraLogic" program installed that communicates with the drive with the "SCP" communication platform via the serial interface.

The projects are stored on the PC and at present only the binary code is loaded to the drive and stored in parameters. For future IndraDrive versions it will be possible to load complete projects with source code to the drive (only with MMC).

Overview of Available Libraries

> **Note:** This chapter only gives a short explanation of the basic functions or libraries. The functional details are described in the separate documentation "Rexroth IndraMotion MLD-S".

There are the following data channels to the drive available:

- **parameter functions**, **function blocks** and **cycl. parameters**
  → library **Base_MPH02.lib**

- **real-time channel** for consistent data exchange
  (a maximum of 4 parameters per direction)
  → library **DSP_MPH02.lib**

- **drive-specific motion blocks** according to PLC-Open
  → library **MXMotion.lib**

- **diagnosis**, **error handling** and **axis addressing** (for multi-axis operation possible in the future)
  → library **CommonTypes.lib**

- **global registers** for data exchange of variables via master communication

Additionally for drive-internal functions (not user-relevant):

- library **Internal_MPH02.lib**

Base_MPH02.lib The **Base_MPH02.lib** library contains important data types, basic firmware modules and cyclic parameters as direct variables (system-wide variables).

General functions:

- ATAN2
- MX_fGetFreeTicks
- MX_fGetHighResTime
- MX_fHighResTimerTicks_to_us

Blocks/functions for drive control:

- MX_Command
- MX_Power
- MX_Reset
- MX_SetControl
- MX_SetDeviceMode
- MX_SetOpMode
- Functions for diagnosis:
  - MX_fGetDriveWarning
  - MX_fSetDriveWarning
  - MX_fSetDriveError
- Blocks/functions for parameters:
  - MX_fReadParamDINT
  - MX_fReadStringParam
  - MX_fWriteParamDINT
  - MX_fWriteStringParam
  - MX_ReadParamDINT
  - MX_WriteParamDINT

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- Functions for scaling:
    - MX_fDINT_AccTo_REAL
    - MX_fDINT_DistTo_REAL
    - MX_fDINT_VelTo_REAL
    - MX_fREAL_AccTo_DINT
    - MX_fREAL_DistTo_DINT
    - MX_fREAL_VelTo_DINT

List of global variables "Direct access variable for idents":

- Direct variables (e.g.):
    - DV_P_0_0009 (*Error_number*)
    - DV_P_0_0038 (*Torquegenerating_current_command_value*)
    - DV_P_0_0039 (*Fluxgenerating_current_command_value*)
- IDN addressing (e.g.):
    - FP_P_0_0008 (*Activation_Estop_function*)
    - FP_P_0_0009 (*Error_number*)
    - FP_P_0_0019 (*Initial_position_value*)
- Axis addressing (e.g.):
    - Axis1: AXIS_REF

DSP_MPH02.lib   The **DSP-MPH02.lib** library contains globally defined real-time variables and a control block:

- list "RTCR_VariablenIdents"
- list "RTCW_VariablenIdents"
- MX_SynchronControl

MXMotion.lib   The **MXMotion.lib** library contains IEC blocks according to PLC-Open.

- MX_MoveAbsolute
- MX_MoveRelative
- MX_MoveAdditive
- MX_MoveVelocity
- MX_MoveVelocityOL (for open-loop)
- MX_Stop

8.11 Drive-Integrated Safety Technology

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

This optional extension of the drive functionality is described in detail in the separate documentation "Rexroth IndraDrive: Integrated Safety Technology" (DOK-INDRV*-SI*-**VRS**-FK01-EN-P; part no. R911297838).

Safety Related Starting Lockout

Note: Before activating this function, the drive has to be shut down using the command value and the drive enable. There is no drive-controlled shutdown!

Hardware Requirements The following configurable control sections can use the function "safety related starting lockout" if they have been equipped with the optional safety module **L1**:

- single-axis BASIC UNIVERSAL   (CSB01.1C)
- single-axis ADVANCED   (CSH01.1C)
- double-axis BASIC UNIVERSAL   (CDB01.1C)

Features

- "safety related standstill" as per stop category 0 according to EN 60204-1
- The power supply to the drive is safely interrupted using two channels. The selection is made via two channels using either an N/C-N/O or an N/C-N/C combination.
- The safe status is acknowledged by an N/C-N/O contact.
- For dynamization of the selection, the function must be activated at least every 168 hours. For this reason, the value since the last time that the starting lockout was deselected is displayed in parameter **P-0-0102, Oper. hours power section at last activat. of start. lockout**.
- The time intervals for activating the starting lockout are set using parameter **P-0-0103, Time interval of forced dynamization**.
- The history of the set time intervals is displayed in parameter **P-0-0104, Change history time interval of forced dynamization**.

Pertinent Parameters

- **P-0-0101, Configuration for starting lockout selector**
- **P-0-0102, Oper. hours power section at last activat. of start. lockout**
- **P-0-0103, Time interval of forced dynamization**
- **P-0-0104, Change history time interval of forced dynamization**

Pertinent Diagnostic Messages

- **A0011 Starting lockout active**
- **E3110 Time interval for forced dynamization exceeded**
- **F8027 Starting lockout while drive enabled**

Integrated Safety Functions

Hardware Requirements The following configurable control sections can use the integrated safety functions if they have been equipped with the optional safety module **S1**:

- single-axis ADVANCED   (CSH01.1C)
- double-axis BASIC UNIVERSAL   (CDB01.1C)

Features

- **Safety related stopping process:**
  - "Safety related standstill" corresponding to stop category 1 according to EN 60204-1 (with drive-controlled best possible deceleration and time monitoring)

  or, alternatively,

  - "Safety related operational stop" corresponding 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. Using 2 channels, the drive monitors the attainment of standstill within the preset tolerance time

  additionally

  - "Safety related drive interlock" → like "Safety related standstill", but switching to "Safety related motion" by actuating the enabling control device is not possible

  Safety switches S1/S2 are used to select "Safety related standstill"/"Safety related operational stop". Separate switches ASP1/ASP2 are used to select the starting lockout.

- **Safety related motion:**
  - Safety related reduced speed
    → 2-channel monitoring for exceeding a velocity threshold
  - Safety related direction of motion
    → 2-channel monitoring for allowed direction of motion
  - Safety related limited increment
    → 2-channel monitoring for allowed travel distance
  - Safety related limited absolute position
    → 2-channel monitoring for allowed absolute position. Safety related homing must be executed for the safety related absolute position!
  - Safety related acceleration/deceleration
    → 2-channel monitoring for maximum deceleration/acceleration

- **Safety related feedback:**
  - Safety related diagnosis outputs
    → to transfer the "Safety related status" to additional system components
  - Safety related safety door
    → A drive that functions as the diagnostic master can summarize the safety related status of several axes within a protective zone and control a safety door.

- **Safety related maximum velocity:**
  - safety related maximum velocity in normal operation
- **Safety related end position (in preparation):**
  - safety related end position in normal operation

Pertinent Parameters

- **P-0-3200, Safety technology firmware code**
- **P-0-3201, Change counter of safety technology memory**
- **P-0-3202, Operating hours at last change of memory**
- **P-0-3203, Memory image of safety technology memory**
- **P-0-3204, Synchronize and store safety technology IDN command**
- **P-0-3206, Safety technology password**
- **P-0-3207, Safety technology password level**
- **P-0-3208, Backup of safety techn. data channel 2**
- **P-0-3209, Safety technology commissioning identifier**
- **P-0-3210, Safety technology control word**
- **P-0-3211, Safety technology I/O control word, channel 2**
- **P-0-3212, Safety technology control word, channel 1**
- **P-0-3213, Safety technology status**
- **P-0-3214, Safety technology signal status word, channel 1**
- **P-0-3215, Selected safety technology mode**
- **P-0-3216, Active safety technology signals**
- **P-0-3217, I/O status channel 2 (optional safety technology module)**
- **P-0-3218, Manually unlocking the safety door**
- **P-0-3219, Diagnostic safety technology message**
- **P-0-3220, Tolerance time transition from normal operation**
- **P-0-3221, Max. tolerance time for different channel states**
- **P-0-3222, Max. activation time of enabling control**
- **P-0-3223, Time interval for dynamization of safety function selection**
- **P-0-3224, Duration of dynamization pulse of safety function selection**
- **P-0-3225, Tolerance time transition from safety rel. oper.**
- **P-0-3228, C4000 Homing procedure command channel 2**
- **P-0-3229, Tolerance window for safety related homing procedure**
- **P-0-3230, Monitoring window for safety related operational stop**
- **P-0-3231, Reference position for safety related reference**
- **P-0-3232, Standstill window for safety related direction of motion**
- **P-0-3233, Velocity threshold for safety related stopping process**
- **P-0-3234, Safety related maximum velocity**
- **P-0-3235, Safety related end position, positive**
- **P-0-3236, Safety related end position, negative**
- **P-0-3237, Safety technology absolute offset**
- **P-0-3238, Test direction safety related brake management**

- **P-0-3239, Nominal load torque safety related brake management**
- **P-0-3240, Control word for safety related motion 1**
- **P-0-3241, Safety related limited absolute position 1, positive**
- **P-0-3242, Safety related limited absolute position 1, negative**
- **P-0-3243, Safety related limited increment 1**
- **P-0-3244, Safety related reduced speed 1**
- **P-0-3245, Safety related deceleration/acceleration ramp 1**
- **P-0-3250, Control word for safety related motion 2**
- **P-0-3251, Safety related limited absolute position 2, positive**
- **P-0-3252, Safety related limited absolute position 2, negative**
- **P-0-3253, Safety related limited increment 2**
- **P-0-3254, Safety related reduced speed 2**
- **P-0-3255, Safety related deceleration/acceleration ramp 2**
- **P-0-3260, Control word for safety related motion 3**
- **P-0-3263, Safety related limited increment 3**
- **P-0-3264, Safety related reduced speed 3**
- **P-0-3265, Safety related deceleration/acceleration ramp 3**
- **P-0-3270, Control word for safety related motion 4**
- **P-0-3273, Safety related limited increment 4**
- **P-0-3274, Safety related reduced speed 4**
- **P-0-3275, Safety related deceleration/acceleration ramp 4**
- **P-0-3280, Actual position value, channel 2**
- **P-0-3281, Actual velocity value, channel 2**

Pertinent Diagnostic Messages

- **A0014 Drive interlock active**
- **A0015 Safety related standstill active**
- **A0016 Safety related operational stop active**
- **A0017 Special mode motion active**
- **C0255 Safety command for system init. incorrect**
- **C0256 Plausibility error of safety control words**
- **C0257 No encoder assigned to slot 1**
- **C3000 Synchronize and store safety technology IDN**
- **C3001 Synchronization and storage failed**
- **C3700 Manually unlocking the safety door**
- **C3701 Error when manually unlocking the safety door**
- **C4000 Homing procedure command channel 2**
- **C4001 Error during safety related homing procedure**
- **E3100 Error when checking input signals**
- **E3101 Error when checking acknowledgment signal**
- **E3102 Plausibility error of actual position values**
- **E3103 Dynamization failed**
- **E3104 Plausibility error of safety parameters**
- **E3105 Plausibility error of safety related operating mode**
- **E3106 System error channel 2**

- **E3107 Error when unlocking the safety door**
- **F3112 Reference missing when selecting safety related pos.**
- **F3117 Plausibility error of actual position values**
- **F3130 Error when checking input signals**
- **F3131 Error when checking acknowledgment signal**
- **F3132 Error when checking diagnostic output signal**
- **F3133 Error when checking interrupting circuit**
- **F3134 Dynamization time interval incorrect**
- **F3135 Dynamization pulse width incorrect**
- **F3140 Plausibility error of safety parameters**
- **F3141 Plausibility error of selection**
- **F3142 Activation time of enabling control exceeded**
- **F3143 Safety command for clearing errors incorrect**
- **F3145 Error when unlocking the safety door**
- **F3146 System error channel 2**
- **F3150 Safety command for system start incorrect**
- **F3151 Safety command for system halt incorrect**
- **F7010 Safety related limited increment exceeded**
- **F7011 Safety rel. position limit val., exc. in pos. dir.**
- **F7012 Safety rel. position limit val., exc. in neg. dir.**
- **F7013 Velocity threshold exceeded**
- **F7014 Acceleration threshold exceeded**
- **F7030 Pos. window for safety rel. operational stop exceeded**
- **F7031 Incorrect direction of motion**
- **F7040 Plausibility error parameterized - effective threshold**
- **F7041 Plausibility error actual position value**
- **F7042 Plausibility error safety related operating mode**
- **F7043 Error of output stage interlock**
- **F7050 Time for stopping process exceeded**
- **F8133 Error when checking interrupting circuit**
- **F8201 Safety command for basic initialization incorrect**
- **F8203 Safety technology configuration parameter invalid**

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Notes

9   Extended Drive Functions

9.1   Probe Function

> Expansion package **synchronization** (order designation **SNC**) in all designs

Brief Description

Features
- up to 2 probe inputs per axis, depending on hardware design of control section (CSH…, CSB…, CDB…)
- measuring signals can be actual position values of motor encoder, external encoder or measuring encoder, in addition master axis position values or cam shaft profile values
- measurement of absolute actual position values, of actual position value differences, detection of time intervals between measuring signals
- measurement triggered by positive and/ore 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") can be defined within which measurement can take place (activation of a "failure counter" when expectation window is passed through without measuring event)
- sampling time for probe signals approx. 0.05 µs
  (For sufficient noise immunity, signal edge change must last for at least 4.0 µs in order to be detected!)

Hardware Requirements

The probe signals can only be evaluated as measured value trigger by "rapid" digital inputs. The hardware design of the control section determines the number of available "rapid" digital inputs.

The following control section designs are available:

- **no** rapid digital input:
  CSB01.1N-FC-…   → BASIC OPENLOOP
  CSB01.1N-AN-…   → BASIC ANALOG
- **one** rapid digital input:
  CSB01.1N-SE-…   → BASIC SERCOS
  CSB01.1N-PB-…   → BASIC PROFIBUS
  CSB01.1C…   → BASIC UNIVERSAL (single-axis)
- **one** rapid digital input **per axis**:
  CDB01.1C-…   → BASIC UNIVERSAL (double-axis)
- **two** rapid digital inputs:
  CSH01.1C-...   → ADVANCED

The terminal designations of the "rapid" digital inputs are contained in the documentation "Project Planning Manual for Control Sections".

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, Measured value status**
- **S-0-0401, Probe 1**
- **S-0-0402, Probe 2**
- **S-0-0405, Probe 1 enable**
- **S-0-0406, Probe 2 enable**
- **S-0-0409, Probe 1 positive latched**
- **S-0-0410, Probe 1 negative latched**
- **S-0-0411, Probe 2 positive latched**
- **S-0-0412, Probe 2 negative latched**
- **S-0-0426, Signal select probe 1**
- **S-0-0427, Signal select probe 2**
- **S-0-0428, Probe, IDN list signal selection**
- **P-0-0202, Difference probe values 1**
- **P-0-0203, Difference probe values 2**
- **P-0-0204, Start position for active probe**
- **P-0-0205, End position for active probe**
- **P-0-0224, Probe, number of marker failures**
- **P-0-0226, Probe, extended control word**
- **P-0-0300, Digital I/Os, assignment list**
- **P-0-0301, Digital I/Os, bit numbers**
- **P-0-0302, Digital I/Os, direction**

Pertinent Diagnostic Messages

- **C0250 Probe inputs incorrectly configured**

Functional Description

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). With confirmation by the probe the signal status changes; the probe input signals a rising (positive) or falling (negative) switching edge.

$\boxed{\mathbf{i}}$ 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".

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**

Activating the Measured Value Detection

A switching edge at the probe input can trigger the detection of a measured value. Switching edges, however, only cause a measured value to be detected when the following requirements have been fulfilled:

- The presetting for measured value detection with positive and/or negative switching edge at the respective probe input was activated in **S-0-0169, Probe control parameter**.

- The measured value detection was started via **S-0-0170, Probing cycle procedure command**.

- The respective probe input for measured value detection was enabled (**S-0-0405, Probe 1 enable** or **S-0-0405, Probe 2 enable**).

"probing cycle procedure" command

probe enable

probe

probe negative latched

detecting the selected signal at this point of time in "probe value negative"; generating new probe value difference

probe positive latched

t (in ms)

detecting the selected signal at this point of time in "probe value positive"; generating new probe value difference

DK0001v1.fh7
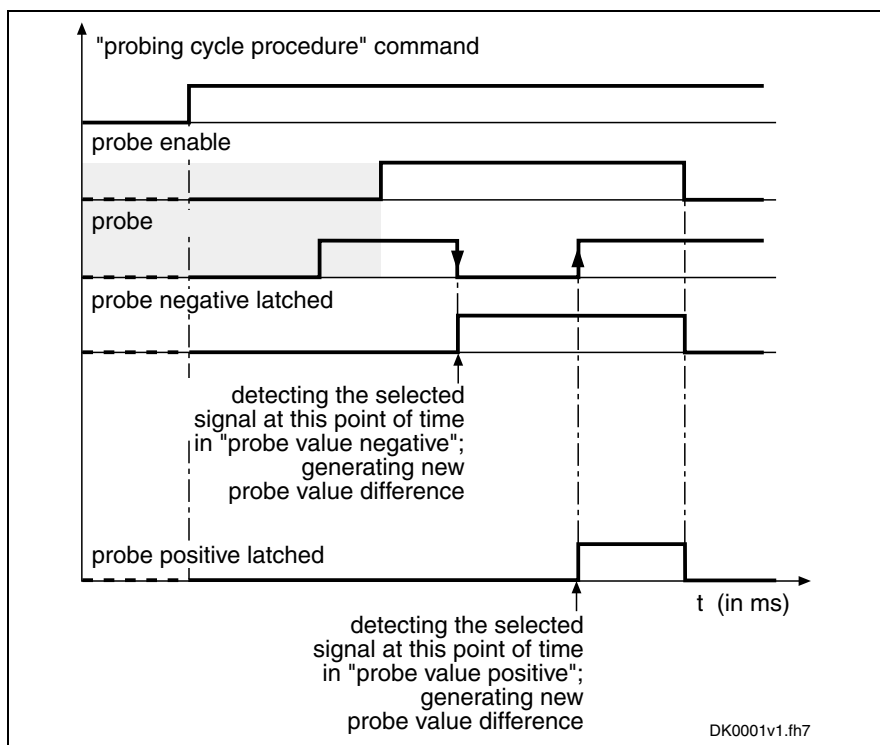
Fig. 9-1:   Evaluating the probe signal edges (with evaluation of positive and negative edges in S-0-0169 switched on)

Mode of Measured Value Detection

In parameter **S-0-0169, Probe control parameter** it is possible to set, separately for probe 1 and 2, in which mode the measurement is to take place. The measured value detection 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 detected at the first measured value trigger. Before every other measurement a 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 detected at each measured value trigger.

In addition, other modalities of measured value detection for <u>one</u> probe input 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.

Measuring Signal Selection

The selection of the signal the value of which is measured at the respective measured value trigger takes place by entering the respective IDN in the corresponding parameter

- **S-0-0426, Signal select probe 1**,
- **S-0-0427, Signal select probe 2**.

The IDNs of the parameters assigned to the selectable measuring signals are listed in **S-0-0428, Probe, IDN list signal selection**:

- **S-0-0051, Position feedback 1 value**
- **S-0-0053, Position feedback 2 value**
- **P-0-0052, Actual position value of measuring encoder**
- **P-0-0227, Cam shaft profile, access angle**
- **P-0-0753, Position actual value in actual value cycle**
- **P-0-0775, Resulting master axis position**
- **P-0-0776, Effective master axis position**

Should the time measurement for a probe input have been activated in **P-0-0226, Probe, extended control word**, the signal selection made for this probe is inactive.

Note: The time measurement is only relative! The generation of the measured value difference () therefore is especially advantageous for the time measurement. Depending on the available hardware and firmware and the performance setting in **P-0-0556, Control word of axis controller**, time differences can be measured with a precision of 4 µs:

- time differences up to 1000 s for basic performance
- time differences up to 500 s for advanced performance

Storing Measured Values and Measured Value Differences

Depending on the switching edge of the probe signal that was activated as measured value trigger (setting in S-0-0169), the measured value of the signal selected from the list parameter S-0-0428 is stored in one of the following parameters:

- **S-0-0130, Probe value 1 positive edge**
- **S-0-0131, Probe value 1 negative edge**
- **S-0-0132, Probe value 2 positive edge**
- **S-0-0133, Probe value 2 negative edge**

In the case of continuous measurement, 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**

| **Note:** | 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. |

| Precision | The controller generates the actual position values, depending on the available hardware and firmware as well as the performance setting in **P-0-0556, Control word of axis controller**, on a fixed time base: |

- 500 µs for basic performance
- 250 µs for advanced performance

The probe signal edge (trigger), however, is detected by the "rapid" digital input on a relatively short time base of 4.0 µs. The actual position value corresponding to the time of the signal edge is determined by linear interpolation between the last and the next actual position value generated by the controller.

| Restart or Deactivation of Measured Value Detection | 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 the probe enable: |

- **S-0-0405, Probe 1 enable**
- **S-0-0406, Probe 2 enable**

When doing this, the following data are cleared:

- the measured values (S-0-0130, S-0-0131 or S-0-0132, S-0-0133),
- the measured value differences (P-0-0202 or P-0-0203),
- the information of the measured value trigger status (S-0-0409/S-0-0410 or S-0-0411/S-0-0412) and
- the counter **P-0-0224, Probe, number of marker failures** (see below)

| Using the "Expectation Window" | The position range of an axis or shaft within which probe signal edges cause measured values to be detected can be limited. In the case of limitation, measured value trigger signals are only expected within position limits that can be set, this range is therefore called "expectation window". The measured value detection limited to the "expectation window" is activated in parameter **P-0-0226, Probe, extended control word**. |

Detecting marker failures with activated "expectation window":

- If the actual position value is outside of the "expectation window", probe signal edges do not cause measured values to be detected!

  If there hasn't any "marker" causing a measured value trigger been detected after completely passing through the "expectation window" (both position limits exceeded), this status can be stored and displayed in parameter **P-0-0224, Probe, number of marker failures**. To do this it is necessary to activate the "marker failure monitor" in parameter P-0-0226. In case of recurrence the value of P-0-0224 is incremented.

- By registering a measured value trigger within the "expectation window" the value in parameter **P-0-0224, Probe, number of marker failures** is cleared.

Note:	The "expectation window" cannot be used with "time measurement"!

Setting the Expectation Window

The limitation values for the "expectation window" are set in the following parameters:

- **P-0-0204, Start position for active probe**
- **P-0-0205, End position for active probe**

The "expectation window" has to cover a minimum range so that at least on actual position value generation can take place within the window after the probe signal edge has been detected:

$$s_{min} = (P-0-0205) - (P-0-0204) \geq v_{max} * \Delta t$$

s_{min}:   minimum value of "expectation window"
P-0-0204:   start position for active probe
P-0-0205:   end position for active probe
v_{max}:   maximum velocity of the axis with activated measured value detection (select time reference of v-unit as Δt–unit!)
Δt: $0.5*10^{-3}$s for basic performance (see P-0-0556)
              $0.25*10^{-3}$s for advanced performance (see P-0-0556)
Fig. 9-2:   Determining the minimum value for the "expectation window"

In the case of modulo scaling of the position data, a maximum value for the "expectation window" mustn't be exceeded as otherwise it exceeds the modulo value range and therefore is without effect:

$$s_{max} = (S-0-0103) - s_{min}$$

s_{max}:   maximum value of "expectation window"
s_{min}:   minimum value of "expectation window"
S-0-0103:   modulo value
Fig. 9-3:   Determining the maximum value for the "expectation window"

Notes on Commissioning

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 **P-0-0226, Probe, extended control word**:

- activation of expectation window and failure monitor
- activation of time measurement
- probe selection

Select measuring signals from **S-0-0428, Probe, IDN list signal selection**; enter the selected parameters in:

- **S-0-0426, Signal select probe 1**
- **S-0-0427, Signal select probe 2**

Activating the Measurement	Activate the measured value detection via **S-0-0170, Probing cycle procedure command**, then enable the respective probe input for measured value detection via

- **S-0-0405, Probe 1 enable** or
- **S-0-0406, Probe 2 enable**.

Single Measurement	Every repeated "single measurement" has to be enabled by resetting and repeatedly setting S-0-0405 or S-0-0406.
Continuous Measurement	If enabling of the probes via S-0-0405 or S-0-0406 has been set with "continuous measurement", a measured value is stored at every measured value trigger. How many measured values were stored by positive or negative trigger of the respective probe, is contained in the status information on the measured value trigger (see below "identifying the measured value detection").
Identifying the Measured Value Detection	When a measuring event took place, the measured value trigger status is updated, i.e. the value of the respective parameter is incremented, starting with the value "0":

- **S-0-0409, Probe 1 positive latched**
- **S-0-0410, Probe 1 negative latched**
- **S-0-0411, Probe 2 positive latched**
- **S-0-0412, Probe 2 negative latched**

The corresponding measured value is stored in:

- **S-0-0130, Probe value 1 positive edge**
- **S-0-0131, Probe value 1 negative edge**
- **S-0-0132, Probe value 2 positive edge**
- **S-0-0133, Probe value 2 negative edge**

In addition, after detection 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-0-0202, Difference probe values 1** (|S-0-0130 - S-0-0131|)
- **P-0-0203, Difference probe values 2** (|S-0-0130 - S-0-0131|)

Note: The differences from the measured values of the positive and negative edges are always generated, even if only one edge polarity has been activated for the measured value trigger! The differences are then generated compared to the value "0".

Setting the "Expectation Window"	Set the limits of the "expectation window" taking the minimum value and, if necessary, the maximum value (for modulo scaling) into account:

- **P-0-0204, Start position for active probe**
- **P-0-0205, End position for active probe**

If the option "marker failure monitor" has been activated, the number of times the "expectation window" is passed through without probe event is displayed in:

- **P-0-0224, Probe, number of marker failures**

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**

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9.2 Measuring Encoder

Expansion package **synchronization** (order code **SNC**) in all characteristics

Brief Description

Position Measurement

Measuring encoders are used for position evaluation of a rotary motion that takes effect as a command variable for drive control. The actual position value of the measuring encoder therefore is of command value nature for drive control, the measuring encoder acts as a master axis encoder, for example.

Evaluating Position Measurement

Depending on its design and the mechanical arrangement at the axis, the measuring encoder can be evaluated as

- relative encoder (incremental encoder)

- or -

- absolute encoder (absolute value encoder)

Relative Position Measurement

In the case of relative position measurement, only position differences can be evaluated by means of the measuring system. The actual position values signaled by the measuring system refer to the (mostly undefined) position at the time the drive is switched on. If the actual position value is to refer to an axis or shaft, it is necessary to establish position data reference ("homing").

Absolute Position Measurement

In the case of absolute position measurement, the encoder signals actual position values with a fixed encoder-dependent reference point to the controller. After the drive is switched on the correct actual position value is immediately available for each axis or shaft position. Due to the mostly undefined mounting situation of the encoder, it is necessary during initial commissioning to once adjust the actual position value to the axis or shaft ("set absolute measuring").

Precision, Resolution

The precision of the position measurement depends on:

- the resolution of the measuring system (division periods = DP)

- the absolute encoder precision

- the digitalization quality of the analog encoder signals

- the size of the selected modulo range of the encoder

Monitoring Functions

The correct position information of the measuring encoder is required for correct detection of a command variable. The encoder signals are therefore monitored for plausibility 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 "Measuring Systems: Monitoring the Measuring Systems" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Hardware Requirements

For connecting the measuring systems to the controller the control section has to be equipped with the corresponding interfaces. Parameter **P-0-0079, Assignment measuring encoder ->optional slot** is used to determine the interface to which the respective encoder is connected.

For controllers with a double-axis control section (CDB01.1-...) it is only possible to assign a measuring encoder to one axis. The assignment is made in parameter **P-0-0076, Encoder type 3 (measuring encoder)**. If a measuring encoder was assigned to both axes, an error message will be displayed!

ℹ️   See also separate documentation "Project Planning Manual for Control Sections"

Pertinent Parameters

- **P-0-0052, Actual position value of measuring encoder**
- **P-0-0076, Encoder 3 (measuring encoder)**
- **P-0-0079, Assignment measuring encoder->optional slot**
- **P-0-0087, Actual position value offset of measuring encoder**
- **P-0-0097, Absolute encoder monitoring window for measuring encoder**
- **P-0-0127, Input revolutions of measuring gear**
- **P-0-0128, Output revolutions of measuring gear**
- **P-0-0179, Absolute encoder buffer 3 (measuring encoder)**
- **P-0-0326, Multiplication of measuring encoder**
- **P-0-0327, Encoder resolution of measuring encoder**
- **P-0-0328, Type of position encoder for measuring encoder**
- **P-0-0329, Smoothing of actual position value 3 of measuring encoder**
- **P-0-0330, Control word of measuring encoder**
- **P-0-0331, Status of measuring encoder**
- **P-0-0332, Actual velocity value of measuring encoder**
- **P-0-0334, Absolute encoder range of measuring encoder**
- **P-0-0347, Encoder 3, cosine signal**
- **P-0-0348, Encoder 3, sine signal**
- **P-0-0765, Modulo factor measuring encoder**
- **P-0-1020, Kind of encoder 3, encoder memory**
- **P-0-1021, Encoder 3 resolution, encoder memory**
- **P-0-1022, Absolute encoder offset 3, encoder memory**

Pertinent Diagnostic Messages

- **C0161 Incorr. parameterization of measuring enc. (hardware)**
- **C0162 Measuring encoder unknown**
- **C0163 Modulo value for measuring encoder cannot be displayed**
- **C0227 Error when initializing position of measuring encoder**
- **C0228 Initialization velocity measuring encoder too high**
- **E2076 Measuring encoder: encoder signals disturbed**
- **F2043 Measuring encoder: encoder signals incorrect**
- **F2076 Actual pos. value 3 outside absolute encoder window**
- **F2176 Loss of measuring encoder reference**
- **F2179 Modulo limitation error of measuring encoder**

Functional Description

Basics on Measuring Encoder, Resolution

The measuring encoder is mechanically connected to an axis or shaft and detects its position data. These position data can be used as measured values or command variable, but not as control variable.

Encoders to be Used

Only rotary encoders can be used as measuring encoders. The possible encoders are listed in parameter **P-0-0076, Encoder 3 (measuring encoder)**.

Scaling of Measuring Encoder Position Data

The scaling of the position data generated with a measuring encoder is rotary and axis- or shaft-related. Due to the infinite motion range of the measuring encoder and the limited value range of the position data, modulo scaling is set automatically.

See also "Mechanical Axis System and Measuring Systems: Scaling of Physical Data" in chapter "Motor, Mechanical Axis System, Measuring Systems"

The modulo range can only be selected as an integral multiple of an axis- of shaft-side revolution and has an upper limit:

$$modulo\ range = n * (axis\ or\ shaft\ revolutions)$$

$$n = P - 0 - 0765 \leq 2047 = 2^{11} - 1; n \in N$$

n: number of revolutions at axis or shaft
P-0-0765:   modulo factor measuring encoder

Fig. 9-4:   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:

- **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)!

measuring encoder (rotary only): $P\text{-}0\text{-}0327 * 2^{15}$

P-0-0327:   encoder resolution of measuring encoder

Fig. 9-5:   Maximum possible encoder resolution of measuring encoder per
              encode 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):

$$value\ range = n * 2^{20} (increments)$$

$$n = P - 0 - 0765 \leq 2047 = 2^{11} - 1; n \in N$$

n: number of revolutions at axis or shaft
P-0-0765:   modulo factor measuring encoder

Fig. 9-6:   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:

drive-internal measuring encoder resolution = P-0-0327 * P-0-0326

auxiliary calculation and drive-internal limitation:

$$P\text{-}0\text{-}0326 = 2^{30} * P\text{-}0\text{-}0128 / (P\text{-}0\text{-}0127 * P\text{-}0\text{-}0327 * P\text{-}0765) \leq 2^{n},$$
$$n \leq 15 \text{ (integral)}$$

P-0-0127:   input revolutions of measuring gear
P-0-0128:   output revolutions of measuring gear
P-0-0326:   multiplication of measuring encoder
P-0-0327:   encoder resolution of measuring encoder
P-0-0765:   modulo factor measuring encoder
n: number of revolutions at axis or shaft

Fig. 9-7:   Drive-internal measuring encoder resolution

Note: The multiplication of the measuring encoder (P-0-0326) is determined automatically and drive-internally!

Encoder Dimensioning   The multiplication value (P-0-0326) calculated according to the formulas "drive-internal measuring encoder resolution" characterizes the encoder dimensioning.
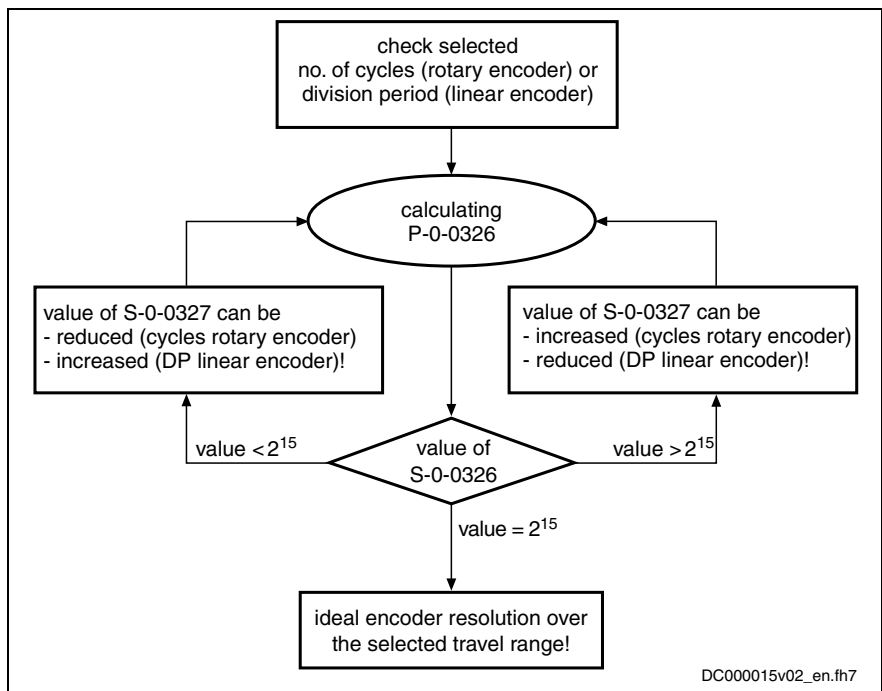
P-0-0326:   multiplication of measuring encoder
P-0-0327:   encoder resolution of measuring encoder

Fig. 9-8:   Checking the selected resolution and determining the ideal resolution for the measuring encoder

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Note:	The value of P-0-0326 calculated according to the formulas "drive-internal measuring encoder resolution" normally will never be exactly 2^{15} (= 32768). With results that are, depending on the encoder, as little as possible greater than 2^{15}, the conditions with regard to the selected number of cycles and the possibilities of encoder evaluation are ideal!

Real Resolution of Measuring Encoder

The lower value from "drive-internal resolution of master axis position data" and "maximum measuring encoder resolution after digitalization" is the real resolution of the position data.

Smoothing the Actual Measuring Encoder Position Value

The actual position values 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 P-0-0329).

Velocity of the Axis or Shaft to be Measured

The velocity of the axis or shaft to be measured is displayed in parameter **P-0-0332, Actual velocity value of measuring encoder**. The scaling of the velocity is axis or shaft revolutions per minute.

Monitoring Functions for Measuring Encoder

For the measuring encoder there are signal monitoring functions that are corresponding to the monitoring functions for motor encoder and optional encoder. The drive, however, outputs warnings or error messages specific to the measuring encoder.

See "Measuring Systems: Monitoring the Measuring Systems" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Signal Monitoring for Sine Encoders

For signal monitoring of sine encoders as measuring encoders the following diagnostic messages can be generated:

- **E2076 Measuring encoder: encoder signals disturbed**
- **F2043 Measuring encoder: encoder signals incorrect**

Monitoring the Axis or Shaft Position

When the drive is switched off, the current encoder data of an absolute measuring encoder are stored in

- **P-0-0179, Absolute encoder buffer 3 (measuring encoder)**.

When switching on a drive with an absolute measuring encoder, a check is run to determine in how far the current actual position value of the measuring encoder differs from the actual position value at the time the drive was switched off the last time. The maximum allowed difference is determined in

- **P-0-0097, Absolute encoder monitoring window for measuring encoder**.

If the difference exceeds the determined value, the following error message is output:

- **F2076 Actual pos. value 3 outside absolute encoder window**

This monitoring function can be deactivated!

Monitoring the Position Data Reference

The position data reference of a measuring encoder that can be evaluated in absolute form gets lost after the following measures have been taken:

- change of parameter values of mechanical connection
- change of encoder resolution
- change of modulo range
- replacement of measuring encoder

During the transition from communication phase "P2" to "P4" (bb), the drive recognizes that the former position data reference of the encoder does no longer exist. It sets P-0-0331, Status of measuring encoder to "not homed" and signals the loss of position data reference by the error message

- **F2176 Loss of measuring encoder reference**.

Establishing the Position Data Reference to the Axis or Shaft

Procedures for Establishing the Position Data Reference

Whether absolute evaluation is possible or not depends on the encoder type (P-0-0076, P-0-0327), the resolution of the measuring encoder and on the modulo range that was set (P-0-0765). This is displayed by a bit in parameter **P-0-0328, Type of position encoder for measuring encoder**.

Note:	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

Note:	After having successfully established the position data reference, the actual position value refers to the axis or shaft. The measuring encoder then is "in reference" or has been "homed".

⚠ **CAUTION**	**When the position data reference is established, the actual position value of the measuring encoder can change abruptly!** ⇒ If the actual position value is used as the command variable of the drive, the control master has to take this into account when establishing the position data reference!

Establishing Position Data Reference for Measuring Encoder to be Evaluated in Absolute Form

Activating "Set Absolute Measuring"

The position data reference of a measuring encoder to be evaluated in absolute form (see respective bits of P-0-0328) to an axis or shaft is established by **P-0-0012, C0300 Command Set absolute measuring**.

As it is possible to connect several encoders to be evaluated in absolute form to the controller, the absolute encoder to be homed is selected by a bit in **P-0-0612, Control word for setting absolute measuring**. The command "set absolute measuring" only takes effect for the selected encoder.

Reference Position

By starting the "set absolute measuring" command the previous, incremental actual position value of the measuring encoder at a reference position of the axis or shaft is set to a defined value. The reference position corresponds to the current axis position at the start of the command.

The new actual position value at the reference position after "set absolute measuring" is the value of parameter

- **P-0-0087, Actual position value offset of measuring encoder**.

$$P\text{-}0\text{-}0052_{new} = P\text{-}0\text{-}0087$$

P-0-0052:   actual position value of measuring encoder
P-0-0087:   actual position value offset of measuring encoder

Fig. 9-9:   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)**).

Note:	Storing the absolute encoder offset in the encoder data memory and in the parameter memory allows recognizing whether the absolute encoder that had been homed was replaced!

Parameter Buffer 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, Parameter buffer mode** it is possible to select whether parameter values are to be stored permanently or temporarily.

Note:	When the absolute encoder offset is stored temporarily, the measuring encoder loses the position data reference to the axis when the controller is switched off or when the parameter mode ("P2") is activated.

Sequence of "Set Absolute Measuring"

For the measuring encoder the command "set absolute measuring" can only be activated when the drive is ready for operation but inactive ("bb", "AB").

When the "set absolute measuring" command is started, the reference of the selected encoder is cleared first (**P-0-0331, Status of measuring encoder**). After the reference was cleared the new actual position value (**P-0-0087, Actual position value offset of measuring encoder**) takes effect immediately and the reference bit is set again.

Establishing Position Data Reference for Relative Measuring Encoder

Activating the Homing Procedure

The position data reference of a relative measuring encoder to an axis or shaft is established by means of a reference mark signal of the encoder. To do this, it is first necessary to activate the reference mark evaluation for the measuring encoder in the respective bit of **P-0-0330, Control word of measuring encoder**.

If the reference mark evaluation is still active, it first has to be deactivated and then activated again.

Note:	In the case of rotary encoders, reference mark signals usually occur once per encoder revolution!

Reference Position

When the reference mark signal is read the next time, the previous, encoder-related actual position value at a reference position of the axis or shaft is set to a defined value. The reference position corresponds to the current axis position at the occurrence of the reference mark signal.

Note:	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 reference position after the homing procedure is the value of parameter

- **P-0-0087, Actual position value offset of measuring encoder**.

$$P\text{-}0\text{-}0052_{new} = P\text{-}0\text{-}0087$$

P-0-0052:   actual position value of measuring encoder
P-0-0087:   actual position value offset of measuring encoder

Fig. 9-10:   Actual position value of the measuring encoder after homing
              procedure

When the position reference of the measuring encoder was established, this is displayed in parameter **P-0-0331, Status of measuring encoder**. The reference mark evaluation for the measuring encoder should then be deactivated in the respective bit of parameter **P-0-0330, Control word of measuring encoder**!

Note:	When a measuring encoder gear is used, the occurrence of the reference mark of the encoder with reference to the actual position value of the axis or shaft to be measured mostly isn't unequivocal! On the control side it is necessary to make sure that the reference mark evaluation is activated at the appropriate axis or shaft position (identification via initiator or the like)!

Shifting the Position Data Reference

Operating Principle

Shifting the position data reference affects the current actual position value of the measuring encoder connected to the drive. Whether the current actual position value has position data reference to the axis or not is irrelevant for the shifting of the position data reference! The shifting is triggered on the master side by writing **P-0-0087, Actual position value offset of measuring encoder** and is immediately carried out on the drive side.

Note:	The reference status of the actual position values is not affected by the shifting of the position data reference.

When the drive is switched on the first time, the offset, set by the current value of P-0-0087, with regard to the original actual position value of the measuring encoder takes immediate effect.

If the position data reference is shifted several times in succession, each new value in P-0-0087 refers to the original actual position value of the measuring encoder, i.e. the shifted values do not act in an additive way!

Resetting the Offset   The offset of the position data reference is reset by entering the old value (before the value was shifted) in parameter P-0-0087.

Notes on Commissioning

Configuration and Setting

Configuring the Controller   The optional interfaces have to be assigned to the measuring encoder connection:

- **P-0-0079, Assignment measuring encoder->optional slot**

Configuring the Encoder   Setting the measuring encoder type:

- **P-0-0076, Encoder 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)

Check Possibility of Absolute Evaluation   Checking absolute encoder range of measuring encoder:

- **P-0-0334, Absolute encoder range of measuring encoder**

Note: The scaling of parameter P-0-0334 is incremental!

When the value range (modulo) is smaller than the absolute encoder range of the measuring encoder, it can be evaluated as absolute encoder. This is displayed in the respective bit of the parameter

- **P-0-0328, Type of position encoder for measuring encoder**.

By means of this parameter it is possible to deactivate the absolute evaluation of an encoder. The actual position values then are only relative, i.e. the encoder has to be homed again each time the machine is restarted or the drive changes to communication phase "P2"!

Setting the Axis or Shaft Position Monitor (Only with Absolute Encoder)   If position monitoring of the axis or shaft to be measured is required when the drive is switched on, enter the threshold value for the error message in parameter

- **P-0-0097, Absolute encoder monitoring window for measuring encoder**.

Note:	Incremental scaling! The threshold of the error message depends on application-specific aspects of operational safety. The monitor is deactivated by the value "0"!

If the change of actual position value between the switching off and switching on is greater than the threshold value that was set, the following error message is generated:

- **F2076 Actual pos. value 3 outside absolute encoder window**.

Information on Measuring Encoder and Position Evaluation

Current information on measuring encoder and position evaluation is stored in the following parameters:

- **P-0-0052, Actual position value of measuring encoder**
- **P-0-0331, Status of measuring encoder**
- **P-0-0326, Multiplication of measuring encoder**

Note:	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 **P-0-0612, Control word for setting absolute measuring**.

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**.

Execute "Set Absolute Measuring"

Start **P-0-0012, C0300 Command Set absolute measuring**. After its execution the command has to be cleared again.

See also "Basic Functions of Master Communication: Command Processing" in chapter "Master Communication"

Checking the Position Data Reference

The position status of the measuring encoder is displayed in:

- **P-0-0331, Status of measuring encoder**

Loss of Reference

If the position data reference of the measuring encoder evaluated in absolute form got lost, the following message appears:

- **F2176 Loss of measuring encoder reference**.

The position data reference has to be established again!

Establishing Position Data Reference for Relative Measuring Encoder

Activating Homing Procedure of Measuring Encoder

Activate reference mark detection in the respective bit of

- **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

- **P-0-0331, Status of measuring encoder**

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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:

- **P-0-0052, Actual position value of measuring encoder**

Other Diagnostic Messages Relevant to Measuring Encoder

- **C0161 Incorr. parameterization of measuring enc. (hardware)**
- **C0162 Measuring encoder unknown**
- **C0227 Error when initializing position of measuring encoder**
- **C0228 Initialization velocity measuring encoder too high**
- **E2076 Measuring encoder: encoder signals disturbed**
- **F2043 Measuring encoder: encoder signals incorrect**
- **F2179 Modulo limitation error of measuring encoder**

9.3   Encoder Emulation

> **Base package** of all variants in **closed-loop** characteristic

Brief Description

By means of encoder emulation is it possible to convert available encoder signals (encoder 1, encoder 2 or measuring encoder) or internal position command values into one of the following two formats:

- **5V-TTL signal of an incremental encoder** in the case of incremental encoder emulation
- **serial 24-bit position of an absolute encoder** (SSI format) in the case of absolute encoder emulation

This allows, for example, evaluating the signals in a higher-level master in order to close the position loop in the external control unit in conjunction with the freely parameterizable resolution and the data reference.

Note:	Using the encoder emulation **in precision applications** (mostly in machine tool applications) is considered as **critical** (see restrictions under "Notes on Commissioning") and always has to be **carefully considered** beforehand! For sophisticated applications Bosch Rexroth recommends to use digital interfaces, such as SERCOS interface.

See "Notes on Commissioning: Restrictions" in the same section

Incremental Encoder Emulation	Incremental encoder emulation is the simulation of a real incremental encoder by the drive controller.

In the form of **incremental encoder signals**, a higher-level numeric control (NC) receives information about the velocity of the motor connected to the controller. By integration of these signals the control unit receives the required position information and it is thereby possible to close a higher-level position control loop.

Note:	Emulation is scaling-dependent (cf. S-0-0076) and the resolution is input in lines (1 line corresponding to 4 increments!).

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.

Note:	Emulation is scaling-dependent (cf. S-0-0076) and the resolution is input is bits.

Hardware Requirements	The 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 **MEM**:

- single-axis **BASIC UNIVERSAL**   (CSB01.1C)
- single-axis **ADVANCED**   (CSH01.1C)
- double-axis **BASIC UNIVERSAL**   (CDB01.1C)

Note:	Encoder emulation is always related to the device, i.e. with a double-axis device (CDB01.1C) emulation can only be used for one of the two axes at a time.

Features

- cyclic calculation of the position or increments output by the emulator in the position loop clock
- freely selectable position signals for emulation (P-0-0900, P-0-0901)
- consistently parameterizable resolution for incremental and absolute encoder emulation in increments (revolution or increments/mm) → P-0-0903
- scaling-related emulation (SSI and incremental) → S-0-0076
- dead-time compensation to be activated for incremental encoder emulation (cf. P-0-0902, bit 3)
- zero pulse to be shifted for incremental encoder emulation (cf. P-0-0904)
- parameterizable cyclic zero pulse output for incremental encoder emulation referring to zero pulse distance (cf. P-0-0904) and position data reference (cf. P-0-0902)

Pertinent Parameters

- **P-0-0900, Encoder emulation signal selection list**
- **P-0-0901, Encoder emulation signal selection**
- **P-0-0902, Encoder emulation control parameter**
- **P-0-0903, Encoder emulation resolution**
- **P-0-0904, Encoder emulation zero pulse offset**
- **P-0-0905, Encoder emulation zero pulse distance**

Pertinent Diagnostic Messages

- **F2053 Incr. encoder emulator: pulse frequency too high**
- **F2054 Incr. encoder emulator: hardware fault**
- **C0260 Incremental enc. emulator resol. cannot be displayed**

Basic Information on the Function

Activating the Function

The kind of encoder emulation including its activation is determined via bit 0 and bit 1 in parameter **P-0-0902, Encoder emulation control parameter**.

P-0-0902, bit 1,0:

- "00" → no encoder emulation activated
- "01" → incremental encoder emulation (IGS) activated
- "10" → absolute encoder emulation (SSI) activated

Note: The settings in parameter P-0-0902 only take effect after progression to the operating mode!

See also Parameter Description "P-0-0902, Encoder emulation control parameter"

Selecting the Signal to be Emulated

Supported Emulation Signals The input of the signals that the drive supports for emulation is depending on the following factors:

- firmware version and enabled functional packages
- hardware of the control section and its configuration

Note: The emulation signals currently supported by the drive are contained in the list parameter **P-0-0900, Encoder emulation signal selection list**.

The following signals are available as a maximum:

- real encoder signals
  - position feedback 1 value (S-0-0051)
  - position feedback 2 value (S-0-0053)
    → requires 2nd encoder!
  - actual position value of measuring encoder (P-0-0052)
    → requires 2nd or 3rd encoder!

- internal digital position values
  - internal position command value (P-0-0434)
  - resulting master axis position (P-0-0775)
    → requires the functional package "synchronization"!
  - effective master axis position (P-0-0776)
    → requires the functional package "synchronization"!

Selecting the Emulation Signal
The emulation signal is determined by entering the desired IDN from the list parameter P-0-0900 in parameter **P-0-0901, Encoder emulation signal selection**.

Note: The resolution of the emulated signal is determined for both kinds of emulation (SSI and IGS) in parameter **P-0-0903, Encoder emulation resolution**.

Incremental Encoder Emulation

The incremental encoder emulation provides a square-wave signal in TTL level with variable frequency. The position difference of the selected signal in the last position loop cycle (Basic: TA = 500µs, Advanced: TA = 250µs) is calculated. The number of lines to be output and therefore the periodic time of the square-wave signal for the next output interval is calculated depending on the input in parameter **P-0-0903, Encoder emulation resolution**.

Incremental Encoder Signals in TTL Format

Tracks A and B
By outputting two signals offset by 90 degrees (track A and track B) the resolution is increased by the factor 4 when the two tracks are evaluated in differential form. One line 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, in case position data reference is existing (axis homed), also be emulated with reference to the machine zero point.

Note: If bit 7 was set in **P-0-0902, Encoder emulation control parameter**, it is only when the drive has been homed (cf. S-0-0403) that the zero pulse is output in the distance of the lines entered in **P-0-0905, Encoder emulation zero pulse distance**. The generated zero pulses are then referring to the actual machine zero point.

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The figure below illustrates the format and time flow of the incremental encoder signals:
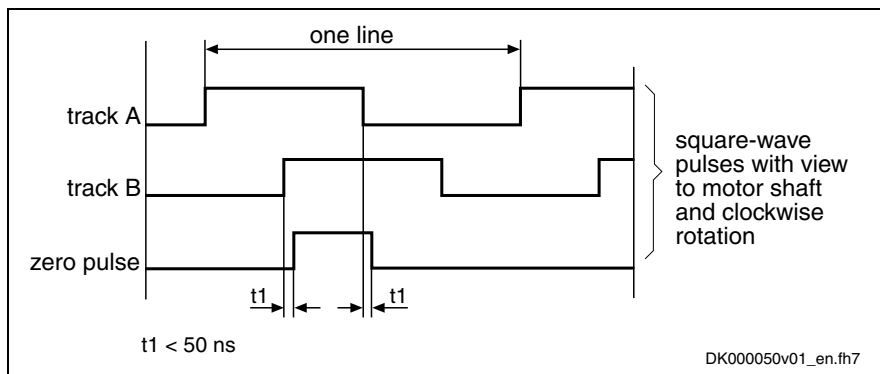
Fig. 9-11: Time flow of the incremental encoder signals

Resolution and Unit of the Emulated Signal

Resolution

The number of increments of the emulated incremental encoder can be determined in parameter **P-0-0903, Encoder emulation resolution** in lines/revolution (or mm or inch for linear motors).

Unit of the Emulated Position

The input range and the unit of the value in parameter P-0-0903 are depending on the following settings:

- type of construction of motor
    - rotary motors   → lines / revolution
    - linear motors   → mm or inch
- parameterized scaling
  (cf. **S-0-0076, Position data scaling type**)

Note: The emulated encoder therefore is parameterized according to the usual formats for rotary and linear square-wave encoders in lines/revolution or mm or inch.

Reference of the Emulated Position – Zero Pulse Output

The zero pulses are output immediately after the drive was run up to the operating mode in the distance of the lines entered in P-0-0905 resp. mm or inch.

Depending on the setting of bit 7 in **P-0-0902, Encoder emulation control parameter**, the zero pulses are output in different ways:

- **P-0-0902, bit 7 = 0**
  The zero pulses are output immediately after progressing to the operating mode (phase 4), independent of whether the drive has been homed or not. The output zero pulses only then have a fixed reference to the machine zero pulse, when the following conditions have been fulfilled:

    - When a relative encoder is used, this encoder has been homed (cf. S-0-0403) or an absolute encoder is used.
    - "Motor reference" was parameterized in parameter S-0-0076.
    - The encoder-side gear is "1".

- **P-0-0902, bit 7 = 1**
  The zero pulses are only output after progressing to the operating mode (phase 4), if the drive has been homed. The output zero pulses

then (if axis has been homed) always have a fixed reference to the machine zero point.
If the axis has not been homed, there aren't any zero pulses output!

Note:	As a prerequisite the drive is moved via the position control loop of the control unit (homing, going to zero) in order to correctly initialize the zero pulse output.

Zero Pulse Offset

With the parameter **P-0-0904, Encoder emulation zero pulse offset** the output of the zero pulse, with incremental encoder emulation having been selected, can be offset by the input value in lines (or mm or inch). The input range in P-0-0904 is determined by the setting in **P-0-0903, Encoder emulation resolution**, because the maximum offset is one revolution, for example for rotary motors.

Cyclical 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:

- If **one zero pulse per revolution** is required, you have to parameterize **P-0-0905 = P-0-0903**.

- A **non-recurring zero pulse** over the entire travel range (at the machine zero point) can be obtained with **P-0-0905 = "0"**.

- Outputting **several zero pulses per revolution** is possible with the parameterization **0 < P-0-0905 < P-0-0903**.

- Outputting **one zero pulse per n revolutions** is possible with the parameterization **P-0-0903 < P-0-0905**.

Note:	For cyclical output you have to take into consideration that a maximum of one zero pulse can be output per output cycle (i.e. position loop clock).

Establishing the Position Data Reference (Drive-Controlled Homing)

Drive-controlled homing is possible, too, if the connected control unit permits it.

Note:	If bit 7 = 1 was set in **P-0-0902, Encoder emulation control parameter**, the zero pulse is only output after the homing procedure was successfully carried out. The zero pulse then is always output at the same position (reference mark).

Note:	When the homing procedure is carried out, the emulated signals jumps from the original position to the reference position. In this case the error message F2053 is suppressed on purpose and the emulator outputs the increments of the previous interval again.

See also "Establishing Position Data Reference: Establishing Position Data Reference for Relative Measuring Systems" in chapter "Drive Functions"

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Absolute Encoder Emulation

The absolute encoder emulation provides a digital, coded, absolute position signal that can be serially read in the position loop clock (Basic: TA = 500µs, Advanced: TA = 250µs). The resolution of the absolute position and therefore the travel range that can be displayed in absolute form are depending on the input in parameter **P-0-0903, Encoder emulation resolution**.

Absolute Encoder Emulation 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 $\geq$ 20 µs
t_v	= delay time max. 650 ns
PFB	= power failure bit (not used and always logically LOW)

SV0202F1.FH7
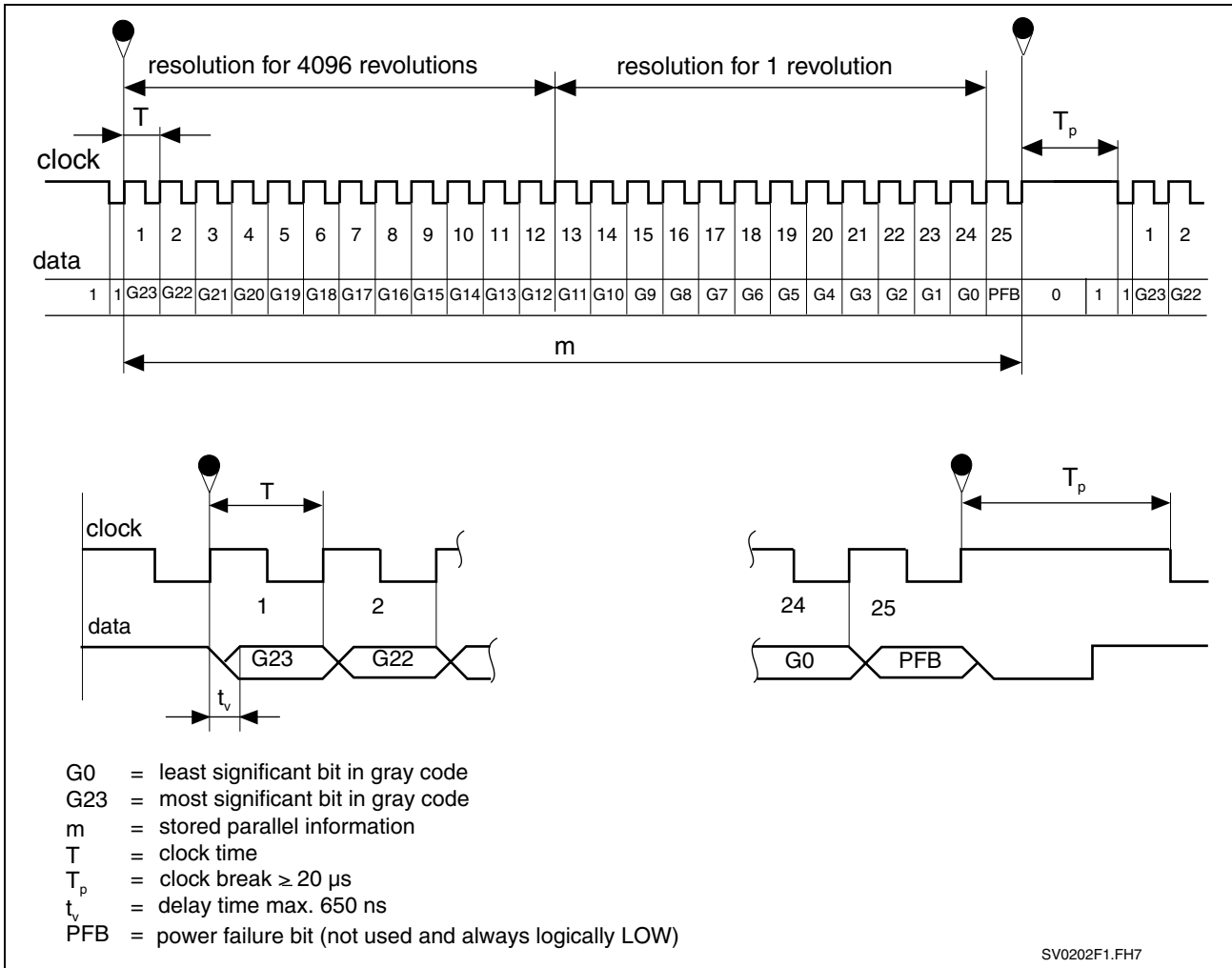
Fig. 9-12:   Pulse diagram SSI format

Note: IndraDrive controllers do not support the power failure bit!

Resolution and Unit of the Emulated Signal

Resolution

The output data format (i.e. the resolution) for the emulated SSI position is determined in parameter **P-0-0903, Encoder emulation resolution**.

Unit of the Emulated Position

The input range and the unit of the value in parameter P-0-0903 are depending on:

- type of construction of motor:
  - rotary motors → bits/revolution
  - linear motors → bits/mm or bits/inch
- parameterized scaling
  (cf. **S-0-0076, Position data scaling type**)

Note: 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 emulator and parameters **S-0-0051, Position feedback 1 value**, **S-0-0053, Position feedback 2 value** or **S-0-0047, Position command value** are synchronous. This simplifies, among other things, emulation control, e.g. with the commissioning tool "DriveTop".

Scaling-Dependent Emulation

If "motor reference" is parameterized in S-0-0076, encoder-related emulation is possible.

If "load reference" is parameterized in S-0-0076, the feed constant and gear ratio must be additionally entered according to the application.

Note: 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 "Mechanical Axis System and Measuring Systems: Scaling of Physical Data" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Establishing the Position Data Reference (Set Absolute Measuring)

Using parameter **P-0-0012, C0300 Command Set absolute measuring** it is possible to home the absolute position that is output by the absolute encoder emulator. When setting absolute measuring, the value of parameter **S-0-0052, Reference distance 1** is processed.

See also "Establishing Position Data Reference: Establishing Position Data Reference for Absolute Measuring Systems" in chapter "Drive Functions"

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Notes on Commissioning

In contrast to a "real" encoder, encoder emulation uses a simulated encoder. In motion the real encoder signal and the output of the emulator can differ. The causes for such differences can be:

- application errors
  (e.g. inadequate wiring, exceeded frequencies, voltage drops, incorrect programming, ...)

- systematic errors due to the technical conditions
  (e.g. beat effects, position jitter, ...)

The restrictions and limits described in the following sections have to be taken into account when encoder emulation is used.

Restrictions of Incremental Encoder Emulation

In contrast to the conventional incremental encoder for which the pulse output frequency can be infinitely changed in fine increments (i.e. the pulses are always assigned to fixed positions), emulated incremental encoder signals are subject to certain restrictions which primarily result from the digital mode of operation of the drive controller.

Maximum Output Frequency

The maximum pulse frequency is 1024 kHz. If this frequency is exceeded, pulses can be missing. The error message **F2053 Incr. encoder emulator: pulse frequency too high** is output. A position offset of the emulated position in contrast to the real position occurs.

$$I_{max} = \frac{f_{max} * 60}{n_{max}}$$

I_{max}:   maximum number of lines
n_{max}:   allowed maximum speed in 1/min

Fig. 9-13:   Calculating the maximum number of lines

Note: The max. output frequency of 1024 kHz always, i.e. independent of the selected number of lines, has to be taken into account for dimensioning the evaluation electronics.

Delay Between Real and Emulated Position Value

Between the position detection and output of the emulated pulses there is a delay (dead time) between real and emulated position value.

Solution:
When incremental encoder emulation has been activated (cf. P-0-0902, bit 1,0), it is possible to activate dead time compensation in **P-0-0902, Encoder emulation control parameter** with bit 3 = 1. The dead time compensation is only effective and useful if there aren't any repeated acceleration and deceleration processes (ideal v = constant).

Rounding Off the Number of Increments in Short Time Intervals

In a time interval of the internal control cycle TA it is only possible to output an integer number of increments (1 increment = ¼ line) at a time. The remainder that cannot be output is added in the next time interval. If there is another remainder of **0 < remainder < 1**, it is added again in the next interval etc.

This effect is the reason why the "**emulated velocity**" is exact on average, but can be by a maximum of **one increment too low** in each of the individual TA time intervals.

Solution:
Use the highest possible number of lines so that as many lines as possible can be output per control cycle TA. The percentage error then is reduced accordingly.

Oscillating Signal Frequency within one Output Cycle

Due to the internal signal processing, the periodic time and duty cycle of the output signals are varying. The periodic time (or frequency) of the resulting cycles can therefore be shorter or longer, too.

This is why the signals of incremental emulation should **not** be used for measuring the speed by means of **frequency measurement**, but the signals may only be evaluated by **counting the increments**.

Restrictions of Absolute Encoder Emulation

Using absolute encoder emulation, it is possible to display 4096 revolutions in absolute form.

Display Limits

When using this kind of emulation at the display limits, small fluctuations of the actual position lead to overflow and a position jump in the emulated position.

This is the case, for example, at position 0 and 4096 revolutions after position zero.
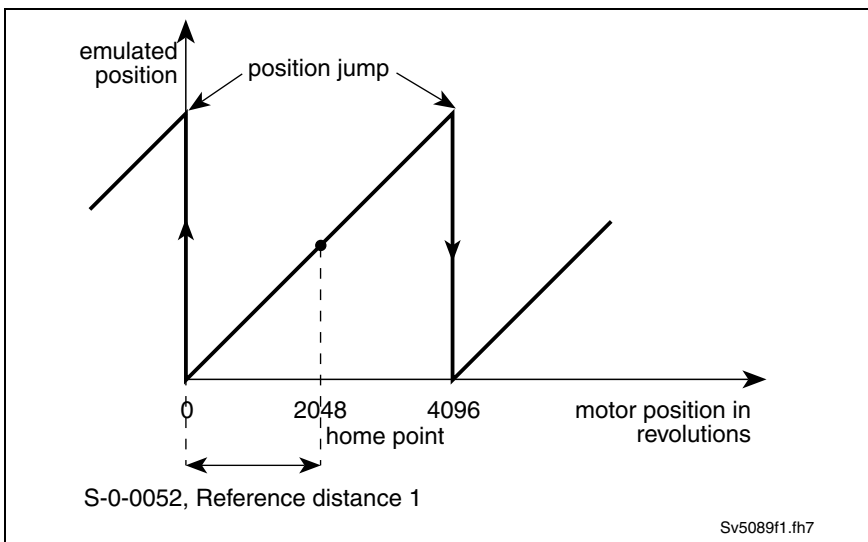
Fig. 9-14:   Display limits with absolute encoder emulation

This effect can be avoided by shifting the home point by executing **P-0-0012, C0300 Command Set absolute measuring**.

Note: By the respective setting in parameter **S-0-0052, Reference distance 1** shift the reference position to the middle of the display range. This allows moving 2048 revolutions to the left and to the right.

Beat Effects in the Emulated Position

In case the position processing in the control unit and the position detection (sampling) in the drive are not synchronized, beat effects can occur in the emulated signal with a periodic time according to the formula below, if the quartz frequencies on the drive and in the control unit cannot be exactly (integrally) divided:

$$T = \Delta t = \frac{1}{\Delta f}$$

Δf: frequency deviation of the quartzes in control unit and drives
T: periodic time for the occurring beat frequency

Fig. 9-15:   Determining the periodic time

Diagnostic and Status Messages

The following diagnostic messages can only occur with incremental encoder emulation:

- **F2053 Incr. encoder emulator: pulse frequency too high**

  The output frequency resulting from the resolution that has been set (P-0-0903) and the travel velocity exceeds the value of the maximum pulse frequency of 1024 kHz.

- **F2054 Incr. encoder emulator: hardware fault**

  At the end of each output interval (= position loop clock) a check is run to find out whether all increments to be output have been output before the next increment output is started. Exceeding the run time or hardware errors can cause overlapping that is detected during the check and signaled by this error message.

- **C0260 Incremental enc. emulator resol. cannot be displayed**

  In the case of incremental encoder emulation, inadmissible overflow can occur for increment output. In order to avoid this overflow, P-0-0903 has to be parameterized accordingly.

9.4   Analog Inputs

Brief Description

In their basic configuration (without optional modules), all IndraDrive controllers already have analog inputs. The number and function of the analog inputs differ according to the type and configuration of control section.

 See documentation "Project Planning Manual for Control Sections"
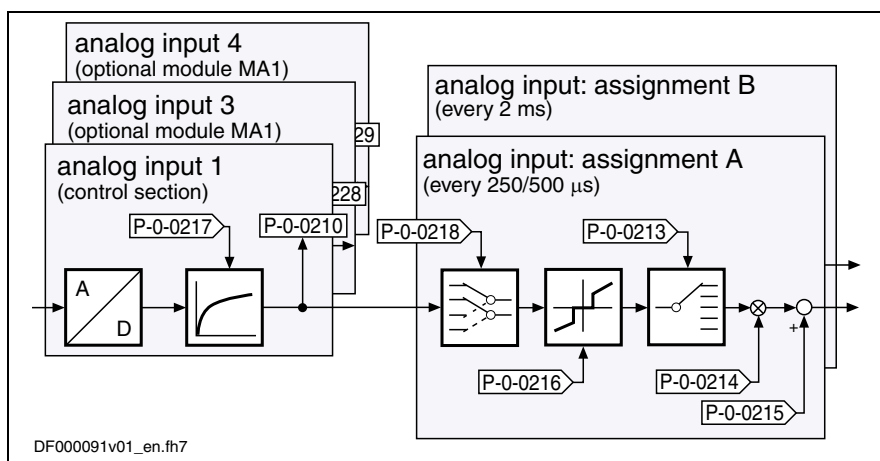
P-0-0210:   analog input 1
P-0-0213:   analog input, assignment A, target parameter
P-0-0214:   analog input, assignment A, scaling per 10V full scale
P-0-0215:   analog input, assignment A, signal value at 0V
P-0-0216:   analog input, assignment A, dead zone
P-0-0217:   analog input, time constant input filter
P-0-0218:   analog input, control parameter
Fig. 9-16:   Overview: analog inputs and their assignments

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 (advanced: T = 250µs, basic: T = 500µs)
  - assignment channel B works in 2-ms-clock
- assignment to command value/limit value/control parameters of the drive by means of adjustable scaling
- possible assignment of only max. 2 analog inputs to internal drive parameters
- variable scaling for 2 analog channels
- dead zone to be entered for suppressing the zero drift for both analog channels
- offset and amplification adjust for both analog channels via command

Analog Inputs on the Control Module

Properties of the analog inputs (or input) on the control module:
- number of analog inputs depending on hardware or control section:
  - **advanced**:   1 analog input with 12 bits
  - **basic**:   basic 4 has 2 analog inputs with 12 bits (other basic types don't have analog inputs)
  - **double-axis**:   1 analog input with 12 bits shared by both axes. The input can, however, be used by both axes at the same time!
- 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

Analog Inputs 3 and 4 on Optional Module MA1

The optional module MA1 was developed according to VDE 0411-part 500 (programmable logic controllers) and should be used according to the specifications contained in this standard.

Properties of the analog inputs on the optional module MA1:
- 2 analog inputs with 12 bits
- 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
- connection via 15-pin D-Sub connector

Pertinent Parameters

- **P-0-0210, Analog input 1**
- **P-0-0212, Analog input, list of assignable parameters**
- **P-0-0217, Analog input 1, time constant input filter**
- **P-0-0218, Analog input, control parameter**
- **P-0-0219, Analog input, maximum value for adjust**
- **P-0-0220, C2800 Analog input adjust command**

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- **P-0-0228, Analog input 3**
- **P-0-0229, Analog input 4**
- **P-0-0232, Analog input 3, time constant input filter**
- **P-0-0233, Analog input 4, time constant input filter**
- **P-0-3901, Adjust values of control section**
- **P-0-3904, Adjust values analog I/O interface**

Additionally for basic design:

- **P-0-0211, Analog input 2**
- **P-0-0231, Analog input 2, time constant input filter**

Assignment A
- **P-0-0213, Analog input, assignment A, target parameter**
- **P-0-0214, Analog input, assignment A, scaling per 10V full scale**
- **P-0-0215, Analog input, assignment A, signal value at 0V**
- **P-0-0216, Analog input, assignment A, dead zone**

Assignment B
- **P-0-0236, Analog input, assignment B, target parameter**
- **P-0-0237, Analog input, assignment B, scaling per 10V full scale**
- **P-0-0238, Analog input, assignment B, signal value at 0V**
- **P-0-0239, Analog input, assignment B, dead zone**

Pertinent Diagnostic Messages

- **C2800 Analog input adjust command**
- **C2802 Oscillations of input signal outside tolerance range**
- **C2803 Measured values at zero point and max. value identical**
- **C2804 Automatic adjust failed**

Functional Description
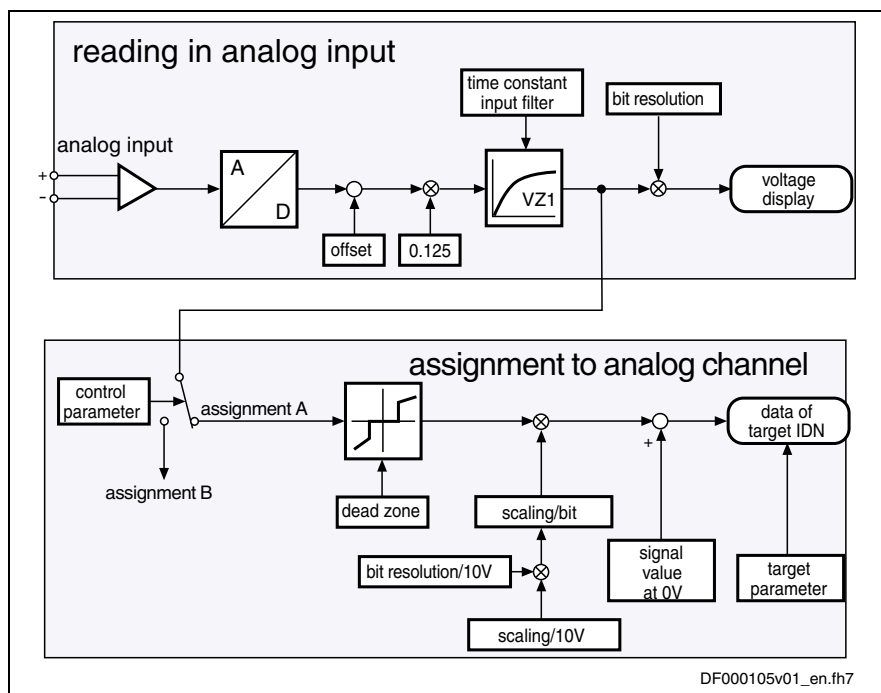
Fig. 9-17:   Overview of functions: reading and assigning an analog input

Sampling and Signal Processing of Analog Inputs

Sampling

The analog input signals (max. 4 analog inputs) are sampled with 8-fold oversampling in the position loop clock (advanced: T = 250µs; basic: T = 500µs).

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-0-0232, Analog input 3, time constant input filter**
- **P-0-0233, Analog input 4, time constant input filter**

Additionally for basic design:

- **P-0-0231, Analog input 2, time constant input filter**

When the filter has been activated its limit frequency (in Hz) results from the input time constant (in ms) by the following relationship:

$$f_g = 1000/(2 * \pi * T)$$

Voltage Display of Analog Inputs

The sampled and possibly smoothed voltage (12-bit resolution) of the analog inputs channels is displayed in the following parameters:

- **P-0-0210, Analog input 1**
- **P-0-0228, Analog input 3**
- **P-0-0229, Analog input 4**

Additionally for basic design:

- **P-0-0211, Analog input 2**

Note: These parameters can be, for example, transmitted to the higher-level master or directly processed in the drive-integrated PLC (IndraMotion MLD-S).

Factory-Provided Adjust

During the adjust of the control module or the optional module MA1 at the factory, the adjust values, among other things for offset and amplification of the analog inputs, are stored in the following parameters:

- **P-0-3901, Adjust values of control section**
- **P-0-3904, Adjust values analog I/O interface**

Internal Processing of Analog Input Values

Via two assignment mechanisms the analog input values can be assigned to internal drive parameters.

Assignment of Analog Inputs

The assignment of an analog input to an internal channel (assignment A or B) takes place via parameter **P-0-0218, Analog input, control parameter**.

- bits 4 to 7: → assignment of an analog input for assignment A
- bits 8 to 11: → assignment of an analog input for assignment B

See also "Notes on Commissioning" in the same section

See also Parameter Description "P-0-0218, Analog input, control parameter"

Note: It is therefore only possible to assign a maximum of 2 analog inputs to internal drive parameters (see assignment A and B). All other analog inputs can then only be used for direct access via the master communication or the drive-integrated PLC (e.g. reading the voltage levels).

The assignment channels to internal parameters available in the drive basically have the same functionality. That is why we will only describe assignment channel A. The description of assignment channel B corresponds to that of assignment channel A.
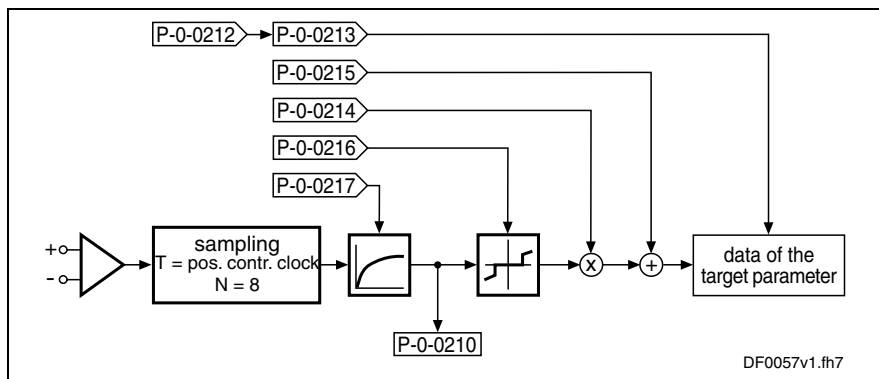
P-0-0210:   analog input 1
P-0-0212:   analog input, list of assignable parameters
P-0-0213:   analog input, assignment A, target parameter
P-0-0214:   analog input, assignment A, scaling per 10V full scale
P-0-0215:   analog input, assignment A, signal value at 0V
P-0-0216:   analog input, assignment A, dead zone
P-0-0217:   analog input, time constant input filter
Fig. 9-18:   Functional principle of analog input (example for assignment A)

Processing Clock for Analog Input Values

The processing of the analog input values in the two channels (assignment A and B) only differs in the cycle time:

- **assignment A**
  → the **position loop clock** (advanced: T = 250μs, basic: T = 500μs) is used

- **assignment B**
  → a clock of **T = 2 ms** is used

Controlling the Internal Processing

Settings in parameter **P-0-0218, Analog input, control parameter** control the internal processing functions (adjust and assignment):

- **bit 0**   → determining the adjust mode
  (for command "C2800 Analog input adjust command")

- **bit 1**   →determining the assignment channel for adjust
  (for command "C2800 Analog input adjust command")

- **bits 4...7**   → assigning the analog inputs for assignment channel A

- **bits 8...11** → assigning the analog inputs for assignment channel B

Automatic Scaling (or Zero Point Shifting)

Apart from manual adjust or scaling of the analog inputs (assignment A or B), it is also possible to adjust them automatically by activating the command "C2800 Analog input adjust command".

In the case of automatic scaling, the parameters P-0-0214 and P-0-0215 or P-0-0237 and P-0-0238 are written by the drive.

Note:	The analog channels are already adjusted at the factory and the correction values are stored in the parameters P-0-3901 and P-0-3904.

Zero Point Shifting   The zero point for processing the analog input value can be automatically shifted by activating command C2800 which allows compensating a possibly existing offset. To do this, the following parameters are relevant:

P-0-0218, Analog input, control parameter:

- bit 0:   defines the step of adjust
(bit 0 = 0 $\rightarrow$ zero point shifting)

- bit 1:   defines the assignment channel for the adjust (A or B)

The result of automatic zero point shifting is directly entered in

- **P-0-0215, Analog input, assignment A, signal value at 0V**

- or -

- **P-0-0238, Analog input, assignment B, signal value at 0V**.

It is also 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.

Note:	Unit, decimal places and data type of the value in P-0-0215 or P-0-0238 depend on the target parameter selected in **P-0-0213, Analog input, assignment A, target parameter**.

Scaling   For scaling the analog input value to the desired range of values it is possible to use the automatic amplification adjust. To do this, command C2800 is started. With scaling, however, there are different starting conditions (cf. P-0-0218 and P-0-0219) and the following parameters are relevant:

- **P-0-0218, Analog input, control parameter**:
  - bit 0:   defines the step of adjust
(bit 0 = 1 $\rightarrow$ amplification adjust)
  - bit 1:   defines the assignment channel for the adjust (A or B)
- **P-0-0219, Analog input, maximum value for adjust**
This parameter indicates the value to which the analog input is set when the amplification adjust (P-0-0218, bit 0 = 1) is carried out.

The result of automatic amplification adjust is directly entered in

- **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**.

It is also 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 ($\rightarrow$ pitch), in P-0-0214 or P-0-0237.

Note:	Unit, decimal places and data type of the value in P-0-0215 or P-0-0238 depend on the target parameter selected in **P-0-0213, Analog input, assignment A, target parameter**.

| "Dead Zone" to be Parameterized | To stabilize the analog signal in the zero range it is possible to parameterize a so-called "dead zone": |

- **P-0-0216, Analog input, assignment A, dead zone**
- **P-0-0239, Analog input, assignment B, dead zone**

| **Note:** | Parameterizing a "dead zone" is useful mainly for noisy analog values! |

Assignment to Internal Drive Parameters

| Assigning Analog Inputs to Parameters | The analog input values are stored in the following parameters for display and further internal processing: |

- **P-0-0210, Analog input 1**
- **P-0-0228, Analog input 3**
- **P-0-0229, Analog input 4**

Additionally for basic design:

- **P-0-0211, Analog input 2**

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-0-0211, P-0-0228, or P-0-0229) to other drive parameters and thereby process them cyclically (cf. **P-0-0212, Analog input, list of assignable parameters**).

| Parameters to be Assigned | Only such parameters can be assigned that are listed in **P-0-0212, Analog inputs, IDN list of assignable parameters**. |

| Configuring the Analog Input | The assignment of an analog input to a parameter is activated when a value unequal S-0-0000 (S-0-0000 corresponding to "off") was parameterized in P-0-0213 or P-0-0236. |

Notes on Commissioning

Carrying Out the Automatic Scaling (or Adjust)

Automatic adjust takes place in 2 steps that have to be carried out one after the other in order to achieve reliable execution of the function.

- **step 1**:   zero point shifting
  (or reference point shifting because reference is not obligatorily established to $U_e = 0V$)
- **step 2**:   amplification or amplitude scaling

There is only one command for both assignment channels. In **P-0-0218, Analog input, control parameter** (bit 1) you have to define which channel is adjusted:

- bit 1 = 0   → scaling assignment channel A
- bit 1 = 1   → scaling assignment channel B

Configuration and Assignment to Drive Parameters

| Assignment to Internal Channel (Assignment A or B) | The assignment of an analog input to an internal analog channel (assignment A or B) takes place via parameter **P-0-0218, Analog input, control parameter**: |

- bits 4 to 7   → selecting analog input for assignment A
- bits 8 to 11   → selecting analog input for assignment B

$\mathbf{i}$ See also Parameter Description "P-0-0218, Analog input, control parameter"

Assignment to Drive Parameters   By means of the assignment mechanism (assignment A or B) it is possible to assign the analog input values to drive parameters. Assignment takes place in the following parameters:

- **P-0-0213, Analog input, assignment A, target parameter**
- **P-0-0236, Analog input, assignment B, target parameter**

Possibilities of Access via Command Communication and IndraMotion MLD-S

The analog input values of the max. 4 analog inputs are stored in the following parameters for display and further internal processing:

- **P-0-0210, Analog input 1**
- **P-0-0228, Analog input 3**
- **P-0-0229, Analog input 4**

Additionally for basic design:

- **P-0-0211, Analog input 2**

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 (MPD02VRS)

Every analog input (1,3 or 4) can be parameterized without restrictions for both axes of a double axis.

Only the provided input voltage is used in common.

The respective evaluation and interpretation depends on how the individual axes have been parameterized (cf. assignment A and B).

Note: The parameters P-0-0210 to P-0-0239 are available separately for each axis. The parameters P-0-3901 and P-0-3904 are only available once per device!

Diagnostic Messages and Status Displays

As regards the "analog inputs" function, the following diagnostic command messages can occur:

- **C2800 Analog input adjust command**
- **C2802 Oscillations of input signal outside tolerance range**
- **C2803 Measured values at zero point and max. value identical**
- **C2804 Automatic adjust failed**

$\mathbf{i}$ See descriptions of diagnostic messages in the separate documentation "Troubleshooting Guide"

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9.5 Analog Outputs

Brief Description

In order to diagnose the drive behavior it is possible to map status variables and internal signals as analog voltage signals and pick them off at output terminal connectors of the drive controller.

When the drive is commissioned or for diagnostic purposes the required status variables or signals are visualized by means of appropriate measuring instruments, such as oscilloscope, multimeter or display elements on the control panel of machines.

In addition, the analog outputs enable the machine control unit to output drive-independent voltage signals. To do this it is possible for the control master to directly assign signals to the analog outputs of the controller via the master communication.

Pertinent Parameters

- **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-0-0418, Analog output, assignment A, signal value at 0V**
- **P-0-0419, Analog output, assignment B, signal value at 0V**
- **P-0-0420, Analog output, assignment A, signal selection**
- **P-0-0422, Analog output, assignment A, scaling [1/V]**
- **P-0-0423, Analog output, assignment B, signal selection**
- **P-0-0425, Analog output, assignment B, scaling [1/V]**
- **P-0-0426, Analog output IDN list of assignable parameters**
- **P-0-0427, Control parameter of analog output**

Hardware Data

The analog outputs 1 and 2 are available on the following control sections:

- CSH01.1C-.... (ADVANCED control section)
- CSB01.1N-FC-..... (BASIC OPENLOOP control section)
- CDB01.1C-.... (BASIC UNIVERSAL double-axis control section)

The analog outputs 3 and 4 are available on the following control sections:

- CSH01.1C-..-...-MA1-... (ADVANCED control section)
- CSH01.1C-..-...-...-MA1-... (ADVANCED control section)
- CSB01.1C-..-...-MA1-... (BASIC UNIVERSAL control section)
- CDB01.1C-..-...-MA1-... (BASIC UNIVERSAL double-axis contr. section)

i   The terminal designations and technical data of the analog outputs are contained in the separate documentation "IndraDrive, Drive Controllers – Control Sections, Project Planning Manual"!

Functional Description

Basic Features

Depending on the design of the control section (type designation), IndraDrive controllers can have the following analog output equipment:

- no analog outputs

- analog outputs 1 and 2

- analog outputs 3 and 4

- analog outputs 1, 2, 3, and 4

The output values available in the drive in digital form are converted according to the resolution in the preset output voltage range indicated in the technical data. The output clock can be set in parameter **P-0-0427, Control parameter of analog output**.

Due to the limited voltage range of the analog outputs the signals to be output

- can be scaled

- or -

- can be set in a limited or "overflowing" way

- or -

- are reference-defined.

Example of "Scaleable" Output

e.g. speed scaling = $50\,\text{min}^{-1}/\text{V}$ e.g. speed scaling = $100\,\text{min}^{-1}/\text{V}$

DK000051v01_en.FH7
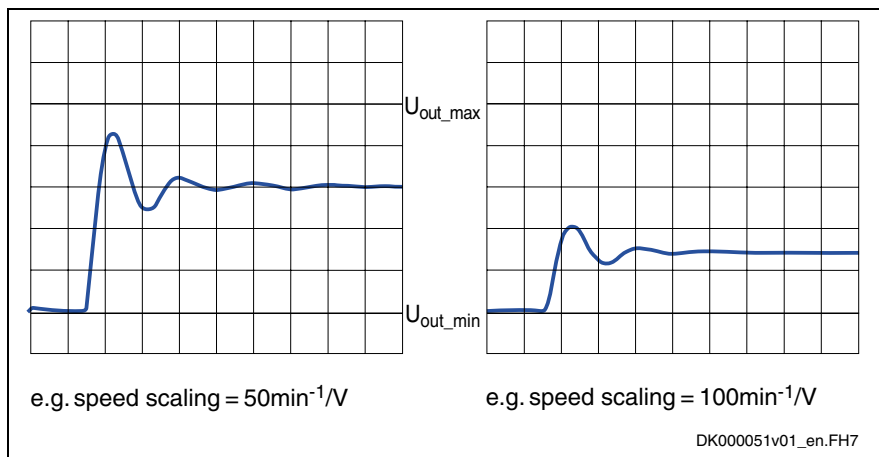
Fig. 9-19:   Example of scaleable analog output

Example of "Limited" or "Overflowing" Output Setting
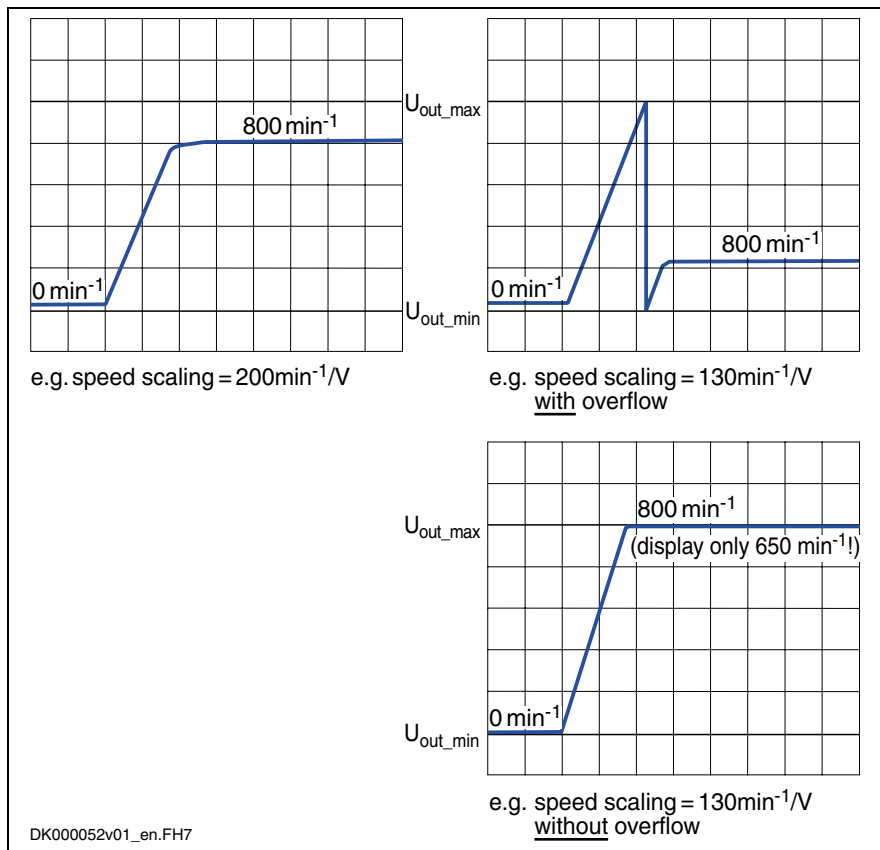
Fig. 9-20: Example of limited or "overflowing" analog output

Example of Output for "Reference-Defined" for Analog Output 1 and 2
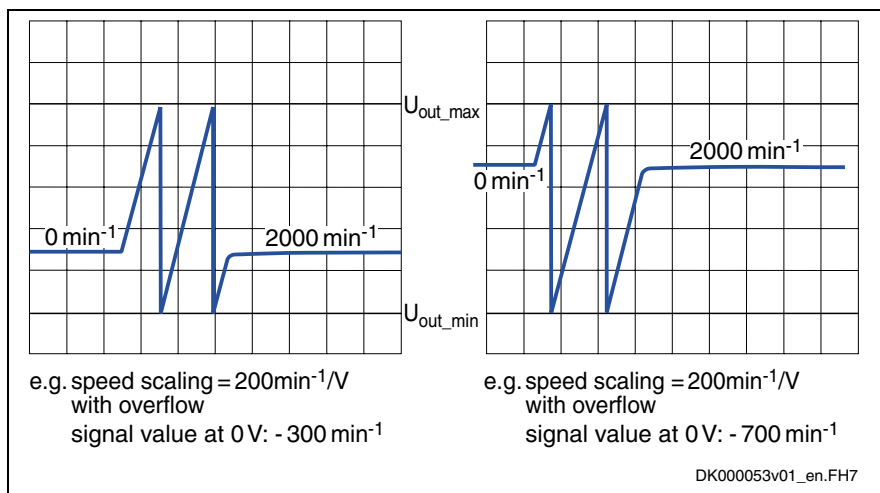
Fig. 9-21: Example of reference-defined analog output

Note: In the case of "overflowing" analog output, the assignment of a signal value to the output voltage is ambiguous due to the overflow!

The output of 0 V, for example, can be:

"signal value at 0 V" $\pm$ n *output voltage range* "scaling [1/V]" (n = 1; 2; 3 …)

Scaling

The analog outputs 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]**

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**

Note:	The parameters for "...assignment A..." act on the analog outputs 1 and 3.
	The parameters for "...assignment B..." act on the analog outputs 2 and 4.

Other Settings

Via the respective bits of **P-0-0427, Control parameter of analog output** definitions are made for the respective assignment (A or B) with regard to

- limitation/overflow and
- clock time of the output value updating.

In addition, a definition is made for each of the four possible analog outputs to determine whether it outputs voltage

- according to assignment A or B

- or -

- voltage signals independent of drive (transmitted by master communication).

Outputting Predefined Standard Parameters

All status variables and signals of the drive that can be output via analog outputs are listed in parameter **P-0-0426, Analog output IDN list of assignable parameters**.

The assignment is made by entering the IDN of the parameter in the respective signal selection parameter:

- **P-0-0420, Analog output, assignment A, signal selection**
- **P-0-0423, Analog output, assignment B, signal selection**

The output mode for the assigned parameters has to be set in **P-0-0427, Control parameter of analog output**.

Note:	The parameters for "...assignment A..." act on the analog outputs 1 and 3.
	The parameters for "...assignment B..." act on the analog outputs 2 and 4.

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Outputting Voltage Signals Independent of the Drive

The machine control unit can output voltage signals independent of the drive at the analog outputs of the drive. Signals from the master can be directly assigned to the analog outputs via the master communication system between drive and master.

The control master directly writes values to the following parameters that are within the limits of the value range of the respective analog output:

- **P-0-0139, Analog output 1**
- **P-0-0140, Analog output 2**
- **P-0-0414, Analog output 3**
- **P-0-0415, Analog output 4**

This output mode is the default setting for the analog outputs (basic parameter set). It can be changed or assigned again in **P-0-0427, Control parameter of analog output**.

Note: In the case of double-axis device (HMD01.1-..., control section CDB01.1-....) analog outputs are used by both axes. Specific parameters, assigned to the individual analog output pin, are identical for both axes!

See Parameter Description "P-0-0427, Control parameter of analog output"

Extended Output of Parameters with Binary Format

For the output of binary parameters, such as **S-0-0403, Position feedback value status**, the following parameters are irrelevant and write-protected:

- **P-0-0422, Analog output, assignment A, scaling [1/V]**
- **P-0-0425, Analog output, assignment B, scaling [1/V]**

Which bit of the respective parameter is to be output is determined 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 output voltage is 1 V when the respective bit has been set, otherwise 0 V are output.

Extended Output of Internal Storage Locations

For special diagnostic purposes in exceptional cases there are extended possibilities of setting for the analog outputs. To use these possibilities of setting it is necessary to know the structure of the drive firmware. The extended setting can therefore only be made by the development staff. If functions of the extended analog output are required it is necessary to contact our development department.

See also "Extended Diagnostic Possibilities: Patch Function" in chapter "Handling, Diagnostic and Service Functions"

Notes on Commissioning

Settings for Analog Output 1, For Example

Presettings for the analog output have to be made in **P-0-0427, Control parameter of analog output**:

- setting the mode (drive-independent voltage signals or assigned parameters)
- determining limitation or overflow with regard to the voltage value
- setting the output clock

With mode "assigning parameters" selected, make assignment in

- **P-0-0420, Analog output, assignment A, signal selection**.

Determine voltage range of signal to be output per 1 V in

- **P-0-0422, Analog output, assignment A, scaling [1/V]**.

Preset signal value at which voltage "0V" is output in

- **P-0-0418, Analog output, assignment A, signal value at 0V**.

The voltage to be output at the analog output is displayed in

- **P-0-0139, Analog output 1**.

Combining the Parameters for the Respective Analog Output

Analog Output 1

- **P-0-0139, Analog output 1**
- **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 2

- **P-0-0140, Analog output 2**
- **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 3

- **P-0-0414, Analog output 3**
- **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 4

- **P-0-0415, Analog output 4**
- **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]**

9.6   Digital Inputs/Outputs

Base package of all variants

Brief Description

In their basic configuration (without optional modules), all IndraDrive controllers already have configurable digital inputs/outputs. The number and function of the inputs/outputs differ according to the type and configuration of control section.

See documentation "Project Planning Manual for Control Sections"

Digital Inputs/Outputs on Control Section

Features
- fixed time base (T = 500 μs) for sampling the digital inputs/outputs and transmitting data to the digital inputs/outputs
- configurable digital inputs/outputs with effective direction that can partly be freely set (input or output):
  - **advanced** control sections (13 pins) with firmware **MPH02**:
    - 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** control sections (10 pins) with firmware **MPB02**:
    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)
  - **double-axis** control sections (24 pins) with firmware **MPD02**:
    - 4 digital inputs/outputs
    - 6 digital inputs
    - 2 inputs can alternatively be used as analog input (differential input)
    - 2 rapid inputs as probe inputs (in steps of μs)
    - 2 isolated relay switch contacts (can be configured)
- all inputs/outputs (except for the relay contact) designed for level of 0 V (LOW) or 24 V (HIGH)
- assignment of inputs/outputs to internal parameters or bits
- status of digital inputs/outputs mapped to separate parameter
- separate 24 V supply of the digital outputs
- inputs/outputs galvanically isolated

Note: Each individual input/output can be assigned to parameters of the drive; IDNs of the allowed parameters from IDN lists in S-0-0398 and S-0-0399.

Pertinent Parameters

- **S-0-0398, IDN list of configurable data in signal status word**
- **S-0-0399, IDN list of configurable data in the signal control word**
- **P-0-0300, Digital I/Os, assignment list**
- **P-0-0301, Digital I/Os, bit numbers**
- **P-0-0302, Digital I/Os, direction**
- **P-0-0303, Digital I/Os, status display**

Pertinent Diagnostic Messages

- **C0246 Trav. range lim. switch not ass. to dig. input**
- **C0247 Dig. output already assigned to another axis**
- **C0248 Dig. input assigned differently to axes**
- **C0249 Dig. I/Os: bit number too large**
- **F2010 Error when init. digital inputs/outputs**
- **F2033 External power supply X10 error**

Digital Inputs/Outputs on Optional Module MD1

It is possible to individually configure a digital I/O extension for the configurable advanced control sections.

The optional module MD1 can be used for the following purposes:

- making available digital I/Os for external control unit
- enabling input/output of drive parameters
- making available digital I/Os for drive-integrated PLC (IndraMotion MLD-S)
- extension of memory (32 kB non-volatile memory) for drive-integrated PLC

Note: Utilization of digital I/O extension by using the optional module MD1 is **only** possible **for advanced** control sections!

Features
- connection via 25-pin D-Sub connector
- all inputs/outputs (except for the relay contact) designed for level of 0 V (LOW) or 24 V (HIGH)
- separate 24 V supply of the digital outputs
- inputs/outputs galvanically isolated
- 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)

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Pertinent Parameters

- **S-0-0144, Signal status word**
- **S-0-0145, Signal control word**
- **S-0-0398, IDN list of configurable data in signal status word**
- **S-0-0399, IDN list of configurable data in the signal control word**
- **P-0-0081, Parallel output 1**
- **P-0-0082, Parallel input 1**
- **P-0-0681, Assignment IDN -> parallel output 1**
- **P-0-0682, Assignment parallel input 1 -> IDN**

Notes on Commissioning for Digital I/Os of Control Section

Overview

Configuration of I/Os   The IDNs of the target or source parameters for digital inputs/outputs are contained in parameter **P-0-0300, Digital I/Os, assignment list**. Further definitions for the indicated IDN are made via parameters P-0-0301 and P-0-0302, the assignment being carried out via the list line number (index).

Direct bit transfer
As a standard, the parameter of an IDN entered in P-0-0300 is considered to be the direct data source (when configured as output) or the target (when configured as input).

Cases to Distinguish for Determining Source or Target   The IDNs entered in the list parameter P-0-0300 can have two different functions:

1. Input
In the case of an input, the bit, configured in **P-0-0301, Digital I/Os, bit numbers**, of a parameter defined via P-0-0300 is written with the logic value (0 or 1) provided at the input.

2. Output
In the case of an output, the content of the bit configured in P-0-0301 is taken from the IDN determined in P-0-0300 and transmitted to the hardware output.

As an example, the following table shows some standard configurations frequently used:

Function	P-0-0300[i]	P-0-0301[i]	P-0-0302[i]	Notes
"ready for operation" relay	P-0-0115	0	1	Only possible when "**i = 0**"!
positive limit switch	P-0-0222	0	0	Only possible when "**i = 3**"!
negative limit switch	P-0-0222	1	0	Only possible when "**i = 4**"!
E-Stop	P-0-0223	0	0	Only possible when "**i = 8**"!

i = index: No. of list line/terminal slot

Fig. 9-22:   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**.

Note:	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

Note:	When determining the operating principle (direction) of the inputs/outputs the hardware requirements have to be taken into consideration. The "bb" relay pins, for example, can only be operated as output.
	See also section "X31/X32, Digital and Analog Inputs/Outputs" in documentation "Project Planning Manual for Control Sections"

As an example, the following figure illustrates the configuration of pin E4 on terminal connector X3 as an input signal for bit 1 of parameter S-0-0222 (negative limit switch); the configuration assignment takes place via i = 4.

Note: This example applies to advanced design; for basic and double-axis design the distribution of the digital I/Os is different.

P-0-0300: digital I/Os, assignment list
P-0-0301: digital I/Os, bit numbers
P-0-0302: digital I/Os, direction
P-0-0303: digital I/Os, status display

Fig. 9-23: Configuring the digital inputs/outputs (configuration for advanced control section with default settings)

Note: The status of the digital I/Os is contained in parameter **P-0-0303, Digital I/Os, status display**.

Deactivation

To deactivate an input/output the IDN "S-0-0000" has to be input in the respective list element of parameter **P-0-0300, Digital I/Os, assignment list**.

Validity Check of Configuration Lists

When a new assignment list is input or an element of the list is changed, all entries are checked for validity. If an entry is invalid (i.e. no allowed IDN entered) only this invalid entry is rejected.

Note: Incorrect entries are rejected when the list is checked and set to the respective default value ("bb" → output; all other pins → inputs).

Specific Features of Double-Axis Devices (Firmware MPD)

Basically, the existing inputs and outputs can be freely assigned to all axes. To do this the parameters P-0-0300, P-0-0301, P-0-0302 are available for both axes.

There are the following restrictions:

- A digital output can only be used by one axis. All other axes have to deactivate this output by the entry "S-0-0000" in parameter P-0-0300.

- The output contact of the relay "Rel1" is an exception. It can be used by both axes. The default assignment is the "ready for operation" message (see Parameter Description P-0-0300). For controlling the relay the information of both axes is ANDed.

- An input can only be used simultaneously by both axes, if it is used by both axes with the same IDN, bit number and directional assignment (for inputs/outputs).

- A digital input **cannot** be used simultaneously by both axes, if the assignment parameters of both axes differ in the respective line with regard to the IDN (P-0-0300), bit number (P-0-0301) or directional assignment (P-0-0302). The respective line of P-0-0300 of one of the two axes has to contain "S-0-0000" ($\rightarrow$ no assignment)!

Note: The above-mentioned restrictions are checked in the transition command from phase 3 to phase 4 (cf. C2000). In the case of conflict, the corresponding diagnostic message is generated.

Special Cases and Exceptions

Probe and Reference Cam Input

In some special cases there is no direct bit transfer, because the function assigned to the input/output is more complex. An example is the probe function. In this case, the entry in P-0-0301 is irrelevant, it is only a valid value that has to be contained (e.g. "0").

All special functions are listed in the following table:

Function	P-0-0300[i]	P-0-0301[i]	P-0-0302[i]	Notes
probe 1	S-0-0401	not relevant	not relevant	Only possible when "**i = 1**"!
probe 2	S-0-0402	not relevant	not relevant	Only possible when "**i = 2**"!
reference cam	S-0-0400	not relevant	not relevant	Only possible when "**i = 5**"!

i = index: No. of list line/terminal slot

Fig. 9-24:   : Special functions via digital I/Os

Fixed Assignment of Function-Relevant Inputs and Default Configuration

As a matter of principle, the inputs/outputs can be freely configured. Only for special functions has a fixed assignment of the inputs/outputs to corresponding parameters been defined. With the default configuration (= condition as supplied or status after "basic parameter load"), the following inputs/outputs are already predefined:

- probe inputs (MT1, MT2)
- travel range limit switches (Limit+, Limit-)
- reference switch cams (NS)
- E-Stop input (E-Stop)
- "ready for operation" output ("bb" contact)

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⚠

CAUTION

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If one of these functions (e.g. travel range limit switch via P-0-0090, bit 1) was activated but not assigned to any digital input via P-0-0300, the functionality (in the limit switch example) is not guaranteed.

⇒ **Therefore, carefully check the configuration and function of the digital inputs/outputs during commissioning!**

</td></tr>
</table>

The above functions are only possible in conjunction with specific inputs (pins BB1, BB2, E1, E2, E3, E4, E5, An+, An-), because hardware requirements (e.g. AD converter, rapid input, ...) must be fulfilled! Assigning the function to a different pin as the one mentioned in the default setting is impossible. If one of these functions is deactivated or not used, the respective pin, however, can be used for a different purpose (freely configurable).

Note:	All other pins do not have any default assignment. The combined inputs/outputs are preconfigured as inputs. All changes in 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 I/Os of Control Section via Master Communication

Access to Digital Outputs   In order to transmit data to the digital I/Os of the control section directly via the master communication, the following steps are required:

- By means of configuration, assign relevant bits of parameter **S-0-0145, Signal control word** to digital I/Os of control section:

P-0-0300, assignment list	P-0-0301, bit numbers	P-0-0302, direction
S-0-0145	defined by user	1
S-0-0145	defined by user	1
S-0-0145	defined by user	1
S-0-0145	defined by user	1

Fig. 9-25:   Configuration for direct access to digital outputs

Note:	Select the list index [i] according to the physical arrangement of the outputs.

- configuration of S-0-0145 in the cyclic data
- including parameter S-0-0145 in the group of cyclic command values (SERCOS: S-0-0024, field bus: P-0-4081)

Note:	Parameter S-0-0145 **mustn't** be configured via the list parameters **S-0-0026, Configuration list signal status word** or **S-0-0328, Assign list signal status word** so that it is available as a "data container" for master communication.

Reading In Status Signals Reading in peripheral status signals is possible via the digital inputs and parameter **P-0-0303, Digital I/Os, status display** (see also Parameter Description):

- configuration of P-0-0303 in the cyclic data

- including parameter P-0-0303 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 I/Os of the control section via the master communication (SERCOS in this case).
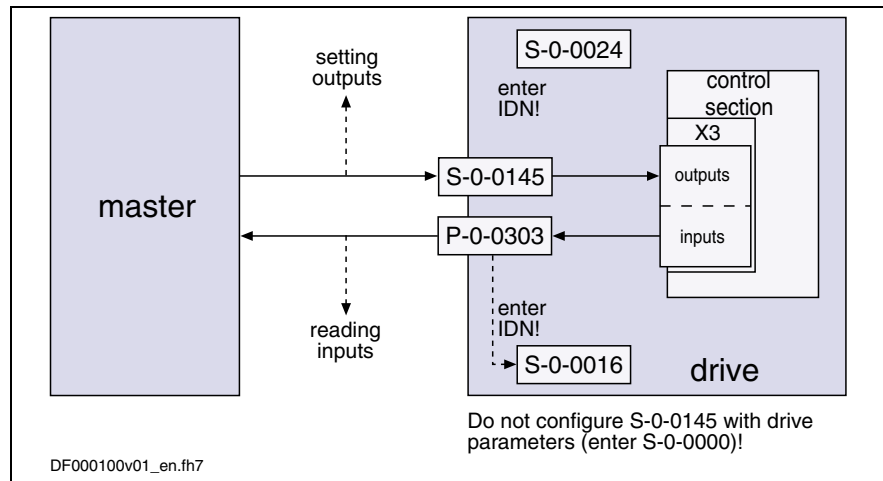
S-0-0016:   configuration list of AT
S-0-0024:   config. list of the master data telegram
S-0-0145:   signal control word
P-0-0303:   digital I/Os, status display

Fig. 9-26:   Access to digital I/Os of the control section via SERCOS master communication

Notes on Commissioning for Digital I/Os of Optional Module MD1

Overview

Mapping the I/Os To map the digital inputs and outputs of the optional module MD1 the following parameters are available

- **P-0-0081, Parallel output 1**
  $\rightarrow$ contains the bits that are output via the digital outputs of the MD1 module

- **P-0-0082, Parallel input 1**
  $\rightarrow$ contains the bits that are read in via the digital inputs of the MD1 module

Note: The parameters P-0-0081 and P-0-0082 are only available when the optional module MD1 has been plugged.

Configuration The two above parameters can be cyclically configured (MDT or AT data). This allows assigning the complete digital inputs or outputs to existing, cyclically configurable drive parameters (see S-0-0398, S-0-0399). The following parameters are used for assignment:

- **P-0-0681, Assignment IDN -> parallel output 1**

- **P-0-0682, Assignment parallel input 1 -> IDN**

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Possibilities of Access

There are the following possibilities for using the digital I/Os on the optional module MD1:

- direct access via master communication by the master (e.g. PLC)
- configuration of I/Os to any (see S-0-0398 and S-0-0399) drive parameter and bit
- direct access to I/Os via integrated PLC
- configuration of digital inputs for safety technology on MD1

Direct Access to Digital I/Os of Optional Module MD1 via Master Communication

In order to transmit data to the digital I/Os directly via the master communication, the following steps are required:

- configuration of:
  - [P-0-0681] = "S-0-0000"
  - [P-0-0682] = "S-0-0000"

  The parameters P-0-0081 and P-0-0082 can then be used as mere "data containers" for exchanging data between drive and master.

- configuration of P-0-0081 and P-0-0082 in the cyclic data
- including parameter P-0-0081 in the group of cyclic command values (SERCOS: S-0-0024, field bus: P-0-4081)
- including parameter P-0-0082 in the group of cyclic actual values (SERCOS: S-0-0016, field bus: P-0-4080)

The figure below illustrates the access to the digital I/Os of the optional module MD1 via the master communication (SERCOS in this case).
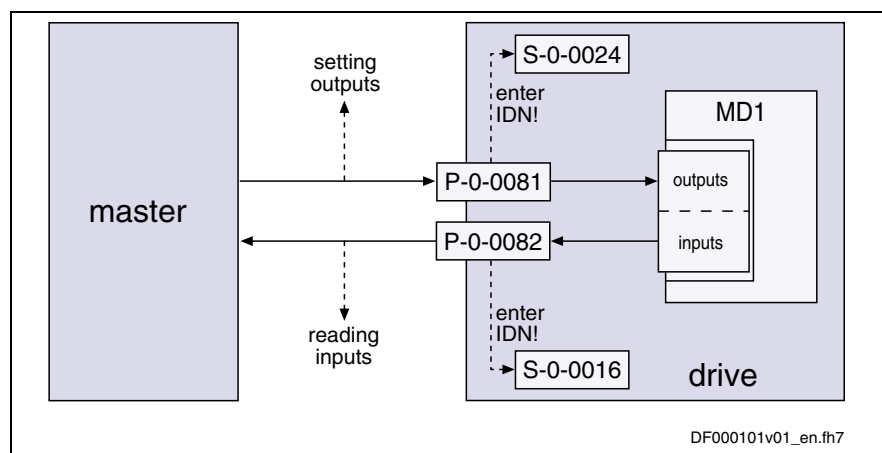
S-0-0016:	configuration list of AT
S-0-0024:	config. list of the master data telegram
P-0-0081:	parallel output 1
P-0-0082:	parallel input 1

Fig. 9-27:   Access to digital I/Os of the optional module MD1 via SERCOS master communication

Configuring the I/Os of the optional module MD1 to any Parameter and Bit

It is possible to assign the digital I/Os 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] $\rightarrow$ [S-0-0144] $\rightarrow$ P-0-0081

    - **P-0-0682 =** [S-0-0145] $\rightarrow$ [P-0-0082] $\rightarrow$ 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 an bits for the digital I/Os by means of the mechanism of the freely configurable signal control word and signal status word (see also Parameter Description for signal control word and signal status word)

- configure 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**)

- configure parameter S-0-0145 via S-0-0027 and S-0-0329
  (see also **S-0-0399, IDN list of configurable data in the signal control word**)

Note: If the parameters **S-0-0144, Signal status word** or **S-0-0145, Signal control word** are used for configuring the digital I/Os 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 I/Os of the optional module MD1.
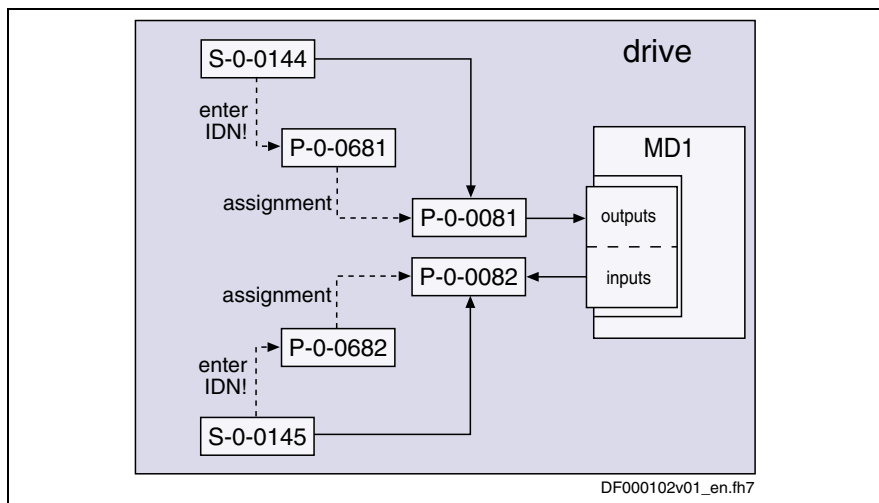
S-0-0144:   signal status word
S-0-0145:   signal control word
P-0-0081:   parallel output 1
P-0-0082:   parallel input 1
P-0-0681:   assignment IDN -> parallel output 1
P-0-0682:   assignment parallel input 1 -> IDN

Fig. 9-28:   Access to any drive parameter via digital I/Os of the optional module MD1

Direct Access to Digital I/Os of Optional Module MD1 via Drive-Integrated PLC

In order to transmit data directly from the drive-integrated PLC (IndraMotion MLD-S) to the digital I/Os, the respective assignments to the drive-integrated PLC have to be made via P-0-0681 and P-0-0682:

• **inputs**   (cf. P-0-1390 to P-0-1397)

• **outputs**   (cf. P-0-1410 to P-0-1417)

• **register**   (cf. P-0-1370 to P-0-1385)

Note: P-0-0081 and P-0-0082 are used as mere display parameters that are mapping the status of the digital I/Os of the optional module MD1.

Example of Application
(PLC uses inputs of MD1)

The digital inputs of the MD1 are to be used as PLC inputs. This requires the following configuration:

Assign **P-0-0082, Parallel input 1** to parameter **P-0-1390, PLC input %IW0** by making the following entry in **P-0-0682, Assignment parallel input 1 -> IDN**:

• [P-0-0682] = "P-0-1390"

Note: 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 I/Os for Integrated Safety Technology

In order to use the digital I/Os for the safety technology integrated in the drive, the corresponding assignments have to be made via the parameters P-0-0681 and P-0-0682:

- **inputs**   (e.g. P-0-3212, Safety technology signal control word, channel 1)

- **outputs**   (e.g. P-0-3214, Safety technology signal status word, channel 1)

Diagnostic Messages and Status Displays

Digital Inputs/Outputs on Control Section

Status of Digital Inputs/Outputs

The status of the digital inputs/outputs is displayed in parameter **P-0-0303, Digital I/Os, status display**.

The following applies to P-0-0303:

- bit set ("1")
  $\rightarrow$ At the assigned input/output a HIGH level (+24 V) is provided or the "bb" contact is closed.

- bit not set ("0")
  $\rightarrow$ At the assigned input/output a LOW level (0 V) is provided or the "bb" contact is opened.

Check for Inadmissible Bit Numbers

When entering data in parameter **P-0-0301, Digital I/Os, bit numbers**, a check is run to find out whether the indicated bit number is a valid bit of the parameter (IDN) configured in parameter P-0-0300.

The following applies:

- **2-byte** parameter $\rightarrow$ only bit numbers between **0 and 15** allowed

- **4-byte** parameter $\rightarrow$ only bit numbers between **0 and 31** allowed

---

Note: In the case of invalid inputs or inputs/outputs that haven't been configured yet, "-1" is displayed as bit number.

Checks in Transition Command

The following monitoring functions are used for guaranteeing an efficient configuration of the digital I/Os and preventing invalid configurations:

- If the limit switch function (Limit+/-) was activated in P-0-0090 (bit 1) but not assigned to any digital input via P-0-0300, the error message **C0246 Trav. range lim. switch not ass. to dig. input** will appear when progressing to the operating mode. This message is output to avoid moving the drive without configured limit switch function.

- For double axis devices the digital I/Os basically can be assigned to both axes. This is the reason why an input or output is sometimes configured for both axes. In this case the error message **C0247 Dig. output already assigned to another axis** will be displayed.

- **C0248 Dig. input assigned differently to axes**

- If the bit number entered in P-0-0301 is too large, the error message **C0249 Dig. I/Os: bit number too large** will be generated.

Digital Inputs/Outputs on Optional Module MD1

Status of Digital Inputs/Outputs   The status of the digital inputs/outputs on the MD1 is displayed in the following parameters:

- **P-0-0081, Parallel output 1**
  $\rightarrow$ contains the information regarding the digital output bits

- **P-0-0082, Parallel input 1**
  $\rightarrow$ contains the information regarding the digital input bits

The following applies to these parameters:

- bit set ("1")
  $\rightarrow$ At the assigned input/output a HIGH level (+24 V) is provided.

- bit not set ("0")
  $\rightarrow$ At the assigned input/output a LOW level (0 V) is provided.

Note: There is no additional configuration check as the restriction of the IDN selection lists already prevents invalid configurations.

Hardware Requirements

The assignment and number of digital inputs/outputs depends on the respective control section and is contained in the respective hardware description (Project Planning Manual).

🛈   See documentation "Project Planning Manual for Control Sections"

10   Handling, Diagnostic and Service Functions

10.1 Parameters, Basics

Properties, Features of Parameters

Brief Description

The controller firmware via data maps the drive to an internal mathematical model. All operating data relevant therefor are mapped to parameters. An identification number (IDN) is assigned to each parameter. The IDN allows accessing operating data via

- the serial interface

- or -

- a master communication interface suited for data transfer.

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

Functional Description

Parameter Structure   Each parameter consists of seven data block elements.

Element No.	Designation	Notes
1	identification number (IDN)	parameter identification / reading of data status
2	name	can be changed by means of language selection
3	attribute	contains decimal places, data length, data type and display format, function
4	unit	can be changed by means of scaling or language selection
5	minimum input value	minimum input value of operating data
6	maximum input value	maximum input value of operating data
7	operating data	parameter value

Fig. 10-1:   Data block elements of a parameter

Note: See also "Definitions" of attributes in the "Parameter Description" for IndraDrive controllers.

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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 also be written.

The operating data of a parameter can be permanently write-protected or always resp. temporarily be written. This write access depends on

- the communication phase
  - and -
- the activation of a password.

Note: When reading and writing the operating data, error messages can occur (see "Errors" in chapter "System Overview").

Data Status

Each parameter has a data status. It contains information on:

- validity/invalidity of the operating data (parameter value)
- status of commands (command acknowledgment) for parameters used for activating commands (see "Commands" in chapter "System Overview")

The controller checks the data status of the parameters for validity of the operating data when changing from parameter mode to operating mode.

Therefor, the operating data (parameter values) of the parameters listed in

- **S-0-0018, IDN list of operating data for communication phase 2**
- **S-0-0019, IDN list of operating data for communication phase 3**

are checked for validity.

The control master can query the IDNs of the parameters with invalid operating data (parameter values) via:

- **S-0-0021, IDN list of invalid operating data for communication phase 2**
- **S-0-0022, IDN list of invalid operating data for communication phase 3**

The data status is signaled when the control master carries out 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 also "Command Processing" in chapter "Master Communication"

Language Selection

In parameter **S-0-0265, Language selection** it is possible to set the language in which parameter names and text in units of parameter values will be displayed.

Notes on Commissioning

During the drive-internal check of parameter values carried out when changing from parameter mode to operating mode, the following command errors can be signaled:

- **C0101 Invalid parameters (see S-0-0021)**
- **C0102 Limit error in parameter (S-0-0021)**

- or -

- **C0201 Invalid parameters (->S-0-0022)**
- **C0202 Parameter limit error (->S-0-0022)**
- **C0203 Parameter calculation error (->S-0-0022)**

When errors of this category are detected, the IDNs of the parameters with the incorrect operating data are listed in:

- **S-0-0021, IDN list of invalid operating data for communication phase 2**

- **S-0-0022, IDN list of invalid operating data for communication phase 3**

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 DriveTop commissioning tool.

Setting the Language   The desired display language of parameter names and text in units of parameter values has to be set in

- **S-0-0265, Language selection**.

Loading, Storing and Saving Parameters

Brief Description

Parameters   All relevant operating data are mapped to parameters and stored in the controller.

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

- in the controller

- in the motor encoder (depending on motor type)

- as a MultiMediaCard (MMC), optional

In addition, the controller has a volatile data memory (working memory).

Condition As Supplied   Condition as supplied of the Rexroth drive components:

- The controller memory contains the drive firmware and the controller-specific parameter values.

- The motor encoder memory contains the encoder-specific and, depending on the motor type, the motor-specific parameter values.

- The MMC contains the drive firmware.

Storing the Application-Specific Parameter Values   The application-specific parameter values are stored in the controller. Due to the limited number of writing cycles of non-volatile storage media, application-specific parameter values can be stored in the working memory (volatile memory), too.

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

- after initial commissioning of the machine axis or the motor

- before replacing the controller for servicing (if possible)

Application-specific parameter values can be saved via:

- MMC → copying the parameter values by command

- "DriveTop" 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 original status (repeated loading of the values saved after initial commissioning)

- replacing the controller for servicing (loading the current parameter values saved before servicing)

Possibilities of loading parameter values to the controller:

- motor encoder data memory → loading the parameter values by command or via the control panel during initial motor commissioning

- MMC → loading the parameter values by command

- "DriveTop" commissioning tool → loading the parameter values from external data carrier

- control master → loading the parameter values from master-side data carrier

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

Pertinent Parameters
- **S-0-0017, IDN list of all operation data**
- **S-0-0192, IDN-list of backup operation data**
- **S-0-0262, C07_x Load defaults procedure command**
- **S-0-0263, C2300 Load working memory procedure command**
- **S-0-0264, C2200 Backup working memory procedure command**
- **S-0-0269, Parameter buffer mode**
- **S-0-0270, Selected IDN list of operation data to backup**
- **S-0-0293, C2400 Selectively backup working memory procedure command**
- **S-0-0326, Parameter checksum**
- **S-0-0327, IDN list of checksum parameter**
- **P-0-0013, IDN list of modified parameters**
- **P-0-4023, C0400 Communication phase 2 transition**
- **P-0-4065, Non-volatile memory active**
- **P-0-4090, Index for C07 Load defaults procedure**
- **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   Switching the communication phase:

- **C0400 Switching to parameter mode**
- **C0402 Only allowed without master**

Load defaults procedure (loading controller parameters):

- **C07_0 Load defaults procedure com. (load controller param.)**
- **C0702 Default parameters not available**
- **C0703 Default parameters invalid**
- **C0704 Parameters not copyable**
- **C0706 Error when reading the controller parameters**

Load defaults procedure (loading basic parameters):

- **C07_1 Load defaults procedure com. (load basic parameters)**
- **C0751 Parameter default value incorrect (-> S-0-0021)**
- **C0752 Locked with password**
- **C0753 'Load basic parameters' not allowed in phases 3 and 4**

Backup working memory procedure:

- **C2200 Backup working memory procedure command**
- **C2201 Parameter conversion error**
- **C2202 Error when writing data to non-volatile memory**

Loading working memory:

- **C2300 Load working memory procedure command**
- **C2301 Error when reading non-volatile memory**
- **C2302 Error when converting parameters**

Selectively backup working memory procedure:

- **C2400 Selectively backup working memory procedure command**
- **C2401 Parameter conversion error**
- **C2402 Error when saving parameters**

Copy parameters from MMC to flash:

- **C2500 Copy IDN from optional memory to internal memory**
- **C2501 MMC not plugged**
- **C2502 Error when accessing the MMC**
- **C2503 Error when reading the MMC**
- **C2504 Error when writing data to the flash**

Copy parameters from flash to MMC:

- **C2600 Copy IDN from internal memory to optional memory**
- **C2601 MMC not plugged**
- **C2602 Error when accessing the MMC**
- **C2603 Error when writing data to the MMC**
- **C2604 Error when reading the flash**

Other diagnostic messages:

- **F2100 Flash defective**
- **F2101 It was impossible to address MMC**
- **F2102 It was impossible to address I2C memory**
- **F2103 It was impossible to address EnDat memory**

Functional Description

Storage Media in the Drive Controller

All operating data referring to hardware are stored in the drive controller. They cannot be changed by the user.

Each circuit board is provided with a non-volatile memory. It carries the circuit board code and circuit board-specific operating data.

On the main circuit board there is a non-volatile memory (flash) and a volatile memory (working memory). The flash memory contains the circuit board-specific operating data. The drive firmware is stored in the flash memory, too. The values of the application-specific parameters can be stored either in the flash memory or in the working memory.

Storage Medium in Motor Encoder

In the case of the MHD, MKD, MKE, MAD and MAF motor series, the data memory of the motor encoder contains all motor- and motor encoder-specific parameter values. In addition, motor-specific control loop parameter values are stored in this data memory; the controller can easily be adjusted to the motor by means of these parameter values.

In the case of the 2AD and ADF motors, the data memory of the motor encoder only contains the encoder-specific parameter values. The motor-specific control loop parameter values for adjusting the controller to the motor are loaded to the controller from a data base of the "DriveTop" commissioning tool.

Storage Medium MultiMediaCard (MMC)

The MultiMediaCard (MMC) is a non-volatile storage medium that can be permanently or temporarily inserted in the slot provided for this purpose on the front of the drive controller. The MMC is not obligatory!

The MMC can be used as

- permanently plugged medium for saving the firmware and the application-specific parameter values

- or -

- temporarily plugged medium for updating the firmware

- or -

- temporarily plugged medium for transmitting application-specific parameter values.

Parameter and Operating Mode

Parameters the operating data of which can be changed, can be written with values in one or possibly several communication phases. We basically distinguish between

- parameter mode (communication phase "P2") and

- operating mode (communication phase "P4").

As a matter of principle, all parameters that can be changed can be written.

"Load Defaults Procedure" Command (Loading Basic Parameters)

Via the **S-0-0262, C07_x Load defaults procedure command** it is possible to set a defined original status of the parameter values in communication phase "P2". To do this, it is necessary to determine via **P-0-4090, Index for C07 Load defaults procedure** whether

- the basic parameter set (default values for all parameters) stored in the firmware

- or -

- the motor-specific default control loop parameter values stored in the motor encoder data memory (if available)

are to be loaded to the controller.

Parameter Buffer Mode

Depending on **S-0-0269, Parameter buffer 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.

Parameter IDN Lists

For saving the relevant application-specific parameter values the drive makes lists of IDNs available that support the complete storage of the values of parameter groups:

- **S-0-0192, IDN-list of backup operation data**
- **S-0-0270, Selected IDN list of operation data to backup**

Parameter S-0-0192 contains a list of IDNs that cannot be modified. Parameter S-0-0270 contains an empty list in which it is possible to enter certain IDNs according to application-specific requirements.

For saving all parameter values the drive makes available the list of the IDNs of all parameters in

- **S-0-0017, IDN-list of all operation data**.

To identify the parameters the value of which has changed compared to their default value, the drive makes available the parameter

- **P-0-0013, IDN list of modified parameters**.

Command "Backup Working Memory" or "Selectively Backup Working Memory"

If "volatile" was set in **S-0-0269, Parameter buffer mode**, the parameter values of the list of S-0-0192 can be saved in the non-volatile flash memory when **S-0-0264, C2200 Backup working memory procedure command** is started.

If the parameter values of the list of S-0-0270 are to be saved, the **S-0-0293, C2400 Selectively backup working memory procedure command** has to be activated. As long as the parameter buffer mode (S-0-0269) is not changed, the values once saved in the flash memory via the commands C2200 or C2400 remain unchanged.

"Load Working Memory Procedure" Command

By means of **S-0-0263, C2300 Load working memory procedure command** the values from the non-volatile flash memory are copied to the volatile working memory.

Note: This only makes sense when volatile parameter buffer 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 **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 parameter buffer mode, command C2200 must have been executed!).

- **"DriveTop" 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.

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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 **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.

- **"DriveTop" 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 to the controller from a master-side data carrier by command of the control master.

Parameter Checksum

When reading the **S-0-0326, Parameter checksum** parameter the checksum of all parameter values is generated the IDNs of which are contained in parameter **S-0-0327, IDN list of checksum parameter**. Changes in the parameter settings can be detected by comparing the checksums.

By comparing the checksum of the parameter values currently active in the drive to a checksum value stored at the time of parameter saving, it is possible to determine whether the active application-specific parameter values are correct.

By default there haven't any IDNs been entered in parameter S-0-0327!

Notes on Commissioning

Initial Commissioning

At the beginning of the initial commissioning of a motor or a machine axis, first make sure the desired firmware is active in the drive. To do this, read parameter

- **S-0-0030, Manufacturer version**.

If the desired firmware is not available in the controller, carry out a firmware update (see "Firmware Update" in chapter "Handling, Diagnostic and Service Functions").

Load Basic Parameters

If the desired firmware is available in the controller, load basic parameter values of the firmware:

1. set **P-0-4090, Index for C07 Load defaults procedure**
2. start **S-0-0262, C07_x Load defaults procedure command**

Respective diagnostic command message:

- **C07_1 Load defaults procedure com. (load basic parameters)**

Respective diagnostic messages in the case of possible command errors:

- C0751 Parameter default value incorrect (-> S-0-0021)
- C0752 Locked with password
- C0753 'Load basic parameters' not allowed in phases 3 and 4

See also "Initial Commissioning/Serial Commissioning" in chapter "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 means of

- pressing the "Esc" button at the control panel

- or -

- command **S-0-0099, C0500 Reset class 1 diagnostics**

the motor-specific control loop parameter values saved in the motor encoder are loaded for adjusting the controller to the motor.

If the original status of the motor-specific control loop parameter values is to be reestablished during commissioning, this is done, in the case of motors with encoder data memory, by starting

- **S-0-0262, C07_x Load defaults procedure command**.

⚠️ **CAUTION**

⇒ By executing this command control loop parameter values that have already been optimized are possibly overwritten!

Note: By automatic reset the **P-0-4090, Index for C07 Load defaults procedure** parameter is correctly preset!

Note: In the case of motors without encoder data memory, loading the motor-specific control loop parameter values by means of the "load defaults procedure" command is impossible! The values can be loaded from a data base of the "DriveTop" commissioning tool.

Respective diagnostic command message:

- **C07_0 Load defaults procedure com. (load controller param.)**

Respective diagnostic messages in the case of possible command errors:

- **C0702 Default parameters not available**
- **C0703 Default parameters invalid**
- **C0704 Parameters not copyable**
- **C0706 Error when reading the controller parameters**

See also "Initial Commissioning/Serial Commissioning" in chapter "Commissioning"

With Parameter Buffer Mode "Volatile Storage"

When "volatile storage" was set in **S-0-0269, Parameter buffer mode** the parameter values are not automatically stored in the drive-internal flash memory. The application-specific parameter values therefore, after complete input by means of

- **S-0-0264, C2200 Backup working memory procedure command**

have to be saved drive-internally in the flash memory. 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**

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Respective diagnostic messages in the case of possible command errors:

- **C2201 Parameter conversion error**
- **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

- **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 list of

- **S-0-0270, Selected IDN list of operation data to backup**

Note: In the case of "volatile storage", the C2200 command has to be executed at least once before starting the C2400 command, because otherwise basic parameter values are maintained for some parameter values in the flash memory.

Respective diagnostic command message:

- **C2400 Selectively backup working memory procedure command**

Respective diagnostic messages in the case of possible command errors:

- **C2401 Parameter conversion error**
- **C2402 Error when saving parameters**

Loading and Saving Parameter Values with MMC   See also "MultiMediaCard (MMC)" in chapter "Handling, Diagnostic and Service Functions"

Loading and Saving Parameter Values via Control Master or DriveTop   An appropriate master communication interface or the serial interface can be used for loading and saving parameter values via the control master or DriveTop.

Loading saved parameter values acc. to list parameter S-0-0192 to reestablish the original status after initial commissioning is impossible in the case of drives with absolute value encoder and modulo scaling (see note).

Note: In the case of drives with absolute value encoder and modulo scaling, the backup of parameter values made after initial commissioning acc. to S-0-0192 mustn't be loaded for reestablishing the original parameter status! **The actual position value after the loading process would be incorrect, but this cannot be detected on the controller side!**

With regard to reestablishing the original parameter status for drives with absolute value encoder and modulo scaling see "Initial Commissioning/Serial Commissioning" in chapter "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 Switching to parameter mode**

Respective diagnostic messages in the case of possible command errors:

- **C0402 Only allowed without master**

Note: The drive returns to the operating mode by a successive start of the commands **S-0-0127, C0100 Communication phase 3 transition check** and **S-0-0128, C0200 Communication phase 4 transition check**!

When reading and writing individual parameters via the control master or DriveTop (without command), the following error messages can possibly occur:

- **F2100 Flash defective**
- **F2101 It was impossible to address MMC**
- **F2102 It was impossible to address I2C memory**
- **F2103 It was impossible to address EnDat memory**

IDN Lists of Parameters

Some of the parameters stored in the drive contain, as their operating data (parameter value), a list of IDNs of drive parameters. These so-called IDN lists enable the master or a commissioning software to handle drive parameters in a specific way.

S-0-0017, IDN-list of all operation data

The parameter **S-0-0017, IDN-list of all operation data** contains the IDNs of all parameters available in the drive.

S-0-0192, IDN-list of backup operation data

The parameter **S-0-0192, IDN-list of backup operation data** contains the IDNs of all parameters that are stored in the non-volatile memory [MultiMediaCard (MMC) or flash memory]. These parameters are required for correct operation of the drive. With the master or a commissioning software it is possible to use this IDN list for making a backup copy of the drive parameters.

S-0-0021, IDN list of invalid operating data for communication phase 2

In parameter **S-0-0021, IDN list of invalid operating data for communication phase 2** the IDNs of those parameters are automatically entered that the drive software detects as being invalid when executing the **S-0-0127, C0100 Communication phase 3 transition check** command.

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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 plausibility rules.

In any event, the parameters entered in **S-0-0021, IDN list of invalid operating data for communication phase 2** upon negative acknowledgment of the **S-0-0127, C0100 Communication phase 3 transition check** command must be corrected.

S-0-0022, IDN list of invalid operating data for communication phase 3

In the parameter **S-0-0022, IDN list of invalid operating data for communication phase 3** the IDNs of those parameters are automatically entered that the drive software detects as being invalid or unduly configured when executing the **S-0-0128, C0200 Communication phase 4 transition check** command.

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 plausibility 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-0-0128, C0200 Communication phase 4 transition check** upon negative acknowledgment of the **S-0-0022, IDN list of invalid operating data for communication phase 3** command must be corrected.

S-0-0018, IDN list of operating data for communication phase 2

The IDNs that are checked for validity when command **S-0-0127, C0100 Communication phase 3 transition check** is executed are stored in the operating data of the **S-0-0018, IDN list of operating data for communication phase 2** parameter.

S-0-0019, IDN list of operating data for communication phase 3

The IDNs that are checked for validity when command **S-0-0128, C0200 Communication phase 4 transition check** is executed are stored in the operating data of the **S-0-0019, IDN list of operating data for communication phase 3** parameter.

S-0-0025, IDN-list of all procedure commands

The IDNs of all the command parameters available in the drive are stored in the operating data of the **S-0-0025, IDN-list of all procedure commands** parameter.

S-0-0270, Selected IDN list of operation data to backup

The IDNs of those parameters are stored in the **S-0-0270, Selected IDN list of operation data to backup** parameter that are to be saved when the **S-0-0293, C2400 Selectively backup working memory procedure command** is executed.

S-0-0279, IDN-list of password-protected operation data

The **S-0-0279, IDN-list of password-protected operation data** parameter contains the IDNs of those parameters that can be protected by a customer password (S-0-0267). By default there haven't been any IDNs entered in this parameter.

S-0-0327, IDN list of checksum parameter

The parameter **S-0-0327, IDN-List of checksum parameter** contains the IDNs of those parameters from which the content of parameter **S-0-0326, Parameter checksum** is to be generated. By default there haven't been any IDNs entered in this parameter.

P-0-0013, List of all IDNs not corresponding to default value

All parameters the operating data of which was changed with regard to the default value are stored in parameter **P-0-0013, List of all IDNs not corresponding to default value**.

Using a Password

Brief Description

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

- Parameters that are write-protected as a standard, such as motor parameters, hardware code parameters, encoder parameters, error memory etc. ("administration parameters"). The values of these parameters guarantee correct function and performance of the drive.

- Parameters the customer can combine in groups and protect them with a so-called customer password. This allows protecting parameter values, that are used for adjusting the drive to the axis, after having determined them.

- All other parameters that can be written and are not contained in the above-mentioned groups. They are not write-protected.

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

- **Customer password**

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

- **Control password**

  Parameters protected by a customer password can be written; "administration parameters" remain write-protected.

- **Master password**

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

Note: The customer password can be defined by the customer, the control password and the master password are defined by the manufacturer!

Pertinent Parameters

- **S-0-0192, IDN-list of backup operation data**
- **S-0-0267, Password**
- **S-0-0279, IDN-list of password-protected operation data**
- **P-0-4064, Password level**

Functional Description

The activation and deactivation of the write protection for parameter values by the three hierarchically different passwords is carried out by an input in parameter **S-0-0267, Password**.

Customer Password

By a password defined by the customer, the parameters of a parameter group to be defined can be protected against unauthorized or accidental write access.

The customer password has to comply with the following conditions:

- at least 3 characters long
- a maximum of 10 characters long
- may only include the characters a…z, A…Z and the numbers 0…9

The group of parameters the values of which can be protected by the customer password is defined in parameter **S-0-0279, IDN-list of password-protected operation data**. In the condition as supplied the parameter S-0-0279 does not yet contain any data. In the list parameter S-0-0279 it is possible to enter parameter IDNs according to application-specific requirements.

Note: The customer password is not obligatory! If it has not been activated, the values of the parameters listed in the list parameter S-0-0279 can still be written.

Control Password

After entering the firmware-specific control password defined by the manufacturer, it is also possible to write parameters protected by a customer password. The control password therefore allows the NC control unit to ignore the write protection established by the individual (unknown) customer password.

Note: 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.

Note: The master password is secret! It mustn't be used on the control unit side or by the customer, because it also allows changing the values of "administration parameters" (motor parameters, hardware code parameters, encoder parameters, error memory, etc.).

Activating/Deactivating the Write Protection
In the condition as supplied the **S-0-0267, Password** parameter contains the value "007". The write protection is activated and deactivated by means of the customer password according to the following procedure:
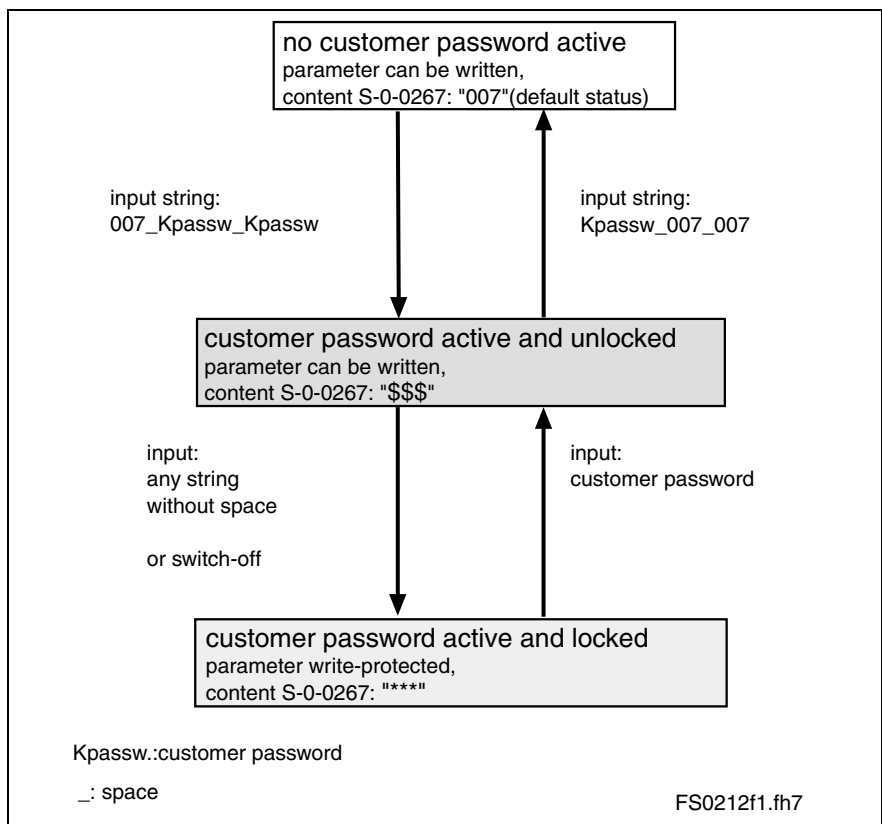
Fig. 10-2: Activating and deactivating the write protection by means of the customer password

The write protection activated via customer password is deactivated by means of the control password by entering the control password in S-0-0267. The write protection required by the customer can be activated again by entering any string in S-0-0267.

The write protection for all parameters that can basically be written can only be deactivated by means of the master password and the right to do this is exclusively reserved to the Bosch Rexroth development and service staff!

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⚠️ **WARNING**

Incorrect control of motors when changing parameter values write-protected on the firmware side ("administration parameters")!

⇒ The master password mustn't be used on the control unit side or by the customer!

Notes on Commissioning

Define the IDNs of the group of parameters the values of which are to be write-protected in

- **S-0-0279, IDN-list of password-protected operation data**.

Activate or deactivate the customer-side write protection for the parameters in S-0-0279 by means of the customer password, as illustrated in Fig. 10-2, by writing data to

- **S-0-0267, Password**.

Note: 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

- **S-0-0267, Password**.

Note: Ask the manufacturer for the control password!

Status Query for Write Protection

The current status of the write protection can be queried via

- **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.

10.2   Device Configuration

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

- **sub module**
  → module only communicates with the master via main module
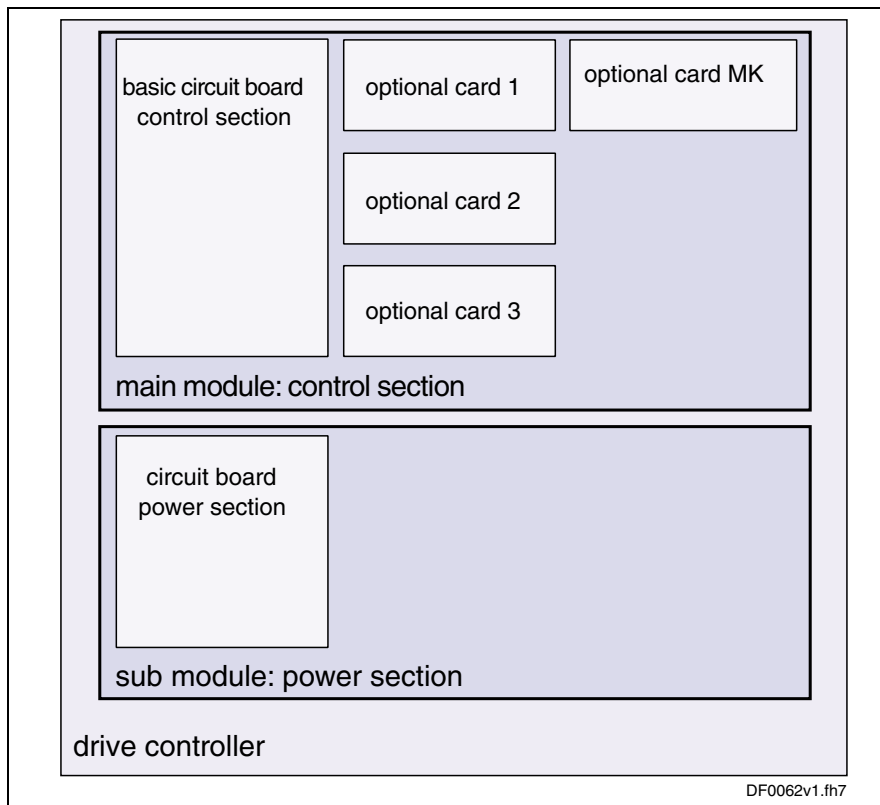
MK: master communication

Fig. 10-3:   Example of design including device, modules and circuit boards for IndraDrive controllers

At present, the following control and power sections are supported by the firmware:

- **control sections:**
  - CSH01.1C-PB…
  - CSH01.1C-SE…

- **power sections:**
  - HMS01.1N-W0020-A-07-NNNN
  - HMS01.1N-W0036-A-07-NNNN
  - HMS01.1N-W0070-A-07-NNNN
  - HMS01.1N-W0150-A-07-NNNN

Note: The devices are configured at the factory and can be read via parameters, if required.

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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 "Project Planning Manual for Control Section").

An individual parameter is assigned to each slot for circuit board or optional module (cf. P-0-1506 to P-0-1511). The specific data (circuit board code) of the circuit board that has been plugged are stored in these parameters.

Note: The circuit board codes are stored directly on the circuit board or the respective optional module.
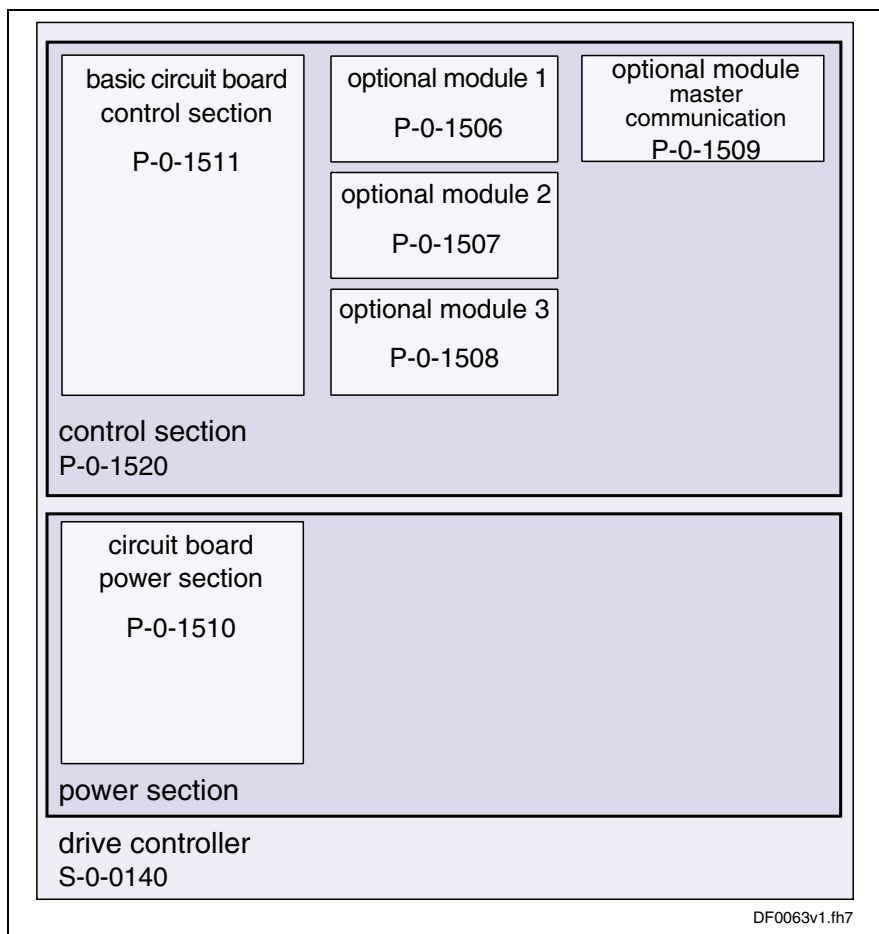
DF0063v1.fh7

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-0-1520:	control section type

Fig. 10-4: Device configuration and circuit board code for IndraDrive

In the initialization phase (when booting), the drive firmware automatically checks the arrangement (configuration) of the control section by means of the individual circuit board codes and on this basis generates the content of parameter **P-0-1520, Control section type**. The configuration of the control section used can be read via this parameter.

> **Note:** 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-0-1520, 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 "Project Planning Manual for Control Section"):

- **F8118 Invalid power section/firmware combination**
- **F8120 Invalid control section/firmware combination**

Hours-Run Meter

Brief Description

There are hours-run meters available in the drive that separately record the operating time for control section and power section. The respective operating time is displayed in the parameters P-0-0190 or P-0-0191. These times are directly stored from the control section or power section so that assignment is maintained also for servicing.

Pertinent Parameters

- **P-0-0190, Operating hours control section**
- **P-0-0191, Operating hours power section**

The parameter **P-0-0190, Operating hours control section** displays the operating time of the drive's control section. The unit is seconds.

The time the drive has been switched on is considered to be the operating time of the control section.

The parameter **P-0-0191, Operating hours power section** displays the operating time of the drive's power section when drive enable has 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.

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Note:	Before delivery, the hours-run meters are set to a defined value at the factory. They can therefore indicate the total runtime of a component in field duty.

Error Memory (Power Section and Control Section)

Brief Description

In the drive, all errors occurred are recorded in an error memory on the control section. If an error occurs in the power section, it is additionally stored in a separate error memory on the power section. It is thereby made sure that the relevant information is still available on the power section after separating the power section and control section.

Note:	When an error occurs, the diagnostic message number and the current count of the operating hours counter are automatically stored.

Pertinent Parameters

- **S-0-0390, Diagnostic message number**
- **P-0-0190, Operating hours control section**
- **P-0-0191, Operating hours power section**
- **P-0-0192, Error memory of diagnostic numbers**
- **P-0-0193, Error memory operating hours of control section**
- **P-0-0194, Error memory of power section**

Note:	The contents of the parameters P-0-0192 and P-0-0193 are stored on the control section. The content of parameter P-0-0194 is stored on the power section.

Functional Description

Error Memory in Control Section

When the drive detects a class 1 diagnostics error, a bit is set in parameter **S-0-0011, Class 1 diagnostics** and bit 13 for "error in class 1 diagnostics" is set in the drive status word.

In order to allow a more detailed diagnosis

- the diagnostic message number appears on the display and is stored in parameter **S-0-0390, Diagnostic message number** (in "hex format"),
- the respective error number is stored in parameter **P-0-0009, Error number** (in "decimal format"),
- the plain text diagnosis 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 the **P-0-0193, Error memory operating hours of control section** parameter,
- the diagnostic message number belonging to the error according to parameter **S-0-0390, Diagnostic message number** is stored in parameter **P-0-0192, Error memory of diagnostic numbers** in the same order.

The parameters P-0-0192 and P-0-0193 have a stack structure and contain, in chronological order, the diagnostic message numbers or the counts of the operating hours counter of the last **50 errors** that occurred.

Note: The count of the operating hours counter at the time the last error occurred is entered at the top of parameter P-0-0193 and the diagnostic message number of the last error occurred at the top of parameter P-0-0192.

Error Memory in Power Section

If the error concerns the power section it is additionally stored in parameter **P-0-0194, Error memory of power section**.

The last 13 errors that occurred and the respective count of the operating hours counter (cf. P-0-0191) are stored in this parameter.

The error **F8060 Bridge fuse**, for example, is an error in the power section. This error would be displayed both in parameter P-0-0193 and in parameter P-0-0194.

10.3 Diagnostic System

Coded Diagnostic Drive Messages

Brief Description

The drive provides a diagnostic system including different possibilities that are basically divided into two groups:

- recognizing and displaying the current drive status by means of drive-internal, priority-dependent generation of diagnostic messages
- collective messages for diverse status messages

Additionally, there are parameters for all important operating data the values of which can be transmitted both via master communication (e.g. SERCOS) and a parameterization interface (RS-232/485 in the ASCII protocol or SIS protocol; see section "Serial Communication").

Pertinent Parameters

- **S-0-0030, Manufacturer version**
- **S-0-0095, Diagnostic message**
- **S-0-0140, Controller type**
- **S-0-0142, Application type**
- **S-0-0375, List of diagnostic numbers**
- **S-0-0390, Diagnostic message number**
- **P-0-0009, Error number**
- **P-0-0478, Logbook event**
- **P-0-0479, Logbook time stamp**

Drive-Internal Generation of Diagnostic Messages

Operating states, activities and reactions of the drive controller are detected by drive-internal generation of diagnostic messages and appear in coded form on the display of the control panel. In addition, these diagnostic messages can be transmitted to the master (control unit or commissioning software, e.g. DriveTop).

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The following categories of diagnostic messages are differentiated (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**

The diagnostic message number appears on the 8-digit display of the standard control panel.

- **S-0-0095, Diagnostic message**

This parameter contains the operating status of the drive at present relevant in the form of a plain text. Preceding the text is the respective content of parameter S-0-0390.

- **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 the **P-0-0009, Error number** parameter. When there isn't any error present, the value of parameter P-0-0009 equals zero.

In the **S-0-0375, List of diagnostic numbers** parameter the last 50 diagnostic message numbers of parameter S-0-0390 are recorded in chronological order. When reading this list, the number of the diagnostic message that last occurred is displayed as parameter element 1.

Priorities of Display   The following priorities apply for displaying the current diagnostic message:
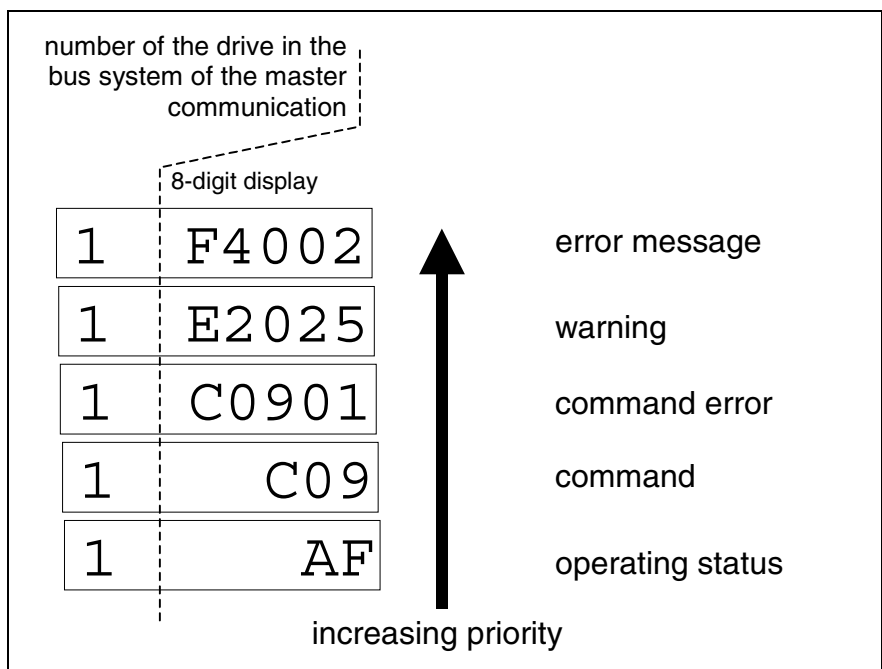
Fig. 10-5:   Priorities of displays (with example displays)

An overview of all diagnostic messages and their meanings is included in the documentation "Troubleshooting Guide" (description of diagnostic messages).

Structure of a Diagnostic Message

Every diagnostic message consists of

- diagnostic message number and
- diagnostic text.

The diagnostic message for the non-fatal error "Excessive deviation", for example, has the following structure:

F2028 Excessive deviation

diagnostic text

diagnostic message number
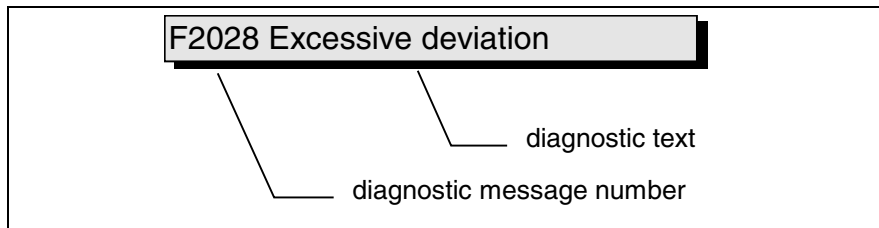
Fig. 10-6: Structure of a diagnostic message

"F2028" flashes on the display of the control panel. The diagnostic message number is contained in the **S-0-0390, Diagnostic message number** parameter in hexadecimal form (for this example: 0x00F2028). The diagnostic message number and the diagnostic text are contained as string **F2028 Excessive deviation** in the **S-0-0095, Diagnostic message** parameter. "2028" (dec) is written to the **P-0-0009, Error number** parameter because it is an error diagnosis.

Diagnostic Message on the Control Panel Display

The diagnostic message number appears on the 8-digit display of the standard control panel. This allows recognizing the current operating status of the drive quickly and without using a communication interface.

As a matter of principle, the following applies:

- status displays (P0, Ab, AF …) are displayed in right-aligned form
- warnings, command errors and other error messages are flashing

Kind of diagnostic message	Diagnostic message number	Display
error	F2xxx	F2xxx
command	C0200	C02
command error	C02xx	C02xx
warning	E2xxx	E2xxx
communication phase e.g. communication phase 1	A0001	P1
drive ready for operation	A0012	Ab
operating mode e.g. velocity control	A0101	AF

Fig. 10-7:   Overview of diagnostic messages displayed

The current operating mode is not shown on the display. When the drive follows the preset operating mode and no command was activated, the display reads "AF".

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Diagnostic Messages in Plain Text

The diagnostic message in plain text contains the diagnostic message number followed by the diagnostic text. It can be read via the **S-0-0095, Diagnostic message** parameter 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 the **S-0-0265, Language selection** parameter.

Diagnostic Message Number

The diagnostic message number contains only the diagnostic number without the diagnostic text. It can be read with the **S-0-0390, Diagnostic message number** parameter and is a language-independent possibility of determining and displaying the drive status on an operator interface.

Error Number

The error number contains only the error number without the diagnostic text. It can be read with the **P-0-0009, Error number** parameter and is a language-independent possibility of determining and displaying an error condition on an operator interface. This parameter only contains a value unequal zero when an error is present in the drive.

The error number is generated from the lowest 4 digits of the diagnostic message number. For example, the **F2028 Excessive deviation** error with the diagnostic message number "(0x)F2028" would produce the error number "2028."

List of Diagnostic Numbers

The last 50 diagnostic message numbers displayed are stored in chronological order in the **S-0-0375, List of diagnostic numbers** parameter. Every change in the content of **S-0-0390, Diagnostic message number** means that the old content is transferred to S-0-0375. When reading S-0-0375 the last transferred diagnostic message number appears in the first element of the parameter, the diagnostic message number transferred before from S-0-0390 in the second element etc.

Language Selection

Via parameter **S-0-0265, Language selection** it is possible to define or switch the language of diagnostic message texts.

See also Parameter Description "S-0-0265, Language selection"

Status Classes, Status Displays, Control Parameters

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" in chapter "Extended Drive Functions"

See "Configurable Signal Status Word" in chapter "Master Communication"

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 status class parameters (S-0-0011, S-0-0012, S-0-0013) that contain the respective status bits.

In addition to these status class parameters there are change bits contained in the status word of the field bus (e.g. S-0-0135 in the case of SERCOS) that display changes in one of the above-mentioned status class parameters (collective information).

Features
- status class parameter for **errors** (cf. S-0-0011)

- status class parameter for **warnings** (cf. S-0-0012)

- status class parameter for **messages** (cf. S-0-0013)

- **change bits in status word** of master communication (e.g. S-0-0135 in the case of SERCOS)

- **change bits** of class 2 and 3 diagnostics (S-0-0097 and S-0-0098) **can be masked** in status word of master communication (e.g. S-0-0135 in the case of SERCOS) to suppress individual bits or status messages

Pertinent Parameters
- **S-0-0011, Class 1 diagnostics**

- **S-0-0012, Class 2 diagnostics**

- **S-0-0013, Class 3 diagnostics**

- **S-0-0097, Mask class 2 diagnostics**

- **S-0-0098, Mask class 3 diagnostics**

- **S-0-0135, Drive status word**

Functional Description

Status Class Parameters
- **S-0-0011, Class 1 diagnostics** (status parameter for drive errors)

  - In case a drive error occurs, the bit assigned to the error is set in parameter S-0-0011. A separate bit is assigned in S-0-0011 to errors defined according to SERCOS.
    Manufacturer-specific errors cause bit 15 to be set in S-0-0011 (see also Parameter Description "S-0-0011, Class 1 diagnostics").

  - In case a drive error occurs, bit 13 (drive interlock; error in class 1 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in the case of SERCOS).

Note: 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"

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- **S-0-0012, Class 2 diagnostics** (status parameter for drive warnings)
    - In case a drive warning occurs, the bit assigned to the warning is set in parameter S-0-0012. A separate bit is assigned in S-0-0012 to warnings defined according to SERCOS.
    Manufacturer-specific warnings cause bit 15 to be set in S-0-0012 (see also Parameter Description "S-0-0012, Class 2 diagnostics").
    - In case a drive warning occurs, bit 12 (change bit class 2 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in the case of SERCOS) when the content of S-0-0012 changes (i.e. at least one bit toggles).
    - The bits in parameter S-0-0012 are automatically cleared when the warning disappears. The change bit in the status word of the master communication (S-0-0135 in the case of SERCOS) remains set, however, until parameter S-0-0012 has been read once.

Note:	Via parameter **S-0-0097, Mask class 2 diagnostics** warnings can be masked in terms of their effect on the change bit.

- **S-0-0013, Class 3 diagnostics** (status parameter for drive messages)
    - Messages of the drive are listed in parameter S-0-0013. A separate bit is assigned in S-0-0013 to messages defined according to SERCOS (see also Parameter Description "S-0-0013, Class 3 diagnostics").
    - In the case of a drive message, bit 11 (change bit class 3 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in the case of SERCOS).

Note:	Each of these messages is stored in a separate parameter (S-0-0330 to S-0-0342).

    - The bits in parameter S-0-0013 are automatically cleared when the message disappears. The change bit in the status word of the master communication (S-0-0135 in the case of SERCOS) remains set, however, until parameter S-0-0013 has at least been read once.

Change Bits in Drive Status Word

If the status of a bit in **S-0-0012, Class 2 diagnostics** or **S-0-0013, Class 3 diagnostics** changes, the change bit for class 2 or 3 diagnostics is set in the field bus status word (e.g. S-0-0135 in the case of SERCOS). A change bit in the status word (bit 11 or 12) is always set due to a change of the parameter content of S-0-0012 or S-0-0013. This enables the master to recognize very quickly whether a change occurred in S-0-0012 or S-0-0013.

A read access to one of the two parameters clears the respective change bit again.

Masking the Change Bit

By means of the parameters **S-0-0097, Mask class 2 diagnostics** and **S-0-0098, Mask class 3 diagnostics** it is possible to mask out certain bits in terms of their effect on the change bit of the status word (bit 12 or bit 11).

The figure below illustrates the principle of masking by means of an example:
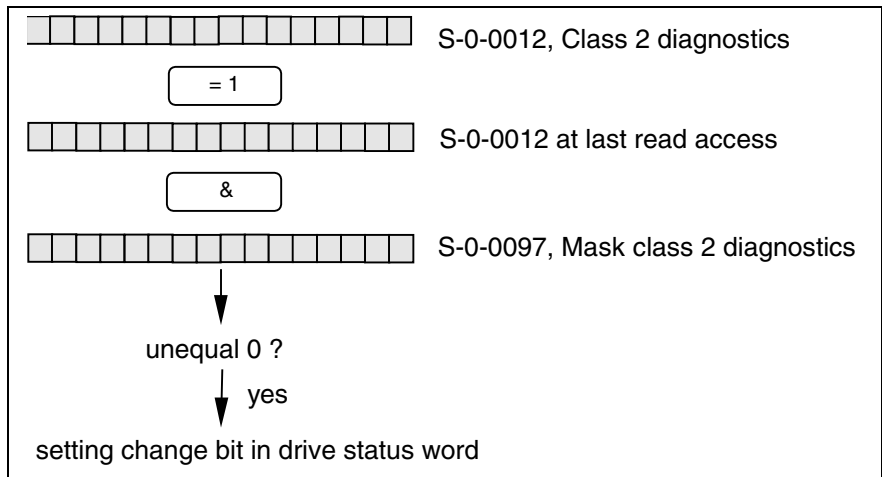
Fig. 10-8: Generating the change bit of class 2 diagnostics

Notes on Commissioning

The figure below illustrates the handling of the change bits in the status word and of the status class parameters:
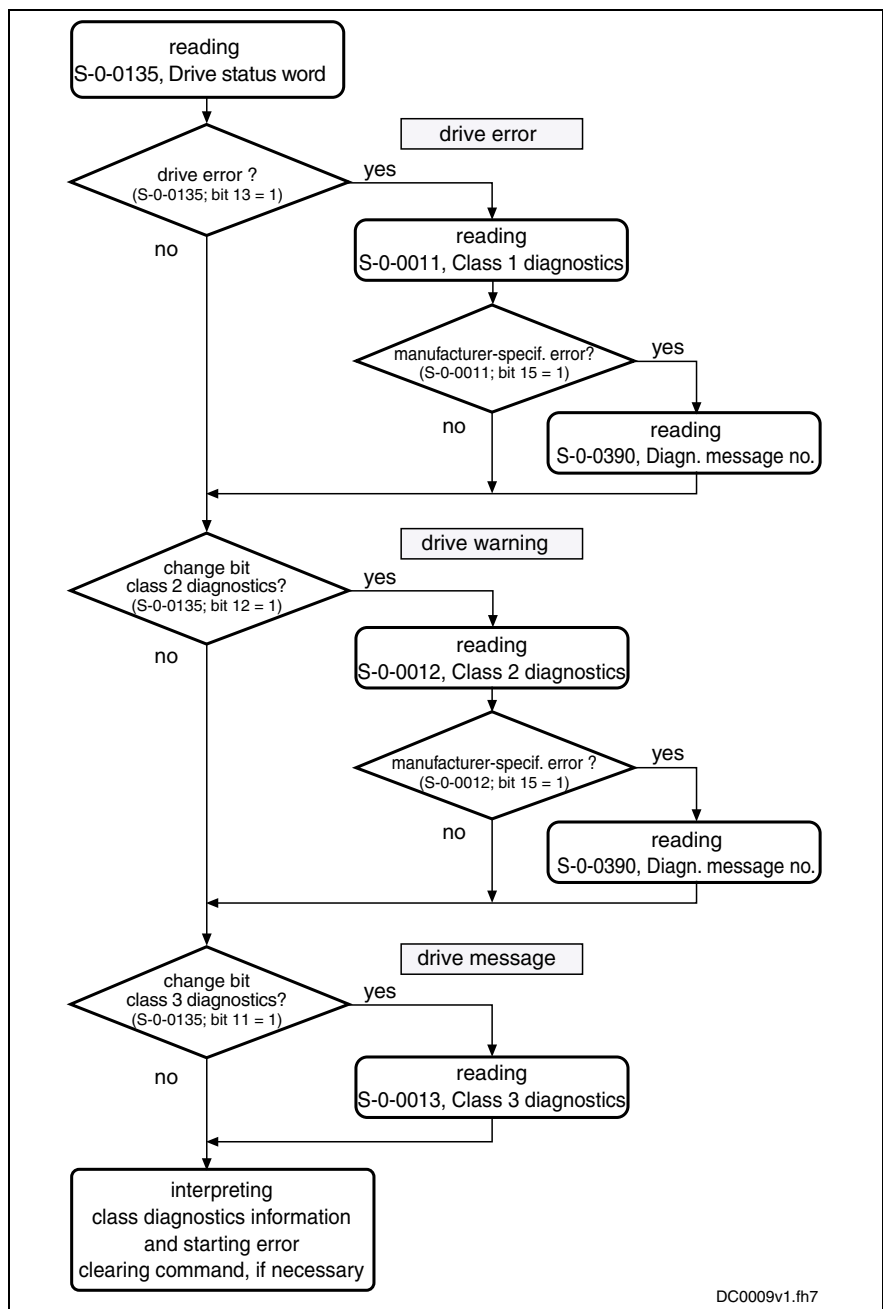
Fig. 10-9:   Handling the change bits and status class parameters

Fixed Status Displays

Function-Related Status Parameters

In the drive there are parameters the content of which has a direct relation to the status of the sequence of different drive functions. These parameters are used to display the current status information of the assigned function.

The following parameters are available for function-related status display:

- **S-0-0014, Interface status**
  This parameter displays the status of the communication phase transition and the cyclic communication.

- **S-0-0135, Drive status word**
  This is the status word of the master communication (SERCOS) and contains all essential status information for the master.

- **S-0-0403, Position feedback value status**
  This parameter contains status bits for the position data reference of the individual measuring systems.

- **S-0-0419, Positioning command acknowledge**
  This status information is used for acknowledgment in the "drive-controlled positioning" mode.

- **P-0-0046, Status word of current controller**
  This parameter contains status bits of the internal motor control (e.g. overvoltage in DC bus).

- **P-0-0115, Device control: status word**
  This parameter contains status bits of device control (see also "Device Control").

- **P-0-0188, Status word positioning generator**
  This parameter contains status bits for the positioning behavior of the drive (e.g. "In target position").

- **P-0-0222, Travel range limit inputs**
  This parameter displays the status of the travel range limit switch inputs (see also "Travel Range Limit Switches").

- **P-0-0223, E-Stop input**
  This parameter displays the status of the E-Stop input (see also "E-Stop Function").

- **P-0-0445, Status word torque/current limit**
  This parameter contains status bits to display the activation of torque/current limitation (see also "Torque/Current Limit").

- **P-0-0539, Holding brake status word**
  This parameter contains status bits for the status of the motor holding brake (see also "Motor Holding Brake").

- **P-0-0555, Status word of axis controller**
  This parameter displays messages with regard to velocity and limits that have been reached.

- **P-0-4029, SCSB diagnostics**
  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 "Master Communication: SERCOS interface"):

- **S-0-0330, Message 'n_actual = n_command'**

- **S-0-0331, Status 'n_feedback = 0'**

- **S-0-0332, Message 'nactual < nx'**

- **S-0-0333, Message 'T >= Tx'**

- **S-0-0334, Message 'T >= Tlimit'**

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- **S-0-0335, Message 'n command > n limit'**
- **S-0-0336, Message In position**
- **S-0-0337, Message 'P >= Px'**
- **S-0-0341, In-Position coarse message**
- **S-0-0342, Target position reached**
- **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 corresponding parameter description):

- **P-0-0045, Control word of current controller**
- **P-0-0427, Control parameter of analog output**
- **P-0-0522, Commutation setting control word**
- **P-0-0556, Control word of axis controller**
- **P-0-0612, Control word for setting absolute measuring**
- **P-0-4028, Device control word**

10.4 Control Panel of the IndraDrive Controllers

Brief Description

The standard design of IndraDrive controllers includes a control panel with an 8-digit display and four buttons located underneath it.

The display shows operating states, command and error diagnoses, as well as present warnings.

Using the four buttons, the commissioning engineer or service technician can opt to display extended diagnostic messages at the drive controller and to activate simple commands (in addition to master communication using the commissioning tool or NC control unit).
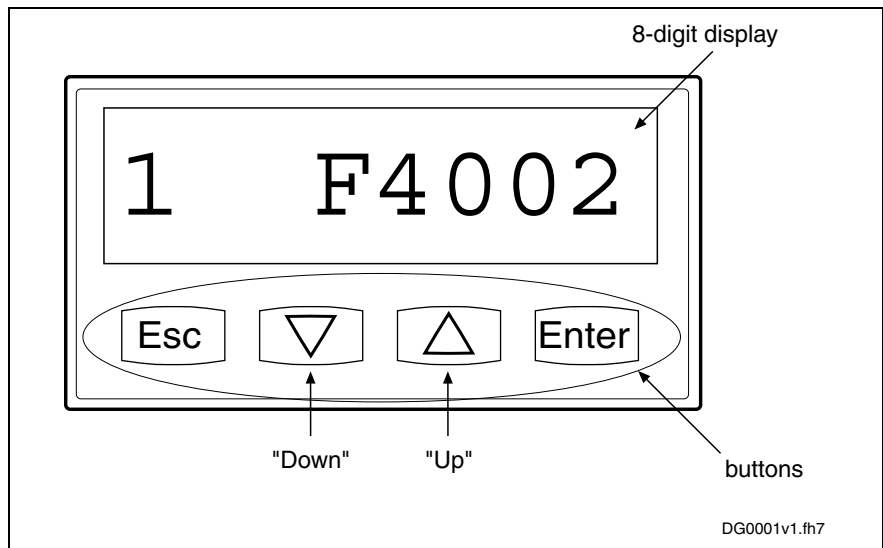
Fig. 10-10: Standard control panel with display and control elements (example
             of display)

Functional Description

Standard Displays   The display of the IndraDrive controller automatically shows:

- status of the master communication
- operating status
- activated commands and command diagnoses
- warnings and error diagnoses

The displays have priorities because it is impossible to have various
displays at the same time.
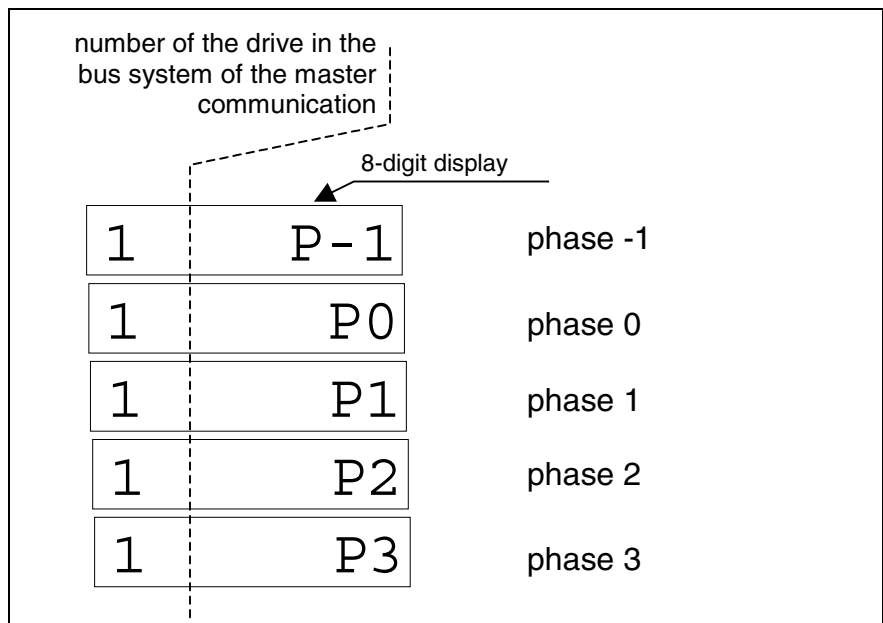
Fig. 10-11: Displays during phase progression of the master communication
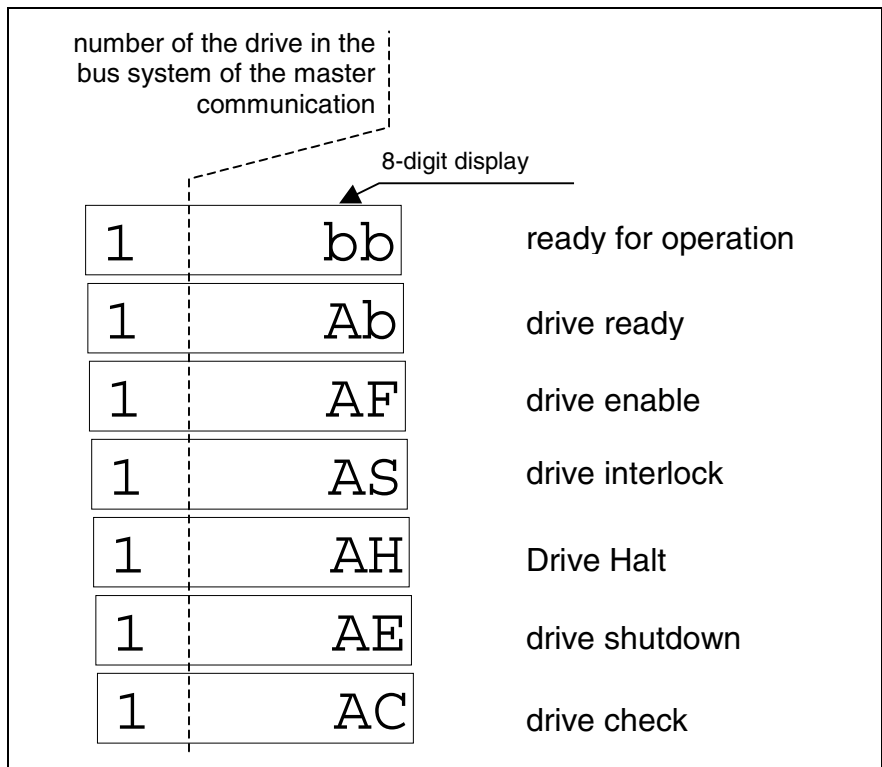
Fig. 10-12: Operating status displays
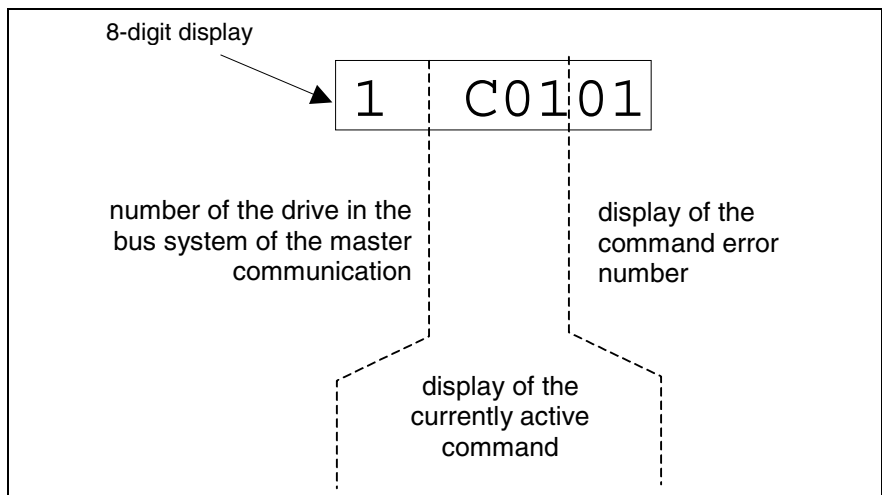
Fig. 10-13: Explanation of command error displays
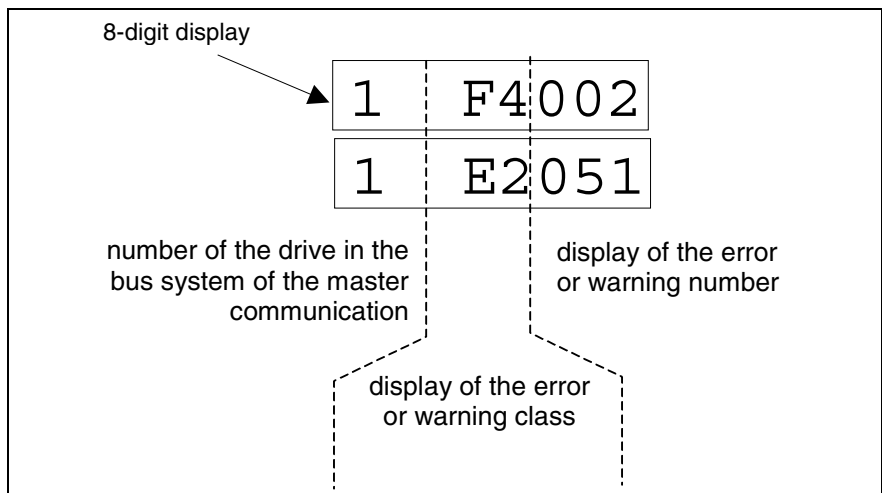
Fig. 10-14: Explanation of error and warning displays

Priorities of Display   The current drive status is displayed with highest priority.
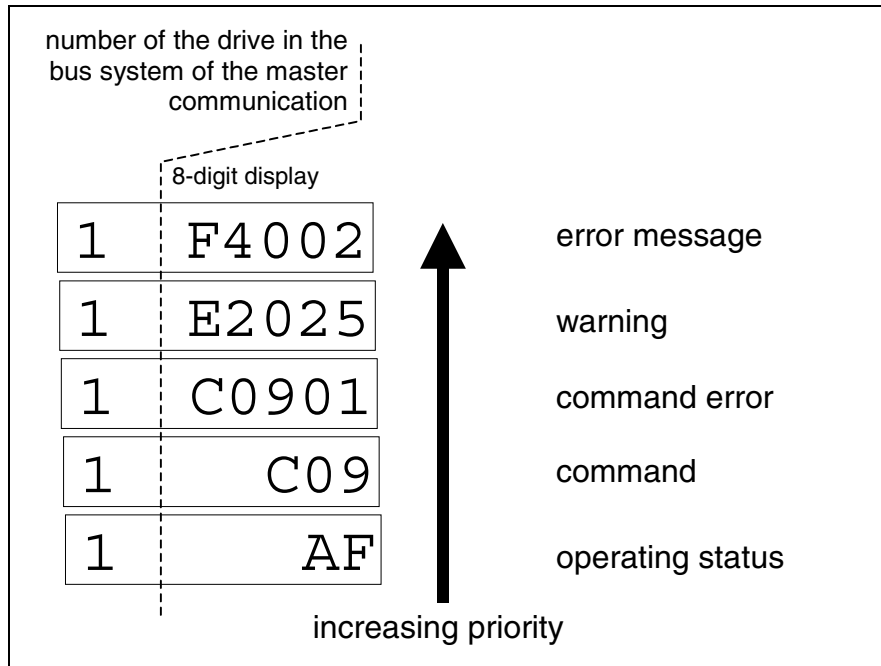
Fig. 10-15: Priority of displays with examples

Activating Extended Display and Command Input   By simultaneously pressing the "Enter" and "Esc" buttons (for 8 s!) you can call up extended displays; subsequently pressing the "Up" button activates the command input.
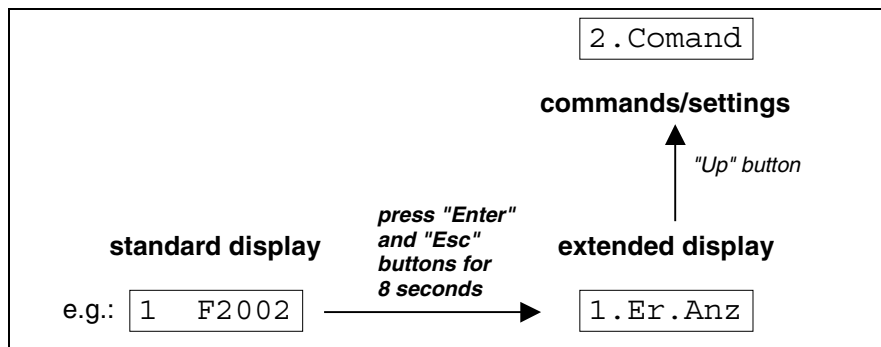
Fig. 10-16: Activating the extended display and the command input

Extended Displays   By means of the extended displays it is possible to additionally call up the contents of certain parameters:

- error memory
- diagnostic message memory
- operating hours counter control section
- operating hours counter power section
- type designation of the firmware active in the device
- safety technology code, if safety technology option available
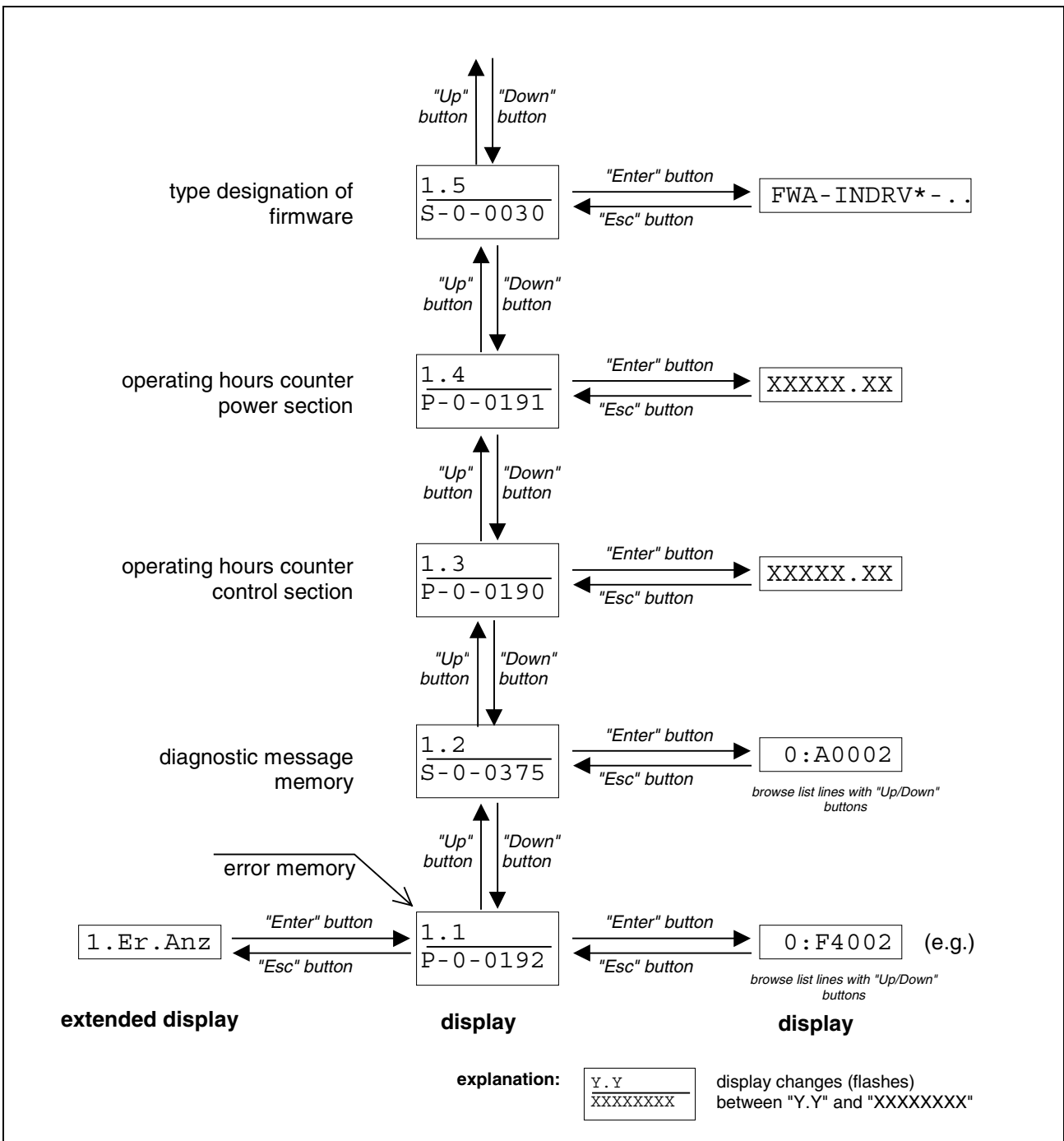
Fig. 10-17: Activating the extended display

For more details on diagnostic messages, error messages and operating hours counters see the respective chapters of the present documentation.

Command Inputs   Starting from the extended display it is possible to activate commands and make settings:

- set the drive address (drive number in the bus system of the master communication)

- set the length of the fiber optic cable

- activate the "analog mode" master communication

- C07_x load defaults procedure command (loading controller parameters resp. base parameters)

- other commands like

    - **C2200 Backup working memory procedure command**

    - **C2300 Load working memory command**

    - **C2500 Copy IDN from optional memory to internal memory**

    - **C2600 Copy IDN from internal memory to optional memory**

    - **C2900 Firmware update from MMC**
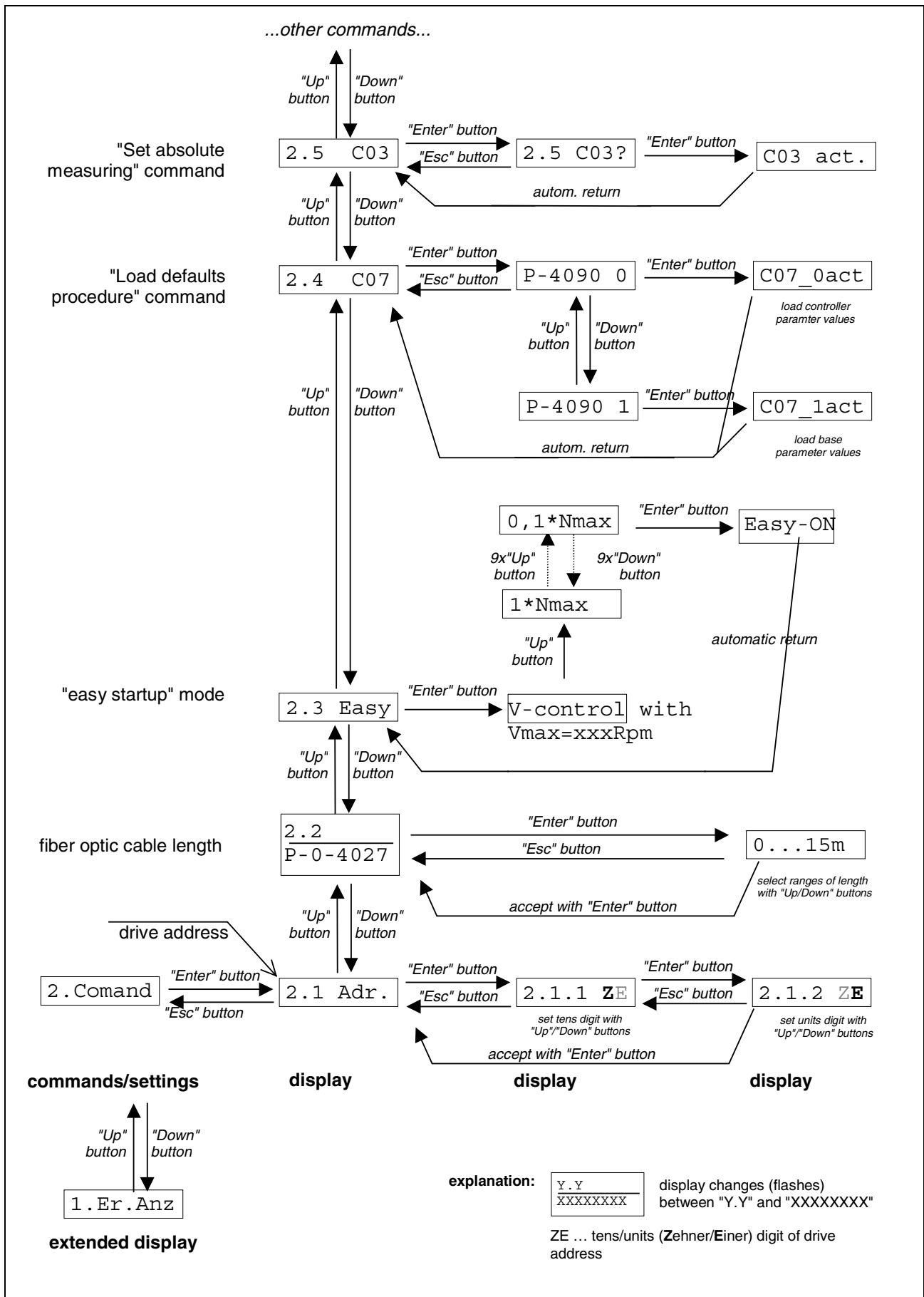
Fig. 10-18: Activating settings and commands that can be accessed via the control panel

Notes on Commissioning

⚠ **CAUTION**	**Property damage caused by command-dependent activation of motors and moving elements!** ⇒ Bring axis resp. moving parts in safe initial position; limit travel range and drive power!

Note:	By pressing the "Esc" button again the standard display will reappear.

Note:	The input via the buttons is polled in an 8 ms-cycle, the display is updated in an 8 ms-cycle, too.

10.5 MultiMediaCard (MMC)

Brief Description

The MultiMediaCard (MMC) is a non-volatile storage medium that can be inserted in the slot provided for this purpose on the front of the controller. The MMC can store drive firmware, drive parameters and other files. The MMC can be used optionally.

As **stationarily** (permanently) plugged storage medium the **MMC** can be used as:

- "programming module", as active, non-volatile memory containing the current axis-specific parameter values and the firmware active in the drive.

As a **temporarily** plugged storage medium the **MMC** can be used for:

- updating 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 original parameter status of the drive (loading the saved parameter values).

  Attention:
  Not for drives with absolute value encoder and modulo format!

  See also "Initial Commissioning/Serial Commissioning" in chapter "Commissioning"

Note:	The MMC commands can be started via the control panel. This is especially advantageous when replacing devices!

Note:	It is only allowed to use MMCs by Bosch Rexroth (type designation PFM02.1-0016-FW)!

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Pertinent Parameters

- **P-0-4072, C2900 Command Firmware update from MMC**
- **P-0-4091, C2500 Copy IDN from optional memory to internal memory**
- **P-0-4092, C2600 Copy IDN from internal memory to optional memory**

Pertinent Diagnostic Messages

Copying Parameters from MMC to Flash
- **C2500 Copy IDN from optional memory to internal memory**
- **C2502 Error when accessing the MMC**
- **C2504 Error when writing data to the flash**

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 flash**

Firmware Update via MMC
- **C2900 Command Firmware update from MMC**
- **C2903 Error when accessing the MMC**
- **C2904 Error when accessing the flash**
- **C2905 Programmed HPC firmware defective**

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. When being used in IndraDrive devices, the MMC has to have the following folder structure:
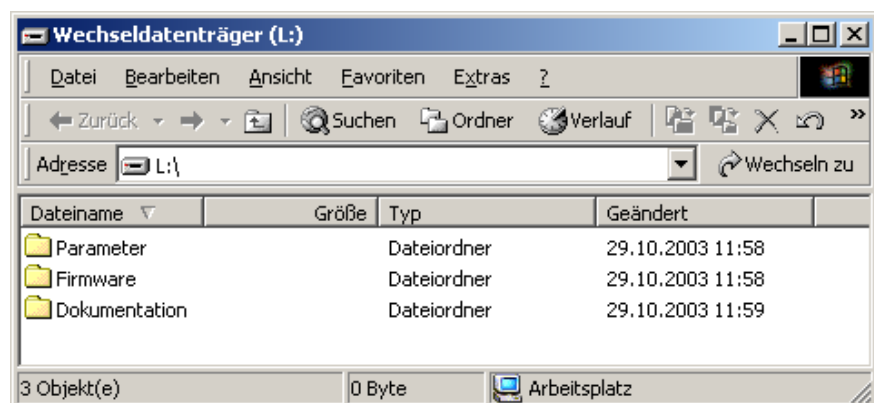
Fig. 10-19: Required folder structure of the MMC

The folders on the MMC are provided for the following contents:

Folder "Firmware" The file with the drive firmware has to be filed in this folder. The file extension has to be **".ibf"**.

The following firmware variants are possible:

- FWA-INDRV*-MPH-02VRS... (Advanced single-axis)
- FWA-INDRV*-MPH-02VRS... (Basic single-axis)
- FWA-INDRV*-MPD-02VRS... (Basic double-axis)

At delivery the MMC has the required folder structure, the "Firmware" folder contains the latest release of the drive firmware.

	Note:	When updating the firmware via MMC make sure that the folder "Firmware" **only** contains **one** file with the extension **".ibf"**. This folder may contain other files but not with the extension **".ibf"**!

Folder "Parameters" In this folder contains the files with the axis-specific parameter values and the parameter values relevant for replacing the devices:

- a file with the extension "....#1.pbf" (parameter values to be saved acc. to S-0-0192, size 320kB)

- a file with the extension "....#1.rbf" ("retain" data for replacing devices acc. to P-0-0195, size 16kB)

Storage takes place automatically when the MMC is used as "programming module" (stationarily plugged). Storage takes place by a command if the MMC has only been plugged temporarily.

	Note:	In the case of the firmware variant "Basic double axis" (FWA-INDRV*-MPD-02VRS...) 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 are corresponding to the mentioned requirements!

At delivery of the MMC the basic parameters for the firmware contained on the MMC are included in the folder "parameters".

Folder "Documentation" At delivery of the MMC this folder does not contain any files. The customer can store any data in this folder that are useful for handling the firmware or the axis.

Ordering a Firmware Update The MMC with the latest release of the drive firmware can be ordered with the type designation

- **PFM02.1-0016-FW** with firmware-dependent sub-item:

    - **FWA-INDRV*-MPH-02VRS-MS** (Advanced single-axis)   - or -

- **FWA-INDRV*-MPD-02VRS-MS** (Basic double-axis) - or -

- **FWA-INDRV*-MPB-02VRS-MS** (Basic single-axis)

	Note:	An MMC with current release of the required firmware can be ordered from our sales and service facilities.

Firmware Update with MMC

The MMC allows transmitting drive firmware to the drive controller in a quick and uncomplicated way. We basically distinguish stationarily and temporarily plugged MMCs.

Firmware Update via Stationarily Plugged MMC

The firmware update with a device having a stationarily plugged MMC (MMC used as "programming module") can be carried out

- using a PC that can read and write a MMC

- or -

- using an MMC that was supplied with the current firmware release for firmware update (without PC).

Firmware Update with PC	This requires a PC with an adapter to plug in and activate the MMC as "alternate data carrier". The new firmware has to be available on a data carrier of the PC as a file with the extension ".ibf".

This file has to be transmitted to the folder "Firmware" of the MMC of the device for which the firmware update is to be carried out. The folder "Parameters" mustn't be changed!

Note:	Use an MMC identical to the one active in the controller! This guarantees the that the axis that was switched off and has stopped can be operated after the firmware update without loss of position data references, target values etc.

Firmware Update without PC (with Update MMC)	This procedure of firmware update can be carried out without PC. It requires replacing the MMC previously active in the drive by the MMC delivered for the update. The axis-specific parameter values stored on the previously used MMC have to be transmitted to the new MMC by temporary storage in the controller! The new MMC remains in the controller.

Firmware Update via Temporarily Plugged MMC

If the MMC does not remain stationarily (permanently) plugged in the device, it can be temporarily plugged in the switched-on device after the booting phase and removed again ("hot plug" or "hot unplug").

Firmware Update	After having plugged the MMC and activated the **P-0-4072, C2900 Firmware update from MMC command**, the drive automatically carries out the firmware update.

Note:	The C2900 command can be started via the control panel.

See "Control Panel of the IndraDrive Controllers" in the same chapter

Saving and Loading Parameter Values	The MMC allows saving application-specific parameter values in a quick and uncomplicated way and/or loading values saved on the MMC to the drive controller.

Parameter values are saved by activating parameter **P-0-4092, C2600 Copy IDN from internal memory to optional memory**. When doing this, the application-specific parameter values active in the drive are saved on the MMC according to the parameters **S-0-0192, IDN-list of backup operation data** and **P-0-0195, IDN list of retain data (replacement of devices)**.

Parameter values are loaded by activating parameter **P-0-4091, C2500 Copy IDN from optional memory to internal memory**. The application-specific parameter values are loaded to the controller-internal, non-volatile memory according to the list parameters S-0-0192 and P-0-0195.

Note:	The C2500 and C2600 commands can be started via the control panel!

See "Control Panel of the IndraDrive Controllers" in the same chapter

MMC when Replacing Devices

See "Control Panel of the IndraDrive Controllers" in the same chapter

Notes on Commissioning

Firmware Update via Stationarily Plugged MMC

Firmware Update with PC

Sequence of firmware update with PC:

1. Put MMC delivered for firmware update in MMC adapter of PC.

2. Store file with new firmware (extension ".ibf", folder "Firmware") on storage medium of PC and remove MMC from PC.

3. Put MMC previously active in drive into PC and on MMC in folder "Firmware" replace file with previously used firmware by new file.

4. Put MMC previously active in drive with now updated firmware into controller that was switched off, then switch controller on.

5. When booting the controller the display shows the message "Firmware update?". Acknowledge this message by pressing the "Enter" button (control panel).

6. New firmware is now loaded to controller (firmware update); display shows corresponding download messages.

7. After firmware download boot process is completed, drive in communication phase P-1 waits for other commands or is put into readiness for operation via the control master.

Note: The MMC previously active in the controller remains active after the firmware update!

Firmware Update without PC

Sequence of firmware update without PC:

1. Store axis-specific parameter values stored on the previously active MMC via command C2500 in non-volatile memory of controller.

2. Switch control voltage of drive off and remove previously active MMC from controller.

3. Switch drive on again without MMC plugged. During boot phase, display shows message "Load new Param.?". Acknowledge this message by pressing the "Enter" button (control panel).

4. After boot phase is over plug new MMC delivered for firmware update into controller, then with command C2600 transmit axis-specific parameter values stored in controller to new MMC.

5. After transmission is over switch control voltage of drive off, leave new MMC in controller and switch drive on again.

6. When booting the controller the display shows the message "Firmware update?". Acknowledge this message by pressing the "Enter" button (control panel).

7. New firmware is now loaded to controller (firmware update); display shows corresponding download messages.

8. Boot process is continued after firmware download and message "Load new Param.?" appears. Acknowledge this message by pressing the "Enter" button (control panel). New MMC now is active MMC of this drive.

9. Boot process is completed, drive in communication phase P-1 waits for other commands or is put into readiness for operation via the control master.

Note: The MMC previously active in the controller is replaced by the new MMC delivered for the firmware update!

Firmware Update via Temporarily Plugged MMC

Note: With PC check whether the folder "Firmware" on the MMC contains the required file for firmware update!

Firmware update via temporarily plugged MMC:

1. Switch controller on. After boot phase is over (display reads "P-1") or in communication phase P2 put MMC with firmware update file into respective slot ("hot plug").

2. With MMC plugged, via the control panel or appropriate master communication, activate

   P-0-4072, C2900 Command Firmware update from MMC.

3. During firmware download (update) different messages for download process appear on display.

4. After end of firmware update, message "End C29" appears on display. Remove MMC from controller ("hot unplug" or when controller switched off).

5. New firmware is activated by switching controller off and on again. Firmware type active in device can be shown on display via control panel.

See "Control Panel of the IndraDrive Controllers" in the same chapter

Saving Parameter Values on MMC

Put MMC into controller after boot phase ("hot plug"). In communication phase P2, via control panel or appropriate master communication activate

- **P-0-4092, C2600 Copy IDN from internal memory to optional memory**.

Diagnostic Messages   Respective diagnostic command message:

- **C2600 Copy IDN from internal memory to optional memory**

The following error diagnoses can be signaled:

- **C2602 Error when accessing the MMC**
- **C2604 Error when reading the flash**

Note: As a matter of principle it is recommended to additionally save the application-specific parameter values via the "DriveTop" commissioning tool or the control master on an external storage medium!

Loading Parameter Values from MMC

Put MMC containing the axis-specific parameter values into controller after boot phase ("hot plug"). In communication phase P2, via control panel or appropriate master communication activate

- **P-0-4091, C2500 Copy IDN from optional memory to internal memory**.

By starting this command the application-specific parameter values can be

- transmitted to other axes of the same type during serial commissioning

- or -

- loaded to the same controller again to reestablish the original status.

Note:	In the case of drives with absolute value encoder and modulo format, the position data reference has to be established again after having loaded the parameter values saved after initial commissioning, even if the actual position values are signaled to be valid via **S-0-0403, Position feedback value status**!

Diagnostic Messages

Respective diagnostic command message:

C2500 Copy IDN from optional memory to internal memory

The following error diagnoses can be signaled:

- **C2502 Error when accessing the MMC**
- **C2504 Error when writing data to the flash**

10.6 Firmware Update

General Information

Basically there are 2 possibilities of updating the firmware:

- update via serial interface (RS232/RS485) by means of the "Dolfi" program
- update by means of MultiMediaCard (MMC)

To be Noticed when Using the Safety Technology Module

Note:	The firmware of the optional safety technology module and of the drive controller are firmly linked. Each firmware update contains the firmware of the optional safety technology module and of the controller. If the controller firmware detects a version on the optional safety technology module that is not suitable, the supplied version is loaded.

When the firmware is replaced, the values of all parameters normally are retained. If values of the safety technology parameters should nevertheless get lost, proceed according to the instructions contained in the separate documentation "Integrated Safety Technology".

🛈 In case safety technology parameter values got lost, see "Replacing a control section without MMC" via the index of the separate documentation "Integrated Safety Technology".

Firmware Update with "Dolfi" Program

With the "Dolfi" program it is possible to carry out firmware updates for the drive controller via the serial interface.

The "Dolfi" program can be ordered from one of our sales and service facilities under the designation **SWA-DOL*PC-INB-01VRS-MS-C1,44-COPY** or part number **R911279804**.

Together with the program you will receive a documentation that describes how to handle the program and how to replace the firmware.

Firmware Update with MultiMediaCard (MMC)

See section "MultiMediaCard (MMC)"

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10.7 Notes on How to Replace the Devices

Supply Units

The concept of Rexroth supply units includes safe, quick and uncomplicated replacement of devices. This allows reducing production downtimes, caused by failures of these devices, to a minimum.

Failures in the supply unit are displayed by means of diagnostic messages. According to the diagnostic error message, the measure "replacing the supply unit" can be indicated.

i   See documentation "Troubleshooting Guide" (description of diagnostic messages for IndraDrive)

The sequence of the replacement of devices is described in the supply unit documentation.

Immediately after having replaced the device the drive is operational again because it is not required to repeat the adjustment of the drive to the machine.

How to Replace Supply Units

Procure Replacement Device   Identify device to be replaced by means of type plate; procure supply unit of same type from Bosch Rexroth!

i   See also documentation of the respective supply unit

Fill Out Fault Report   A fault report form to be copied can be found in the documentation of the respective supply unit. Please copy this fault report, fill it out carefully and completely and enclose it to the defective device! The fault report filled out completely supports quick handling of repair and helps recognizing application-related failure causes.

Replace Supply Unit   De-energize drive system; wait for DC bus to discharge!

DANGER   **Live conductor bars (higher than 50 V), even if mains voltage switched off!**

Electric shock when touching!

⇒ Wait for the DC bus (L+/L-) to discharge; before touching the conductor bar check whether below 50 V!

i   Notes on how to mount and dismount the supply unit see documentation of the respective supply unit!

Put Drive System into Operation Again   Put machine into operation again according to machine manufacturer's instructions!

Drive Controllers

The concept of Rexroth controllers includes safe, quick and uncomplicated replacement of devices. This allows reducing production downtimes, caused by failures of these devices, to a minimum.

Failures in the drive controller are displayed by means of diagnostic messages. According to the diagnostic error message, the measure "replacing the controller" can be indicated.

i   See documentation "Troubleshooting Guide" (description of diagnostic messages for IndraDrive)

The sequence of the replacement of devices is described in the documentation "Project Planning Manual for Power Sections".

Note:	IndraDrive controllers are delivered completely with the control section and should be replaced completely, too. Only Bosch Rexroth service engineers or especially trained users are allowed to replace the control section separately. Only service engineers are allowed to replace optional modules of the control section.

Immediately after the device has been replaced and

• the operating data saved before have been loaded

- or -

• the MultiMediaCard (MMC) possibly plugged in the defective device has been plugged in the replacement device

the drive is operational again because it is not required to repeat the adjustment of the drive to the machine.

Note:	When using the drive-internal safety technology, particular instructions have to be observed for replacing a device!
	See separate documentation "Integrated Safety Technology"

How to Replace Controllers

Procure Replacement Device   Identify defective controller by means of type plates; procure controller of same type from Bosch Rexroth!

The following type designations have to match:

• type designation of power section

• type designation of control section

Note:	Ideally the firmware type designation of the replacement device should also comply with that of the defective device.
	If the available replacement device has a different firmware type designation (differences in version and release), the same firmware as the one active in the defective device has to be loaded to the replacement controller!

The type designations can be seen on the adhesive labels at the power section and control section (see also documentation for the respective device component).

The firmware type active in the device can be shown on the display of the control panel.

See "Control Panel of the IndraDrive Controllers" in chapter "Handling, Diagnostic and Service Functions"

Fill Out Fault Report

A fault report form to be copied can be found in the documentation "Project Planning Manual for Power Sections or Control Sections". Please copy this fault report, fill it out carefully and completely and enclose it to the defective device! The fault report filled out completely supports quick handling of repair and helps recognizing application-related failure causes.

Replacing a Device with Stationarily Plugged MMC

Saving Parameter Values

When the device having a stationarily plugged MMC is switched off (MMC used as "programming module"), the current parameter values are automatically saved on the MMC.

Replace Controller

Replace the controller in the following steps:

1. De-energize drive; wait for DC bus to discharge!
2. Take MMC out of device to be replaced and plug it in new device!

⚠ **DANGER**

Live conductor bars (higher than 50 V), even if mains voltage switched off!
Electric shock when touching!
⇒ Wait for the DC bus (L+/L-) to discharge; before touching the conductor bar check whether below 50 V!

ℹ Notes on how to mount and dismount the controller see documentation "Project Planning Manual for Power Sections"!

Put Controller Into Ready-For-Operation Status Again

Put machine into ready-for-operation status again according to machine manufacturer's instructions; then switch on control voltage!

Depending on the previous configuration of the replacement device, the following messages can appear during the booting phase:

Firmware Download

- "Firmware update?"

Acknowledge this message by pressing the "Enter" button of the control panel. The firmware download is then running, the respective messages are appearing.

The drive then is in the booting phase again and the display reads:

Loading Parameter Values

- "Load new Param.?"

Acknowledge the message by pressing the "Enter" button of the control panel. The drive then completes the booting phase and in communication phase "P1" waits for further actions of the control master.

Note: The drive is now running again with the same firmware and the same parameter values as before the device was replaced. The absolute position data reference of measuring systems is maintained!

When the MMC was not plugged in the controller before the control voltage is switched on, the following message is displayed:

- "Load new Param.?".

In this case switch the control voltage off, plug the MMC of the defective device in the replacement device and then switch the control voltage on again.

Note: The message "Load new Param.?" does not always appear when the MMC hasn't been plugged (depending on the previous configuration of the replacement device)!

Replacing a Device without Stationarily Plugged MMC

An MMC temporarily plugged in the controller can be used as update medium for firmware and as update and backup medium for parameter values.

Save Parameter Values   Before dismounting defective device save drive parameter values, if possible. To do this, switch drive off and on again, then save parameter values in communication phase "P2".

Parameter values of defective device can be saved via:

- **Control panel of the controller with temporarily plugged MMC ("hot plug")**
  By pressing the buttons on the control panel in a certain order **C2600 Copy data from flash to MMC command** (P-0-4092) can be started. By doing this 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)**] are copied from the controller-internal memory to an MMC temporarily plugged in the controller.

Note: If the MMC does not remain stationarily (permanently) plugged in the device, it may be temporarily plugged **in the switched-on device after the booting phase** and removed again ("hot plug" or "hot unplug").

See also "Control Panel of the IndraDrive Controllers" in chapter "Handling, Diagnostic and Service Functions"

- **"DriveTop" commissioning tool**
  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.

Replace Controller   De-energize drive; wait for DC bus to discharge!

> ⚠ **Live conductor bars (higher than 50 V), even if mains voltage switched off!**
>
> Electric shock when touching!
>
> **DANGER**   ⇒ Wait for the DC bus (L+/L-) to discharge; before touching the conductor bar check whether below 50 V!

ℹ   Notes on how to mount and dismount the controller see documentation "Project Planning Manual for Power Sections"!

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Put Controller Into Ready-For-Operation Status Again

Put machine into ready-for-operation status again according to machine manufacturer's instructions; then switch on control voltage!

Depending on the previous configuration of the replacement device, the following message can appear during the booting phase:

- "Load new Param.?"

Acknowledge this message by pressing the "Enter" button of the control panel. The drive then completes the booting phase and in communication phase "P1" waits for further actions of the control master.

Load Firmware

First load the same firmware as installed before replacing the device to the replacement device (if it is not already available there). The firmware can be loaded via:

- **Control panel of the controller with temporarily plugged MMC ("hot plug")**

Note: The MMC may only be plugged in its slot at the device when the booting process has been completed (communication phase > "P1"). Otherwise it is possible that axis-specific drive parameters are overwritten with incorrect values!

By pressing the buttons on the control panel in a certain order the command **C2900 Firmware update from MMC** (P-0-4072) can be started. By doing this the firmware is loaded from the plugged MMC to the controller. At the end of the loading process the display reads "End C29". Now switch the drive off and, after the MMC has been removed, switch it on again (without plugged MMC, see note)!

See also "Control Panel of the IndraDrive Controllers" in chapter "Handling, Diagnostic and Service Functions"

- **Service program "Dolfi"**
  By selecting the respective menu item, the firmware stored on an external data carrier (hard disk, floppy disk or the like) is loaded to the controller (serial communication with the controller).

Load Parameter Values (Saved Before Replacing Device)

The axis-specific parameter values saved before replacing the device can be loaded via:

- **Control panel of the controller with temporarily plugged MMC ("hot plug")**
  By pressing the buttons on the control panel in a certain order the command **C2500 Copy IDN from optional memory to internal memory** (P-0-4091) can be started. By doing this the parameter values stored on the MMC [according to **S-0-0192, IDN-list of backup operation data** and **P-0-0195, IDN list of retain data (replacement of devices)**] are loaded to the internal flash memory.

  See also "Control Panel of the IndraDrive Controllers" in chapter "Handling, Diagnostic and Service Functions"

- **"DriveTop" commissioning tool**
  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 lists S-0-0192 and P-0-0195 are loaded to the controller (serial communication with the controller or via SYSDA/SERCOS interface).

- **Control master**
  The parameter values saved immediately before the replacement of the device on a master-side data carrier (according to list parameters S-0-0192 and P-0-0195) are loaded to the controller by the control master.

Load Parameter Values in Case of Total Breakdown of Device

If it should have been impossible to save the parameter values according to the list parameters S-0-0192 and P-0-0195 immediately before replacing the device (total breakdown of device), the parameter values saved after initial commissioning have to be loaded.

Note:	In the case of drives with absolute value encoder and modulo format, the position data reference has to be established again after having loaded the parameter values saved after initial commissioning, even if the actual position values are signaled to be valid via **S-0-0403, Position feedback value status**!

WARNING

The parameter values saved after initial commissioning are not generally suited for reestablishing the operatability of the drive after replacement of devices!

⇒ Check actual position values and active target position before drive enable!

Put Machine Into Ready-For-Operation Status

Reestablish ready-for-operation status of the machine:

- put machine into ready-for-operation status again according to machine manufacturer's instructions
- check functions of drive

10.8 Enabling of Functional Packages

Brief Description

The scope of functionality of the IndraDrive firmware can be scaled by the user. This allows adjusting the scope of firmware functions to the respective requirements and, if necessary, reducing its complexity.

The drive functionality is scaled by licensing (enabling) optional expansion packages that are available in addition to the standard base package of the respective IndraDrive firmware.

Note:	In the case of drives of double-axis design (firmware variant MPD), it is only possible to enable the same functional packages for both axes. In case the enabling for drive 1 is changed, the enabling for drive 2 is automatically changed, too.

See also "Functional Packages" in chapter "System Overview"

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

- **C0101 Invalid parameters (->S-0-0021)**

Functional Description

Changing the Active Functional Package Selection

The functionality of the drive firmware is divided into several functional packages. By enabling certain packages it can be adjusted to the requirements of the respective application.

Basically there are the following possibilities of subsequent scaling of the drive functionality:

- **reducing** the already licensed scope of functions in order to reduce the complexity of the firmware
- **expanding** the scope of functions originally ordered (additional licensing)

Note: Non-licensed functional packages mustn't be used. Enabling functional packages which aren't part of the originally ordered scope of functions requires additional licensing that is not free of charge! If you use a non-licensed function, any guarantee on the part of Bosch Rexroth will expire.

The count of the operating hours counter at the change of access enable for functional packages is stored in parameter P-0-2002. The Bosch Rexroth staff can therefore provide evidence of non-licensed drive functions that have been enabled.

Parameter P-0-2003 is available for selecting the functional packages; parameter P-0-2004 for displaying the activated packages.

The following assignment applies:

Bit No.	Name of package (bit = 1 → package is selected)	Rules for selection via P-0-2003
0	base package "open-loop"	select one package (alternative selection)
1	base package "closed-loop"	
2	not used	
3	not used	
4	expansion package "servo"	select one package (alternative selection) or all bits = 0
5	expansion package "synchronization"	
6	expansion package "main spindle"	
7	not used	
8	not used	
9	additional package "IndraMotion MLD-S"	additive selection (yes/no)
10 to 31	not used	

Fig. 10-20:   Selection of functional packages

Example   Enabling the base package "closed-loop" and the expansion package "servo", for example, requires the following setting in P-0-2003:

- bit 1 = 1   for the base package "closed-loop"
- bit 4 = 1   for the expansion package "servo"

→ P-0-2003 = 0x0012

These settings are displayed in parameter P-0-2004, in case parameter P-0-2003 is changed they are only displayed after repeated booting process.

The figure below illustrates the interaction of the parameters involved in enabling of functional packages.
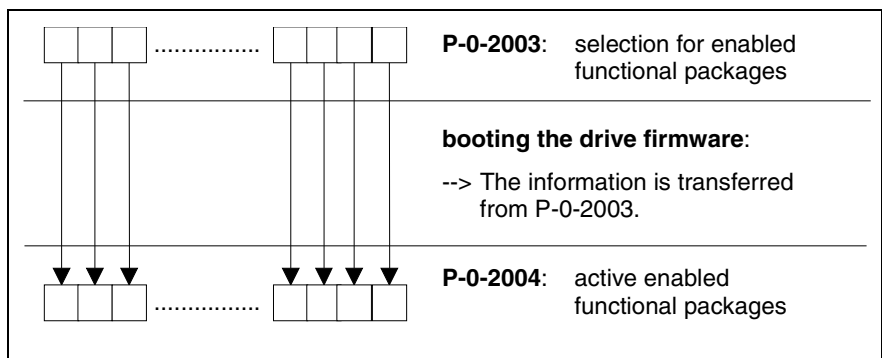
Fig. 10-21:   Overview of parameters for functional package selection

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**.

Note: Bosch Rexroth can at any time provide evidence of non-licensed functional packages that have been enabled subsequently.

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For input in **P-0-2003, Selection of functional packages** there presently are the following possible combinations:

Open-Loop Packages

- **open-loop** without expansion packages — P-0-2003 = 0x0000 000**1**
- open-loop with **synchronization (SNC)** — P-0-2003 = 0x0000 00**21**
- open-loop with **IndraMotion MLD-S (ML)** — P-0-2003 = 0x0000 0**2**01
- open-loop with **synchronization + IndraMotion MLD-S** — P-0-2003 = 0x0000 0**221**

Closed-Loop Packages

- **closed-loop** without expansion packages — P-0-2003 = 0x0000 000**2**
- closed-loop with **servo (SRV)** — P-0-2003 = 0x0000 00**12**
- closed-loop with **synchronization (SNC)** — P-0-2003 = 0x0000 00**22**
- closed-loop with **main spindle (MSP)** — P-0-2003 = 0x0000 00**42**
- closed-loop with **IndraMotion MLD-S (ML)** — P-0-2003 = 0x0000 0**2**02
- closed-loop with **servo + IndraMotion MLD-S** — P-0-2003 = 0x0000 0**212**
- closed-loop with **synchronization + IndraMotion MLD-S** — P-0-2003 = 0x0000 0**222**
- closed-loop with **main spindle + IndraMotion MLD-S** — P-0-2003 = 0x0000 0**242**

Note: 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 functional packages that are not required are reset (deactivated) in parameter **P-0-2003, Selection of functional packages**.

Subsequent Expansion (Additional Licensing)

The required functions are normally licensed by ordering the IndraDrive firmware. At delivery, the licensed functions are indicated as firmware type on the type plate of the control section and in addition internally registered by Rexroth.

Note: Bosch Rexroth can at any time prove which scope of functions had been activated and thus licensed at delivery. If you use a non-licensed function, any guarantee on the part of Bosch Rexroth will expire!

In individual cases it is possible make an additional licensing, if you whish to enable other functions than the ones contained in the ordered and paid functionality. The procedure is described in the following section "Notes on Commissioning".

Notes on Commissioning

Condition As Supplied

When a drive is delivered, there have basically all licensed functional packages been enabled. The contents of the parameters P-0-2003 and P-0-2004 describe the maximum usable scope of firmware functions defined by the purchase order.

Note:	The firmware type printed on the firmware type plate has to comply with the content of parameter **S-0-0030, Manufacturer version**. The content of parameter S-0-0030 can be read via the standard control panel (see "Control Panel of the IndraDrive Controllers").

The example below shows the relation between content of S-0-0030 and type plate:

Example
- Content of S-0-0030: FWA-INDRV*-MPH02V09-MS-CL-SNC-ML
- Imprint on type plate: FWA-INDRV*-MPH02V09-MS-CL-SNC-ML

Reducing the Functionality

The scaling is made by deactivating functional packages via an entry in parameter **P-0-2003, Selection of functional packages**.

This change can be made by directly writing data to the parameter via the master communication or the respective dialog in the "DriveTop" 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**.

Note:	A change in parameter P-0-2003 only takes effect after repeated booting process. The active functional packages are displayed in P-0-2004.

Additional Licensing (Expansion of Functionality)

If the firmware originally ordered and delivered does not contain all required functions, it is possible to subsequently enable further functional packages. This requires additional licensing that is not free of charge.

Note:	For test purposes it is possible to enable non-licensed functional packages via P-0-2003 for a limited time (max. 2 weeks). If you use a non-licensed functional package permanently, any guarantee on the part of Bosch Rexroth will expire!

How to Proceed for Additional Licensing

For additional licensing proceed as follows:

1. enable required functional packages in P-0-2003
2. boot drive again and verify content of P-0-2004
   (content must comply with that of P-0-2003!)
3. see parameter **S-0-0030, Manufacturer version** for firmware type and write it down; this parameter displays current firmware configuration defined via P-0-2003

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4. see **P-0-1511, Circuit board code control section** (list element 3) for serial number of control section and write it down

5. send purchase order to Bosch Rexroth indicating serial number (from P-0-1511) and desired firmware configuration (from S-0-0030)

6. receive adjusted firmware type plate from Bosch Rexroth to stick it on type plate of control section so that content of S-0-0030 complies with firmware description on type plate

If there hasn't any functional package been previously enabled by the customer, the additional licensing can start with step 4. In step 5 the desired new firmware configuration then cannot be read from S-0-0030, but has to be taken from the overview of firmware types (see "Firmware Types That Can Be Ordered" in chapter "System Overview: Functional Packages").

Note:	For handling the purchase order please contact your Bosch Rexroth sales representative!

Scope of Supply   The scope of supply consists of

*   ordered new firmware type as FWA file incl. parameter file (as files or on MMC)

*   adjusted firmware type plate (to stick on)

Monitoring the Enabling of Functional Packages

As regards the enabling of functional packages, a check is run in the transition command from phase 2 to phase 3 (cf. **S-0-0127, C0100 Communication phase 3 transition check**) to find out whether several alternative packages have been selected simultaneously. If yes, the error message C0101 is generated and the parameter IDN "P-0-2003" is entered in the list parameter **S-0-0021, IDN list of invalid operating data for communication phase 2**.

i   See also Troubleshooting Guide for "C0101 Invalid parameters (-> S-0-0021)"

10.9 Extended Diagnostic Possibilities

Monitoring Function

Brief Description

Note:	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 makes the following possibilities available:

- displaying memory ranges
- changing storage locations
- writing/reading EEPROM memory cells (controller and encoder)
- adjusting analog measured values
- displaying internal system states
- executing several test routines for software and hardware

Note:	Using the monitoring function requires a VT100 terminal, an ANSI terminal or a corresponding emulation. It is recommended to have a 132-column display.

Notes on Commissioning/Operation

Serial Interface Connection to the drive is realized via the serial interface. The setting has to be made in accordance with the parameterization of the serial interface in the drive (parameters P-0-4021, P-0-4025, P-0-4095).

Default settings of the serial interface:

- 9600 baud
- 8 data bits
- no parity
- 1 stop bit
- hardware protocol

Opening the Communication Channel After starting the terminal (Windows hyper terminal) and the drive, there isn't any output appearing on the terminal.

In order to establish connection to the drive, the following input is required:

> **- BCD:**<*drive address*>

The drive address corresponds to the number set in parameter P-0-4025 (or can be read on the display, default address in "99"). The drive now responds with:

> "***E***<*drive address*>**:>**"

Note:	After the input there isn't any "echo" appearing on the terminal (i.e. the input is invisible when the local echo of the terminal was disabled).

In order to get to the monitoring mode, now enter

>*"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> "*.

Note: The monitoring function was started!

Operation   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"*

Sub menus are called like normal commands. The sub menu is exited with:

>*"exit"*

Note: With the "exit" command the monitoring mode is exited, too, and the drive switches to normal RS232 communication again.

The content of the screen can be cleared with command

>*"cls"*

Logbook Function

Brief Description

A logbook function is realized in the drive firmware in order to obtain a detailed diagnostic error message in the case of error. The information provided by the logbook function allows reproducing the internal firmware sequence, if required.

Pertinent Parameters

- **P-0-0478, Logbook event**
- **P-0-0479, Logbook time stamp**

Functional Description

The list parameters **P-0-0478, Logbook event** and **P-0-0479, Logbook time stamp** are organized as ring buffers and can contain 128 elements. The entries in these parameters are realized automatically by the controller subject to internal states. The entry in P-0-0478 marks the event (or the status); the time of the entry is stored in P-0-0479.

Content and Format of the Logbook Entries   The entries in parameter P-0-0478 are hexadecimal numbers with the following assignment:

- **bits 31 to 16** → module code
- **bits 15 to 0**   → internal diagnosis key

The displayed values of this parameter can only be interpreted with internal knowledge of the drive firmware.
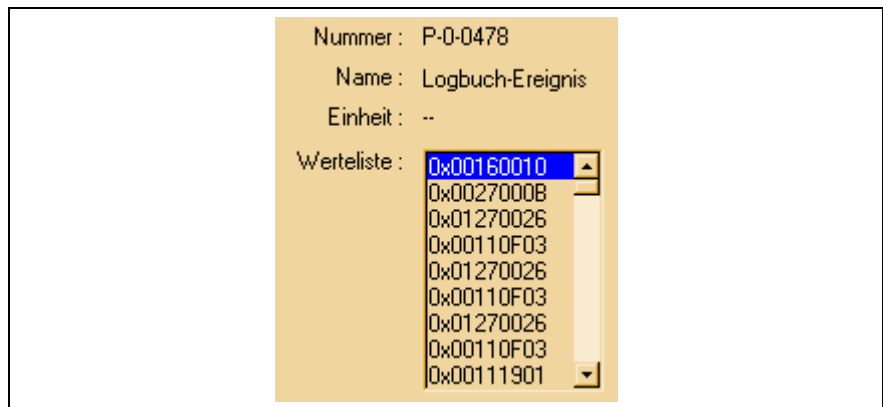
Fig. 10-22: Logbook entries (example)

Note: Each time the control section is switched on "0xFFFFFFFF" is entered in P-0-0478 as a separator in order to mark the "new start".

The entries in P-0-0479 contain the operating hours of the control section in seconds at the time of the respective event.
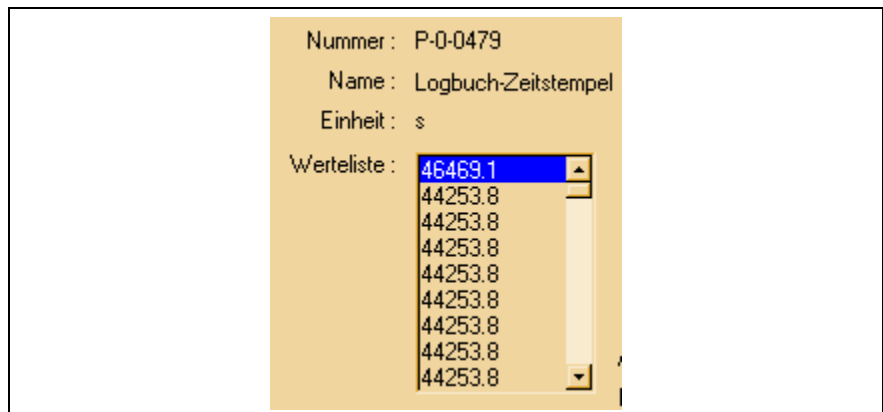
Fig. 10-23: Content of parameter P-0-0479 (example)

Patch Function

Brief Description

For reading and writing any storage location (or internal variable) as a data object via the master communication, the analog output or the oscilloscope feature, the patch function can be used.

In conjunction with the analog output or the oscilloscope feature this functionality can be used for locating errors.

Note: As it is a function for exclusive use by the development staff, the patch display parameters P-0-0485 and P-0-0491 are read- and write-protected with the master password. The contents of these parameters are **not stored in the flash** but are lost when the drive is switched off.

Pertinent Parameters

- **P-0-0480, Patch function 1, source pointer**
- **P-0-0481, Patch function 1, attribute**
- **P-0-0482, Patch function 1, bit mask**
- **P-0-0483, Patch function 1, exponent**
- **P-0-0485, Patch function 1, display**
- **P-0-0486, Patch function 2, source pointer**
- **P-0-0487, Patch function 2, attribute**
- **P-0-0488, Patch function 2, bit mask**
- **P-0-0489, Patch function 2, exponent**
- **P-0-0491, Patch function 2, display**

Functional Description

Read Access (Displaying Internal Storage Locations/Signals)

The patch function allows transforming any storage location into a data object that can be read via the master communication. To do this, a storage location is preset via the parameters **P-0-0480, Patch function 1, source pointer** and **P-0-0486, Patch function 2, source pointer**. The access to this address is configured via bits 0 to 2 of the parameters **P-0-0481, Patch function 1, attribute** and **P—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.

Note:	If you want to change the access mode via bits 0 to 2 of the patch attribute parameters (P-0-0481/P-0-0487), this is only possible if the patch source pointer that has just been set (P-0-0480/P-0-0486) allows the new access mode (see table).

	possible access to source addresses that ...		
access as...	can be divided by 4 (DWORD-aligned)	can be divided by 2, but not by 4 (WORD-aligned)	do not have any particular alignment (BYTE-aligned)
INT4	✓	X	X
INT2	✓	✓	X
INT1	✓	✓	✓
FLOAT8	✓	X	X
FLOAT4	✓	X	X

✓:   access allowed
X: access prohibited

Fig. 10-24: Possible access modes

The desired display format is set via bits 4 to 7 of the patch attribute parameters (P-0-0481/P-0-0487). This allows interpreting the value read as a decimal number with or without sign, as a hexadecimal number or as

a binary number. When selecting "BOOL" as the display type, "1" is output when a value unequal zero was read, otherwise "0" is displayed.

The processing of the values read is illustrated on the diagram in Fig. "Sequence diagram of the patch function "read storage location"". If a storage location is read as integer and output in a non-float format, the value read is ANDed with the bit mask set via the patch bit mask parameters (P-0-0482/P-0-0488). The standard setting of this mask is 0xFFFFFFFF so that the value read is not changed.

When a storage location is read as a float value and a non-float format is selected for display, the value read is multiplied with $10^{-exponent}$. This allows making an adjustment to the displayed value range (-2147483648 to 2147483647, value range of a "signed int"). The exponent can be set via the parameters **P-0-0483, Patch function 1, exponent** or **P-0-0489, Patch function 2, exponent**.

Note:	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. The sequence of write access is illustrated in Fig. "Sequence diagram of the patch function "write 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).

Note:	Please observe that in the "BOOL" display mode it is impossible to write the storage location because it is impossible to assign an unequivocal numeric value to the value "TRUE" (displayed as "1"). Any value unequal zero is interpreted as "TRUE".

Note:	As in the case of read access, odd addresses in the case of write access are only allowed in the INT1 mode. In contrast to read access, the write access is directly carried out as a byte access. You should therefore avoid activating addresses outside the DRAM in this way because this can lead to undefined hardware behavior.

Examples of Application

Using the Patch Function in Conjunction with the Analog Output

In conjunction with the "analog output" function it is possible to transmit the content of a storage location to an analog output. To do this, the IDN of the desired patch display (P-0-0485/P-0-0491) has to be entered in one of the parameters **P-0-0420, Analog output 1 signal selection** or **P-0-0423, Analog output 2 signal selection**.

Note:	Please observe that changes in the patch attributes (P-0-0481/P-0-0487) are not automatically transmitted to the parameters P-0-0418/P-0-0419 and P-0-0422/P-0-0425. After a change in the patch attribute you should therefore write the parameters P-0-0420/P-0-0423, P-0-0418/P-0-0419 and P-0-0422/P-0-0425 again.

See also "Analog Outputs" in chapter "Extended Drive Functions"
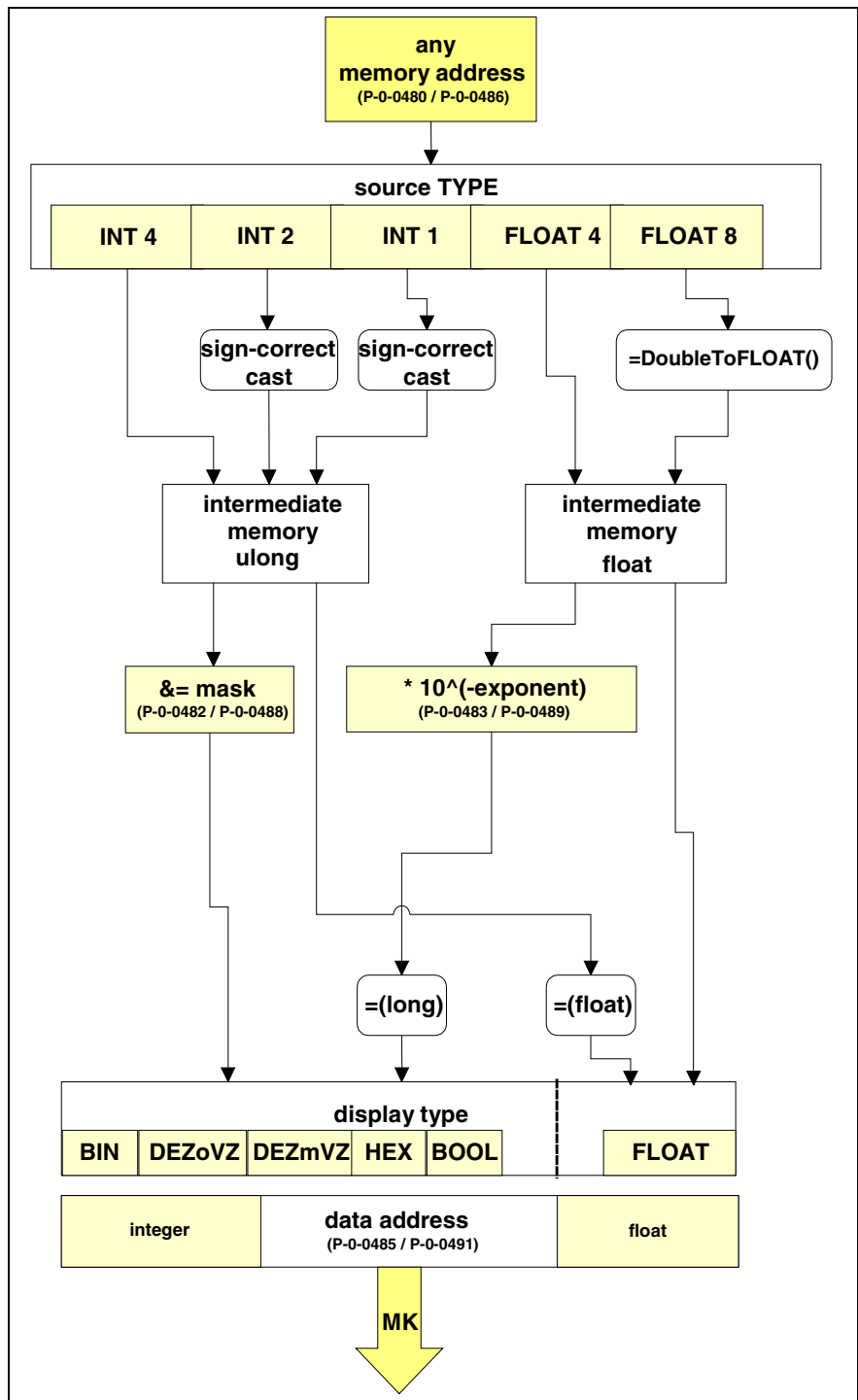
Fig. 10-25: Sequence diagram of the patch function "read storage location"
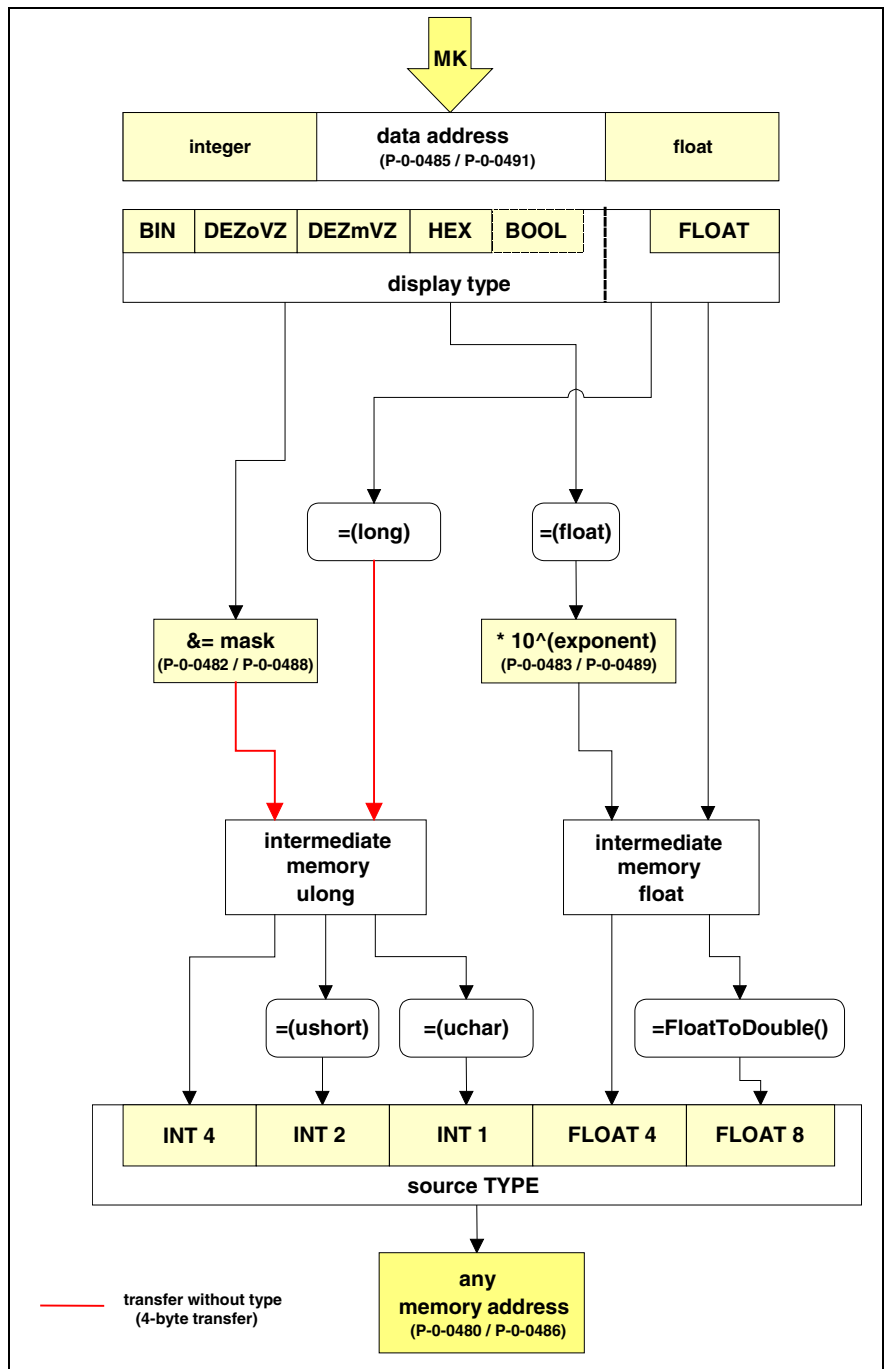
Fig. 10-26: Sequence diagram of the patch function "write storage location"

10.10 Oscilloscope Function

Brief Description

The oscilloscope function can be used to record drive-internal and external signals and status variables (parameter contents). This function can be effectively used both for initial commissioning and debugging. Its functionality can be compared to that of a 4-channel oscilloscope.

The total scope of the oscilloscope function is divided into the following function blocks:

- **recording measured values**
  It is possible to record 4 channels at the same time, the signals being selected by configuration of signal selection lists (IDN lists).

- **configuration (basic settings)**
  The control/status block determines the basic functions (start/stop, time resolution, size of memory, operating mode). The current status (status diagram) of the oscilloscope is continuously transmitted to the master.

- **trigger function**
  Besides extensive trigger functions, the drive provides the possibility of triggering at different signals and events in the drive.

Features

The oscilloscope function is characterized by the following features:

- **recording measured values**
  - 4 channels, each with a maximum of 8192 measuring values
  - time resolution to be freely selected in steps of the position loop clock (Advanced: T = 250 µs, Basic: T = 500 µs)
  - signal selection by indicating the IDN of the respective parameter

- **configuration (basic settings)**
  - 4-channel display in "DriveTop" (DTOP16)
  - more than 100 different measuring and trigger signals (cf. P-0-0149)
  - expanded oscilloscope feature using patch function

- **trigger function**
  - trigger signal selection by indicating the parameter IDN
  - internal trigger or external trigger
  - external trigger with trigger offset determination for synchronizing multiple-axis measurements
  - unit of trigger level adjusting to trigger signal selection
  - possibility of triggering at internal memory contents with patch signal

Pertinent Parameters

Control/Status
- **P-0-0028, Oscilloscope: control word**
- **P-0-0029, Oscilloscope: status word**
- **P-0-0031, Oscilloscope: time resolution**
- **P-0-0032, Oscilloscope: size of memory**
- **P-0-0149, Oscilloscope: signal selection list**
- **P-0-0150, Oscilloscope: number of valid measured values**

Measuring Channels
- **P-0-0021, Oscilloscope: list of measured values 1**
- **P-0-0022, Oscilloscope: list of measured values 2**
- **P-0-0023, Oscilloscope: signal selection 1**
- **P-0-0024, Oscilloscope: signal selection 2**
- **P-0-0145, Oscilloscope: list of measured values 3**
- **P-0-0146, Oscilloscope: list of measured values 4**
- **P-0-0147, Oscilloscope: signal selection 3**
- **P-0-0148, Oscilloscope: signal selection 4**

Trigger Function
- **P-0-0025, Oscilloscope: trigger mask**
- **P-0-0026, Oscilloscope: trigger signal selection**
- **P-0-0027, Oscilloscope: trigger level**
- **P-0-0030, Oscilloscope: trigger edge**
- **P-0-0033, Oscilloscope: number of measured values after trigger event**
- **P-0-0035, Oscilloscope: control offset**
- **P-0-0036, Oscilloscope: external trigger signal**
- **P-0-0037, Oscilloscope: internal trigger signal**

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General Information on the Oscilloscope Function

Sequence of a Measurement/Status Diagram
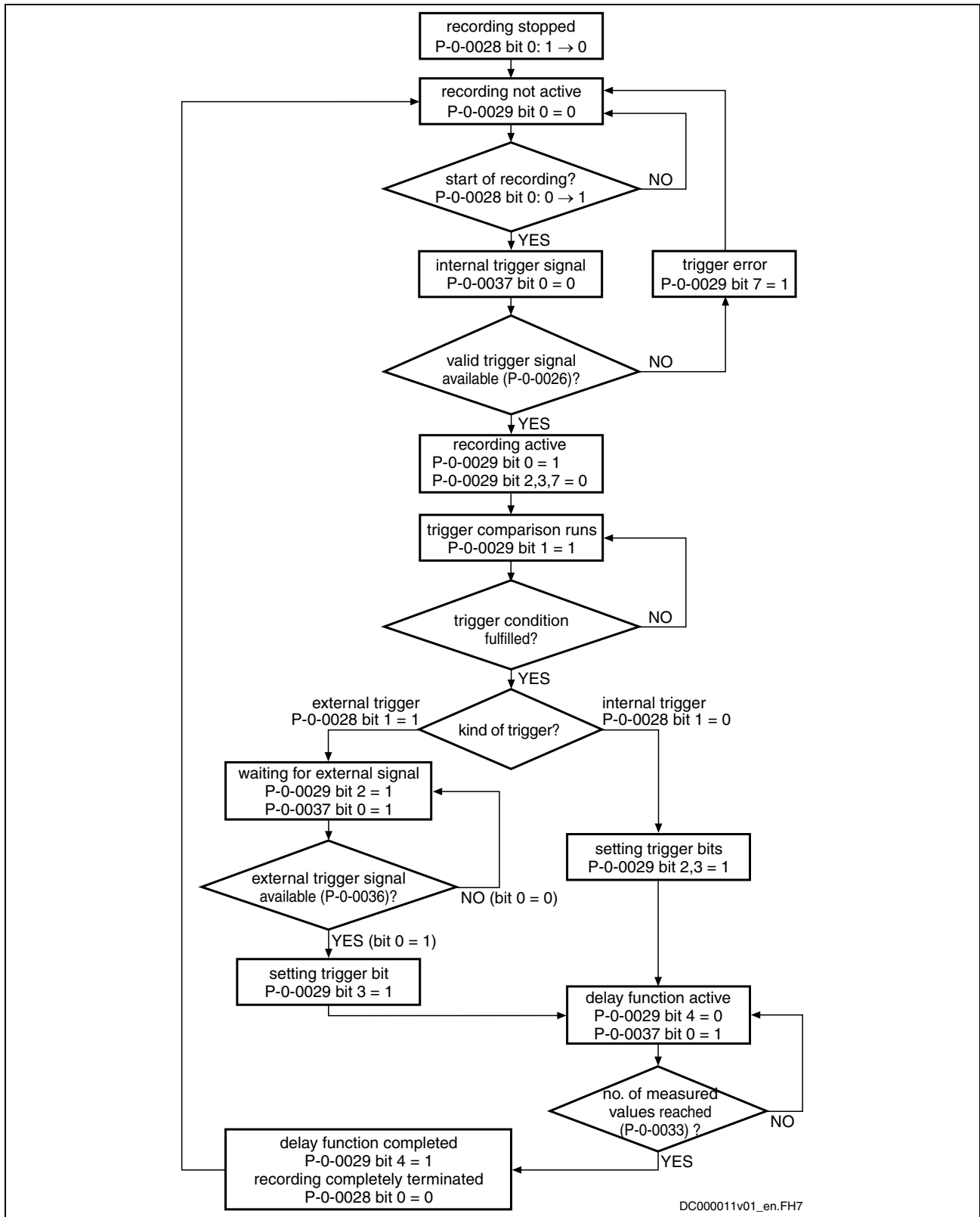
Fig. 10-27: Status diagram of oscilloscope function

Configuring the Measured Value Channels

A measured value channel is configured by inputting the IDN of the desired parameter in the respective signal selection parameter:

- **P-0-0023, Oscilloscope: signal selection 1**
- **P-0-0024, Oscilloscope: signal selection 2**
- **P-0-0147, Oscilloscope: signal selection 3**
- **P-0-0148, Oscilloscope: signal selection 4**

Signal Selection List (P-0-0149)   All IDNs contained in parameter **P-0-0149, Oscilloscope: signal selection list** can be input.

The parameter P-0-0149 contains all parameters that are suitable as trigger signal (P-0-0026) or measuring signal (P-0-0023, P-0-0024, P-0-0147, P-0-0148). By reading P-0-0149 the master can recognize the signals that can be recorded in the drive.

Note: At present, all cyclically configurable parameters (> 100) are contained in the list!

Example of Signal Selection   Example of the signal selection of the oscilloscope function:

- **S-0-0051, Position feedback 1 value** is selected as signal to be recorded
- actual position value of encoder 1 (S-0-0051) is written to parameter **P-0-0023, Oscilloscope: signal selection 1**

$\rightarrow$ when the limiting conditions occur, actual position value of axis 1 is recorded in the oscilloscope and transmitted to the master
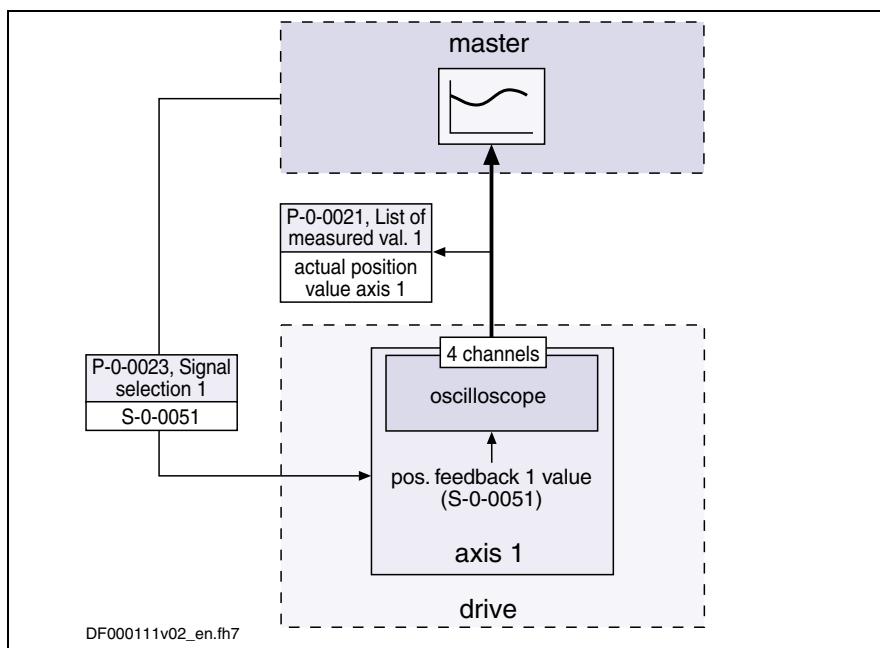
Fig. 10-28:   Example of signal selection

Expanded Oscilloscope Function (Patch Function)

Besides the recording of parameter contents via the oscilloscope function, the drive provides the possibility of recording any internal signal, i.e. memory address (patch function).

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Note:	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).

Note:	The patch function has to be parameterized before the assignment as trigger or measuring signal.

See also "Extended Diagnostic Possibilities: Patch Function" in the same chapter

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

By setting bit 0 in P-0-0028 the oscilloscope function is activated, i.e. the recording of measured values of the selected signal starts. The oscilloscope function waits for the selected trigger edge or level to occur. At detection of a valid edge the measured values keep being written to the measured value memory until the number of measured values defined in parameter **P-0-0033, Oscilloscope: number of measured values after trigger event** has been reached (delay function).

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.

Note:	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!

Trigger Function

The drive provides extensive and flexible possibilities of triggering.

Trigger Signal Selection

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**.

Note: If there isn't any valid trigger signal available when the oscilloscope function is activated, bit 7 for "trigger error" is set in parameter **P-0-0029, Oscilloscope: status word**.

The parameter **P-0-0026, Oscilloscope: trigger signal selection** determines which signal is monitored with regard to the parameterized edge reversal or threshold value.

Triggering at Any Signal   Besides the triggering of parameter contents, the drive provides the possibility of recording any internal signal, i.e. memory address (patch function).

Note: 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 **Patch function 2, display** have to be configured in P-0-0026.

See also "Extended Diagnostic Possibilities: Patch Function" in the same chapter

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 **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 the bit "delay function completed" is set (P-0-0029; bit 4). Setting this bit terminates the complete recording. Independent of the trigger source, the bit indicates the end of the recording.

When internal trigger source has been selected, the status bit "trigger function completed" (P-0-0029, bit 3) is set simultaneously with the bit for "internal trigger event" (P-0-0029, bit 2) (see status diagram).
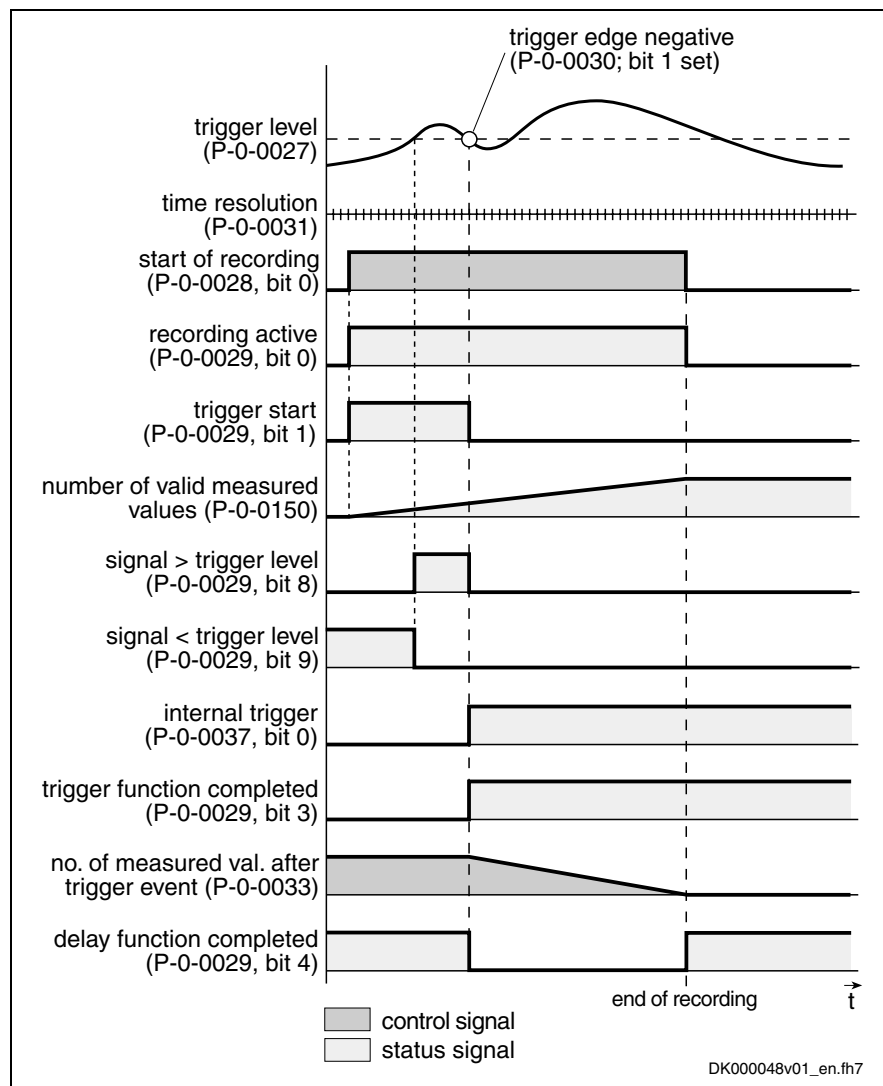
Fig. 10-29: Internal trigger without offset measurement (P-0-0028; bit 1 = 0)

Note: By parameterizing P-0-0036 (external trigger signal) in **P-0-0026, Oscilloscope: trigger signal selection** it is possible to release the internal trigger function by the external trigger input.

External trigger (with Offset Measurement)

When the kind of trigger "external trigger with offset measurement" (P-0-0028; bit 1 = 1) has been selected, the internal and external trigger are used for the master axis.

When "external trigger" has been selected, the behavior, until the internal trigger event has been reached, corresponds to the behavior for the case when trigger source "internal trigger" has been selected. Until the external trigger signal occurs (P-0-0036; bit 0), the trigger offset between both trigger events is determined and displayed in parameter P-0-0035. Then the bit "trigger function completed" (P-0-0029; bit 3) is set in the status word. The rest of the sequence is the same as in the case of internal trigger source without offset measurement.
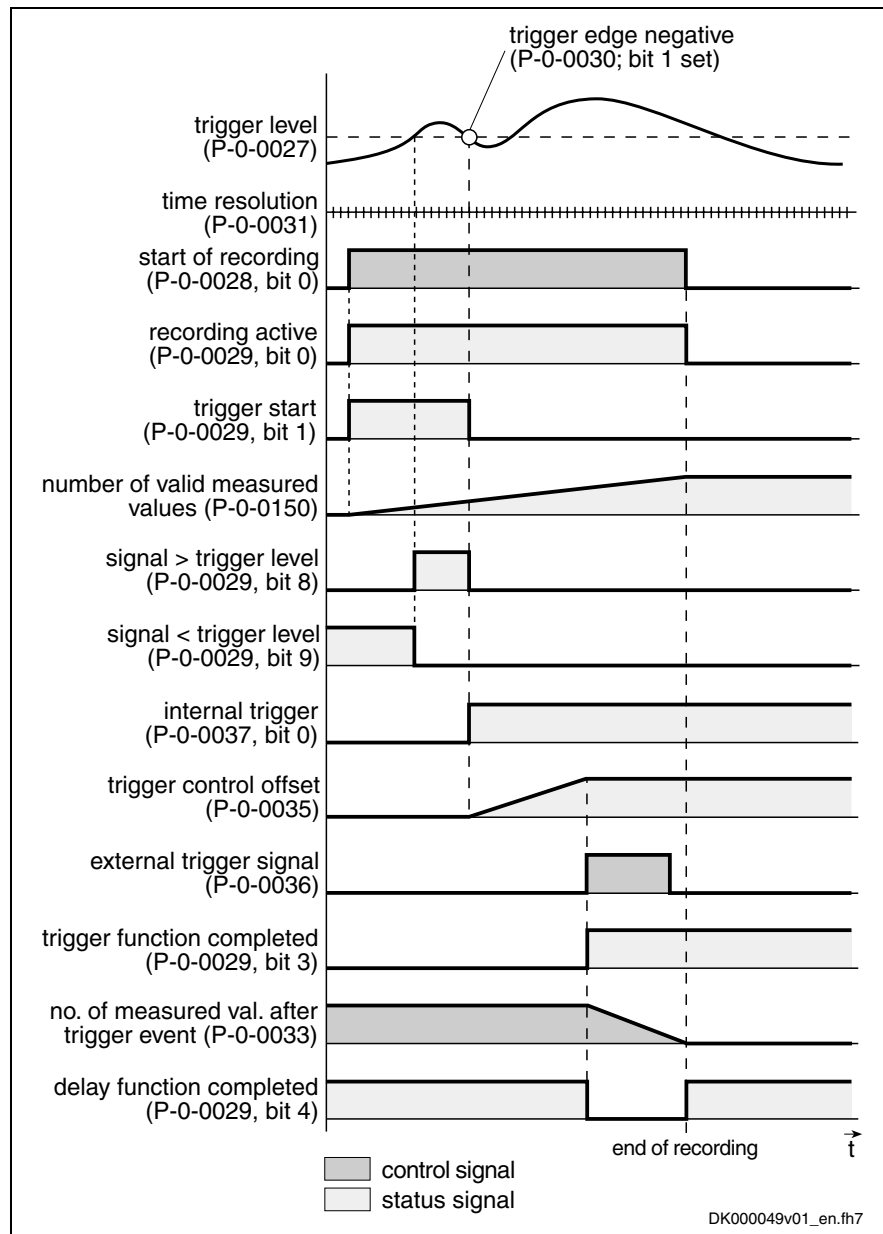
Fig. 10-30: External trigger with offset measurement (P-0-0028; bit 1 = 1)

Note: The use of the external trigger source with trigger offset determination is described in the 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

⚊ℹ⚊ See Parameter Description "P-0-0030, Oscilloscope: trigger edge"

Setting the Trigger Delay

Trigger Delay Function

Via parameter **P-0-0033, Oscilloscope: number of measured values after trigger event** it is possible to reach a trigger delay independent of the preset trigger source (external/internal). For this purpose the number of measured values that is to be recorded after the respective trigger event is set in parameter P-0-0033.

Note: It is also possible to record measured values before the trigger event occurs (trigger delay functions of an oscilloscope).

By entering "0" in P-0-0033 only data available before the trigger event will be recorded.

If the value of parameter P-0-0032 is entered, only the measured values that occurred after the trigger event will be recorded.
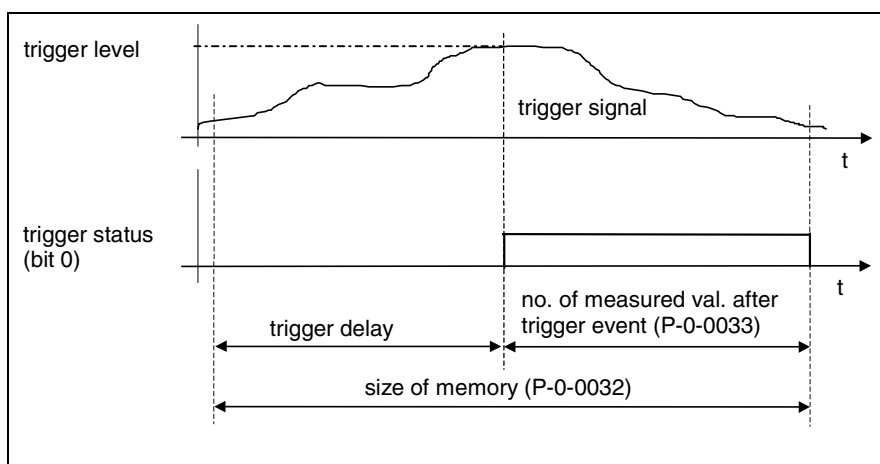
Fig. 10-31: Trigger delay: number of measured values after trigger event

Expanded Trigger Function

Trigger Mask (P-0-0025)

Parameter **P-0-0025, Oscilloscope: trigger mask** provides the possibility of triggering 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.

ℹ️   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.

ℹ️   See Parameter Description "P-0-0027, Oscilloscope: trigger level"

Synchronizing the Measuring Signals of Several Axes

The parameter **P-0-0035, Oscilloscope: control offset** contains the number of measured values between the occurrence of the internal trigger event (P-0-0029; bit 2) and the external trigger event (P-0-0036; bit 0).

Trigger Control Offset (P-0-0035)   The transmission of the trigger event via the master causes a delay between the detection of the trigger event and the release of the trigger. This delay is measured by drive 1 (master drive) and stored in parameter **P-0-0035, Oscilloscope: control offset**. A time-correct display of the signals of several drives can be guaranteed by taking this parameter into account for the visualization of the measured values.

See also above "Internal or External Trigger"
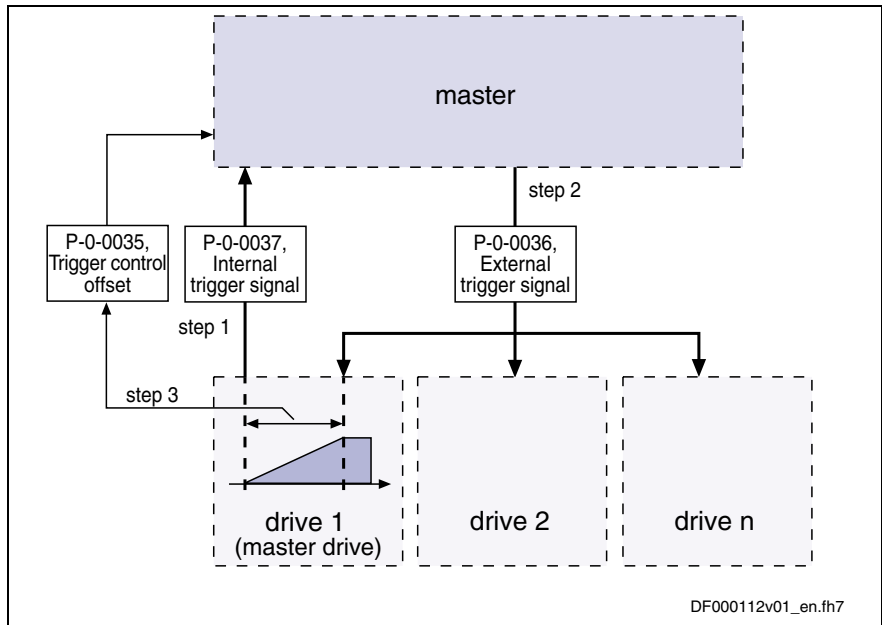
Fig. 10-32: Application for trigger source "external" with determination of trigger offset

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Note: The value in parameter P-0-0035 can be used by the master for synchronizing the measuring signals of several axes with the internal trigger event of the master axis.
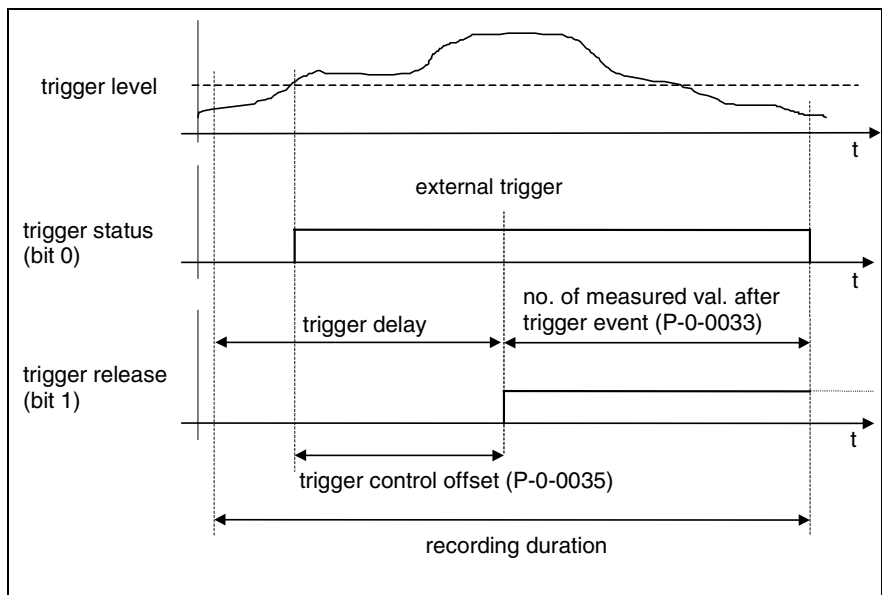
Fig. 10-33: Trigger control offset

<table>
<tr><td>Status of Internal Trigger (P-0-0037)</td><td>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 and control bits to several drives at the same time and to release the trigger.</td></tr>
</table>

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 and control bits to several drives at the same time and to release the trigger.
External Trigger Signal (P-0-0036)	As real-time control information, the parameter **P-0-0036, Oscilloscope: external trigger signal** can be parameterized both in the real-time channel of the interface and as hardware input. This allows triggering at internal signals that are preset via

- the master communication

- or -

- an analog or digital input

Parameterizing the Oscilloscope Function

Recording Duration

The recording duration is determined according to the following relationship:

$$\text{recording duration (in } \mu s) = \text{time resolution (P - 0 - 0031)} \bullet \text{size of memory (P - 0 - 0032)}$$

Fig. 10-34: Determining the recording duration

Parameterizing the Selection of Measured Values

For the oscilloscope function it is possible to select 4 signals that are defined by the IDNs of their respective parameters and assigned to the following parameters:

- **P-0-0023, Oscilloscope: signal selection 1**
- **P-0-0024, Oscilloscope: signal selection 2**
- **P-0-0147, Oscilloscope: signal selection 3**
- **P-0-0148, Oscilloscope: signal selection 4**

Only such parameter IDNs are allowed that are contained in the list parameter **P-0-0149, Oscilloscope: signal selection list**.

Note:	The selected signal (parameter IDN) defines the unit of the data stored in the list of measured values.

Parameterizing the Trigger Function

See above "Trigger Function"

Parameterizing Time Resolution and Size of Memory

The recording range or the recording duration can be adjusted to the measurement requirements via the following parameters:

- **P-0-0031, Oscilloscope: time resolution**
- **P-0-0032, Oscilloscope: size of memory**

Size of Memory of Oscilloscope Function	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 for advanced design, a maximum of 4096 measured values for basic design.

Time Resolution of Oscilloscope Function

Parameter **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 ($T_{osci} = N*T_{pos}$).

The position loop cycle time depends on the control performance (Advanced: $T_{pos} = 250\mu s$; Basic: $T_{pos} = 500\mu s$; N = 1, 2, 3, 4, …).

The control performance in turn depends on the hardware design of the controller and the setting in **P-0-0556, Control word of axis controller** (bit 2).

Diagnostic and Status Messages

Status of the Oscilloscope Function

The parameter **P-0-0029, Oscilloscope: status word** displays the current status of the oscilloscope function.

Parameter P-0-0029 contains, for example, status information on:

- start/end of recording
- trigger function
- status of trigger signal
- delay function

i   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. As real-time control information, this parameter can be parameterized 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.

i   See also Parameter Description "P-0-0150, Oscilloscope: number of valid measured values"

10.11 Serial Communication

Overview of Serial Communication

The serial interface of the drive controller is used as a universal medium of communication for different services. It can be used for master communication (in addition to SERCOS), for reading and writing parameters, for replacing the firmware, for locating errors and for other services. The physical standards used are RS232 and RS485.

Two protocols are supported for serial communication:

- ASCII-based protocol
- SIS protocol (Rexroth-standard serial binary protocol)

Note:	The protocol is automatically recognized by the drive!

The following functions are made possible via the serial interface:

- reading and writing parameters via terminal or commissioning tool (DriveTop) in parallel with the existing master communication
- connecting a control terminal (BTV04)
- downloading firmware via the "Dolfi" 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, Delay answer RS-232/485**
- **P-0-4095, RS-232/485 Parity**

General Information on the Parameter Structure

All parameters of the drive controller are stored in a uniform parameter structure. Each parameter consists of 7 elements. The table below describes the individual elements and the possibilities of access. The following sections will also refer to the parameter structure below.

Element No.	Data block element	Possibility of access
1	IDN	read
2	name	read
3	attribute	read
4	unit	read
5	min. input value	read
6	max. input value	read
7	operating data	read / write

Fig. 10-35: Parameter structure

Interface Mode

The serial interface can optionally be operated in the

- RS232 mode or
- RS485 mode.

Note: Communication via RS485 is only possible in conjunction with an external RS232/485 converter.

Depending on the mode, it is necessary to use different cables (see Project Planning Manual).

Transmission Protocols

Two different protocols are supported on the drive side:

- ASCII protocol
- SIS protocol

When switching on the 24 V supply voltage an automatic protocol detection is activated when receiving signals via the serial interface.

A soon as either

- a valid ASCII start sequence

  or

- a valid SIS telegram

was received the drive internally switches to the respective kind of protocol.

Properties of ASCII Protocol
- transmission rates of 9600 and 19200 baud
- 8-bit ASCII protocol
- no parity bit
- one stop bit

Note: There isn't any telegram frame used but the transmitted ASCII signs are converted and interpreted. It is only necessary to comply with a certain order.

Properties of SIS Protocol
- binary protocol
- checksum test (higher Hamming distance D)
- all telegrams are identified by an unequivocal start character ("0x02")
- defined structure of the telegram frame
- it is possible to activate motions (e.g. jogging)

Functional Principle Independent of Protocol

Basic State After Applying the Control Voltage

After the control voltage has been applied the serial communication in the drive is in the "passive mode". In the passive mode communication is impossible.

Determining the Protocol In order to establish the serial communication with the drive it is necessary to determine the kind of communication (protocol) by

- a CHANGE DRIVE command (in the case of ASCII protocol)

- or -

- a valid SIS telegram (in the case of SIS protocol).

Setting the Drive Address

The drive address of the serial interface is set by writing data to the **P-0-4022, Drive address of serial interface**. parameter.

This can be done, for example, by means of the standard control panel or the "DriveTop" commissioning tool.

Exception:
If the value "256" (default value) was entered in parameter P-0-4022, the device address set in parameter **P-0-4025, Drive address of master communication** is used for serial communication.

RS232 Mode In this mode it is **not obligatory** to set the drive address because only one node is connected (peer-to-peer connection).

Note:	When communicating via the SIS protocol the address 128 is provided for peer-to-peer communication. Independent of the setting in parameter P-0-4022, the address 128 is always valid.

RS485 Mode In the case of communication via RS485 bus, it is obligatory to set the drive address because each bus node is addressed via a specific bus address.

Note:	In order to avoid access conflicts each drive address may be assigned only once.

Communication via RS232 Interface

The RS232 interface is particularly intended to be used for connecting a PC with installed "DriveTop" commissioning tool.

Features

- transmission rates from 9600 to 115,200 Baud

- max. transmission distance 15 m

- ASCII protocol or SIS protocol (8-bit each)

- parity bit according to parameter **P-0-4095, RS-232/485 Parity**

- one stop bit
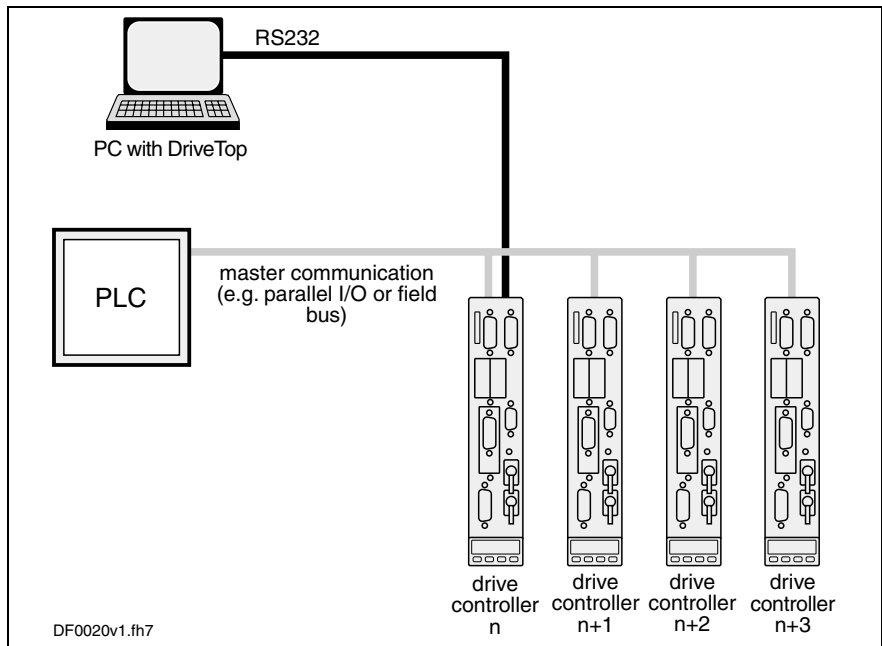
Fig. 10-36: Communication via RS232 interface (example: DriveTop)

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Communication via RS485 Interface

The communication via the RS485 interface allows realizing a serial bus with the following data:

Features

- it is possible to connect up to 31 drives with one bus master

- transmission rates from 9600 to 115,200 Baud

- max. transmission distance 500 m

- semi-duplex operation via 2-wire line

- ASCII protocol or SIS protocol (8-bit each)

- parity bit according to parameter **P-0-4095, RS-232/485 Parity**

- one stop bit

Note: Communication via RS485 is only possible in conjunction with an external RS232/485 converter.

Operating Several Drives with DriveTop

Advantages for Application

- commissioning several drive controllers without plugging the interface cable into a different connection (central parameterization and diagnosis connection)

- realizing a central PC-based visualization unit
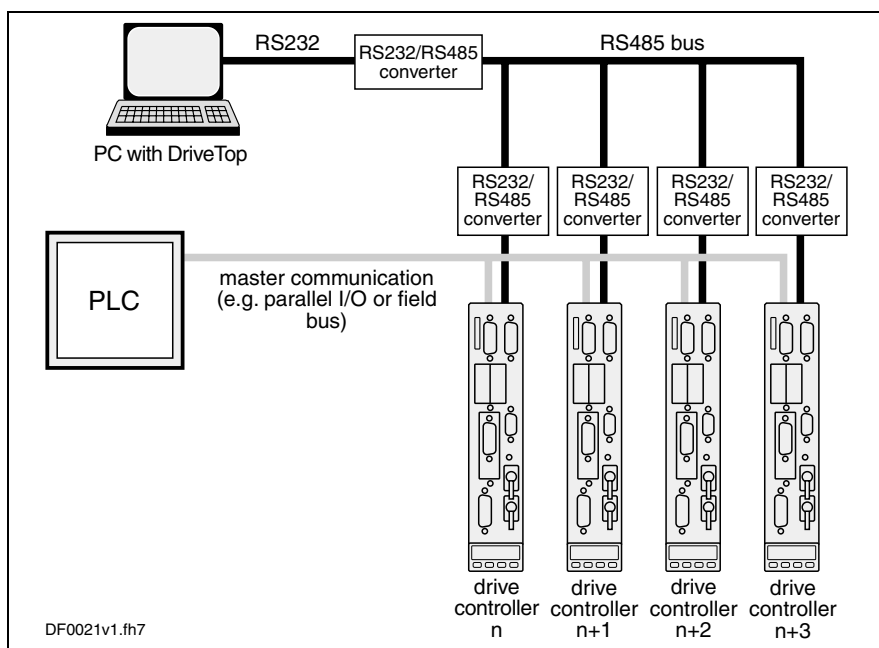
Fig. 10-37:   Operating Several Drives with DriveTop

Parameterization and Diagnosis via a PLC

Advantages for Application

- parameters can be changed via PLC (e.g. adjustment of positioning blocks)

- extended diagnostic possibilities for the PLC by taking over the error code
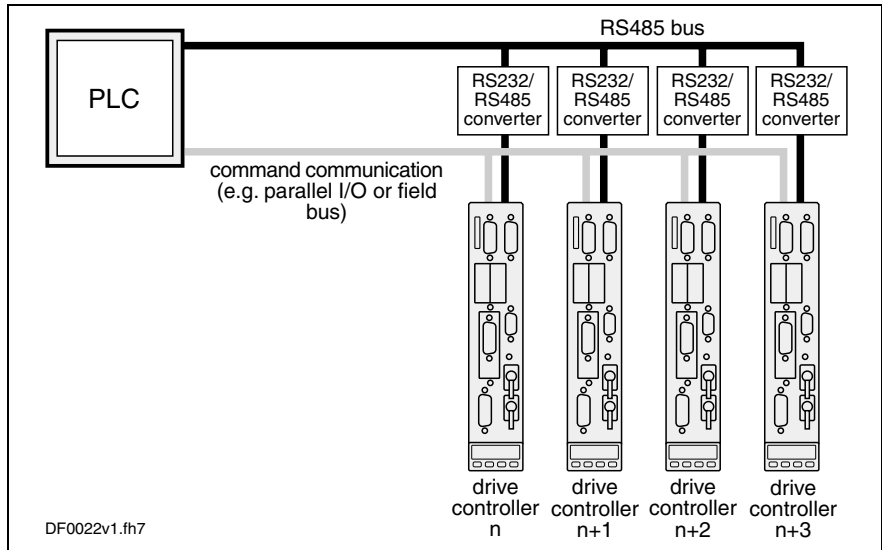
Fig. 10-38: Parameterization and Diagnosis via a PLC

Parameterization and Diagnosis of Drive Groups by an Operator Unit

Advantages for Application

- realizing a central visualization unit
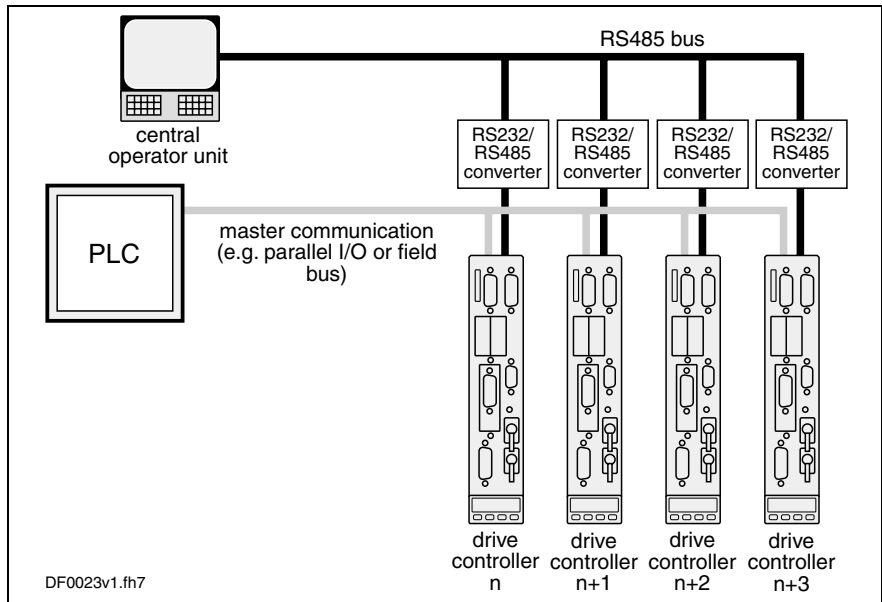
Fig. 10-39: Parameterization and diagnosis of drive groups by an operator unit

Connection System

 See separate Project Planning Manual "Control Sections"

Error Messages in the Case of Serial Communication

The error codes defined in the SERCOS interface specification are used for the different errors (see "Specification SERCOS interface", section 7.4.2.3 "Service channel error messages"). These codes are also used in the case of incorrect access to control and system parameters.

Error code	Description
0x1001	no IDN
0x1009	invalid access to element 1
0x2001	no name
0x2002	name transmission too short
0x2003	name transmission too long
0x2004	name cannot be changed (read only)
0x2005	name is write-protected at this time
0x3002	attribute transmission too short
0x3003	attribute transmission too long
0x3004	attribute cannot be changed (read only)
0x3005	attribute is write-protected at this time
0x4001	no units
0x4002	unit transmission too short
0x4003	unit transmission too long
0x4004	unit cannot be changed (read only)
0x4005	unit is write-protected at this time
0x5001	no minimum input value
0x5002	minimum input value transmission too short
0x5003	minimum input value transmission too long
0x5004	minimum input value cannot be changed (read only)
0x5005	minimum input value is write-protected at this time
0x6001	no maximum input value
0x6002	maximum input value transmission too short
0x6003	maximum input value transmission too long
0x6004	maximum input value cannot be changed (read only)
0x6005	maximum input value is write-protected at this time
0x7002	operation data transmission too short
0x7003	operation data transmission too long
0x7004	operation data cannot be changed (read only)
0x7005	operation data is write-protected at this time (e.g. communication phase)
0x7006	operation data is smaller than the minimum input value
0x7007	operation data is greater than the maximum input value
0x7008	invalid operation data
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.)

Fig. 10-40:   Error specification according to SERCOS

Communication with ASCII Protocol

Addressing a Specific Bus Node

In order to start the communication with a bus node, this node has to be specifically addressed by a CHANGE DRIVE command (CD command) indicating the drive address. With each CD command the drive addressed via the indicated address is activated; all other drives are thereby switched to the passive mode. The drive that has been addressed responds with its prompt. As from now the communication with the activated drive continues until another CD command causes the switching to another drive.
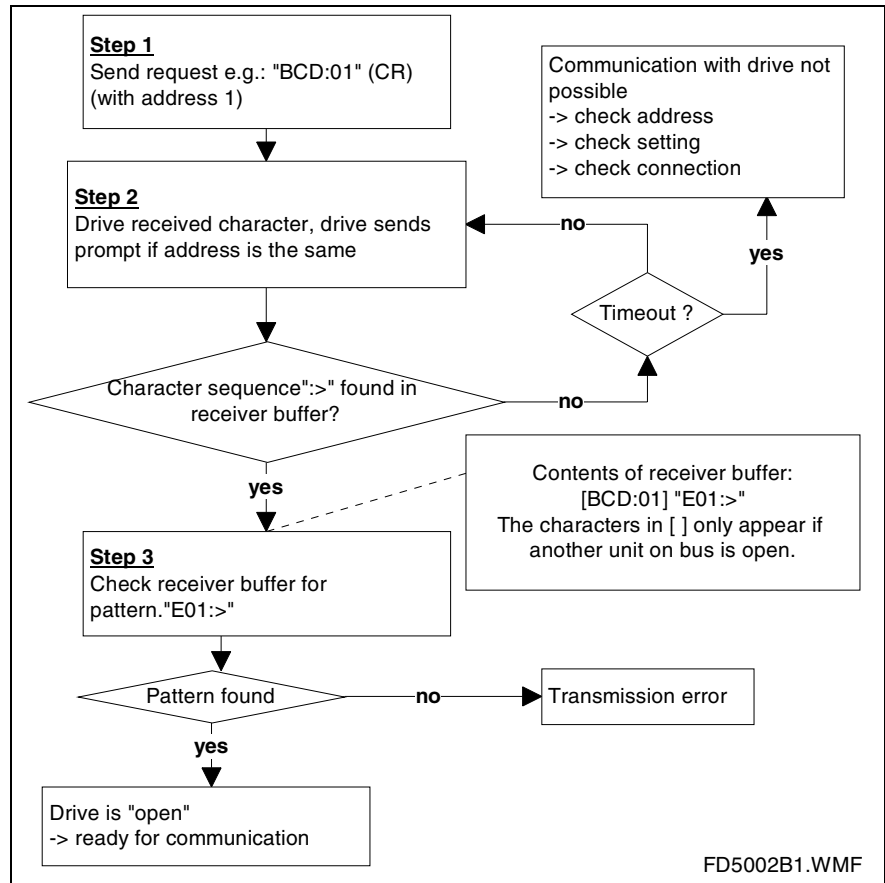
Fig. 10-41:   Addressing a bus node

Write Access to a Parameter

As a basic principle, write access to a parameter is carried out as follows:

IDN of the parameter, data block element number, w, operating data (Carriage Return)

After the writing operation the drive responds with its prompt again.

In order to access the parameter value of the P-0-4073 parameter, for example, the following input is required:
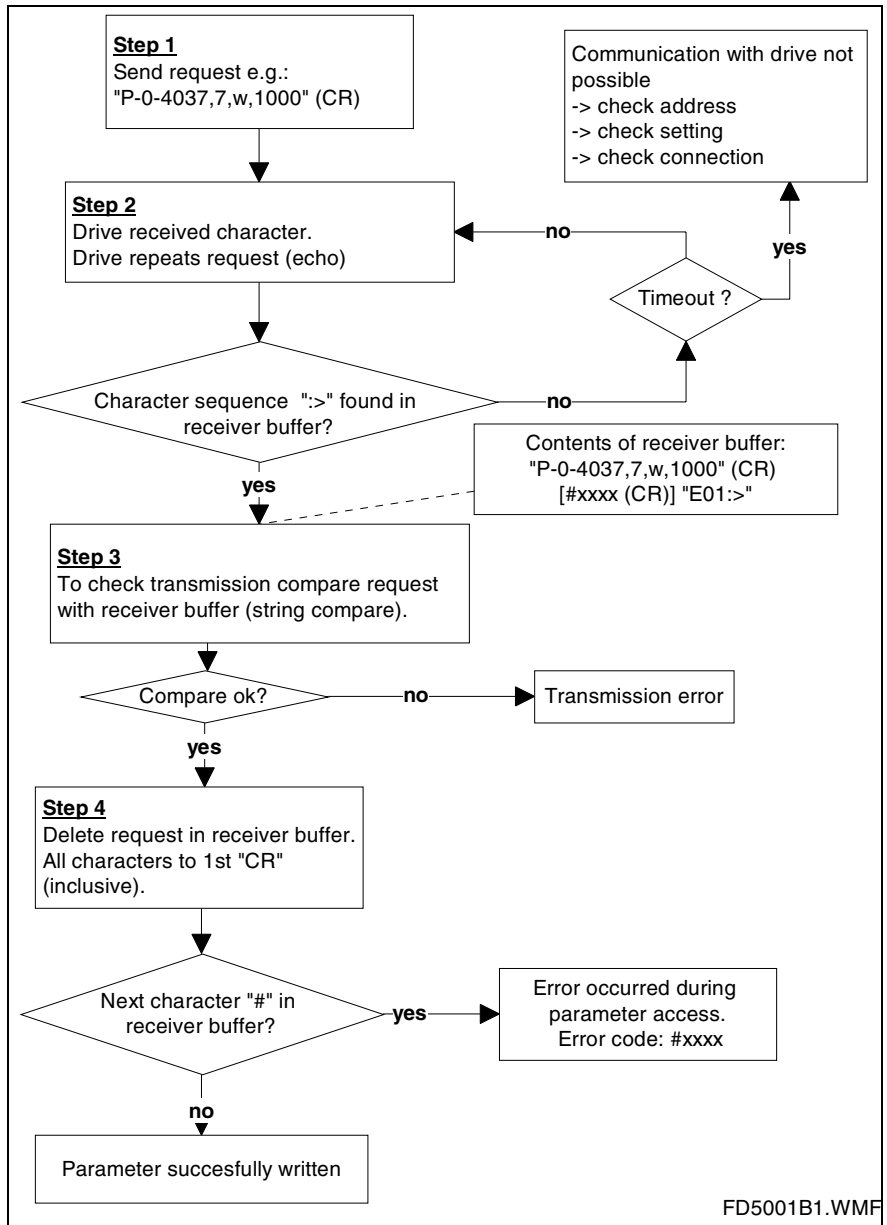
Fig. 10-42: Write access to a parameter

Note: The entered data must correspond to the data type defined in the attribute (HEX, BIN or DEC).

See also chapter "Error Messages in the Case of Serial Communication"

Read Access to a Parameter

As a basic principle, read access to a parameter is carried out as follows:

IDN of the parameter, data block element number, r (Carriage Return)

The drive then displays the content of the data block element that was addressed.

In order to access the operating data of the P-0-4040 parameter, for example, the following input is required:
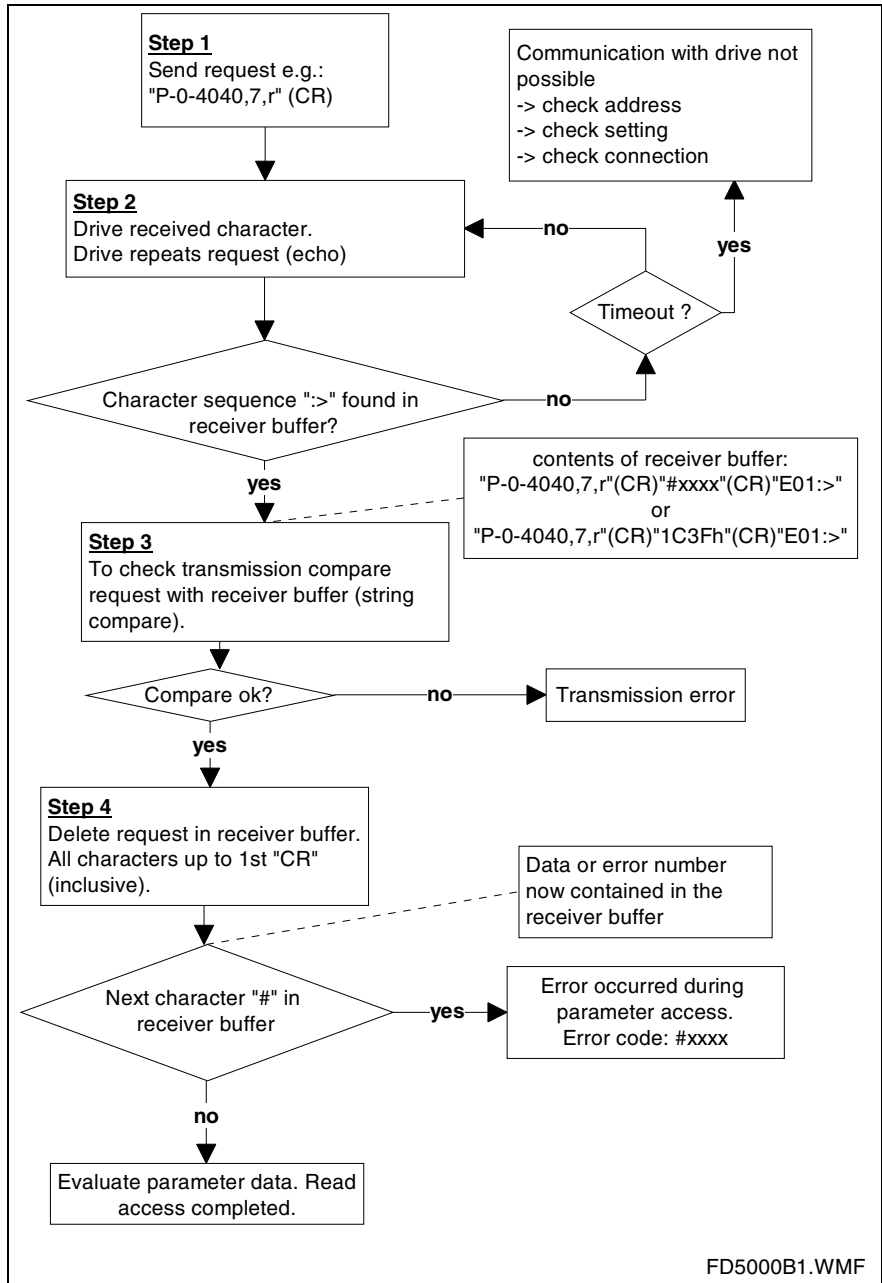
Fig. 10-43: Read access to a parameter

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Write Access to List Parameters

There is a number of list parameters in the drive. When writing, these parameters have to be addressed in modified form:
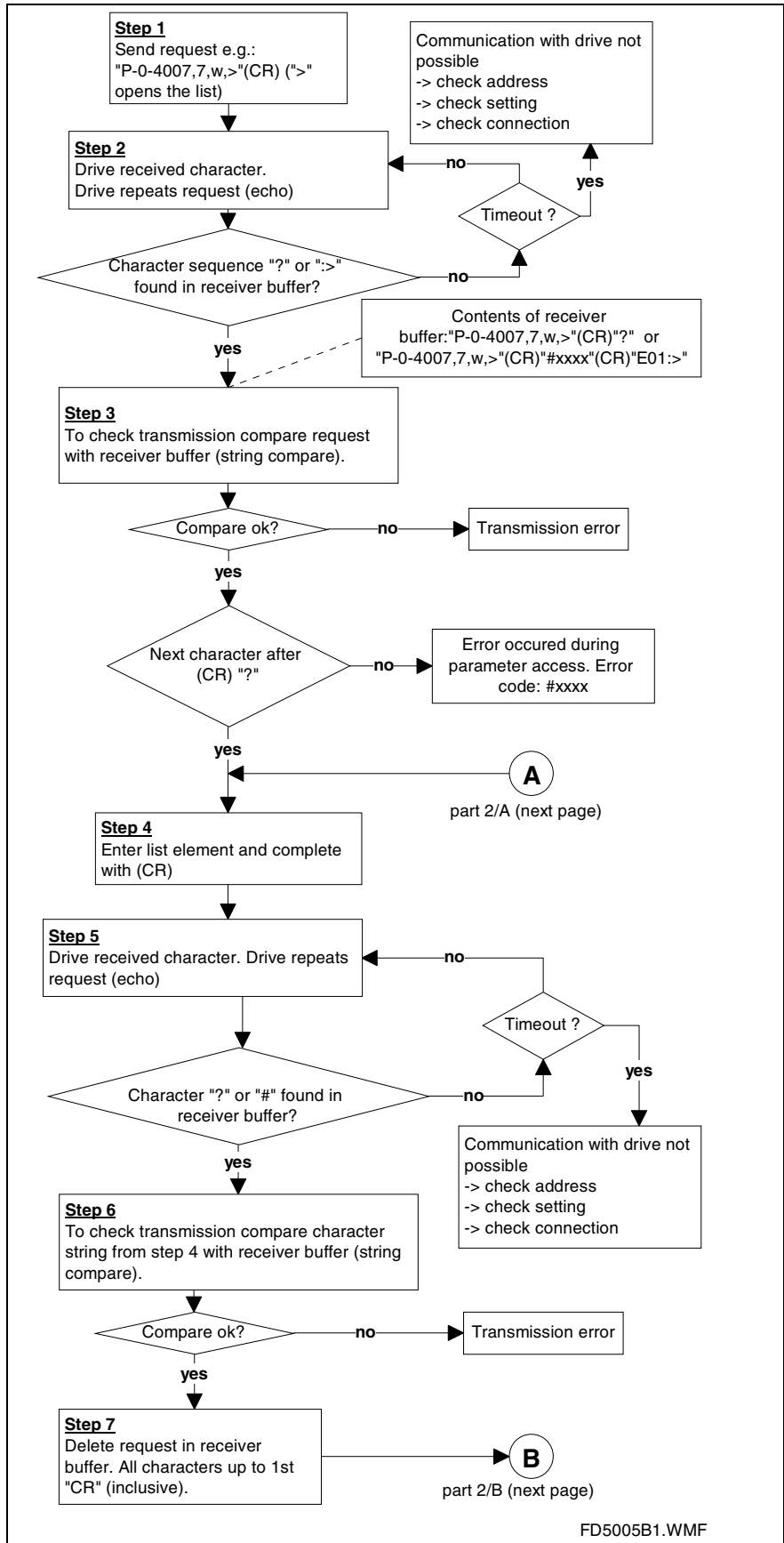
Fig. 10-44: Write access to list parameters (part 1)
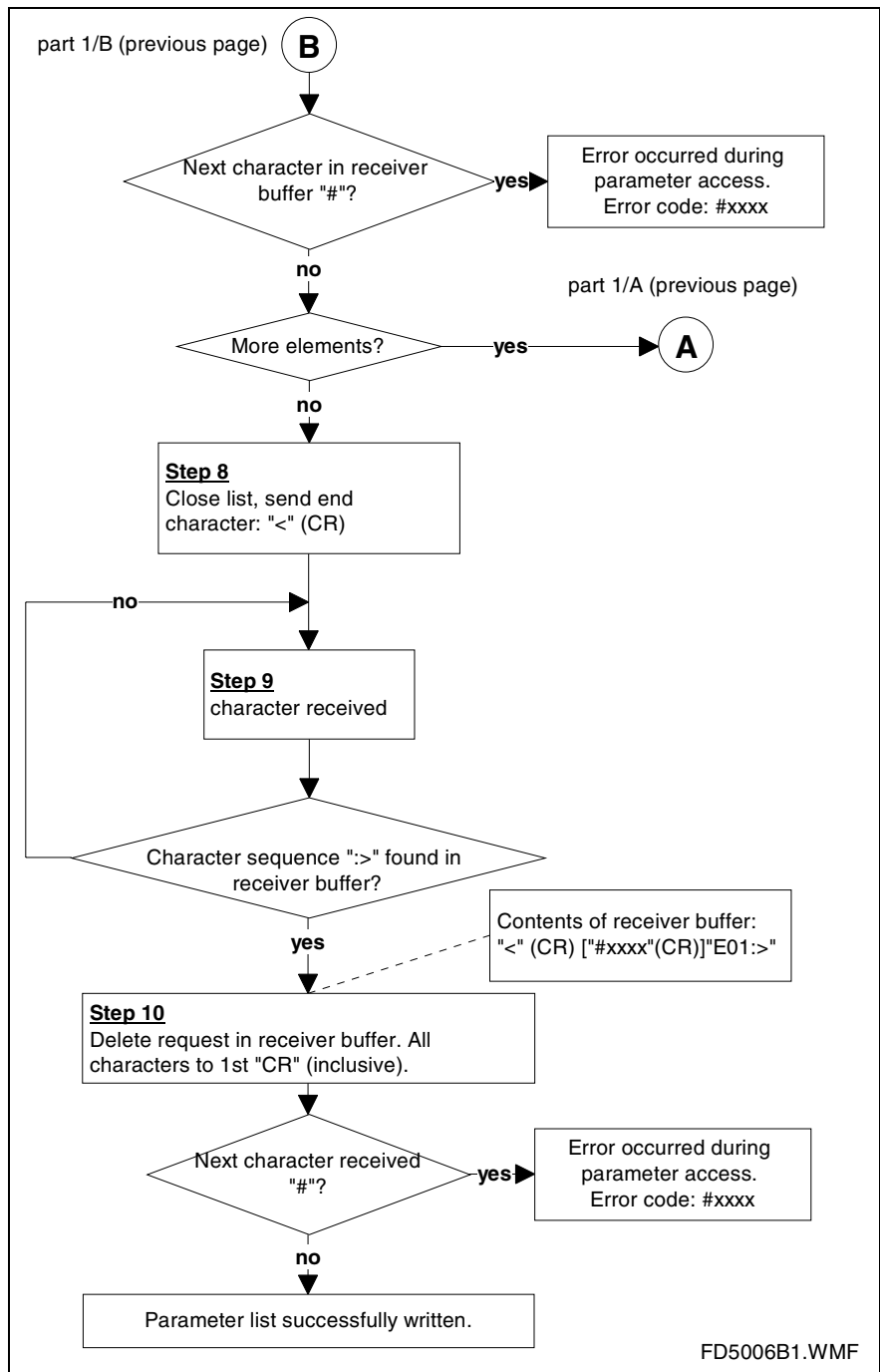
Fig. 10-45: Write access to list parameters (part 2)

Note: It is important to complete the input with the "<" character because only then the data are accepted in the drive.

Read Access to List Parameters

The read access to list parameters is carried out in the same way as in the case of other parameters. The drive, however, provides all list elements as its answer.

Step 1
Send request
e.g.: "P-0-4006,7,r" (CR)

Communication with drive not possible
-> check address
-> check setting
-> check connection

Step 2
Drive received character.
Drive repeats request (echo).

Timeout ?

Character sequence ":>" found in receiver buffer?

no

yes

no

Contents of receiver buffer:
"P-0-4006,7,r"(CR)
"element 1" (CR)
"element 2" (CR)
:
"element n" (CR) "E01:>"
or
"P-0-4006,7,r"(CR)"#xxxx" (CR) "E01:>"

Step 3
To check transmission compare request with receiver buffer (string compare).

Compare ok?   **no**   Transmission error

yes

Step 4
Delete request in receiver buffer. All characters to 1st "CR" (inclusive). Replace last (CR) by "string end" (e.g. "0" in C).

List elements seperated by (CR) or an error number now contained in receiver buffer.

Next character "#" in receiver buffer?   **yes**   Error occured during parameter access. Error code: #xxxx

no

Evaluate list element

Set string pointer to 1st character after next (CR) -> (new list element)

End of list reached?

yes

List succesfully read

FD5004B1.WMF

Fig. 10-46:   Read access to list parameters

Activating a Command

In the drive controller a number of commands can be activated the execution of which takes place automatically within the controller.

The following command parameters are available:

- switching between operating mode and parameter mode:
  - **S-0-0127, C0100 Communication phase 3 transition check**
  - **S-0-0128, C0200 Communication phase 4 transition check**
  - **P-0-4023, C0400 Communication phase 2 transition**
- **S-0-0262, C07_x Load defaults procedure command**
- **S-0-0099, C0500 Reset class 1 diagnostics**
- **S-0-0148, C0600 Drive-controlled homing procedure command**
- **P-0-0012, C0300 Command Set absolute measuring**

Via the serial interface it is possible to start, interrupt and complete the execution of a command. In addition, the status of the command execution can be read.

A command is activated as follows:
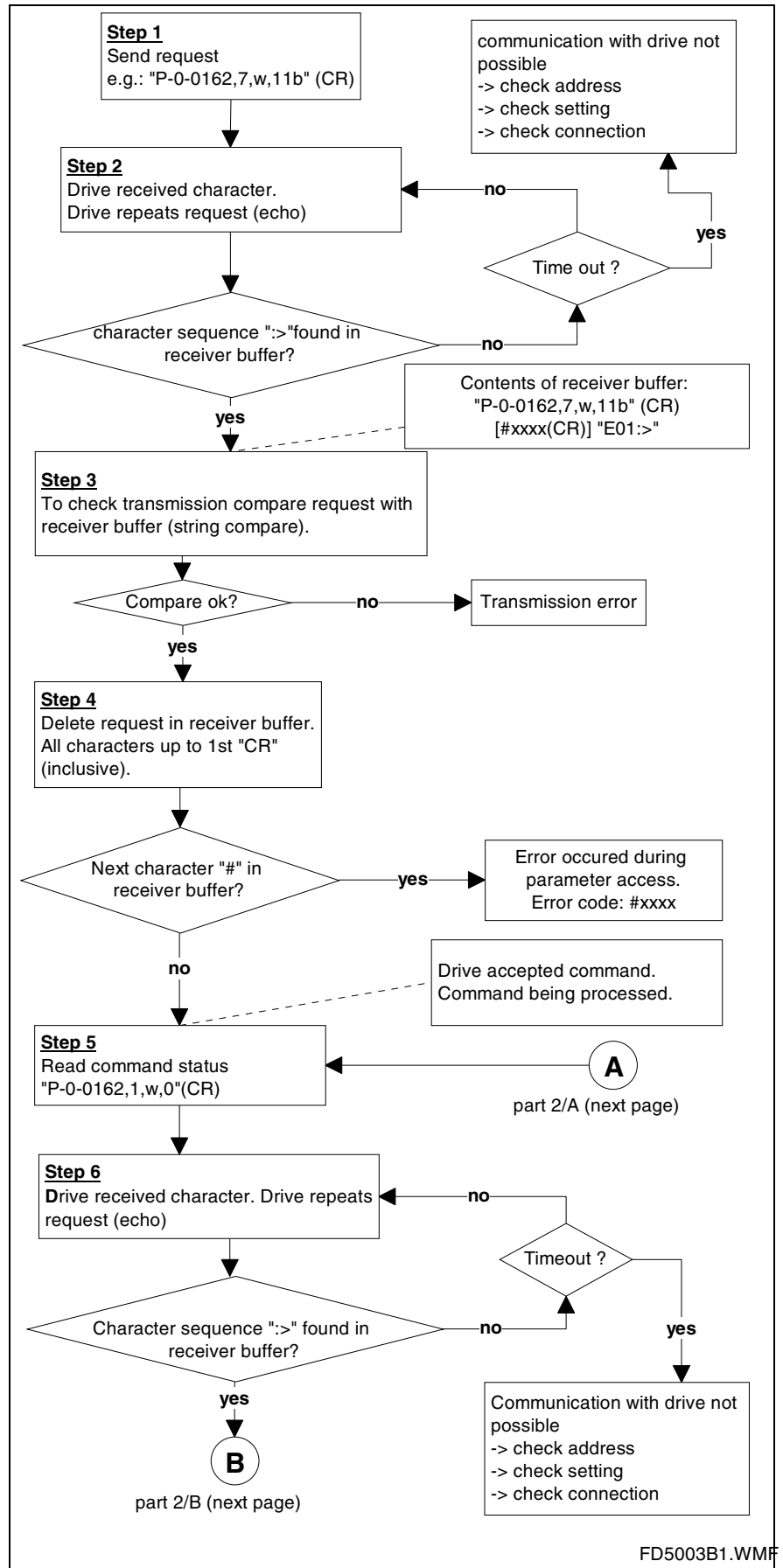
Fig. 10-47: Activating a command, part 1
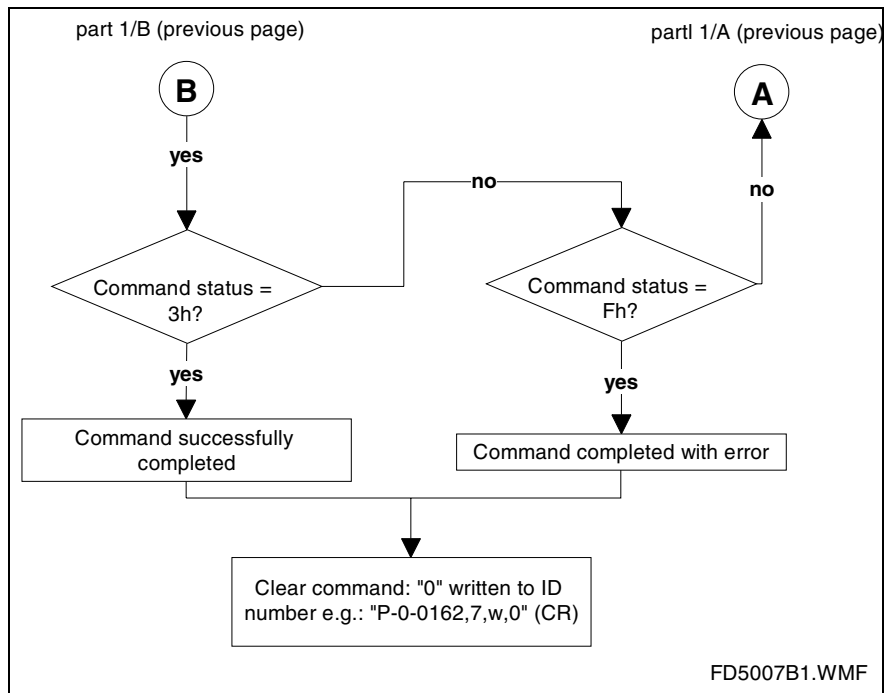
Fig. 10-48: Activating a command, part 2

Interrogating the Command Status

The current status of a command can be interrogated. The interrogation of the command status is used to make sure that the drive-side command execution is completed before the connected control unit (or the PC) completes the command.

The command status is interrogated as follows:

IDN of the command,1,w,0 (Carriage Return)

After the IDN of the command parameter was written the drive signals the current command status.

Possible Status Messages

0 h	Command not set in the drive.
1 h	Command set in the drive.
3 h	Command set, enabled and correctly executed.
5 h	Command set and enabled in the drive.
7 h	Command set and enabled, but not yet executed.
F h	Command set and enabled, but not executed due to error.

Fig. 10-49: Status messages

The command status is transmitted in the form of a bit list. The meaning of the individual bits is illustrated below.

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bit 0:
0 : command not set in the drive
1 : command set in the drive

bit 1:
0 : command execution interrupted in the drive
1 : command execution enabled in the drive

bit 2:
0 : command correctly executed
1 : command not yet executed

bit 3:
0 : no error
1 : error → execution of command impossible

bit 8:
0 : operating data is valid
1 : operating data is invalid

reserved   reserved
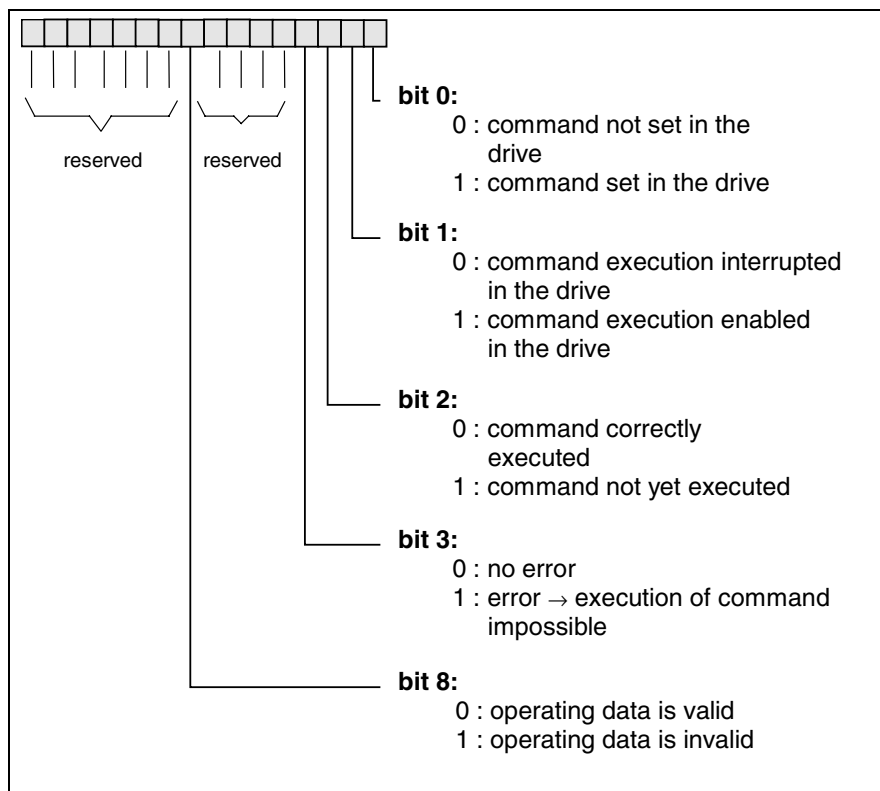
Fig. 10-50: Command acknowledgment (data status)

Completing a Command

A command is completed as follows:

IDN of the command,7,w,0 (Carriage Return)

Example of Application (Changing the Assign List for the Signal Status Word)

Assumption: Several drives are connected to a PLC via an RS485 interface. The address of the drive we consider is "01".

Establishing the communication with the respective axis

BCD: 01 (CR) Command for switching to drive **A01:>**
echo of the connected drive. All other drives are passive.

Note: The drive does not send an echo after each character, but it is only after having received the "CR" that the drive returns the complete sequence that was input.

Writing the assign list for the signal status word to the drive

The assignment of the relevant bits for the signal status word (S-0-0144) is stored in parameter **S-0-0328, Assign list signal status word** in the form of a list. In order to change one or more values in this list, it is necessary to always write all relevant values of this list. That is to say if four elements are used, it is necessary to write all 4 bits even if only one element (bit) is to be changed.

Input:

S-0-0328,7,w,> (CR)
?   1 *(CR)*   bit1
?   *2 (CR)*   bit2
         etc.
?   *<(CR)*
E01:>

Errors Messages in the Case of ASCII Communication

The following error messages specifically occur in the case of communication with ASCII protocol:

Error code	Description
0x9001	fatal error (characters cannot be identified)
0x9002	parameter type error
0x9003	invalid data block number
0x9004	input cannot be identified
0x9005	data element number not defined
0x9006	error in the write-read identifier (r/w)
0x9007	invalid character in the data

Fig. 10-51: Error messages in the case of ASCII communication

Communication with SIS Protocol

Telegram Structure, Telegram Frame

An SIS telegram is basically divided into 3 blocks:

- telegram header
- useful data header
- useful data

	telegram header	useful data header	useful data	
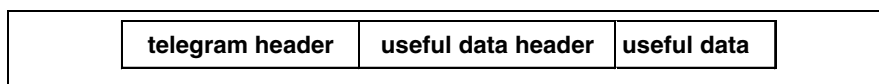
Fig. 10-52: Structure of an SIS telegram

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 contains 8 byte and is contained in each SIS telegram.

Byte	Name	Description of the bytes in the static part of the telegram header
1	**StZ**	Start character: STX (0x02)
2	**CS**	Checksum byte The checksum is generated in three steps: 1) the "CS" byte is cleared 2) all characters in the telegram are added byte by byte 3) the negated sum is stored in the "CS" byte The result of the byte-by-byte addition of all characters in an SIS telegram is always 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 byte.** Therefore, a maximum of 247 byte of useful data can be transmitted.
4	**DatLW**	Data length repetition

5	**Ctrl**	Control byte
		In the control byte, the telegram type and the structure of the dynamic telegram header are declared:
		bit 0…2: number of subaddresses in the dynamic part of the telegram header
		bit 3: specifying whether dynamic telegram header contains "PaketN" (package number) byte
		            0 => without package number; 1 => with package number
		bit 4: determining the telegram type
		            0 => command telegram; 1 => reaction telegram
		bit 5: reserved
		bit 6: reserved in command telegrams
		            in reaction telegrams bit 6 signals a system warning in the slave
		bit 7: reserved in command telegrams
		            in reaction telegrams bit 7 signals a system error in the slave

6	**Dienst**	SIS service The byte specifies the SIS service of the telegrams. Subservices are defined in some SIS services. In these cases the subservice is specified in the useful data header. The useful data of the command and reaction telegrams can be defined in a different way for each SIS service and its subservice.
7	**AdrS**	Address of the transmitter in command telegrams: address of the master, valid from 0 to 126 in reaction telegrams: address of the slave

8	**AdrE**	Address of the receiver
		in command telegrams: address of the slave, valid from 0 to 126
		            address 128: special address for a "point-to-point" connection
		                        Each slave reacts to the special address independent of its station number.
		            address 254: collective message to all slaves in the direct hierarchical level
		            address 255: collective message to all slaves in the SIS network below the master
		            Slave do not respond to collective messages.
		in reaction telegrams: address of the master

Fig. 10-53: SIS telegram header, static part

Dynamic part of the telegram header

The dynamic part of the telegram header can contain up to 8 byte. The telegram number ('PaketN' byte), when it was declared in the control byte ('Ctrl' byte in the static part), is always in the last place in the dynamic part of the telegram header. If not all subaddresses are required, they are not available in the telegram. When a command telegram is transmitted from one hierarchical level to the hierarchical level below it, the subaddress block is reduced by one address. On the way back one address is added to the subaddress block in the reaction telegram.

Byte	Name	Description of the bytes in the dynamic part of the telegram header
9	**AdrES1**	slave address in the 1st sublevel
10	**AdrES2**	slave address in the 2nd sublevel
11	**AdrES3**	slave address in the 3rd sublevel
12	**AdrES4**	slave address in the 4th sublevel
13	**AdrES5**	slave address in the 5th sublevel
14	**AdrES6**	slave address in the 6th sublevel
15	**AdrES7**	slave address in the 7th sublevel
16	**PaketN**	Package number (when bit 3 was set in "Ctrl" byte) - At the first request with a package number $\neq 0$ the request is processed. The reaction telegram is stored and sent by the slave. - When the request is repeated (with the same package number), it is not processed. The slave sends the stored reaction telegram. - When there is another request with a new package number $\neq 0$ or when there is a changed request (static telegram header), the request is processed. The stored reaction telegram is overwritten with the new reaction telegram and the new reaction telegram is sent by the slave. - When there is request with package number = 0, it is always processed. The reaction telegram is sent by the slave but not stored. Reaction telegrams that still are stored are cleared (re-initialization)! - When there is request without package number, it is always processed. The reaction telegram is sent by the slave but not stored. Reaction telegrams that still are stored are maintained! Only with the package monitor is it possible to repeat individual sequential telegrams that were incorrectly transmitted, without canceling the running sequential telegram cycle!

Fig. 10-54: SIS telegram header, dynamic part

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Structure of the Useful Data Header

Note: The structure of the useful data header depends on the direction of transmission. The useful data headers described below are only valid for the services 0x80 … 0x8F.

In the structure of the useful data header we distinguish between command telegram and reaction telegram.

Command Telegram

The command telegram is the telegram the master (drive) sends to the slave (master → slave).
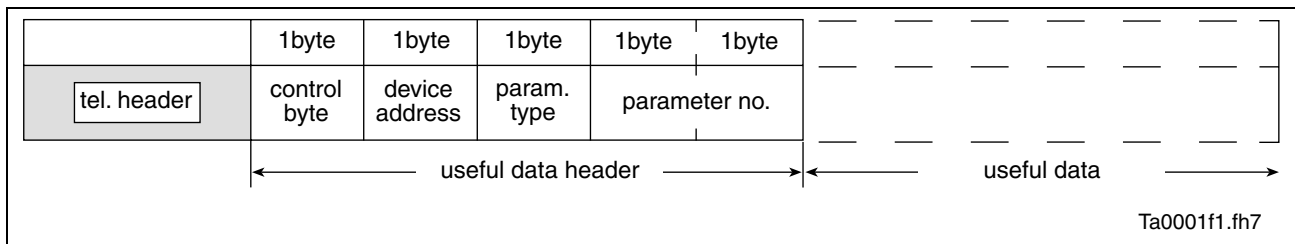
Fig. 10-55: Structure of the useful data header in the command telegram

Significance of the Useful Data Header   In the command telegram the useful data header describes the kind of request.

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   In this byte the device address set at the address switches has to be entered.

Parameter Type and Number   The parameter number has the format defined in the specification for SERCOS interface. In order to be able to address control parameters, a byte for characterizing the parameter type precedes the address.
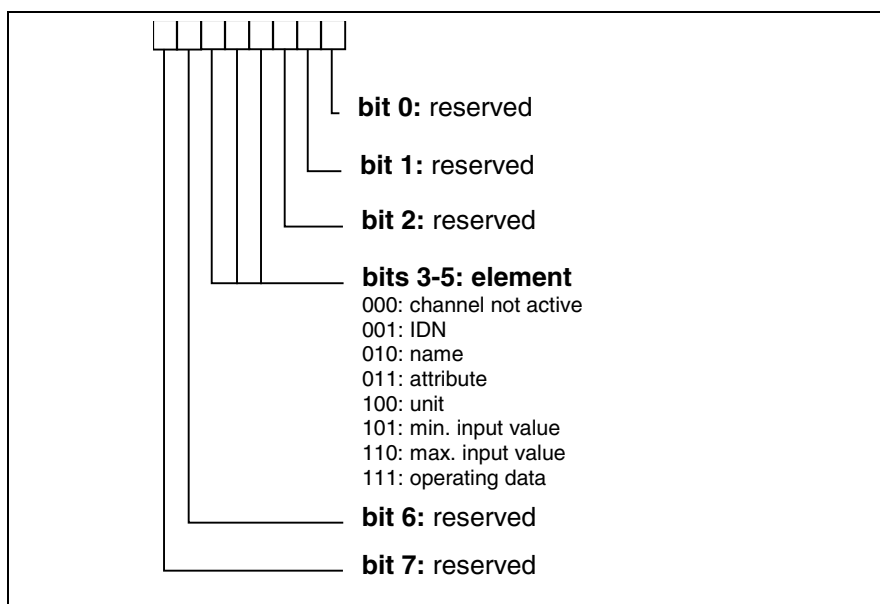
Fig. 10-56:   Structure of the control byte
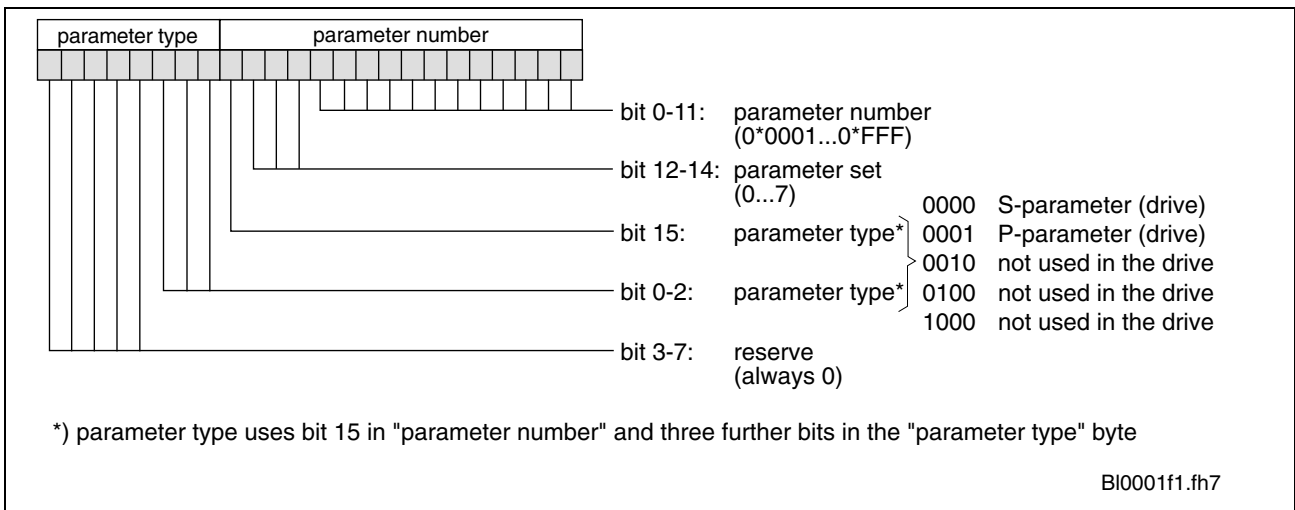
Fig. 10-57:   Parameter type and number in the useful data header

Reaction Telegram

The reaction telegram is the telegram the slave (drive) sends to the master (slave → master).
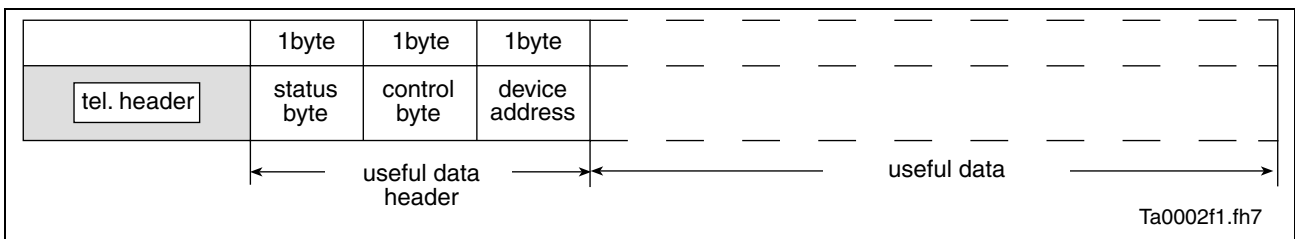
Fig. 10-58:   Structure of the useful data header in the reaction telegram

Status Byte	In the status byte an error code is returned, if necessary. In the case of an error-free transmission, a 0x00 is returned in the status byte.
Control Byte	The control byte contains the information regarding which data block element of a parameter is accessed. Bit 2 controls the transmission of sequential telegrams (writing lists in several steps).
Device Address	In this byte the device address set at in the **P-0-4022, Drive address of serial interface** parameter has to be entered.
Structure of the Useful Data Field	In the useful data bytes it is possible to enter any value that is interpreted in a different way according to 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 of the useful data header are entered in the DatL and DatLW bytes.
Status Messages	

Status Byte	Description	Kind of error
00h	error-free transmission	without error
01h	During the execution of the requested service an error occurred. The **service-specific error code** is contained in the useful data of the reaction telegram.	execution error
F0h	The requested service is not supported by the addressed slave.	telegram error
F8h	In the sequential telegram, data in the	telegram error

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	useful data header, the transmitter address or the service have changed.	
F9h	The command telegram contains subaddresses. The routing of telegrams is not supported by the slave.	telegram error
FAh	Useful data are missing in the command telegram. The telegram cannot be executed.	telegram error
FBh	The requested subservice is not supported in the addressed slave.	telegram error
FCh	The requested component is not available in the addressed slave. The component address is invalid.	telegram error

Fig. 10-59: List of the defined telegram states

Error Codes

Error code	Service	Description
0700h	03h	baud rate not supported
0800h	03h	baud rate not supported
800Ch	80h, 81h, 8Eh, 8Fh	Access to parameter denied; the parameter is occupied by the sequential telegram channel.
9002h	02h	firmware was deleted
9004h	02h	shutdown not allowed in phase IV (in FWA MT01VRS instead of 9010h!)
9010h	02h	shutdown not allowed in operating mode (as of FWA MP02VRS!)
9102h	02h	firmware was deleted
9104h	02h	reboot not allowed in phase IV (in FWA MT01VRS instead of 9110h!)
9110h	02h	reboot not allowed in operating mode (as of FWA MP02VRS!)
9200h	02h	error when reading
920Bh	02h	The requested data volume exceeds the max. useful data volume in the reaction telegram.
9400h	02h	timeout during deleting procedure
940Ah	02h	deleting only possible in loader
96E0h	02h	verify error when programming the flash
96E1h	02h	timeout when programming the flash
96FFh	02h	error when writing to the flash
9701h	02h	additional checksum incorrect
9702h	02h	CRC32 checksum incorrect

Fig. 10-60: List of the defined error codes

Communication via SIS Protocol

Addressing a Drive

In the case of communication with SIS protocols we distinguish between command telegrams and reaction telegrams, according to the direction of transmission. A node can only be addressed under its address (see program module) when a specific telegram format (frame) is observed.

Note:	Only when the drive has received at least one valid SIS telegram is the SIS channel enabled for further communication.

Read Access

When the reading of a parameter is started in a command telegram, a check is run in the drive to determine whether a sequential telegram is required. In this case, bit 2 (current/last transmission) is kept at "0" in the control byte of the reaction telegram until the last reaction telegram is sent. In the last reaction telegram, bit 2 is set to "1".

The sending of a sequential reaction telegram is activated by the repeated sending of the unchanged command telegram.

Sequential Telegram Access

When the writing or reading of a parameter with sequential telegrams was started in the drive, it is necessary to complete or cancel this process before another service with sequential telegrams can be started. If another service was started nevertheless, the "0x800C unauthorized access" error code is sent in the reaction telegram. The service with sequential telegram started before can then be normally processed or cancelled with the next command telegram.

Supported Services and Subservices

SIS service	Description	Subservices	Subservice description	Notes
0x00	node identification	0x01	reading SIS version	subservice is implemented but not active
		0x02	reading firmware version	supplies content of S-0-0030
		0x03	reading controller type	supplies content of S-0-0140
		0x04	reading supported baud rates	9600 baud, 19200 baud, 38400 baud, 57600 baud, 115200 baud
0x01	data transmission canceled	none		
0x02	flash operations	0x90	shutdown	switches drive firmware to the loading mode
		0x91	reboot	causes restart
		0x92	read flash	reads content of the flash
		0x93	find header	supplies header address of the first IBF module
		0x94	erase flash	deletes content of the flash
		0x96	program flash	programs content of the flash
		0x97	build checksum	supplies CRC32 checksum of the indicated IBF module
		0x9F	error reset in the slave	clears error in loading mode
0x03	initialization of the SIS communication	0x01	determining TrS	initializes max. reaction time in the slave
		0x02	determining TzA	initializes max. character interval on the bus
		0x03	determining Tmas	subservice is implemented but not active
		0x07	determining the baud rate	initializes the baud rate of the serial transmission
		0x08	time-controlled baud rate test	allows temporary change of the baud rate
		0xFF	accepting the determined values	activates the values initialized with the subservices 0x01, 0x02 and 0x07
0x10	reading parameter	none		0x10 = 0x80
0x11	reading list segment	none		segment information in byte
0x1E	writing list segment	none		segment information in byte
0x1F	writing parameter	none		0x1F = 0x8F
0x80	reading parameter	none		0x80 = 0x10
0x81	reading list segment	none		segment information in word
0x8E	writing list segment	none		segment information in word
0x8F	writing parameter	none		0x8F = 0x1F

Fig. 10-61: Supported services and subservices

Service 0x01 Canceling a Data Transmission

With this service it is possible 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 with the sequential telegram sequence. When the command telegram is transmitted without the device address and without service to be cancelled, this service is always executed.

Command Telegram
- Enter 0x01 in the service of the telegram header.
- Enter the service to be cancelled in the useful data.

Reaction Telegram   If there isn't any error, the reaction telegram has the following structure:

telegram header	useful data header

Fig. 10-62: Structure of the reaction telegram

In the case of an error, the useful data that contain the error code are transmitted. The useful data header corresponds to the SIS specification.

telegram header	useful data header	useful data
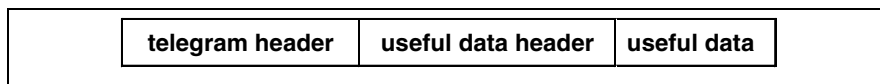
Fig. 10-63: Structure of the reaction telegram in the case of error

Note: When there wasn't any sequential telegram processed and this service was transmitted nevertheless, there isn't any error reaction telegram transmitted!

Service 0x80 Reading a Parameter

A one-time read access is completed with one transmission step. The master enters the following information in the command telegram:
- In the control byte the desired element is selected in the bits 3 ... 5 ("element"). Das Bit 2 wird auf "1" (letzte Übertragung) gesetzt.
- The device address is entered.
- Parameter type and number are entered.
- There aren't any useful data entered.

The answer to a read access contains the following data:
- In the Ctrl byte of the telegram header bit 4 is set to "1" in order to identify it as a reaction telegram.
- The status byte of the useful data header contains the information whether an error occurred during the processing of the command telegram.
- The control byte is read from the command telegram and copied to the reaction telegram.
- The device address is read from the command telegram and copied to the reaction telegram.
- The requested data is written to the useful data.

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Example:

Reading the **S-0-0044, Velocity data scaling type** parameter from the drive with the address "3". The parameter has the value "0x0042".

Command Telegram:

	3C	03	00	2C	00
tel. header	control byte	device address	param. type	parameter no. (LSB)	(MSB)

useful data header

Ta0005f1.fh7
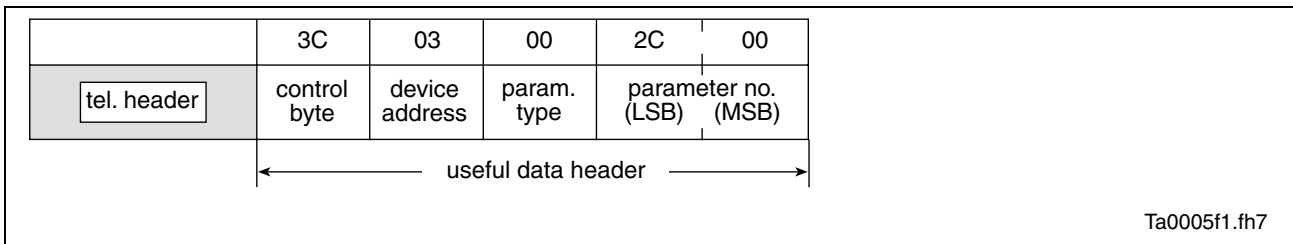
Fig. 10-64: Reading the S-0-0044 parameter (command telegram)

Reaction Telegram:

	00	3C	03	42	00
tel. header	status byte	control byte	device address	useful data (LSB)	(MSB)

useful data header

Ta0006f1.fh7
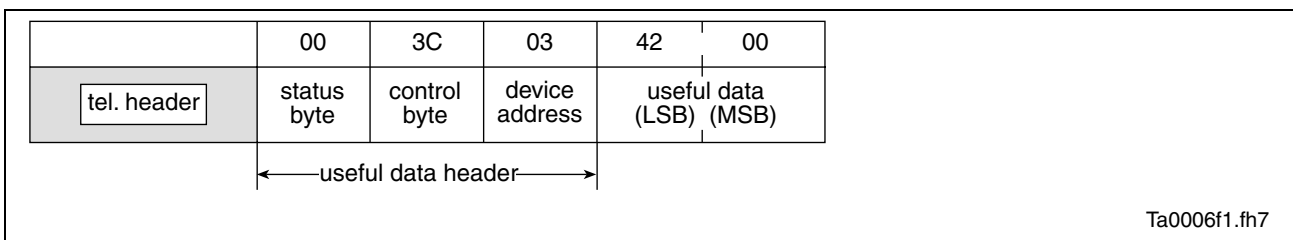
Fig. 10-65: Reading the S-0-0044 parameter (reaction telegram)

Service 0x8F Writing a Parameter

Note: By means of this service, all available commands can be started in the drive.

Command Telegram
- Enter 0x8F in the service of the telegram header.
- Enter the parameter to be written in the "parameter type" and "parameter no." bytes of the useful data header.
- Enter the value to be written in the useful data.

Reaction Telegram

Note: By means of this service, all available commands can be started in the drive.

A one-time write access is completed with one transmission step.

The master enters the following information in the command telegram:

- The device address is entered.
- In the control byte the operating data is selected in the bits 3 ... 5 ("element"). Bit 2 is set to "1" (last transmission).
- The IDN of the parameter to be written is written to the parameter number.
- The value of the operating data is written to the useful data.

The answer to a write access contains the following data:

• In the Ctrl byte of the telegram header bit 4 is set to "1" in order to identify it as a reaction telegram.

• The status byte of the useful data header contains the information whether an error occurred during the processing of the command telegram.

• The control byte is read from the command telegram and copied to the reaction telegram.

• The device address is read from the command telegram and copied to the reaction telegram.

• There aren't any useful data entered.

Example:

Transmitting the **S-0-0044, Velocity data scaling type** parameter to the drive with the address "3". The value 0x0042 is written to the parameter.

Command Telegram:

	3C	03	00	2C	00	42	00
tel. header	control byte	device address	param. type	parameter no. (LSB) (MSB)		useful data	
	useful data header →						

Ta0009f1.fh7
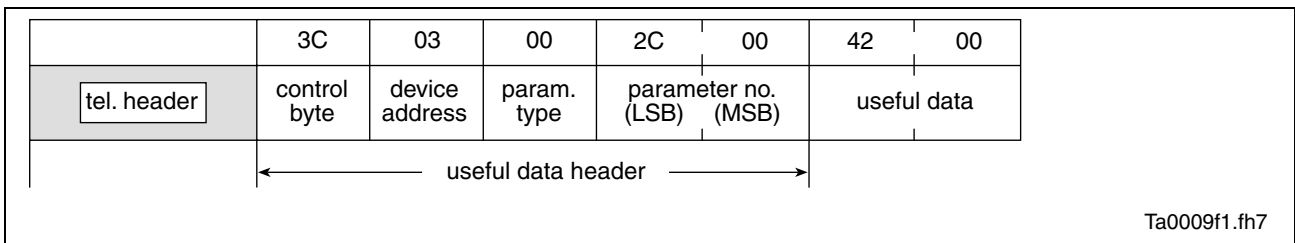
Fig. 10-66: Writing the S-0-0044 parameter (command telegram)

Reaction Telegram:

	00	3C	03
tel. header	status byte	control byte	device address
	useful data header		

Ta0010f1.fh7
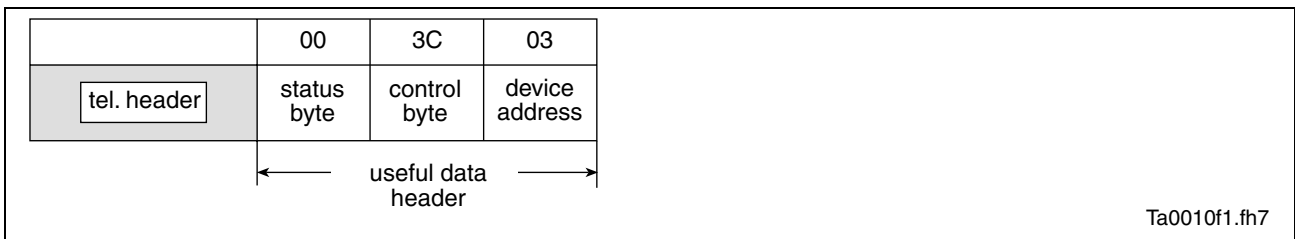
Fig. 10-67: Writing the S-0-0044 parameter (reaction telegram)

Starting a Command

With the **service 0x8F "Writing a parameter"** all commands can be started in the drive via the SIS protocol.

telegram header	useful data header	2 bytes useful data

Fig. 10-68: Structure of the command telegram

• Enter 0x8F in the service of the telegram header.

• Enter the command to be activated in the "parameter type" and "parameter no." bytes of the useful data header.

• Enter the input of the command in the useful data byte.

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Service 0x81 Reading a List Segment

Command Telegram

- Enter 0x81 in the service of the telegram header.
- Enter the parameter type and parameter no. of the parameter to be read in the useful data header.
- Enter the 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

- In the control byte of the reaction telegram the current/last transmission is marked with bit 2.

Note:	The output of a sequential telegram is started by the repeated sending of the unchanged command telegram.

Service 0x8E Writing a List Segment

Command Telegram

- Enter 0x8E in the service of the telegram header.
- Enter the parameter type and parameter no. of the parameter to be read in the useful data header.
- Enter the 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

- A possible error is entered in the useful data in the reaction telegram.

Note:	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 has to be written. Operation in the sequential telegram mode is impossible.

Examples of Application (Sequential Telegrams)

Service 0x8F Write Access (with Sequential Telegrams)

Parameters or elements longer than 243 byte are read in several steps. The transmission of such lists is carried out in several steps. Bit 2 in the control byte marks the current transmission step as the current or last transmission.

The figures below illustrate the control word for a transmission in several steps.

1st step:
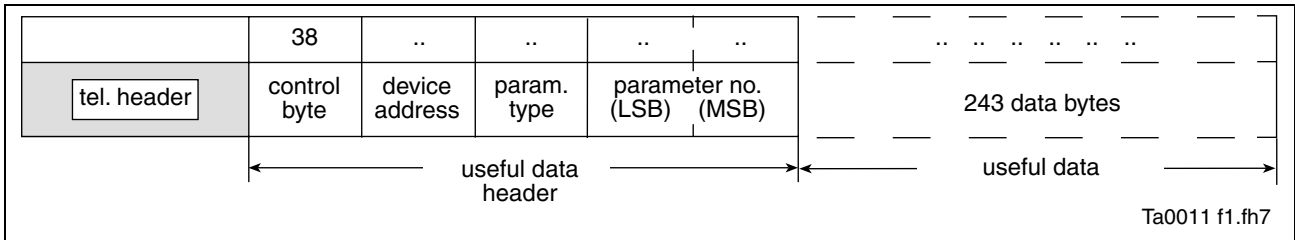
Fig. 10-69: Writing with sequential **command** telegram (step1)
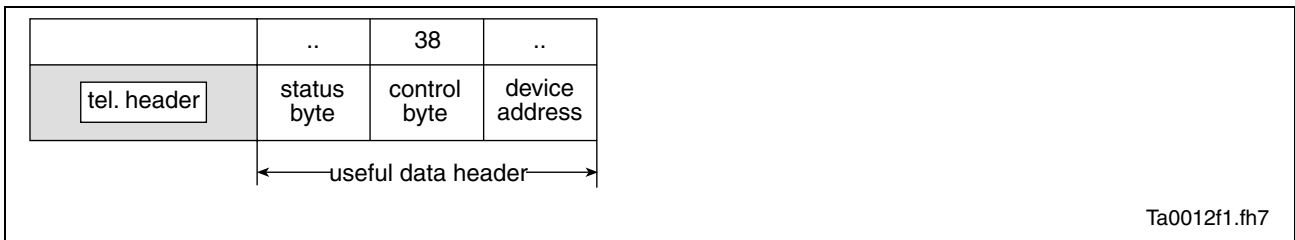
Fig. 10-70: Writing with sequential **reaction** telegram (step1)

2nd step:
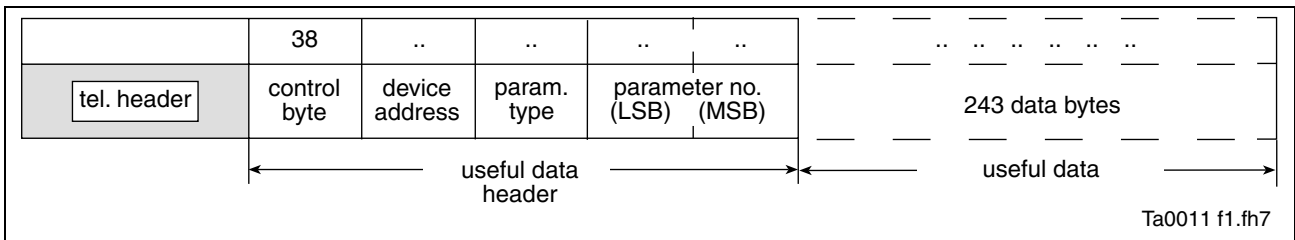
Fig. 10-71: Writing with sequential **command** telegram (step2)
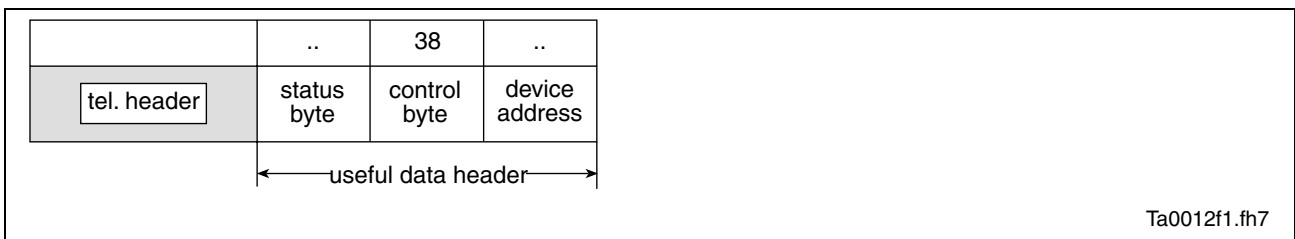
Fig. 10-72: Writing with sequential **reaction** telegram (step2)

Last step:

tel. header	control byte	device address	param. type	parameter no. (LSB) (MSB)	243 data bytes
	3C	..	..	.. ..	.. ..

useful data header — useful data

Ta0013 f1.fh7
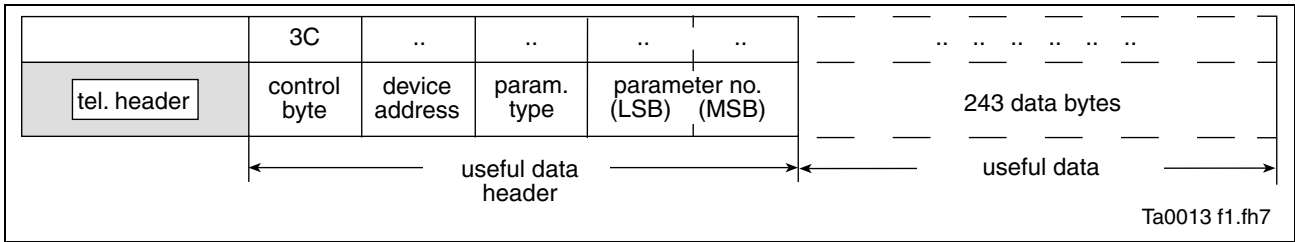
Fig. 10-73: Writing with sequential **command** telegram (step3)

tel. header	status byte	control byte	device address
	..	3C	..

useful data header

Ta0014f1.fh7
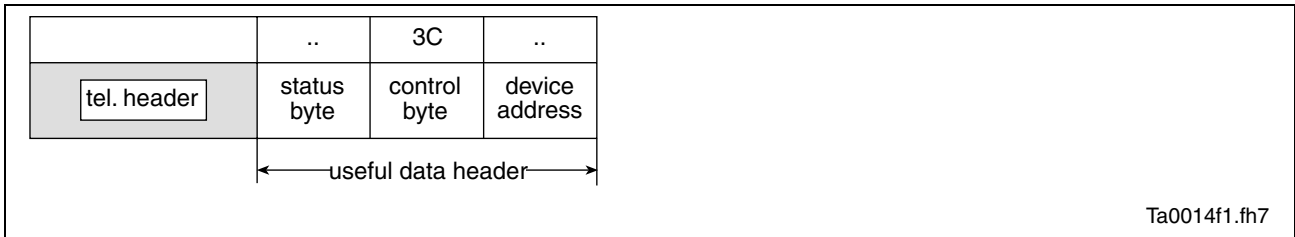
Fig. 10-74: Writing with sequential **reaction** telegram (step3)

Service 0x80 Read Access (with Sequential Telegrams)

Parameters or elements the length of which exceeds the max. data field length of 245 byte are read in several steps. Bit 2 in the control byte of the reaction telegram marks the current transmission step as the current or last transmission.

The figures below illustrate the control word for a transmission in several steps.

1st step:

tel. header	control byte	device address	param. type	parameter no. (LSB) (MSB)
	3C	..	..	.. ..

useful data header

Ta0007f1.fh7
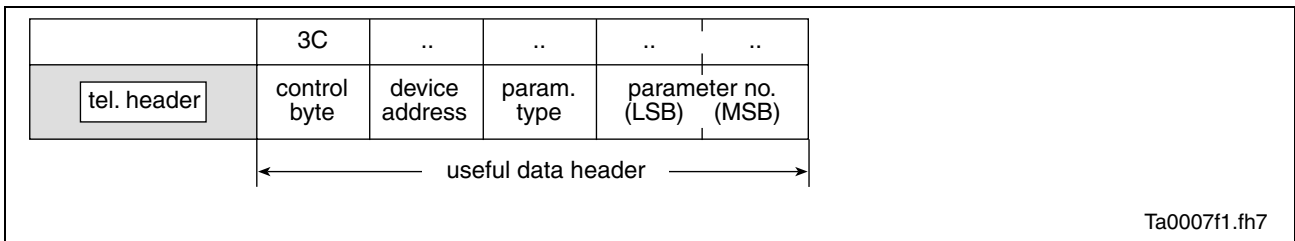
Fig. 10-75: Sequential **command** telegram1

tel. header	status byte	control byte	device address	245 data bytes
	..	38	..	.. ..

useful data header — useful data

Ta0008f1.fh7
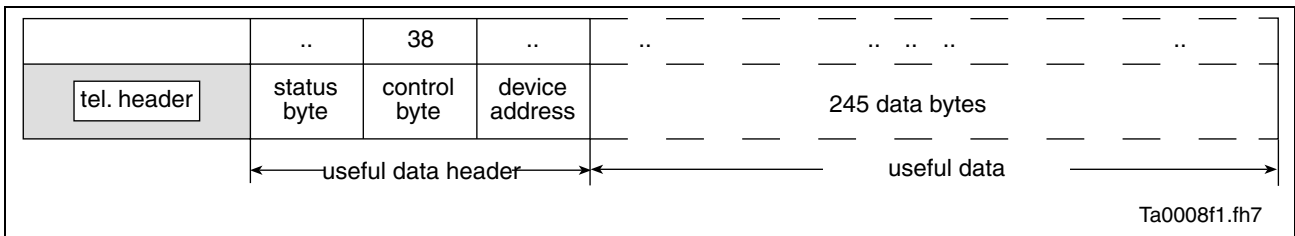
Fig. 10-76: Sequential **reaction** telegram1

2nd step:

tel. header	3C	..	..	..	..
	control byte	device address	param. type	parameter no. (LSB)	(MSB)

useful data header

Ta0007f1.fh7
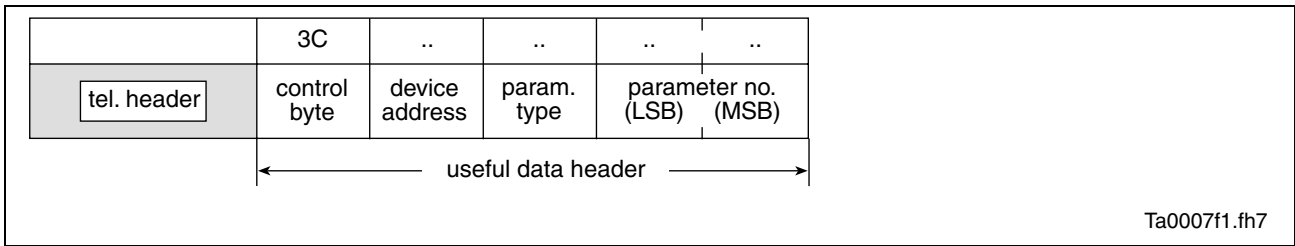
Fig. 10-77:   Sequential **command** telegram2

tel. header	..	38	..	..
	status byte	control byte	device address	245 data bytes

useful data header | useful data

Ta0008f1.fh7
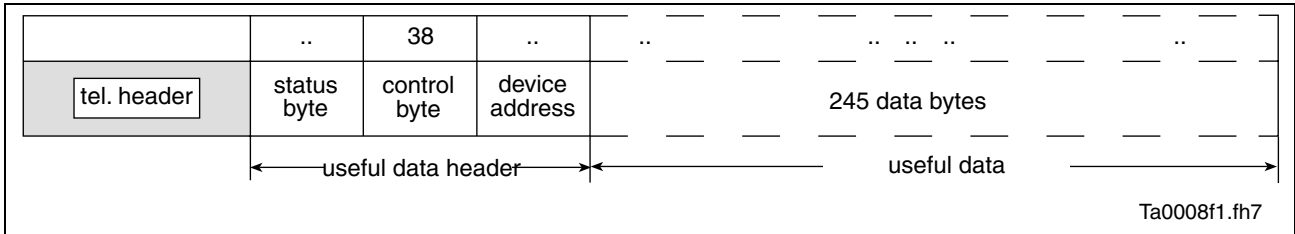
Fig. 10-78:   Sequential **reaction** telegram2

Last step:

tel. header	3C	..	..	..	..
	control byte	device address	param. type	parameter no. (LSB)	(MSB)

useful data header

Ta0007f1.fh7
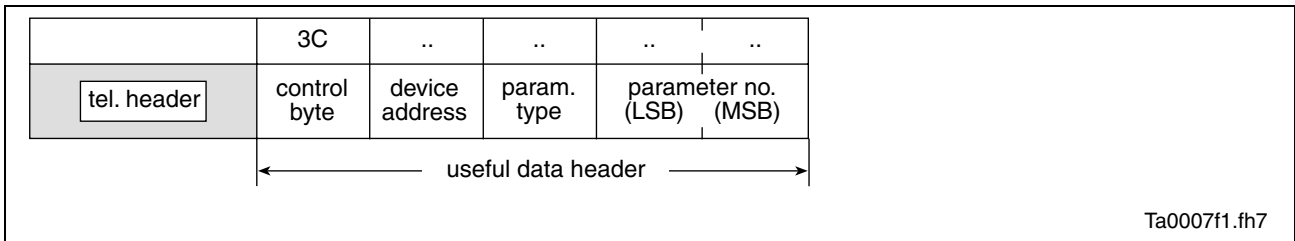
Fig. 10-79:   Sequential **command** telegram3

tel. header	..	3C	..	..
	status byte	control byte	device address	245 data bytes

useful data header | useful data

Ta0015f1.fh7
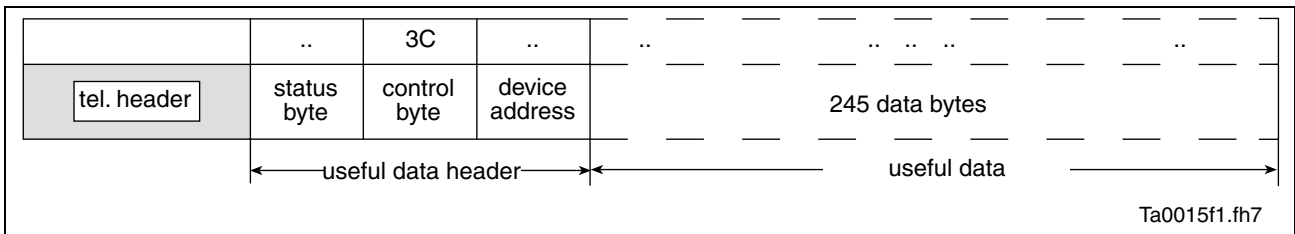
Fig. 10-80:   Sequential **reaction** telegram3

Errors in the Case of SIS Communication

Errors During Parameter Transmission

If an error occurs during the parameter transmission, an "error during parameter transmission" is signaled in the status byte.

The first two bytes of the useful data transmit an error code that describes the kind of error.

During the parameter transmission the following errors can occur:

Error code	Description
0x0000	no error
0x0001	service channel not open
0x0009	invalid access to element 0
0x8001	"Service channel currently occupied (BUSY)" The desired access is currently impossible because the service channel is occupied.
0x8002	"Failure in service channel" It is currently impossible to access the desired drive.
0x800B	"Transmission canceled (higher priority)"
0x800C	"Unauthorized access (service channel still active)" A new request is started before the last transmission was completed.

Fig. 10-81: Error messages in the serial protocol

Execution and Protocol Acknowledgment

With each reaction telegram a status byte is transmitted. The status byte provides the result of a transmission in the form of a code number.

In general, the following applies:

Result of the transmission	Code number in the status byte
transmission without error	0x00
Protocol error	0xF0 … 0xFF
Execution error	0x01 … 0xEF

Fig. 10-82: Definition of the status byte

Protocol error	Code number	Description of error
invalid service	0xF0	The requested service is was not specified or is not supported by the addressed node.

Fig. 10-83: Definition of the protocol error

Execution error	Code number	Description of error
error during parameter transmission	0x01	When reading or writing a parameter an error occurred.

Fig. 10-84: Definition of the execution error

Example:

Write access to the write-protected parameter **S-0-0106, Current loop proportional gain 1**.

The master tries to write the value "0" to the parameter. The drive acknowledges with the "0x7004" ("Data cannot be changed") error message.

Command Telegram:

	3C	00	04	0B	00	00	00
tel. header	control byte	device address	param. type	parameter no. (LSB)	(MSB)	useful data	
				useful data header			

Ta0003f1.fh7
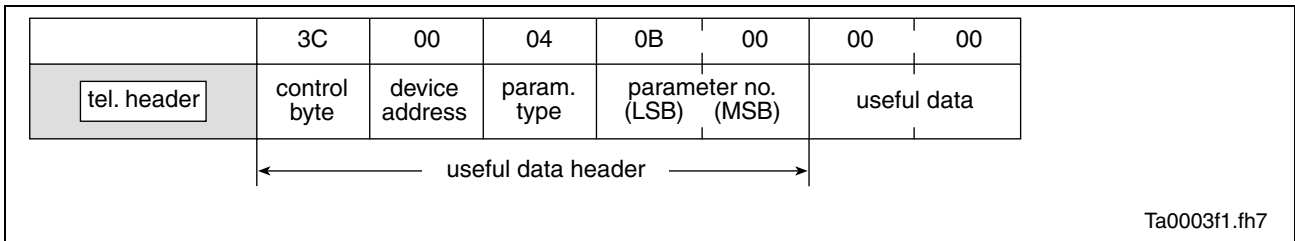
Fig. 10-85: Writing the S-0-0106 parameter (command telegram)

Reaction Telegram:

	01	3C	00	04	70
tel. header	status byte	control byte	device address	useful data	
		useful data header			

Ta0004f1.fh7
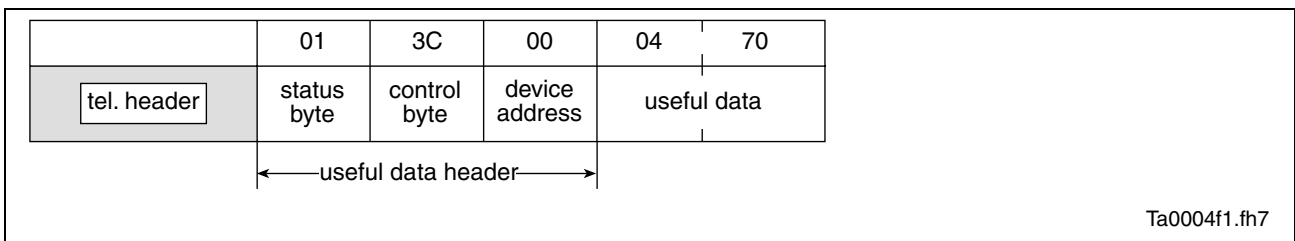
Fig. 10-86: Reading the S-0-0106 parameter (reaction telegram)

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Notes

11   Commissioning

11.1   Commissioning Motors

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 in the "Project Planning Manual" product documentation.

Checking the Installation

i   Check the wiring of control cabinet and machine with regard to correct implementation according to the data in the Project Planning Manual and the recommendations in the "Electromagnetic Compatibility (EMC) in Drive and Control Systems" documentation.

Initial Commissioning/Serial Commissioning

Brief Description

The drive can be commissioned after assembly and installation have been correctly implemented.

Initial Commissioning   The initial commissioning of a drive differs from the commissioning of other identical drives (serial commissioning).

The initial commissioning is carried out in the following steps:

- establishing the operatability of the drive (including the required measuring systems)
- adjusting the drive behavior to the requirements of the application
- adjusting the master communication interface between master and drive
- integrating drive functionalities in the machine processes

In each of the mentioned steps, values of relevant parameters are adjusted to the requirements. The result of the initial commissioning is a drive the behavior of which is exactly adjusted to the axis. By storing the values of the initial commissioning in the form of a parameter set the drive behavior can be reproduced.

Serial Commissioning   For the commissioning of other identical axis drives on machines of the same type, the set of parameter values determined during the initial commissioning is loaded to the respective controller (serial commissioning). This allows

- exactly reproducing the drive behavior

    - and -

- reducing the effort for further commissioning to a little adjustment work and, if necessary, search and elimination of assembly/installation errors.

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Possibilities of Commissioning

As a matter of principle, commissioning can be carried out by means of

- the "DriveTop" commissioning tool by Bosch Rexroth connected to the drive via SERCOS interface or via a serial interface,
- the control panel of the controller and digital and analog input signals,
- a control unit connected to the drive via a master communication interface.

Two-Step Commissioning

It is basically recommended to always carry out both the initial commissioning and the serial commissioning in two steps:

- 1st objective: Initial Start of the Motor
- 2nd objective: providing drive functions for the machine axis
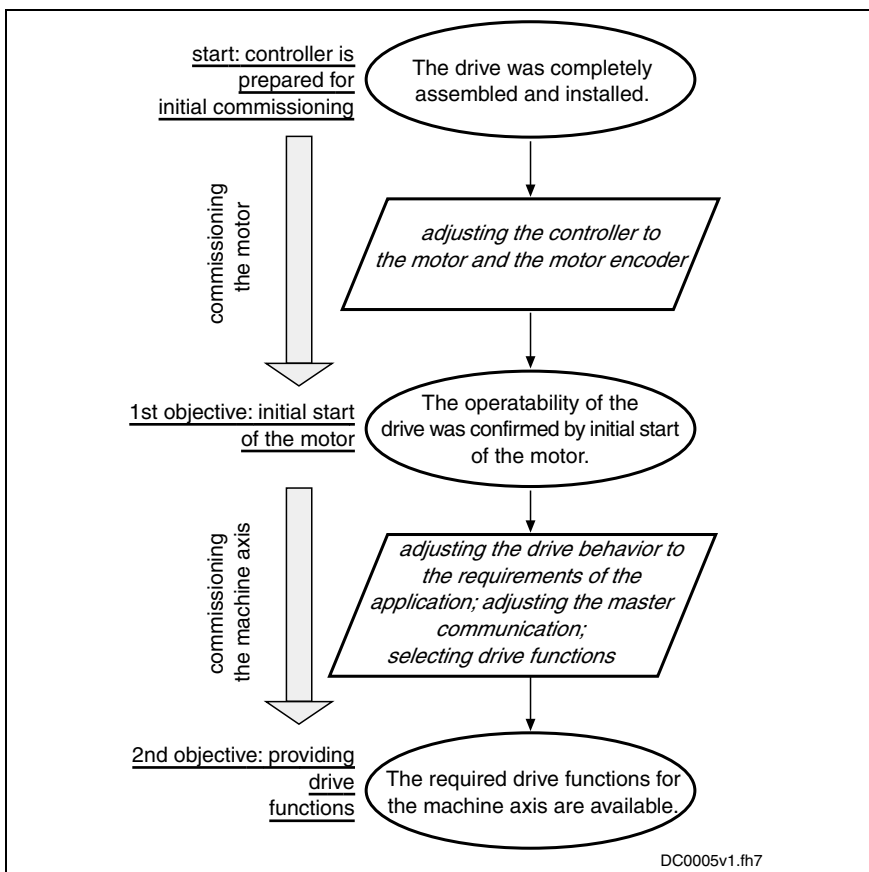
Fig. 11-1:   Two-step drive commissioning, schematic

In the first step, the two-step procedure ensures the operatability of the drive (1st objective during initial commissioning and serial commissioning). In the second step, the drive functions required for the machine axis and the drive's advantageous properties are individually adjusted to the machine axis in a reasonable order (2nd objective during initial commissioning) or the expected functional principle is checked (2nd objective during serial commissioning).

Note: As a matter of principle, it is advantageous to establish the operatability of a drive independent of a higher-level control system. The drive should therefore first be commissioned as a self-contained unit via DriveTop or in the "Easy Startup" mode!

See following sections:

- "Initial Start in "Easy Startup" Mode"

- "Initial Start with the DriveTop Commissioning Tool"

Notes on Commissioning

Initial Start of the Motor

See "Initial Start in "Easy Startup" Mode"

See "Initial Start with the DriveTop Commissioning Tool"

Providing Drive Functions

See "Commissioning Machine Axes"

Initial Commissioning

After initial commissioning has been carried out the defined application-specific parameter values have to be saved. The saved parameter values allow reproducing the drive behavior required at the respective machine axis.

Note:	For saving the parameter values the drive provides parameter lists supporting the complete storage of the relevant parameter values.

By reloading the saved parameter values the original status after initial commissioning can be established again for the axis drive!

See also "Parameters, Basics: Loading, Storing and Saving Parameters" in chapter "Handling, Diagnostic and Service Functions"

Attention: Reestablishing Original Status After Initial Commissioning for Drives with Absolute Encoders

⚠ **CAUTION**

Possible property damage for drives with absolute encoders caused by incorrect actual position value after repeated loading of parameter values saved according to S-0-0192!

⇒ Save parameter values by means of accordingly modified IDN list of parameter S-0-0270 (see below)

For drives with absolute value encoder and modulo scaling it is recommended to determine the parameter set for saving the parameter values after initial commissioning by means of a list of **S-0-0270, Selected IDN list of operation data to backup** modified by the customer so that there cannot occur any actual position value error when the saved parameter values are loaded to the same axis drive again.

Note:	This is only possible via a control master. MMC and DriveTop are only working with the list from S-0-0192!

In its original status the list in S-0-0270 first corresponds to the list of S-0-0192 and should be modified as follows:

- Remove the IDNs P-0-0177 and P-0-0178

These parameters contain information on the current position data of the absolute encoders at the time of parameter backup. If the current data of P-0-0177 and P-0-0178 during the loading of the saved parameter values were overwritten with data referring to a different axis position current at the time of parameter backup, the actual position values would then correspond to the other axis position! The actual position values would remain valid (**S-0-0403, Position feedback value status**) because it still is the same absolute value encoder.

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Note:	The incorrect actual position value generated in this case cannot be detected on the drive side because otherwise unjustified errors would be generated in service cases when devices are replaced!
	See also "Notes on How to Replace the Devices" in chapter "Handling, Diagnostic and Service Functions"

Note:	The list of parameter S-0-0270 modified as described can also be used for saving and loading the parameter values of axes with relative measuring systems, because P-0-0177 and P-0-0178 in this case do not contain relevant information!

Note:	The possibly modified list of parameter S-0-0270 is also contained in the list of S-0-0192! This means that when the backup is made via S-0-0192, parameter S-0-0270 can be read from the stored list in order to load only these individually selected parameter values!

Serial Commissioning

The serial commissioning of axis drives of machines of the same type is supported by the application-specific parameter set of the respective axis drive saved after initial commissioning.

During serial commissioning the saved parameter sets are loaded to the controllers of the respective axis drives of other machines of the same type. This allows easily reproducing the behavior of the drives of a "model machine"!

After the application-specific parameter set of an axis drive has been loaded only some more adjustments are required:

- setting the drive address (see "Basic Functions of Master Communication: Address Assignment" in chapter "Master Communication")

- establishing the position data reference for axes with measuring systems to be evaluated in absolute form (see "Establishing the Position Data Reference: Establishing Position Data Reference for Absolute Measuring Systems" in chapter "Drive Functions")

See also "Parameters, Basics: Loading, Storing and Saving Parameters" in chapter "Handling, Diagnostic and Service Functions"

Initial Start in "Easy Startup" Mode

Brief Description

After complete and correct assembly and wiring of the drive or the drives it makes sense to establish the operatability. This is easily and practically done by means of initial start in velocity-controlled operation.

"Easy Startup" Mode

With IndraDrive controllers the initial start in the so-called "easy startup" mode can be carried out very easily **when using Rexroth motors with encoder data memory**. It can be activated via the control panel of the controller. The "easy startup" mode only requires two digital input signals. Other accessories or commissioning tools such as PCs or the like are not required for the initial start in the "easy startup" mode!

Note:	For controllers with control section type designations "CSB01.1N-FC-..." (BASIC OPENLOOP) and "CSB01.1N-AN-..." (BASIC ANALOG) the "easy startup" mode is the standard and does not have to be activated!
	See also "Analog Interface" in chapter "Master Communication"

If the initial start in the "easy startup" mode should not work via the mentioned signals, the installation of the drive has to be checked in detail!

Setting Parameters   By activating the "easy startup" mode parameters are automatically set in the drive so that

- operation without master communication is possible and
- the digital input signals are mapped to the corresponding parameters.

Diagnostic Messages   There aren't any specific diagnostic messages for the "easy startup" mode. Simple diagnostic texts, however, will appear on the display of the control panel in light writing if the "easy startup" mode cannot be activated.

Hardware Requirements

Control sections BASIC SERCOS, BASIC PROFIBUS, BASIC UNIVERSAL and ADVANCED

For using the "easy startup" mode the digital inputs and outputs (X31,X32) must be connected as follows:

- connect 24V/0V power supply to respective terminal connectors
- X31/4:   +24 V for activating drive enable
- X32/7 and X32/8: 0V/+24V for activating the positive or negative rotational direction

Control sections BASIC OPENLOOP and BASIC ANALOG

For drives with these control section the "easy startup" mode is not available because these drives can easily be moved with an analog command value.

See also "Analog Interface" in chapter "Master Communication"

Functional Description

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

- The wiring of the drive is complete and correct.
- A Rexroth motor with encoder data memory is used.
- There mustn't any master communication have been activated.
- The controller must be supplied with control voltage and it must be possible to switch power on.
- There mustn't any error message be present.

Activation   The "easy startup" mode is activated via the control panel of the controller.

Sequence for activating the "easy startup" mode via the control panel:
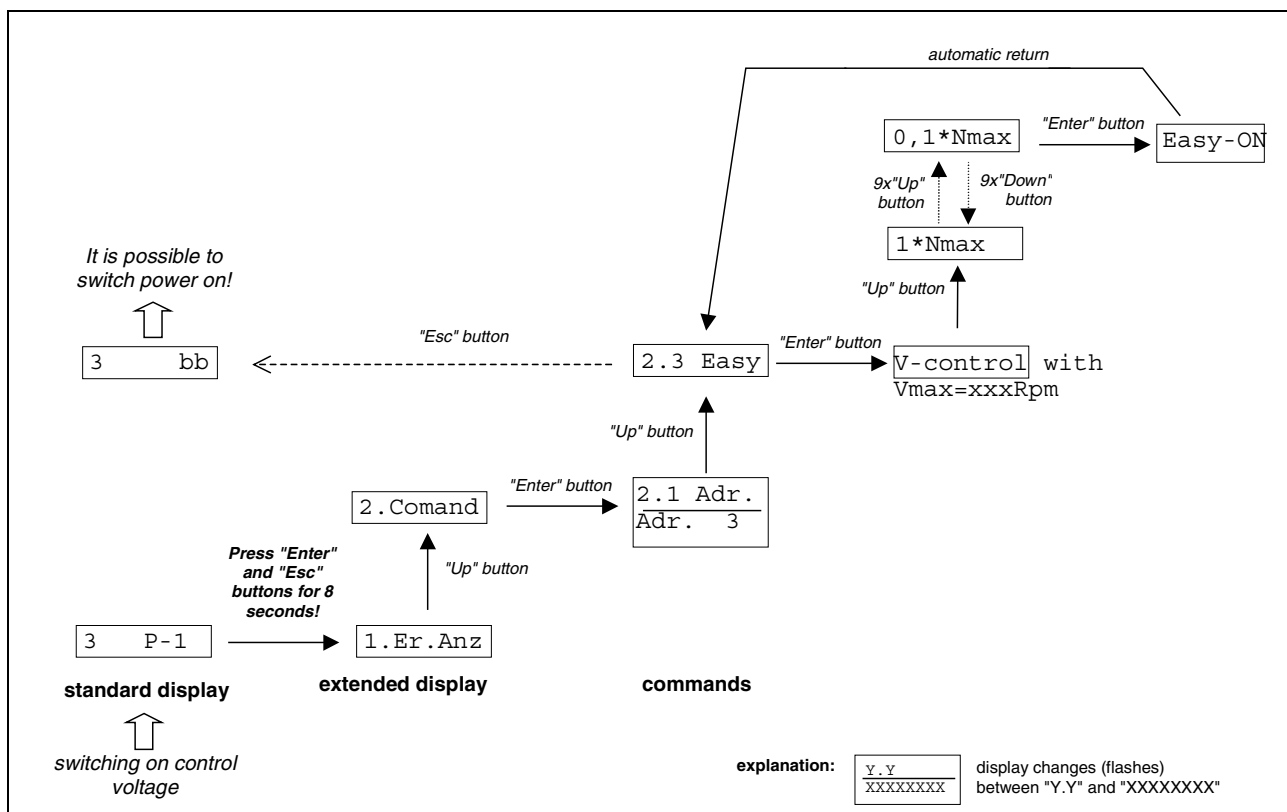
Fig. 11-2:   Activating the "easy startup" mode

For the description of the control panel and the display see "Control Panel of the IndraDrive Controllers" in chapter "Handling, Diagnostic and Service Functions"

By activating the "easy startup" mode the following settings are automatically made:

- activation of "volatile storage" of parameters (i.e. the changes in the parameter values required for the "easy startup" mode are not stored and get lost by switching the control voltage off)

Note: Do not trigger the commands for backup of working memory (**C2200 Backup working memory procedure command** and **C2400 Selectively backup working memory procedure command**) becuase 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"!

- deactivation of the master communication interface
- activation of **P-0-4028, Device control word** for setting "drive enable"
- assignment of input E3 (X31/5) to the "drive enable" bit in parameter P-0-4028
- assignment of EA9 (X32/7) to bit 0, of EA10 (X32,8) to bit 1 of **P-0-1200, Control word of velocity control mode**
- assignment of the command velocity selected via the control panel in percent of **S-0-0091, Bipolar velocity limit value**; with positive sign to

element 1, with negative sign to element 2 of **P-0-1206, Memory of velocity command values**

Note: The assignments are made in **P-0-0300, Digital I/Os, assignment list**, **P-0-0301, Digital I/Os, bit numbers** and **P-0-0302, Digital I/Os, direction**.

• activation of the "velocity control" mode in parameter **S-0-0032, Primary mode of operation** and switching to "bb"

Switching Between "Ready for Operation" and Parameterization Mode

After activating the "easy startup" mode the drive normally is ready for operation ("bb" or "Ab" → communication phase 4). When the drive stops in communication phase 3 due to inadmissible parameter values, valid base parameter values can be loaded via the control panel (see "Control Panel of the IndraDrive Controllers"). To do this the drive first has to be switched to the parameterization mode ("P2" = communication phase 2).
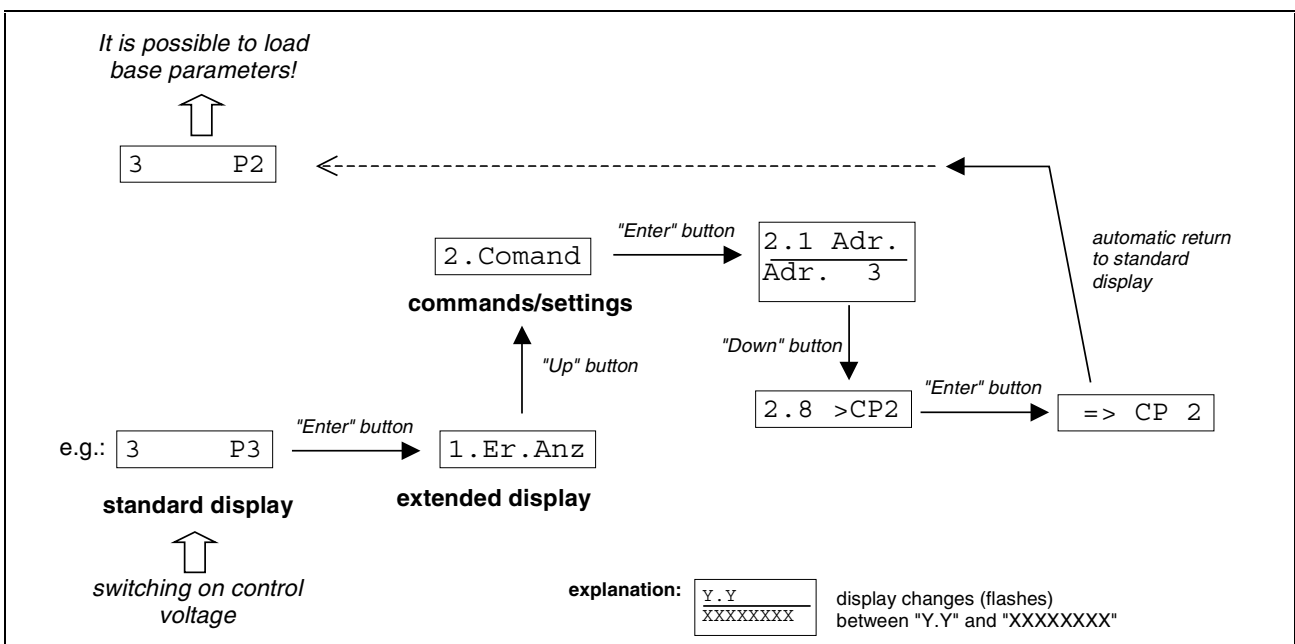
Fig. 11-3:   Activating the "easy startup" mode via the control panel

In order to commission the drive in the "easy startup" mode it must be switched back from the parameterization mode to "ready for operation".
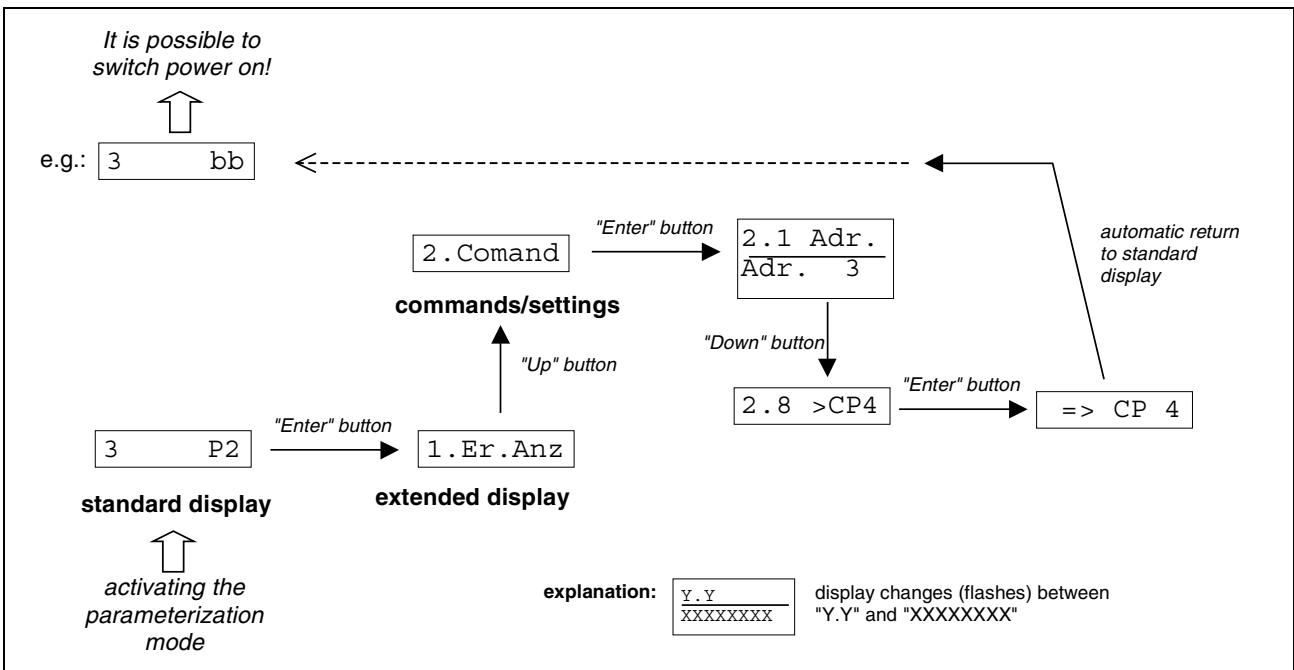
Fig. 11-4: Switching the drive in the "easy startup" mode" back from the parameterization mode to "ready for operation" via the control panel

Terminating the "Easy Startup" Mode

The "easy startup" mode can only be terminated by switching the controller off!

When the controller is switched on again it first is in its original state. If the "easy startup" mode is required again, it has to be activated again.

Notes on Commissioning

⚠️ **CAUTION**

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

⇒ For motors without encoder data memory, the initial start in the "easy startup" mode during initial commissioning is not allowed because the automatic adjustment of the controller to the motor is impossible!

How to use the "Easy Startup" Mode

- During initial commissioning the initial start in the "easy startup" mode is only allowed for motors with encoder data memory!

- For serial commissioning (parameter values determined by initial commissioning are already stored in the controller) the initial start in the "easy startup" mode is possible for motors with and without encoder data memory!

Activating the "Easy Startup" Mode

Steps to follow for the initial start in the "easy startup" mode during initial commissioning:

1. Connect power supply of inputs/outputs (X31/X32) with 24V/0V, then switch control voltage on.

2. When drive displays communication phase "P2", activate "easy startup" mode via buttons of control panel: "Enter" → "Up" → "Enter" → "Up" → "Up" → "Enter" → "Enter"

   Activated "easy startup" mode is displayed for a short time with the letters "Easy-ON". Then the operating status message "bb" will be displayed (see also fig. "Activating the "easy startup" mode").

Note:	The following has to be observed for step 2:

- During the initial commissioning of a motor with encoder data memory the controller requests "load controller parameters" after activation of the "easy startup" mode. This is shown on the display by "RL" flashing.

- The controller parameters for adjusting the controller to the motor are loaded by pressing the "Esc" button; the motor can now be commissioned.

- If "RL" is not displayed a motor of the same type was already commissioned with this controller or a parameter set was loaded that was created for a motor of the same type.

- If the display shows communication phase "P3" (due to possibly inadmissible parameter values), it is useful to load the base parameter values. To do this it is first necessary to switch to communication phase "P2" (see above).

Enable and Move the Drive

3. Switch power on; display now reads "Ab".

4. Enable the drive. To do this apply 24 V input signal to E2 (X31/4) only. Drive thus has been enabled and is in velocity control. Display reads "AF".

⚠ **CAUTION**

Property damage caused by errors when controlling motors!

⇒   Caution when applying the digital input signals!

5. Drive can now be moved with 24 V input signal at EA9 (X32/7) with positive command value, with 0 V at EA9 (X32/7) and 24 V at EA10 (X32/8) with negative command value. The maximum speed corresponds to the value of S-0-0091, the effective command value can be reduced via the control panel up to 10% of the maximum speed (see fig. "Activating the "easy startup" mode via the control panel").

Displaying the Operating Status   The activated "easy startup" mode is not displayed. For controlling whether the "easy startup" mode has already been activated, carry out the steps for activating it again. If the drive already is in the "easy startup" mode and this mode is activated again, the display reads "Easy active".

Terminating the "Easy Startup" Mode   The "easy startup" mode is terminated by switching the controller off.

The "easy startup" mode active before is not stored; if necessary, it has to be activated again!

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Initial Start with DriveTop Commissioning Tool

Brief Description

After complete and correct assembly and wiring of the drive or the drives it makes sense to establish the operatability. The easiest way to do this by means of initial start in velocity-controlled operation.

DriveTop For commissioning IndraDrive drives Bosch Rexroth makes available a PC program with the product name "DriveTop".

By means of the DriveTop commissioning tool communication with the drive can be established via

- SERCANS box (SYSDA02.2) and SERCOS interface

- or -

- serial interface RS232/RS485.

DriveTop offers the following possibilities and advantages:

- The functions and features made available by the drive are structurally visualized, the respective parameter values are displayed in their functional context.

- Parameter values can be directly changed and thereby adjusted to the respective requirements.

- The parameter values available in the drive can be saved drive-externally as a group (parameter set), e.g. on the PC hard disk, and can be reloaded from the hard disk.

- Diagnostic messages and operating status messages are displayed in clearly arranged form.

- The drive can be commissioned and moved via DriveTop.

- For commissioning purposes, it is possible to start commands via DriveTop.

Functional Description

Before the initial start of the motor, the steps illustrated below have to be followed:
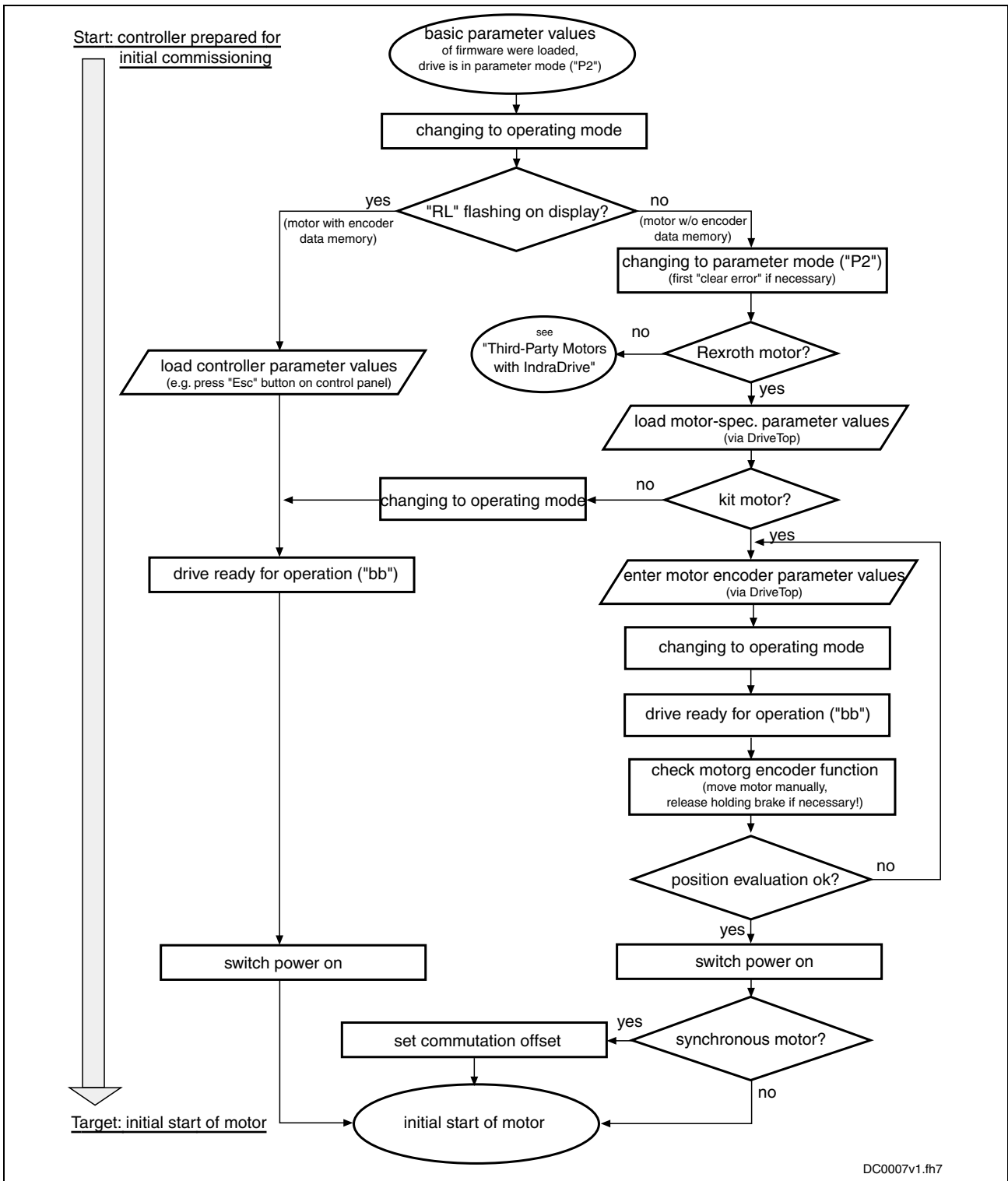
Fig. 11-5:   Steps before the initial start of a Rexroth motor

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Notes on Commissioning in Conjunction with DriveTop and SYSDA02.2

The steps for initial start illustrated in the figure (above) are described below as a detailed sequence for a Rexroth motor in conjunction with DriveTop and SYSDA02.2 (SERCOS interface):

Basic Actions

1. Connect "SYSDA02.2" hardware according to installation instructions:

   voltage supply must be available, establish serial communication with PC that makes DriveTop available and establish fiber optic SERCOS connection to controller (observe Tx -> Rx!) *(see technical documentation of SYSDA02.2).*

2. Switch on supply voltage of the controller(s).

   Display of controller(s) first shows boot phases. Then drive address and communication phase "P-1" will be displayed.

3. In DriveTop, enter drive address appearing on display:

   enter drive address(es) in "System overview" *(open "System overview" dialog under menu item "Setup" – "SERCANS basic configuration").*

4. From communication phase "P-1" change to parameter mode "P2":

   activate "parameterization mode" ("P2") *(press right mouse key, activate with cursor).*

5. Now select drive in the SERCOS ring that is to be commissioned:

   have list of drives connected by SERCOS ring displayed and select a drive *(to do this, activate "System overview" in menu item "Overview" and select a drive with cursor).*

   The drive to be commissioned can now be addressed via DriveTop!

6. First prepare loading of basic firmware parameters:

   write value "0x001" to parameter P-0-4090 *(Select dialog "Drive commands" under menu item "Extras". Press right mouse key, select "Single parameters" with cursor, call "p4090" and write data).*

7. Now load basic firmware parameters:

   start C0700 Load defaults procedure command *(select command "S-0-0262, C07_x Load defaults procedure command" from list with cursor, start with corresponding button).*

   After command execution message, basic firmware parameter values (default parameter values) were loaded to drive parameters, drive now is in an operable initial state.

8. From communication phase "P2" change to phase "bb" (operating mode, P4):

   activate "operating mode" *(press right mouse key, select with cursor).*

   If controller now requests loading of controller parameter values by "RL" flashing, continue with no.9, if a different diagnostic message is displayed, continue with no.11.

Rexroth Motor with Encoder Data Memory

9. When "RL" is flashing on the display, a Rexroth motor with encoder data memory was connected to controller. Now adjust controller to motor:

   Start "Clear error" command *(press right mouse key, activate with cursor or "Esc" at control panel).*

   Drive now is ready for operation, display of drive addressed by DriveTop reads "bb".

   If there are other drives in the SERCOS ring, repeat steps from no.5 onward!

10. Continue sequence with no.16

Rexroth Motor with Motor Encoder without Data Memory

11. If "RL" is not flashing on right side next to drive address at controller display, a five-digit diagnostic message text appears in most cases. In this case, motor does not have an encoder memory. Therefore, there aren't any motor-specific parameter values made available on motor side. If connected motor is a Rexroth motor, motor-specific parameter values can be loaded to controller via DriveTop:

    activate "Parameter mode" *(press right mouse key, select with cursor)*.

    On right side next to drive address display reads "P2".

12. Load motor-specific parameter values:

    select Rexroth motor type in "Motor parameters" dialog *(Open "Drive functions – motor parameters" dialog. Select tab page "Kit motor" or "without feedback data memory". Enter type designation of stator and rotor. Then activate "Edit motor parameters", if necessary, and activate "Set motor parameters")*.

    Motor-specific parameter values are now loaded to drive. If the motor is a Rexroth housing motor without encoder data memory, change to operating mode (cf. no.14), then continue with no.16, if it is a Rexroth kit motor, continue with no.13.

Rexroth Kit Motor

13. Control motor encoder parameters, adjust to encoder used, if necessary:

    Select motor encoder used in "Encoder settings" dialog, set line count, negation if necessary and encoder interface used *(open "Drive functions – encoder settings" dialog)*.

14. From communication phase "P2" change to phase "bb" (operating mode, P4):

    activate "Operating mode" *(press right mouse key, select with cursor)*.

    Drive now is ready for operation, display of drive addressed by DriveTop reads "bb".

15. Now check function of motor encoder:

    To do this, manually move motor shaft or linear motor slide in pos. direction (see requirements regarding direction of movement in Project Planning Manual of respective motor!). *(to do this, select "Drive status" in "Overview" menu item with cursor)*

    When actual position values of motor are increasing and traveled distance corresponds to actual position value difference displayed, motor encoder evaluation is okay; if not, return to no.13 of sequence!

Switching Power On

When displays of all drives in SERCOS ring read "bb", power can be switched on via supply unit:

    When DC bus voltage was supplied, controller displays read "Ab" (ready for power output).

Configuring and Activating Command Value Box

16. Each drive in SERCOS ring can be individually addressed with command values via DriveTop:

    Select respective drive in system overview *(to do this, activate "System overview" in menu item "Overview" and select a drive with cursor)*.

Note: In the case of synchronous kit motors, commutation setting has to be carried out first; see "Rexroth Kit Motors, Synchronous". This process is also supported by DriveTop *(see "Drive commands" dialog under menu item "Extras")*!

Configure command value box of DriveTop *(via menu bar "Extras" – "Virtual battery box" – "Virtual battery box selection" select command value function "configured" and the desired operating mode)*.

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Note:	For initial start of kit motors it is important first to check correct direction of movement in torque/force control!
	For moving the drive during initial start a velocity-controlled operating mode is useful!

Activate command value box of DriveTop *(via DriveTop menu bar "Extras" – "Virtual battery box" – "Virtual battery box adjustments" set travel profile of selected operating mode)*.

Note:	Reduce velocity and torque/force limits to safe values!

Enable Drive   17. Now put drive into operation:

⚠️ **CAUTION**

Possible damage caused by errors when controlling motors and moving parts!

⇒ Only enable axis from safe initial position! E-Stop pushbutton must be available in position easy to reach!

Set drive enable *(activate "Enable" button with cursor)*!

Negatively acknowledge warning dialog for possibly dangerous movements if requirements for safe drive functioning have not been fulfilled *(activate "Cancel" button with cursor)*!

Positively acknowledge warning dialog if requirements for safe drive functioning have been fulfilled *(activate "OK" button with cursor)*!

18. Correctly moving the drive according to command values preset by DriveTop confirms operatability of drive.

If drive does not follow command values, shut it down fast as can *(activate "Drives OFF" button with cursor or press E-Stop pushbutton)*.

If drive follows command values, this is the basis for further commissioning steps regarding master communication via NC and further machine-axis-related functions!

11.2 Commissioning Machine Axes

Overview and Practical Tips

Brief Description

Before commissioning machine axis-specific functions it is useful to make sure that the drive, consisting of controller, motor and motor encoder, is operational. The best way to do this is the initial start of the drive with the PC-based commissioning tool "DriveTop" by Bosch Rexroth (see "Initial Start with the DriveTop Commissioning Tool").

The commissioning of machine axis-specific functions should also be carried out via DriveTop, if possible. The advantage is that the correct sequence of an axis-specific function can be configured and ensured independent of the control unit. Further commissioning of the drive, with widely complete configuration, is then easier for the control unit.

Schematic Sequence

Commissioning procedure as a sequence of steps:
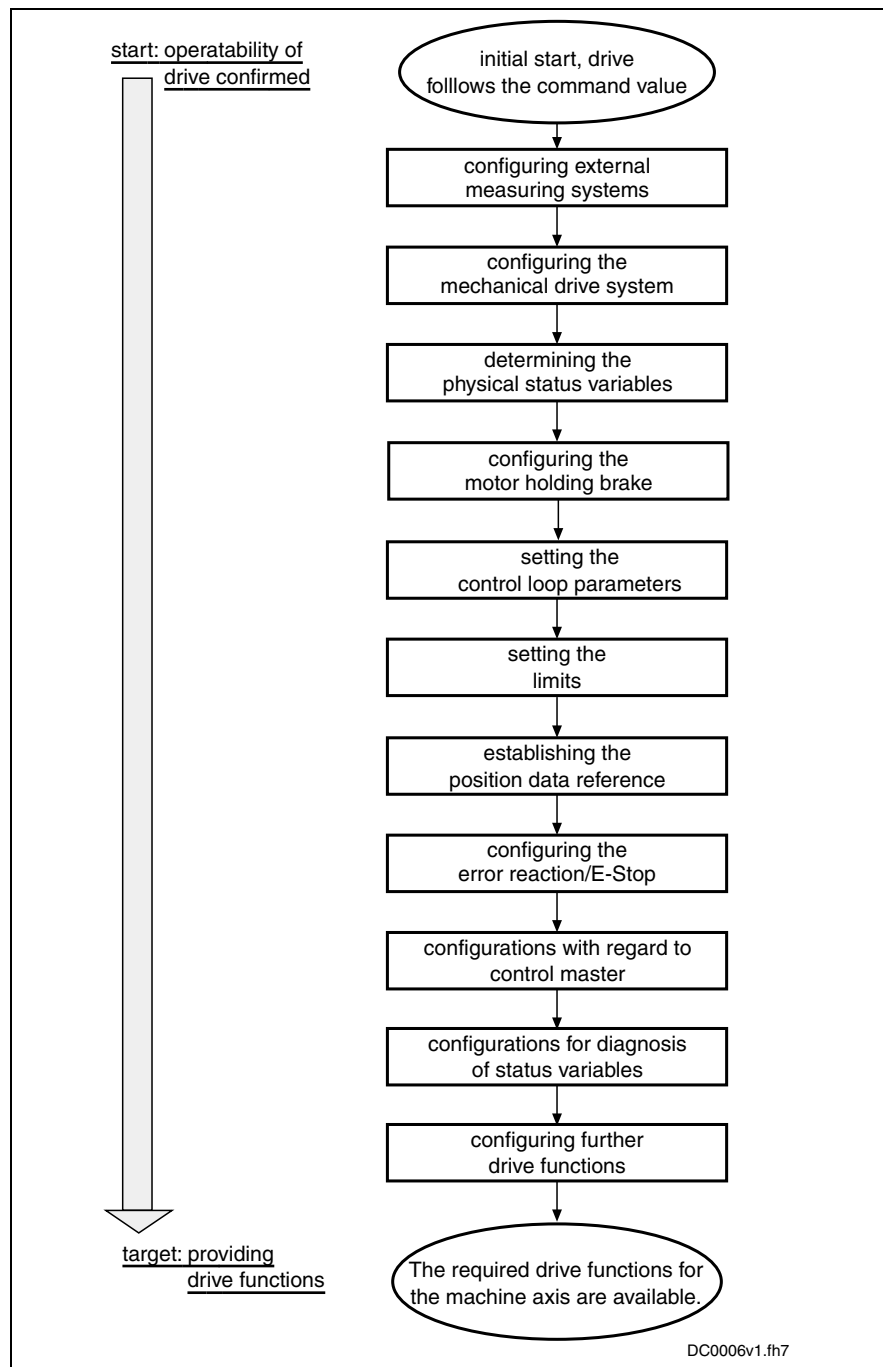
Fig. 11-6:   Steps of machine axis-related commissioning

Notes on the Commissioning Steps

The subjects of the individual commissioning steps are treated in detail in different chapters of this firmware documentation. The information contained in the chapter is basically divided into:

- Brief Description
- Functional Description
- Notes on Commissioning

To explain the individual commissioning steps we refer to the Notes on Commissioning for the respective subject, if possible.

i 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

Configure controller and encoder (set travel range, if necessary)

See also "Basics on Measuring Systems, Resolution: Notes on Commissioning" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Relative Encoders

Set initial position value; configure distance-coded measuring systems

See "Relative Measuring Systems: Notes on Commissioning" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Absolute Encoders

Check whether absolute encoder evaluation is possible (depending on travel range), set initial position value

See "Absolute Measuring Systems: Notes on Commissioning" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Position Monitoring

Set position monitors:

- axis position monitor (position at time drive is switched on) for absolute encoders
- position difference monitor of motor encoder and external encoder
- configure spindle encoder monitor

See "Monitoring the Measuring Systems: Notes on Commissioning" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Configuring the Mechanical Axis System

Depending on the mechanical properties, make the following settings:

- enter load gear ratio
- enter feed constant
- enter motor encoder gear ratio
- enter gear ratio for external encoder

See "Measuring Systems for Motor and Axis Control, Arrangement: Notes on Commissioning" in chapter "Measuring Systems for Motor and Axis Control, Arrangement"

Determining the Physical Status Variables

Make scaling settings for position, velocity, acceleration, torque/force and temperature data.

See "Scaling of Physical Data: Notes on Commissioning" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Configuring the Holding Brake

If the motor to be controlled is equipped with a holding brake or the controller has to control an external holding brake (for kit motors, if necessary), make the following settings:

- enter maximum "drive off" delay time
- enter holding brake data (external brake), if necessary
- configure type, functioning principle and monitor of brake in holding brake control word

See "Motor Holding Brake: Notes on Commissioning" in chapter "Motor, Mechanical Axis System, Measuring Systems"

Setting the Control Loop Parameters

Set controller and filter parameters for the control loops:

- velocity control loop
- position control loop

See "Notes on Commissioning" in the sections of chapter "Drive Control"

Setting the Limitations

The controller offers the possibility of limiting physical status variables of the drive. Depending on the application, limit values can be set for:

- torque/force command value
- velocity command value
- position command values and actual position values

Limiting Torque/Force Command Value

On the user side, limitations are available for:

- maximum allowed torque/force (S-0-0092, P-0-0109)
- motive and generating load at stationary velocity (S-0-0082, S-0-0083)

The limit values currently effective due to the user-side limit settings are displayed in:

- **P-0-0444, Actual value peak torque limit**
- **P-0-0442, Actual value torque limit positive (stationary)**
- **P-0-0443, Actual value torque limit negative (stationary)**

Current command values are displayed in:

- **P-0-0049, Effective torque/force command value**
- **P-0-0038, Torque-generating current, command value**

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

Apart from the user-side limits, further limits take effect in the torque/force or current control loop:

- absolute current limit values due to controller and motor
- load-dependent (dynamic), thermal current limit values

See also "Limitations: Current and Torque Limitation" in chapter "Drive Control"

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Limiting the Actual Velocity Value	On the user-side, the limitation of the actual velocity value to the lower value of

- 1.125 * **S-0-0091, Bipolar velocity limit value** and
- **S-0-0113, Maximum motor speed**

are available on the user side.

See also "Torque/Force Control" in chapter "Operating Modes"

Limiting the Velocity Command Value	In the "velocity control" mode the limitation of the velocity command value

- **S-0-0091, Bipolar velocity limit value**

and in the "position control" mode the limitation of the

- position command value difference to S-0-0091 and S-0-0113

are available on the user side.

See also "Velocity Control" and "Position Control with Cyclic Command Value Input" in chapter "Operating Modes"

Limiting the Position

There are the following possibilities on the user side for limiting the position:

- limitation of actual position value (firmware "limit switch")
- limitation of travel range of the axis (hardware limit switch)

See also "Limitations: Position Limitation/Travel Range Limit Switches" in chapter "Drive Control"

Establishing the Position Data Reference

Measuring Systems to be Evaluated in Absolute Form

For measuring systems that can be evaluated in absolute form the position data reference has to be established once during initial commissioning:

See also "Establishing Position Data Reference for Absolute Measuring Systems: Notes on Commissioning" in chapter "Drive Functions"

Relative Measuring Systems

For relative measuring systems all settings have to be made in such a way that the position data reference can be established internally and automatically (after switching on the machine at a command of the control master to the respective axis drive).

See "Establishing Position Data Reference for Relative Measuring Systems: Notes on Commissioning" in chapter "Drive Functions"

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" in chapter "Drive Functions"

The setting has to be made whether a drive is to carry out an E-Stop reaction at a hardware-side E-Stop signal and how the E-Stop reaction of the drive is to take place.

See "E-Stop Function" in chapter "Drive Functions"

Configurations with Regard to Control Unit (Master)

With regard to master-controlled drive operation the following settings are required:

- presetting of operating modes (primary mode of operation and secondary operating modes)

  See "Overview of Operating Modes: Operating Mode Handling" in chapter "Operating Modes"

- settings for the determined primary or secondary operating modes

    See description of the respective operating mode in chapter "Operating Modes"

With regard to the master communication interface used by the control master it is possible to make presettings for:

- SERCOS interface
(When using the "DriveTop" commissioning tool, this is only appropriate via serial communication!)

- PROFIBUS-DP

- parallel interface

- analog interface

See chapter "Master Communication"

Configurations for Diagnosis of Status Variables

If status variables of the drive are to be evaluated during operation, these status variables can be transmitted to the control master in different ways.

Diagnostic possibilities with SERCOS interface:

- content of a parameter cyclically updated that can be cyclically transmitted and that contains the value of the respective status variable

    See "SERCOS interface" in chapter "Master Communication"

- message in terms of whether a threshold value of the status variable was exceeded, via **S-0-0144, Signal status word**

    See "Possibilities of Control/Additional Functions: Configurable Signal Status Word" in chapter "Master Communication"

- drive-internal oscilloscope feature

    See also "Oscilloscope Feature" in chapter "Handling, Diagnostic and Service Functions"

Diagnostic possibilities independent of the master communication interface:

- analog output of the value of the respective status variable as voltage signal

    See "Analog Outputs" in chapter "Extended Drive Functions"

- digital message in terms of whether a threshold value of the status variable was exceeded, by assigning bits from **S-0-0144, Signal status word** to digital outputs

    See "Digital Inputs/Outputs" in chapter "Extended Drive Functions"

Configuring Further Drive Functions

Further configurable drive functions are:

- Drive Halt

- friction torque compensation

- detecting marker position

- spindle positioning

- probe

- digital and analog inputs/outputs

See description of the respective function in chapter "Drive Functions" or "Extended Drive Functions"

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13   Service & Support

13.1 Helpdesk

Unser Kundendienst-Helpdesk im Hauptwerk Lohr am Main steht Ihnen mit Rat und Tat zur Seite. Sie erreichen uns

Our service helpdesk at our headquarters in Lohr am Main, Germany can assist you in all kinds of inquiries. Contact us

- telefonisch - by phone: über Service Call Entry Center - via Service Call Entry Center	**49 (0) 9352 40 50 60** Mo-Fr 07:00-18:00 Mo-Fr 7:00 am - 6:00 pm
- per Fax - by fax:	**+49 (0) 9352 40 49 41**
- per e-Mail - by e-mail:	**service.svc@boschrexroth.de**

13.2 Service-Hotline

Außerhalb der Helpdesk-Zeiten ist der Service direkt ansprechbar unter

After helpdesk hours, contact our service department directly at

+49 (0) 171 333 88 26

oder - or   **+49 (0) 172 660 04 06**

13.3 Internet

Unter **www.boschrexroth.com** finden Sie ergänzende Hinweise zu Service, Reparatur und Training sowie die **aktuellen** Adressen *) unserer auf den folgenden Seiten aufgeführten Vertriebs- und Servicebüros.

At **www.boschrexroth.com** you may find additional notes about service, repairs and training in the Internet, as well as the **actual** addresses *) of our sales- and service facilities figuring on the following pages.

☐ Verkaufsniederlassungen
▨ Niederlassungen mit Kundendienst

Außerhalb Deutschlands nehmen Sie bitte zuerst Kontakt mit unserem für Sie nächstgelegenen Ansprechpartner auf.

☐ sales agencies
▨ offices providing service

Please contact our sales / service office in your area first.

*) Die Angaben in der vorliegenden Dokumentation können seit Drucklegung überholt sein.

*) Data in the present documentation may have become obsolete since printing.

13.4 Vor der Kontaktaufnahme... - Before contacting us...

Wir können Ihnen schnell und effizient helfen wenn Sie folgende Informationen bereithalten:

1. detaillierte Beschreibung der Störung und der Umstände.

2. Angaben auf dem Typenschild der betreffenden Produkte, insbesondere Typenschlüssel und Seriennummern.

3. Tel.-/Faxnummern und e-Mail-Adresse, unter denen Sie für Rückfragen zu erreichen sind.

For quick and efficient help, please have the following information ready:

1. Detailed description of the failure and circumstances.

2. Information on the type plate of the affected products, especially type codes and serial numbers.

3. Your phone/fax numbers and e-mail address, so we can contact you in case of questions.

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13.5 Kundenbetreuungsstellen - Sales & Service Facilities

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<u>from abroad</u>: don't dial (0) after country code!

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