The Drive & Control Company

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# Rexroth HydraulicDrive HDx-18 Functions

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HDx-18
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This documentation describes all the functional properties of the HydraulicDrive firmware in the variant HDx-18.

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Zum Eisengießer 1 ■ D-97816 Lohr a. Main
Telephone +49 (0) 93 52 / 18-0
http://www.boschrexroth.com/
E-mail: dokusupport@boschrexroth.de

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# 1 System Overview

## 1.1 General Information

### 1.1.1 About This Documentation

**Means of Representation in This Documentation**

To facilitate reading this documentation, the table below contains the means of representation and notations of recurring terms.

| What? | How? | For example... |
|---|---|---|
| Important facts which are to be highlighted in the body text | Boldface | Transmission of freely configurable external **process data** (command values and actual values of the external control unit) |
| Parameter names, diagnostic message names, function designations | Quotation marks | ...the function "set/shift coordinate system" for firmware HDx18... |

*Tab. 1-1: Conventions of Notation*

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

**⚠ DANGER** ...

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

**⚠ WARNING** ...

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

**⚠ CAUTION** ...

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

***NOTICE*** ...

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

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

This box provides important information which should be taken into consideration.

This symbol highlights useful tips and tricks.

**Your Feedback**

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

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

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We need the following information to handle your feedback:

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

## 1.1.2 How to Use This Documentation

### Structure of the Functional Description

The functional descriptions of the HydraulicDrive firmware are subdivided into firmly defined chapters. The individual subjects of the firmware description are assigned to these chapters according to their content.

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

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

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

**Brief Description**

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

**Functional Description**

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

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

The detailed description of the diagnostic messages, their causes and remedies is contained in the separate documentation "Rexroth HydraulicDrive, 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 dis-

plays available for the respective function and describes them briefly. If there are function-specific monitoring functions, they are also described in this section.

### Markers and Terms

The complete functionality of the HydraulicDrive firmware is subdivided 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.:

Assignment to functional firmware package, see chapter "Supported Operation Modes".

**Terms**

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

- Firmware **family** e.g. HydraulicDrive
- Firmware **design** e.g. single-axis, double-axis
- Firmware **variant** e.g. HD**B**, HD**C**
- Firmware **version** e.g. HDx-**18**VRS
- Firmware **characteristic** e.g. open-loop/closed-loop
- Firmware **performance** e.g. Basic/Economy/Low
- Firmware **type** complete firmware type designation

### Cross-References

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

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

- References to sections within this documentation are specified by indicating the title of the respective section and the designation of the superordinate topic, if necessary (both can be easily found via the index).
- References to other documents are additionally signaled by the "info icon", unless contained in a note, in a table or in brackets.

## 1.1.3 Reference Documentations

Only deal with the product when you have the documentation identified with the book symbol 🕮 at hand and have observed it:

System Overview

| | Title | Document number | Document type |
|---|---|---|---|
| 🕮 | High-response valve with integrated digital controller (IAC-Multi-Ethernet) | RE 29391 | Technical data sheet<br>Available on the Internet at www.boschrexroth.com |
| 🕮 | High-response valve with integrated digital axis controller (IAC Multi-Ethernet) | RE 29391-B | Operating Instructions<br>Available on the Internet at www.boschrexroth.com |
| 🕮 | High-response valve with integrated digital axis controller (IAC Multi-Ethernet), pilot operated | RE 29288 | Technical data sheet<br>Available on the Internet at www.boschrexroth.com |
| 🕮 | Rexroth HydraulicDrive HDS-16, HDB-17 and HDx-18 | RE 30330-PA | Parameter description<br>Available on the Internet at www.boschrexroth.com |
| 🕮 | Rexroth HydraulicDrive HDS-16, HDB-17 and HDx-18 | RE 30330-WA | Diagnostic Messages<br>Available on the Internet at www.boschrexroth.com |
| 🕮 | Rexroth HydraulicDrive HDS-16, HDB-17 | RE 30330-FK | Functional Description<br>Available on the Internet at www.boschrexroth.com |
| 🕮 | Rexroth HydraulicDrive HDx-18 | RE 30331-FK | Functional Description<br>Available on the Internet at www.boschrexroth.com |
| 🕮 | Digital axis control HMC | RE 30239 | Technical data sheet<br>Available on the Internet at www.boschrexroth.com |
| 🕮 | Rexroth IndraMotion MLD (2G), Libraries as of HDx-18 | RE 30336-RE | Library Description<br>Available on the Internet at www.boschrexroth.com |
| 🕮 | Rexroth IndraMotion MLD (2G), Libraries as of HDx-18 | RE 30336-AP | Application Manual<br>Available on the Internet at www.boschrexroth.com |

*Tab. 1-2: Additional Documentations*

## 1.1.4 Terms, Basic Principles

### Engineering Tool "IndraWorks Ds/D/MLD"

"IndraWorks Ds/D/MLD" is a component of the software family "IndraWorks", which supports parameterization and commissioning of controls and drives from Rexroth. The commissioning tool "IndraWorks Ds/D/MLD" offers the following possibilities and advantages:

- The functions and features made available by the drive are visualized in a structured manner; the associated parameter values are displayed in the functional context
- Parameter valves can be changed directly and therefore adjusted to the individual requirements

- The parameter values in the drive can be be saved as group (parameter set) outside the drive, e.g. on a PC hard disk, from where they can also be re-loaded
- Diagnostic messages and operating status messages are displayed in clearly arranged form
- For commissioning purposes, commands can be started
- Via the “easy startup” modus drives can be commissioned and operated

"IndraWorks Ds/D/MLD" is available with different characteristics.

**IndraWorks Ds** IndraWorks Ds is sufficient for commissioning a single drive controller without PLC. It is characterized by the following features:

- Only for 1:1 connection between drive and PC
- Does not contain a project administration or a possibility of PLC programming
- Download version available on the Internet

**IndraWorks D/MLD** Apart from the above IndraWorks Ds functions, IndraWorks D/MLD comprises:

- Project administration
- Integrated PLC programming

IndraWorks D/MLD must be purchased on a data carrier (DVD).

## Master Communication

**Multi-Ethernet** Term for the support of several Ethernet-based communication types in one drive controller. The desired type of communication is selected by means of a parameter.

**Drive Bus** A drive bus transmits command and actual values clock-synchronously with the controller cycle of the drive or a multiple thereof. The time of transmitting this data can be determined with reference to the controller cycle. Typical representatives are sercos, EtherCAT® and VARAN.

**Field Bus** A field bus can transmit cyclic data, but there is no fixed time-based assignment to the controller cycle of the drive.

**Profiles** With field bus interfaces, profiles can be used to select certain pre-configured data in cyclic communication. Moreover, a specific behavior of the drive can be configured.

**Analog Master Communication** Alternatively to command triggering for a drive over a bus system, this can also be effected via an analog interface.

## Parameters

Communication between master and drive takes place, with a few exceptions, with the help 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 is mapped to parameters!

The operating data stored in parameters can be identified by means of the IDN. It can be read and transferred, if required. The user write access to parameters depends on the properties of the respective parameter and the cur-

rent communication phase. The drive firmware checks specific parameter values (operating data) for validity.

## Data Storage and Parameter Handling

**Data Memory**

Several non-volatile data memories are available in a HydraulicDrive device:

- In the controller
- Optional plug-in SD card (depending on device type)

The SD card is not hot-plug-capable. It must be plugged in before the drive is started.

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.

**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 also be stored in the working memory (volatile memory).

**Storing Parameter Values**

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

- After initial commissioning of the drive
- Before replacing the controller in the case of repairs (if possible)

Application-specific parameter values can be saved via:

- Commissioning tool "IndraWorks Ds/D/MLD"
  → Saving parameter values on external data carrier
- Control master
  → Saving parameter values on master-side data carrier

**Parameter IDN Lists**

The drive supports saving of parameter values on the master side 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, e.g. list of password-protected parameters.

**Loading Parameter Values**

Loading parameter values is required in the following cases:

- Initial commissioning of the drive
  → Loading of default values (factory settings)
- Series commissioning of machine axes in series machines
  → Loading of parameter values saved after initial commissioning
- Restoring of a defined as-supplied condition
  → Re-loading of parameter values saved after initial commissioning
- In case a repair is required, change of the drive controller
  → Loading of the current parameter values saved before the repair

Possibilities of loading parameter values to the controller:

- Commissioning tool "IndraWorks Ds/D/MLD"
  → Loading parameter values from an external data carrier
- Control master

→ Loading of 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 (see parameter S-0-0326).

## Password

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

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

**Kinds of Passwords**

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

- **Customer password**

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

- **Control password**

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

- **Master password**

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

## Commands

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

Each command is assigned to a parameter by means of which the execution of the command can be controlled.

Each command that was started must be actively cleared again.

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

**Types of Commands**

There are 3 different types of commands:

- **Drive control commands**
  - can cause automatic drive motion,
  - can be started only when drive enable has been set,
  - deactivate the active operation mode while they are being executed.
- **Monitor commands**
  - activate or deactivate monitoring or other functions in the drive.

System Overview

- **Administration commands**
  - carry out administration tasks,
  - cannot be interrupted.

See also section "Command Processing"

## Operation Modes

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

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

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

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

See also chapter "Operation Modes"

## Warnings

Depending on the active operation mode and the parameter settings, many monitoring functions are carried out. When a state is recognized that still allows proper operation, but, if the state persists, will result in the occurrence of a fault or error and thus to the automatic shutdown of the drive, the drive firmware generates a warning message.

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

**Classes of Warnings**

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

The warning class can be recognized by the diagnostic message.

The following classes of warnings are distinguished:

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

See also Diagnostic Messages (description of diagnostic messages)

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

## Errors

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

**Error Classes**

Errors are assigned to various error classes, which differ in different error reactions of the drive.

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

| Diagnostic message number | Error class |
|---|---|
| F2xxx | Non-fatal error |
| F4xxx | Interface error |
| F6xxx | Travel range error |
| F8xxx | Fatal error |
| F9xxx | Fatal system error |

*Tab. 1-3: Overview of Error Classes*

☞ Apart from the mentioned error classes that can occur during operation, errors can occur when the devices are booted and during firmware download. Boot and firmware download errors are described in a separate "Troubleshooting Guide" documentation (description of diagnostic messages).

**Error Reactions of the Drive**

If the drive controller is in closed-loop control and an error condition is detected, the execution of a drive error reaction is automatically started.

The drive reaction in the case of F2xxx, F4xxx, F6xxx errors is determined in parameter "P-0-0119, Best possible deceleration". At the end of each error reaction, the drive outputs the standstill value determined in "P-0-2873.000.014, Valve control variable standstill value".

See also "Error Reactions"

**Clearing an Error Message**

Error messages are not cleared automatically, but according to a procedure that depends on the severity of the error, see separate documentation "Troubleshooting Guide" (description of diagnostic messages).

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

**Clearing Error Messages When Drive Enable Was Set**

If a drive error occurs during operation with set controller enable, 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
- preset a 0-1 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.

The diagnostic message numbers in the error memory are mapped in parameter "P-0-0192, Error memory of diagnostic numbers". The

System Overview

"IndraWorks Ds/D/MLD" commissioning tool allows displaying the diagnostic message numbers and the respective times when the errors occurred.

**Reclassifying Errors as Warning**

The user can reclassify some error cases as warning. After an error has been reclassified, no error reaction takes place, but a warning is issued upon the occurrence of such an error.

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

# 1.2 Drive Controllers

## 1.2.1 Overview of Devices

### HydraulicDrive Product Family

The HydraulicDrive product family consists of product lines that are based on common platforms and technologies.

### Product Lines

The product lines can be classified into devices, which have to be installed in the control cabinet and feature protection class IP20, and devices, which are mounted directly to the relevant hydraulic components and feature protection class IP67. The individual products are described in more detail in the following.

**HMC (Hydraulic Motion Controller)**

At present, this device is available in the configuration for controlling one hydraulic axis. It is characterized by the following features:

- Required firmware derivate: HDC
- Functional packages: Axis controller open loop and closed loop
- The following encoder types are supported: SSI, EnDat2.2, TTL
- The following operation modes are supported:
  - Direct valve control
  - Closed-loop pressure control (p/Q function)
  - Closed-loop velocity control
  - Closed-loop position control, including alternating control (covers all position operation modes)
  - Closed-loop torque/force control
- Integrated PLC (MLD function)
- Master communication: sercos, Profinet, Ethernet/IP, EtherCAT, Profibus-DP

**WRxD, High-Response Valve With IAC Function (Integrated Axis Control) as Axis Controller**

The IAC electronics is mounted directly on the hydraulic valve and is characterized by the following features:

- Required firmware derivate: HDB
- Functional packages: Axis controller open loop and closed loop
- The following encoders are supported: SSI, EnDat2.2, 1Vss
- The following operation modes are supported:
  - Direct valve control
  - Closed-loop pressure control (p/Q function)

  - Closed-loop velocity control
  - Closed-loop position control, including alternating control (covers all position operation modes)
  - Closed-loop torque/force control
- Master communication: sercos, Profinet, Ethernet/IP, EtherCAT, Varan

**WRxQ, High-Response Valve With IAC Function (Integrated Axis Control) as p/Q Valve**

The IAC electronics is mounted directly on the hydraulic valve. In addition, pressure sensors are integrated to measure the pressures in the valve chambers. This device can generate a constant flow (electronic pressure compensator) by establishing the pressure drop across a control edge and taking account of a saved, normalized flow characteristic curve. It is characterized by the following features:

- Required firmware derivate: HDB
- Functional package: p/Q
- The following operation modes are supported:
  - Direct valve control
  - Closed-loop flow control
  - Closed-loop pressure control (with direct valve control or closed-loop flow control)
- Master communication: sercos, Profinet, Ethernet/IP, EtherCAT, Varan

**DFE-4x**

Together with the pilot valve, the IAC electronics is mounted to a hydraulic pump. This allows closed-loop controlling of the swivel angle and pressure of this pump unit. It is characterized by the following features:

- Required firmware derivate: HDB
- Functional package: DFE
- The following operation mode is supported:
  - Pump control
- Master communication: sercos, Profinet, Ethernet/IP, EtherCAT, Varan

## 1.2.2 Firmware Overview, Variants

### General Information

The available functionality of the HydraulicDrive controllers is basically defined by the following:

- Basic hardware characteristic as well as hardware options
- Firmware variant used
- Functional packages activated for the firmware variant used

### Overview of Firmware Variants

**Model Variants**

The basic characteristic of the firmware version **HDx** means

**HD: "HydraulicDrive":** Drives for general automation (including machine tool applications) with MultiEthernet interface (sercos, EtherCAT®, PROFINET®, EtherNet/IP, Varan), field bus interface (e.g. Profibus-DP) and analog interface

"x“ stands for the various model variants.

At present HD**B**, HD**C** und HD**S** are available:

- B: Single-axis firmware for IAC devices
- C: Single-axis firmware for HMC devices

- S: Central controller axis for MLC (used only for parameter and diagnostics DB)

This results in the following firmware variants

- FWA-HYDRV*-HDB-18VRS-D5
- FWA-HYDRV*-HDC-18VRS-D5

**Firmware Variant for Basic Hardware Characteristic**

Which firmware variant can be used for which hardware characteristic is described in the device overview!

**Functionality in Firmware Variants**

The scope of functions of the individual model variants HD**B** und HD**C** is determined by the definition of "derivate-specific firmware projects" from the entirety of the HydraulicDrive firmware functionality ("module library").

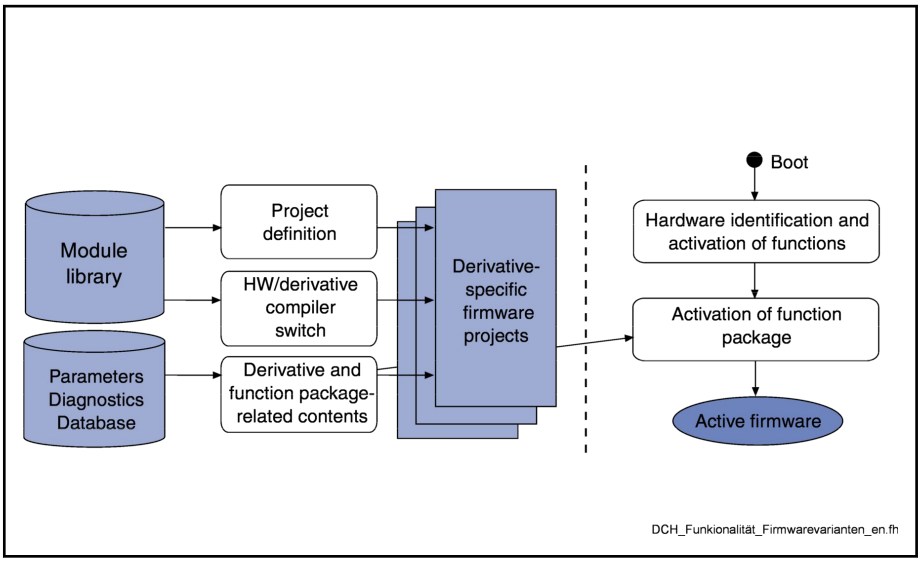



*Fig. 1-1: Functionality in Firmware Variants*

☞ When the model variant is booted, the final available functionality of the concrete firmware characteristic is determined at runtime by hardware identification and functional package configuration.

See also:

Hardware enabling

Overview of functional packages

Enabling of functional packages

# 1.3 Overview of Master Communication

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

**Interfaces for master communication**

| | Firmware derivate | |
|---|---|---|
| Master communication | HDB | HDC |
| sercos | ■ | ■ |
| Profibus-DP | - | ■ 1) |
| Ethernet/IP | ■ | ■ |
| PROFINET | ■ | ■ |

| | | |
|---|---|---|
| EtherCAT | ■ | ■ |
| VARAN | ■ | - |

1) Available only in conjunction with the relevant hardware option

*Tab. 1-4: Supported interfaces for master communication*

# 1.4 Functional Packages

## 1.4.1 Overview

### General Information

The scope of functions of the drive firmware **FWA–HYDRV*–HD*–**VRS** that can be used for the specific application depends on

- the available device configuration

and

- the licensed functional firmware packages.

### Overview of Functional Packages

The scope of functionality of the HydraulicDrive 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 overall functionality of a HydraulicDrive device is subdivided into groups of functions, the so-called "functional packages". The firmware FWA–HYDRV*–HD*–**VRS supports the functional packages listed below.

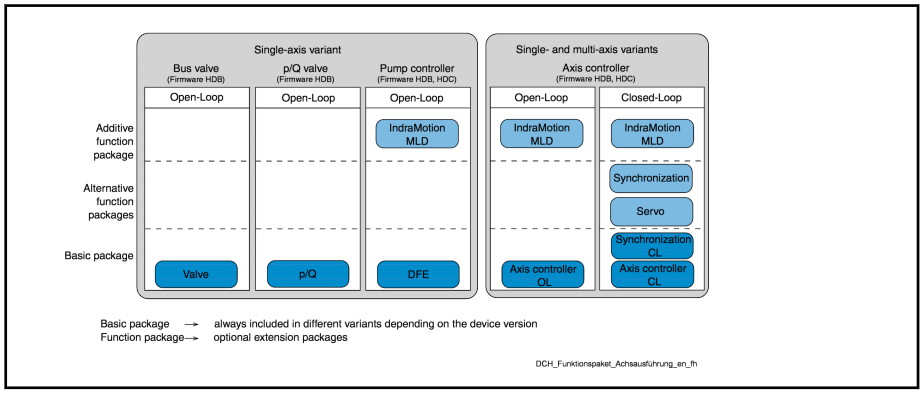



*Fig. 1-2: Functional Packages per Axis Variant*

System Overview

## Overview of Firmware Derivates/Functional Packages

| Firmware derivate | | HDB | | HDC | |
|---|---|---|---|---|---|
| Firmware characteristic | | OL | CL | OL | CL |
| Base packages including alternative functional package | p/Q | ■ | – | – | – |
| | DFE | ■ | – | ■ | – |
| | Axis controller OL | ■ | – | ■ | – |
| | Axis controller CL | – | ■ | – | ■ |
| | Axis controller CL + servo | – | ■ | – | ■ |
| Additive Functional Packages | ML | – | – | ■ | ■ |

*Tab. 1-5: Overview of Firmware Derivates/Functional Packages*

## Overview of Firmware String

| Firmware | Derivate | Version | Release | Language | OL/CL | Base packages including alternative functional package | Additive Functional Package |
|---|---|---|---|---|---|---|---|
| FWA-HYDRV* | –HDB– | 18 | VRS– | D5– | x– | xxx– | xx |
| FWA-HYDRV* | –HDC– | 18 | VRS– | D5– | x– | xxx– | xx |

*Tab. 1-6: Overview of Firmware String*

☞ The firmware string is always valid per axis!

**Examples:**

FWA–HYDRV*–HDB–18V04–D5–1–SRV–NN (axis controller closed loop with servo package)

FWA–HYDRV*–HDC–18V02–D5–0–AXR–ML (axis controller open loop with MLD)

**Function-Specific Abbreviations in the Type Designation of Firmware:**

**Firmware derivates:**

- **HDB** Single-axis firmware with basic performance for IAC devices
- **HDC** Single-axis firmware with basic performance for HMC

**Firmware characteristic(OL/CL):**

- **0** Open Loop (OL)
- **1** Closed Loop (CL)

**Base packages including alternative functional package:**

- **p_Q** Closed-loop flow/pressure control
- **DFE** Closed-loop pressure and flow (displacement) control
- **AXR** Open-loop or closed-loop axis control
- **SRV** Axis control (closed loop) and servo package

**Additive functional packages:**

- **NN** Without additive extension package
- **ML** IndraMotion MLD for free programming

## Base Packages Including Alternative Functional Package

### Base Package"p_Q" (Closed-Loop Flow/Pressure Control)

The base package "p_Q" provides the functionality for closed-loop flow control with outer-loop pressure control.

The available basic functionality consists of:

- Basic functions of device control (operation mode handling, error reactions, ...)
- Closed-loop pressure/flow control mode and closed-loop pressure / direct valve control mode
- Master communication with all associated functions
- All monitoring and limitation functions
- Basic functions for setting the scaling (except for scaling of position and force)
- All diagnostic functions (oscilloscope, diagnostics, diagnostic classes, error memory)
- Basic commissioning functions (Easy Startup, command value generator, ...)

### Base Package "Pump Control (DFE)" (Pressure and Flow Control for Variable Displacement Pumps)

The base package "DFE" provides the functionality for closed-loop flow control (swivel angle) with outer-loop pressure control and power limitation.

The available basic functionality consists of:

- Basic functions of device control (operation mode handling, error reactions, ...)
- Pump control mode in parallel structure
- Master communication with all associated functions
- All monitoring and limitation functions
- Basic functions for setting the scaling → (except for scaling of position and force)
- All diagnostic functions (oscilloscope, diagnostics, diagnostic classes, error memory)
- Basic commissioning functions (Easy Startup, command value generator, ...)

### Base Package "Axis Controller(AXR)" (Open/Closed-Loop Axis Control

The base package "axis controller" provides the minimal basic functionality for traversing an axis. Depending on whether OL or CL is set, the following functionality is offered.

- OL: Open-loop axis control

  The available minimal basic functionality consists of:

  - Axis control without position transducer
  - Basic functions of device control (operation mode handling, error reactions, ...)
  - Operation modes

    - Direct valve control
    - Direct valve control / closed-loop torque/force control
  - Master communication with all associated functions
  - All monitoring and limitation functions
  - Basic functions for setting the scaling (except for position scaling)
  - All diagnostic functions (oscilloscope, diagnostics, diagnostic classes, error memory)
  - Basic commissioning functions (Easy Startup, command value generator, ...)

No encoder evaluation or related functions. As a consequence, no position control modes are provided.

- CL: Axis control

  In addition to the OL scope, encoder evaluation is provided and thus position evaluation and related functions and operation modes!

  Additional functions provided are:
  - Position transducer evaluation
  - Functions for closed-loop position control
  - Operation Modes
    - Cyclic closed-loop position control
    - Closed-loop velocity control
    - Drive-internal interpolation and drive-controlled positioning
    - Positioning block mode
  - Scaling of position data
  - Functions for establishing the position data reference (homing, setting absolute position data reference, shifting the coordinate system)

#### Base Package "Axis Controller (CL) Including Alternative Functional Package Servo (SRV)" (Axis Control)

In addition to the scope of the CL axis controller base package, the following functions are provided:

- Error reaction return movement
- Axis error correction
- Quadrant error correction

### Extension Packages

#### Additive Functional Package "IndraMotion MLD (ML)"

In addition to the base package, functions are provided for the integrated Motion Logic Control MLD.

- The MLD functionality (PLC function)

The alternative functional package **"PLC"** can be selected as OL or CL depending on the device variant.

## 1.4.2 Functional Package Enabling

### General Information

Enabling and activation of the functional packages is indicated as follows:

- 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
- Activation/deactivation of functional packages via parameter P-0-2003
- Saving of the operating hours counter reading with the last change of enabling in parameter P-0-2002

## Changing the Active Functional Package Selection

Generally, the drive functionality can subsequently be scaled in the following ways:

- Reducing the already licensed scope of functions in order to reduce the complexity of the firmware
- Expanding the scope of functions originally ordered

Parameter P-0-2003 is available for selecting the functional packages.

The activated packages are shown by parameter P-0-2004 and parameter S-0-0030.

The following assignment applies:

| Bit No. | Designation of the package (bit=1 → package is selected) | Rules for selection via P-0-2003 |
|---|---|---|
| 0 | Base package "open loop" | - As an alternative to bit 1 |
| 1 | Base package "closed loop" | - As an alternative to bit 0 |
| 2 | Not used | -- |
| 3 | Not used | -- |
| 4 | Expansion package "servo function" (SRV) | - As an alternative to bit 5 or 6<br>- Not with "open loop" |
| 5 | Reserved | - As an alternative to bit 4 or 6<br>- Not with "open loop" |
| 6 | Reserved | -- |
| 7 | Not used | -- |
| 8 | Reserved | .. |
| 9 | Additional package "IndraMotion MLD" (ML) | - For HDC only |
| 10 | Reserved | - For HDC only |
| 11 to 15 | Not used | -- |
| 16 | Reserved | - For HDB only<br>- With "open loop" only |
| 17 | Base package "p/Q" (p_Q) | - For HDB only<br>- With "open loop" only |
| 18 | Base package "pump control" (DFE) | - For HDB or HDC only<br>- With "open loop" only |

| Bit No. | Designation of the package (bit=1 → package is selected) | Rules for selection via P-0-2003 |
|---|---|---|
| 19 | Base package "axis controller" (AXR) | |
| 20 | Reserved | - For HDC only<br>- With "closed loop" only |
| 21 to 31 | Not used | -- |

*Tab. 1-7:*

Selection of functional packages via parameter P-0-2003

Enabling the base package "closed loop" and the expansion package "servo function", for example, requires the following setting in P-0-2003:

- Bit 1 = 1 for the base package "closed loop"
- Bit 4 = 1 for the expansion package "servo function"
- Bit 19 = 1 for the axis controller must be set

Consequently: Set P-0-2003 = 0x80012.

The settings in parameter P-0-2003 are accepted by P-0-2004 during next booting. The selected functional packages are also activated only upon booting.

The figure below illustrates the interaction of the parameters involved in enabling of functional packages.

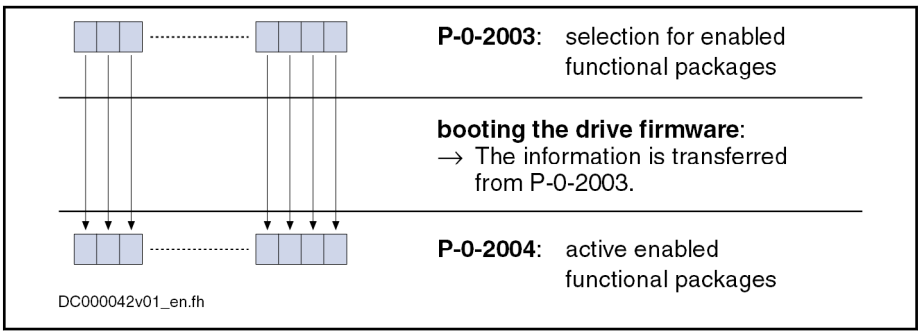



*Fig. 1-3: Interaction of Parameters for Functional Package Selection*

Every change of the selected functional packages is stored 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". The change in the functional package is thus documented.

As long as the values of P-0-2003 and P-0-2004 are different, it is impossible to switch over to OM. The changeover command is terminated with command error "C0299 Configuration changed. Restart".

The table below shows the currently possible combinations for entry in parameter "P-0-2003, Selection of functional packages". Whether the respective combination can be used, depends on the available hardware variant.

For HydraulicDrive:

| Base package/expansion package(s) | Content of P-0-2003 |
|---|---|
| **Open-loop packages** | |
| Reserved | 0x0001 0001 |

| Base package/expansion package(s) | Content of P-0-2003 |
|---|---|
| p/Q (p_Q) | 0x0002 0001 |
| Pump Control (DFE) | 0x0004 0001 |
| Axis controller open loop (AXR) | 0x0008 0001 |
| Axis controller open loop (AXR) + IndraMotion MLD (ML) | 0x0008 0201 |
| **Closed-loop packages** | |
| Axis controller closed loop (AXR) | 0x0008 0002 |
| Axis controller open loop (AXR) + IndraMotion MLD (ML) | 0x0008 0202 |
| Axis controller closed loop (AXR) + servo function (SRV) | 0x0008 0012 |
| Reserved | 0x0008 0022 |
| Axis controller closed loop (AXR) + servo function (SRV) + IndraMotion MLD (ML) | 0x0008 0212 |
| Reserved | 0x0008 0222 |
| Reserved | 0x0010 0202 |

*Tab. 1-8:*

☞ Changes in parameter "P-0-2003, Selection of functional packages" are only accepted by the drive after repeated booting process.

**Reducing the Active Functional Packages**

The user can at any time reduce the scope of functions of the firmware by deactivating individual functional packages. To do this, the bits assigned to the functional packages which are not required are reset in parameter ""P-0-2003, Selection of functional packages".

**Subsequent Extension for HydraulicDrive**

Functions required additionally can be activated by enabling further functional packages. Re-licensing is not provided. The available functional packages depend on the individual hardware variant.

**Pertinent Parameters**

- 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**

- C0299, Configuration changed. Restart

## 1.4.3 Hardware-Dependent Enabling of Functions

Depending on existing hardware options, associated functionalities are enabled and relevant parameters made visible.

To this end, optional hardware, which can be operated with the relevant firmware derivate, is identified during the booting process.

# 2 Important Directions for Use

## 2.1 Appropriate Use

### 2.1.1 Introduction

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

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

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

☞ Rexroth as manufacturer is not liable for any damage 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 bears responsibility for the risks.

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

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

### 2.1.2 Areas of Use and Application

Drive controllers made by Rexroth are designed to control hydraulic drives and monitor their operation.

Control and monitoring of the drive controllers may require the connection of additional sensors and actuators.

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

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

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

Drive controllers of the HydraulicDrive line have been developed for use in single- and multiple-axis drive and control tasks.

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

Typical applications include, for example:

- Plastics machines,
- Presses,
- Printing and paper processing machines and
- Machine tools.

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

## 2.2 Inappropriate Use

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

Drive controllers may not be used, if...

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

# 3 Safety Instructions for Electric and Hydraulic Drives and Controls

## 3.1 Definitions of Terms

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

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

**Hydraulic Drive System** A hydraulic drive system comprises all components, starting with the pressure supply through to the actual drive. This includes, for example, hydraulic cylinders, hydraulic motors, hydraulic valves, hydraulic pumps, transducers and associated lines and cables.

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

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

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

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

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

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

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

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

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

Safety Instructions for Electric and Hydraulic Drives and Controls

**Qualified Persons** The activities described in this documentation require knowledge of the electrical installation, the control technology, programming and hydraulics as well as knowledge of the associated technical terms. To ensure safe usage, these activities may therefore only be carried out by qualified personnel or under the direction and supervision of qualified personnel. Qualified personnel are those who can recognize possible hazards and institute the appropriate safety measures due to their professional training, knowledge and experience, as well as their understanding of the relevant regulations pertaining to the work to be done. Qualified personnel must observe the rules relevant to the subject area.

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

# 3.2 General Information

## 3.2.1 Using the Safety Instructions and Passing Them on to Others

Do not isntall or operate the product unless you have thoroughly read all enclosed documents. Read and understand these safety instructions and all user information prior to working with these components. If you do not have the user documentation for the components, contact your responsible Bosch Rexroth sales partner. Ask for these documents to be sent immediately to the person or persons responsible for the safe operation of the components.

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

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

## 3.2.2 Requirements for Safe Use

Read the following instructions before initial commissioning of the product components in order to eliminate the risk of injury and/or property damage. You must comply with these safety instructions.

- Bosch Rexroth is not liable for damage resulting from failure to observe the safety instructions.
- Read the operating, maintenance and safety instructions before commissioning. If you find that you cannot completely understand the application documentation in the available language, please ask your supplier to clarify.
- Proper and correct transport, storage, mounting and installation, as well as care in operation and maintenance, are prerequisites for optimal and safe operation of the component.
- Only qualified personnel are authorized to work on the product components or in their vicinity.
- Only use accessories and spare parts approved by Bosch Rexroth.
- Observe the safety regulations and stipulations of the country in which the components of the electric drive and control system are operated.
- Only use the product according to the intended use. See chapter "Appropriate Use".

- The ambient and operating conditions given in the available application documentation must be adhered to.
- Applications for functional safety are only allowed if clearly and explicitly specified in the application documentation "Integrated Safety Technology". If this is not the case, they are excluded. Functional safety includes parts of the overall safety concept, in which measures of risk reduction for personal safety depend on electrical, electronic or programmable control systems.
- The information given in the application documentation with regard to the use of the delivered components contains only application examples and suggestions.

  The machine and installation manufacturers must

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

  The machine or installation manufacturer is responsible for compliance with the limit values as prescribed in national regulations.
- The technical data, connection and installation conditions of the components are specified in the respective application documentations and must be strictly observed at all times.
- Observe safety-relevant information and information on risks in the operating instructions of the manufacturer of the connected hydraulic system before you commission a control in conjunction with a hydraulic system.

*National regulations which the user must take into account*

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

Safety Instructions for Electric and Hydraulic Drives and Controls

## 3.2.3 Hazards by Improper Use

- High electrical voltage and high operating current! Danger to life or serious injury by electric shock!
- High electrical voltage by incorrect connection! Danger to life or injury by electric shock!
- Dangerous movements! Danger to life, serious injury or damage to property due to unintended movements of the drive resulting from misuse or incorrect actuation!
- Health hazard for persons with cardiac pacemakers, metal implants and hearing aids in close proximity to electric drive systems!
- Risk of burns by hot housing surfaces!
- Risk of injury by improper handling! Injury by crushing, shearing, cutting, hitting!
- Risk of injury by improper handling of batteries!
- Risk of injury by improper handling of pressurized lines and components!

# 3.3 Instructions with Regard to Specific Hazards

## 3.3.1 Protection Against Contact With Electrical Parts and Housings

☞ This section is related to components of the electric drive and control system with voltages of **more than 50 volt**.

Contact with parts conducting voltages above 50 volt can be dangerous and lead to electric shock. When operating components of the electric drive and control system, it is unavoidable that some parts of these components conduct dangerous voltage.

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

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

  Always wait **30 minutes** after switching off power to allow live capacitors to discharge before accessing an electric component. Measure the electrical voltage of live parts before beginning to work to make sure that the equipment is safe to touch.
- Install covers and guards provided for this purpose before switching on.
- Never touch electrical connection points of the components while power is turned on.
- Do not remove or plug in connectors when the component is connected to the power supply.
- Under certain conditions, electric drive systems can be operated at mains protected by residual-current-operated circuit-breakers sensitive to universal current (RCDs/RCMs).
- For built-in devices, ensure protection against the ingress of foreign bodies and water as well as against direct contact by providing an external housing, for example a control cabinet.

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

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

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

| Cross-section of the external conductor | Minimum cross-section of grounding conductor<br>Leakage current ≥ 3.5 mA | |
|---|---|---|
| | 1 protective earth conductor | 2 protective earth conductors |
| 1.5 $mm^2$ (AWG 16) | 10 $mm^2$ (AWG 8) | 2 × 1.5 $mm^2$ (AWG 16) |
| 2.5 $mm^2$ (AWG 14) | | 2 × 2.5 $mm^2$ (AWG 14) |
| 4 $mm^2$ (AWG 12) | | 2 × 4 $mm^2$ (AWG 12) |
| 6 $mm^2$ (AWG 10) | | 2 × 6 $mm^2$ (AWG 10) |
| 10 $mm^2$ (AWG 8) | | - |
| 16 $mm^2$ (AWG 6) | 16 $mm^2$ (AWG 6) | - |
| 25 $mm^2$ (AWG 4) | | - |
| 35 $mm^2$ (AWG 2) | | - |
| 50 $mm^2$ (AWG 1/0) | 25 $mm^2$ (AWG 4) | - |
| 70 $mm^2$ (AWG 2/0) | 35 $mm^2$ (AWG 2) | - |
| ... | ... | ... |

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

## 3.3.2 Protective Extra-Low Voltage as Protection Against Electric Shock

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

All connections and terminals with voltages between 5 and 50 volt at the components of the drive and control systems from Bosch Rexroth are PELV ("Protective Extra-Low Voltage") systems. It is allowed to connect devices equipped with basic insulation (such as programming devices, PCs, notebooks, display units) to these connections.

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

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

## 3.3.3 Protection Against Dangerous Movements

Dangerous movements can be caused by incorrect actuation of connected drives. Some common examples are:

- Improper or wrong wiring or cable connection
- Operator errors
- Wrong input of parameters before commissioning
- Errors in transducers and signal generators
- Defective components
- Software or firmware errors

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

The monitoring functions in the components of the electric drive and control system will normally be sufficient to avoid malfunction in the connected drives. With regard to personal safety, especially the risk of injury and/or property damage, it is critical to rely on these monitoring functions alone to ensure complete safety. Until the integrated monitoring functions become effective, it must be assumed in any case that incorrect drive movements will occur. The extent of incorrect drive movements depends on the type of control and the operating state.

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

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

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

In case of malfunction imparing safety, immediately shut down the product and inform responsible personnel about the malfunction.

**To avoid accidents, injury and/or property damage:**

- Controls alone do not include safety functions for personnel safety and are not safety-relevant components
- Keep away from the machine’s range of motion and moving machine parts. Prevent personnel from accidentally entering the machine’s range of motion by using, for example:
  - Safety fences
  - Safety guards
  - Protective covers
  - Light barriers
- Ensure a sufficient stability of safety fences and protective covers against the maximum possible kinetic energy.
- Mount emergency stop switches in the immediate reach of the operator. Before commissioning, verify that the emergency stop equipment works. Do not operate the machine if the emergency stop switch is not working.

- Prevent unintended start-up. Isolate the drive power connection by means of OFF switches/OFF buttons, depressurize the hydraulic system or use a safety interlock.
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- Additionally, secure vertical axes against falling or lowering after switching off the motor by, for example,
  - mechanical locking of the vertical axes,
  - an external braking/arrester/clamping mechanism or
  - ensuring sufficient counterbalancing of the vertical axes.
- The **motor holding brake**, which is part of the standard electric drive system, or an external holding brake activated by the drive controller is **not sufficient to guarantee personal safety**!
- Disconnect all relevant system parts via the main switch from the power supply, depressurize hydraulic systems and protect them against restarting in the case of:
  - Maintenance and repair work
  - Cleaning of equipment
  - Long service interruptions
- Avoid the operation of high-frequency, remote control and radio equipment in the direct vicinity of components of the electric drive and control system and their supply leads. If the use of these devices cannot be avoided, check the machine or installation at initial commissioning of the electric drive and control system for possible malfunctions when operating such high-frequency, remote control and radio equipment in its possible positions of normal use. A special EMC test might be required.

### 3.3.4 Protection Against Magnetic and Electromagnetic Fields During Operation and Mounting

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

**Health hazard for persons with cardiac pacemakers, metal implants and hearing aids in the direct proximity to electric components!**

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

### 3.3.5 Protection Against Contact With Hot Parts

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

- Avoid touching hot surfaces! Depending on the operating conditions, temperatures of the surfaces can be **higher than 60 °C** (140 °F) during or after operation.
- Before touching motors after having switched them off, let them cool down sufficiently. Cooling down can take **up to 140 minutes**!
- Before touching components after having switched them off, wait **15 minutes** to allow them to cool down.
- Wear safety gloves or do not work on hot surfaces.
- For certain applications, measures to prevent burns in the final application have to be taken by the machine or system manufacturer in accordance with the safety regulations. These measures can be, for example: Warnings on the machine or installation, guards (shielding or barriers) or safety instructions in the application documentation.

### 3.3.6 Protection During Handling and Mounting

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

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

### 3.3.7 Battery Safety

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

**Risk of injury by improper handling!**

- Do not attempt to reactivate low batteries by heating or other methods (risk of explosion and cauterization).
- Do not attempt to recharge the batteries as this may cause leakage or explosion.
- Do not throw batteries into open flames.
- Do not dismantle batteries.
- When replacing the battery/batteries, do not damage the electrical parts installed in the devices.
- Only use the battery types specified for the product.

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

### 3.3.8 Protection Against Pressurized Lines

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

**Risk of injury by improper handling of pressurized lines!**

- Do not attempt to disconnect, open or cut pressurized lines (risk of ejecting oil jet).
- Observe the relevant manufacturer's operating instructions.
- Before disconnecting lines, depressurize the relevant system section and let the medium drain.
- Use suitable protective equipment (safety goggles, safety shoes, safety gloves, for example).
- Immediately clean up any spilled liquids from the floor due to risk of slipping!

☞ Environmental protection and disposal! The media used for the operation of the product might not be environmentally friendly. Dispose of environmentally harmful media separately from other waste. Observe the national regulations of your country.

## 3.4 Explanation of Signal Words and the Safety Alert Symbol

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

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

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

**⚠ DANGER**

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

Safety Instructions for Electric and Hydraulic Drives and Controls

**⚠ WARNING**

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

**⚠ CAUTION**

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

***NOTICE***

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

# 4 Master Communication

## 4.1 Basic Functions of Master Communication

### 4.1.1 Brief Description

#### General Information

**Section Safety Messages**

**General Information**

The basic functions of master communication for HydraulicDrive devices apply equally to the MultiEthernet interface, field bus interface and analog interface.

☞ The valve on-board electronics can be ordered with the respectively required bus, but can also be subsequently reconfigured. However, master communication VARAN can only be selected if it was explicitly ordered.

HydraulicDrive devices can be operated with a MultiEthernet interface. This allows operating the following master communications:

- sercos
- EtherCAT®
- PROFINET®
- EtherNet/IP™
- VARAN (only if explicitly ordered)

The protocol is selected or deactivated via "P-0-4089.0.1, Master communication: Protocol" (e.g. using the IndraWorks dialog “Master Communication”. The change will only take effect after the device has been restarted.

IP engineering is carried out via the MultiEthernet interface. IP engineering cannot be carried out when the EtherCAT® protocol has been activated, because EtherCAT® does not support IP engineering; EoE (Ethernet over EtherCAT) for EtherCAT® can be used instead. When the VARAN protocol is activated, IP engineering can also not be carried out; in this case, engineering can be accessed via the Foreign Package mechanism.

**Note on Parameter Accesses**

For control units that are not able to access 4-byte EIDN parameters, the following mechanisms are available:

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

| 4-byte EIDN parameters | 2-byte IDN parameters |
|---|---|
| P-0-4089.0.1, Master communication: Protocol | P-0-2310, Master communication: Protocol |
| P-0-4089.0.2, Master communication: Device name | P-0-2311, Master communication: Device name |
| P-0-4089.0.10, Master communication: MAC address device | P-0-2312, Master communication: MAC address device |

Master Communication

| 4-byte EIDN parameters | 2-byte IDN parameters |
|---|---|
| P-0-4089.0.11, Master communication: MAC address Port1 | P-0-2313, Master communication: MAC address Port1 |
| P-0-4089.0.12, Master communication: MAC address Port2 | P-0-2314, Master communication: MAC address Port2 |
| P-0-4089.0.13, Master communication: IP address | P-0-2315, Master communication: IP address |
| P-0-4089.0.14, Master communication: Network mask | P-0-2316, Master communication: Network mask |
| P-0-4089.0.15, Master communication: Gateway address | P-0-2317, Master communication: Gateway address |

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

## Features

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

  → Drive commands that can be externally activated (via master communication and "Engineering over IP")
- **Device control** (state machine)

  → Individual state machines for master communication and device
  - Depending on the variant of master communication, the master communication state machine has different functionalities and complexities. The communication-specific states are distinguished and mapped to the status words of the corresponding master communication (e.g., for sercos: "S-0-0135, Drive status word"; "S-0-1045, sercos: Device Status (S-Dev)".
  - The device state machine is independent of the variant of master communication and maps the device-specific states to parameter "S-0-0424, Status parameterization level". We always distinguish operating mode (OM) and parameter mode (PM).
- **Extended possibilities of control**
  - Signal control word (S-0-0145) and signal status word (S-0-0144)
  - Multiplex channel

  See chapter "Control Options / Additional Functions".

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

## Pertinent Parameters

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

**Parameters for State Machine and Phase Switching**

- S-0-0011, Class 1 diagnostics

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

**Operation Mode Parameters**

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

**sercos-Specific Control and Status Words**

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

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

**Field Bus-Specific Parameters**

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

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

**Specific Parameters for Analog Interface**

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

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

### Pertinent Diagnostic Messages

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

## 4.1.2 Device Control and State Machines

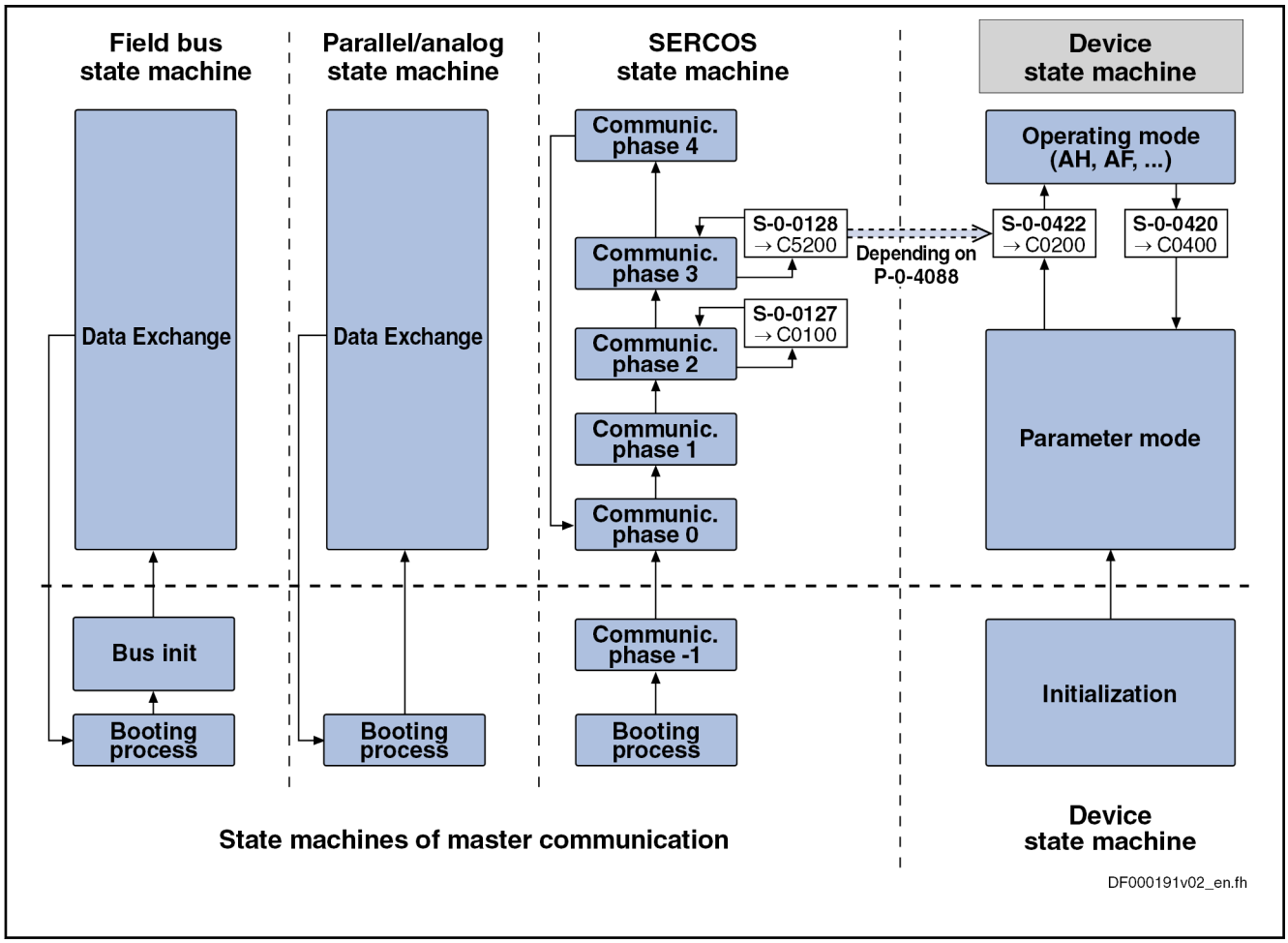
### Overview

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

We distinguish between:

Master Communication

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




**S-0-0127,** C0100 Communication phase 3 transition check
**S-0-0128,** C5200 Communication phase 4 transition check
**S-0-0420,** C0400 Activate parameterization level 1 procedure command
**S-0-0422,** C0200 Exit parameterization level procedure command
**P-0-4088,** Master communication: Drive configuration
*Fig. 4-1: Overview: State Machines of Master Communications and Device*

## Device-Internal State Machine

**Parameter Mode/Operating Mode**

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

- **Parameter mode (PM)**

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

- **Operating mode (OM)**

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

**Switching**

Switching between these two states can be performed using the following commands:

- S-0-0420, C0400 Activate parameterization level procedure command

- S-0-0422, C0200 Exit parameterization level procedure command

Observe the following aspects for switching:

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

**Control Word and Status Word**

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

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

Master Communication

# State Machine of Master Communication

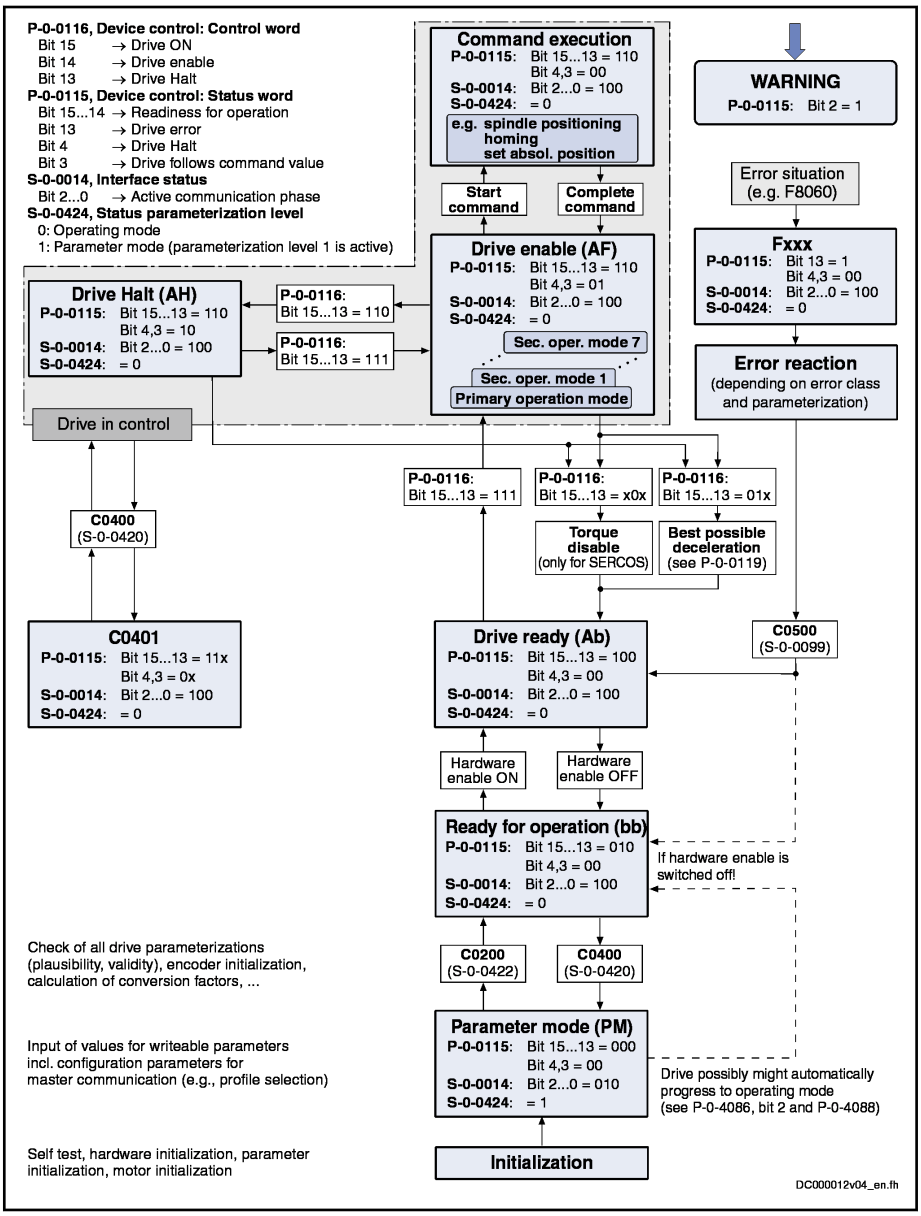



*Fig. 4-2: Device Control (General State Machine)*

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

- sercos state machine
- Field Bus State Machine
- Analog state machine

The following sections only describe the most important states; more details can be found in the section of the respective master communication.

**sercos State Machine**

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

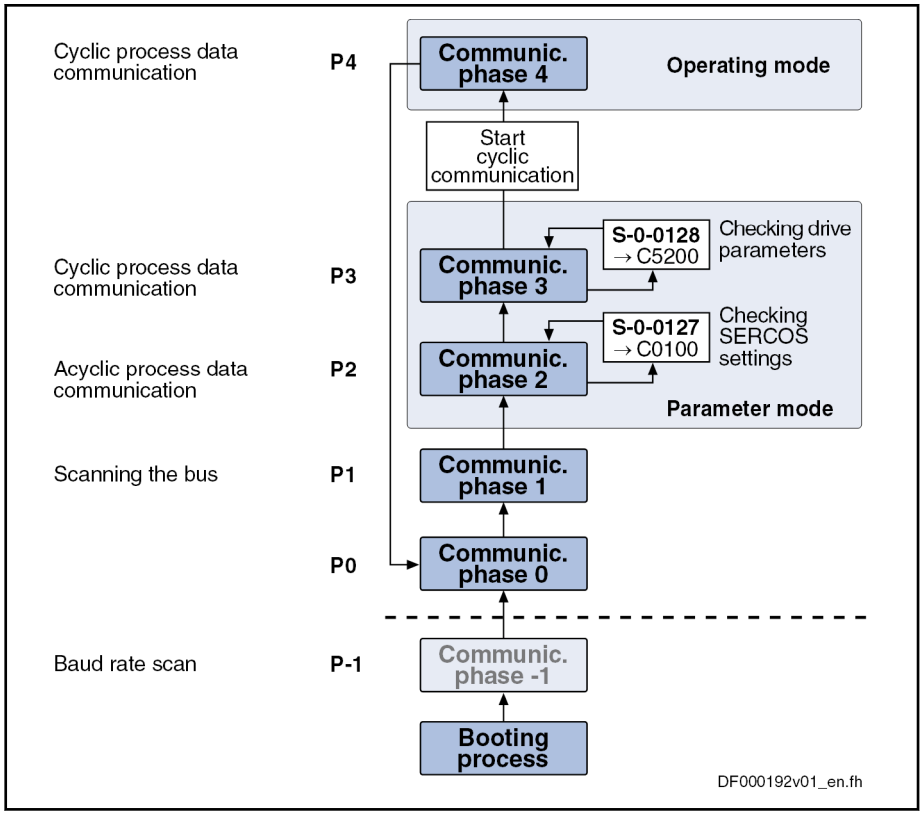



*Fig. 4-3: State Machine of the Communication Phases of the Drive According to sercos Specification*

Also refer to chapter "sercos" in the "Rexroth HydraulicDrive Firmware for HDB-18 Drive Controllers" manual.

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

**Field Bus State Machine**

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

Master Communication

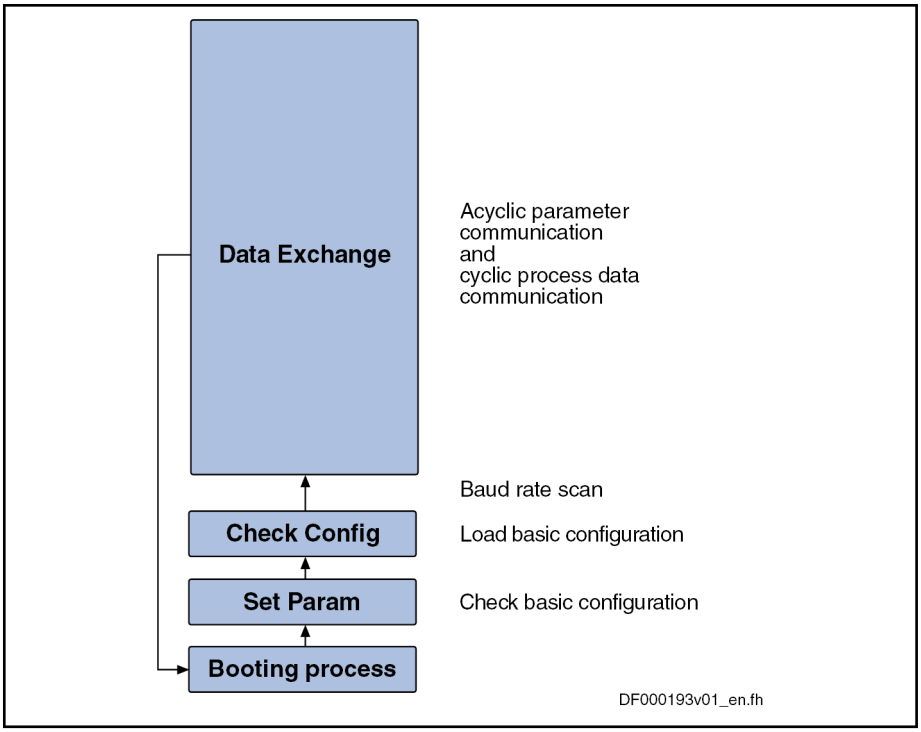



*Fig. 4-4: State Machine for Field Bus Interfaces*

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

## Communication Phases of Master Communication

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

**Communication Phases according to sercos Specification**

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

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

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

  – Communication parameters (according to sercos)
  – Configuration of axis control (sampling times)
  – All factory-specific settings (can only be changed via master password)
- **P3**: When changing from P2 → P3, only the parameters that can be changed in phase 2 (see above) are checked.

  In phase 3, the following parameters can be changed:

  – Parameters for operation mode configuration

- Error reaction settings
- Encoder configuration parameters
- Mechanical transmission elements (gear, feed constant)
- Scaling and polarity parameters, position data format, modulo value
- Configuration of analog and digital inputs/outputs
- Configuration of switch-on / switch-off sequence of drive enable (waiting times, ...)



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

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

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

- After the controller has been switched on, it does not automatically go to the operating mode, but has to be switched to this mode by the master.
- This changeover of the drive controller to the operating mode is closely connected to establishing the readiness for operation.
- The procedure comprises several steps and is controlled by the master by presetting communication phases -1 to 4 and starting/completing the following commands:
  - S-0-0127, C0100 Communication phase 3 transition check
  - S-0-0128, C5200 Communication phase 4 transition check



For sercos devices, **all 5 communication phases** are supported. According to sercos specification, switching takes place by the master setting the communication phase.

**Communication Phases for Field Bus Interface**

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

- Parameter Mode
- Operating Mode

**Communication Phases for Analog Interface**

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

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



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

## Control Words and Status Words of Master Communication

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

Master Communication

Depending on the master communication, different parameters are used:

- EtherCAT® and VARAN (servo drive profile)
  - S-0-0134, Master control word
  - S-0-0135, Drive status word
- Field bus interface (e.g. PROFIBUS®, PROFINET®, EtherNet/IP™)
  - P-0-4077, Field bus: Control word

    - or -

    P-0-4068, Field bus: Control word IO

    - or -

    P-0-4094.0.1, Field bus: control word Fluid Power
  - P-0-4078, Field bus: Status word

    - or -

    S-0-0144, Signal status word

    - or -

    P-0-4094.00.2, Field bus: status word fluid power
- Analog interface (analog mode)
  - P-0-4028, Device control word
  - P-0-0115, Device control: Status word

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

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

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

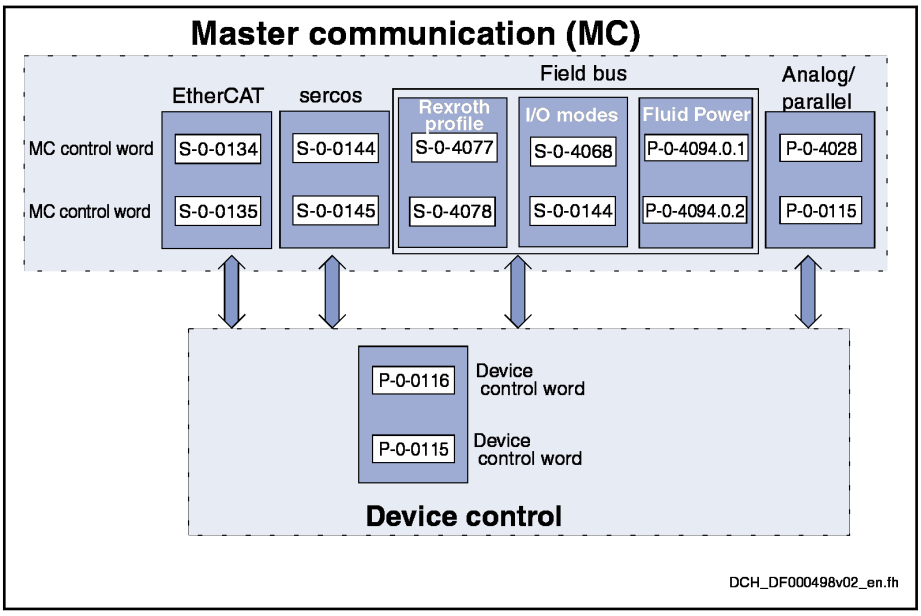


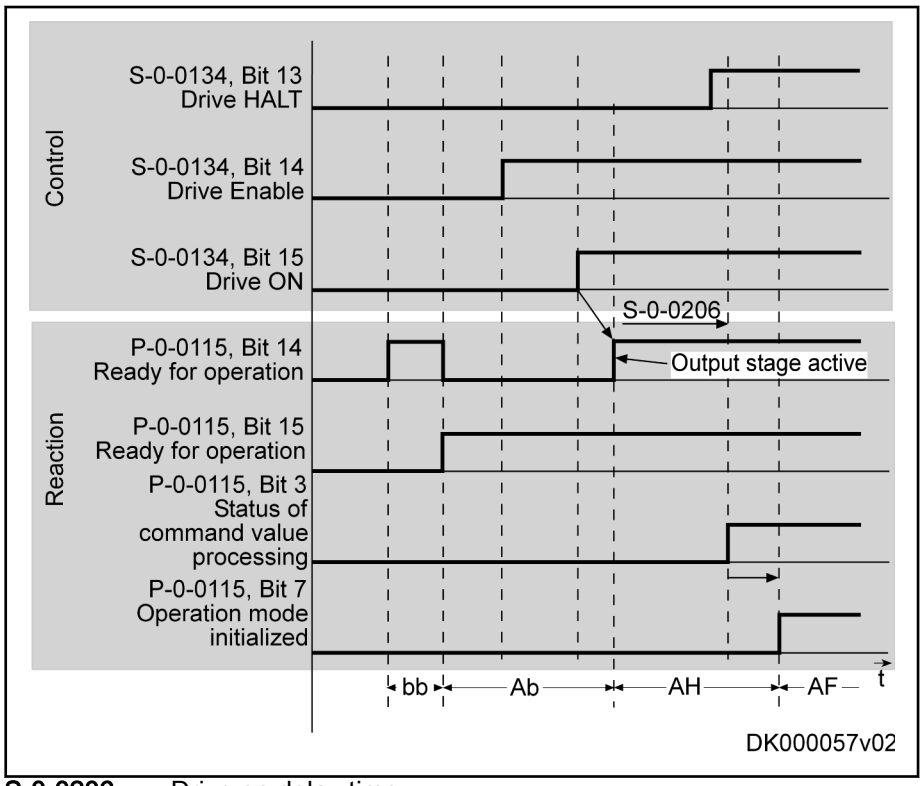

*Fig. 4-5: Interaction of the Available Control and Status Words*

## Timing Diagrams for Device Control

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

☞ It is assumed that the drive is already in the operating mode and the hardware enable (if available) is set.

### Bit Sequence During Switch-On Process

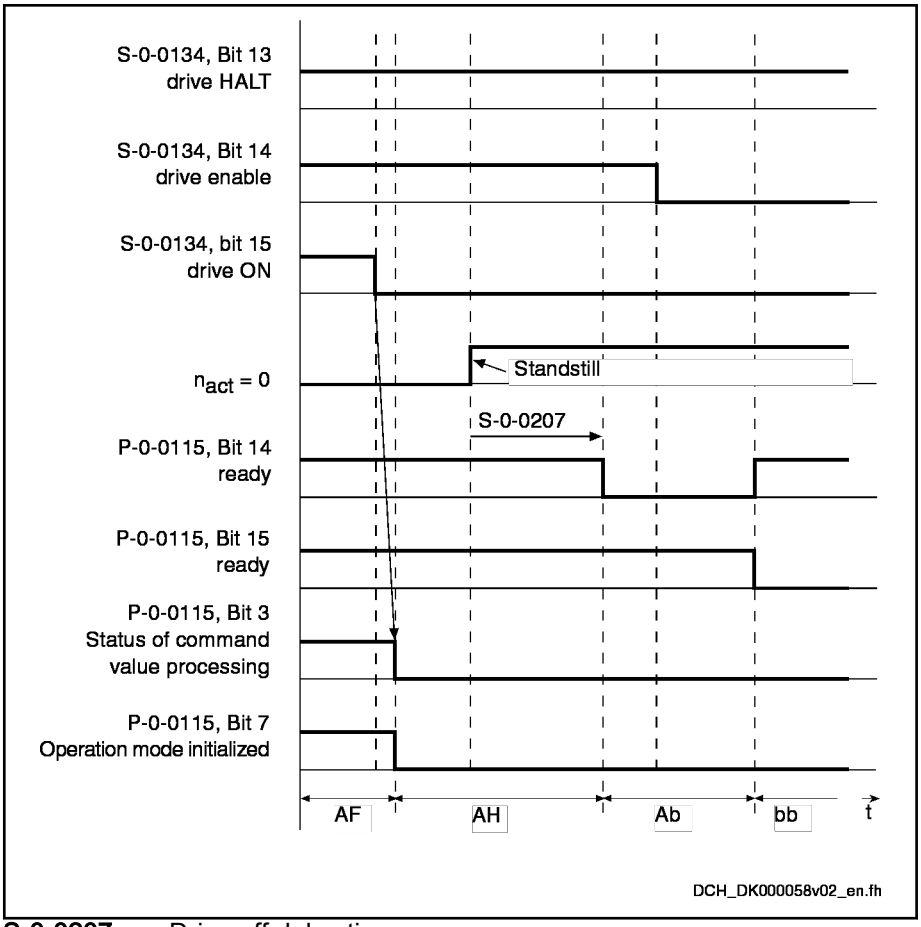



**S-0-0206,** Drive on delay time

*Fig. 4-6: Bit Sequence During Switch-On Process*

Master Communication

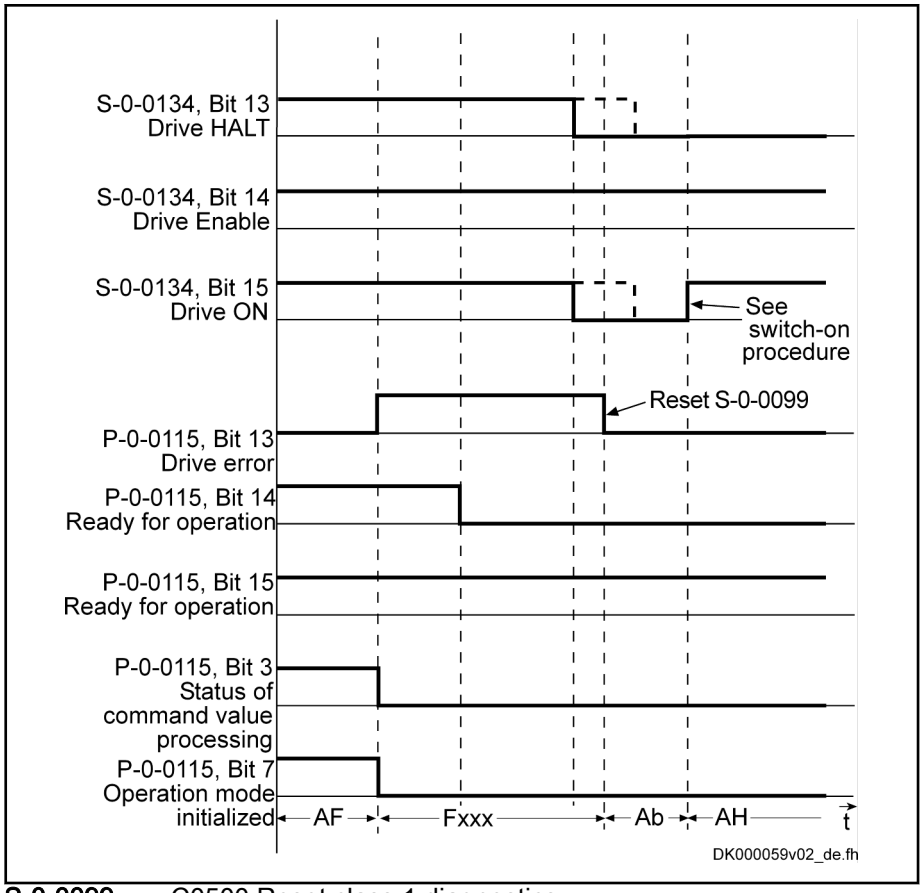
### Bit Sequence During Switch-Off Process




**S-0-0207** Drive off delay time

*Fig. 4-7: Bit Sequence During Switch-Off Process*

**Bit Sequence During Error Reaction**




**S-0-0099** C0500 Reset class 1 diagnostics

*Fig. 4-8: Bit Sequence During Error Reaction*

Master Communication

**Bit Sequence During Change of Operation Modes**

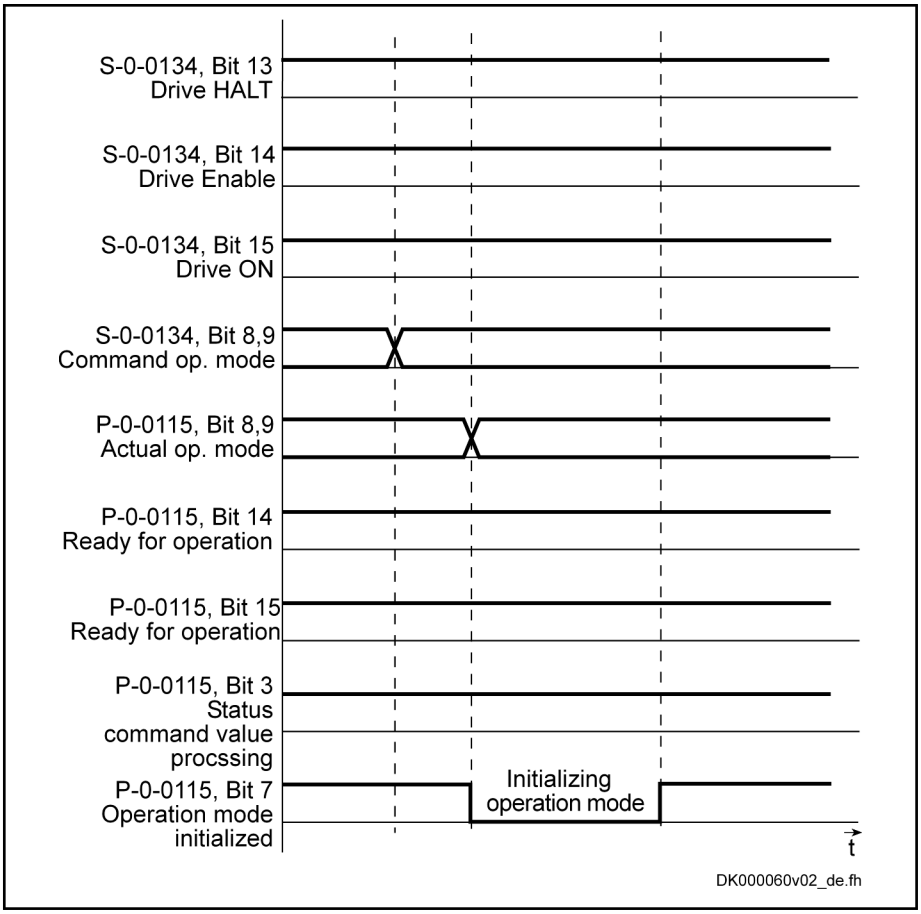



*Fig. 4-9: Bit Sequence During Change of Operation Modes*

## Commands and Diagnostic Messages for Mode Change and Phase Switch

**Distinguishing the Commands**

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

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

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

**Communication Phase 3 Transition Check**

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

- Checking validity of parameters required for switching to phase 3

If one of these parameters has never been written or the backup was carried out incorrectly, the error message "C0101Invalid parameters (-> S-0-0021)" is generated. The IDNs of the incorrect parameters are listed in parameter "S-0-0021, IDN-list of invalid operation data for CP2". These parameters have to be set valid by writing correct values to them.

- Checking device configuration
- 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.
- If necessary, checking timing parameters for sercos communication in phases 3 and 4 for plausibility and compliance with requirements
- Limit value check of communication parameters and system

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

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

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

    → Drive has to be rebooted before it is possible to switch to the operating mode (OM)
- Checking validity of parameters required for subsequent initializations
  - C0201 Invalid parameters (->S-0-0423)
  - C0212 Invalid control section data (->S-0-0423)
- Checking device configuration
  - C0223 Invalid settings for controller cycle times
- If necessary, checking parameters for field bus communication for validity and compliance with requirements
  - C0229 Field bus: IDN for cycl. command val. not configurable
  - C0230 Field bus: Max. length for cycl. command val. exceeded
  - C0231 Field bus: IDN for cycl. actual val. not configurable
  - C0232 Field bus: Length for cycl. actual values exceeded
  - C0233 Field bus: Tcyc (P-0-4076) incorrect
  - C0234 Field bus: P-0-4077 missing for cycl. command values
- Checking configuration of multiplex channel
  - C0238 Order of cyclic command value configuration incorrect
  - C0239 IDN for command value data container not allowed
  - C0240 IDN for actual value data container not allowed
- Checking the encoder configuration
  - C0219 Max. travel range too large
  - C0271 Incorrect parameterization of encoder 1 (hardware)
  - C0272 Incorr. parameteriz. of encoder 1 (mechanical system)
  - C0273 Modulo value for encoder 1 cannot be displayed
  - C0274 Encoder 1 unknown

  - C0280 Maximum travel range cannot be displayed internally
  - C0284 Invalid motor data in encoder memory (->S-0-0423)
  - C0285 Type of construction of motor P-0-4014 incorrect
  - C0286 Several motor encoders connected
  - C0287 Error during initialization of motor data (->S-0-0423)
  - C0288 Rotary scaling not allowed
- Checks during encoder initialization
  - C0220 Error when initializing position of encoder 1
  - C0221 Initialization velocity encoder 1 too high
- Limit value check
  - C0202 Parameter limit error (->S-0-0423)
  - C0203 Parameter conversion error (->S-0-0423)
- General system checks
  - C0245 Operation mode configuration (->S-0-0423) not allowed
- Initializing fine interpolator
  - C0258 Error in relation TNcyc (S-0-0001) to fine interpol.
- Checking interface configuration
  - C0242 Multiple configuration of a parameter (->S-0-0423)
- Checking master communication
  - C0251 Error during synchronization to master communication
- Checking whether boot error is present or firmware download has been carried out
  - C0298 Impossible to exit parameterization level

**"Error-free" message**

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

- A0013 Ready for power on

# 4.2 Control Options/Additional Functions

## 4.2.1 Configurable Signal Control Word

### Brief Description

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

**Examples of Use**

This functionality can be used, for example,

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

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

**Pertinent Parameters**

- S-0-0027, Configuration list for signal control word

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

### Notes on Commissioning of the Signal Control Word

**Selection List**

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

**Configuring the IDNs**

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

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

**Configuring the Bit Numbers**

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

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

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

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

**Exceptions**

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

### Diagnostic Messages and Error Messages

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

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

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

## 4.2.2 Configurable Signal Status Word

### Brief Description

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

Master Communication

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

**Pertinent Parameters**

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

## Notes on Commissioning of the Signal Status Word

**Configuring the IDNs**

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

**Configuring the bit numbers**

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

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

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

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

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

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

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

## Diagnostic Messages and Error Messages

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

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

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

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

## 4.2.3 Multiplex Channel

### Brief Description

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

☞ To use the "multiplex channel" mechanism, it is necessary to use a master communication via sercos or field bus and configure the multiplex parameters in the cyclic real-time channel.

**Features**

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

**Possible Applications**

By means of the multiplex channel it is possible:

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

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

**Pertinent Parameters**

Parameters for command value channel:

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

  - to -

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

Parameters for actual value channel:

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

  - to -

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

Configuration lists of the command value data containers:

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

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

  - to -

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

Configuration lists of the actual value data containers:

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

  - to -

  S-0-0506, Data container A: Configuration list feedback value 8

**Pertinent Diagnostic Messages**

- C0238 Order of cyclic command value configuration incorrect
- E4008 Invalid addressing command value data container A
- E4009 Invalid addressing actual value data container A

# Functional Description

## General Information

**Possible Multiplex Data**

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

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

**Data Containers**

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

- Master → drive: Data container A: command value-x
- Drive → master: Data container A: Actual value-x

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

**Configuration Lists**

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

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

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

## Addressing the Data Containers

**Addressing the Parameters to be Transmitted**

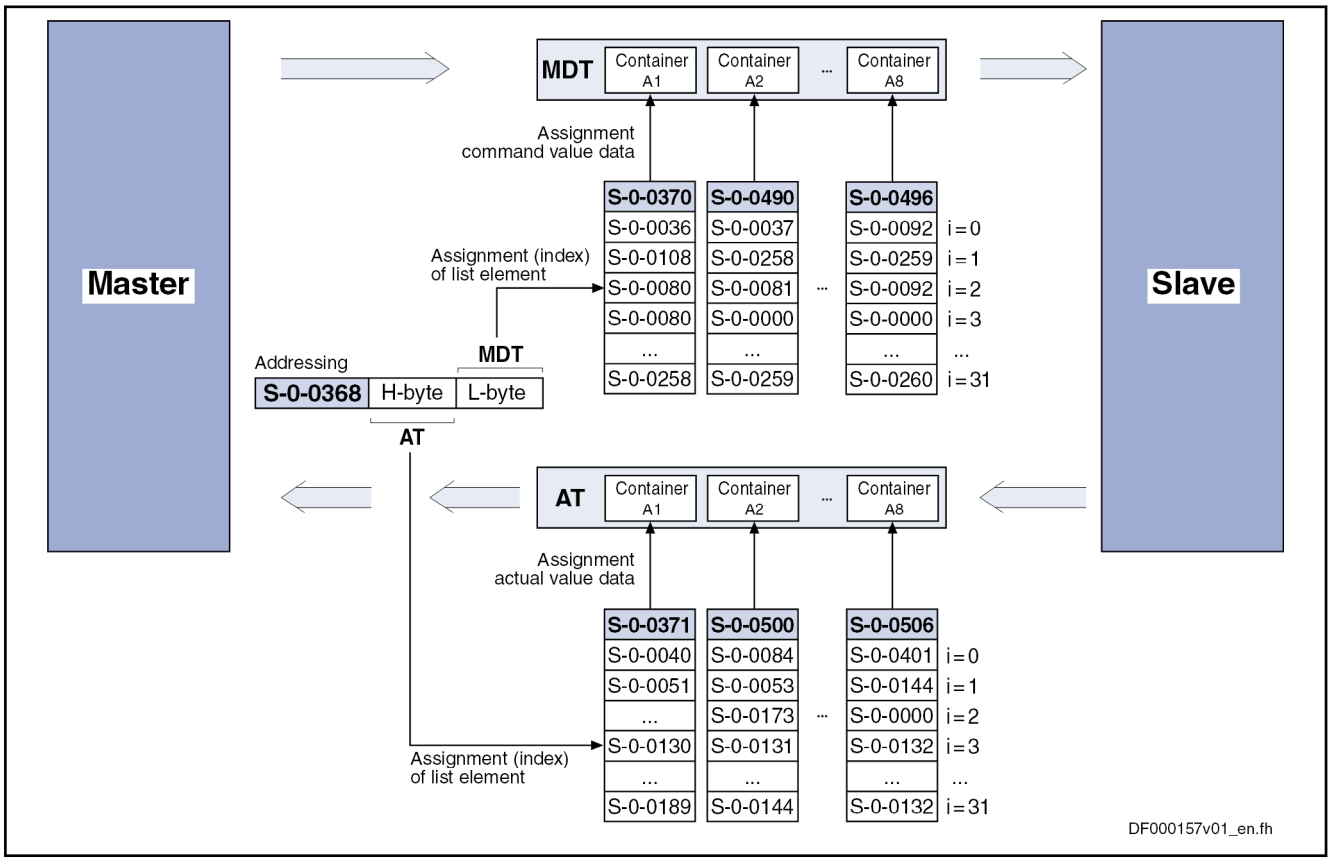
Parameter "S-0-0368, Data container A: Addressing" contains the indices for selecting the parameters from the configuration lists the values of which are to be transmitted to the data containers (command values and actual values).

The following assignment applies to S-0-0368:

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

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

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




| | |
|---|---|
| **i** | index (= list element no.) |
| **S-0-0368** | Data container A: Addressing |
| **S-0-0370** | Data container A: configuration list command value -1 |
| **S-0-0490** | Data container A: configuration list command value 2 |
| **S-0-0496** | Data container A: configuration list command value 8 |
| **S-0-0371** | Data container A: configuration list actual value -1 |
| **S-0-0500** | Data container A: configuration list actual value 2 |
| **S-0-0506** | Data container A: configuration list actual value 8 |

*Fig. 4-10: Addressing and Assignment for Multiplex Channel*

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

Master Communication

### Assigning Single List Elements

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

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

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

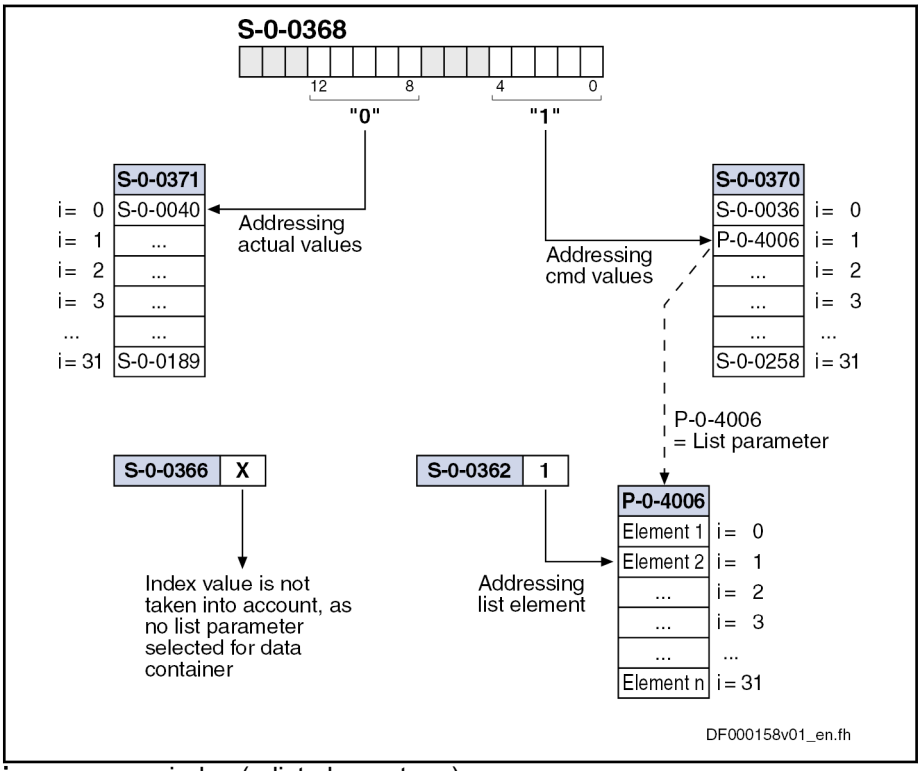
  → Addressing elements of list parameters that have been entered as target for the content of command value data containers (for **write access**)

- S-0-0366, Data container A: List index feedback values

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

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

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




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

*Fig. 4-11: Access to Elements of a List Parameter via Multiplex Channel (Example of Command Values → MDT Data Container)*

## Notes on Commissioning

**Activation**

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

**Data Container A: Command Value-x**

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

- **Single parameters**

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

- **List parameters**

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

---

☞ The display format is hexadecimal without decimal places.

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

---

**Data Container A: Actual Value-x**

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

- **Single parameters**

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

- **List parameters**

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

---

☞ The display format is hexadecimal without decimal places.

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

---

## Diagnostic and Status Messages

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

**Checking the Configured IDN Order**

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

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

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

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

**Checking the Configuration Lists**

It has to be ensured that the IDN contained in the configuration lists are existing and the corresponding parameters can be cyclically configured.

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

There are the following possible error messages:

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

**Checking the Index**

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

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

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

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

# 4.3 Operation Modes of Master Communication

## 4.3.1 Introduction and Overview

### Overview of Operation Modes and Possibilities of Command Triggering

Command triggering for the drive can be carried out by an external control master (remote mode) or via the inputs/outputs which are available (local mode).

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

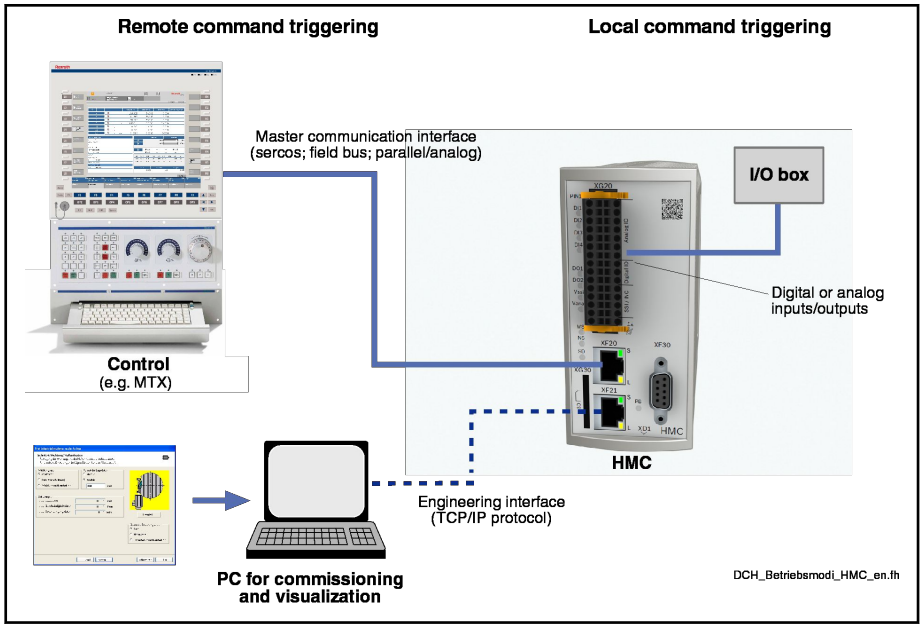



*Fig. 4-12: Overview of Possibilities of Command Triggering for an HMC Control*

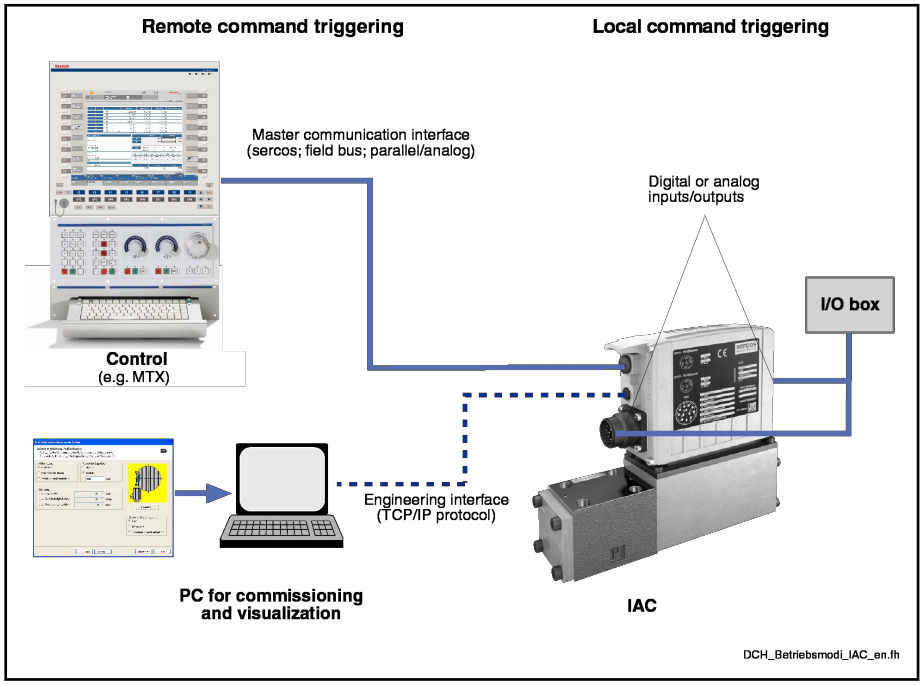



*Fig. 4-13: Overview of Possibilities of Command Triggering for an IAC Control*

**Operation Modes and Changes of State**

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

Master Communication

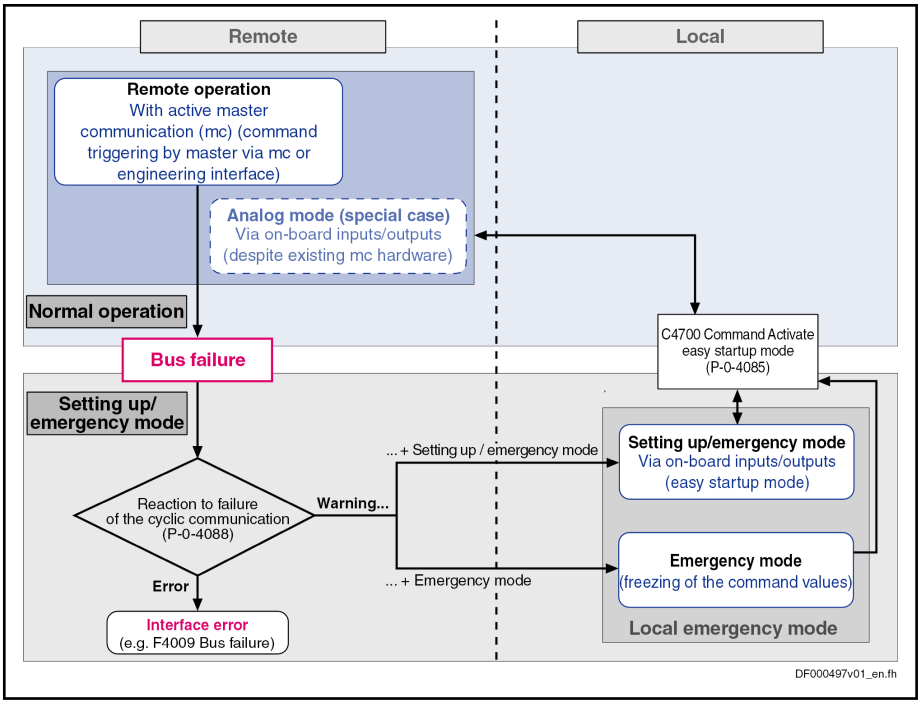



*Fig. 4-14: Operating States and Operation Modes of Master Communication*

**Device Control and State Machine**

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

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

## Normal Operation (via Internal or External Control Unit)

In the so-called normal operation, command triggering for the drive takes place via an external control unit (e.g. IndraMotion MTX or MLC), with the following cases having to be distinguished:

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

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

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

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

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

  → For commissioning or the setting-up procedure, the drive can temporarily be moved via the inputs/outputs (digital and analog), independently of the external master.

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

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

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

## 4.3.2 Normal Operation (Remote or Local)

### Remote Mode With External Control Unit and Active Master Communication

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

See description of the respective master communication:

- sercos
- EtherCAT®
- VARAN
- EtherNet/IP(TM)
- PROFINET
- PROFIBUS-DP

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

## 4.3.3 Setting-Up Mode (Easy Startup Mode)

### Brief Description of Easy Startup Mode

The setting-up mode as so-called easy startup mode allows moving the drive without connected or active control unit (or master communication master) or external command value box.

**Fields of Application**

The easy startup mode is particularly suited for

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

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

**Features**

The easy startup mode is characterized by the following features:

- **Activation/deactivation** of the easy startup mode:
  - by writing parameter "P-0-4085, C4700 Command Activate easy startup mode"
- **Command triggering** (axis control) via digital inputs/outputs by
  - predefined digital I/O configuration in operation mode "**direct valve control**" with a command value (default) that can be parameterized
  - freely configurable I/O configuration and operation mode with active easy startup mode
  - selecting the **travel direction** (positive/negative) via digital input signals

Master Communication

- **Deactivating command triggering** by the master communication interface (see "P-0-4077, Field bus: Control word", "S-0-0134, Master control word")

**Pertinent Parameters**

- S-0-0014, Interface status
- P-0-0120, Control word easy startup
- P-0-0300, Digital inputs, assignment list
- P-0-0301, Digital inputs, bit numbers
- P-0-4085, C4700 Command Activate easy startup mode
- P-0-4086, Master communication status
- P-0-4088, Master communication: Drive configuration

## Functional Description of Easy Startup Mode

In the setting-up mode (easy startup mode), the drive can be controlled either via the digital and analog inputs or via the engineering interface. Direct valve control is the default operation mode for easy startup. Depending on the derivate und functional packages, further secondary operation modes are available.

**Control via Digital or Analog Inputs**

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

- Automatically by activating the easy startup mode

- or -

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

**Automatic Configuration of the Inputs**

For automatic configuration of the inputs, the following actions are carried out:

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

**Manual Configuration of the Inputs**

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

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

**Alternatively**, the following manual configurations can be set additionally:

- Direct valve control
- Presetting of the valve command value (P-0-1468)

**Operating the Drive via Engineering Interface**

The drive can also be controlled via the engineering interface via which it is possible to write command values apart from the control word.

The following has to be taken into account:

- "P-0-1468,PLC/setting-up mode, valve command value" must not have been assigned to an analog input
- Drive enable must not have been assigned to any digital input ("P-0-0120, Control word easy startup").

## Notes on Commissioning for Easy Startup Mode

**Requirements**

The following requirements and conditions are to be fulfilled for using the easy startup mode:

- Master communication should not to be active, as the easy startup mode switches off any possibly active command triggering via master communication!
- No error message must be present in the drive, not even a transition command error (C01xx, C02xx).
- The drive must be ready for operation ("bb").
  - In the case of conventional field bus interfaces (e.g. PROFIBUS®), the drive is automatically ready for operation ("bb") after run-up, even if master communication is not active. In this way, the requirements for manual mode basically are always fulfilled!
  - With sercos, EtherNet/IP™ interface, …, after run-up the drive is **not ready for operation** if master communication is not active (e.g., communication phase "P-1" with sercos).

**Possibilities of Activation**

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

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

**Activation via Digital Input**

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

See "Digital Inputs/Outputs"

**Activation via Engineering Interface**

To activate the easy startup mode via the engineering interface, the parameter P-0-4085 is written via SIS telegrams.

---

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

---

**Acknowledgment of Activation**

The activation of the easy startup mode is acknowledged by:

- Setting bit 8 in parameter "P-0-4086, Master communication status"
- Clearing the bit "drive follows (ext.) command value input" in parameter P-0-0115 (bit 3)

---

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

---

**Deactivating/Exiting the Easy Startup Mode**

The easy startup mode is deactivated by completing the command activation. The command can be completed by writing the parameter P-0-4085.

---

☞ After exiting the easy startup mode, the previously active status becomes active again. The command triggering of the drive again takes place via the master communication (see P-0-4077, S-0-0134, …) and the originally active operation modes are executed.

---

**Control Parameter P-0-0120**

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

- Via digital inputs, if they were configured accordingly before

- Via the engineering interface by direct writing of parameter P-0-0120

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

**Invalid Commands**

The commands for the backup of the working memory ("C2200Backup working memory procedure command" and "C2400 Selectively backup working memory procedure command") is not to be triggered in the easy startup mode, because otherwise the settings of the easy startup mode will be stored in the non-volatile memory and will be active again after the drive is switched on the next time!

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

Before initial start in easy startup mode, the required controller parameters are to be checked!

**Recommissioning**

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

## 4.3.4 Local Mode

### Overview

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

- **Emergency run (local mode)** for bus failure → With the corresponding configuration, operation of the drive can continued in an emergency mode, even if master communication (field bus, sercos …) has failed.

### Emergency Mode (When Master Communication Has Failed)

**Behavior in Case of Bus Failure**

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

- **Bus failure as error**

  → The drive normally switches off, generates the message of an interface error (e.g. "F4009Bus failure") and carries out the defined **error reaction** ("best possible deceleration").

- **Bus failure as warning**

  → In the case of bus failure, the drive does **not** react by switching off and generating an error message, but the state of the last command triggering is maintained (command value and control word are "frozen") or the easy startup mode is automatically activated and the warning "E4005No command value input via master communication" is output.

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

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

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

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

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

## 4.3.5 Notes on Commissioning and Utilization

### Using the Operation Modes

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

| Place of command triggering | Mode | Use | Execution of command triggering | Activation | Operation Modes | Notes |
|---|---|---|---|---|---|---|
| **Control unit** (remote) | **Master comm. mode** (remote) | Field bus or sercos device is operated as usual via existing interface of master communication | via external control unit (bus or inputs/ outputs) | Not required | Standard operation modes 0...7 take effect and can be selected | Standard Case |
| | **Special case: Analog operation** | Field bus device can be permanently operated as analog drive, if master comm. option deactivated (for mounting spare parts or emergency mode without master) | Only via digital onboard inputs/ outputs and analog inputs | Configuration of parameter P-0-4088<br>**Note:** Activation requires complete booting process | Standard operation modes 0...7 take effect and can be defined according to the specific application, if required | Special case in which master comm. option exists, but is not active |
| **Local** | **Setting-up mode** | Setting-up and commissioning of axes, even without running master | Via digital inputs/outputs or acyclic channel with "IndraWorks Ds /D/MLD" | Command "Easy startup mode" | Internal operation modes 8…12 take effect<br>**Note:** Operation modes 8…12 have been permanently configured | |
| | **Emergency mode** | Moving of the axes when master communication fails | Digital inputs/ outputs or acyclic channel with "IndraWorks Ds /D/MLD" | "Easy startup mode" command, can be manually started in the case of bus failure | The operation modes last active take effect (0...7) | Control via activation of easy startup mode is possible |

**Master comm. option** hardware option for master communication

*Tab. 4-3: Operation Criteria of the Operation Modes*

Master Communication

### Control Words of the Operation Modes and Master Communications

Depending on the operation mode or master communication used, different control words take effect; they are shown in the figure below.

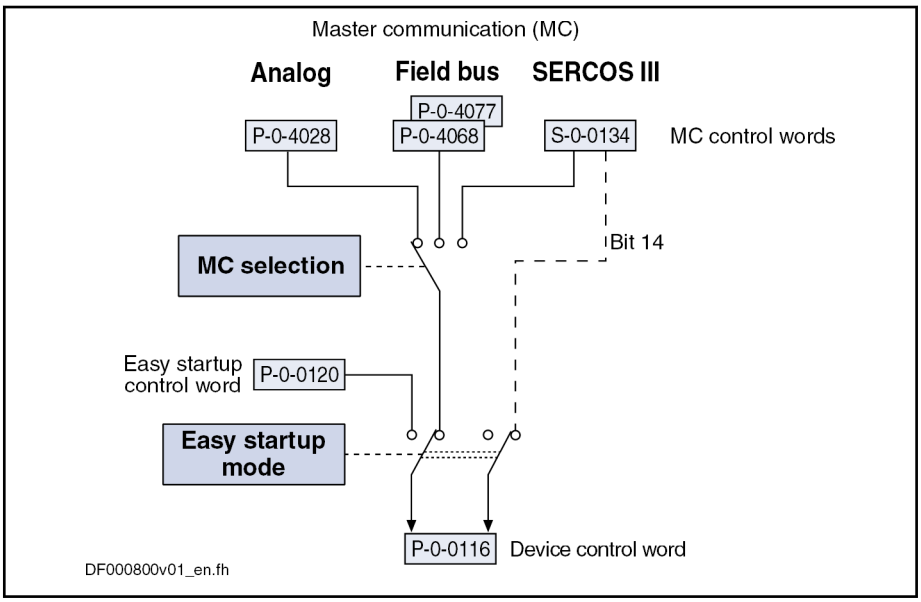



*Fig. 4-15: Overview of Control Words of Operation Modes and Master Communication*

### Special Cases of Operation With External Control Unit

For operation via external master communication, the following special case exists:

- EtherNet/IP™ communication via the engineering interface

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

- Deactivation of master communication and activation of the analog mode take place in the parameter "P-0-4088, Master communication: Drive configuration".
- The configuration will only take effect after re-booting, i.e. the control voltage of the drive controller must be switched off and on again.
- In order to control the device via the digital inputs, the drive enable signal, among others, needs to be assigned (see Parameter Description "P-0-0120, Control word easy startup") to a digital input of the control section.

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

  See "Velocity Control" and "Positioning Block Mode"

# 4.4 Profile Types (With Field Bus Interfaces)

## 4.4.1 Brief Description

### Supported Profile Types, Overview

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

- "No profile"

- I/O mode positioning
- I/O mode preset velocity
- Fluid Power profile
- Freely configurable mode

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

| Profile Type: "No Profile" | | | |
|---|---|---|---|
| **Content of "P-0-4084, Field bus: Profile type"** | **Master communication** | **Field bus or drive operation mode** | **Features** |
| **0x0000** | PROFIBUS®<br>PROFINET®<br>EtherNet/IP™<br>EtherCAT | - With the profile type "No profile", all settings relevant to the profile type are deactivated<br>- The profile type "No profile" is mainly relevant to MLD applications with "permanent control" on the axis | - Profile type without field bus control word and field bus status word<br>- Real-time data can be freely configured<br>- Operation mode can be freely selected |

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

| Profile type: "Fluid Power" | | | |
|---|---|---|---|
| **Content of "P-0-4084, Field bus: Profile type"** | **Master communication** | **Field bus or drive operation mode** | **Features** |
| **0x0113** | EtherCAT | • The profile type "Fluid Power" is used for CANopen over EtherCAT<br>• Only available with functional package “open loop"<br>• All "open-loop" operation modes possible | • Use of the individual Fluid Power control and status words P-0-4094.0.1 and P-0-4094.0.2<br>• Free configuration of cycl. data |

*Tab. 4-5: Profile Type "Fluid Power"*

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

*Tab. 4-6: Profile Type "I/O Mode Positioning"*

Master Communication

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

*Tab. 4-7: Profile Type "IO Mode Preset Velocity"*

| Servodrive profile | | | |
|---|---|---|---|
| **Content of "P-0-4084, Field bus: Profile type"** | **Master communication** | **Field bus or drive operation mode** | **Features** |
| **0x0114** | VARAN<br>EtherCAT | The profile type “servodrive profile" is used for Servodrive Profile over EtherCAT and VARAN | - Use of control and status words S-0-0134 and S-0-135<br>- Free configuration of cyclic data |

*Tab. 4-8: Profile Type "Servodrive Profile"*

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

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

**Pertinent Parameters**

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

- P-0-4081, Field bus: Config. list of cyclic command value data ch.
- P-0-4082, Field bus: Length of cyclic actual value data channel
- P-0-4083, Parameter channel: Length
- P-0-4084, Field bus: Profile type

### Supported Profile Types, Basic Principles and Terms

**Drive Profile**

The drive profile defines

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

Through the selection of a profile type, commissioning of field bus drives becomes very easy for the user. The advantage of 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 often defined independently of the bus, the transfer of applications from one field bus to the other is also facilitated.

**State Machine**

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

**Abbreviations**

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

## 4.4.2 Profile Type “No Profile”

### I/O Mode (Positioning and Preset Velocity)

#### Brief Description

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

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

**General Features**

The I/O mode is characterized by the following features:

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

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

Master Communication

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

– **Slave → master** (drive)

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

- Freely configurable field bus status word (cf. S-0-0144)
- Relationship between profile type selection and effective operation mode
  – In the **I/O modes**, there is a determined relationship between profile type (P-0-4084) and predefined primary operation mode (S-0-0032).
  – The **freely configurable mode** allows free selection of the operation modes (S-0-0032, S-0-0033, …).

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

**Structure of the Real-Time Channel**

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

*Tab. 4-10: Structure of the Real-Time Channel for the I/O Modes*

**Features "I/O-Mode Positioning"**

Specific features of "I/O mode positioning":

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

**Features "I/O Mode Preset Velocity"**

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

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

## State Machine in I/O Mode

Interaction of control and status bits (state machine):

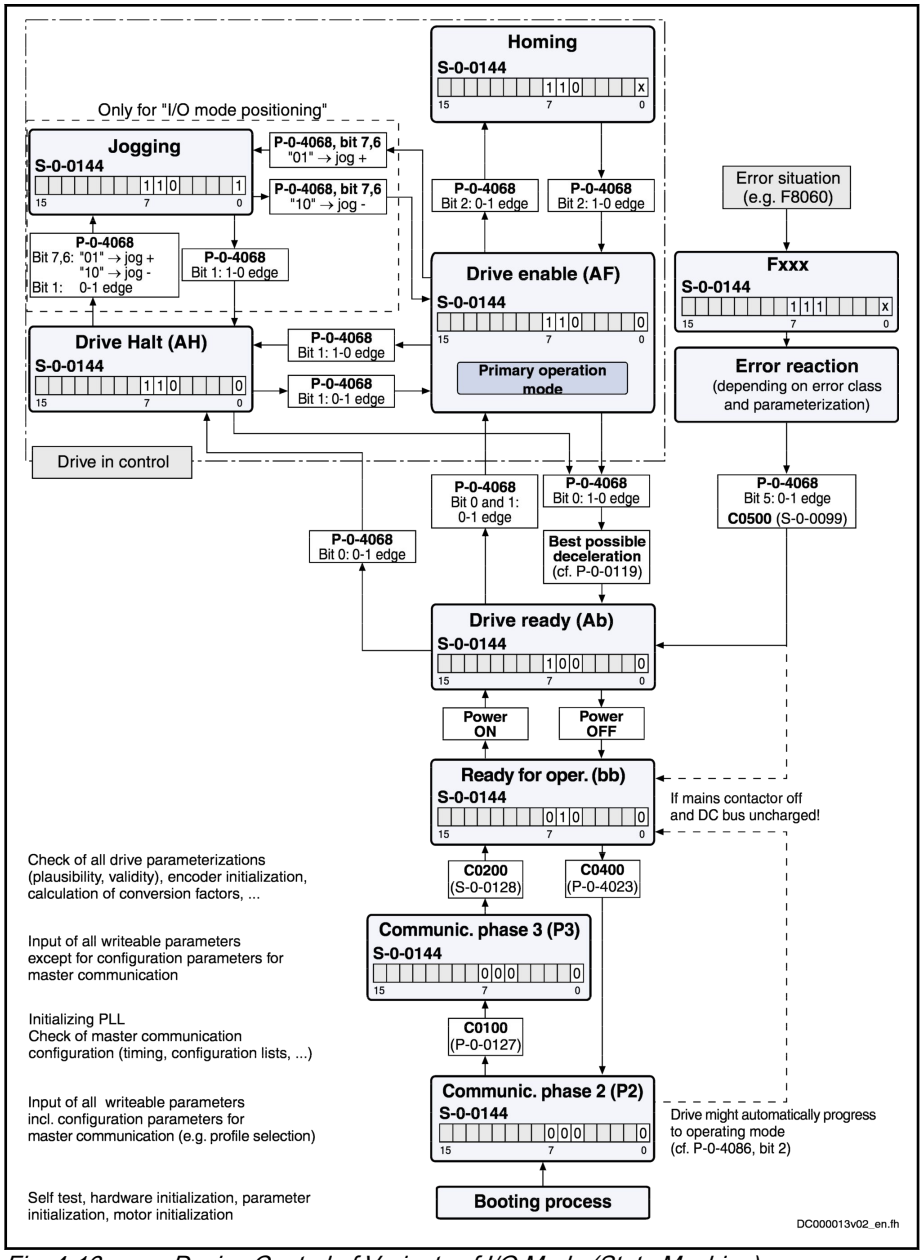



*Fig. 4-16: Device Control of Variants of I/O Mode (State Machine)*

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

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

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

Master Communication

**Field Bus Control Word in I/O Mode**

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

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

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

**Field Bus Control Word in I/O Mode**

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

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

| Bit | Assignment | Significance |
|---|---|---|
| **0** | Active operation mode | **1**: Jogging (S-0-0437)<br>**0**: Positioning |
| **1** | Position switch point (PSP) | **1:** To the right of PSP<br>**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)<br>**0:** No error |
| **6** | Readiness for operation | **1:** Ready for operation (P-0-0115) |
| **7** | Power switched on | **1**: Power switched on (P-0-0115) |
| **13…8** | Positioning block acknowledgment | P-0-4051, Positioning block acknowledgment |
| **15…14** | Not assigned | |

*Tab. 4-11: Default Assignment of Parameter "S-0-0144, Signal Status Word" for "I/O Mode Positioning" (P-0-4084 = 0xFF82)*

| Bit | Assignment | Significance |
|---|---|---|
| **0** | Status of ramp-function generator | **1:** Run-up stop active (P-0-1210, bit 1) |
| **1** | Status of ramp-function generator | **1:** Accelerating active (P-0-1210, bit 2) |
| **2** | Status of ramp-function generator | **1:** Accelerating active (P-0-1210, bit 3) |
| **3** | In motion | **1:** Message n_feedback = 0 (S-0-0331, bit 0) |

| Bit | Assignment | Significance |
|---|---|---|
| 4 | Status of ramp-function generator | **1:** Command value reached (P-0-1210, bit 0) |
| 5 | drive error (error flag) | **1:** Error (P-0-0115)<br>**0:** No error |
| 6 | Readiness for operation | **1:** Ready for operation (P-0-0115) |
| 7 | Power switched on | **1:** Power switched on (P-0-0115) |
| 8 | Status of ramp-function generator | **1:** Command value within masking window P-0-1210, bit 4) |
| 9 | Status of ramp-function generator | **1:** V-ramp within masking window (P-0-1210, bit 5) |
| 15...10 | Not assigned | |

*Tab. 4-12: Default Assignment of Parameter "S-0-0144, Signal Status Word" for "I/O Mode Velocity" (P-0-4084 = 0xFF92)*

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

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

## Notes on Parameterization/Commissioning

**Features With Default Configuration**

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

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

**Features/Settings With Free Configuration or Extension**

There are the following possibilities for free configuration/extension:

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

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

Master Communication

## 4.4.3 Fluid Power Profile

### Brief Description

#### General Information

**General Information**

If the field bus interface is used for master communication, the device function is supported by the drive according to VDMA Fluid Power Profile, Version 1.6 and CiA408 Fluid Power Profile.

Device function, status and control word as well as cyclic communication are implemented according to the profile. In order to ensure that all communication objects (profile-defined and manufacturer-specific) can be displayed in a uniform format, no support of profile-conforming parameters (0x6000 ff) was provided. All communication objects can be accessed in uniform formats via manufacturer-specific objects (refer to "Manufacturer-Specific Objects (0x2000 to 0x3FFF)").

The table below contains an overview of the most important properties and features of the profile.

| Fluid Power profile | | | |
|---|---|---|---|
| Content of “P-0-4084, Field bus: Profile type“ | Master communication | Field bus or drive operation mode | Features |
| 0x0113 | CAN application layer over EtherCAT, CoE | Fluid Power profile | - Apart from control and status word, other real-time data can be configured (in P-0-4080 Field bus: Config. list of cyclic actual value data ch. und P-0-4081 Field bus: Config. list of cyclic command value data ch.) |

*Tab. 4-13: "Fluid Power" Profile Type*

**General Features**

The Fluid Power profile has the following features:

- Real-time channel consisting of at least one 4-byte parameter, P-0-4094.0.1, Field bus: control word Fluid Power, and P-0-4094.0.2, Field bus: status word fluid power.
- Maximum number of user data per real-time channel (incl. Fluid Power control and status word):

| Bus cycle | Max. length of cyclic user data |
|---|---|
| >= 2 ms | 48 bytes |
| >= 1 ms | 32 bytes |
| 0.5 ms | 16 bytes |

- Freely expandable real-time channel by configuration of real-time data:

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

  **Slave (drive) → master** Configuration of "P-0-4080, Field bus: Config. list of cyclic actual value data ch."

The respective default settings are activated by selecting the profile type (in P-0-4084, Field bus: Profile type) and subsequent action “load default communication parameters” (see also P-0-4090, Configuration for loading default values, and S-0-0262, C07_x Load defaults procedure command).

**Structure of the Real-Time Channel**

| Data direction | Parameter 1 | Format |
|---|---|---|
| **Master → slave** | P-0-4094.0.1, Field bus: control word fluid power | u32 |
| **Slave → master** | P-0-4094.0.2, Field bus: status word fluid power | u32 |

*Tab. 4-14: Structure of the Real-Time Channel of the Fluid Power Profile*

**Abbreviations**

- **u32:**32-bit variable without sign (2 words) in Intel format

**Pertinent Parameters**

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-0-4080, 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-0-4084, Field bus: Profile type
P-0-4088, Master communication: Drive configuration
P-0-4089.0.1, Master communication: Protocol
P-0-4094.0.1, Field bus: control word fluid power
P-0-4094.0.2, Field bus: status word fluid power

## State Machine in Fluid Power Profile

If the profile Fluid Power is activated, the drive functions according to the following state machine:

Master Communication

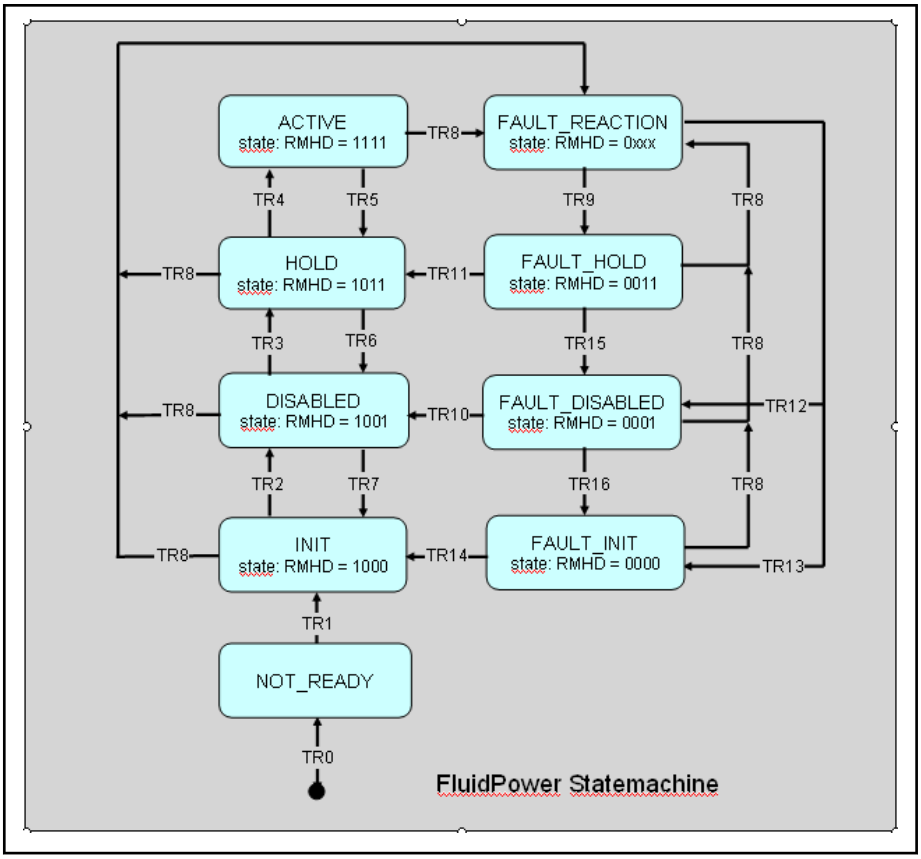



*Fig. 4-17: Fluid Power State Machine*

## States of the Fluid Power State Machine

| State / change in state | Description |
|---|---|
| NOT_READY | When the drive is activated, it runs through the state NOT_READY. Here, basic initializations are performed. After these are complete, the drive automatically changes to state INIT. |
| INIT | After the drive is switched on and the basic initialization is completed, it automatically switches to state INIT. In this state, basic initializations are completed. The drive is waiting for data from the control system. |
| DISABLED | The drive is in status Disabled. |
| HOLD | The drive is in status Drive Halt (AH) and already in control. |
| ACTIVE | The drive is in status Drive Enable (AF) and follows the input of command values from the control unit. |
| FAULT_INIT | Error condition |
| FAULT_DISABLED | Error condition |
| FAULT_HOLD | Error condition |
| FAULT_REACTION | Depending on the state in which the error was detected, a respective error reaction is performed. Afterwards, the drive switches to one of the FAULT_xxx states. |

*Tab. 4-15: States of the Fluid Power State Machine*

The behavior of the drive is controlled by RMHD bits in the Fluid Power control word (P-0-4094.0.1, Field bus: control word fluid power, bit 0..3)

The drive reports the status of the Fluid Power state machine via the RMHD bits in the Fluid Power status word (P-0-4094.0.2, Field bus: status word fluid power, bit 0..3).

| Bit | Control word | | Status Word | |
|---|---|---|---|---|
| 3 | R | reset fault (R) | R | ready (R) |
| 2 | M | device mode active enable (M) | M | device mode active enable (M) |
| 1 | H | hold enable (H) | H | hold enable (H) |
| 0 | D | disabled (D) | D | disabled (D) |

*Tab. 4-16: RMHD Bits*

### Device Control Commands

The control unit can control the states of the drive. For this, several transitions are implemented in the drive. These are triggered by special bits (RMHD) in the Fluid Power control word P-0-4094.0.1, Field bus: control word fluid power.

#### Important Transitions of the Fluid Power State Machine

| Transition | RMHD bits | Description |
|---|---|---|
| TR2 activate DISABLED | xxx1 | Transition from status INIT to DISABLED |
| TR3 activate HOLD | xx11 | Transition from status DISABLED to HOLD |
| TR4 activate ACTIVE | x111 | Transition from status HOLD to ACTIVE |
| TR5 de-activate ACTIVE | x0xx | Transition from ACTIVE to HOLD |
| TR6 de-activate HOLD | x00x | Transition from HOLD to DISABLED |
| TR7 de-activate DISABLED | x000 | Transition from DISABLED to INIT |
| TR10 reset FAULT_DISABLED | 0001 → 1001 (edge of R) | Transition from FAULT_DISABLED to DISABLED |
| TR11 reset FAULT_HOLD | 0011 → 1011 (edge of R) | Transition from FAULT_HOLD to HOLD |
| TR14 reset FAULT_INIT | 0000 → 1000 (edge of R) | Transition from FAULT_INIT to INIT |

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| | | |
|---|---|---|
| TR15 FAULT_HOLD to FAULT_DISABLED | x001 | Transition from FAULT_HOLD to FAULT_DISABLED |
| TR16 FAULT_DISABLED to FAULT_INIT | x000 | Transition from FAULT_DISABLED to FAULT_INIT |

*Tab. 4-17: Table of Transitions of the Internal State Machine*

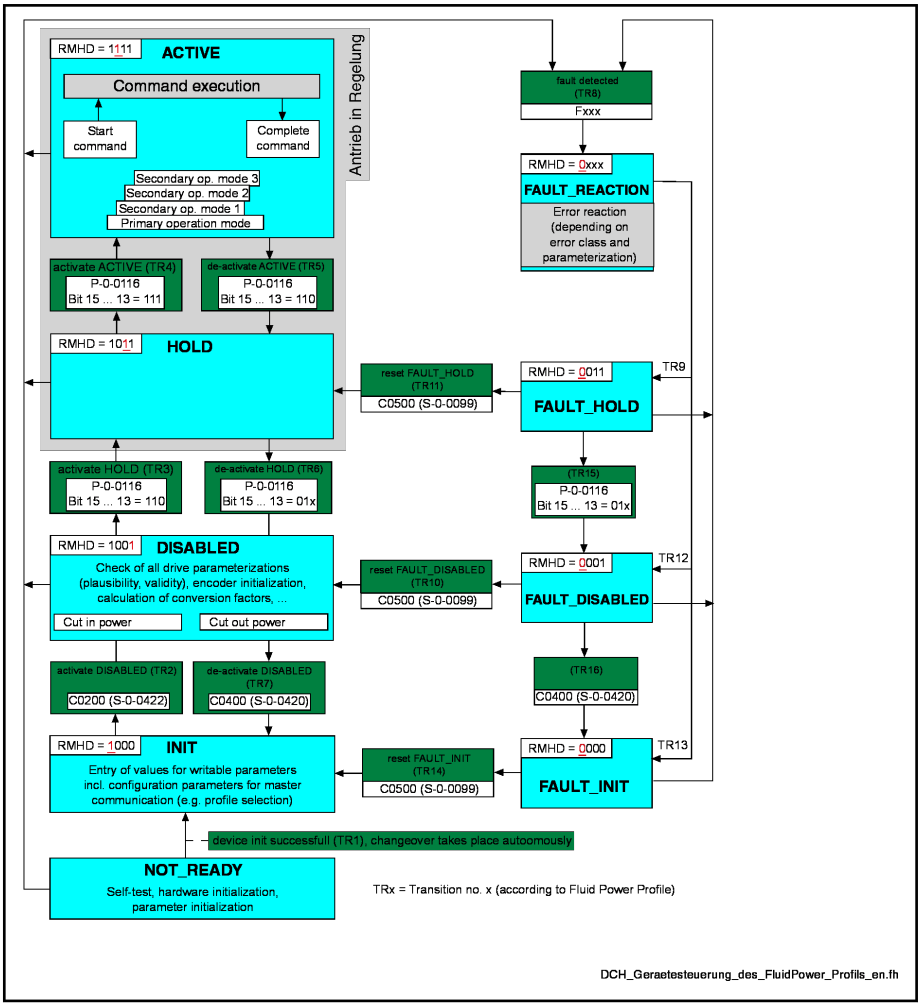


*Fig. 4-18: Device Control of the Fluid Power Profile (State Machine)*

**Automatic restart after bus failure!**

In the case of bus failure (message "F4009" or "E4005"), an error reaction is to be carried out in the control unit, too, to prevent automatic restart after the bus has been reestablished. This means, in case of bus failure, the bits "disabled (D)", "hold enable (H)" and "device mode active (M)" (bits 1..3 in parameter "P-0-4094.0.1, Field bus: control word fluid power") should be reset in the control unit.

## Notes on Parameterization/Commissioning

In order to successfully communicate with the drive via Fluid Power profile, the following parameters are to be set to the listed values.

| Parameter | Description | Value |
|---|---|---|
| P-0-4080 | Field bus: Config. list of cyclic actual value data ch. | 0: P-0-4094.0.2 x: cyclic actual values |
| P-0-4081 | Field bus: Config. list of cyclic command value data ch. | 0: P-0-4094.0.1 x: cyclic command values |
| P-0-4084 | Field bus: Profile type | 0x0113 (=Fluid Power profile) |
| P-0-4088 | Master communication: Drive configuration | Bit 0 = 1 |
| P-0-4089.0.1 | Master communication: Protocol | Bit 8 (=CAN application layer over EtherCAT, CoE) |

*Tab. 4-18: Parameter Settings with Fluid Power*

### Additional Informal Parameters

| Parameter | Description | Value |
|---|---|---|
| P-0-4073 | Field bus: Diagnostics | Displays the current state of the Fluid Power state machine in plain text (only from communication status Operational, otherwise current state of the communication state machine CiA301) |
| P-0-4094.0.1 | Field bus: control word Fluid Power | Fluid Power control word |
| P-0-4094.0.2 | Field bus: status word Fluid Power | Fluid Power status word |

*Tab. 4-19: Additional informal parameters of Fluid Power*

When the drive is switched on, it is in the so-called parameter mode.

To bring the drive in control via the PDO channel, the following steps are to be performed:

#### Activating Status DISABLED

- Set the **Disabled (D)** bit in the control word (1)
- The **Disabled (D)** bit in the status word is set by the drive (2)

Master Communication

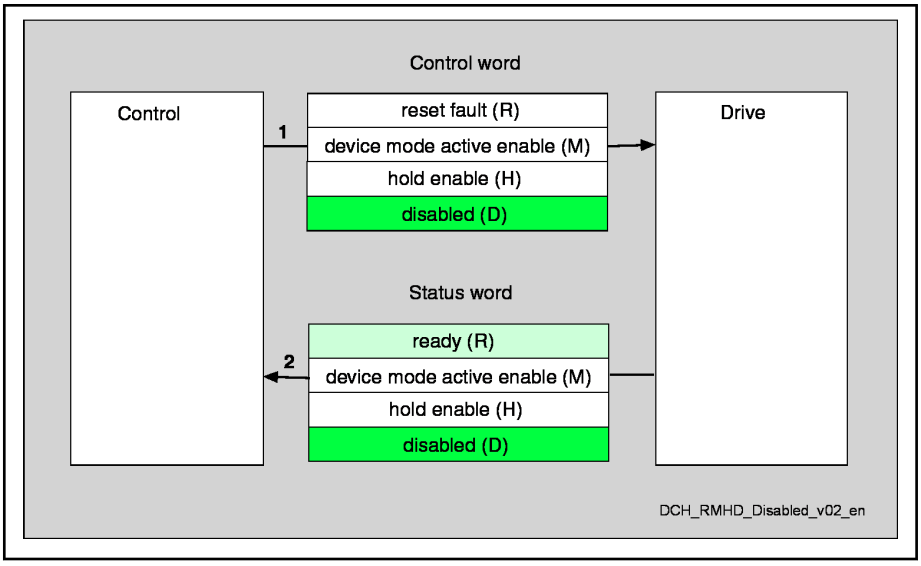


*Fig. 4-19: Activating Status DISABLED*

**Activating Status HOLD**

- Set the **Hold enable (H)** bit in the control word (3)
- The drive activates the "Drive Halt function", i.e., the axis is shut down with a defined acceleration and a defined jerk
- The drive is now in control
- The **Hold enable (H)** bit in the status word is set by the drive (4)

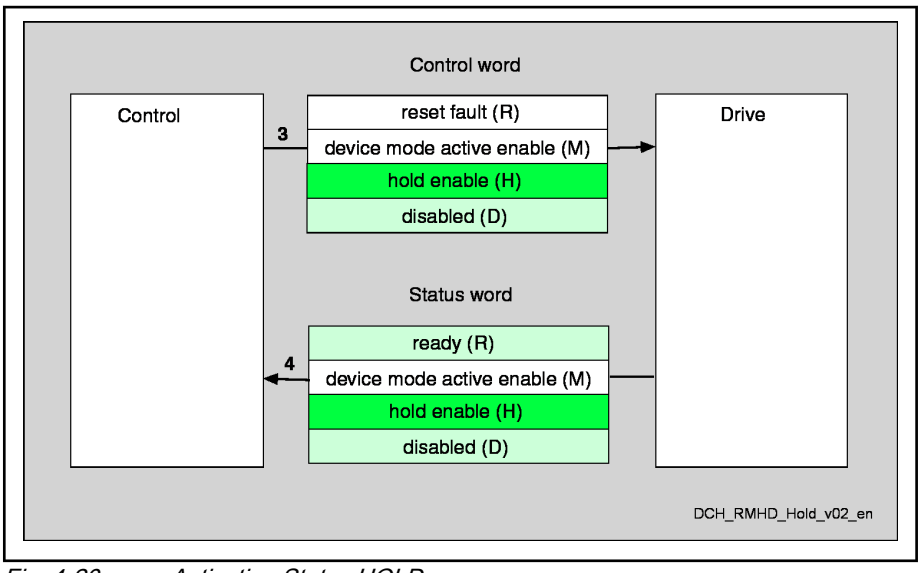


*Fig. 4-20: Activating Status HOLD*

**Activating Device MODE ACTIVE ENABLE**

- Set the **Device mode active enable** (M) bit in the control word (5)
- The drive is enabled
- The drive now follows the input via the PDO channel (command values)
- The drive returns the actual values to the control unit

  The **Device mode active enable** (M) bit in the status word is set by the drive (6)

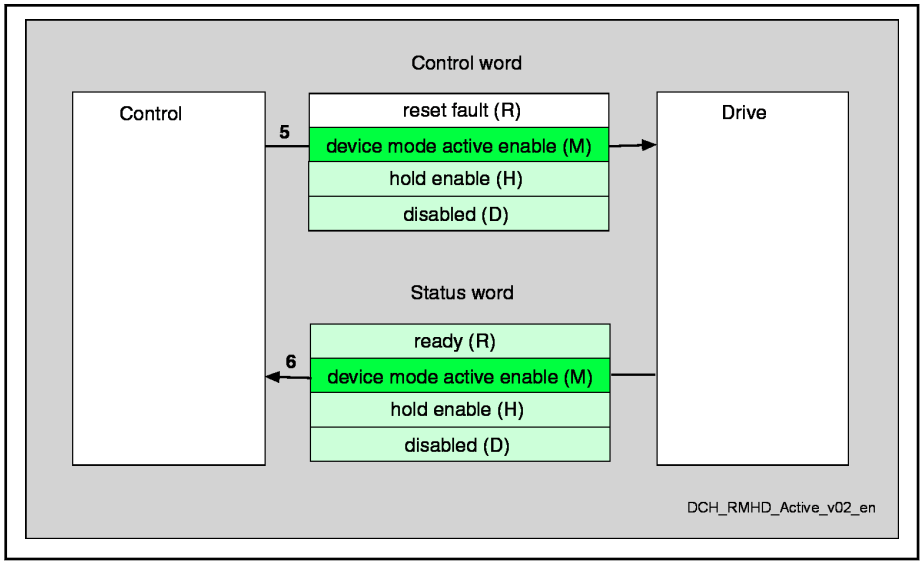


*Fig. 4-21: Activating the Status MODE ACTIVE ENABLE*

By setting above-mentioned bits, the respective states are set drive-internally according to the Fluid Power state machine. When the disabled (D) bit is set, the drive internally switches from status INIT to DISABLED. By subsequently setting the hold enable (H) bit, the drive internally switches from DISABLED to HOLD. By subsequently setting the device mode active enable (M) bit, the drive internally switches from HOLD to ACTIVE. If the bits are withdrawn in reverse order, the drive internally follows the respective states!

By simultaneously setting or resetting several control bits, states can be skipped. For example, it is possible to switch from DISABLED to ACTIVE by simultaneously setting hold enable (H) and device mode active enable (M).

In case of an error in the drive, the **Ready (R)** bit is set to 0. The error can then be acknowledged in the control word by sending the **Reset Fault (R)** bit. If the **Ready (R)** bit is not set to 1 after acknowledgement by the control unit, the error cause can be searched and remedied with the engineering software IndraWorks.

## 4.4.4 Parameter Channel for PROFIBUS and PROFINET

### Functional Description

Via the parameter channel, the drive(s) can be parameterized over the field bus. The parameter channel is part of the cyclic data.

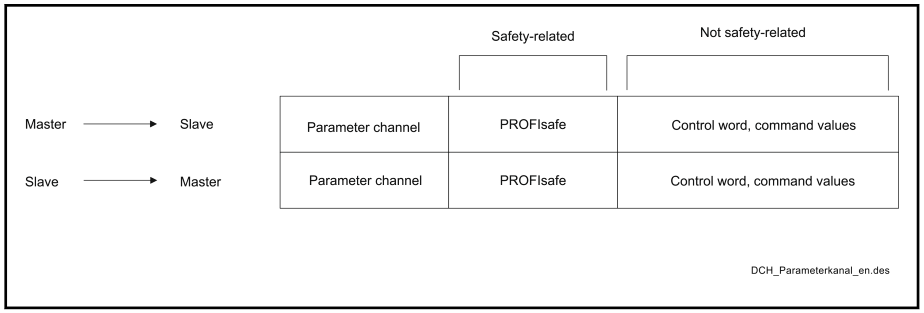


*Fig. 4-22: Parameter Channel as Part of Cyclic I/O Data*

The figure shows the parameter channel, which is transmitted at the beginning of cyclic I/O data. In principle, the parameter channel data block can be

transmitted at any position of cyclic I/O data. At present, the parameter channel is used with PROFIBUS and PROFINET.

For Siemens S7 and PLC Open, function blocks are available which implement the parameter channel protocol. The customer does not need to deal with the parameter channel details.

However, should the parameter channel be used for other field bus masters, function blocks from Bosch Rexroth can be used as template in conjunction with this description.

## Configuration

The parameter channel supports parameters of IDN and EIDN format. The customer must set the format, which the drive is to expect, using parameter P-0-4083.0.001"Parameter channel: Configuration". (1: IDN access, 1: EIDN access).

With PROFIBUS, the length of the parameter channel is recognized during run-up. If the user has not configured the parameter format, the IDN format is automatically expected from the drive and configured in parameter P-0-4083.0.001.

With PROFIBUS, the length of the parameter channel is not recognized during run-up. The length of the parameter channel is indirectly set via the configuration of parameter P-0-4083.0.001"Parameter channel: Configuration".

| Content of P-0-4083.0.1 | Designation / function | Comment | Length of parameter channel |
|---|---|---|---|
| 0 | Deactivated | The parameter is deactivated. | 0 bytes |
| 1 | IDN access | Access to the IDN parameters of the drive via the parameter channel | 10 bytes |
| 2 | EIDN access | Access to the IDN and EIDN parameters of the drive via the EIDN parameter channel | 12 bytes |

*Tab. 4-20: The table shows the interrelationship between the parameter channel configuration and the resulting parameter channel length in conjunction with PROFINET*

The length of the parameter channel is displayed in parameter P-0-4083, "Parameter channel: Length".

## Project Planning

The parameter channel is set by selecting the respective I/O modules in the configuration software of PROFIBUS. The following parameter channel modules can be selected. They are made available via the GSD/GSDML file.

- ParamCh not used: No parameter channel selected (length 0 words)
- ParamCH IDN: Used for accessing IDN parameters/EIDN substitute parameters (length 5 words).
- ParamCh EIDN: Used for accessing EIDN parameters (length 6 words).

In case of PROFIBUS and PROFINET the selected parameter channel module must be plugged into slot 1.

## Error Codes

The table below provides an overview of the possible parameter channel telegram error messages and their significance:

| Error code | Significance |
|---|---|
| 0x0082 | Total volume of transmitted data is too low, i.e. less than 4 bytes |
| 0x0083 | The data volume still to be transmitted exceeds 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 is still data to be retrieved. |
| 0x008D | The length of data indicated as still to be transmitted in the control word is incorrect |
| 0x008E | The EIDN/IDN access mode set in control word bit 15 does not correspond to the access mode configured in P-0-4083.0.1. |

*Tab. 4-21: Error Codes*

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

| Error code | Significance |
|---|---|
| 0x0009 | Invalid access to element 0 |
| 0x1001 | No IDN |
| 0x1009 | Invalid access to element 1 |
| 0x2001 | No name available |
| 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 | Datum transmission too short |
| 0x7003 | Datum transmission too long |
| 0x7004 | Datum cannot be changed (read only) |
| 0x7005 | Datum can currently not be written |
| 0x7006 | Datum is smaller than minimum input value |
| 0x7007 | Datum exceeds the maximum input value |
| 0x7008 | IDN is not supported, invalid bit number or bit combination |
| 0x7009 | Datum write-protected by customer password |
| 0x700A | Datum is currently write-protected, as it is configured cyclically |

| Error code | Significance |
|---|---|
| 0x700B | Invalid indirect addressing (e.g. data container, list handling) |
| 0x700C | Datum is currently write-protected due to other settings (e.g. parameter, operation mode, drive enable, ...) |
| 0x7010 | Procedure command already active |
| 0x7011 | Procedure command not interruptible |
| 0x7012 | Procedure command at this time not executable (e.g., the procedure command cannot be activated in this phase) |
| 0x7013 | Procedure command not executable (invalid or false parameters) |
| 0x9001 | Input cannot be identified as application |
| 0x9002 | Parameter type error |
| 0x9003 | Invalid data record number |
| 0x9004 | Invalid data block number |
| 0x9005 | Data element number invalid |
| 0x9006 | Error in R/W flag |
| 0x9007 | Invalid character in the datum |

*Tab. 4-22: Overview Parameter Access Errors*

## Structure of the Parameter Channel Protocol (More Detailed Information in Case PLC Standard FBs Made Available by Bosch Rexroth Are Not Used)

### Length of the Parameter Channel Protocol

In the GSD/GSDML file, certain modules, which correspond to a parameter channel length of 0 (ParamCh not used), 5 (ParamCh IDN) and 6 (ParamCh EIDN) words, are made available.

Moreover, the drive also supports parameter channel lengths of 2, 3, 4 and 7 words. With these lengths, the parameter channel functionality is net checked for the enable. In justified exceptional cases, developers can make available a GSD file, which supports these parameter channel lengths.

### Basic Structure of the Parameter Channel Protocol

At the beginning of every parameter channel protocol the control word (master→drive) or status word (drive→master) is transmitted.

| Control word / status word | ... |
|---|---|
| 1 word | 1 to 7 words |

*Tab. 4-23: Basic Structure of the Parameter Channel Protocol*

### Structure of the Control Word

The control word is sent in the direction from the master to the slave (drive). It is 16 bit wide and the individual bits have the following significance:

| Bit | Significance |
|---|---|
| 15 | **PF** parameter format (0: 2-byte IDN format, 1: 4-byte IDN format) |
| 14 | **G** no basic position |
| 13 | **L** load bit |

| Bit | Significance |
|---|---|
| 12 | **T** toggle bit |
| 11-8 | **FL** length of user data in the fragment (4 bits) |
| 7-0 | **GL** length of the data yet to be transmitted, including those in the current fragment (8 bits) |

*Tab. 4-24: Parameter Channel Control Word*

### Structure of the Status Word

The status word is sent in the direction from the slave (drive) to the master. It is 16 bit wide and the individual bits have the following significance:

| Bit | Significance |
|---|---|
| 15 | **res** reserved (always 0) |
| 14 | **F** error |
| 13 | **L** load bit |
| 12 | **T** toggle bit |
| 11-8 | **FL** length of user data in the fragment (4 bits) |
| 7-0 | **GL** length of the data yet to be transmitted, including those in the current fragment (8 bits) |

*Tab. 4-25: Parameter Channel Status Word*

### Addressing the Drive Parameters

With regard to addressing, we distinguish between:

- Standard ("S") and product ("P") data
- Data block numbers from 0 to 4095
- 8 selectable parameter sets
- Addressing of different axes (for double-axis devices, CCD data)
- Access to different elements of a parameter (datum, min. input value...)
- The parameter format (2-byte IDN format / 4-byte IDN format). With the 4-byte IDN format, the parameter protocol is extended by structure instance and structure element.

To this end, for parameter addressing an index, axis number and subindex was introduced for the parameter channel.

**Index Structure**

| Bit | Significance |
|---|---|
| 13-15 | Fixed identifier |
| 12:0 | Standard data (S-x-xxxx) |
| 12:1 | Product data (P-x-xxxx) |
| 11-0 | Data block number from 0 to 4095 |

*Tab. 4-26: Index Structure*

**Axis number**

| Bit | Significance |
|---|---|
| 7-0 | Axis number |

*Tab. 4-27: Axis Number*

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**Subindex Structure**

| Bit | Significance |
|---|---|
| 7-5 | Parameter sets 0-7 |
| 4-0 | Element number 0-31 |

*Tab. 4-28: Subindex Structure*

**Structure Instance**

The structure instance is used only in the 4-byte IDN parameter format.

| Bit | Significance |
|---|---|
| 7-0 | Instance number |

*Tab. 4-29: Structure Instance*

**Structure Element**

The structure element is used only in the 4-byte IDN parameter format.

| Bit | Significance |
|---|---|
| 7-0 | Element number |

*Tab. 4-30: Structure Element*

## Format/Type of Operating Datum with Field Buses

The operating datum can have four different formats:

**W** 2 byte data length

**L** 4 byte data length

**X** 8 byte data length (prepared)

**T** ASCII text with a minimum length of 64 bytes

There are three parameter types:

- Single parameters
- Command
- List

## Addressing of Parameter Elements

The parameter elements are addressed as part of the subindex.

Irrespective of the parameter type, each parameter has the following read-only elements):

| No. | Name | Function | Form |
|---|---|---|---|
| 0 | Number of elements | Number of supported elements | W |
| 1 | IDN | sercos IDN | T(8) |
| 2 | Name | Parameter name | T(60) |
| 3 | Attribute | Display mode of the parameter | L |
| 4 | Unit | Parameter unit | T(12) |
| 5 | Min. input value | Max. possible value of the datum | W/L/X/T |
| 6 | Max. input value | Max. possible value of the datum | W/L/X/T |

Depending on its type, each parameter has further elements, which differ in their function:

| No. | Name | Form |
|---|---|---|
| 7 | Operating datum | W/L/X/T |
| 8 | Max. number of list elements / length of text | L |
| 9 | Actual number of list elements / length of text | L |
| 10 | Pointer to the element which is processed on the next access to element 7 | L |
| 11 | 1 list element | W/L/X/T |
| 12 | 2 list elements | W/L/X/T |
| 13 | 3 list elements | W/L/X/T |
| 14 | 4 list elements | W/L/X/T |
| 15 | 5 list elements | W/L/X/T |
| 16 | 6 list elements | W/L/X/T |
| 17 | 7 list elements | W/L/X/T |
| 18 | 8 list elements | W/L/X/T |
| 19 | 9 list elements | W/L/X/T |
| 20 | 10 list elements | W/L/X/T |

## Structure of the Parameter Channel

Irrespective of fragmentation or an error, the parameter channel, when a parameter is written, is composed of the following:

| | Control word | Index | Axis | Subindex | SI (depending on parameter format) | SE (depending on parameter format) | Data |
|---|---|---|---|---|---|---|---|
| M→S | 2 bytes | 2 bytes | 1 byte | 1 byte | 1 byte | 1 byte | Max. 80 bytes |

*Tab. 4-31: Parameter Channel While Writing a Parameter*

| | Status word |
|---|---|
| S→M | 2 bytes |

*Tab. 4-32: Parameter Channel While Writing a Parameter*

Irrespective of fragmentation or an error, the parameter channel, when a parameter is written, is composed of the following:

| | Control word | Index | Axis | Subindex | SI (depending on parameter format) | SE (depending on parameter format) |
|---|---|---|---|---|---|---|
| M→S | 2 bytes | 2 bytes | 1 byte | 1 byte | 1 byte | 1 byte |

*Tab. 4-33: Parameter Channel While Reading a Parameter*

| | Status word | Data |
|---|---|---|
| S→M | 2 bytes | Max. 80 bytes |

*Tab. 4-34: Parameter Channel While Reading a Parameter*

## Parameter Communication Examples

### Basic Position

The control determines the basic position and the drive replies with the 2-byte identifier of the supported parameter channel format, in this case, 02V00.

| | Control word / status word | | | | | | User Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Res | G/F | L | T | FL | GL | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 |
| M→S | 0 | 0 | 1 | 0/1 | 0 | 0 | - | - | - | - | - | - | - | - |
| S→M | 0 | 0 | 1 | 0/1 | 2 | 2 | 02 h | 00 h | - | - | - | - | - | - |

*Tab. 4-35: Basic Position*

### Non-Fragmented Reading

The control reads out the operating datum of parameter S-0-0057. It is a double word, which means that fragmenting is not necessary. The value is 100.

Parameter mapping:

Index = 2039 h

Subindex = 7 h

| | 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 | 20 h | 39 h | 00 h | 07 h | - | - | - | - |
| S→M | 0 | 0 | 1 | 1/0 | 4 | 4 | 00 h | 00 h | 00 h | 64 h | - | - | - | - |

*Tab. 4-36: Non-Fragmented Reading*

### Non-Fragmented Reading Without Error

The control writes a new operating datum to parameter S-0-0057. It is a double word, which means that fragmenting is not necessary. The value is 200. The drive returns an acknowledgement that mirrors the length.

Parameter mapping:

Index = 2039 h

Subindex = 7 h

| | 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 | 20 h | 39 h | 00 h | 07 h | 00 h | 00 h | 00 h | 00 h |
| S→M | 0 | 0 | 1 | 0/1 | 0 | 0 | - | - | - | - | - | - | - | - |

*Tab. 4-37: Non-Fragmented Writing Without Error*

### Non-Fragmented Writing With Error Feedback

The control writes a new operating datum to parameter S-0-0057. The value is 20000 and exceeds the permissible maximum. The drive returns an error message; in this example: 7006h.

Parameter mapping:

Index = 2039 h

Subindex = 7 h

| | 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 | 20 h | 39 h | 00 h | 07 h | 00 h | 00 h | 4E h | 20 h |
| S→M | 0 | 0 | 1 | 0/1 | 2 | 2 | 70 h | 06 h | - | - | - | - | - | - |

*Tab. 4-38: Non-Fragmented Writing With Error Feedback*

### Fragmented Reading

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

Parameter mapping:

Index = 2010h

Subindex = 11 h → 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 | 20 h | 10 h | 00 h | 0A h | 00 h | 00 h | 00 h | 00 h |
| S→M | 0 | 0 | 1 | 1/0 | 0 | 0 | - | - | - | - | - | - | - | - |
| M→S | 0 | 1 | 1 | 0/1 | 4 | 4 | 20 h | 10 h | 00 h | 11 h | - | - | - | - |
| S→M | 0 | 0 | 0 | 0/1 | 8 | 14 | 00 h | 28 h | 00 h | 33 h | 00 h | 36 h | 00 h | 54 h |
| M→S | 0 | 1 | 1 | 1/0 | 0 | 6 | - | - | - | - | - | - | - | - |
| S→M | 0 | 0 | 1 | 1/0 | 6 | 6 | 00 h | 5F h | 00 h | 82 h | 00 h | 83 h | - | - |

*Tab. 4-39: Fragmented Reading*

### Fragmented Writing

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

Parameter mapping:

Index = 3FA6h

Subindex = 10 h → 16 → 6 elements

Length = 4 bytes header + (6*4 bytes data) = 28 bytes

Master Communication

| | 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 |
| S→M | 0 | 0 | 1 | 0/1 | 0 | 12 | - | - | - | - | - | - | - | - |
| M→S | 0 | 1 | 0 | 1/0 | 8 | 12 | 00h | 00h | 01h | 90h | 00h | 00h | 01h | F4h |
| S→M | 0 | 0 | 1 | 1/0 | 0 | 4 | - | - | - | - | - | - | - | - |
| M→S | 0 | 1 | 1 | 0/1 | 4 | 4 | 00h | 00h | 02h | 58h | - | - | - | - |
| S→M | 0 | 0 | 1 | 0/1 | 0 | 0 | - | - | - | - | - | - | - | - |

*Tab. 4-40: Fragmented Reading*

### Requesting the Next Fragment

For the request for the next fragment of a fragmented transmission, GL must be calculated on the basis of the received data from the control word/status word:

$$GL_{Sende} = GL_{Empfang} - FL_{Empfang}$$

*Fig. 4-23: Requesting the Next Fragment*

**GL** Length of the data yet to be transmitted, including those in the current fragment (8 bits)

**FL** length of user data in the fragment (4 bits)

### Pertinent Parameters

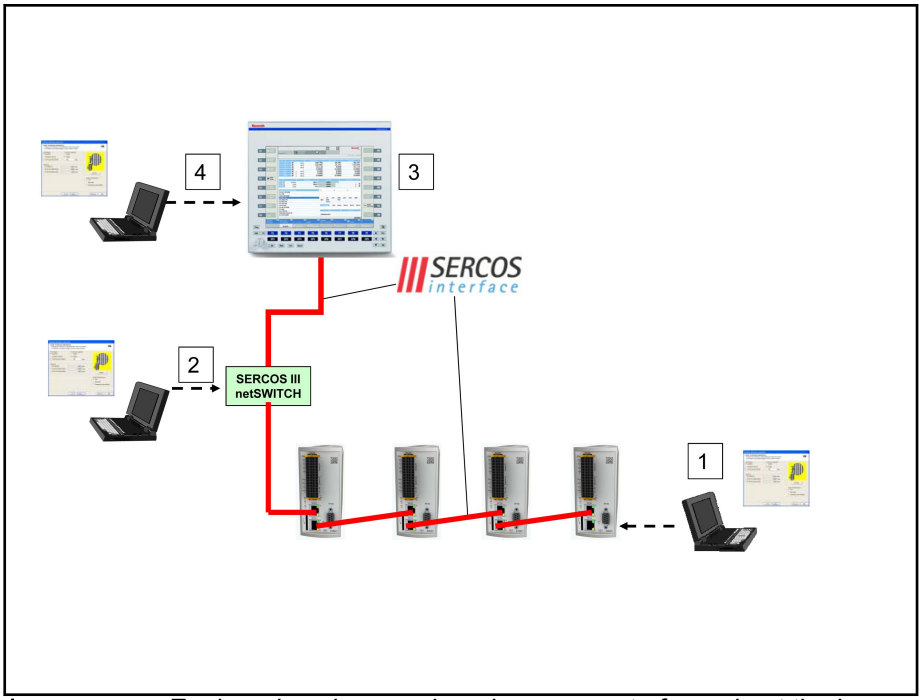
**Parameters**

- P-0-4083, Parameter channel: Length
- P-0-4083.001, Parameter channel: Configuration

# 4.5 sercos

## 4.5.1 Brief Description

**Topology**




**1** Engineering via unassigned sercos port of a node at the bus
**2** Engineering via optional sercos-netSwitch
**3** Engineering via IndraWorks on sercos control
**4** Engineering via routing via control (if routing control available)

*Fig. 4-24: Engineering Options via sercos*

It is possible to operate HydraulicDrive with a MultiEthernet interface (ET) or a sercos interface (S3) as sercos master communication. Via these modules, it is possible to exchange real-time data with a sercos master.

The following communication channels are distinguished:

- **Cyclic data channel**
  → Channel for cyclic transmission of user data (**process data**) in real time
- **Acyclic data channel** (service channel)
  → Channel for acyclic transmission of user data (**service data**)
- **Non-real time channel (NRT channel)**
  → Defined time slot within the cycle time for transmission of standard Ethernet telegrams

**General Features**

- Transmission rate 100 Mbit/s
- Cyclical data exchange of command and actual values in equal time intervals
- Data transmission via Ethernet cable (CAT5e copper)
- Service channel for parameterization and diagnosis
- Free configuration of telegram contents
- Synchronization between time command value takes effect and measurement starting time of the actual values for all devices on a ring
- Overall synchronization of all connected devices

Master Communication

**Firmware-Specific Features**

| | | | | |
|---|---|---|---|---|
| **Controller cycle time** | $T_{position}$ | ms | 1 | 0 |
| **Master communication cycle time** | min | ms | 1 | 0 |
| | max | ms | 65 | |
| **MotionData** in each case for MDT/AT [excl. 2-byte connection control word (C_Con)] | $T_{sercos}$=>$T_{Position}$ | Byte | **50** | |
| | | IDN | 16 | |
| **CC connections** [excl. 2-byte connection control word (C_Con)] | | Byte | 8 | |
| | | IDN | 2 | |

*Tab. 4-41: sercos Key Data*

- HydraulicDrive supports 2 connections between control unit and drive.
- Cycle time: min. 1 ms, max. 65 ms (multiple of the position controller cycle can be set)
- Max. quantity of configurable consumer data: 50 bytes/16 IDNs
- Max. quantity of configurable producer - consumer data: 50 bytes/ 16 IDNs

☞ The NRT channel is only possible, if a time slot of more than 125 µs is available.

**Axis Addressing**

The address can be directly changed or displayed via the parameter "S-0-1040, Drive address of master communication". With sercos and the remote address assignment, the address can be set automatically via the master in a remote way. This function must be supported by the master.

**Pertinent Parameters**

Specific parameters for sercos communication

- S-0-1000, sercos: SCP Type & Version
- S-0-1002, sercos: Communication Cycle time (tScyc)
- S-0-1005, sercos: Minimum feedback processing time (t5)
- S-0-1006, sercos: AT0 transmission starting time (t1)
- S-0-1007, sercos: Feedback acquisition capture point (t4)
- S-0-1008, sercos: Command value valid time (t3)
- S-0-1009, sercos: Device Control (C-Dev) offset in MDT
- S-0-1010, sercos: Lengths of MDTs
- S-0-1011, sercos: Device Status (S-Dev) offset in AT
- S-0-1012, sercos: Length of ATs
- S-0-1013, sercos: SVC offset in MDT
- S-0-1014, sercos: SVC offset in AT
- S-0-1015, sercos: Ring delay
- S-0-1016, sercos: Slave delay (P/S)
- S-0-1017, sercos: NRT transmission time
- S-0-1019, Master comm. engineering over IP: MAC address
- S-0-1020, Master comm. engineering over IP: IP address
- S-0-1021, Master comm. engineering over IP: Network mask
- S-0-1022, Master comm. engineering over IP: Gateway address

- S-0-1023, sercos: SYNC jitter
- S-0-1024, C5300 sercos: SYNC delay measuring procedure command
- S-0-1026, sercos: Version of communication hardware
- P-0-1027.0.1, sercos: Requested MTU
- P-0-1027.0.2, sercos: Effective MTU
- S-0-1031, sercos: Signal assignment TSx
- S-0-1034, sercos: PHY error counter Port1 and Port2
- S-0-1035, sercos: Error counter Port1 & Port2
- P-0-1035.0.1, sercos: Error counter P&S
- S-0-1036, sercos: Inter Frame Gap
- S-0-1037, sercos: Slave Jitter
- S-0-1040, Drive address of master communication
- S-0-1041, sercos: AT Command value valid time (t9)
- S-0-1042, sercos: Topology index
- S-0-1044, sercos: Device Control (C-Dev)
- S-0-1045, sercos: Device Status (S-Dev)
- S-0-1046, sercos: Slave addresses of the device
- S-0-1047, sercos: Maximum Consumer Activation Time
- S-0-1050.x.1, sercos Connection: Connection setup
- S-0-1050.x.2, sercos Connection: Connection number
- S-0-1050.x.3, sercos Connection: Telegram assignment
- S-0-1050.x.4, sercos Connection: Max. length of connection
- S-0-1050.x.5, sercos Connection: Current length of connection
- S-0-1050.x.6, sercos Connection: Configuration list
- S-0-1050.x.8, sercos Connection: Connection control (C-Con)
- S-0-1050.x.10, sercos Connection: Producer cycle time
- S-0-1050.x.11, sercos Connection: Allowed data losses
- S-0-1050.x.12, sercos Connection: Error counter data losses
- S-0-1050.x.20, sercos Connection: IDN allocation of real-time bit
- S-0-1050.x.21, sercos Connection: Bit allocation of real-time bit
- S-0-1051, sercos Connection: Image of connection setups
- S-0-1060.x.1, sercos Connectiontype: Default configuration
- S-0-1060.x.2, sercos Connectiontype: Configuration mask
- S-0-1060.x.3, sercos Connectiontype: Max. quantity of conn. Capability
- S-0-1060.x.4, sercos Connectiontype: Max. Length of Connection
- S-0-1060.x.6, sercos Connectiontype: Configurable IDNs
- S-0-1060.x.7, sercos Connectiontype: Min. processing time
- S-0-1060.x.10, sercos Connectiontype: Minimum producer cycle time

**Pertinent Diagnostic Messages**

- A0000 Communication phase 0
- A0001 Communication phase 1
- A0002 Communication phase 2
- A0003 Communication phase 3

Master Communication

- A0008 sercos: NRT-Mode
- E4020 sercos: Ring interruption (FF to LF)
- F4001 Sync telegram failure
- F4002 RTD telegram failure
- F4003 Invalid communication phase shutdown
- F4004 Error during phase progression
- F4005 Error during phase regression
- F4006 Phase switching without ready signal
- F4017 sercos: Incorrect sequence during phase switch
- F4020 sercos: Cable break (L+F to NRT)

## 4.5.2 Functional Description

**sercos Diagnostic LED**

In the HydraulicDrive a diagnostic LED is implemented according to the sercos specification, see also chapter "Diagnostic and Status Messages".

| Blinking code | | | | | | | | | | | | Function | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | No sercos telegrams (NRT mode) | 6 |
| orange | orange | orange | orange | orange | orange | orange | orange | orange | orange | orange | orange | CP0 | 6 |
| orange | green | orange | orange | orange | orange | orange | orange | orange | orange | orange | orange | CP1 | 6 |
| orange | green | orange | green | orange | orange | orange | orange | orange | orange | orange | orange | CP2 | 6 |
| orange | green | orange | green | orange | green | orange | orange | orange | orange | orange | orange | CP3 | 6 |
| green | green | green | green | green | green | green | green | green | green | green | green | CP4 | 6 |
| green | | green | | green | | green | | green | | green | | CPx →Loop-back | 5 |
| red | orange | red | orange | red | orange | red | orange | red | orange | red | orange | Applicative C1D | 4 |
| red | green | red | green | red | green | red | green | red | green | red | green | S-Dev.Bit15 (MST warning) | 3 |
| red | red | red | red | red | red | red | red | red | red | red | red | C1D of Communication | 2 |
| orange | | orange | | orange | | orange | | orange | | orange | | C-Dev.Bit15 (identification) | 1 |
| red | | red | | red | | red | | red | | red | | Internal watch-dog has responded | 0 |

**P** Display priority, (1 = highest)
**black** LED is off
**CP** Communication phase

*Tab. 4-42: The Supported Blinking Codes and the Meaning of the Diagnostic LEDs Comply With the sercos Specification*

### 4.5.3 sercos Timing

In the HydraulicDrive, process data are processed in a clock-synchronously. An indicator of clock-synchronous processing is that a master can exactly determine the time of actual value establishment (and command value acceptance) via timing parameters. For the calculation the HydraulicDrive makes its time-related framework conditions available by way of parameters. The master provides the time of processing as TS (S-0-1007, sercos: Feedback acquisition capture point (t4)).

A slave indicates its maximum processing time (tmp-P) as producer in parameter "S-0-1005, sercos: Minimum feedback processing time (t5)".

**Rule**: Process data (actual values) are sent in the AT block, between the start and synchronization time TS of which lies the maximum processing time **complete**.

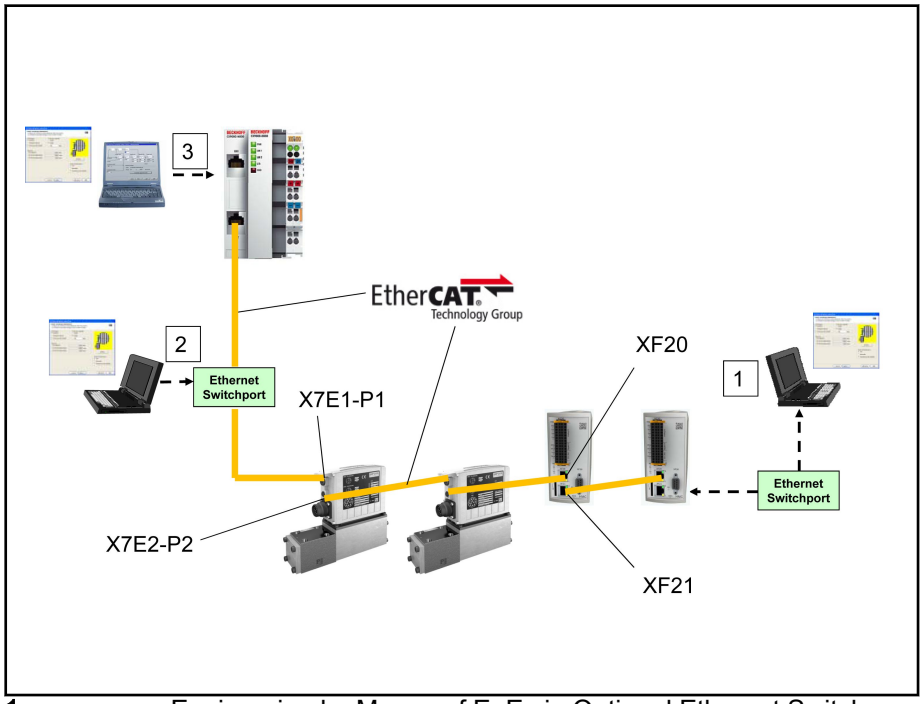
A slave indicates its maximum activation time (tmp-C) as consumer in parameter "S-0-1047, sercos: Maximum Consumer Activation Time".

**Rule**: Process data (command values) are taken from the telegram block (MDT and/or AT). The maximum activation time **complete** lies between the telegram block end and synchronization time TS.

## 4.6 EtherCAT®

### 4.6.1 Brief Description

**Topology**




**1** Engineering by Means of EoE via Optional Ethernet Switch Port

**2** Engineering by Means of EoE via Optional Ethernet Switch Port

**3** Engineering by Means of ADS Interface Via Third-Party Control Unit Using EoE (Control Includes Switch Port)

*Fig. 4-25: Engineering Options With EtherCAT®*

Master Communication

HydraulicDrives can be operated with EtherCAT® master communication. It is possible to exchange real-time data with an EtherCAT® master. "Servo Drive Profile over EtherCAT®" is supported, which is in line with the sercos II specification and the CANopen profile.

The following communication channels are distinguished:

- **Cyclic data channel** (process data)

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

  → EtherCAT® mailbox method for acyclic transmission of user data (**service data**)
- **Non-real time channel** [Ethernet over EtherCAT® (EoE)]

  → Transmission of Ethernet telegrams via an EtherCAT® mailbox method

**General Features**

- Transmission rate 100 Mbit/s
- Data transmission via Ethernet cable (CAT5e copper)
- Access to 16-bit sercos parameters of the drive via "SoE" protocol (“Servo Drive Profile over EtherCAT®“).
- EtherCAT® mailbox method for parameterization and diagnosis
- Cyclic data exchange of command values and actual values
- Free configuration of telegram contents
- Max. length of the configurable MDT/AT data: 15 IDNs with max. 48 bytes; with bus cycle = position cycle, the max. length is halved to 24 bytes
- Cycle time: min. 1 ms (multiples of the position controller cycle can be set)
- "Distributed clock synchronization" (exact adjustment of distributed clocks)
- Synchronization between the time the command value takes effect and the measurement starting time of the actual values for all drives on a ring
- Overall synchronization of all connected drives with the master
- Only released in connection with "Beckhoff TwinCAT"

**Axis Addressing**



The drives identify themselves by means of the order in the bus (example: address = "1" in master corresponds to "1st drive" in the line).

**Pertinent Parameters**

- S-0-0001, NC cycle time (TNcyc)
- S-0-0002, sercos cycle time (TScyc)
- S-0-0005, Minimum feedback acquisition time (T4min)
- S-0-0007, Feedback acquisition starting time (T4)
- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0016, Configuration list of AT
- S-0-0024, Configuration list of MDT
- S-0-0097, Mask class 2 diagnostics

- S-0-0098, Mask class 3 diagnostics
- S-0-0127, C0100 Communication phase 3 transition check
- S-0-0128, C5200 Communication phase 4 transition check
- S-0-0134, Master control word
- S-0-0135, Drive status word
- S-0-0185, Length of the configurable data record in the AT
- S-0-0186, Length of the configurable data record in the MDT
- S-0-0187, List of configurable data in the AT
- S-0-0188, List of configurable data in the MDT
- S-0-0301, Allocation of real-time control bit 1
- S-0-0303, Allocation of real-time control bit 2
- S-0-0305, Allocation of real-time status bit 1
- S-0-0307, Allocation of real-time status bit 2
- S-0-0413, Bit number allocation of real-time control bit 1
- S-0-0414, Bit number allocation of real-time control bit 2
- S-0-0415, Bit number allocation of real-time status bit 1
- S-0-0416, Bit number allocation of real-time status bit 2

**Pertinent Diagnostic Messages**

- C0101 Invalid parameters (-> S-0-0021)
- C0104 Config. IDN for MDT not configurable
- C0105 Maximum length for MDT exceeded
- C0106 Config. IDNs for AT not configurable
- C0107 Maximum length for AT exceeded
- C0108 Time slot parameter > sercos cycle time
- C0112 TNcyc (S-0-0001) or TScyc (S-0-0002) error
- C0113 Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error
- C0114 T4 > TScyc (S-0-0002) - T4min (S-0-0005)
- C0201 Invalid parameters (->S-0-0423)
- C0299 Configuration changed. Restart
- E4005 No command value input via master communication
- F4002 RTD telegram failure
- F4009 Bus failure

## 4.6.2 CAN Application Layer over EtherCAT (CoE)

### Brief Description

#### General Information

**General Information**

It is possible to communicate with the drive via the "CAN application layer over EtherCAT" protocol (CoE, according to ETG.1000.6, V1.0.2). In this process, it is also possible to exchange real-time data with an EtherCAT master.

The following communication channels are distinguished:

- **Cyclic data channel** (process data objects → PDO)

  The field bus provides data containers in which user data can be cyclically transmitted in real time (process data objects).
- **Acyclic data channel** (service data objects → SDO)

Master Communication

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

- **Ethernet data channel**

  The field bus channels standard Ethernet telegrams via the “Ethernet over EtherCAT” mechanism (EoE). This way, the drive can be configured using the commissioning tool "IndraWorks".

Process data is always transmitted via PDOs.

**General Features**

- Configurable cyclic data up to 12 parameters (incl. field bus control word and field bus status word) in both data directions (max. 48 bytes)
- LED indicator lamps on the drive for easy diagnostics of bus functions and the most important communication relationships between drive and field bus (a two-colored LED: “Run“ status (= green) and “Error“ status (= red))
- All parameters of the drive can be directly read via SDO and, if permitted, can be written
- Support of the device function according to Fluid Power profile CiA408 (refer to "profile types")

**Pertinent Parameters**

Communication parameters

Specific parameters for "CAN application layer over EtherCAT" communication:

- P-0-4089.0.1, Master communication: Protocol

Parameters for general field bus communication:

- P-0-4073, Field bus: Diagnostic message
- P-0-4074, Field bus: Data format

  **Profile type parameters**

  Apart from mere communication parameters, parameters related to the profile types are used.

  Refer to "profile types"

**Pertinent Diagnostic Messages**

- F4001 Sync telegram failure
- F4002 RTD telegram failure
- F4009 Bus failure

## CAN Application Layer Over EtherCAT Communication

**EDS File**

The EDS (Electronic Data Sheet) simplifies the configuration of "CAN application layer over EtherCAT" networks. The EDS file writes the parameters that are supported by the drive in a "CAN application layer over EtherCAT" network. In general, the EDS file can be read by a "CAN application layer over EtherCAT" master (PLC or PC).

Due to the different object directories, there is a separate "CAN application layer over EtherCAT" (CoE) EDS file.

This file complies with the specification according to CiA306 version 4.01. Its name is a combination of the firmware designation and the abbreviated name of the multi-Ethernet communication:

- HDBxx_CoE.EDS

### Configuring the Cyclic Data (PDO)

#### PDO configuration

The drive provides a data container in which user data can be cyclically transmitted in real time (process data objects).

The parameters for configuring the cyclic data 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. contain 16 elements each, of which four each have been reserved for each PDO. The max. data length of a PDO is 16 byte. PDOs have to be always filled with 4 elements. Before that, the next PDO cannot be configured.

| Bus cycle | Max. length of cyclic user data |
|---|---|
| >= 2 ms | 48 bytes |
| >= 1 ms | 32 bytes |
| 0.5 ms | 16 bytes |

*Tab. 4-43: Maximum Number of User Data per Real-Time Channel*

| Element in P-0-4080 | PDO (tx) | | Element in P-0-4081 | PDO (rx) |
|---|---|---|---|---|
| 0 | PDO1 (tx) | | 0 | PDO1 (rx) |
| 1 | | | 1 | |
| 2 | | | 2 | |
| 3 | | | 3 | |
| 4 | PDO2 (tx) | | 4 | PDO2 (rx) |
| 5 | | | 5 | |
| 6 | | | 6 | |
| 7 | | | 7 | |
| 8 | PDO3 (tx) | | 8 | PDO3 (rx) |
| 9 | | | 9 | |
| 10 | | | 10 | |
| 11 | | | 11 | |
| 12 | PDO4 (tx) | | 12 | PDO4 (rx) |
| 13 | | | 13 | |
| 14 | | | 14 | |
| 15 | | | 15 | |

*Tab. 4-44: Cyclic Data Configuration*

### Acyclic Parameter Access (SDO)

All drive parameters can be read or written with the SDO services.

#### The following SDO services are supported

- Initiate SDO download to write max. 4-byte data into the drive (with “Initiate SDO Download" the data length is transmitted)

- Download SDO segment to transmit a fragment with data to the drive
- Initiate SDO upload to transmit max. 4-byte data from the drive to the master (the drive communicates the response data length to the master)
- Upload SDO segment to transmit a fragment with data from drive to master
- Abort SDO transfer to report errors and abort SDO accesses

### Communication Objects (0x1000 to 0x1FFF)

**The "CAN application layer over EtherCAT" communication objects are written in CANopen standard CiA301.**

These objects have one of the following functions within the "CAN application layer over EtherCAT" communication:

- Access to drive parameters
- Constants
- Read-only objects

The table below contains an overview of the objects specified for "CAN application layer over EtherCAT" communication:

| Index | Name |
|---|---|
| 0x1000:0 | Device type |
| 0x1001:0 | Error register |
| 0x1008:0 | Manufacturer device name |
| 0x1009:0 | Manufacturer hardware version |
| 0x100A:0 | Manufacturer software version |
| 0x1018:0 | Identity |
| 0x1018:1 | Vendor ID |
| 0x1018:2 | Product code |
| 0x1018:3 | Revision |
| 0x1018:4 | Serial number |
| 0x1600:0 | 1. Receive PDO mapping parameter |
| 0x1600:1 | 1. Application object mapping |
| 0x1600:2 | 2. Application object mapping |
| 0x1600:3 | 3. Application object mapping |
| 0x1600:4 | 4. Application object mapping |
| 0x1601:0 | 2. Receive PDO mapping parameter |
| 0x1601:1 | 1. Application object mapping |
| 0x1601:2 | 2. Application object mapping |
| 0x1601:3 | 3. Application object mapping |
| 0x1601:4 | 4. Application object mapping |
| 0x1602:0 | 3. Receive PDO mapping parameter |
| 0x1602:1 | 1. Application object mapping |
| 0x1602:2 | 2. Application object mapping |

| | |
|---|---|
| 0x1602:3 | 3. Application object mapping |
| 0x1602:4 | 4. Application object mapping |
| 0x1603:0 | 4. Receive PDO mapping parameter |
| 0x1603:1 | 1. Application object mapping |
| 0x1603:2 | 2. Application object mapping |
| 0x1603:3 | 3. Application object mapping |
| 0x1603:4 | 4. Application object mapping |
| 0x1A00:0 | 1. Transmit PDO mapping parameter |
| 0x1A00:1 | 1. Application object mapping |
| 0x1A00:2 | 2. Application object mapping |
| 0x1A00:3 | 3. Application object mapping |
| 0x1A00:4 | 4. Application object mapping |
| 0x1A01:0 | 2. Transmit PDO mapping parameter |
| 0x1A01:1 | 1. Application object mapping |
| 0x1A01:2 | 2. Application object mapping |
| 0x1A01:3 | 3. Application object mapping |
| 0x1A01:4 | 4. Application object mapping |
| 0x1A02:0 | 3. Transmit PDO mapping parameter |
| 0x1A02:1 | 1. Application object mapping |
| 0x1A02:2 | 2. Application object mapping |
| 0x1A02:3 | 3. Application object mapping |
| 0x1A02:4 | 4. Application object mapping |
| 0x1A03:0 | 4. Transmit PDO mapping parameter |
| 0x1A03:1 | 1. Application object mapping |
| 0x1A03:2 | 2. Application object mapping |
| 0x1A03:3 | 3. Application object mapping |
| 0x1A03:4 | 4. Application object mapping |
| 0x1100:0 | EtherCAT address (for EtherCAT only) |
| 0x1110:0 | Virtual MAC address (for EtherCAT only) |
| 0x1111:0 | IP address info (for EtherCAT only) |
| 0x1111:1 | IP address (for EtherCAT only) |
| 0x1111:2 | Subnet mask (for EtherCAT only) |
| 0x1111:3 | Default Gateway (for EtherCAT only) |
| 0x1C00:0 | Sync manager type (for EtherCAT only) |
| 0x1C00:1 | Number of Sync Manager (for EtherCAT only) |
| 0x1C00:2 | Number of Sync Manager (for EtherCAT only) |
| 0x1C00:3 | Number of Sync Manager (for EtherCAT only) |

| | |
|---|---|
| 0x1C00:4 | Number of Sync Manager (for EtherCAT only) |
| 0x1C12:0 | PDO Assign Outputs (for EtherCAT only) |
| 0x1C12:1 | Index of the corresponding RXPDO (for EtherCAT only) |
| 0x1C12:2 | Index of the corresponding RXPDO (for EtherCAT only) |
| 0x1C12:3 | Index of the corresponding RXPDO (for EtherCAT only) |
| 0x1C12:4 | Index of the corresponding RXPDO (for EtherCAT only) |
| 0x1C13:0 | PDO Assign Inputs (for EtherCAT only) |
| 0x1C13:1 | Index of the corresponding TXPDO (for EtherCAT only) |
| 0x1C13:2 | Index of the corresponding TXPDO (for EtherCAT only) |
| 0x1C13:3 | Index of the corresponding TXPDO (for EtherCAT only) |
| 0x1C13:4 | Index of the corresponding TXPDO (for EtherCAT only) |

*Tab. 4-45: Overview of Supported "CAN Application Layer Over EtherCAT" Objects*

Other communication objects are listed in the annex of the separate documentation "Rexroth HydraulicDrive Parameter Description" and the corresponding EDS file.

### Manufacturer-Specific Objects (0x2000 to 0x3FFF)

All parameters of the drive can be reached via the manufacturer-specific objects.

The S-parameters are addressed via the objects 0x2000 to 0x2FFF, the P-parameters via the objects 0x3000 to 0x3FFF. The manufacturer-specific objects have the following structure:

#### Parameter access

| Subindex | Description |
|---|---|
| 0 | Number of object entries |
| 1 | Operating datum block 0 |
| 2 | Operating datum block 1 (if available) |
| 3 | Operating datum block 2 (if available) |
| 4 | Operating datum block 3 (if available) |
| 5 | Operating datum block 4 (if available) |
| 6 | Operating datum block 5 (if available) |
| 7 | Operating datum block 6 (if available) |
| 8 | Operating data block 7 (if available) |
| 9 | Number of parameter sets (1 or 8) |
| 10 | Index of list pointer |
| 11 | List element to which element 10 points (for list parameter only) |
| 12 - 18 | List element to which element 10 points (if 8 parameter sets available); for list parameter only |
| 21 | Name of parameter |
| 22 - 28 | Name of parameter (if 8 parameter sets available) |

| | |
|---|---|
| 31 | Attribute of parameter |
| 32 - 38 | Attribute of parameter (if 8 parameter sets available) |
| 41 | Unit of parameter |
| 42 - 48 | Unit of parameter (if 8 parameter sets available) |
| 51 | Minimum value of parameter |
| 52 - 58 | Minimum value of parameter (if 8 parameter sets available) |
| 61 | Maximum value of parameter |
| 62 - 68 | Maximum value of parameter (if 8 parameter sets available) |
| 71 | Maximum length of list parameter |
| 72 - 78 | Maximum length of list parameter (if 8 parameter sets available) |
| 81 | Actual length of list parameter |
| 82 - 88 | Actual length of list parameter (if 8 parameter sets available) |

*Tab. 4-46: Overview of Supported "CAN Application Layer Over EtherCAT" Objects*

#### List Access

The complete list of a list parameter can be read or written by accessing the operating datum of the parameter.

To access individual list elements, it is possible to set a list index (subindex 10) and access the respective list element of the list index via subindex 11 (to subindex 18). With each access via subindex 11 (to subindex 18), the list index is incremented by one element. This allows processing a continuous part of a list in the case of repeated access to subindex 11 (to subindex 18).

With one of the following actions, the list index is reset to the first element:

- Change of parameter set
- Change of parameter
- Termination of connection

For each list element access which does not start from the first element, it is therefore necessary to set the list index.

If the length of the list has to be changed, this can be corrected by changing the actual length of the list parameter (subindex 81 - 88). The maximum list length can be read via the subindices 71 - 78.

With one of the following actions, the parameter value is stored:

- Writing to last element
- Change of parameter set

The changes are discarded when the control voltage fails.

## ESM (EtherCAT State Machine)

#### EtherCAT State Machine

With the exception of a few details, the EtherCAT State Machine corresponds to the CANopen Communication State Machine according to CiA301. It is responsible for the coordination of master and slave applications during commissioning and operation. State changes are started by means of queries of the master.

Four states are supported:

- Init

Master Communication

- Pre-Operational
- Safe-Operational
- Operational

States and permissible state transitions are illustrated in the figure below. After run-up, the EtherCAT slave is usually in state Operational.

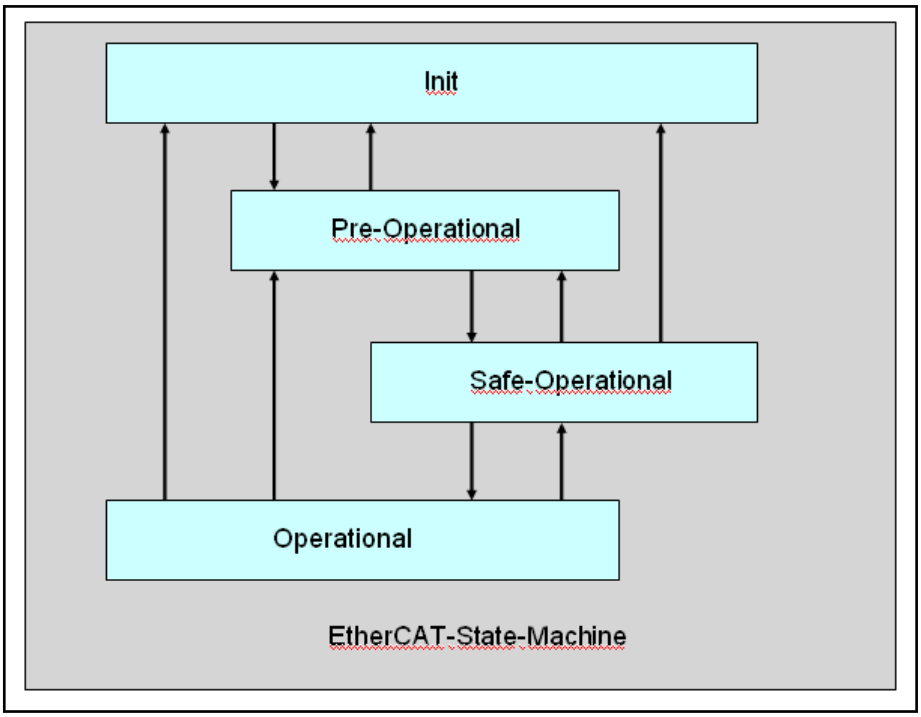



*Fig. 4-26: EtherCAT State Machine*

| State / change in state | Description |
|---|---|
| INIT | Neither mailbox nor process data communication possible. |
| INIT → PREOP | On transition from INIT to PREOP, the EtherCAT slave checks whether the mailbox has been correctly initiated. |
| PREOP | Mailbox communication possible, however, no process data communication. SDO transfer is activated, parameterization is possible. |
| PREOP → SAFEOP | On transition from PREOP to SAFEOP, the EtherCAT slave checks whether the correct Sync Manager channels for process data communication are available |
| SAFEOP | Already valid actual values are sent to the master while the command values are not applied |

| | |
|---|---|
| SAFEOP → OP | Before the EtherCAT master switches the EtherCAT slave from SAFEOP to OP, it must transmit already valid command values. |
| OP | Process data and mailbox communication is possible. |

*Tab. 4-47: State/Change in State Table*

## Diagnostic Messages and Monitoring Functions

The LED display for diagnosis is operated according to "EtherCAT Indicator Specification, V0.91". The drive is equipped with an LED (green/red) for simultaneous display of the "Run" and "Error" state. With master communication "CAN application layer over EtherCAT", the displays have the significance described below.

### LED Indicator Lamp "Run" (Green)

Behavior of the "Run" LED (green) according to EtherCAT Indicator Specification:

| Behavior of LED "Run" | Status | Significance |
|---|---|---|
| LED off | Init | Drive is in EtherCAT status "Init" |
| LED flashes permanently | Pre-Operational | Drive is in EtherCAT status "Pre-Operational" |
| LED flashes briefly (followed by break of approx. 1s, then flashes again) | Safe-Operational | Drive is in EtherCAT status "Safe-Operational" |
| LED permanently lit | Operational | Drive is in EtherCAT status "Operational" |

*Tab. 4-48: Behavior and Significance of the "Run" LED*

### LED Indicator Lamp "Error" (Red)

Behavior of the "Error" LED (red) according to EtherCAT Indicator Specification:

| Behavior of LED "Error" | Status | Significance |
|---|---|---|
| LED off | No error | CANopen communication works without errors |
| LED flashes permanently | Incorrect configuration | Drive detected many errors during transmission or reception of telegrams |
| LED flashes once (followed by break of approx. 1s, then flashes again) | Non-requested change of state | The drive has independently changed the EtherCAT state |
| LED flashes twice (followed by break of approx. 1s, then flashes again) | Application Watchdog Timeout | Sync Manager Watchdog Timeout |

*Tab. 4-49: Behavior and Significance of the "Error" LED*

### CAN Application Layer over EtherCAT Diagnostic Messages

Depending on the EtherCAT status, a diagnostic message is generated that can be read out via parameter "P-0-4073, Field bus: Diagnostic message.

#### Emergency Telegram

When an error occurs, an EMCY telegram is transmitted. The EMCY telegram transports 8-byte data.

Master Communication

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 0xFF00 | | 0x81 | P-0-0009 | | S-0-0390 (three least significant bytes) | | |

*Tab. 4-50: Emergency Telegram: Error Telegram*

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 0x0000 | | 0x00 | P-0-0009 | | S-0-0390 (three least significant bytes) | | |

*Tab. 4-51: Emergency Telegram: Error-Cleared Telegram*

**Diagnostic Error Messages**

Diagnostic error messages and their significances in conjunction with EtherCAT master communication:

- F4001 Sync telegram failure
  → In two successive cycles, no SYNC signal has been received.
- F4002 RTD telegram failure
  → In two successive cycles, no cyclic PDO telegram has been received.
- F4009 Bus failure
  → A failure of the bus communication has been detected.

With the corresponding setting in parameter "P-0-4088, Master communication: Drive configuration" (bits 1 and 2), this error message can be replaced by the warning "E4005 Command value input impossible via master communication".

## 4.6.3 ServoDrive Over EtherCAT® (SoE)

### Brief Description

#### General Information

Drive controllers with MultiEthernet interface (ET) can be operated as EtherCAT® master communication. Via these modules, it is possible to exchange real-time data with an EtherCAT® master.

The following communication channels are distinguished:

- Cyclic data channel (process data)
  - Data container for cyclic transmission of user data (process data) in real time
- Acyclic data channel
  - EtherCAT® mailbox method for acyclic transmission of service data (parameter channel)
  - Transmission of Ethernet telegrams via the EtherCAT® mailbox method [Ethernet over EtherCAT® (EoE)]

#### General Features

- Transmission rate 100 Mbit/s
- Data transmission via Ethernet cable (CAT5e copper)
- Topology: "Line"
- Support of "EtherNet over EtherCAT" (EoE)
- Support of "Servo Drive Profile over EtherCAT®" (based on the sercos II specification) (SoE)

- Support of "CAN application protocol over EtherCAT" (CoE)
- Access to 16-bit sercos parameters of the drive via "SoE" protocol ("Servo Drive Profile over EtherCAT®" protocol)
- Access to 16-bit sercos parameters of the drive via "CoE" protocol ("CAN over EtherCAT®" protocol)
- Cyclic data exchange of command values and actual values
- Free configuration of telegram contents
- Max. length of the configurable MDT/AT data 15 IDNs with max. 48 bytes; with bus cycle = position controller cycle, the max. length is halved to 24 bytes
- Minimum cycle time 1 ms. Only multiples of the position controller cycle can be set as cycle time.
- "Distributed clock synchronization" (exact adjustment of distributed clocks)
- Synchronization between the time the command value takes effect and the measurement starting time of the actual values for all drives on a ring
- Overall synchronization of all connected drives with the master
- Only released in connection with "Beckhoff TwinCAT"

### Physical Wiring

When setting up an EtherCAT® network with HydraulicDrive, make sure that the slots are used as follows:

| IAC2x | HMC |
|---|---|
| Slot X7E2 as output ("OUT") | Slot XF20 as output ("OUT") |
| Slot X7E1 as input ("IN") | Slot XF21 as input ("IN") |

*Tab. 4-52: Use of the Slots*

### Addressing

With EtherCAT, there are various options to address a slave. The most important options are listed below:

- **Auto Increment Address:** The Auto Increment Address is used (during initialization) to address each EtherCAT device according to its physical position in the communication ring. The first EtherCAT slave in the ring is assigned the address 0000hex, and for each further slave, the address is reduced by 1 (FFFFhex, FFFEhex, etc.). With TwinCAT, the Auto Increment Address of the slave is displayed as illustrated:

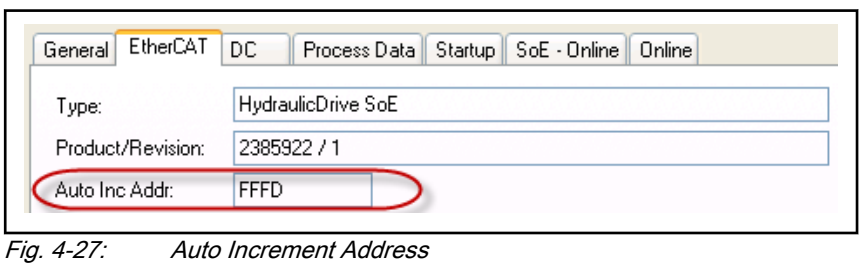



*Fig. 4-27: Auto Increment Address*

- **Configured Station/Node Address:** This address is assigned by the EtherCAT master during initialization. The slave itself cannot influence it and it is lost when the drive is switched off. The address is displayed under "Drive" in parameter P-0-4089.0.4 and in TwinCAT:

Master Communication

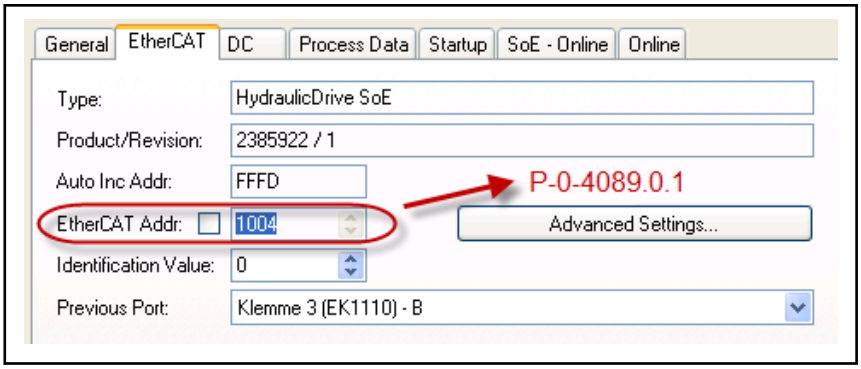



*Fig. 4-28: EtherCAT Address*

During initialization of the master, the address is written to the "Configured Station Address" register of the slave. **As the master uses the "Auto Increment Address" to write to this register, this address depends indirectly on the topology.**

- **Logical addressing:**"Logical addressing" is used for the process data. In this process, instead of an individual slave, a range with a virtual memory range of max. 4 GB is addressed. This range can be distributed over several slaves. The assignment of a physical memory address to a logical address is applied by the "Field Bus Memory Management Unit" (FMMU) of the slave. The slave FMMU is configured by the master (on transition PreOp→SafeOp).

  As the node address is used for initialization of the logical address, this address remains indirectly dependent on the topology.

  **This means that all these addressing types are actually dependent on the topology. The order in the project always has to correspond to the actual order on the bus.**

**Topology-Independent Addressing / Identification**

Newer TwinCAT versions offer an extension on addressing.

Under "Advanced Settings" of the slave, there are two new options:

General -> Identification:

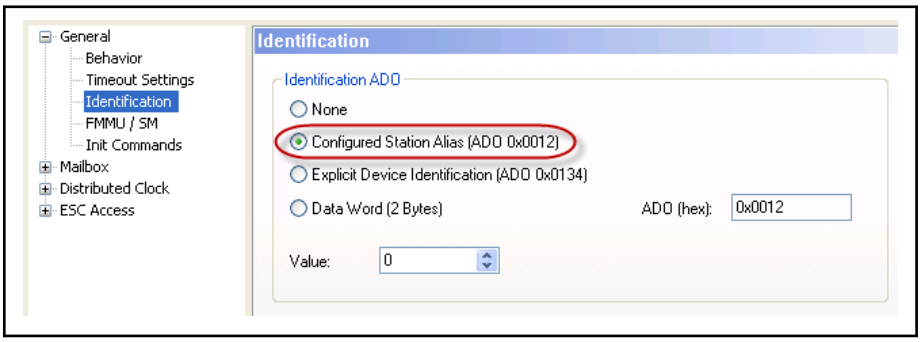



*Fig. 4-29: Configured Station Alias*

General→Behavior→"Check Identification":

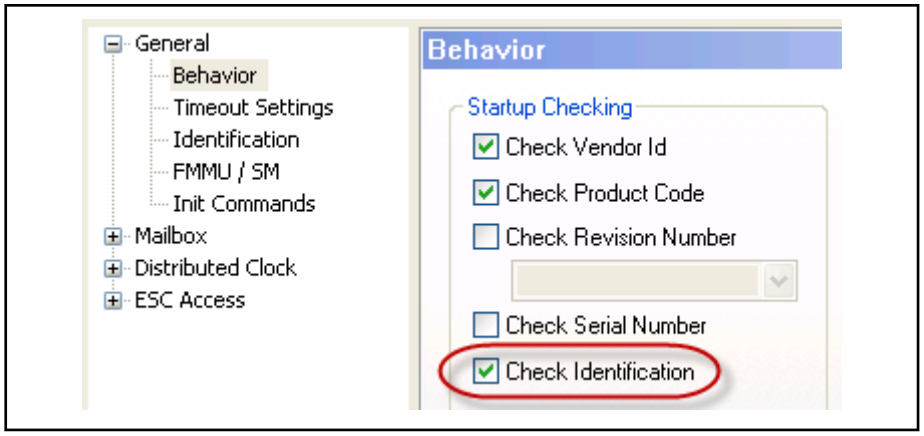



*Fig. 4-30: Check Identification*

If these options are selected, it is checked during bus initialization whether the value defined under "Identification Value":

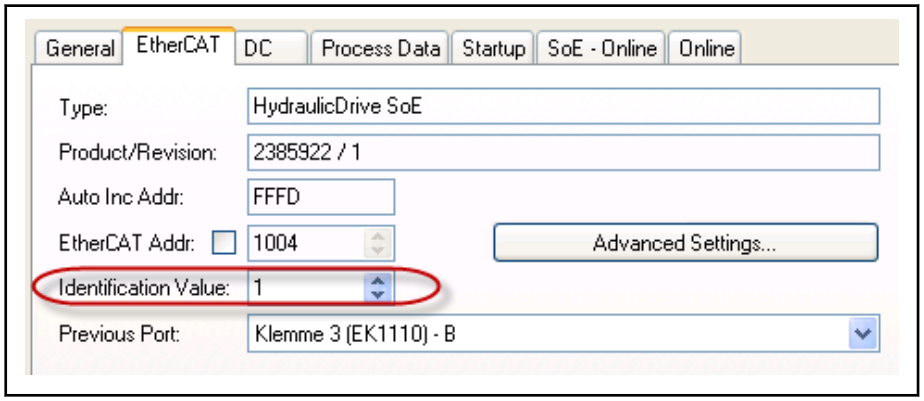



*Fig. 4-31: Identification Value*

corresponds to the value in the "Station Alias" register.

If the values do not correspond, the drive remains in phase "Init" and a "check Identification failed" message is displayed in the TwinCAT logger window:

Currently, the value from parameter P-0-4089.0.3 is applied in the "Station Alias" register during booting.

If the address in P-0-4089.0.3 is changed, this value is applied as Alias during next booting. If the parameter is changed without rebooting the drive, an inconsistency can occur between Alias and P-0-4089.0.3.

### Pertinent Parameters

- S-0-0001, NC cycle time (TNcyc)
- S-0-0002, sercos cycle time (TScyc)
- S-0-0007, Feedback acquisition starting time (T4)
- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0016, Configuration list of AT
- S-0-0024, Configuration list of MDT
- S-0-0029, MDT error counter
- S-0-0097, Mask class 2 diagnostics
- S-0-0098, Mask class 3 diagnostics

- S-0-0134, Master control word
- S-0-0135, Drive status word
- S-0-0185, Length of the configurable data record in the AT
- S-0-0186, Length of the configurable data record in the MDT
- S-0-0187, List of configurable data in the AT
- S-0-0188, List of configurable data in the MDT
- S-0-0301, Allocation of real-time control bit 1
- S-0-0303, Allocation of real-time control bit 2
- S-0-0305, Allocation of real-time status bit 1
- S-0-0307, Allocation of real-time status bit 2
- S-0-0413, Bit number allocation of real-time control bit 1
- S-0-0414, Bit number allocation of real-time control bit 2
- S-0-0415, Bit number allocation of real-time status bit 1
- S-0-0416, Bit number allocation of real-time status bit 2
- P-0-4089.0.3, Device Address
- P-0-4089.0.4, Active Device Address

### Pertinent Diagnostic Messages

- C0101, Invalid parameters (-> S-0-0021)
- C0104, Config. IDN for MDT not configurable
- C0105, Maximum length for MDT exceeded
- C0106, Config. IDNs for AT not configurable
- C0107, Maximum length for AT exceeded
- C0108, Time slot parameter > sercos cycle time
- C0112, TNcyc (S-0-0001) or TScyc (S-0-0002) error
- C0113, Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error
- C0114, T4 > TScyc (S-0-0002) - T4min (S-0-0005)
- C0201, Invalid parameters (->S-0-0423)
- C0299, Configuration changed. Restart
- E4005, No command value input via master communication
- F4002, RTD telegram failure
- F4009, Bus failure

## EtherCAT State Machine

### EtherCAT and sercos State Machine Comparison

The following figure illustrates the comparison of the EtherCAT and the sercos state machine.

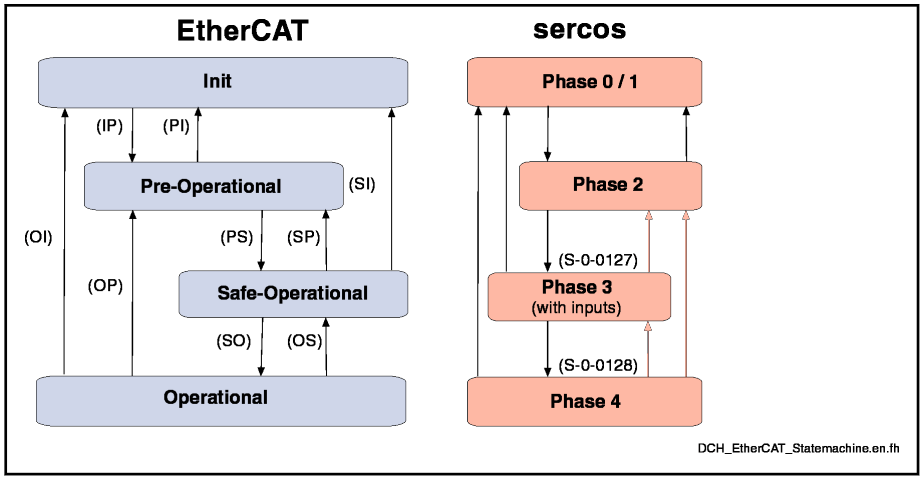



*Fig. 4-32: EtherCAT and sercos State Machine*

### EtherCAT Phases

**Init:**

- No communication on the application layer
- Master can access the slave FPGA registers via the bus

**Pre-Operational:**

- Mailbox communication: SoE (read/write parameters) and EoE
- No process data transmission takes place

**Safe-Operational:**

- Mailbox communication: SoE (read/write parameters) and EoE
- Process data transmission: However, only actual values are transmitted/ evaluated. No command value evaluation takes place
- Synchronization via "Distributed Clocks"

**Operational:**

- Mailbox communication: SoE (read/write parameters) and EoE
- Process data transmission: Command/actual values are cyclically transmitted/evaluated
- Synchronization via "Distributed Clocks"

## Cyclic and Acyclic Data Channel

### Cyclic Data/Process Data

The cyclic data consist of parameter "S-0-0134, Master control word" or "S-0-0135, Drive status word" and the parameters entered in "S-0-0016, Configuration list of AT" or "S-0-0024, Configuration list of MDT".

In S-0-0016/S-0-0024 max. 15 IDNs can be entered each. The length of the parameters entered in S-0-0016/S-0-0024 may be max. 48 bytes. In case of bus cycle time == position cycle time, this length is reduced to 24 bytes.

The cyclic data has to be configured via the master. Then, the master configures the cyclic telegram and writes the parameters S-0-0016 and S-0-0024 on phase run-up.

### Acyclic Data Channel

**Parameter Channel**

Access to 16-bit sercos parameters of the drive via "SoE" protocol ("Servo Drive Profile over EtherCAT®" protocol). EIDN access is only possible if a corresponding 16-bit Alias is available.

### Device Description File

The XML device description file communicates the device type (drive, IO, etc.) and the individual device properties to the master.

The device description of all HydraulicDrives with EtherCAT is provided by the manufacturer.

It has to be provided to the EtherCAT master (for TwinCAT, the archive is to be unpacked into the folder \TwinCAT\Io\EtherCAT\). If the device description is updated, older versions must be deleted.

## Synchronization and Timing

### Synchronization

Synchronization takes place via the "Distributed Clocks" of EtherCAT.

Via the "Distributed Clocks", a cyclic sync signal (in the bus cycle) is generated for each drive. As the "Distributed Clocks" ensure that the same system time is available on all slaves, this sync signal is simultaneously generated on all drives.

### Timing

The correct DC sync signal timing and respectively command/actual value processing in the drive is set by the master. For this purpose, the values are directly written to the respective slave registers. These registers are assigned default values by the XML device description. These need to be adapted only in exceptional cases.

The actual values are generated in the drive simultaneously with the sync1 signal. The command values are taken over in the drive already one position controller cycle before the actual values are generated. The telegram is to arrive shortly before the "logical sync". It is offset by one position cycle in comparison to the sync1 signal (by means of Sync0Shift). This way, the telegram arrives shortly before the command value is accepted by the drive.

If the bus clock cycle corresponds to the position controller cycle, the command value is accepted and the actual value generated in the same position controller cycle (with the max. data length (P-0-4080/P-0-4081) being halved with a bus clock cycle ≤ 1 ms).

**Command Value Acceptance**

During position control, fine interpolation of the position command values starts at the sync1 time (T4). One bus cycle later, the actual command value is reached (in case of linear fine interpolation).

With closed-loop velocity, force, pressure, and flow control, the command value is usually (depending on the system load) transmitted to the V controller half a position cycle after the MDT Run and directly applied.

**DC Settings in TwinCAT**

The default settings (from the XML device description) are as follows:

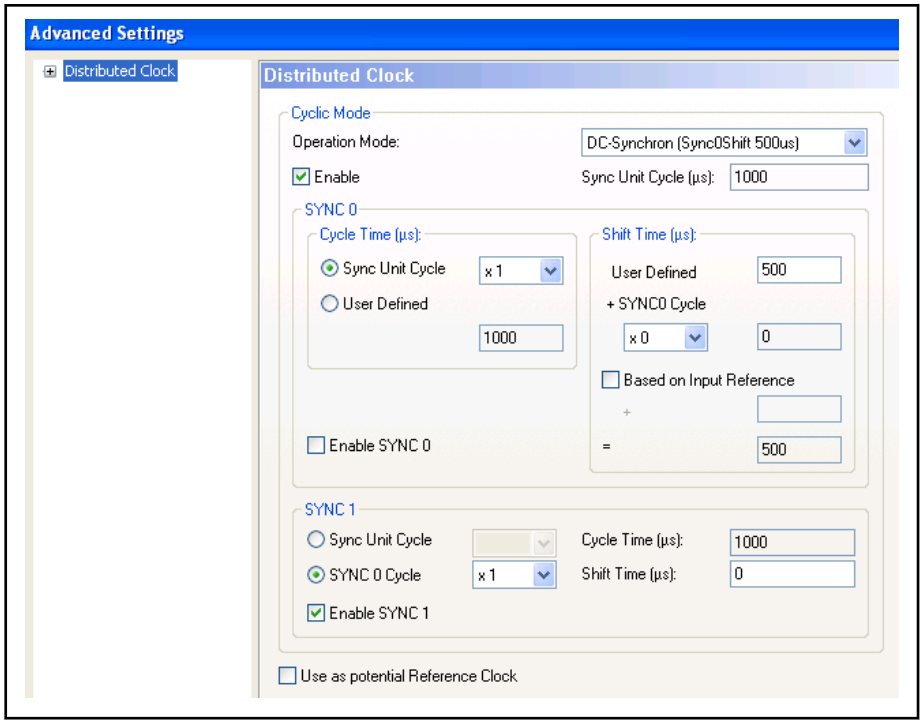



*Fig. 4-33: Advanced Settings - "Distributed Clock"*

Position controller cycles can have a length of 1000 µs or 2000 µs, depending on the device and the set performance level (refer to P-0-0556). For this reason, the respective shift times can be selected:

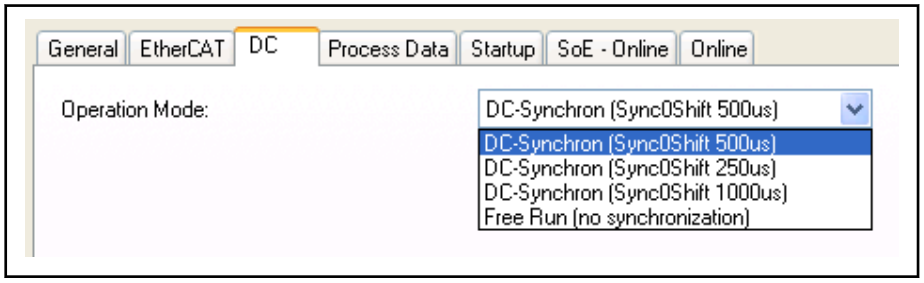



*Fig. 4-34: Shift Time Selection*

**Timing Monitoring**

In phase "Operational", if two command value telegrams are expected in succession but no telegram is received, the error F4002, "RTD telegram failure", is generated in AF (otherwise the warning E4005).

The value of the parameter S-0-0029, "MDT error counter", is set to 0 on transition to "Operational". If a command value telegram was expected (in phase Op) but none has been received, the value is incremented. The error counter stops at 65535 (0xFFFF).

**Process Data Watchdog**

The PD watchdog is reset when process data is received. The watchdog can either be triggered by AT or MDT data. If this data fails for a certain period, a flag is set. By querying these flags, cyclic data failures can be detected.

The response time can be set in the following menu under TwinCAT:

Master Communication

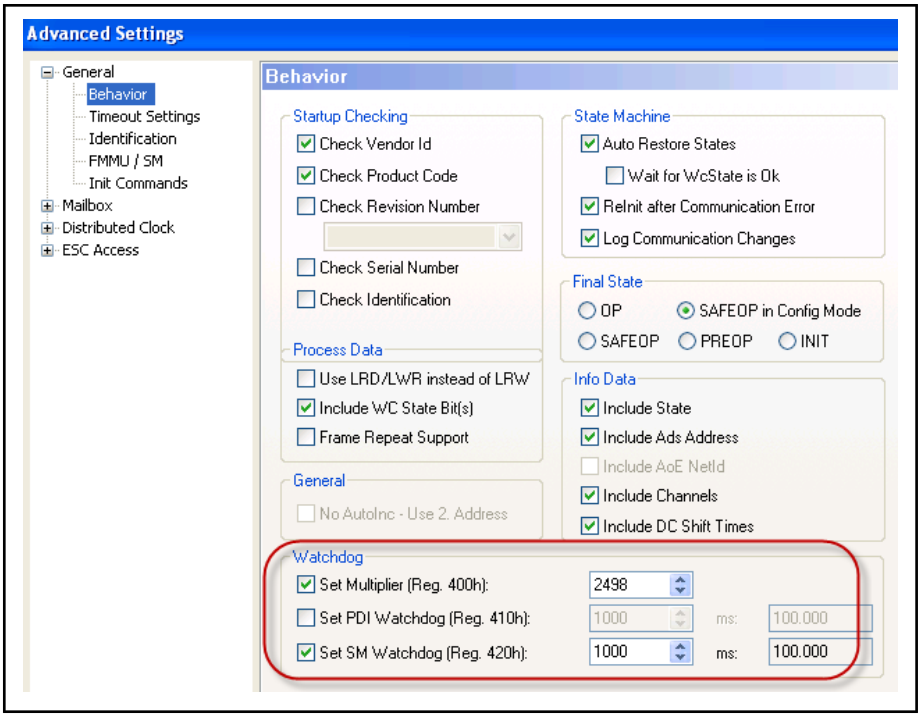



*Fig. 4-35: Setting the Watchdog Response Time under TwinCAT*

Setting the time to 0 deactivates the watchdog.

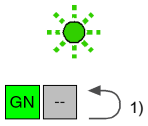
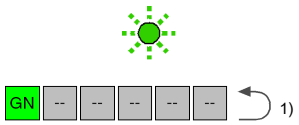
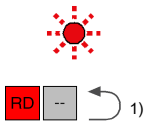
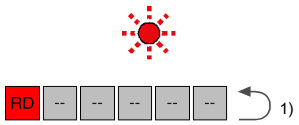
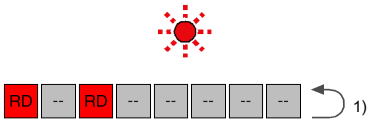
**Minimum Cycle Time**

The minimum cycle time of all HydraulicDrive derivates is 1 ms. Only multiples of the position controller cycle can be set as cycle time.

# Diagnostic and Status Messages, Monitoring Functions

## Communication Status LED

The two-colored LED (IAC) or NS (HMC) at the drive controller is used for EtherCAT® communication diagnosis.

| LED designation | | Significance | Color / flashing pattern | Description |
|---|---|---|---|---|
| HMC | IAC | | | |
| NS | 3 | Status INIT | Off | • Cyclic process data and acyclic data channel are not transmitted<br>• No error |
| | | Status PRE-OPERATIONAL |  Flashing green | Acyclic data channel is transmitted |
| | | Status SAFE-OPERATIONAL |  Green, single flash pattern | Acyclic data channel is transmitted |
| | | Status OPERATIONAL | Permanently lit green | Cyclic process data and acyclic data channel are transmitted |
| | | Configuration error |  Flashing red | • The drive controller has not been synchronized to the EtherCAT master<br>• Communication error of the drive controller |
| | | Synchronization error |  Red, single flash pattern | • The drive controller has not been synchronized to the EtherCAT master<br>• Communication error of the drive controller |
| | | Timeout - watchdog |  Red, double flash pattern | • Timeout during monitoring of the cyclic process data<br>• Watchdog of the EtherCAT master |

1) Flashing pattern: One square corresponds to a duration of 200 ms; the arrow marks the end of a cycle; abbreviations on the squares: GN = LED permanently lit green, RD = LED permanently lit red, -- = LED is off

Master Communication

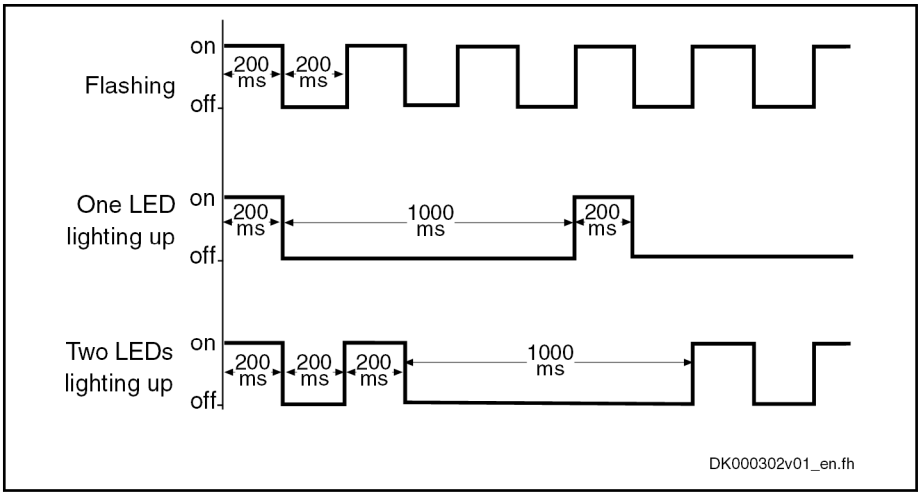



*Fig. 4-36: Pulse Interval Ratio*

## LEDs on the housing

The LEDs serve for diagnosis of the physical EtherCAT® connection.

| LED designation | | Significance | Color / flashing pattern | Description |
|---|---|---|---|---|
| HMC | IAC | | | |
| L | 1, 5 | None | - | With EtherCAT, these LEDs have no function |
| S | 2, 6 | Link | Off | No connection to the network |
| | | | Permanently lit green | Connection to network available, but no telegram exchange (EtherCAT bus inactive) |
| | | | Flickering green | Connection to network available with telegram exchange (EtherCAT bus active) |

The yellow LED is not used for EtherCAT®

## Diagnostic Messages Used

- A0004, Initialization
- A0005, Pre-Operational
- A0006, Safe-Operational
- C0101, Invalid parameters (-> S-0-0021)
- C0104, Config. IDN for MDT not configurable
- C0105, Maximum length for MDT exceeded
- C0106, Config. IDNs for AT not configurable
- C0107, Maximum length for AT exceeded
- C0108, Time slot parameter > sercos cycle time
- C0112, TNcyc (S-0-0001) or TScyc (S-0-0002) error
- C0113, Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error
- C0114, T4 > TScyc (S-0-0002) - T4min (S-0-0005)

- C0201, Invalid parameters (->S-0-0423)
- C0299, Configuration changed. Restart
- E4005, No command value input via master communication
- F4002, RTD telegram failure
- F4009, Bus failure

## 4.6.4 Ethernet over EtherCAT®

### Functional Description

#### General Information

With "EtherNET over EtherCAT" (EoE), standard Ethernet telegrams are channeled to the drive via the EtherCAT mailbox. This way, the drive can be accessed via the standard Ethernet and the following engineering possibilities arise:

- Engineering by means of EoE via optional Ethernet switch port
- Engineering by means of EoE via optional Ethernet switch port
- Engineering by means of EoE (or ADS interface via third party control unit)

#### Address Settings

**Slave Address**

The IP address of the slave is set in the master and then transmitted to the slave. For this reason, the parameters S-0-1020, S-0-1021 and S-0-1022 must not be changed (manually) directly in the drive. The (virtual) Mac address of the slave is not displayed in a parameter.

The command C6100 "Activate IP settings" (P-0-1534) is automatically started in the drive to apply the IP settings that were changed by the master.

In TwinCAT, the dialog for EoE IP settings is displayed as follows:

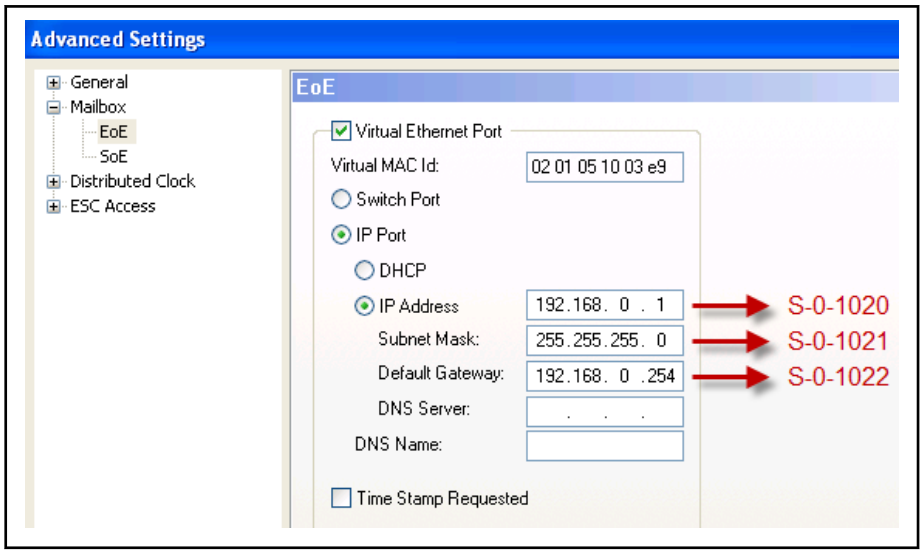



*Fig. 4-37: IP Settings in EoE*

**Master Address**

If an EoE slave is to be directly accessed from a master PC, the IP address (of the master) has to be in the same network segment as the address of the slave.

Master Communication

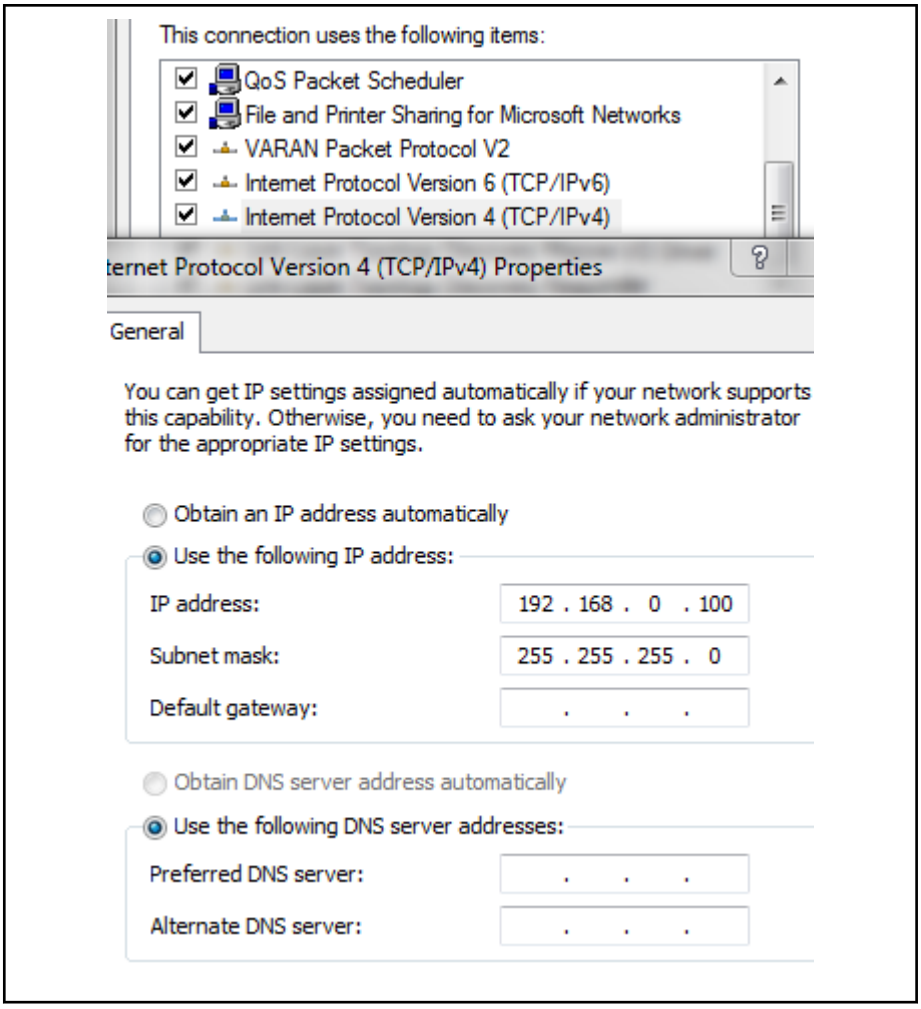



*Fig. 4-38: Master IP address*

If IndraWorks is directly installed on the EtherCAT master, the option "Connect to TCP/ IP stack" is to be activated for TwinCAT:

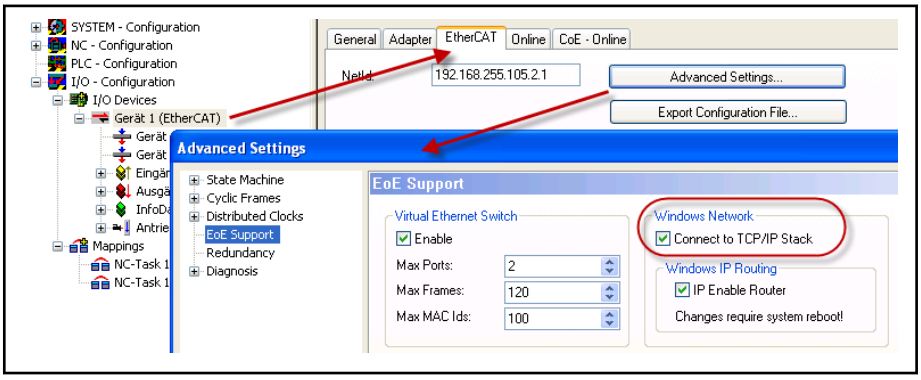



*Fig. 4-39: TwinCAT settings*

## Connection via EoE

In IndraWorks, the connection to the drive is established via Ethernet as usual. The connection is selected in the "Connection selection" dialog.

### Switch Port

The switch port is implemented in the EtherCAT string and offers an additional EtherNET connection. The Ethernet telegrams are fed into the EtherCAT string via the switch port.

This type of switch port is, for instance, available from Beckhoff under the designation EL6601.

To use the EL6601 switch port, it has to be connected to EtherCAT terminals as it does not feature an RJ45 EtherCAT port.

### Pertinent Parameters

- S-0-1020, Master comm. engineering over IP: IP address
- S-0-1021, Master comm. engineering over IP: Network mask
- S-0-1022, Master comm. engineering over IP: Gateway address
- P-0-1534, C6100 Command Activate IP settings
- P-0-1044, Master comm. engineering over IP: Status IP communication

### Protocol switching

Initial commissioning requires particular care. If an "incorrect" protocol is set for this type of devices, operation is impossible, maybe not even the communication with IndraWorks for setting the correct protocol. To establish a connection to the drive, the following protocol switching options are provided:

Switching can be performed directly in the IndraWorks connection selection dialog if no EtherCAT master has been connected to the device after start-up.

Master Communication

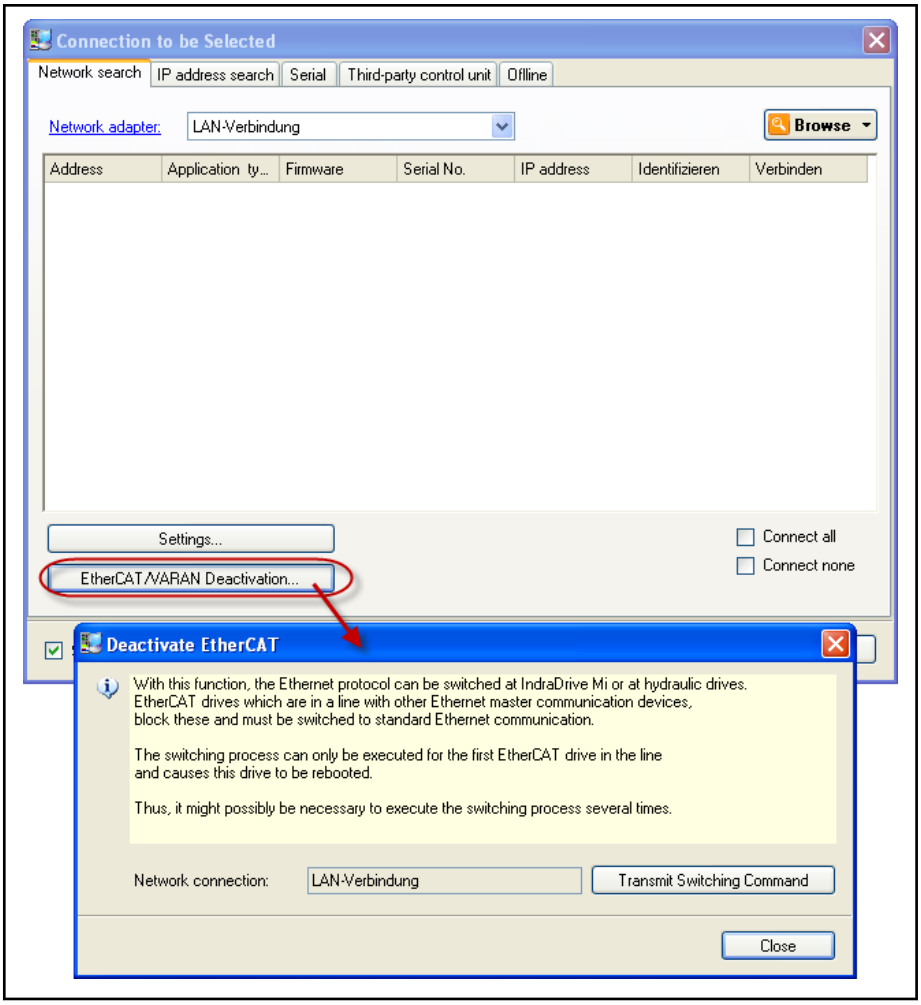
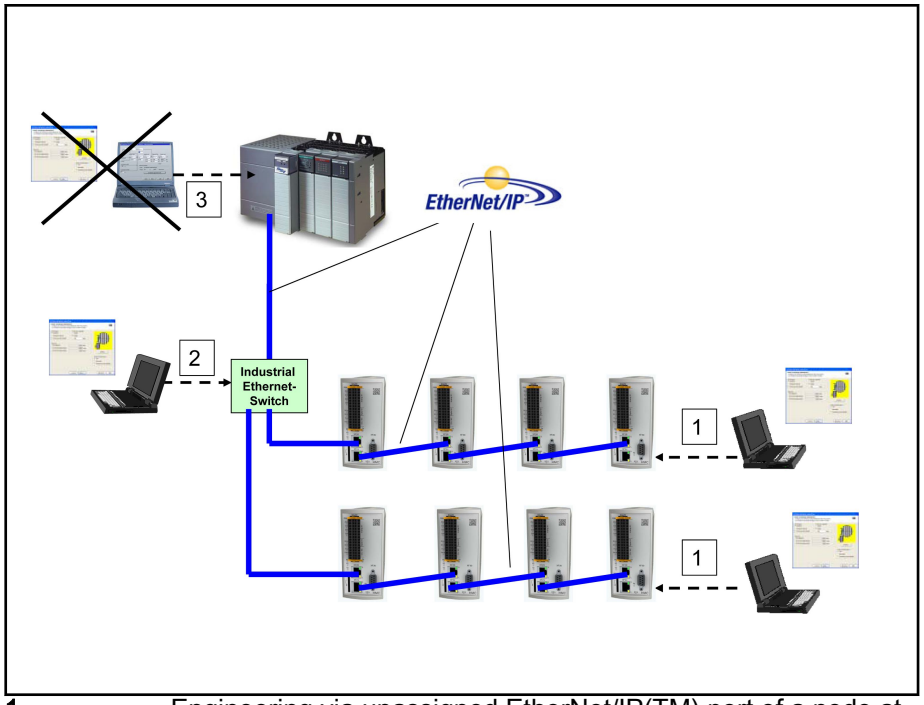



*Fig. 4-40: Connection Selection Dialog in IndraWorks*

# 4.7 EtherNET/IP(TM) Interface

## 4.7.1 Brief Description

**Topology**




**1** Engineering via unassigned EtherNet/IP(TM) port of a node at the bus
**2** Engineering via optional industrial Ethernet switch
**3** Engineering via third party control unit not possible

*Fig. 4-41: EhterNet/IP(TM) Topology*

HydraulicDrive controllers with MultiEthernet interface can be operated as EtherNet/IP™ master communication. Via this module, it is possible to exchange real-time data with an EtherNet/IP™ scanner.

Real-time data can be transmitted via this interface by means of an I/O connection (class 1 connection).

To achieve high system flexibility, all data is accessible via objects. With the Ethernet/IP™ interface, these objects can be addressed through class, instance and attribute. Some of these objects can be assigned to the I/O connection as real-time data and thus be cyclically transmitted. There is also the option of transmitting via "Explicit Message", but no objects defined in the real-time channel (P-0-4081) may be written by the master via "Explicit Message".

**Features**

- Transmission rate 100 Mbit/s (full duplex)
- Data transmission via Ethernet cable (CAT5e copper)
- Topologies: "Star", "Line" (by integrated cut-through switch)
- Autonegotiation is supported, provided the above-mentioned transmission rate is available
- The profile type is "Generic Device", specified in ODVA 2.0 (**O**pen **D**eviceNet **V**endors **A**ssociation)
- EtherNet/IP™ Level 2 Server
- Cyclic exchange via "EtherNet/IP™ I/O Messaging" (Class 1)
- Acyclic data transmission via "Ethernet/IP™ Unconnected Explicit Messaging" and "Explicit Messaging" (Class 3)
- The smallest supported cycle time (API → Actual Packet Interval) is 2 ms

Master Communication

- Configurable cyclic data up to 15 parameters (incl. field bus control word and field bus status word) in both data directions (max. 48 bytes or 24 words)

- It is recommended not to couple the Industrial Ethernet network to a corporate network (office communication). (Alternatively, a level 3 router can be used to connect the industrial Ethernet network to a corporate network).
- It is recommended to only use cut-through switches for industrial Ethernet communication.
- Particularly for cables leading out of the control cabinet and cables that are longer than 10 m, it is recommended that a star topology with cable type AWG22 or shielded cables be used.

- Supported field bus profiles:
  - 0x0000: "No profile"
  - 0xFF82: I/O mode "positioning" with configurable real-time data
  - 0xFF92: I/O mode "preset velocity" with configurable real-time data
  - 0xFFFD: Freely configurable mode "operation mode neutral"
  - 0xFFFE: Freely configurable mode

**Axis Addressing**

With EtherNet/IP, the master communication address is an IP address. It can be set in "P-0-4089.0.13, Master communication: IP address"

The device address set in "P-0-4089.0.3Device Address" is applied in the parameter "P-0-4089.0.4Active Device Address" after the device is restarted. This address does not influence the EtherNet/IP communication!

**Pertinent Parameters**

- P-0-4073, Field bus: Diagnostic message
- P-0-4074, Field bus: Data format
- P-0-4075, Field bus: Watchdog
- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: Baud rate
- P-0-4088, Master communication: Drive configuration
- P-0-4089.0.2, Master communication: Device name
- P-0-4089.0.10, Master communication: MAC address device
- P-0-4089.0.13, Master communication: IP address
- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

**Profile type parameters**

Apart from mere communication parameters, parameters related to the profile types are used.

See "Profile Types (with Field Bus Interfaces)"

**Parameters for extended communication**

Additional parameters for extended communication are used.

See the following sections:

- "Configurable signal control word"

- "Configurable signal status word"
- "Multiplex channel"

**Pertinent Diagnostic Messages**

- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable
- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- C0299 Configuration changed. Restart
- E4005 No command value input via master communication
- E4006 Communication module overload
- E4011 Communication watchdog: Overload of cyclic communication
- F4009 Bus failure
- F4011 Communication watchdog: Overload of cyclic communication

## 4.7.2 Configuration of the EtherNet/IP Slave

### EDS File

For each EtherNet/IP™ device, it is necessary to have an EDS file (*.EDS) which contains the data required for operating the device on the field bus. This file is required for every node when configuring the bus masters supporting the EDS file.

The EDS file for HydraulicDrive is an ASCII file with the name "HydraulicDrive_EIP_HDx18.EDS".

### Setting the IP Address of the Slave

These parameters are set using the commissioning tool "IndraWorks".

The IP address of the EtherNet/IP™ adapter is stored in parameter "P-0-4089.0.13, Master communication: IP address", the subnet mask in parameter "P-0-4089.0.14, Master communication: Network mask" and the gateway address in parameter "P-0-4089.0.15, Master communication: Gateway address".

☞ The device address set in "P-0-4089.0.3Device Address" is applied in the parameter "P-0-4089.0.4Active Device Address" after the device is restarted. This address does not influence the EtherNet/IP communication!

☞ This IP address is only relevant for the communication with the scanner! For engineering (e.g. IndraWorks), the engineering address (S-0-1020, Master comm. engineering over IP: IP address) must be used.

### Cyclic Data Configuration

The parameters for configuring the cyclic data (P-0-4080 and P-0-4081) can contain a maximum of 15 elements each. The maximum length is limited to 24 words.

Setting options via "P-0-4076, Field bus: Process data - updating clock", min. 2 ms, max. 65 ms (multiple of the position controller cycle).

Parameter "P-0-4076, Field bus: Process data - updating clock" is used to define the update cycle for applying the data from the MultiEthernet interface onto the drive and vice versa.

These parameters are set using the commissioning tool "IndraWorks".

## 4.7.3 Specification of the EtherNet/IP(TM) Interface

The drive works with the EtherNet/IP™ interface switched on as Level 2 device. This means that the drive provides one server each for implicit messages (Class 1) and explicit messages (Class 3). Explicit messages are limited to standard objects.

The implemented EtherNet/IP™ object directory contains the objects specified for a "Generic Device":

- Identity Object (0x01)
- Message Router Object (0x02)
- Ethernet Link Object (0xF6)
- TCP/IP Object (0xF5)
- Port Object (0xF4)
- Connection Manager Object (0x06)
- Assembly Object (0x04)

## 4.7.4 Cyclic Communication via the Process Data Channel (Class 1)

### EtherNet/IP(TM) Connection Types

With a drive as EtherNet/IP™, parameters can be cyclically transmitted via an I/O container. This can be done via an "Exclusive Owner Connection" (Transport-Class-1) or a "Listen Only Connection" (Transport-Class-1).

With the "Exclusive Owner Connection", the EtherNet/IP™ input image is transmitted to the drive by means of "point-to-point" connection. The output image can be transmitted by means of "point-to-point" or "multicast" connection.

With an already existing "Multicast-Exclusive Owner Connection", a second master can read the EtherNet/IP™ output image of the drive with a "Listen Only Connection". In this case, a "Heartbeat Connection Point" is used as Consuming Connection Point and the same Connection Point is used as Producing Connection Point that is also used with the "Exclusive Owner Connection".

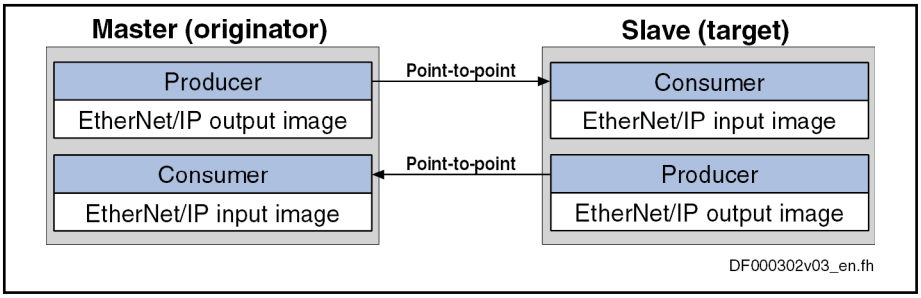



*Fig. 4-42: EtherNet/IP(TM) Connection Type "Point-to-Point"*

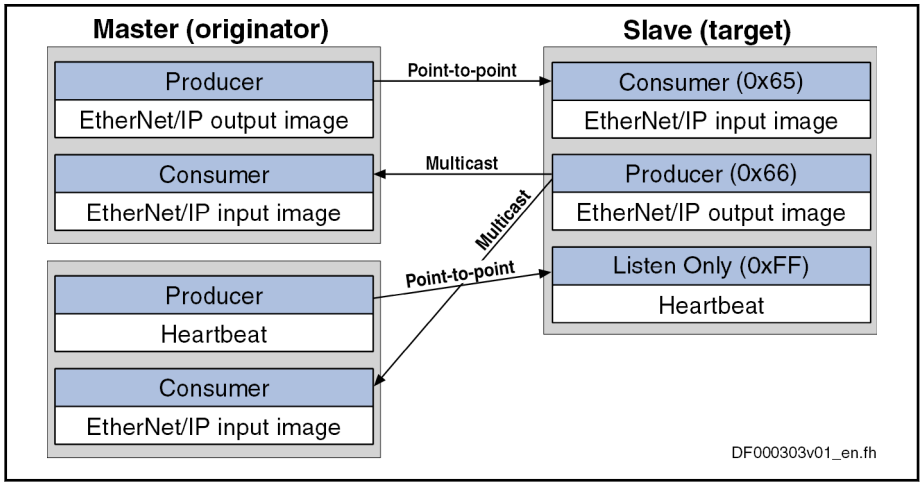



*Fig. 4-43: EtherNet/IP(TM) Connection Type "Multicast"*

For the cyclic I/O data channel ("Implicit Message"), the drive provides a Consumer and a Producer, i.e. it consumes the command values from the master and produces the actual values for the master.

In this case, communication runs using an UDP protocol whereas the direction from master to slave is transmitted with unicast telegrams and the opposite direction is transmitted with multicast telegrams.

## Characteristic of the Cyclic Data Transmission

**Features**

- The smallest cycle time that is supported by HydraulicDrive (API → Actual Packet Interval) is 2 ms.
- The "Idle/Run Header" of the EtherNet/IP™ interface is supported (32 bits). The header is not visible in the cyclic I/O image of the drive. The reaction of the drive to the Idle/Run Header is defined via the settings of the setting-up mode (easy startup mode).
- The consumer instance of the drive monitors the cyclic transmission of the master output image via a so-called "TimeOut" that is determined by the master when the connection is established.

The monitoring time is calculated according to the formula below:

$$t = TM \times API$$

$$TM = 2^{(TMV + 2)}$$

**t** Monitoring time (in ms)
**TM** TimeOut Multiplier
**API** Actual Packet Interval
**TMV** TimeOut Multiplier Value

*Fig. 4-44: Calculating the Monitoring Time in Two Steps*

**Examples**

| TMV | TM | API (in ms) | t (in ms) |
|---|---|---|---|
| 0 | 4 | 2 | 8 |
| 0 | 4 | 5 | 20 |
| 1 | 8 | 2 | 16 |
| 1 | 8 | 5 | 40 |

Master Communication

| TMV | TM | API (in ms) | t (in ms) |
|---|---|---|---|
| 2 | 16 | 2 | 32 |
| 3 | 32 | 2 | 64 |
| 4 | 64 | 5 | 320 |
| 2 | 16 | 10 | 160 |

*Tab. 4-53: Exemplary Values of the Monitoring Time*

In most of the configuration user interfaces, it is possible to directly enter the "TimeOut Multiplier". The user then does not have to take the first formula into account.

### Configuring the Cyclic Process Data

The cyclic channel is configured by parameterization of "P-0-4080, Field bus: Config. list of cyclic actual value data ch." and "P-0-4081, Field bus: Config. list of cyclic command value data ch.".

On the EtherNet/IP™ communication level, a static Output Assembly Instance (Class 4, instance 101) and a static Input Assembly Instance (Class 4, instance 102) are created in the cyclic channel. In this case, the data direction is written from the master's point of view. If the parameter setting of P-0-4080 and P-0-4081 is changed, new assembly instances are created during the transition from parameter mode (PM) to operating mode (OM). This results in a short interruption of the communication.

## 4.7.5 Acyclic Parameter Access via "Explicit Message" (Class 3 / UCM)

### General Information on Parameter Setting

To enable parameter setting via EtherNet/IP™, all IDN parameters can be reached via a manufacturer-specific class object with the corresponding instances for each IDN parameter. The parameters can be addressed either via an "Unconnected Explicit Message" (UCM) or via a "Connected Explicit Message" (Class 3).

Acyclic parameter access via "Explicit Message" (Class 3/UCM) only enables access to IDN parameters, e.g. "P-0-4006Positioning block target position". EIDN, also refer to "Note on parameter access"

The field bus control word cannot be operated via "Explicit Message". To enable axis control, the higher-level control of the cyclic data channel must be used according to the "Class 1 Connection" specification or programmed according to the MLD logic with permanent control. If the control is not equipped with a "Class 1 Connection", no axis control can be carried out without MLD.

### Addressing

For EtherNet/IP communication, the objects are addressed according to the following scheme:

Class → instance → attribute

**Class** All subdevice parameters (e.g. drive) are mapped to the manufacturer-specific classes 100 (0x64) + subdevice index, i.e. subdevice 0 --> class 100, subdevice 1 --> class 101,…, subdevice 98 --> class 198.

**Instance** The instance number is identical to the IDN of the drive parameter.

| Bit | Significance |
|---|---|
| **15** | **0**: Standard data (standardized)<br>**1**: Product data (specified by the manufacturer) |
| **14 … 12** | Parameter sets from 0 to 7 |
| **11 … 0** | Data block number from 0 to 4095 |

*Tab. 4-54: Structure of the IDN*

The instance number can be calculated with the following formula:

$$Inst = (32768 \times type) + (4096 \times set) + block$$

**Inst** Instance number
**type** Parameter type (0 for S-parameters and 1 for P-parameters)
**set** Set number
**block** Data block number

*Fig. 4-45: Calculating the Instance Number*

**Attribute**

The format of the parameter depends on the attribute number.

The operating datum can have four different formats:

- Data length 2 bytes → **W**
- Data length 4 bytes → **L**
- ASCII text with max. length of 64 bytes → **T**

There are three types of parameters:

- Single parameters
- Command parameters
- List parameters

Irrespective of its type, each parameter has these attributes (read-only):

| No. | Name | Function | Format |
|---|---|---|---|
| 0 | Number of elements | Number of supported elements | W |
| 1 | IDN | sercos IDN | T [8] |
| 2 | Name | Parameter name | T [60] |
| 3 | Attribute | Display mode of the parameter | L |
| 4 | Unit | Parameter unit | T [12] |
| 5 | Min. input value | Min. possible value of the datum | W/L/T |
| 6 | Max. input value | Max. possible value of the data | W/L/T |

*Tab. 4-55: Basic Attributes of a Drive Parameter*

Depending on its type, each parameter has other attributes of different significance:

Master Communication

| No. | Name/function | Format |
|---|---|---|
| 7 | Operating datum | W/L/T |
| 8 | Max. number of list elements / length of text | L |
| 9 | Actual number of list elements / length of text | L |
| 10 | Pointer to the element which is processed on the next access to element 11 - 20 | L |
| 11 | Action for 1 list element (list pointer is applied) | W/L/T |
| 12 | Action for 2 list elements (list pointer is applied) | W/L/T |
| 13 | Action for 3 list elements (list pointer is applied) | W/L/T |
| 14 | Action for 4 list elements (list pointer is applied) | W/L/T |
| 15 | Action for 5 list elements (list pointer is applied) | W/L/T |
| 16 | Action for 6 list elements (list pointer is applied) | W/L/T |
| 17 | Action for 7 list elements (list pointer is applied) | W/L/T |
| 18 | Action for 8 list elements (list pointer is applied) | W/L/T |
| 19 | Action for 9 list elements (list pointer is applied) | W/L/T |
| 20 | Action for 10 list elements (list pointer is applied) | W/L/T |

*Tab. 4-56: Type-Dependent Attributes of a Drive Parameter*

## Accessing Single Parameters

The value can be accessed by writing and reading the operating datum of the parameter. For single parameters, the value of number of attributes is "7".

## Access to Texts

The value can be accessed by writing and reading the operating datum of the parameter. The maximum length of the text and the actual length of the text can be read with attributes 8 and 9. Additionally, a text can be treated as a 1-byte list. On access to parameter texts, the value of number of attributes is "20".

## Accessing Command Parameters

A command can be started by writing "3" to the operating datum, the command status is obtained by read-accessing the operating datum. On access to command parameters, the value of number of attributes is "7".

## Accessing List Parameters

The maximum list size can be determined by reading the maximum amount of data of the parameter (attribute 8). The real size is stored in the actual quantity of data of the parameter (attribute 9) and can be modified unless the list is write-protected. All data refer to the parameter format. Data to be processed in the list are defined by the pointer to the data (attribute 10). If the data value is zero, the pointer is automatically modified in the following situations:

- Zero is loaded when changing from another parameter to this parameter.
- After each operating data access, the pointer is raised by the number of elements which were read.

By accessing attribute 11, one element is processed, attribute 12, two elements are processed, etc. up to attribute 20 for processing 10 elements. The pointer is increased by the processed elements. On access to list parameters, the value of number of attributes is "20".



For successful access to the operating datum, the pointer has to be smaller than the actual length.

**Example** Parameter (P-0-0013) has 18 list elements and is to be read:

- Calculate instance with formula

  Input:

  – P-parameter → type = 1
  – Parameter set 0 → set = 0
  – Data block number 13 → block = 13

  → Instance = 32781
- Read: class 100, instance 32781, attribute 9 = 18 (actual length)
- Write: class 100, instance 32781, attribute 10 = 0 (list pointer)
- Read: class 100, instance 32781, attribute 11 = element 0

  → List pointer now automatically pointing to 1
- Read: class 100, instance 32781, attribute 20 = elements 1 to 10

  → List pointer now automatically pointing to 11
- Read: class 100, instance 32781, attribute 12 = element 11, 12

  → List pointer now automatically pointing to 13
- Read: class 100, instance 32781, attribute 15 = elements 13 to 17

  → List pointer now automatically pointing to 18
- Read: class 100, instance 32781, attribute 10 = 18 (pointer)

Another access to the operating datum would not supply any data without loading the list pointer again (list pointer = actual length). The number of attributes supplies the value "20".

## Storing List Elements

List elements are not directly stored in permanent form. Storing takes place by one of the following actions:

- Writing the last element of the list
- Read-accessing the list
- Accessing another parameter
- Termination of connection

When the control voltage fails, all changes which were not stored are deleted!

## Error Codes while Accessing Parameters

When a vendor-specific error occurs during parameter access, the additional error code points out the cause of the error.

The following table lists the most important error codes.

Master Communication

| Error No. (hex) | Significance |
|---|---|
| 0x03 | Invalid parameter value<br>• Value is smaller than minimum input value<br>• Value is greater than maximum input value<br>• Incorrect value<br>• Invalid indirect addressing<br>• Procedure command not executable (invalid or false parameters) |
| 0x0E | Parameter cannot be changed |
| 0x0F | Parameter is password-protected |
| 0x10 | Parameter is write-protected<br>• Parameter is currently write-protected<br>• Parameter write-protected since it is cyclically configured in MDT<br>• Parameter is currently write protected due to other settings (parameter, operation mode, drive enable...)<br>• Procedure command currently not executable (e.g., procedure command cannot be activated in this phase) |
| 0x13 | Parameter transmitted too short |
| 0x15 | Parameter transmitted too long |
| 0x1F | • Procedure command already active<br>• Procedure command cannot be interrupted |

*Tab. 4-57: Error Codes and Their Significances While Accessing Parameters*

## 4.7.6 Diagnostic and Status Messages

### Diagnostic Messages via LEDs

The diagnostic displays via LED (module status, network status) required according to EtherNet/IP™ specification have been realized by the corresponding display messages.

**Module Status** Display of the "Module status LED" is described in chapter "Diagnostic LED".

**Network Status** The EtherNet/IP™ network status is displayed via the respective "Network status LED".

| LED | | Significance | Color | Description |
|---|---|---|---|---|
| IAC | HMC | | | |
| 2, 6 | S-XF20, S-XF21 | Status | Permanently lit yellow | Data transmission running |
| 1, 5 | L-XF20, L-XF21 | Link | Permanently lit green | Connection to network available |

| LED | | Significance | Color | Description |
|---|---|---|---|---|
| IAC | HMC | | | |
| 3 | NS | Not active | Off | Interface has been switched off (24 V supply) or has no IP address |
| | | Not connected | Flashing green | Interface has an IP address, but no connection |
| | | Connected | Permanently lit green | Connection to network available, data transmission running |
| | | Timeout | Flashing red | Existing connection was aborted |
| | | Invalid IP address | Permanently lit red | Assigned IP address is already used by another device |
| | | Self test | Flashing red-green | After switching on, interface carries out a self test |

*Tab. 4-58: EtherNet/IP™ Display Elements*

### Diagnostic Messages

Diagnostic messages and their significance in conjunction with the EtherNet/IP™ master communication:

- E4005 No command value input via master communication

  → The master is in the stop mode and the EtherNet/IP™ stack thereby is in the status "IDLE" or the master has specifically aborted the I/O connection and the EtherNet/IP™ stack thereby is in the status "CLOSED".

- F4009 Bus failure

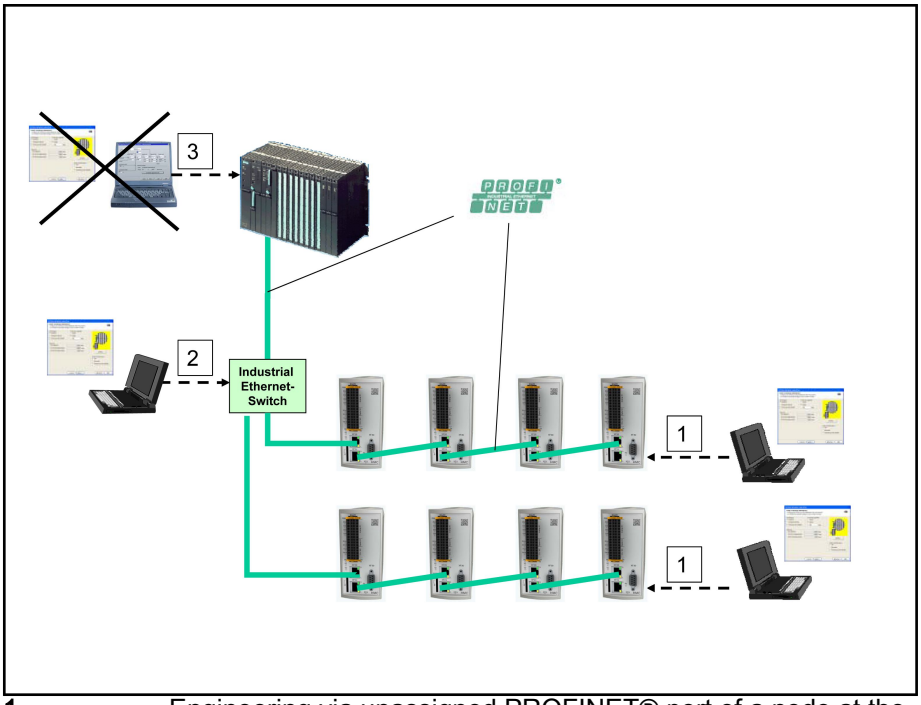
  → The master has not received any telegram within the watchdog time. The watchdog time is calculated according to the described formula for the "Timeout" time.

# 4.8 PROFINET®

## 4.8.1 Brief Description

**Topology**

Master Communication




**1** Engineering via unassigned PROFINET® port of a node at the bus
**2** Engineering via optional Industrial Ethernet switch
**3** Engineering via third-party control unit by means of TCI not possible

*Fig. 4-46: Engineering Options with PROFINET®*

HydraulicDrives with MultiEthernet interface (ET) can be operated as PROFINET® master communication. Via this module, it is possible to exchange real-time data with a PROFINET® controller.

The field bus provides data containers in which user data can be cyclically transmitted. This section is referred to as **cyclic data channel** (PROFINET®).

The cyclic data channel is divided as follows:

- One (optional) **device-specific parameter channel** for reading and writing of all parameters via PROFINET®.

---

☞ The **device-specific parameter channel** does not provide any "real-time properties"!

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- One **axis-specific process data channel** (real-time channel) which contains firmly declared information that can be directly interpreted by the receiver.

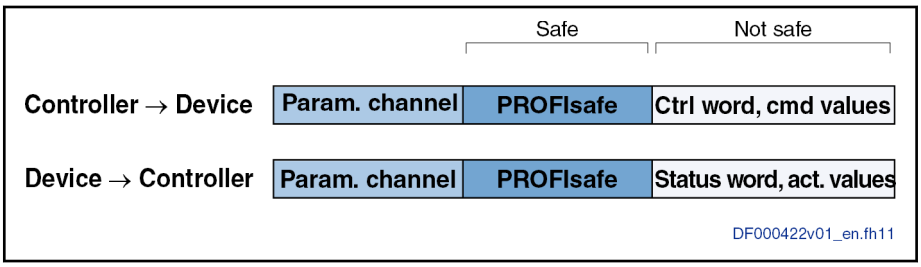


*Fig. 4-47: Overview of Cyclic Data Channel*

☞ To simplify field bus communication, PLC function blocks for different programmable logic controllers (PLCs) are provided. The function blocks support the basic functionalities of axis-specific process data channels and device-specific parameter channels. The principles applied can be easily used for other PROFINET® controllers.

**Features**

The PROFINET® device interface with MultiEthernet interface offers the following features:

- Ethernet according to IEEE 802.3 and prioritization according to IEEE 802.1Q
- Transmission rate 100 Mbit/s
- Data transmission via Ethernet cable (CAT5e copper)
- Topologies: "Star", "Line" (by integrated cut-through switch)
- Assignment of IP addresses via DCP protocol (**D**iscovery and **B**asic **C**onfiguration)
- The smallest supported cycle time (IO cycle update time) is 2 ms.

☞ The IO cycle update time is defined by the controller and is the time cycle in which the process data from the PROFINET network is written to the MultiEthernet interface and vice versa.

- Configurable cyclic data up to 15 parameters (incl. field bus control word and field bus status word) in both data directions (max. 48 bytes or 24 words)
- Setting options via "P-0-4076, Field bus: Process data - updating clock", min. 2 ms, max. 65 ms (multiple of the position controller cycle).

☞ Parameter "P-0-4076, Field bus: Process data - updating clock", defines the update cycle for applying the data from the MultiEthernet interface onto the drive and vice versa.

☞ During planning, installation and commissioning of a system, reference is made to the following guidelines (PROFINET trilogy):

- Panning guideline
- Installation guideline
- Commissioning guideline

The guidelines can be obtained from the PNO secretariat (PROFIBUS Nutzerorganisation e. V.).

☞ It is recommended

- not to couple the Industrial Ethernet network to a corporate network (office communication). (Alternatively, a level 3 router can be used to connect the industrial Ethernet network to a corporate network).
- to only use cut-through switches for Industrial Ethernet communication.
- to use a star topology with cable type AWG22 or shielded cables particularly for cables leading out of the control cabinet and cables that are longer than 10 m.

- Additional optional parameter channel in the cyclic channel with up to 16 bytes (8 words)
- LED for PROFINET® status diagnosis (network status)
- LEDs to display the link/activity status
- CCA and RT_CLASS1 support
- For reasons of compatibility with drive controllers with PROFIBUS® master communication module, no diagnostic messages and alarms are used
- PROFINET® IRT is not supported
- Operation in PROFINET® IRT networks is not possible
- Supported field bus profiles:
  - 0x0000: "No profile" selected
  - 0xFF82: I/O mode "positioning" with configurable real-time data
  - 0xFF92: I/O mode "preset velocity" with configurable real-time data
  - 0xFFFD: Freely configurable mode "operation mode neutral"
  - 0xFFFE: Freely configurable mode

**Axis Addressing**

In PROFINET, nodes are addressed by means of the device name. It is stored and can be changed in P-0-4089.0.2.

☞ The device address set in "P-0-4089.0.3Device Address", is applied in the parameter "P-0-4089.0.4Active Device Address", after the device is restarted. This address does not influence the PROFINET communication!

**Pertinent Parameters**

Communication parameters

Specific parameters for communication via PROFINET®:

- P-0-4089.0.11, Master communication: MAC address Port1
- P-0-4089.0.12, Master communication: MAC address Port2

Parameters for general communication via field bus interfaces:

- P-0-4073, Field bus: Diagnostic message
- P-0-4074, Field bus: Data format
- P-0-4075, Field bus: Watchdog
- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: Baud rate
- P-0-4083, Parameter channel: Length
- P-0-4083.0.1, Parameter channel: Configuration

- P-0-4088, Master communication: Drive configuration
- P-0-4089.0.2, Master communication: Device name
- P-0-4089.0.10, Master communication: MAC address device
- P-0-4089.0.13, Master communication: IP address
- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

**Profile type parameters**

Apart from mere communication parameters, parameters related to the profile types are used.

See "Profile Types (with Field Bus Interfaces)"

See "Engineering/Diagnostic Interfaces"

**Parameters for extended communication**

Additional parameters are used for extended communication possibilities.

See the following sections:

- "Configurable signal control word"
- "Configurable signal status word"
- "Multiplex channel"

**Pertinent Diagnostic Messages**

- C0229 Field bus: IDN for cycl. command val. not configurable
- C0230 Field bus: Max. length for cycl. command val. exceeded
- C0231 Field bus: IDN for cycl. actual val. not configurable
- C0232 Field bus: Length for cycl. actual values exceeded
- C0233 Field bus: Tcyc (P-0-4076) incorrect
- C0234 Field bus: P-0-4077 missing for cycl. command values
- C0299 Configuration changed. Restart
- E4005 No command value input via master communication
- E4006 Communication module overload
- E4011 Communication watchdog: Overload of cyclic communication
- F4009 Bus failure
- F4011 Communication watchdog: Overload of cyclic communication
- F4012 Incorrect I/O length

## 4.8.2 Configuring the PROFINET® Slave

### General Station Description for HydraulicDrive

As any other PROFINET® device, also HydraulicDrive controllers must be configured in the field bus controller. For this purpose, the respective general station description (GSML) "**GSDML-V2.25-Bosch Rexroth AG-011F-HydraulicDrive_xxVxx-xxxxxxxx.xml**" is required and must be implemented in the project ("YYYYMMDD" stands for the creation date of the GSDML file). When configuring the bus controller, this GSDML file is required for each node.



The general station description for HydraulicDrive supports all hardware variants and enabling of functional packages.

HydraulicDrives assign their data to four slots (in the case of single-axis devices) or seven slots (for double-axis devices), which must be configured. A slot is an interface for one module.

Master Communication

Each slot has a certain module assignment that has to be complied with for correct configuration.

- Slot 1: Parameter channel
- Slot 2: F-module axis 0 (reserved for PROFIsafe, currently not used)
- Slot 3: Inputs axis 0
- Slot 4: Outputs axis 0
- Slot 5: F-module axis 1 (reserved for PROFIsafe, currently not used)
- Slot 6: Inputs axis 1
- Slot 7: Outputs axis 1

The default configuration stored in the device data sheet "Input 1 Word" and "Output 1 Word" (single-axis device) without safety technology and without parameter channel. This setting is active after loading of the default values.

☞ By default, "IndraWorks Ds/D/MLD" stores the general station description in the directory "C:\Programme\REXROTH\IndraWorks \DeviceDataSheets\IndraDrive\Profinet".

**Module 1: Parameter Channel**

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

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

- IDN parameters

  To write a 2-byte EIDN parameter (e.g. P-0-4006), the "ParamCh 5 Words" module must be included and configured accordingly in the parameter "P-0-4083.0.1, Parameter channel: Configuration".

- EIDN parameters

  To write a 4-byte EIDN parameter (e.g. P-0-4006.0.0), the "ParamCh 6 Words" module must be included and configured accordingly in the parameter "P-0-4083.0.1, Parameter channel: Configuration".

☞ The parameter channel is displayed in bytes in parameter "P-0-4083, Parameter channel: Length".

If the command/actual values are incorrectly configured, the error "F4012Incorrect I/O length" is displayed.

**F-Module**

Slot 2 is assigned the blank module "F-Module not used".

**Inputs Module**

For these modules, the length of the input data is set in words. The module identifier is "Input". For successful data exchange of the axis-specific process data channel, the set length must be equal to the value in parameter "P-0-4082, Field bus: Length of cyclic actual value data channel", that specifies the length in bytes.

☞ Also if an incorrect input data length is specified, communication via the device-specific parameter channel is possible.

☞ If the configuration of the controller does not correspond to the configuration of the HydraulicDrive, the HydraulicDrive will generate the error message "F4012Incorrect I/O length".

**Outputs Module**

For these modules, the length of the output data is set in words. The module identifier is "Output". The set length of the output data has to correspond to the value of parameter "P-0-4071, Field bus: Length of cyclic command value data channel".

☞ If the configuration of the controller does not correspond to the configuration of the HydraulicDrive, the HydraulicDrive will generate the error message "F4012Incorrect I/O length".

**Modules 5 to 7**

Used exclusively for double-axis devices.

## Display of the Device Name/IP Address of the HydraulicDrive Device

The assigned device name is displayed in parameter "P-0-4089.0.2, Master communication: Device name". If a device is replaced, the device name can be manually set via IndraWorks by means of this parameter. The IP settings that are assigned to the device during project planning are displayed in the following parameters:

- P-0-4089.0.13, Master communication: IP address
- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

If "temporary assignment" is configured, (assignment by the controller during run-up) the IP address "0.0.0.0" is displayed in the parameters.

☞ The device address set in "P-0-4089.0.3Device Address", is applied in the parameter "P-0-4089.0.4Active Device Address", after the device is restarted. This address is shown in the display and does not influence the PROFINET communication!

☞ The IP address is only relevant for the communication with the controller! For engineering (e.g. IndraWorks), the engineering address (S-0-1020, Master comm. engineering over IP: IP address) must be used.

## Configuring the Process Data Channel

**Standard Process Data Channel (Not Safety-Related)**

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

☞ For the profile types "freely configurable mode" (P-0-4084 = 0xFFFE), "I/O modus positioning" (P-0-4084 = 0xFF82) or "I/O mode" (P-0-4084 = 0xFF92 preset velocity) a default configuration is set, which can be changed by the user at any time.

Also refer to "Profile Types (With Field Bus Interfaces)"

**Configuration List of Cyclic Actual Value Data Channel**

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

**Configuration List of Cyclic Command Value Data Channel**

In parameter"P-0-4081, Field bus: Config. list of cyclic command value data ch.", the structure of the process output data (controller → device) is mapped. This enables reading the current structure and hence the assignments in the field bus over the parameter channel.

Master Communication

☞ Up to 15 real-time parameters (incl. control and status word) can be configured on the bus per data direction (max. 48 bytes or 24 words).

**PROFIsafe process data channel (safety-related)**

☞ The **safety-related, axis-specific process data channel** is not available in HydraulicDrive. For configuration, however, the module "F-Module not used" is to be integrated!

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

**Standard Process Data Channel (Not Safety-Related)**

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

The PROFINET® device interface allows flexible configuration of the process data channel and the length of the process data channel is thereby changing accordingly.

☞ The currently active length is specified 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. The length, however, is specified in bytes to ensure compatibility with other bus systems.

The length of the process data channel is defined by the content of the configuration lists "P-0-4080, Field bus: Config. list of cyclic actual value data ch.", or "P-0-4081, Field bus: Config. list of cyclic command value data ch.", and is specified in the following parameters:

- P-0-4071, Field bus: Length of cyclic command value data channel
- P-0-4082, Field bus: Length of cyclic actual value data channel

The setting is calculated from the contents of the parameters P-0-4080 and P-0-4081 and takes effect as the drive controller runs up to operating mode.

☞ Note that a change in the length of the process data channel also requires a change in the controller configuration. The set length of the process data channel has to be in accordance with the projected length in the controller. If not, the error message "F4012Incorrect I/O length" is generated.

## 4.8.3 Cyclic Communication via Process Data Channel

### Communication Cycle Time

The smallest supported cycle time (IO cycle update time) is 2 ms and is defined by the control unit. It describes the time in which cycle the data from the PROFINET network is applied or read out to the MultiEthernet interface.

Setting options via "P-0-4076, Field bus: Process data - updating clock", min. 2 ms, max. 65 ms (multiple of the position controller cycle).

☞ Parameter "P-0-4076, Field bus: Process data - updating clock", is used to define the update cycle for applying the data from the MultiEthernet interface onto the drive and vice versa.

## Axis-Specific Process Data Channel

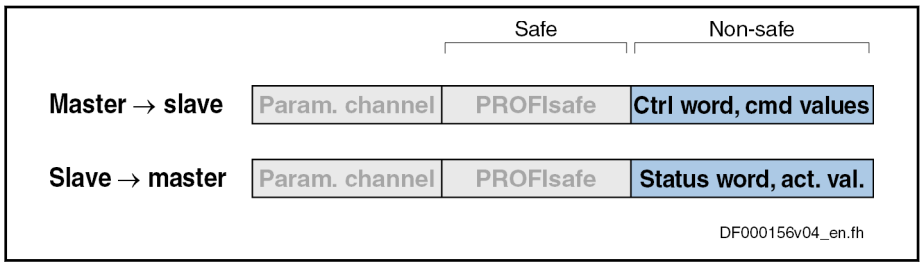


*Fig. 4-48: Position of the Not Safety-Related Process Data Channel in the Cyclic Data Channel*

**Processing the Cyclic Data**

Internal processing of the command values and actual values is carried out synchronously with the control clock cycle. As the communication via PROFINET® RT is not carried out clock-synchronously, this type of master communication is not suited for clock-synchronized operation modes such as "position control with cyclic command value input", but only for positioning modes and the "velocity control" mode.

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

**Cyclic Data Configuration**

The cyclic data have to be configured in the parameter mode.

## Parameter Channel in the Cyclic Channel (Device-Specific)

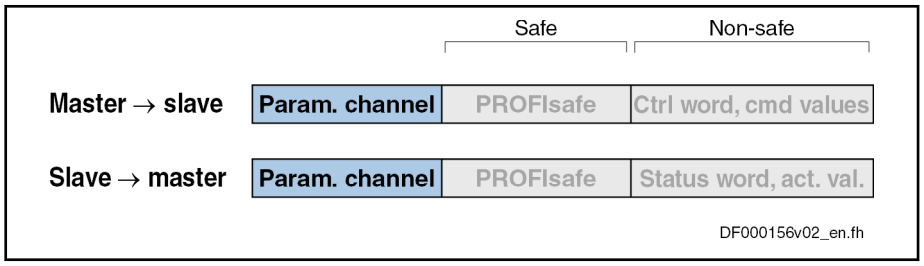


*Fig. 4-49: Position of the parameter channel in the cyclic data channel*

Via the parameter channel, the drive can be parameterized via the field bus. The parameter channel is part of the cyclic data.

For IndraLogic and Siemens S7, there are function blocks available which implement the parameter channel protocol. The user does not need to deal with the parameter channel details.

The parameter channel is described in the Technical Note "TN_40_Bosch_Rexroth PROFIBUS_PROFINET_Parameterkanal_V1.x".

☞ The parameter channel is always at the beginning of the cyclic data channel. The length of the parameter channel is configured in the controller and the drive. To this end, parameter "P-0-4083.0.1, Parameter channel: Configuration", must be used.

☞ The field bus control word cannot be operated via the optional parameter channel. To enable axis control, the cyclic data channel is to be used in the higher-level control or the respective logic must be programmed in the MLD with permanent control. If the control is not equipped with a cyclic data channel, the axis cannot be controlled without MLD.

Master Communication

## 4.8.4 Diagnostic and Status Messages

### Diagnostic Possibilities

For easy diagnosis of the network status, a network status LED is provided.

The following table illustrates the possible states:

| LED | | Significance | Color | Description |
|---|---|---|---|---|
| IAC | HMC | | | |
| 3 | NS | Status | Off | The device has no valid IP address or is switched off |
| | | Link | Flashing green | The device has booted with a valid IP address but does not have a cyclic connection. |
| | | Connected | Permanently lit green | The I/O connection has been established without error. |
| | | Timeout | Flashing red | The existing I/O connection was unexpectedly terminated (e.g. watchdog). |
| | | Invalid IP address | Permanently lit red | The Duplicate IP Address Check detected that the set IP address already exists in the network. |
| | | Self test | Flashing red-green | The device is booting and performs a self-check. |

*Tab. 4-59: Overview of Parameter Channel Errors ™*

### Error Codes of PROFINET® Communication

**Parameter Channel Errors**

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

| Error code | Significance |
|---|---|
| 0x0082 | Total volume of transmitted data is too low, i.e. less than 4 bytes |
| 0x0083 | The data volume still to be transmitted exceeds 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 is still data to be transmitted |
| 0x008D | The length of data indicated as still to be transmitted in the control word is incorrect |
| 0x008E | The EIDN/IDN access mode set in control word bit 15 does not correspond to the access mode configured in P-0-4083.0.1. |

*Tab. 4-60: Overview of Parameter Channel Errors*

**Parameter Access Errors**

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

| Error No. (hex) | Significance |
|---|---|
| 0x1001 | No IDN |
| 0x1009 | Invalid access to element 1 |
| 0x2001 | No name available |
| 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 | Datum transmission too short |
| 0x7003 | Datum transmission too long |
| 0x7004 | Datum cannot be changed (read only) |
| 0x7005 | Datum is currently write-protected |
| 0x7006 | Datum is smaller than minimum input value |
| 0x7007 | Datum exceeds the maximum input value |
| 0x7008 | IDN is not supported, invalid bit number or bit combination |
| 0x7009 | Datum write-protected by customer password |
| 0x700A | Datum is currently write-protected, as it is configured cyclically |
| 0x700B | Invalid indirect addressing (e.g. data container, list handling) |
| 0x700C | Operation data is write-protected due to different 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., the procedure command cannot be activated in this phase) |
| 0x7013 | Procedure command not executable (invalid or false parameters) |
| 0x9001 | Input cannot be identified as application |
| 0x9002 | Parameter type error |
| 0x9003 | Invalid data record number |
| 0x9004 | Invalid data block number |
| 0x9005 | Data element number invalid |
| 0x9006 | Error in R/W flag |
| 0x9007 | Invalid character in the datum |

*Tab. 4-61: Overview Parameter Access Errors*

# 4.9 PROFIBUS-DP

## 4.9.1 Brief Description

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

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

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

The cyclic data channel is subdivided as follows:

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

☞ The **device-specific parameter channel** does not provide any "real-time properties"!

- One **axis-specific process data channel** (real-time channel) which contains firmly declared information that can be directly interpreted by the receiver.

*Fig. 4-50: Overview of Cyclic Data Channel*

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

**Features**

The slave/PROFIBUS-DP connection offers the following features:

- Support of **RS485 interface according to IEC 61158-2**
- Support of all **data rates according to IEC 61158-2** with exclusive use of PROFIBUS-DP (9.6 kBaud, 19.2 kBaud, 45.45 kBaud, 93.75 kBaud, 187.5 kBaud, 500 kBaud, 1.5 MBaud, 3 MBaud, 6 MBaud, 12 MBaud)
- Automatic baud rate recognition
- Configurable cyclic data up to 15 parameters (incl. field bus control word and field bus status word) in both data directions (max. 48 bytes or 24 words)
- Setting possibilities for P-0-4076, min. 2 ms, max. 65 ms (adjustable in steps of 1 ms).

Parameter "P-0-4076, Field bus: Process data - updating clock" is used to define the update cycle for applying the process data from the PROFIBUS interface onto the drive and vice versa.

- Additional optional parameter channel in the cyclic channel with up to 16 bytes (8 words)
- Monitoring of the cyclic data exchange (watchdog function)
- LED for PROFIBUS interface diagnosis
- Supported DPV0 services:
  - Slave_Diag (read diagnostic data)
  - Get_Cfg (read out configuration data)
  - Set_Prm (send parameterization data)
  - Chk_Cfg (check configuration data)
  - Data Exchange (transferring I/O data)
  - Global Control (synchronization)
  - RD_Outp (read output data)
  - RD_Inp (read input data)
- Supported DPV1-class-1 services:
  - DDLM_Initiate (establishment of connection)
  - DDLM_Read (acyclic read access)
  - DDLM_Write (acyclic write access)
  - DDLM_Abort (termination of connection)
  - DDLM_Idle (connection monitoring)
- Support of up to two DPV1-class-2 connections
- TCI (Tool Calling Interface) support
- Supported field bus profiles:
  - 0x0000: "No profile" selected
  - 0xFF82: I/O mode "positioning" with configurable real-time data
  - 0xFF92: I/O mode "preset velocity" with configurable real-time data
  - 0xFFFD: Freely configurable mode "operation mode neutral"
  - 0xFFFE: Freely configurable mode

**Hardware Requirements**

The master communication "PROFIBUS-DP" requires the following device variant:

- HMC (Hydraulic Motion Controller) with the Profibus DP option

**Axis Addressing**

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

**Pertinent Parameters**

Communication parameters

Specific parameters for communication via PROFIBUS-DP:

- P-0-4069, Field bus: Module diagnosis

Parameters for general communication via field bus interfaces:

- P-0-4073, Field bus: Diagnostic message
- P-0-4074, Field bus: Data format
- P-0-4075, Field bus: Watchdog

- P-0-4076, Field bus: Process data - updating clock
- P-0-4079, Field bus: Baud rate
- P-0-4083, Parameter channel: Length
- P-0-4083.0.1, Parameter channel: Configuration

**Profile type parameters**

Apart from mere communication parameters, parameters related to the profile types are used.

See "Profile Types (with Field Bus Interfaces)"

**Parameters for extended communication**

Additional parameters for extended communication possibilities are used.

See the following sections:

- "Configurable signal control word"
- "Configurable signal status word"
- "Multiplex channel"

**Pertinent Diagnostic Messages**

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

## 4.9.2 Configuration of the PROFIBUS-DP Slave

### General Station Description File

Like any other PROFIBUS slave, HydraulicDrive controllers must be configured in the field bus master. To this end, the respective general station description (GSD) "**RX**0170.GSD**" is necessary, which must be integrated in the project ("**" stands for the version number of the GSD file). When configuring the bus master, this GSD file is required for each node.

The general station description (GSD) for HydraulicDrive controllers supports all hardware types and enabling of functional packages.

HydraulicDrive controllers divide their data to four slots (for single-axis devices), which may have to be configured. Each drive is provided with an F-module, an input module and an output module. A slot is an interface for one module. Example: A parameter channel module is plugged into slot 1. The parameter channel module can have various lengths as described.

IndraDrive controllers divide their data to four slots (for single-axis devices), into which certain modules have to be plugged.

- Slot 1: Parameter channel module (device-specific)
- Slot 2: F-module (axis 0)
- Slot 3: Inputs module (axis 0)
- Slot 4: Outputs module (axis 0)

- Slot 1: Parameter channel
- Slot 2: F-module axis 0 (optional for PROFIsafe)
- Slot 3: Inputs axis 0
- Slot 4: Outputs axis 0

The default configuration stored in the general station description file are "Input 1 Word" and "Output 1 Word" (single-axis device) without parameter channel. This default configuration is set automatically in the case of configurators, which support GSD version 03 or higher. With IndraDrive, this setting is active after loading of the default values.

The general station description file also contains the IDN assigned to the HydraulicDrive controller by the PROFIBUS user organization (PNO):

- **IDN 170 hex**



By default, "IndraWorks MLD" stores the general station description in the directory "C:\Programs\REXROTH\IndraWorks\DeviceDataSheets\IndraDrive\Profibus" in the course of the installation.

**Module 1: Parameter Channel**

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

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

- IDN parameters

  To write a 2-byte IDN parameter (e.g. P-0-4006), the "ParamCh 5 Words" module must be included and configured accordingly in the parameter "P-0-4083.0.1, Parameter channel: Configuration".

- EIDN parameters

  To write a 4-byte EIDN parameter (e.g. P-0-4006.0.0), the "ParamCh 6 Words" module must be included and configured accordingly in the parameter "P-0-4083.0.1, Parameter channel: Configuration".



The parameter channel is displayed in bytes in parameter "P-0-4083, Parameter channel: Length".

If the command/actual values are incorrectly configured, the error "F4012Incorrect I/O length", is displayed.

The drive automatically recognizes the configuration of the master and adjusts itself accordingly. Consequently, parameterizing by the master is always possible, also with an incorrect configuration of the command/actual values. This allows downloading of parameters from the master after a device was replaced.

**F-Module**

Slot 2 is assigned the blank module "F-Module not used".

**Inputs Module**

For these modules, the length of the input data is set in words. The module identifier is "Input". For successful data exchange of the axis-specific process data channel, the set length must be equal to the value specified in parameter "P-0-4082, Field bus: Length of cyclic actual value data channel", that specifies the length in bytes.



Also if an incorrect input data length is specified, communication via the device-specific parameter channel is possible.

Master Communication

☞ If the configuration of the master does not correspond to the configuration of the IndraDrive controller, the IndraDrive will generate the error message "F4012Incorrect I/O length".

**Outputs Module**

For these modules, the length of the output data is set in words. The module identifier is "Output". The set length of the output data has to correspond to the value of parameter "P-0-4071, Field bus: Length of cyclic command value data channel".

☞ If the configuration of the master does not correspond to the configuration of the IndraDrive controller, the IndraDrive will generate the error message "F4012Incorrect I/O length".

## Configuring the Process Data Channel

**Standard Process Data Channel**

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

☞ For the profile types "freely configurable mode" (P-0-4084 = 0xFFFE), "operating mode neutral" (P-0-4084 = 0xFFFD), "I/O mode" (P-0-4084 = 0xFF82), "I/O mode" (P-0-4084 = 0xFF92 preset velocity) or "no profile" (P-0-4084 = 0x0000) a default configuration is set, which can be changed by the user at any time.

Also refer to "Profile Types (With Field Bus Interfaces)"

**Configuration List of Cyclic Actual Value Data Channel**

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

**Configuration List of Cyclic Command Value Data Channel**

The structure of the process output data (master → slave) is mapped in parameter "P-0-4081, Field bus: Config. list of cyclic command value data ch.". This enables reading the current structure and hence the assignments in the field bus over the parameter channel.

☞ Up to 15 real-time parameters (incl. control and status word) can be configured on the bus per data direction (max. 48 bytes or 24 words).

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

**Standard Process 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 connection allows a flexible configuration of the process data channel, and the length of the process data channel is thereby changing accordingly.

☞ The currently active length is specified 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. The length, however, is specified in bytes to ensure compatibility with other bus systems.

The length of the process data channel can be 1…24 words or 2…48 bytes in both directions.

The length of the process data channel is defined by the content of the configuration lists "P-0-4080, Field bus: Config. list of cyclic actual value data ch.", or "P-0-4081, Field bus: Config. list of cyclic command value data ch.", and is specified in the following parameters:

- P-0-4071, Field bus: Length of cyclic command value data channel
- P-0-4082, Field bus: Length of cyclic actual value data channel

The setting is calculated from the contents of the parameters P-0-4080 and P-0-4081 and takes effect as the drive controller runs up to operating mode.

☞ Note that a change in the length of the process data channel also requires a change in the master configuration. The set length of the process data channel has to be in accordance with the projected length in the master. If not, the error message "F4012Incorrect I/O length" is generated.

## 4.9.3 Cyclic Communication via Process Data Channel

### Communication Cycle Time

The communication cycle time is determined by the baud rate set in the master. It is transferred to the slave and shown in parameter "P-0-4079, Field bus: Baud rate".

Via the parameter "P-0-4076, Field bus: Process data - updating clock", the update cycle for applying the data from the PROFIBUS® interface onto the drive and vice versa is defined. For reasons of performance, the default settings should be maintained.

Enter valid values for "P-0-4076, Field bus: Process data - updating clock": min. 2 ms, max. 65 ms (adjustable in 1-ms steps)

### Axis-Specific Process Data Channel

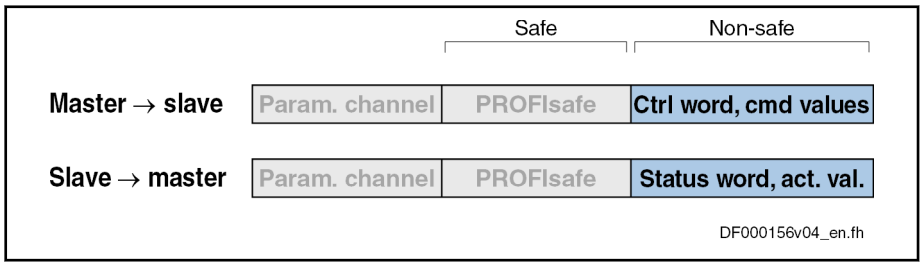


*Fig. 4-51: Position of the not safety-related process data channel in the cyclic data channel*

**Processing the Cyclic Data**

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

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

**Cyclic Data Configuration**

Cyclic data have to be configured in the parameter mode. This is described in section "Configuring the PROFIBUS-DP Slave".

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### Parameter Channel in the Cyclic Channel (Device-Specific)

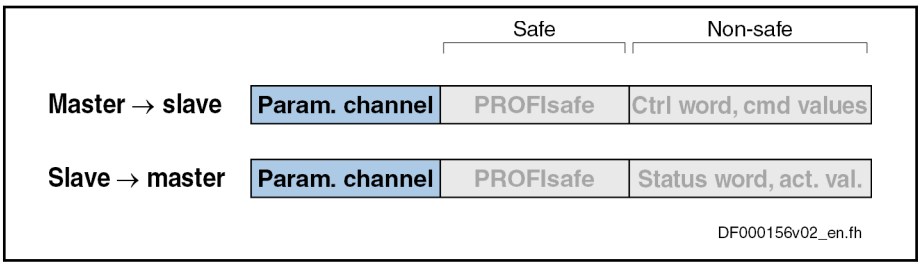


*Fig. 4-52: Position of the Parameter Channel in the Cyclic Data Channel*

Via the parameter channel, the drive(s) can be parameterized over the field bus. The parameter channel is part of the cyclic data.

For IndraLogic and Siemens S7, function blocks are available which implement the parameter channel protocol. The user does not need to deal with the parameter channel details.

The parameter channel is described in chapter 4.4.4.

☞ The parameter channel is always at the beginning of the cyclic data channel. The length of the parameter channel is configured in the master and accepted by the drive in parameter "P-0-4083, Parameter channel: Length".

☞ The field bus control word cannot be operated via the optional parameter channel. To enable axis control, the cyclic data channel is to be used in the higher-level control or the respective logic must be programmed in the MLD with permanent control. If the control is not equipped with a cyclic data channel, the axis cannot be controlled without MLD.

## 4.9.4 Acyclic Data Exchange (DPV1)

### Overview of Acyclic Communication

**DP-Master Class 1**

An acyclic communication relationship of type "MSAC_C1" with 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 Classe 2**

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

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

## 4.9.5 Diagnostic and Status Messages

### Monitoring Functions

**Watchdog for Cyclic Communication**

In standard cases, the time required by watchdog monitoring is automatically calculated and configured by the configuration program of the master. It is displayed (in ms) in parameter "P-0-4075, Field bus: Watchdog".

☞ The entry "0" in parameter "P-0-4075, Field bus: Watchdog" means that watchdog monitoring is deactivated.

**F4012 Incorrect I/A Length**

If the error message "F4012Incorrect I/O length" is generated, the drive is in the PROFIBUS state "Data_Exchange"; the diagnostic LED is on. The parameter channel functions, but internally the data of the input and the output module are not processed.

## Diagnostic Possibilities

Diagnostics of the state of field bus master communication of a HydraulicDrive is carried out via

- diagnostic LED on the front panel of the controller

  - and -

- diagnostic parameter "P-0-4073, Field bus: Diagnostic message".

**Diagnostic LED**

The diagnostic LED is on, when the drive is in the PROFIBUS state "Data_Exchange". This means that real-time data are exchanged between the drive and the master.

**Parameters for Field Bus Diagnostics**

The status of the field bus master communication is stored in parameter "P-0-4073, Field bus: Diagnostic message", in clear text. The contents in parameter P-0-4073 have the following meaning:

| Text | Significance |
|---|---|
| "OFFLINE" | Initialization value of diagnostics |
| "Power-On" | PROFIBUS-DP was recognized as master communication and hardware is checked. |
| "Baud Search" | The hardware is ok; the PROFIBUS interface is monitored in order to recognize the baud rate used. |
| "Wait-Prm" | The baud rate was found; the drive is waiting for a parameterization telegram of the master, which contains its IDN (is stored in the general station description). |
| "Wait-Cfg" | The drive has received a valid parameterization telegram and now waits for the configuration telegram in which the master tells the drive which modules it is expecting for input/output configuration. |
| "Data-Exch WD+" | The drive has received a valid configuration and exchanges real-time data with the master. The communication is monitored by a watchdog. |
| "Data-Exch WD-" | The drive has received a valid configuration. The drive has received a valid configuration and exchanges real-time data with the master. |

*Tab. 4-62: Significance of Entries in Parameter P-0-4073*

## Error Codes of PROFIBUS Communication

**Parameter Channel Errors**

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

| Error code | Significance |
|---|---|
| 0x0082 | Total volume of transmitted data is too low, i.e. less than 4 bytes |
| 0x0083 | The data volume still to be transmitted exceeds the internal buffer |

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| Error code | Significance |
|---|---|
| 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 is still data to be transmitted |
| 0x008D | The length of data indicated as still to be transmitted in the control word is incorrect |
| 0x008E | The EIDN/IDN access mode set in control word bit 15 does not correspond to the access mode configured in P-0-4083.0.1 |

*Tab. 4-63: Overview of Parameter Channel Errors*

**DPV1 Errors**

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

| Error code | Significance | Designation 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 | No 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 | In one access, only one parameters may be processed. | DPV1, access, invalid parameter |
| 0x80 0xC0 0x00 | The request is still being processed, the read request has to be repeated. | DPV1, resource, read constrain conflict |

*Tab. 4-64: Overview of DPV1 Errors*

**Parameter Access Errors**

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

| Error No. (hex) | Significance |
|---|---|
| 0x1001 | No IDN |
| 0x1009 | Invalid access to element 1 |

| Error No. (hex) | Significance |
|---|---|
| 0x2001 | No name available |
| 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 | Datum transmission too short |
| 0x7003 | Datum transmission too long |
| 0x7004 | Datum cannot be changed (read only) |
| 0x7005 | Datum is currently write-protected |
| 0x7006 | Datum is smaller than minimum input value |
| 0x7007 | Datum exceeds the maximum input value |
| 0x7008 | Configured IDN is not supported, invalid bit number or bit combination |
| 0x7009 | Datum write-protected by customer password |
| 0x700A | Datum is currently write-protected, as it is configured cyclically |
| 0x700B | Invalid indirect addressing (e.g. data container, list handling) |
| 0x700C | Datum is currently write-protected due to other settings (e.g. parameter, operation mode, drive enable, ...) |
| 0x7010 | Procedure command already active |
| 0x7011 | Procedure command not interruptible |
| 0x7012 | Procedure command at this time not executable (e.g., the procedure command cannot be activated in this phase) |
| 0x7013 | Procedure command not executable (invalid or false parameters) |
| 0x9001 | Input cannot be identified as application |
| 0x9002 | Parameter type error |
| 0x9003 | Invalid data record number |
| 0x9004 | Invalid data block number |
| 0x9005 | Data element number invalid |
| 0x9006 | Error in R/W flag |
| 0x9007 | Invalid character in the datum |

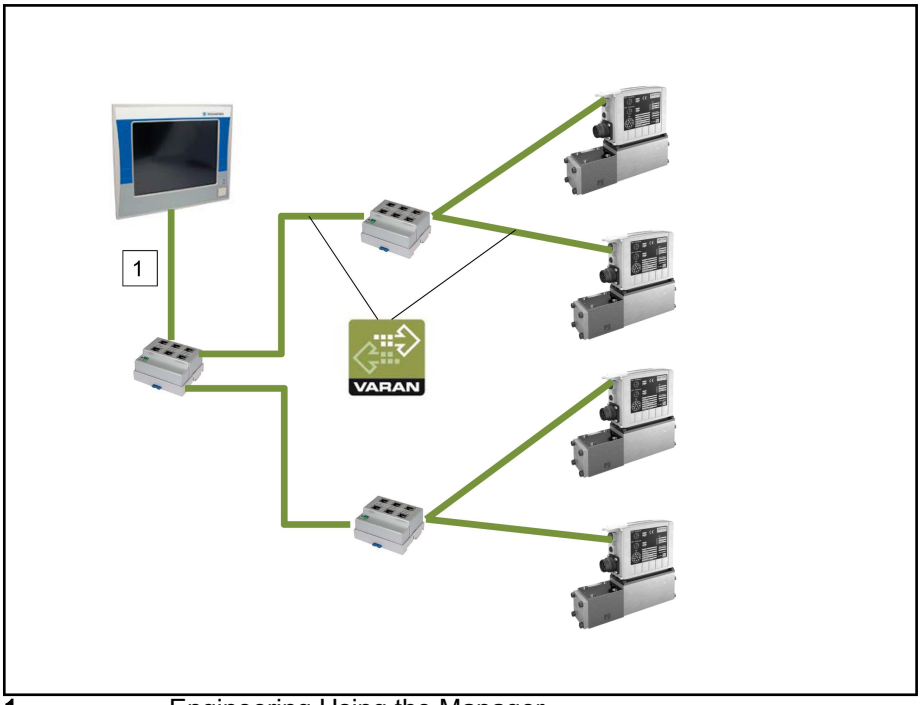
*Tab. 4-65: Overview Parameter Access Errors*

Master Communication

# 4.10 VARAN

## 4.10.1 Brief Description

### Topology




**1** Engineering Using the Manager

*Fig. 4-53: Engineering via VARAN*

HydraulicDrives can be operated as VARAN master communication. Via these modules, it is possible to exchange real-time data with a VARAN master.

The "Servo Drive Profile over VARAN" (SoV) is supported, which is based on the sercos II specification.

The following communication channels are distinguished:

- Cyclic data channel (process data)
  - Data container for cyclic transmission of user data (process data) in real time
- Acyclic data channel
  - Process for acyclic transmission of service data (parameter channel)
  - Process for acyclic transmission of Ethernet telegrams (EoV/ Foreign Package)

When setting up a VARAN network it is to be observed that the VARAN bus supports star as well as line topologies. For star topology, an additional VARAN splitter may be necessary. A line topology can only be used for HydraulicDrive if it is equipped with 2 VARAN ports.

### General Features

- Transmission rate 100 Mbit/s
- Data transmission via Ethernet cable (CAT5-copper)
- 100 m maximum cable length

- Topology: "Star" and/or "Line" (depending on whether port 2 is occupied)
- Access to 16-bit sercos parameters of the drive via "SoE" protocol ("Servo Drive Profile over VARAN" protocol)
- Cyclic data exchange of command values and actual values
- Free configuration of telegram contents
- Max. length of the configurable MDT/AT data 15 IDNs with max. 48 bytes; with bus cycle = position controller cycle, the max. length is halved to 24 bytes with bus cycle times below 1 ms
- Minimum Cycle Time: Position controller cycle
- Overall synchronization of all connected drives with the master
- Support of "Ethernet over VARAN" (EoV/ Foreign Package)

## Addressing

Under VARAN, addressing is always achieved by projecting the bus stations in the master. Each bus device is assigned a separate 64 kB address range that is included in the total address range of 4 GB that is used for addressing. All axes of a drive in multi-axis devices share this 64 kB address range. If the master sends data to one of the drives, it has to write to the respective address range of the drive. The drive itself cannot define its own bus address. Addressing is exclusively carried out via the master.

## Pertinent Parameters

- S-0-0001, NC cycle time (TNcyc)
- S-0-0002, sercos cycle time (TScyc)
- S-0-0007, Feedback acquisition starting time (T4)
- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0016, Configuration list of AT
- S-0-0024, Configuration list of MDT
- S-0-0029, MDT error counter
- S-0-0011, 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-0-0134, Master control word
- S-0-0135, Drive status word
- S-0-0185, Length of the configurable data record in the AT
- S-0-0186, Length of the configurable data record in the MDT
- S-0-0187, List of configurable data in the AT
- S-0-0188, List of configurable data in the MDT
- S-0-0301, Allocation of real-time control bit 1
- S-0-0303, Allocation of real-time control bit 2
- S-0-0305, Allocation of real-time status bit 1
- S-0-0307, Allocation of real-time status bit 2

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- 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-0-4089.0.1, Master communication: Protocol
- S-0-0032, Primary operation mode
- S-0-0033, Secondary operation mode 1
- S-0-0034, Secondary operation mode 2
- S-0-0035, Secondary operation mode 3
- S-0-0284, Secondary operation mode 4
- S-0-0285, Secondary operation mode 5
- S-0-0286, Secondary operation mode 6
- S-0-0287, Secondary operation mode 7

### Pertinent Diagnostic Messages

- C0101, Invalid parameters (-> S-0-0021)
- C0104, Config. IDN for MDT not configurable
- C0105, Maximum length for MDT exceeded
- C0106, Config. IDNs for AT not configurable
- C0107, Maximum length for AT exceeded
- C0108, Time slot parameter > sercos cycle time
- C0112, TNcyc (S-0-0001) or TScyc (S-0-0002) error
- C0113, Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error
- C0114, T4 > TScyc (S-0-0002) - T4min (S-0-0005)
- C0201, Invalid parameters (->S-0-0423)
- C0299, Configuration changed. Restart
- E4005, No command value input via master communication
- F4002, RTD telegram failure
- F4009, Bus failure

## 4.10.2 Servodrive over VARAN

### VARAN State Machine

The following figure illustrates the comparison of the VARAN and the sercos state machine.

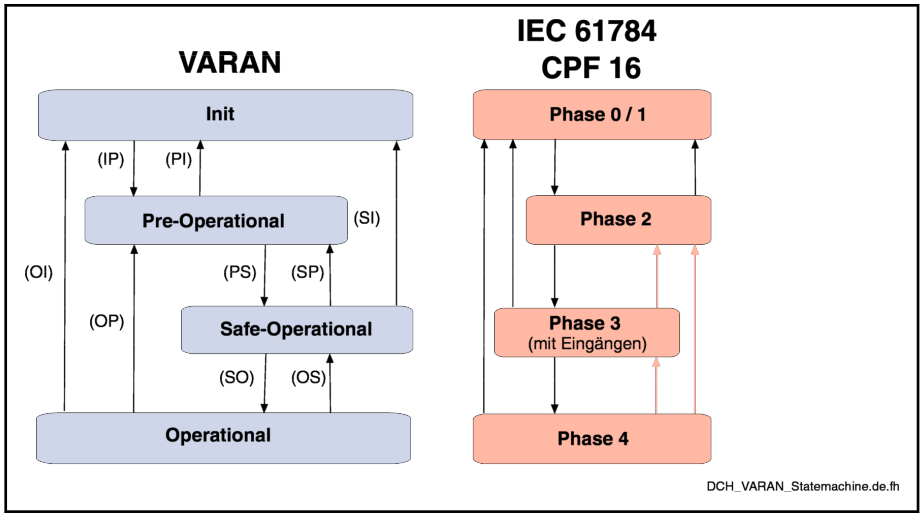


*Fig. 4-54: VSM and 61158-4-16 State Machine*

In contrast to sercos, also "switch backs" between the phases (here states) are possible, i.e. from "Operation" to "Safe-Operational" (OS transition).

- In "Init", communication with the drive is only possible via "EoV/ Foreign Package". Communication via the SoV protocol is not possible.
- In "Pre-Operational", acyclic communication with the drive via the SoV protocol is possible. Cyclic data is not yet processed.
- In "Safe-Operational", the drive transmits its actual values to the master, but does not apply any command values.
- In "Operational", the complete cyclic channel is valid. If a drive detects an error, it is switched to "Safe-Operational" instead to "Init". This way, the communication in the system is maintained at least partly.

From state "Safe-Operational", the drive has to deliver valid actual values. From state "Operational", also the command values must be processed.

If a drive is switched from "Operational" to "Safe-Operational" due to an error reaction or if the master initiates this change in state in the drive, it is automatically switched off.

If a drive can no longer ensure validity of the actual values, it automatically switches back to "Pre-Operational" and enters an error state.

## Cyclic and Acyclic Data Channel

### Cyclic Data/Process Data

The cyclic data consist of parameter "S-0-0134, Master control word", or "S-0-0135, Drive status word", and the parameters entered in "S-0-0016, Configuration list of AT", or "S-0-0024, Configuration list of MDT".

In S-0-0016/S-0-0024 max. 15 IDNs can be entered each. The length of the parameters entered in S-0-0016/S-0-0024 may be max. 48 bytes. In case of bus cycle time == position cycle time, this length is reduced to 24 bytes. However, this reduction only applies if the position cycle is set below 1 ms. Above a position cycle of 1 ms, also bus cycles = position controller cycles 48 bytes can be entered in S-0-0016/S-0-0024.

The cyclic data has to be configured via the master. Then, the master configures the cyclic telegram and writes the parameters S-0-0016 and S-0-0024 on phase run-up.

Master Communication

### Acyclic Data Channel

#### Parameter channel

Access to 16-bit sercos parameters of the drive via "SoV" protocol ("Servo Drive Profile over VARAN" protocol). 32-bit EIDN access is only possible if the corresponding 16-bit Alias is available.

## Synchronization and Timing

### Ensuring data integrity

If the client does not respond to a telegram of the manager, the manager automatically repeats the last telegram within a current bus cycle. The message counter is not increased to ensure that the repetition can be detected by the client.

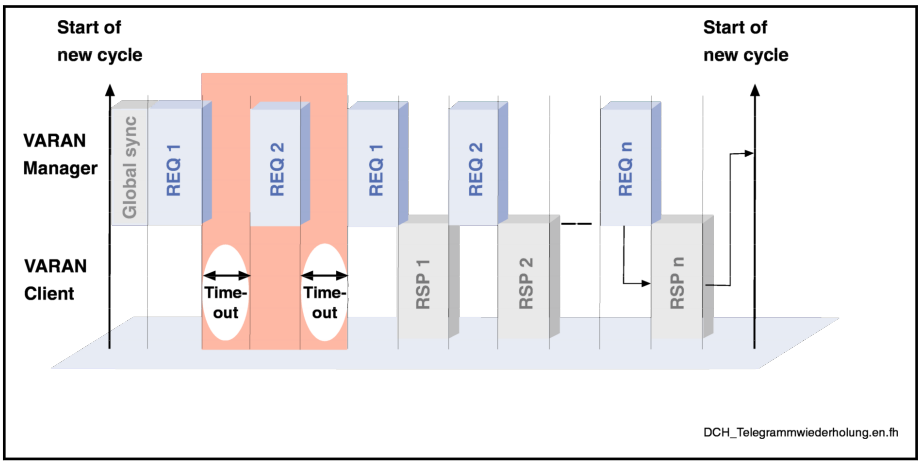


*Fig. 4-55: Repetition of a Telegram in the Same Bus Cycle*

### Synchronization

In VARAN, synchronization of drives is also possible without Distributed Clocks according to IEEE 1588. The VARAN logicware cyclically creates a Sync signal in the bus cycle that can be used for synchronization of the drive PLL. The Sync signal is always generated in the logicware when the "isochronous VARAN task" is started. During booting of the internal state machine from PreOperational to SafeOperational, the drive can synchronize according to the Sync signal. When switching to "Operational", drive synchronization needs to be successful as switch-over is otherwise denied.

### Timing

Depending on the ratio between bus and position cycle, the cyclic command and actual values are either processed within a position controller cycle (= bus cycle at timing 1:1) or divided on several position controller cycles. Processing starts at the position controller cycle in which the Sync signal is received from the FPGA. In this process, T4 always occurs directly after the Sync signal. A switch-over buffer connection in the VARAN logicware ensures that no conflicts arise during access to cyclic data in FPGA. Data consistency is always guaranteed.

## Diagnosis and Status

For use of "Servodrive profile over VARAN", several LEDs on the housing of the HydraulicDrive controller are available for diagnosis. These can be used to diagnose the current status of the drive.

**PHY LEDs on the Housing**

The PHY LEDs on the HydraulicDrive housing (L1, S1) serve for diagnosis of the physical VARAN connection. The green link LED indicates if the VARAN cable has been connected to the HydraulicDrive. The yellow activity LED indicates the data transmission to and from the HydraulicDrive controller.

**STATUS LED on the Housing**

The two-colored STATUS LED on the HydraulicDrive controller (S3) is used for VARAN communication diagnosis. The flashing codes are triggered according to "CANopen Draft 303 Part 3 – Indicator Specification". The applied flashing codes are specified in the table below.

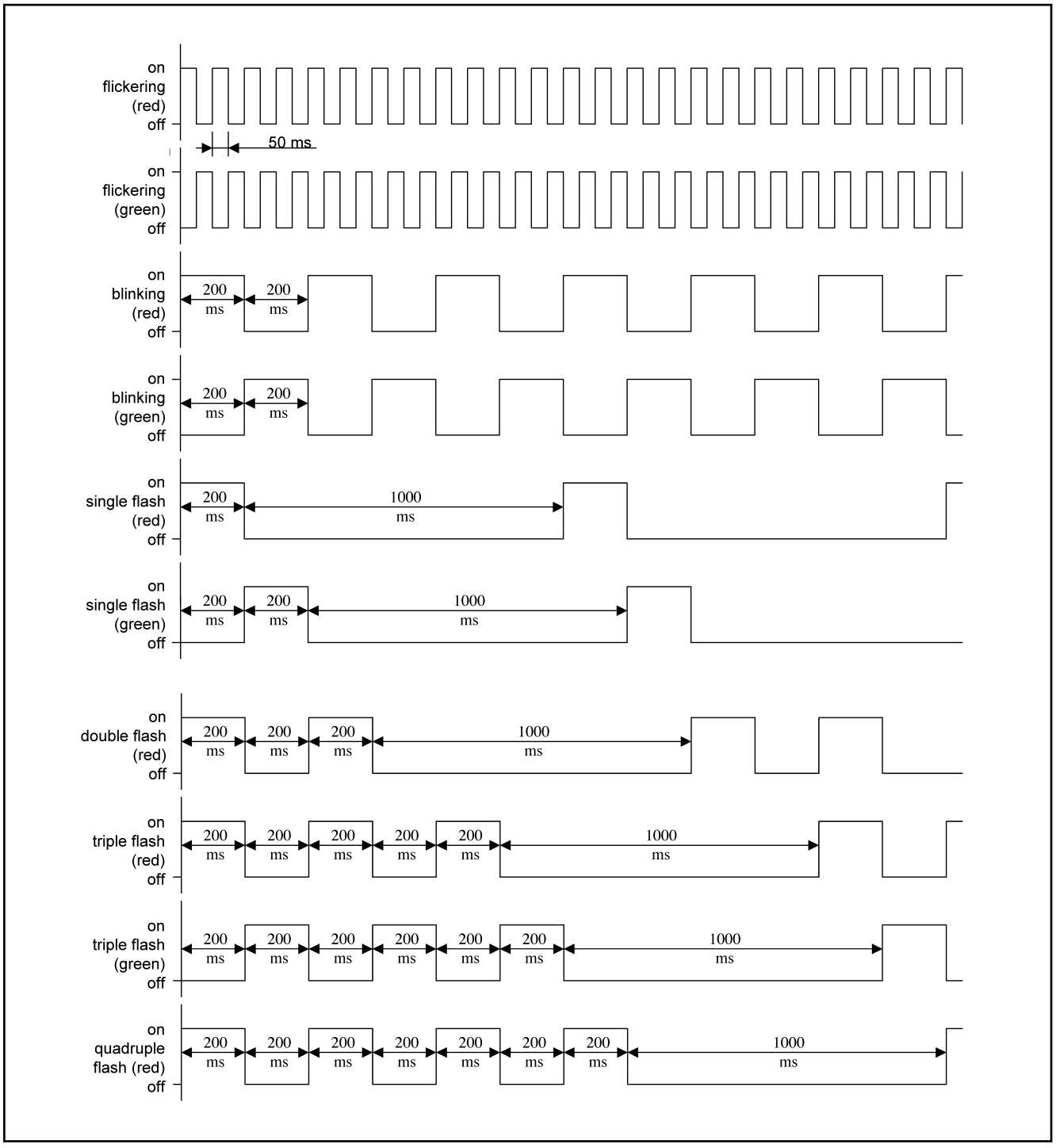


*Fig. 4-56: LED Activation According to CANopen Draft 303 Part 3*

Master Communication

| BUS status | LED control | Description |
|---|---|---|
| INIT | GREEN: off | The VARAN bus is in state "INIT". No transmission of cyclic or service channel data. EoV data is transmitted. |
| PRE-OPERATIONAL | GREEN: on, blinking | The VARAN bus is in state "Pre-Operational". Service channel data can be transmitted. |
| SAFE-OPERATIONAL | GREEN: on, single flash | The VARAN bus is in state "Safe-Operational". The drive already delivers valid actual values. Command values are not yet applied. |
| OPERATIONAL | GREEN: on | The VARAN bus is in state "Operational". The drive delivers actual values and processes command values. |
| Configuration error | RED: on, flashing | The drive is incorrectly configured and denies switch-over of states. |
| Synchronization error | RED: on, single flash | Error on synchronization of the drive with the VARAN master. |
| Timeout | RED: on, double flash | Error during transmission of cycl. process data. |

*Tab. 4-66: Flashing codes of the HydraulicDrive at SoV*

**MODULE STATUS LED on the housing**

For internal diagnosis of the HydraulicDrive controller, the housing features a two-colored MODULE STATUS LED to display the drive-internal status (S3).

The additional two LEDS on the HydraulicDrive housing (L2, S2) do not have any function if the VARAN bus is used.

**Pertinent Diagnostic Messages**

- A0004, Initialization
- A0005, Pre-Operational
- A0006, Safe-Operational
- C0101, Invalid parameters (-> S-0-0021)
- C0104, Config. IDN for MDT not configurable
- C0105, Maximum length for MDT exceeded
- C0106, Config. IDNs for AT not configurable
- C0107, Maximum length for AT exceeded
- C0201, Invalid parameters (->S-0-0423)
- F4002, RTD telegram failure
- F4009, Bus failure

## 4.10.3 Ethernet over VARAN

### Functional Description

#### General Information

With "EtherNET over VARAN" (EoV), standard Ethernet telegrams are channeled to the drive via the "Foreign Package" mechanism. This enables access to the drive via standard Ethernet.

#### Protocol Switching

Initial commissioning with multi-Ethernet devices without control panel or VARAN master requires particular care. If an "incorrect" protocol is set for this type of devices, operation and potentially communication with IndraWorks to set the correct protocol may be impossible. Via IndraWorks, however, the drive protocol can be switched to "Standard Ethernet". Switching is possible after starting of the drive until a VARAN master is connected to the drive.

For switching, the engineering tool Indraworks-Ds is to be connected and "EtherCAT/VARAN" is to be deactivated. Refer to the following dialog:

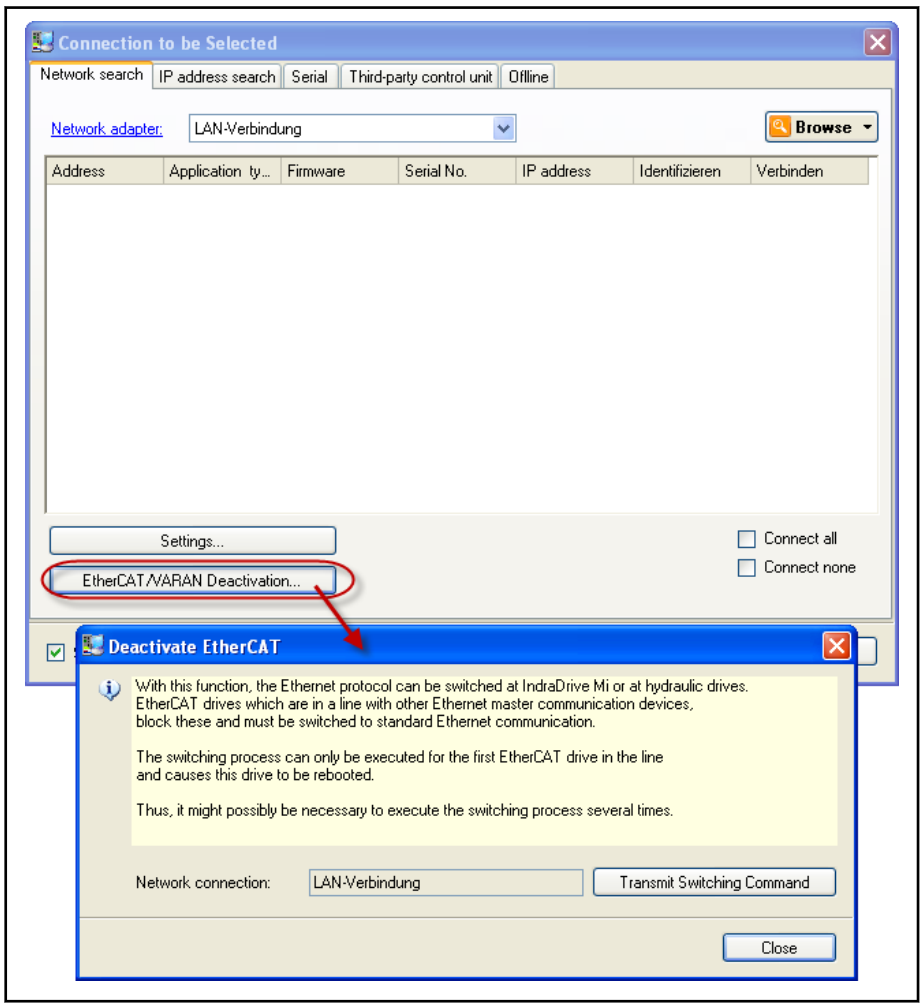


*Fig. 4-57: Connection Selection Dialog*

#### Pertinent Parameters

- S-0-1020, Master comm. engineering over IP: IP address
- S-0-1021, Master comm. engineering over IP: Network mask

Master Communication

- S-0-1022, Master comm. engineering over IP: Gateway address
- P-0-1534, C6100 Command Activate IP settings
- P-0-1044, Master comm. engineering over IP: Status IP communication

# 5 Drive, Mechanical Axis System, Measuring Systems

## 5.1 Mechanical Axis System and Arrangement of Measuring Systems

### 5.1.1 Position Measurement

For acquiring the position of a drive, a position measuring system is required.

This position measurement is required for the:

- Velocity control loop
- Position control loop

The quality and resolution of position measurement is decisive for the quality of the feedback values.

### 5.1.2 Possibilities of Arranging Measuring Systems

The figure below shows an overview of arrangement options of the mechanical drive system and measuring systems.

With a linear encoder, no encoder gear is supported.

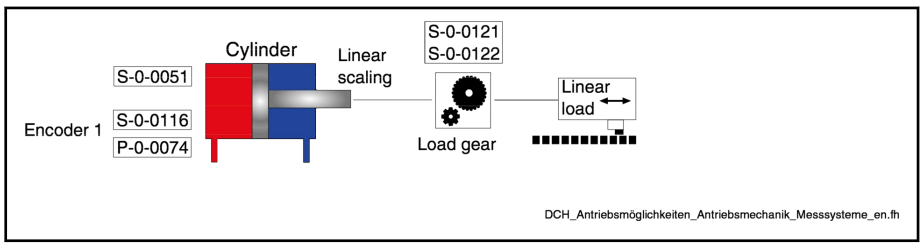


*Fig. 5-1:*

At present, only cylinder drives with linear position sensing are supported. The measurement can be taken at both, the cylinder or the load.

If the encoder is connected to a load, no position gear may be configured.

**Pertinent Parameters**

- S-0-0051, Position feedback value 1
- S-0-0059, Position switch flag parameter
- S-0-0076, Position data scaling type
- S-0-0116, Resolution of feedback 1
- S-0-0123, Feed constant
- S-0-0277, Position feedback 1 type
- S-0-0278, Maximum travel range
- P-0-0074, Encoder type 1
- P-0-0121, Gear 1 motor-side (motor encoder)
- P-0-0122, Gear 1 encoder-side (motor encoder)

## 5.2 Position Measurement

### 5.2.1 Basics on Measuring Systems, Resolution

#### General Information

For acquiring the actual values of the velocity and position control loop, position measuring systems are available that can be configured by the user. For a HydraulicDrive the position measurement is always taken by an external

Drive, Mechanical Axis System, Measuring Systems

position measuring system (encoder), which is mechanically coupled to the hydraulic axis to be controlled.

## Basic Designs

Position measuring systems are available for the different kinds of motion in adapted designs: At present, HydraulicDrives support the following designs with suitable signal specification:

- Linear encoders

Rotary encoders are not yet supported in the current firmware.

## Relative / Absolute Evaluation

Depending on their design and the mechanical mounting to the hydraulic axis, position encoders can be evaluated as

- Relative encoders (incremental encoders)
- 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 when the drive is being switched on. To operate the drive within a limited travel range a position reference must be established ("homing"") each time after the drive is switched on again.

### Absolute Position Measurement

In the case of absolute position measurement, the encoder signals to the drive actual position values with a fixed encoder-dependent reference point. After the drive is switched on the correct actual position value is immediately available in any axis position. Due to the mostly undefined mounting situation of the encoder to the hydraulic axis, it is necessary to determine the position offset ("set absolute position") once during initial commissioning.

## Encoder Types That Can Be Used

The list below shows, which controller types are at present supported in conjunction with a HydraulicDrive:

- Sensorless operation (open-loop operation)
- Simulation encoder
- SSI encoder
- 1Vss encoder
- EnDat 2.2 encoder
- Incremental encoder with square-wave signals (5 V supply, Heidenhain-compatible signal specification)

## Resolution / Accuracy

The accuracy of position mesaurement depends on:

- The resolution of the measuring system
- The absolute encoder precision
- The dimension of the travel range of the axis

# Monitoring the Measuring Systems

## 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
- scaling of the physical data has been changed
- the maximum travel range of an axis has been changed

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 encoder 1 reference

## Encoder Jump Suppression

The actual velocity value is monitored. If the actual velocity value exceeds the effective positive or negative velocity limit (see S-0-0038, Positive velocity limit value, S-0-0039, Negative velocity limit value, S-0-0091, Bipolar velocity limit value and S-0-0113, Maximal-Geschwindigkeit des Antriebs), an encoder jump is recognized. Such an encoder jump can be suppressed by means of encoder jump suppression for a maximum number of velocity controller cycles (P-0-2936.0.6, Maximum number of cycles of encoder jump suppression). During this time, the old actual velocity value is used for further calculations and the actual position value is thus extrapolated. When the encoder jump is no longer present, the current encoder values are used for further calculations.

If the maximum time resulting from P-0-2936.0.6 is exceeded, changing over to the encoder values takes place in any case. Because the monitoring function is again active afterwards, an error is generated via the monitoring functions (e.g. actual velocity value, lag error).

# Absolute Measuring Systems

## Absolute Encoders

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 to the axis and on position data scaling, calculates the travel range of the axis that can be displayed in absolute actual position values.

**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:**

The following parameters indicate the maximum extent of the travel range that may be selected so that an absolute encoder can be evaluated in absolute form:

- S-0-0378, Absolute encoder range of encoder 1

  The user determines the travel range of the axis:

- S-0-0278, Maximum travel range

If the travel range is smaller than the absolute encoder range established by the drive, the relevant control encoder can be evaluated as absolute encoder.

This is indicated in the respective bits of the following parameters:

S-0-0277, Position feedback 1 type

If absolute evaluation of an encoder is possible but not desired, the absolute evaluation can be switched off by setting the respective bit in parameter S-0-0277! The encoder can then only be evaluated in relative form.

### Establishing Absolute Position

The actual position values of an absolute encoder first only relate to the encoder itself. Due to the mostly undefined mounting situation of the encoder to the hydraulic axis, it is necessary to determine the position offset between the encoder zero point and the axis zero point once during initial commissioning.

### Actual Position Value of Encoders to be Evaluated in Absolute Form After Switching on

If only one absolute encoder is available, there are the following cases to be distinguished for the actual position value after the drive has been switched on:

| Absolute evaluation | Actual position value of encoder when switching on | Notes on the commissioning status | Current position status (S–0–0403, bit 0 ... 1) |
|---|---|---|---|
| Active<br>→ evaluation as absolute measuring system | Original position of encoder | Position data reference has not yet been set, encoder is not "in reference". | 0b ... 00 |
| | Absolute encoder value | Position data reference has been set, the encoder is "in reference". | 0b ... 1x |
| Inactive<br>→ evaluation as relative measuring system intended | P-0-0019 | Homing procedure has not yet been carried out, encoder is not "in reference". | 0b ... 00 |
| Not possible<br>→ evaluation as relative measuring system, e.g. due to length of travel range | P-0-0019 | Homing procedure has not yet been carried out, encoder is not "in reference". | 0b ... 00 |

## Relative Measuring Systems

### Measuring Systems

When the drive is switched on, the initial position value (P-0-0019) is written to the actual position values of relative encoders.

| Actual position value when switching on | Notes on the operational state | Current position status (S–0–0403, bit 0 ... 1) |
|---|---|---|
| P-0-0019 | Axis has not moved after switching on, axis has not yet been homed. | 0b ... 00 |
| Absolute encoder value<br>→ evaluation as relative measuring system intended | Axis has been homed via the encoder | 0b ... 11 |

### Pertinent Parameters

- P-0-0019, Initial position value

- P-0-0074, Encoder type 1
- P-0-0121, Gear 1 motor-side (motor encoder)
- P-0-0122, Gear 1 encoder-side (motor encoder)
- P-0-0129, Internal position data format
- P-0-0177, Absolute encoder buffer 1
- P-0-0343, Encoder 1, cosine signal
- P-0-0344, Encoder 1, sine signal
- P-0-0910, SSI control parameter
- P-0-2936.0.6, Maximum number of cycles of encoder jump suppression
- P-0-4014, Type of construction of motor / cylinder
- S-0-0038, Positive velocity limit value
- S-0-0039, Negative velocity limit value
- S-0-0051, Position feedback value 1
- S-0-0059, Position switch flag parameter
- S-0-0060, Position switch point 1 "On"
- S-0-0091, Bipolar velocity limit value
- S-0-0103, Modulo value
- S-0-0116, Resolution of feedback 1
- S-0-0164, Acceleration feedback value 1
- S-0-0256, Multiplication 1
- S-0-0277, Position feedback 1 type
- S-0-0278, Maximum travel range
- S-0-0378, Absolute encoder range of encoder 1
- S-0-0386, Active position feedback value
- S-0-0440, Marker position feedback 1
- S-0-0442, Counter marker position feedback 1
- S-0-0460, Position switch point 1 "Off"

## Pertinent Diagnostic Messages

- F8022, Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)
- E2074, Encoder 1: Encoder signals disturbed

## Hardware Requirements

### Valve Electronics

With regard to the valve electronics (→ HDB) different hardware is available for the different encoder types supported (SSI, 1Vss and EnDat 2.2). This hardware must be ordered separately (for ordering codes, see relevant data sheet)

### Control Cabinet Electronics

With regard to the control cabinet electronics (→ HDC) all possible encoder types (SSI, EnDat 2.2 and incremental) are supported. The required encoder type needs not to be ordered specifically.

Drive, Mechanical Axis System, Measuring Systems

## 5.2.2 Establishing the Position Data Reference

### General Information on Establishing the Position Data Reference

For the actual position values fed back by the measuring systems, a reference to the machine axis must be established. This applies to

- relative measuring systems each time when the drive is switched on
- absolute measuring systems during initial commissioning

**Absolute Measuring Systems**

The position data reference of an absolute measuring system to the axis has to be established once during initial commissioning after a replacement of the encoder or changes in the mechanical axis system. The position data reference is maintained and the actual position values are axis-related immediately after the drive is switched on.

Procedures for establishing the position data reference:

- "Set absolute position" for encoders to be evaluated in absolute form

**Relative Measuring Systems**

The position data reference of a relative measuring system to the axis has to be re-established each time when the drive is switched on or after the position data reference is lost (switching to PM). For this it is necessary to move to a defined axis position and set the actual position value to an axis-related value in a defined position.

Procedures for establishing the position data reference:

- "Drive-controlled homing procedure" for relative encoders

- or -

- "NC-controlled homing procedure" for relative encoders

**Indicating the Position Data Reference**

The position status parameter (S-0-0403) signals whether the position data reference of a measuring system has been established.

**Actual Position Value Offset**

The difference of the actual position value before and after having established the position data reference is shown in offset parameter 1 (S-0-0175).

The respective values are written to the offset parameter 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!

**Clearing the Position Data Reference**

By activating parameter "S-0-0191, C1500 Cancel reference point procedure command" it is possible to clear the position data reference of the encoder selected via bit 3 of "S-0-0147, Homing parameter". The respective bits of parameter "S-0-0403, Position feedback value status" are thereby reset (cleared), too.

**Pertinent Parameters**

- P-0-0014, C1400 Command Get marker position
- P-0-0153, Optimum distance home switch-reference mark
- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- S-0-0052, Reference distance 1
- S-0-0146, C4300 NC-controlled homing procedure command
- S-0-0147, Homing parameter
- S-0-0148, C0600 Drive-controlled homing procedure command
- S-0-0150, Reference offset 1
- S-0-0165, Distance-coded reference offset A
- S-0-0166, Distance-coded reference offset B

- S-0-0171, C4400 Calculate displacement procedure command.
- S-0-0172, C4500 Displacement to referenced system procedure command.
- S-0-0173, Marker position A
- S-0-0175, Offset parameter 1
- S-0-0177, Absolute offset 1
- S-0-0191, C1500 Cancel reference point procedure command
- S-0-0298, Reference cam shift
- S-0-0299, Home switch offset
- S-0-0400, Home switch
- S-0-0403, Position feedback value status
- S-0-0404, Position command value status
- S-0-0407, Homing enable
- S-0-0408, Reference marker pulse registered
- S-0-0447, C0300 Set absolute position procedure command
- S-0-0448, Set absolute position control

**Pertinent Diagnostic Messages**

- C0300, Set absolute position procedure command
- C0301, Measuring system unavailable
- C0302, Absolute evaluation of measuring system impossible
- C0303, Absolute encoder offset cannot be saved
- C0304, Command cannot be executed under drive enable
- C0600, Drive-controlled homing procedure command
- C0601, Homing only possible with drive enable
- C0602, Distance home switch - reference mark erroneous
- C0603, Homing impossible with optional encoder
- C0604, Homing impossible with absolute encoder
- C0606, Reference mark not detected
- C0607, Reference cam input not assigned
- C0608, Pos. stop a. HW lim. switch not allowed f. modulo axes
- C0609, Different travel directions parameterized
- C0610, Absolute encoder offset could not be saved
- C1400, Command Get marker position
- C1402, Faulty reference mark signal
- C1500, Cancel reference point procedure command
- C4300, NC-controlled homing procedure command
- C4302, Distance home switch - reference mark erroneous
- C4304, Homing impossible with absolute encoder
- C4306, Reference mark not detected
- C4307, Reference cam input not assigned
- C4308, Pos. stop a. HW lim. switch not allowed f. modulo axes
- C4400, Calculate displacement procedure command
- C4500, Displacement to referenced system procedure command

Drive, Mechanical Axis System, Measuring Systems

**Interrelationships**

Establishing the position data reference is provided by the functional package "Closed Loop“.

## Establishing Position Data Reference for Absolute Measuring Systems

### Brief Description

**Base package** of all variants with **closed-loop** characteristic.

See also section "General Information on Establishing the Position Data Reference".

The position data reference of an absolute measuring system to the axis has to be established once during initial commissioning, after a replacement of the encoder or changes in the mechanical axis system.

**Establishing Position Data Reference via Drive Commands**

In the case of measuring systems to be evaluated in absolute form, the position data reference can be automatically established by the drive by starting the command

- "C0300Set absolute position procedure command"

- or -

- "C0600Drive-controlled homing procedure command".

Once established, the position data reference is maintained until one of the two commands is executed again. The actual position values therefore are axis-related ("homed") immediately after the drive is switched on.

**Command "Set Absolute Position"**

It is recommended to start the "set absolute position" command when the axis is at standstill without drive enable. In cases in which the axis, for establishing the position data reference, is to be brought to a defined position on the master side and held in this position by the drive, "set absolute position" can also be executed while the drive is active.

**Command "Drive-Controlled Homing Procedure"**

Upon the start of command "C0600Drive-controlled homing procedure command" without a reference, the drive moves the axis automatically as defined in parameter "S-0-0147, Homing parameter", thus establishing the position data reference. If the position system of the drive is already referenced when the command "C0600Drive-controlled homing procedure command" is started, the reference point already established is approached and then the command is positively acknowledged.

For absolute encoders, the command "drive-controlled homing procedure" is useful in the case of loss of position data reference after:

- encoder replacement in conjunction with a home switch or
- encoder error with peripheral causes in the case of modulo-scaled axes (e.g. encoder cable damage).

"Active drive" means the drive that is in control. The drive enable ("AF") has been set.

**Assigning the Axis-Related Actual Position Value with "Set Absolute Position"**

By starting the command "set absolute position", the previous actual position value of an encoder at a dedicated position of the axis is set to a new value. This value is the current axis position related to the coordinate system of the machine.

The dedicated position is defined by:

- the current axis position

- or -

- positioning of the axis at a "striking" axis position (e.g. value "0").

The required assignments and configurations for "setting absolute position" are realized via parameter settings.

**Assigning the Axis-Related Actual Position Value with "Drive-Controlled Homing"**

By starting the command "drive-controlled homing", the previous actual position value of an encoder at a dedicated position of the axis is set to a new value. This value is the current axis position related to the coordinate system of the machine.

The necessary assignments and configurations for "drive-controlled homing procedure" are made via parameter settings (see details on "drive-controlled homing procedure" in the section "Establishing position data reference for relative measuring systems").

**Pertinent Parameters**

- S-0-0052, Reference distance 1
- S-0-0148, C0600 Drive-controlled homing procedure command
- S-0-0447, C0300 Set absolute position procedure command
- S-0-0448, Set absolute position control
- P-0-0177, Absolute encoder buffer 1

**Pertinent Diagnostic Messages**

- C0300 Set absolute position procedure command
- C0301 Measuring system unavailable
- C0302 Absolute evaluation of measuring system impossible
- C0303 Absolute encoder offset cannot be saved
- C0304 Command cannot be executed under drive enable
- C0600 Drive-controlled homing procedure command
- C0601 Homing only possible with drive enable
- C0602 Distance home switch - reference mark erroneous
- C0603 Homing impossible with optional encoder
- C0606 Reference mark not detected
- C0607 Reference cam input not assigned
- C0608 Pos. stop a. HW lim. switch not allowed f. modulo axes
- C0609 Different travel directions parameterized
- C0610 Absolute encoder offset could not be saved

## Functional Description

### Command "Drive-Controlled Homing Procedure" with Absolute Measuring Systems

**Application-Related Aspect**

The command "drive-controlled homing procedure" is mainly used for homing relative measuring systems. The position data reference of a relative encoder must be re-established each time the drive is switched on again (or when changing from communication phase "P2" to "bb" or "Ab" or when changing over from PM to OM).

The function "drive-controlled homing procedure" is described in section "Establishing Position Data Reference for Relative Measuring Systems".

In the case of absolute measuring systems, the position data reference to the axis only has to be established once during initial commissioning (or after encoder replacement or encoder error, for example).

If "S-0-0148, C0600 Drive-controlled homing procedure command" is to be used for homing an absolute measuring system, the relevant bit in parameter "S-0-0448, Set absolute position control" must be set.

**Absolute Offset**

When "C0600 Drive-controlled homing procedure command" was successfully completed, an absolute offset value was determined. This value is used for calculation together with the encoder-side absolute values, stored in the encoder and the reference bit is set in parameter "S-0-0403, Position feedback value status". The position data reference has now been established and the actual position value is valid. This is also valid immediately each time the drive is switched on again.

## Command "Set Absolute Position"

**Dedicated Position**

By starting the "C0300 set absolute position procedure command", the previous actual position value of an encoder at a dedicated position of the axis is set to a new value. The dedicated position corresponds to the current axis position at the start of the command.

The new actual position value at the dedicated position after "set absolute position" is the value of parameter

- "S-0-0052, Reference distance 1"

$$\text{Encoder 1 S-0-0051}_{new} = \text{S-0-0052}$$

**S-0-0051** Position feedback 1 value
**S-0-0052** Reference distance 1

*Fig. 5-2: Actual Position Values after "Set Absolute Position"*

**Storing the Absolute Encoder Offset**

In order that an encoder, which can be evaluated in absolute form, maintains the position data reference to the axis after "set absolute position", the absolute encoder offset is stored in the parameter memory (P-0-0177).

**Possible Operational States Before "Set Absolute Position"**

The "C0300 set absolute position procedure command" can be activated in the following operational states:

- Drive is ready for operation, but not active ("OM", "bb", "Ab")
- Drive is active in position control ("AF")
- Drive is active and in "Drive Halt" ("AH")

☞ In the last two cases, when the drive is active, bit 2 "set absolute position procedure command allowed with drive enable (AF)" of parameter "S-0-0448, Set absolute position control" must be set.

**Sequence for "Set Absolute Position" while the Drive is Inactive ("OM", "bb", "Ab") or in "Drive Halt (AH)"**

When the "C0300 set absolute position procedure command" is started, the reference of the selected encoder is cleared first (S-0-0403).

After the reference was cleared, while the drive is inactive ("OM", "bb" or "Ab") and when the drive is in "Drive Halt (AH)", the new position feedback value (S-0-0051) is set according to the preselected dedicated position (see formula in "Dedicated Position" on page 178, "Actual position values after "set absolute position")". The new position reference takes immediate effect.

**Sequence of "Set Absolute Position" when the Drive is Enabled ("AF")**

When the "C0300 set absolute position procedure command" is started, the reference of the selected encoder is cleared first (S-0-0403).

After the reference was cleared and when the drive is active, there are the following possibilities regarding the changeover of the actual position value to the new position reference:

- Deactivating the drive enable

→ When the drive goes to the inactive state, the new actual position value (S-0-0051) is set according to the preselected dedicated position (see formula fig. 5-2 " Actual Position Values after Set Absolute Position" on page 178) .

- Starting the "drive-controlled homing procedure" command:

  → The drive no longer follows the command values. The new position feedback value (S-0-0051) is set (see formula fig. 5-2 " Actual Position Values after Set Absolute Position" on page 178), and the drive signals that the "drive-controlled homing" command was executed. The master now has to "synchronize" to the new actual position value of the encoder used in the active operation mode. After the master cleared the "drive-controlled homing procedure" command, the drive goes to master-controlled operation again.

**Sequence of "Set Absolute Position" After Position Reference Has Been Established**

When the "C0300 set absolute position procedure command" is started, the reference of the selected encoder is cleared first (S-0-0403).

When the new position reference of the encoder has been established, the reference of the respective encoder is displayed in "S-0-0403, Position feedback value status" and the absolute encoder offset is stored. Finally, the "set absolute position" command has to be cleared by the master!

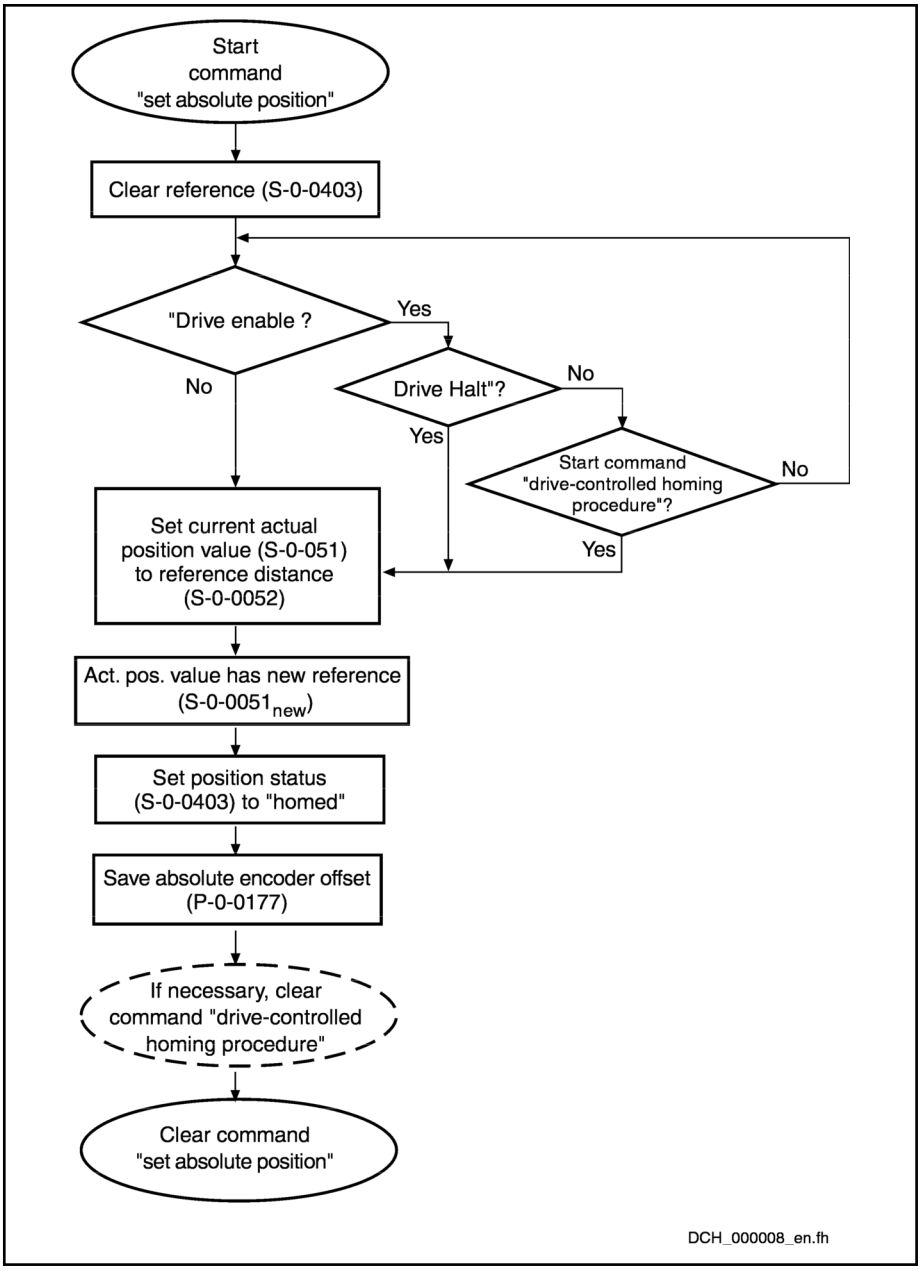


*Fig. 5-3: Sequence of "Set Absolute Position" Command Execution*

## Notes on Commissioning

See also notes on commissioning for "General Information on Establishing the Position Data Reference"

**Checking the Possibility of Absolute Encoder Evaluation**

The possibility of absolute evaluation of encoder 1 is displayed by the respective bits of

- "S-0-0277, Position feedback 1 type"

See also "Absolute Measuring Systems" and "Relative Measuring Systems"

**Presetting**

In "S-0-0448, Set absolute position control" presettings must be made for "set absolute position":

- The encoder for "set absolute position" must be determined.

- It must be determined, whether the execution of the command "C0300Set absolute position procedure command" is also allowed when the drive enable (AF) is given, and whether the execution of "S-0-0148, C0600 Drive-controlled homing procedure command" is to be possible with an absolute measuring system.

See commissioning notes on "drive-controlled homing procedure" in section "Establishing Position Data reference for Relative Measuring Systems".

**Starting "Set Absolute Position"**

Starting the command "S-0-0447, C0300 Set absolute position procedure command".

See also section Command Processing

**If Necessary, Start of "Drive-Controlled Homing Procedure"**

If "set absolute position" is to be carried out with active drive, you either have to start the command "S-0-0148, C0600 Drive-controlled homing procedure command" or bring the drive to the status "Drive Halt" (AH) to switch the actual position value over. Withdrawing the drive enable (inactive drive) also results in a changeover of the actual position value (see chapter "Command Set Absolute Position" on page 178).

**Procedure**:

Set the drive to drive enable (AF) and start "S-0-0447, C0300 Set absolute position procedure command"; the further proceeding is as follows:

- Start "S-0-0148, C0600 Drive-controlled homing procedure command"

  or

- trigger "Drive Halt" (AH)

  or

- withdraw the drive enable (AF)

Any of the above options results in the actual position value being set to a new value:

- According to the interrelationships with "C0600Drive-controlled homing procedure command"
- According to "S-0-0052Reference distance 1" or "S-0-0054, Reference distance 2" with "AH" or withdrawal of "AF"

After the changeover of the actual position value, command C0300 must be reset.

See also section "Command Processing"

**Checking Whether Position Data Reference was Established**

The respective bit of the parameter "S-0-0403, Position feedback value status" displays whether the encoder selected via "S-0-0448, Set absolute position control" has been homed.

If the absolute encoder had already been homed, the respective bit only changes for a short time during command execution!

When "set absolute position" was executed again for an absolute encoder, a value for the "offset" of the actual position values before and after command execution is entered in:

- S-0-0175, Offset parameter 1

**Clearing the Executed Commands**

After the commands have been executed (diagnosis possible via parameter "S-0-0403, Position feedback value status"), the commands started have to be cleared again in reverse order when "set absolute position" is carried out via command "drive-controlled homing procedure".

**Change of Encoder**

If an absolute encoder was replaced, the position data reference has to be established again.

Drive, Mechanical Axis System, Measuring Systems

# Establishing Position Data Reference for Relative Measuring Systems (Homing)

## Brief Description

**Base package** of all variants with **closed-loop** characteristic.

See also section "General Information on Establishing the Position Data Reference"

**Actual Position Value of Relative Measuring Systems when Switching On**

After the drive is switched on the actual position values signaled by relative measuring systems do not yet have any reference to the machine axis.

For the arrangement of encoders and the mechanical axis system, see also "mechanical axis system and arrangement of measuring system"

The position data reference of relative measuring systems to the axis has to be established again each time the drive is switched on or after all procedures that cause the position data reference to get lost (homing procedure).

**Establishing the Position Data Reference, Drive-Controlled**

After start of the respective command by the master, the drive can automatically establish the position data reference.

To do this, the drive moves the axis until the controller can detect a dedicated point. The actual position values are then automatically switched to axis reference. The presettings for the sequence for establishing the position data reference are made via assigned parameters.

**Establishing the Position Data Reference, NC-Controlled**

As an alternative to establishing the position data reference in a drive-controlled way, the NC ("master") can control the homing procedure.

In this case the master provides the command values for moving the axis to the dedicated point and controls the homing procedure via commands and assigned parameters.

The NC-controlled homing procedure can be advantageous for drives with a rigid mechanical connection, because the master can input coordinated command values for the drives for the homing motion.

**Dedicated Point for Establishing the Position Data Reference**

In the case of linear axes, the dedicated point for establishing the position data reference is at one end of the travel range. This allows finding the dedicated point from any axis position (situation when switched on) by moving in a defined direction. Rotary axes do not have an axis end position; the dedicated point is at a defined position within the travel range.

**Reference Mark for Relative Measuring Systems**

The precision with which this dedicated point is detected has a considerable influence on the absolute precision of the axis. Apart from the signals for position detection, relative measuring systems therefore also provide a signal for the 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 on axes performing a linear movement, the reference mark of the encoder can occur several times over the entire travel range. In this case it is required to identify **one** reference mark signal by activation of a switch contact on the axis side at the end of the travel range. This defines an unequivocal dedicated point that can be found with reproducible precision. This switching contact is called "home switch". A travel range limit switch, if available, can be used like a home switch, too.

In addition, a reference mark signal can be identified by detecting axis blocking when the positive stop at the end of the axis has been reached.

Irrespective of the number of reference marks over the travel range, an axis-side additional device (home switch or travel range limit switches or positive stop), is indispensable for linear axes for detecting the axis end position!

If only one reference mark occurs over the travel range in the case of rotary axes, a home switch is not required in most cases!

**Dedicated Point and Reference Point of an Axis**

The dedicated point identified by an encoder reference mark and, if necessary, by a home switch, is in most cases 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 the dedicated point and the reference point of the axis can be compensated by an offset value (reference offset).

See also section "General Information on Establishing the Position Data Reference"

**Pertinent Parameters**

Parameters for relative measuring systems:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- S-0-0052, Reference distance 1
- S-0-0108, Feedrate override
- S-0-0147, Homing parameter
- S-0-0148, C0600 Drive-controlled homing procedure command
- S-0-0150, Reference offset 1
- S-0-0173, Marker position A
- S-0-0191, C1500 Cancel reference point procedure command
- S-0-0298, Reference cam shift
- S-0-0299, Home switch offset
- S-0-0349, Bipolar jerk limit
- S-0-0400, Home switch
- S-0-0403, Position feedback value status
- P-0-0153, Optimum distance home switch-reference mark

Parameters for NC-controlled homing:

- S-0-0146 C4300 NC-controlled homing procedure command
- S-0-0171, C4400 Calculate displacement procedure command.
- S-0-0172, C4500 Displacement to referenced system procedure command.
- S-0-0175, Offset parameter 1
- S-0-0404, Position command value status
- S-0-0407, Homing enable
- S-0-0408, Reference marker pulse registered

Parameters for relative measuring systems, distance-coded:

- S-0-0165, Distance-coded reference offset A
- S-0-0166, Distance-coded reference offset B
- S-0-0177, Absolute offset 1

Parameters for homing at travel range limit switches:

- S-0-0532, Travel range limit parameter (Alias: P-0-0090, Travel range limit parameter)
- P-0-0222, Travel range limit switch inputs

Parameters for homing at positive stop:

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0331, Status "n_feedback = 0"
- S-0-0333, Status "T >= Tx"

**Pertinent Diagnostic Messages**

Diagnostic messages for drive-controlled homing:

- C0600 Drive-controlled homing procedure command
- C0601 Homing only possible with drive enable
- C0602 Distance home switch - reference mark erroneous
- C0606 Reference mark not detected
- C0607 Reference cam input not assigned

Diagnostic messages for NC-controlled homing:

- C4302 Distance home switch - reference mark erroneous
- C4304 Homing impossible with absolute encoder
- C4306 Reference mark not detected
- C4307 Reference cam input not assigned
- C4308 Pos. stop a. HW lim. switch not allowed f. modulo axes
- C4400 Calculate displacement procedure command

## Functional Description

### General Information

**Type and Arrangement of Reference Marks**

Relative measuring systems can have one or several reference marks in terms of type and arrangement:

**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 perform the following movement over the dedicated point (drive-controlled or NC-controlled):

**Identifying a Dedicated Point**

To identify a dedicated point of an axis the following signals can be used:

- Reference marks of the encoder
- Home switch at the axis
- Travel range limit switches
- Axis blocking when positive stop at the end of travel range has been reached (positive stop detection)

The reference mark signal of an encoder is generally used for detecting the position of the dedicated point because this signal allows detecting the position within the framework of the encoder precision.

Depending on the encoder type and the mechanical arrangement of the encoder in the mechanical drive system, reference mark signals can occur **once or several times** within the travel range of an axis.

If the reference marks occur several times, only one reference mark signal may determine the dedicated point at an unequivocal axis position. Identifying a mark signal requires one of the following axis-side additional devices:

- Travel range limit switches
- Home switch (if no travel range limit switch is available)
- Positive stop at the end of the axis (if no switches are to be used)

☞ The mentioned axis-side additional devices are also used for detecting the end of the axis during the homing procedure.

| Encoder | Number of reference mark signals occurring over the travel range | | | |
|---|---|---|---|---|
| | One signal | | Several signals | |
| | Rotary axis | Linear axis | Rotary axis | Linear axis |
| Rotary encoder | AD: No | AD: Yes | AD: Yes (home switch) | AD: Yes |
| Rotary encoder | --- | AD: Yes | --- | AD: Yes |

**AD** Additional device

*Tab. 5-1: Recommendation for Axis-Side Additional Devices (AD) for Determining the dedicated point*

In "S-0-0147, Homing parameter" select, which signals are to be evaluated by the controller for determining the dedicated point (reference marks and/or home switches, travel range limit switches or positive stop).

☞ If there is no reference mark signal available on the encoder side, the edge reversal of the home switch signal or the travel range limit switch signal or the detection of the positive stop can also be used for detecting the dedicated point. This has to be set in parameter S-0-0147 by deactivating the reference mark evaluation (only possible with drive-controlled homing!).

**Reference Point, Axis Zero Point and Dedicated Point**

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, is mostly influenced by the encoder arrangement. The position difference between reference point and dedicated point is transmitted to the controller via the so-called reference offset.

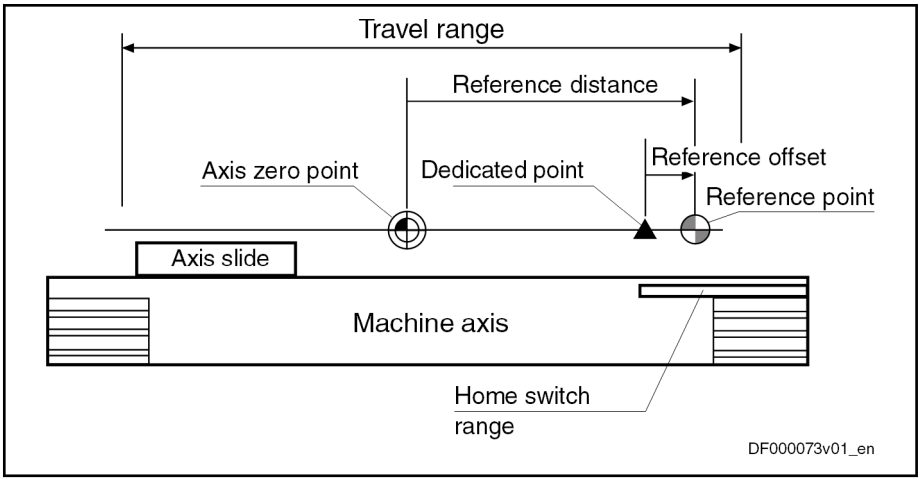


*Fig. 5-4: Example of positions of axis zero point, dedicated point and reference point*

The reference offset is specified in parameter S-0-0150, Reference offset 1.

The reference distance S-0-0052, Reference distance 1 is the distance of the reference point from the axis zero point.

**Detecting the End of the Travel Range**

When homing relative measuring systems, the axis always has to be moved in a defined direction (to be determined) so that the dedicated point can be reliably identified. As a prerequisite the axis has to be within the allowed travel range.

But the axis, when the search for the dedicated point is started, can also already be at that end of the axis at which the dedicated point is situated. For a reliable detection of the dedicated point the drive has to be able to recognize this situation. This is only possible by means of axis-side additional devices (AD):

- Home switch at end of axis
- Travel range limit switches
- Positive stop at end of axis for axis blocking (detection of positive stop)

One of these devices has to be mounted at the end of the axis with the dedicated point, and its signals have to be evaluated by the drive controller.

For NC-controlled homing a home switch is obligatory! For NC-controlled homing, travel range limit switches and positive stop can neither be used for detecting the end of the travel range nor for identifying the dedicated point.

The status "activated" (switching logic) of home switch and travel range limit switch is set in the following parameters:

- "S-0-0147, Homing parameter" for the home switch ("edge evaluation...")
- "P-0-0090, Travel range limit parameter" for the travel range limit switch ("signal behavior")

## Identifying the Dedicated Point by Means of Reference Mark and Home Switch

**Home Switch for Selecting a Reference Mark**

If several reference mark signals can occur over the travel distance of an axis and the dedicated point is to be determined by one of the marks, for drive-controlled homing a home switch can be used as axis-side additional device for selecting a reference mark.

For NC-controlled homing, a reference switch on the axis side is obligatory!

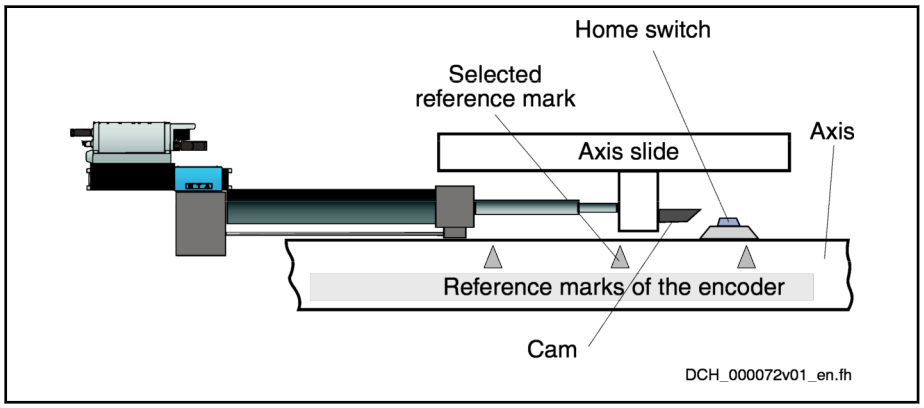


*Fig. 5-5: Selecting a Reference Mark via Home Switch Using the Example of a Linear Axis*

After the start of drive-controlled or NC-controlled homing, the dedicated point is detected when the first reference mark signal occurs after the "activated" signal of the home switch.

**Arranging the Home Switch**

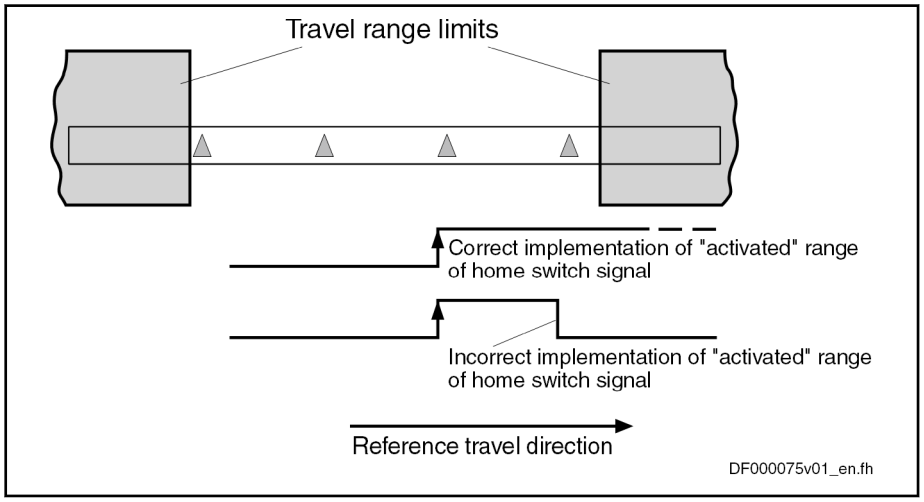


*Fig. 5-6: Arrangement of the Home Switch with Regard to Travel Range Limits Using a Linear Axis as Example*

In the case of linear axes, the "activated" range of the home switch has to reach beyond the next travel range limit. The home switch signal thereby indicates the proximity of the end of the travel range if the reference travel direction was appropriately selected. The travel range limit is not passed during the homing procedure when the "activated" range of the home switch signal begins with sufficient distance to the travel range limit!

**Distance Dedicated Point – Travel Range Limit for Linear Axes with Home Switch**

The distance between dedicated point (first reference mark after home switch signal) and travel range limit is sufficient, if the drive can safely shut down the axis out of maximum homing velocity (S-0-0041 for drive-controlled homing) with homing acceleration (S-0-0042 for drive-controlled homing) within the travel range. The following applies to the minimum distance between home switch and travel range limit:

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$$x_{HS_TrLimit} \geq x_{RefMarks} + \frac{v^2}{2 \times a}$$

$x_{RS_VbLimit}$ minimum distance to travel range limit
$x_{RefMarks}$ distance between the reference marks on the axis
**v** homing velocity (value of S-0-0041 or preset by NC)
**a** homing acceleration (value of S-0-0042 or preset by NC)

*Fig. 5-7: Minimum Distance of Home Switch Signal to Travel Range Limit*

☞ Generally, several reference marks may occur in the "activated" range of the home switch signal!

☞ For rotary axes a home switch is only required when a gear with a gear ratio unequal to "1" was installed between the axis and the drive!

**Axis Position when Switching on, Detection of End of Travel Range**

When the axis drive is switched on, the real axis can be at any position within the travel range, also at the end of the travel range. The home switch mounted at the end of the axis can be activated.

It must be possible to carry out the homing procedure even from this start position:

- In the case of drive-controlled homing, the drive automatically passes the dedicated point depending on the signal status and the settings for the "activated" signal of the home switch.
- In the case of NC-controlled homing, the master has to set the required command values so that the dedicated point can be unequivocally detected.

**Searching for the Dedicated Point in the Case of an Axis with Home Switch**

The drive must move the axis in the determined homing direction to the end of the axis to start the search for the dedicated point after having recognized the "activated" signal. The end of the travel range is also detected via the signal status of the home switch.

| Determined edge evaluation (S-0-0147) | Signal status of home switch (bit in S-0-0400) | Drive action |
|---|---|---|
| Positive | 0 ("not actuated") | Motion in reference travel direction until home switch is actuated, then search for dedicated point after positive signal edge was detected |
| Negative | 1 ("not actuated") | Motion in reference travel direction until home switch is actuated, then search for dedicated point after negative signal edge was detected |
| Negative | 0 ("actuated") | Motion against reference travel direction until home switch is not actuated, then reversal of motion; search for dedicated point after negative signal edge was detected |
| Positive | 1 ("actuated") | Motion against reference travel direction until home switch is not actuated, then reversal of motion; search for dedicated point after positive signal edge was detected |

*Tab. 5-2: Movements of the drive for searching the dedicated point, depending on the axis position (drive-controlled or NC-controlled)*

**Connecting the Home Switch**

With drive-controlled homing, the home switch must be connected to the assigned digital input of the HydraulicDrive. Observe the allowed signal levels! The signal status of the home switch is shown in parameter "S-0-0400, Home switch".

For "NC-controlled homing", the obligatory home switch can be connected either to the drive controller or to the master (NC control unit)!

See "Digital Inputs/Outputs"

**Activating the Evaluation of Reference Marks and Home Switch**

The evaluation of the reference marks and the home switch signal have to be activated in the respective bit of "S-0-0147, Homing parameter". The evaluation of the travel range limit switch and positive stop mustn't be activated at the same time!



If the evaluation of the reference marks has not been activated, the dedicated point is determined only by the signal of the home switch!

## Identifying the Dedicated Point by Means of Reference Mark and Travel Range Limit Switch

**Travel Range Limit Switch for Selecting a Reference Mark**

A travel range limit switch, too, can be used as axis-side additional device (AD) for selecting a reference mark, if several reference mark signals can occur over the travel distance of an axis and the dedicated point is to be determined by one of the marks.

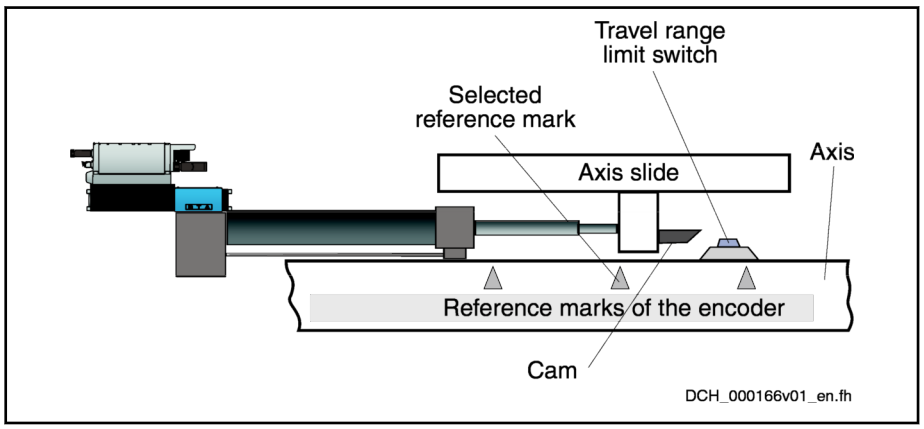


*Fig. 5-8: Selecting a Reference Mark via Travel Range Limit Switch*

After the start of drive-controlled homing (command C0600), the axis is moved in the determined direction of motion until the travel range limit switch is actuated. The drive then changes the direction of motion, the dedicated point is detected when the first reference mark signal occurs.

If the travel range limit switches for hardware-side limitation of the allowed travel range have been actuated, this monitoring function is deactivated during the homing procedure!

**Axis Position when Switching on; Detecting the End of the Travel Range**

When the axis drive is switched on, the real axis can be at any position within the travel range, also at the end of the travel range. The travel range limit switch mounted at the end of the axis can be activated.

It must be possible to carry out the homing procedure even from this start position. In the case of drive-controlled homing, the drive automatically passes the dedicated point depending on the signal status and the settings for the "activated" signal of the travel range limit switches.

**Searching for the Dedicated Point on Axis with Travel Range Limit Switch**

The drive must move the axis in the determined reference travel direction to the end of the axis to start the search for the dedicated point after a signal change of the travel range limit switch.

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| Determined signal behavior of travel range limit switch (P-0-0090) | Signal status of travel range limit switch (P-0-0222) | Drive action |
|---|---|---|
| Not inverted | 0 ("not actuated") | Movement in reference travel direction when limit switch activated, reversal of motion and search for dedicated point |
| Inverted | 1 ("not actuated") | See line above |
| Inverted | 0 ("actuated") | Movement against reference travel direction until limit switch is not activated, then search for dedicated point |
| Not inverted | 1 ("actuated") | See line above |

*Tab. 5-3: Drive movements for search for dedicated point at the start of command C0600 (in the case of use of travel range limit switches), depending on the axis position*

**Connecting the Travel Range Limit Switches**

The travel range limit switches have to be connected to the assigned digital inputs of the control section of the drive controller. Observe the allowed signal levels! The signal status of the respective travel range limit switch is displayed in parameter "P-0-0222, Travel range limit switch inputs".

See "Digital Inputs/Outputs"

**Activating the Evaluation of Reference Marks and Travel Range Limit Switch**

The evaluation of the reference marks and the travel range limit switch as additional devices for homing has to be activated in the respective bits of "S-0-0147, Homing parameter".

The evaluation of the home switch and/or positive stop mustn't be activated at the same time!

If evaluation of the reference marks has not been activated, the dedicated point is determined only by the signal of the travel range limit switch!

## Identifying the Dedicated Point by Means of Reference Mark and Positive Stop

**Positive Stop for Selecting a Reference Mark**

A positive stop on an axis, too, can be used as axis-side additional device (AD) for selecting a reference mark, if several reference mark signals can occur over the travel distance of an axis and the dedicated point is to be determined by one of the marks.

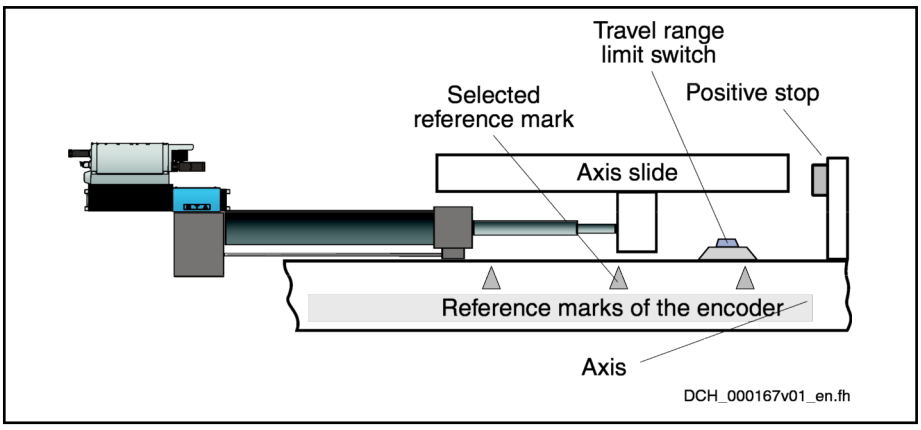



*Fig. 5-9: Selecting a Reference Mark via Positive Stop at the End of the Axis*

**Detecting the End of Travel Range by Axis Blocking (Positive Stop)**

After the start of drive-controlled homing (command C0600), the drive first moves in the determined reference travel direction (see S-0-0147). There is no switch signal required for identifying the end of the axis!

**Search for Dedicated Point**

The axis continues to move until it is blocked by a positive stop.

When the positive stop was recognized,

- condition 1: Standstill of the drive was recognized ("S-0-0331, Status "n_feedback = 0"") and
- condition 2:
  - The force controller is active (S-0-0084, Torque/force feedback value) and exceeded the torque/force limit value (minimum of S-0-0092 and S-0-0082 or S-0-0092 and S-0-0083) or
  - the following distance (S-0-0189) is greater than the monitoring window (S-0-0159),

the drive changes the direction of motion, the dedicated point is determined by the occurrence of the first reference mark signal.

**Activation of Axis Blocking Detection (Positive Stop) for Homing Procedure**

The evaluation of the reference marks and the positive stop as additional devices for homing has to be activated in the respective bits of "S-0-0147, Homing parameter". The evaluation of the home switch and/or travel range limit switch mustn't be activated at the same time!

Monitoring of position command value, actual position value and acceleration is switched off during the homing procedure!

If travel range limit switches for hardware-side limitation of the allowed travel range have been activated, monitoring of this limitation is deactivated during the homing procedure!

## Requirements for Selecting a Reference Mark

If an axis-side additional device (AD), such as home switch, travel range limit switch or positive stop at the end of the axis, is to be used for selecting a reference mark signal (in the case of several signals occurring over the travel range), you have to make sure that it is always the same reference mark signal that is evaluated by the controller for detecting the position of the dedicated point!

Activation of the home switch or the travel range limit switch or detection of positive stop is detected by the controller with a position inaccuracy inherent in the system. This inaccuracy depends on the following factors:

- The reading cycle of the digital input via which the home switch or the travel range limit switch is evaluated (corresponding to the position loop cycle when command C0600 is executed)
- Position loop cycle when using a positive stop when command C0600 is executed
- Actual velocity value at which the axis moves during the homing procedure

Within the range of inaccuracy of position detection there mustn't occur any encoder reference mark, because a reliably reproducible detection of the dedicated point is impossible within this range!

Drive, Mechanical Axis System, Measuring Systems

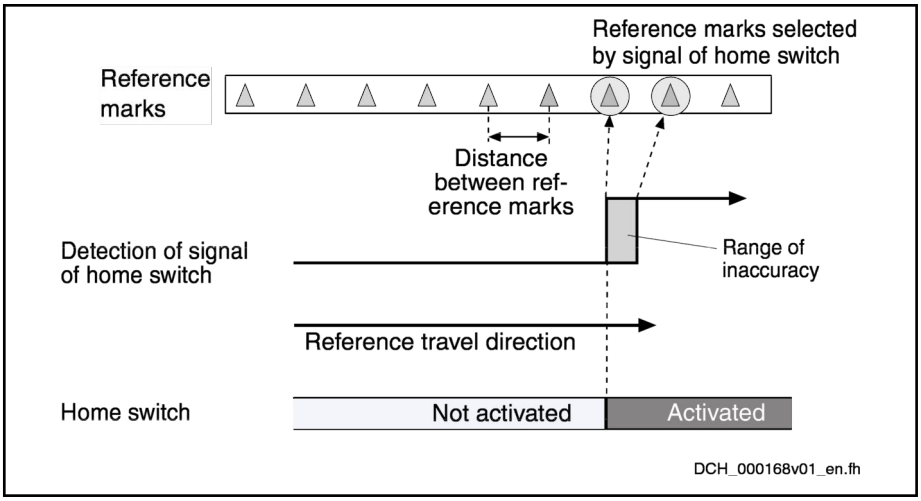



*Fig. 5-10: Ambiguous Detection of Reference Marks within the Inaccuracy Range of Home Switch Detection*

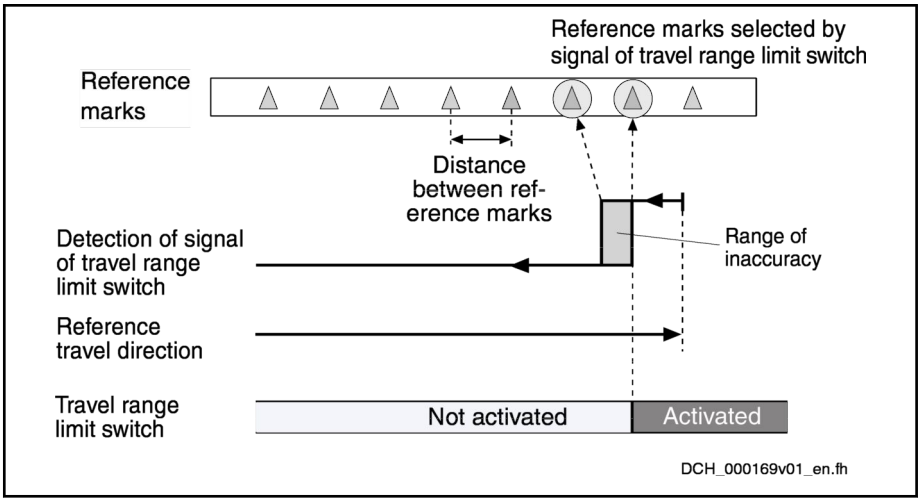



*Fig. 5-11: Ambiguous Detection of Reference Marks within the Inaccuracy Range of Travel Range Limit Switch or Positive Stop Detection*

**Distance Monitoring Switch Edge or Positive Stop Detection/Reference Mark**

Due to the range of position inaccuracy of the switch edge or positive stop detection, the distance to the position of the next reference mark is monitored. If the distance falls below a certain value, the error message "C0602Distance home switch - reference mark erroneous" is generated.

| Classification of distance | Distance | Drive reaction |
|---|---|---|
| Critical distance | < 0.25 × reference mark distance | Shutdown with message C0602 |
| Optimum distance | 0.5 × reference mark distance | -- |
| Allowed distance range | (0.25 … 0.75) × reference mark distance | -- |

*Tab. 5-4: Data Regarding the Distance Between Switch Edge or Positive Stop Detection and Reference Mark*

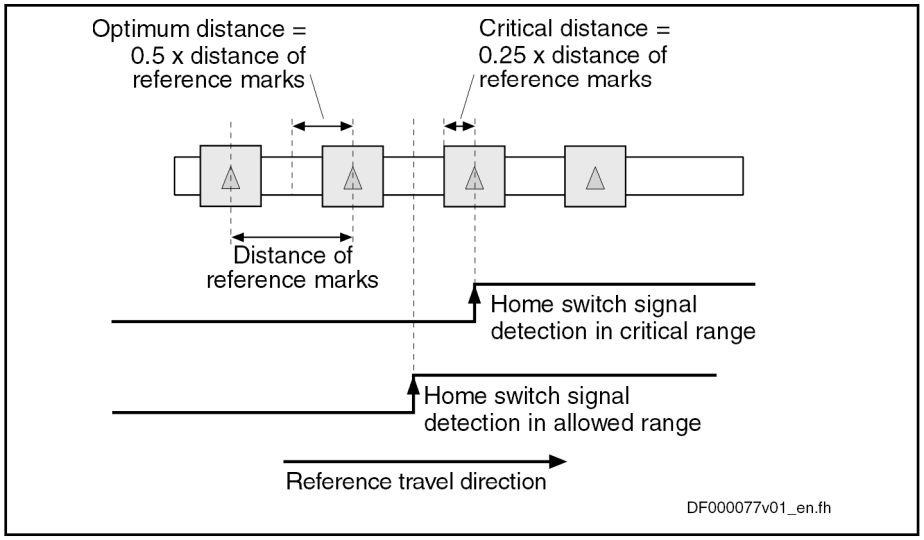



*Fig. 5-12: Critical and Optimum Distance of Switch Edge and Reference Mark in the Case of the Home Switch*

To monitor the distance, the optimum distance has to be preset in parameter "P-0-0153, Optimum distance home switch-reference mark".

For input values of P-0-0153 for distance monitoring to the next reference mark in the case of switch edge or positive stop detection, see separate documentation "Parameter Description"

**Distance Correction**

For each homing procedure with home switch, travel range limit switch or positive stop detection as well as reference mark evaluation, the difference between the actual distance to the next reference mark and the optimum distance is monitored. The difference is stored in parameter "S-0-0298, Reference cam shift". For optimum setting of the home switch or travel range limit switch, these switches can be mechanically shifted by the value of S-0-0298.

The distance can also be optimized drive-internally without mechanical shifting. In this case, the controller shifts the activation of the reference mark evaluation after detection of the switch edge or axis blocking (positive stop) by the value specified in parameter "S-0-0299, Home switch offset". For this purpose, the value of S-0-0298 has to be entered in parameter S-0-0299.

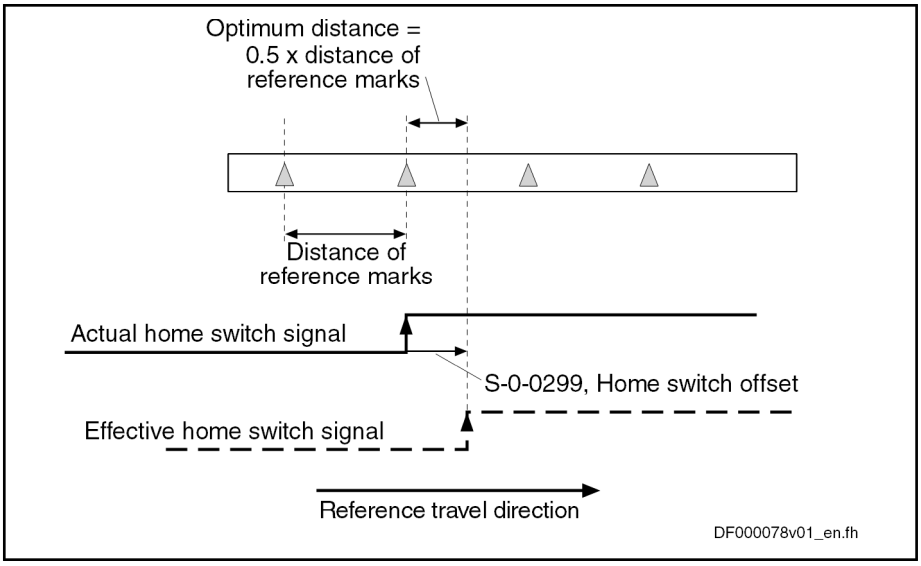



*Fig. 5-13: Operating Principle of Parameter S-0-0299 Using the Home Switch Signal as an Example*

**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 is determined by the drive controller depending on the type of the individual encoder used and the value in "P-0-0153, Optimum distance home switch-reference mark". This allows detecting:

- Parameter values for reference mark evaluation have been correctly set

- or -

- Reference mark signals are correctly read in

☞ Parameter P-0-0153 refers to the encoder to be homed according to the setting in "S-0-0147, Homing parameter".

## Notes on Commissioning

See also notes on commissioning for "General Information on Establishing the Position Data Reference"

**Settings for Connected Encoders**

The required settings with regard to the encoders used need to have been made so that establishing the position data reference is possible.

See also Notes on Commissioning for "Basics on Measuring Systems, Resolution"

**General Settings for Drive-Controlled Homing**

In "S-0-0147, Homing parameter", it is necessary to make basic settings regarding encoder selection and use of axis-side additional devices:

- Activation/deactivation of reference mark evaluation

  → Select whether the dedicated point is determined by an encoder reference mark (to be selected with drive-controlled homing, automatically active with NC-controlled homing).

- Determinations for Utilizing an Axis-Side Additional Device for Identification of Dedicated Point:

  – Home switch

  - or -

– Travel range limit switch as a replacement for home switch (optional with drive-controlled homing, not possible with NC-controlled homing)

- or -

– Activation of detection of axis blocking with positive stop drive procedure (optional for drive-controlled homing, not possible for NC-controlled homing)

**Settings for Axis-Side Additional Devices (if Available)**

Depending on whether axis-side additional devices are used, further settings have to be made.

**Home switch:**

- Activation of home switch evaluation in "S-0-0147, Homing parameter"
- Setting for edge evaluation of home switch signal in "S-0-0147, Homing parameter"

**Travel range limit switch:**

- Activation of travel range limit switch evaluation in "S-0-0147, Homing parameter"
- Determination of switching behavior in "S-0-0532, Travel range limit parameter"

**Detection of axis blocking (positive stop):**

- Setting of torque/force threshold for detection of blocking in parameter "S-0-0092, Bipolar torque/force limit value", or "S-0-0082, Torque/force limit value positive" or "S-0-0083, Torque/force limit value negative"
- Setting of standstill threshold for detection of blocking in "S-0-0124, Standstill window"
- Determination of monitoring window for the following distance in "S-0-0159, Monitoring window"

**Distance Monitoring of Reference Mark Signals**

With active reference mark evaluation (obligatory for NC-controlled homing, optional for drive-controlled homing), encoder-specific values for monitoring of the reference mark signals have to be entered in "P-0-0153, Optimum distance home switch-reference mark". Monitoring takes place during the homing procedure (see Parameter Description P-0-0153).

***NOTICE*** **Property damage to the installation caused by incorrect setting of the home switch edge!**

⇒ Make sure the home switch edge was correctly set and is within the travel range!

**Distance Control Home Switch Edge - Travel Range Limit**

In the case of home switch evaluation, first control whether the minimum distance between home switch edge and travel range limit has been complied with:

- Search for switching point of home switch, e.g. by jogging the axis to switch cams; check switch status in "S-0-0400, Home switch"; retain actual position value (S-0-0051)
- Jog axis to travel range limit, retain actual position value (S-0-0051)

The minimum distance has to be calculated on the basis of the values for velocity and acceleration intended for the homing procedure (see section above "Identifying the Dedicated Point by Means of Reference Mark and Home Switch"):

- For drive-controlled homing, determine the minimum distance with "S-0-0041, Homing velocity" and "S-0-0042, Homing acceleration"
- For NC-controlled homing determine the minimum distance while taking the homing velocity and homing acceleration into account

If the distance between home switch edge and travel range limit is smaller than the calculated minimum distance, the home switch has to be mechanically brought to the respective distance!

**Checking and, If Necessary, Correcting the Distance to the Reference Mark**

When using axis-side additional devices (optional), such as home switch, travel range limit switches or positive stop (setting in parameter S-0-0147), you have to check whether the distance switch edge – reference mark or positive stop – reference mark is within the allowed range.

How to proceed for checking the distance:

- Make presettings for activation of the reference marks for use of axis-side additional devices and for encoder selection in "S-0-0147, Homing parameter"
- Make settings for respective axis-side additional device that might be used (see above)
- Check whether the encoder-specific value was entered in parameter "P-0-0153, Optimum distance home switch-reference mark"
- Execution of the drive-controlled homing procedure (command C0600) with "S-0-0299, Home switch offset" = 0 and the setting "Hold" in parameter S-0-0147. If the distance lies within the allowed range (0.25… 0.75 × (2 × P-0-0153)), the drive will not generate a respective error message after standstill.

If the message "C0602Distance home switch - reference mark erroneous" is generated, the distance must be corrected:

1. Enter the value from parameter "S-0-0298, Reference cam shift" in parameter "S-0-0299, Home switch offset"
2. Check: When homing is repeated, value "0" should be displayed for parameter S-0-0298.

## Drive-Controlled Homing

### Brief Description

**Basic Sequence of "Search for Dedicated Point"**

After activation of "S-0-0148, C0600 Drive-controlled homing procedure command", the drive moves the axis according to the reference travel direction set in "S-0-0147, Homing parameter" for searching the dedicated point. When the controller has detected the position of the dedicated point, e.g. by reference mark detection of the encoder selected in S-0-0147, the position data reference of the actual position values in relation to the axis can be established.

Determining the appropriate homing procedure for the existing axis type (settings in S-0-0147) ensures that during the search for the dedicated point the axis only moves within the allowed travel range!

For information on the actual position value after the position reference was established, see section "General Information on Establishing the Position Data Reference"

### Functional Description

### Functional Sequence "Drive-Controlled Homing Procedure"

**Command Value Profile for Homing Procedure**

After activation of "S-0-0148, C0600 Drive-controlled homing procedure command", the drive moves the axis according to the reference travel direc-

tion set in "S-0-0147, Homing parameter". The command value profile generated by the controller depends on:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- S-0-0108, Feedrate override

The controller ignores command values of the control master during the execution of command C0600!

---

☞ If the respective encoder, at the start of command C0600, should have already been homed, the reference is cleared first!

See also Parameter Description "S-0-0403, Position feedback value status"

---

**Homing Motion**

At the start of command C0600, two situations have to be distinguished with regard to the initial position of a linear axis. The moving part of the axis is

- within the travel range, the home switch or travel range limit switch has not been activated,

- or -

- near the end of the travel range, the home switch or travel range limit switch has been activated, the positive stop, possibly used for homing, is almost reached.

If the switch has not been activated or the positive stop has not yet been reached, the drive moves the axis in reference travel direction.

When the home switch has already been activated, the drive moves the axis against the reference travel direction.

The drive reverses the direction of movement for searching for the dedicated point as soon as the home switch is recognized as "Not actuated".

When a positive stop is used for homing, the search for the dedicated point, after axis blocking has been detected, is always carried out against the reference travel direction!

---

☞ If the dedicated point is the current actual position value of the encoder to be homed, no homing movement takes place.

This means that for the identification of the dedicated point

- neither reference mark evaluation
- nor an axis-side additional device was selected

---

**Jerk Limitation**

To limit acceleration jumps it is possible to additionally activate a jerk limit. This is done by entering the value in parameter "S-0-0349, Bipolar jerk limit".

**Motion Range for Homing**

The process for searching the dedicated point requires axis motion. The axis motion to be expected depends on the selected measuring system and on the position of the axis at the start of drive-controlled homing (for information on axis motion, see above under the description of the respective paragraph "Identifying the Dedicated Point by Means of ..." from chapter "Identifying the Dedicated Point by Means of Reference Mark and Home Switch" on page 186).

**Maximum Velocity**

As with 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 due to 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). The shutdown can be carried out as:

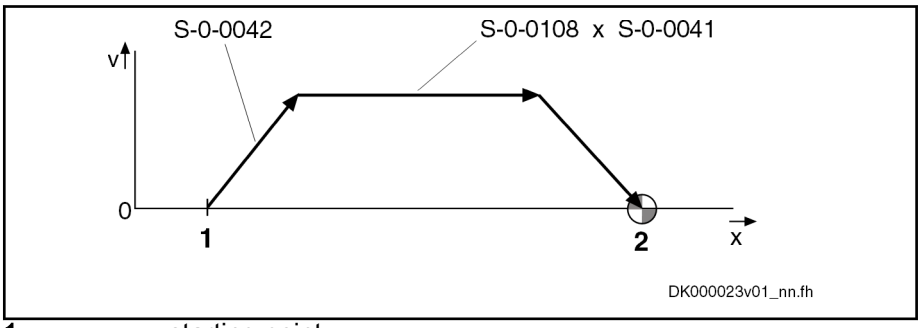
- "Stop"

  → Non-target-oriented immediate braking motion that possibly is of shorter duration

- or -

- "Positioning"

  → target-oriented movement to the reference point (axis-related value in parameter "S-0-0052, Reference distance 1"), provided that the reference point is within the allowed travel range




**1** starting point
**2** reference point
**S-0-0041** Homing velocity
**S-0-0042** Homing acceleration
**S-0-0108** Feedrate override

*Fig. 5-14: Command Value Profile for Drive-Controlled Homing with Constant Feedrate Factor and "Positioning" Shutdown*

☞ If the parameter "S-0-0108, Feedrate override" starts at zero, the warning "E2055Feedrate override S-0-0108 = 0" is generated.

## Actions of the Control Unit in the Case of "Drive-Controlled Homing"

**Starting Command C0600**

The control master starts the command by writing data to parameter "S-0-0148, C0600 Drive-controlled homing procedure command". The command has to be set and enabled. The command acknowledgment has to be taken from the data status of the same parameter. The command execution is completed when the command change bit in parameter "S-0-0135, Drive status word" has been set and the acknowledgment changes from "in process" to "command executed" or to "command error".

**Interrupting Command C0600**

If the command is interrupted by the control master while being executed, the drive reacts by activating the "Drive Halt" function. The command execution is continued by removing the interruption.

**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

### General Information

**Settings for Homing Motion**

For drive-controlled homing motion, settings for kinematics have to be made:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration

**Settings for Drive-Controlled Homing**

Apart from general settings, further settings for drive-controlled homing have to be made in "S-0-0147, Homing parameter":

- Reference travel direction

  → determine direction of motion in which search for dedicated point takes place, if the axis is not at the end of the axis
- Activation/deactivation of reference mark evaluation

  → determine, whether reference point is determined by an encoder reference mark
- Determinations for utilizing an axis-side additional device for identification of dedicated point:
  - Use of a home switch and setting for edge evaluation of home switch signal

  - or -

  - Use of a travel range limit switch as a substitute for home switch

  - or -

  - Activation of blocking detection for positive stop drive procedure

  **Note:** Only one of the possible axis-side additional devices for drive-controlled homing may be selected!
- Setting for shutting the axis down after detection of dedicated point ("stop", "positioning" or "run path")

**Axis-Related Settings for Establishing the Position Data Reference**

Depending on the kind of reference mark of the encoder, the axis-related parameter settings for establishing the position data reference are explained in the following sections.

## Notes on Commissioning with Relative Encoder

**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 in relation to the axis zero point have to be entered.

To do this the following steps have to be carried out:

1. First set the parameters below to value "0":
   - S-0-0052, Reference distance 1
   - S-0-0150, Reference offset 1
2. If encoder reference marks are not to be evaluated, make corresponding settings in "S-0-0147, Homing parameter" (default setting: Encoder reference marks are evaluated!).
3. For initial commissioning set parameters for homing procedure to low values:
   - S-0-0041, Homing velocity
   - S-0-0042, Homing acceleration
4. Execution of "C0600Drive-controlled homing procedure command" (S-0-0148), if drive in "AF"

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**NOTICE** **Property damage caused by step change of actual position value!**

⇒ By clearing the command, the original operation mode becomes active again. When the "drive-internal interpolation" mode was set, for example, the drive immediately moves to the position according to the value in parameter "S-0-0258, Target position". Take change in actual position value into consideration!

**Axis Zero Point and Dedicated Point**

After the command was executed the axis zero point is at the same axis position as the dedicated point, because the reference distance (S-0-0052) and the reference offset (S-0-0150) were set to the value "0". The actual position value in parameter "S-0-0051, Position feedback value 1" now has an 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 the dedicated point and the reference point must be entered in the parameter for reference offset 1.

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 the axis to the determined reference point and enter the actual position value shown here with the identical sign in parameter "S-0-0150, Reference offset 1".

To establish the position reference, the desired axis-related actual position value of the reference point must be entered in parameter "S-0-0052, Reference distance 1". 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. The axis-related position of the reference point can be determined by measuring the distance between the current position and the determined axis zero point. Enter measured distance as axis-related actual position value for the reference point in the respective reference distance parameter with the correct sign.

After repeated execution of the command C0600 ("drive-controlled homing procedure" command) the actual position values refer to the axis zero point.

**Settings for Drive-Controlled Homing Motion**

Set the parameter values reduced for initial commissioning to their definite values:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration

For checking purposes, execute the command "C0600Drive-controlled homing procedure command" again!

Drive-controlled homing can be completed with "stop" or "positioning":

**"Stop" After Detecting the Dedicated Point**

If in "S-0-0147, Homing parameter" the setting "stop" is made after the dedicated point was detected (default setting), the drive stops the axis after the dedicated point was recognized.

**"Positioning" After Detecting the Dedicated Point**

If the axis is to position to the reference point after the dedicated point was detected, this must be determined in parameter S-0-0147. The position can be specified via "S-0-0150, Reference offset 1" .

***NOTICE*** **The system can be damaged, if the reference point is outside the allowed travel range and the position limit hasn't been activated yet!**

⇒ Make sure that the reference point is within the travel range and activate the position limit!

### Possible Error Messages during Drive-Controlled Homing

While command C0600 is being executed, the following command errors can occur:

- C0601 Homing only possible with drive enable
- C0602 Distance home switch - reference mark erroneous
- C0606 Reference mark not detected
- C0607 Reference cam input not assigned

## NC-Controlled Homing

### Brief Description

**Sequence of NC-Controlled Homing**

For NC-controlled homing the master (NC control unit) controls the homing motion for searching the dedicated point of the axis. To do this, the master activates the parameter

- S-0-0146, C4300 NC-controlled homing procedure command

and presets the command value for axis motion according to the active operation mode.

When the drive has detected the dedicated point, it informs the master of this fact and stores the position of the dedicated point. The master then completes the execution of command C4300 and afterwards activates the parameter

- S-0-0171, C4400 Calculate displacement procedure command.

The required displacement of the actual position values is now calculated in the drive controller in order to establish the reference of the actual position value to the axis zero point.

When the displacement of the actual position value required for establishing the position data reference has been determined, the master completes the execution of command C4400 and then activates the parameter

- S-0-0172, C4500 Displacement to referenced system procedure command.

The actual position value now is changed drive-internally by the calculated absolute displacement value and thereby the reference of the actual position value to the axis zero point is established. The master has to adjust its command value input to the changed actual position value, before it completes the NC-controlled homing procedure by deactivating command C4500.

## Functional Sequence "NC-Controlled Homing Procedure"

**Searching the Dedicated Point, Basic Procedure**

After the master has started NC-controlled homing by activating "S-0-0146, C4300 NC-controlled homing procedure command", it has to preset an axis motion command value for the drive for identifying the dedicated point.

The dedicated point can only be identified, if "S-0-0407, Homing enable" has been set on the master side. If a home switch was connected to the drive controller (setting in S-0-0147), it has to be detected as "activated".

For details on the search for the dedicated point in the case of NC-controlled homing, see section above "Identifying the Dedicated Point by Means of Reference Mark and Home Switch"!

When the drive has found the dedicated point of the encoder selected in "S-0-0147, Homing parameter", this is displayed in parameter "S-0-0408, Reference marker pulse registered". The position of the dedicated point is stored in parameter "S-0-0173, Marker position A".

To provide for a correct and time-optimized sequence of the execution of command C4300, the following assignments are required:

- Bit "homing enable" (S-0-0407) in real-time control bit of "S-0-0134, Master control word"
- Bit "reference mark detected" (S-0-0408) in real-time status bit of "S-0-0135, Drive status word"

When the bit "reference mark detected" (S-0-0408) has been set, the master can complete the execution of command C4300.

**Drive-Side Calculation of Actual Position Value Displacement for Zero Point Reference**

By master-side activation of parameter "S-0-0171, C4400 Calculate displacement procedure command", the actual position value displacement for the encoder selected in "S-0-0147, Homing parameter" is calculated.

The calculation of displacement is based on the non-homed actual position value at the dedicated point (S-0-0173) and the values of reference distance 1 (S-0-0052) and reference offset 1 (S-0-0150).

The calculated displacement value is shown in S-0-0175, Offset parameter 1 (encoder)

When the required displacement of the actual position value has been determined, the master can complete the execution of command C4400.

It would also be possible to calculate the displacement on the master side and directly preset it for the drive via parameter S-0-0175. In this case the execution of command C4400 wouldn't be required!

**Displacement of Actual Position Value for Zero Point Reference**

To switch the actual position values to axis reference, the master now activates parameter "S-0-0172, C4500 Displacement to referenced system procedure command". The displacement of the actual position value for the encoder selected in "S-0-0147, Homing parameter" is thereby carried out.

The calculated displacement value (S-0-0175) is now added to the non-homed actual position value; the new actual position value is displayed in S-0-0051, Position feedback value 1

The homing status of the encoders connected to the drive is also displayed in "S-0-0403, Position feedback value status". By means of this parameter the master recognizes when the position command value is to be switched to axis reference. The master signals the completed changeover to the homed position command value in parameter "S-0-0404, Position command value status". The drive then signals the execution of command C4500 to have

been completed and the master on its part can complete the execution of command C4500.

The correct, time-optimized execution of command C4500 requires the following assignments:

- Position command value status bit (S-0-0404) in real-time control bit of "S-0-0134, Master control word"
- Reference encoder status bit (S-0-0403) in real-time status bit of "S-0-0135, Drive status word"

For information on the actual position value after the position reference was established, see section "General Information on Establishing the Position Data Reference"

## Notes on Commissioning

**Settings for NC-Controlled Homing**

Apart from general settings (encoder selection, "activated" signal of home switch), further specific settings for NC-controlled homing have to be made in parameter "S-0-0147, Homing parameter":

- Setting for whether the home switch is connected to drive or master (NC control unit)
- Setting for activation of dedicated point detection:
  - Master-side homing enable

  - or -

  - Master-side homing enable and "activated" signal of home switch (for this purpose, the home switch has to be connected to the drive)

**Axis-Related Settings for Establishing the Position Data Reference**

The following axis-related parameter values have to be determined for relative, distance-coded measuring systems:

- S-0-0052, Reference distance 1
- S-0-0150, Reference offset 1

The following axis-related parameter values have to be determined for relative, distance-coded measuring systems:

- S-0-0177, Absolute offset 1

The axis-related settings for establishing the position data reference are basically the same for drive-controlled and NC-controlled homing! For determining the axis-related parameter values it is advantageous to use "drive-controlled homing"!

**Searching for the Dedicated Point**

The master starts "C4300NC-controlled homing procedure command" (S-0-0146) and sets the command value for the homing motion (if drive in "AF").

Detection of dedicated point takes place when:

- Homing enable (S-0-0407) has been set

- or -

- "S-0-0407, Homing enable" has been set and the home switch is in the "activated" status (S-0-0400)

The non-homed position of the acquired dedicated point is stored in:

- S-0-0173, Marker position A

When the dedicated point was detected, this is displayed by a bit in parameter "S-0-0408, Reference marker pulse registered" and the master then completes the execution of command C4300.

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**Drive-Side Calculation of Actual Position Value Displacement for Zero Point Reference**

The master starts "C4400Calculate displacement procedure command" (S-0-0171).

The calculated displacement value is displayed in the following parameter:

- S-0-0175, Offset parameter 1

When the required displacement of the actual position value has been determined, the master completes the execution of the command C4400.

It would also be possible to calculate the displacement on the master side and directly preset it for the drive via the parameter S-0-0175. In this case the execution of the drive command C4400 is not required!

**Actual Position Value Displacement for Zero Point Reference**

The master starts "C4500Displacement to referenced system procedure command" (S-0-0172).

The calculated displacement value (S-0-017) is now added to the non-homed actual position value; the new actual position value is displayed in the following parameter:

- S-0-0051, Position feedback value 1

The actual position values thereby change from a non-homed to a homed value, because the corresponding displacement value was taken into account.

When the reference of the encoder selected in parameter S-0-0147 is displayed in "S-0-0403, Position feedback value status", the master changes the position command value from the non-homed value to the homed value:

- P-0-0047, Position command value control

In parameter "S-0-0404, Position command value status", the master simultaneously signals the homed status of the position command value to the drive and completes the execution of command C4500.

### Possible Error Messages during NC-Controlled Homing

While NC-controlled homing is executed, the following command errors can occur:

- C4302 Distance home switch - reference mark erroneous
- C4304 Homing impossible with absolute encoder
- C4306 Reference mark not detected
- C4307 Reference cam input not assigned

## Shifting the Position Data Reference for Absolute and Relative Measuring Systems (Shift Coordinate System Procedure)

### Brief Description

#### Fields of Application

**Base package** of all variants with **closed-loop** characteristic.

The existing position data reference of the measuring systems to the axis can be shifted if the respective command was activated by the master. It is possible to shift the data reference in standstill or while the axis is moving. This does not affect the position reference of the axis because it is only the actual position values output for the master that are displayed in "shifted" form. Internally the original ("non-shifted") position data reference is maintained.

**Pertinent Parameters**

- S-0-0197, C3300 Set coordinate system procedure command
- S-0-0198, Initial coordinate value
- S-0-0199, C3400 Shift coordinate system procedure command
- S-0-0275, Coordinate offset value
- S-0-0283, Current coordinate offset

**Pertinent Diagnostic Messages**

- C3300 Set coordinate system procedure command
- C3400 Shift coordinate system procedure command
- C0600 Drive-controlled homing procedure command

## Functional Description

**Operating Principle of Function "Shifting Position Data Reference"**

Shifting of the position data reference has an effect on the current actual position value. Whether the current actual position value has a position data reference to the axis or not is irrelevant for the shifting of the position data reference! Shifting is carried out on the drive-side by means of a command started by the master.

---

☞ The reference status of the actual position values is not affected by 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"**

Shifting of the position data reference is reset by switching the drive to communication phase 2. Therefore, no shifted position data reference can be active when the drive is switched on the first time, because former offsets are cleared when the drive is switched off.

---

☞ After resetting the shifted position data reference 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 ("C0300Set coordinate system procedure command" or "C0600Drive-controlled homing procedure command") is established after the actual position values have been shifted ("S-0-0283, Current coordinate offset" unequal to "0"), the current offset of the coordinate system is cleared and in parameter S-0-0283 the value "0" is shown.

**"Set Coordinate System" Procedure Command**

When the control master triggers the "C3300Set coordinate system procedure command" (S-0-0197), the drive becomes independent of the command values preset by the master and goes to a standstill in a drive-controlled way. Deceleration takes place according to the function "A0010Drive HALT".

See also description of diagnostic messages "A0010Drive 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 "C3400Shift 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 in-

put of the previous velocity command value. The actual position values now are shifted by addition of "S-0-0275, Coordinate offset value". The difference between the new and the 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 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 activated!

**Change in Position Data by "Shifting Position Data Reference"**

**Measured position values** refer to the actual position value system in which they were measured, i.e.:

- When measured after shifting, they refer to the "shifted" measuring system.
- When measured before shifting, they refer to the original measuring system.

**Command values** (cyclic command values, target position, etc.) have to refer to the current actual position value system, i.e. to the possibly shifted position data reference.

**Change in Position Data by "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 involves the risk of incorrect command value provision after shifting has been completed! Commissioning basically makes sense only in conjunction with the control master. Check whether command value handling of the master is correct!

| ***NOTICE*** | **Property damage caused by error in command value input after shifting the position data reference!** |
|---|---|

⇒ Protect the travel range of the axis, activate axis limit switches and make sure they are working!

**"Set Coordinate System Procedure"**

It is recommended that you begin with "set coordinate system procedure". But first the parameter "S-0-0283, Current coordinate offset" should be read. When shifting of the position data reference has not yet been carried out after the transition from "P2" to "AF", the value has to be "0"!

With master-side command value input, the "S-0-0197, C3300 Set coordinate system procedure command" command has to be started by the master.

See also section "Command Processing"

**Checking the Offset of Position Data Reference**

When the command was acknowledged by the drive, the offset of the position data reference has to be checked:

- The actual position value (S-0-0051) must be identical with "S-0-0198, Initial coordinate value".

- The parameter "S-0-0283, Current coordinate offset" must be read. With a value unequal to "0" shifting took place; with value "0" shifting either has not taken place or the actual position value of the axis approximately equaled the value of S-0-0198 when the position data reference was shifted.

**Checking the Command Value Input and Clearing the Command**

To check the command value input the master has to preset a position command value that corresponds to the value of parameter S-0-0198. Before the master resets the executed command, it is necessary to check whether the master-side command value corresponds to the current actual position value of the encoder active in position control (S-0-0051, 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 that you control the axis on the master-side with velocity command value "0" or at very low velocity. The parameter "S-0-0283, Current coordinate offset" must be read. When 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"!

Then start "C3400Shift coordinate system procedure command" on the master side.

See also section "Command Processing"

**Checking the Offset of Position Data Reference**

When the command was acknowledged by the drive, the offset of the position data reference has to be checked:

- The values of "S-0-0283, Current coordinate offset" and "S-0-0275, Coordinate offset value" have to correspond.

**Checking the Command Value Input and Clearing the Command**

Before the master resets the executed command, it is necessary to check whether the master-side command value corresponds to the current actual position value of the encoder active in position control (S-0-0051, shifted position data reference). If not, do not clear the command but reset "AF", if necessary, and search for the cause of the incorrect command value!

## Detecting the Marker Position

### Brief Description

**Base package** of all variants with **closed-loop** characteristic.

The function "get marker position", which can be activated via a corresponding command, is used to check, whether the reference mark of an incremental measuring system is detected without any errors.

A possibly available home switch is not evaluated with this function!

**Pertinent Parameters**

- S-0-0173, Marker position A
- P-0-0014, C1400 Command Get marker position

**Pertinent Diagnostic Messages**

- C1400 Command Get marker position

### Functional Description

After the start of "P-0-0014, C1400 Command Get marker position", the following actions are carried out:

- The diagnostic message "C1400Command Get marker position" is generated.

- If a relative measuring system was selected, the search for reference marks is activated and the drive waits for reaching the next reference mark.
- When a reference mark is detected (i.e. the drive passes the position of a reference mark), the actual position value of this mark is stored in parameter "S-0-0173, Marker position A" and then the command execution is signaled to be completed.

☞ The drive does not generate any command value. The operation mode active at the start of the command remains unchanged. In order to pass the reference mark the control master has to preset such command values (e.g. by means of jogging) that lead to a movement in the direction of the reference mark to be detected.

☞ In parameter "S-0-0173, Marker position A", the position of the reference mark is also stored during the execution of the "C0600Drive-controlled homing procedure command" (S-0-0148). This position, however, refers to the "old" coordinate system (before switching the coordinate system when executing the homing procedure).

# 5.3 Scaling of Physical Data

## 5.3.1 Brief Description

The controller maps the drive via data to an internal mathematical model. The status variables of the drive are determined on the basis of the following measurements:

- Position measurement
- Pressure measurement
- Force measurement
- Temperature measurement

The measured values collected in this way are converted into physical data:

- Position, velocity, acceleration, and jerk data
- Torque and force data
- Temperature data

The master transmits command values to the drive, which are used by the controller as input values for implementation. The drive in return registers and transmits actual values, signals operational 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 datum (numeric value) can only be evaluated as a physical value, if the numeric value is connected to a physical unit and the position of the decimal point (decimal places). The datum thereby is "scaled" in qualitative and quantitative terms.

**Parameters** All data are saved in parameters and transmitted as parameter values. Scaling of parameters containing data of the following physical values can be defined by the customer:

- Position
- Velocity

- Acceleration
- Torque/force
- Pressure and flow
- Temperature

**Preferred Scaling/Parameter Scaling**

To simplify the scaling definition so-called "preferred scalings" were predefined. But physical data can also be exchanged in the control-internal format, i.e. without specific reference to physical units. To do this, scaling for certain data can be freely set ("parameter scaling").

**Linear and Rotary Data**

Depending on the kind of motion of the drive or load, the data can be displayed as follows:

- linear (linear axis movement)

- or -

- rotary (rotary axis movement)

---

☞ Scaling is not supported at present.

---

**Cylinder Reference/Load Reference**

The drive firmware contains mechanical transmission elements between the cylinder and load, which are mapped by means of mathematical models. The physical data can thereby be referred to

- the load action point (load-side data reference)

- or -

- the force introduction point (cylinder-side data reference).

**Absolute/Modulo Evaluation**

For technical reasons, the value range of the position data the controller can display is limited.

In the case of axes with limited travel range (e.g. linear axes), the current axis position within the controller-side value range can be unequivocally displayed (see "Basics on Measuring Systems, Resolution"

**Pertinent Parameters**

- S-0-0043, Velocity polarity parameter
- S-0-0044, Velocity data scaling type
- S-0-0045, Velocity data scaling factor
- S-0-0046, Velocity data scaling exponent
- S-0-0055, Position polarities
- S-0-0076, Position data scaling type
- S-0-0077, Linear position data scaling factor
- S-0-0078, Linear position data scaling exponent
- S-0-0079, Rotational position resolution
- S-0-0085, Torque/force polarity parameter
- S-0-0086, Torque/force data scaling type
- S-0-0093, Torque/force data scaling factor
- S-0-0094, Torque/force data scaling exponent
- S-0-0103, Modulo value
- S-0-0121, Input revolutions of load gear
- S-0-0122, Output revolutions of load gear
- S-0-0123, Feed constant
- S-0-0160, Acceleration data scaling type
- S-0-0161, Acceleration data scaling factor

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- S-0-0162, Acceleration data scaling exponent
- S-0-0208, Temperature data scaling type
- S-0-0806, Pressure data scaling type
- S-0-0807, Pressure data scaling factor
- S-0-0808, Pressure data scaling exponent
- S-0-0845, Flow data scaling type
- S-0-0846, Flow data scaling factor
- S-0-0847, Flow data scaling exponent
- S-0-0848, Flow polarities

## 5.3.2 Scaling of Flow

For flow data you can select from

- Percentage-based scaling
- Preferred scaling
- Preferred scaling [l/min]
- Preferred scaling [l/s]
- Preferred scaling [gal/min]
- Preferred scaling [gal/s]
- Parameter scaling

If percentage-based scaling is selected, parameter scaling is not allowed.

| S-0-0846 (binary) | Scaling type | Preferred scaling | S-0-0846 (factor) | S-0-0847 (exponent) | Unit | Attribute decimal places | Attribute scaling factor |
|---|---|---|---|---|---|---|---|
| ..xx00.0000 | In percent | Yes | 1 | -3 | % | 3 | 1 |
| ..xx00.0001 | Flow | Yes | 1 | -3 | l/min | 3 | 1 |
| ..xx01.0001 | Flow | Yes | 1 | -4 | gal/min | 4 | 1 |
| ..xx10.1001 | Flow | Yes | 1 | -3 | l/s | 3 | 1 |
| ..xx00.1001 | Flow | Yes | 1 | -4 | gal/s | 4 | 1 |
| ..xx00.1001 | Flow | No | $1...2^{16}-1$ | -9...9 | l/min | (S-0-0847) | (S-0-0846) |
| ..xx01.1001 | Flow | No | $1...2^{16}-1$ | -9...9 | gal/min | (S-0-0847) | (S-0-0846) |
| ..xx10.1001 | Flow | No | $1...2^{16}-1$ | -9...9 | l/s | (S-0-0847) | (S-0-0846) |
| ..xx11.1001 | Flow | No | $1...2^{16}-1$ | -9...9 | gal/s | (S-0-0847) | (S-0-0846) |

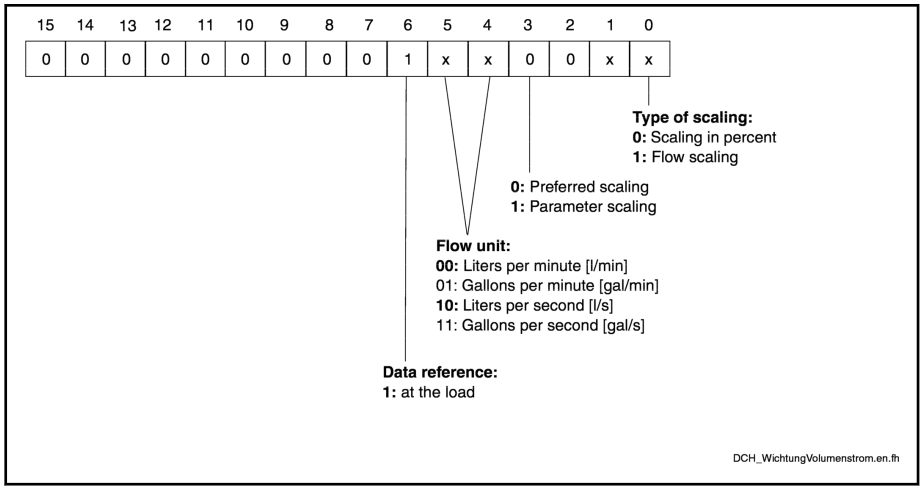


*Fig. 5-15: Flow Data Scaling Type*

**Parameters**

| IDN | Alias IDN | Name | Mod-ule | DocuObj |
|---|---|---|---|---|
| S-0-845 | | Flow data scaling type | CALC | S-0-0845_V1.0.xml |
| S-0-0846 | | Flow data scaling type | CALC | S-0-0846.000.000_V01.xml |
| S-0-0847 | | Flow data scaling expo-nent | CALC | S-0-0847.000.000_V01.xml |
| S-0-0848 | | Flow polarities | CALC | S-0-0848.000.000_V01.xml |

## 5.3.3 Scaling of Pressure

### General Information

For pressure scaling, you can select from

- Percentage-based scaling
- Preferred scaling [bar]
- Preferred scaling [psi]
- Parameter scaling

If percentage-based scaling is selected, parameter scaling is not allowed.

| S-0-0806 (binary) | Scaling type | Preferred scaling | S-0-0807 (factor) | S-0-0808 (exponent) | Unit | Attribute decimal places | Attribute scal-ing factor |
|---|---|---|---|---|---|---|---|
| ..xx00.0000 | In percent | Yes | 1 | -1 | % | 1 | 1 |
| ..xx00.0001 | Pressure | Yes | 1 | -3 | bar | 3 | 1 |
| ..xx01.0001 | Pressure | Yes | 1 | -2 | psi | 4 | 1 |
| ..xx00.1001 | Pressure | No | 1...$2^{15}$-1 | -6...9 | bar | (S-0-0808) | (S-0-0807) |
| ..xx01.1001 | Pressure | No | 1...$2^{15}$-1 | -6...9 | psi | (S-0-0808) | (S-0-0807) |

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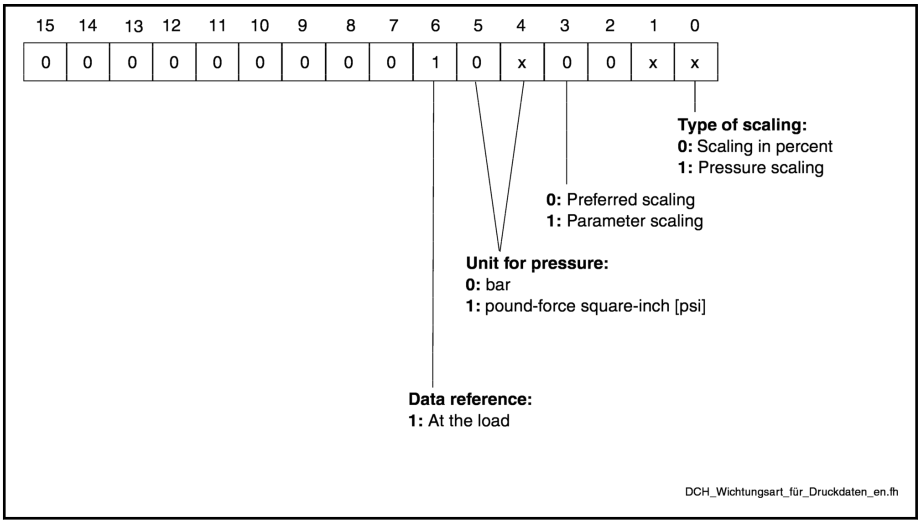


*Fig. 5-16: Pressure Data Scaling Type*

## Pressure Scaling with Time Reference

Pressure scaling an also be used in conjunction with a time reference. In this case, bar/s or psi/s, for example, can be specified as unit in the relevant parameters.

Pressure parameters with time reference have the same attributes as other parameters with pressure scaling without time reference, i.e. the number of decimal places is identical, the type of scaling is identical, etc. With parameter scaling, the same scaling parameters S-0-0806, S-0-0807 and S-0-0808 are effective as well.

## Pertinent Parameters

- S-0-0805, Pressure polarity parameter
- S-0-0806, Pressure data scaling type
- S-0-0807, Pressure data scaling factor
- S-0-0808, Pressure data scaling exponent

# 5.3.4 Scaling of Position, Velocity and Acceleration

For position, velocity and acceleration data there are the following basic scaling types:

- Linear
- Rotary (scaling is not supported at present)

It is possible to choose from preferred scaling (predefined scaling) and parameter scaling (scaling can be individually defined).

**Preferred Scalings (Predefined)**

Depending on the scaling type setting, the following predefined preferred scalings are available:

| | Preferred scaling | | |
|---|---|---|---|
| | Linear | Linear | Rotary |
| Physical data | with unit "m" | with unit "inch" | |
| Position data | 0.0001 mm | 0.000001 inch | 0.0001 dgr |
| Velocity data | 0.001 mm/min | 0.00001 inch/min | 0.0001 1/min or 0.000001 1/s |

*Tab. 5-5: Overview: Preferred Scalings for Position Data and Velocity Data*

| Physical data | Preferred scaling | | | |
|---|---|---|---|---|
| | Linear | Linear | Rotary | Ramp time |
| | with unit "m" | with unit "inch" | Unit:"rad" | Unit:"s" |
| Acceleration data | 0.001 mm/s$^2$ | 0.00001 inch/s$^2$ | 0.001 rad/s$^2$ | 0.001 s |
| Jerk data | 0.000001 mm/s$^3$ | 0.00001 inch/s$^3$ | 0.001 rad/s$^3$ | 0.001 s$^2$ |

*Tab. 5-6: Overview: Preferred Scalings for Acceleration Data and Jerk Data*

☞ Jerk data scaling is derived from acceleration data scaling.

**To be Noticed: Ramp Time Scaling Type**

The acceleration data can also be scaled with reference to a velocity ramp:

$$\text{reference vel. ramp} = \frac{\text{S-0-0446}}{\text{ramp reference time}} = \frac{\text{S-0-0446}}{1.0\ \text{ms}} \quad \text{(with preferred scaling)}$$

**S-0-0446** Ramp Reference Velocity for Acceleration Data

*Fig. 5-17: Definition of the Velocity Reference Ramp for Scaling Acceleration Data in the Case of Preferred Scaling*

**Settings for Preferred Scaling**

The scaling types, units and the selection of preferred scaling are determined in the respective bits of the following parameters:

- S-0-0076, Position data scaling type
- S-0-0044, Velocity data scaling type
- S-0-0160, Acceleration data scaling type

When using preferred scaling, the parameter values for scaling type, unit, scaling factor, and scaling exponent as well as the number of decimal places are automatically set for the respective data. The following tables contain an overview.

| Physical data | Scaling type | Unit | S-0-0076 | S-0-0077 | S-0-0078 | Attribute number of decimal places |
|---|---|---|---|---|---|---|
| Position data | Linear | mm | ..xx00.0001 | 1 | -7 | 4 |
| | Linear | inch | ..xx01.0001 | 1 | -6 | 6 |
| | Rotary | dgr | ..xx00.0010 | 1 | -4 | 4 |

**S-0-0076** Position data scaling type
**S-0-0077** Position data scaling factor
**S-0-0078** Position data scaling exponent

*Tab. 5-7: Values of Scaling Parameters and Decimal Places of Position Data Determined by Preferred Scaling*

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| Physical data | Scaling type | Unit | S-0-0044 | S-0-0045 | S-0-0046 | Attribute number of decimal places |
|---|---|---|---|---|---|---|
| Velocity data | Linear | mm/min | ..0x00.0001 | 1 | -6 | 3 |
| | Linear | inch/min | ..0x01.0001 | 1 | -5 | 5 |
| | Rotary | 1/min | ..0x00.0010 | 1 | -4 | 4 |
| | Rotary | 1/s | ..0x10.0010 | 1 | -6 | 6 |

**S-0-0044** Velocity data scaling type
**S-0-0045** Velocity data scaling exponent
**S-0-0046** Velocity data scaling exponent

*Tab. 5-8: Values of Scaling Parameters and Decimal Places of Velocity Data Determined by Preferred Scaling*

| Physical data | Scaling type | Unit | S-0-0160 | S-0-0161 | S-0-0162 | Attribute number of decimal places |
|---|---|---|---|---|---|---|
| Acceleration data | Linear | $mm/s^2$ | ..0x00.0001 | 1 | -6 | 3 |
| | Linear | $inch/s^2$ | ..0x01.0001 | 1 | -5 | 5 |
| | Rotary | $rad/s^2$ | ..0x00.0010 | 1 | -3 | 3 |
| | Ramp time | s | ..0x00.0011 | 1 | -3 | 3 |

**S-0-0160** Acceleration data scaling type
**S-0-0161** Acceleration data scaling factor
**S-0-0162** Acceleration data scaling exponent

*Tab. 5-9: Values of Scaling Parameters and Decimal Places of Acceleration Data Determined by Preferred Scaling*

For practical reasons, the metric measures of length in the case of preferred scaling are scaled in "mm". This can also be seen from the corresponding "unit" data element when a respective parameter is being read. 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 datum can be individually defined.

By means of parameter scaling it is possible to modify the range of values of physical data!

Example: The maximum value for "S-0-0278, Maximum travel range" can be increased by reducing the number of decimal places of the position data.

| | |
|---|---|
| position data, linear | $LSB = unit^{1)} \times scaling\ factor^{1)} \times 10^{SE}$ |
| position data, rotary | $LSB = \frac{360}{rotational\ pos.\ resolution^{2)}} \times unit^{2)}$ |
| velocity data | $LSB = \frac{unit\ (position\ data)}{TU} \times scaling\ factor \times 10^{SE}$ |
| acceleration data (linear, rotary) | $LSB = \frac{unit\ (position\ data)}{TU^2} \times scaling\ factor \times 10^{SE}$ |
| acceleration data (ramp time scaling) | $LSB = \frac{S\text{-}0\text{-}0446}{scaling\ factor \times 10^{SE}}$ |
| jerk data | $LSB = \frac{unit\ (position\ data)}{TU^3} \times scaling\ factor \times 10^{SE}$ |

**1)** With a scaling factor ≠ 1 the unit is no longer indicated as in S-0-0076, but only "incrementally" (control-dependent unit reference).

**2)** With rotational position resolutions (S-0-0079) which do not result in powers of 10 of 360, the unit is no longer angular degrees (acc. to S-0-0076) but only "incremental" (control-dependent unit reference).

**LSB** least significant bit
**SE** scaling exponent
**TU** unit of time
**S-0-0446** Ramp reference velocity for acceleration data

*Fig. 5-18: Defining the Least Significant Bit (LSB) for Parameter Scaling*

☞ Jerk data scaling is derived from acceleration data scaling.

Respective units of measurement and time defined in the parameters:

- S-0-0076, Position data scaling type
- S-0-0044, Velocity data scaling type
- S-0-0160, Acceleration data scaling type

Respective scaling factor and scaling exponent defined in the following parameters:

- S-0-0077, Linear position data scaling factor
- S-0-0078, Linear position data scaling exponent
- S-0-0045, Velocity data scaling factor
- S-0-0046, Velocity data scaling exponent
- S-0-0161, Acceleration data scaling factor
- S-0-0162, Acceleration data scaling exponent

For rotary position data the value of the following parameter, in the case of parameter scaling, must be determined for defining the LSB:

- S-0-0079, Rotational position resolution

## 5.3.5 Scaling of Torque and Force

For torque/force data there are the following basic scaling types:

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- Linear
- Rotary (scaling is not supported at present)
- Percentage-based

It is possible to choose between preferred scaling (predefined scaling) and parameter scaling (scaling can be individually defined). If percentage-based scaling is selected, parameter scaling is not allowed.

**Preferred Scalings (Predefined)**

Depending on the scaling type setting, the following predefined preferred scalings are available:

| Physical quantity | Preferred scaling, decimal places and value ranges | | |
|---|---|---|---|
| | Linear | Rotary | Percentage-based |
| Torque | -- | 0.01 Nm...327.67 Nm<br>or<br>0.1 inlbf...3276.7 inlbf | 0.1% |
| Force | 1 N...32767 N<br>or<br>0.1 lbf...3276.7 lbf | -- | 0.1% |

*Tab. 5-10: Preferred Scalings for Torque/Force Data*

The scaling types and units can be determined in the respective bits of parameter

- S-0-0086, Torque/force data scaling type

Respective scaling factor and scaling exponent defined in the following parameters:

- S-0-0093, Torque/force data scaling factor and
- S-0-0094, Torque/force data scaling exponent

**Parameter Scaling (Individually Defined)**

As an alternative to preferred scaling it is also possible to activate parameter scaling. For parameter scaling the least significant bit (LSB) of the respective operating datum can be individually defined.

**Torque/force data LSB = unit x scaling factor x $10^{WE}$**

**= unit x S-0-0093 x $10^{S\text{-}0\text{-}0094}$**

This results in the following maximum value ranges for SI units:

| Physical quantity | Parameter scaling with S-0-0093 ="1", S-0-0094 = -2....6; decimal places and value ranges | |
|---|---|---|
| | Linear | Rotary |
| Torque | -- | 0.01 Nm...3270.67 MNm |
| Force | 1 N...32767 MN or | -- |

*Tab. 5-11: Parameter Scaling for Torque/Force Data, SI Unit System*

This results in the following maximum value in the imperial system:

| Physical quantity | Parameter scaling with S-0-0093 ="1", S-0-0094 = -2....6; decimal places and value ranges | |
|---|---|---|
| | Linear | Rotary |

| | | |
|---|---|---|
| Torque | -- | 0.1 inlbf...3276.7 kinlbf |
| Force | 0.1 lbf...3276.7 klbf | -- |

*Tab. 5-12: Parameter Scaling for Torque/Force Data, Imperial System*

☞ The number of decimal places remains constant, the symbol for the power of 10 of 1000 (kilo or mega) depends on the amount of the value to be represented.

## 5.3.6 Scaling of Temperature

For temperature data only the following units can be selected:

- Degree Celsius (°C)
- Fahrenheit (F)

☞ For temperature data is it only possible to select preferred scaling (predefined scaling)!

| | Preferred scaling | |
|---|---|---|
| **Physical quantity** | **Celsius** | **Fahrenheit** |
| Temperature | 0.1 °C | 0.1 F |

*Tab. 5-13: Preferred Scalings for Temperature Data*

# 6 Operation Modes

## 6.1 General Information on the Operation Modes

### 6.1.1 Supported Operation Modes

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

The following overview shows the operation modes supported by the individual devices.

| Operation mode | provided by product ... | | | |
|---|---|---|---|---|
| | WRxQ (HDB) | DFE (HDB) | WRxD (HDB) | HMC (HDC) |
| - Direct valve control | p/Q | – | OL / CL | OL / CL |
| - Closed-loop pressure control / direct valve control | p/Q | – | OL / CL | OL / CL |
| - Closed-loop flow control | p/Q | – | – | – |
| - Closed-loop pressure/flow control | p/Q | – | – | – |
| - Pump control | – | DFE | – | – |
| - Closed-loop torque/force control | – | – | OL / CL | OL / CL |
| - Closed-loop torque/force control / direct valve control | – | – | OL / CL | OL / CL |
| - Closed-loop velocity control | – | – | CL | CL |
| - Closed-loop position control | – | – | CL | CL |
| - Drive-internal interpolation | – | – | CL | CL |
| - Drive-controlled positioning | – | – | CL | CL |
| - Positioning block mode | – | – | CL | CL |

*Tab. 6-1: Supported Operation Modes*

☞ For the designation of functional packages, see Functional package enable

☞ Closed-loop position control only possible with synchronous FKM (-> sercos, EtherCAT, VARAN)

In order that a functional package can be used, it must have been activated (enabled). The currently enabled functional packages are displayed in parameter "P-0-2004, Active functional packages".

## 6.1.2 Operation Mode Handling

### Selecting the Operation Mode

Up to 8 different operation modes can be configured in the drive (depending on "S-0-0292, List of supported operation modes"). Assignment and configuration are made via the following parameters:

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

☞ If the value "0" was entered in one of these parameters, the error message "F6007Switching to non-initialized operation mode" is generated when this operation mode is activated.

**Activation of Operation Mode**

The operation mode is activated and controlled using the entries in the drive control words, which depend on the master communication type:

- S-0-0134, Master control word
- – P-0-4077, Field bus: Control word
  – P-0-4068, Field bus: Control word IO
- P-0-4028, Device control word
- P-0-0120, Control word easy startup

8 additional internal operation modes (internally firmly configured) are available for the provision of commands to the axis by the integrated control MLD as well as for use by the Easy Startup Mode. It is possible to switch between these operation modes during operation.

The effective specification is shown in bits 8, 9, 11, and 12 of parameter "P-0-0116, Device control: Control word".

The following is valid for parameter P-0-0116:

- Bits 8 and 9 → selection of primary operation mode and secondary operation modes 1 to 3
- Bit 11 → selection of secondary operation modes 4 to 7 (sercos only)

☞ The secondary operation modes 4 to 7 can only be utilized over sercos interface. For this reason, bit 11 is only effective in conjunction with parameter S-0-0134 (master control word with sercos) in the control word of the device control (P-0-0116)!

The following graphic shows the relationship between the control word of the relevant master communication and the device control word/device status word with regard to the selection of operation modes.

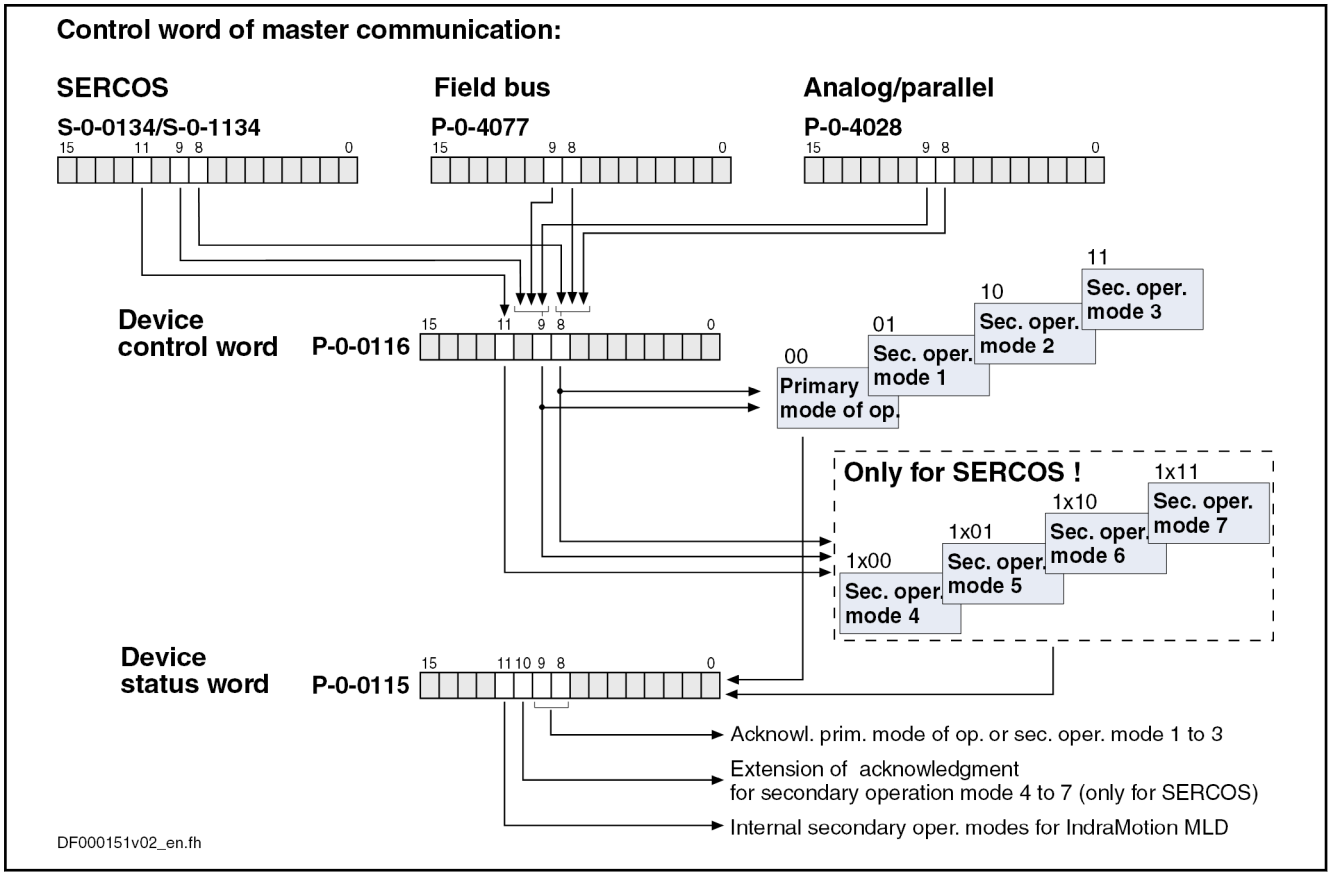



*Fig. 6-1: Selection of Control Modes via the Control Word*

The control bits (8 and 9) in parameter P-0-0116 are also contained in the control words that are dependent on master communication (cf. S-0-0134, P-0-4077, P-0-4068 and P-0-4028) and can consequently also be handled in these control words.

An operation mode defined via the operation mode selection is active when:

- the drive (control section and power section) is ready for operation

- and -

- a positive edge of the controller enable signal was given.

**Acknowledgement of the Active Operation Mode**

In conjunction with the activation of an operation mode, the following feedback is given:

- Parameter "S-0-0390, Diagnostic message number" shows the associated diagnostic message number of the active operation mode (e.g. "A0101" in the "closed-loop velocity control" mode).
- Parameter "S-0-0095, Diagnostic message" shows the active mode of operation in text form (e.g. "A0101Velocity control").
- In parameter "P-0-0115, Device control: Status word", bit 3 ("drive follows external command values") is used to acknowledge whether or not the drive is operating in the preset operation mode.
- In parameter "P-0-0115, Device control: Status word", bits 8, 9 and 10 ("acknowledgment of operation mode") are used to signal the operation mode currently active.

Operation Modes

☞ The status bits (3, 8, 9, and 10) in parameter P-0-0115 are also contained in the status words (S-0-0135, P-0-4078) that are dependent on master communication and can consequently also be read out from there. Bit 10 is, however, only provided in conjunction with sercos interface!

## Changing the Operation Mode

When the controller enable of the drive is activated and after the initialization routines were run, the drive changes over to the operation mode selected via bit 8 and 9 of the specific control word of the relevant master communication (S-0-0134, P-0-4077, P-0-4068, P-0-4028 oder P-0-0116).

☞ The change of operation mode is accomplished within a position controller cycle. Before the command values of the activated operation mode become effective, a further position controller cycle is run, because the operation mode must be initialized first.

**Special Cases**

With the following **exceptional situations** the desired operation mode is not executed, in spite of the operation mode having been correctly selected:

- **Drive error** is present
  → The associated error reaction is run.
- **Fatal warning** was triggered
  → The associated reaction is run.
- Execution of a "**drive command**" (e.g. homing, set absolute position, ...)
  → The started command is being executed.
- **Drive halt**
  → This drive function is being executed.

**Drive-Controlled Change of Operation Mode**

In order to achieve a quick and smooth change of operation mode in running operation, it is possible to make a "drive-controlled change of operation mode". It ensures within the drive that when the operation mode is changed, the transition takes place in a synchronized form, even if the command value changes step-like.

## Command Value Acceptance and Acknowledgment

**Immediate Acceptance of Command Value**

The specified command value is accepted directly when the relevant command value parameter (e.g S-0-0036, S-0-0080, S-0-0258, …) is written in the following operation modes:

- Direct valve control
- Open/closed-loop flow control
- Closed-loop pressure control
- Pump Control
- Closed-loop torque/force control
- Closed-loop velocity control
- Closed-loop position control with cyclic command value provision
- Drive-internal interpolation

**Acceptance of Command Value upon Request by Master**

In contrast to this, in **positioning operation modes** (drive-controlled positioning, positioning block operation), the command value (target position, velocity, positioning block modes, ....) is only accepted, if the master requests this explicitly with a "command value acceptance".

The command value acceptance is executed in different ways depending on the positioning block type or profile type:

- Operation mode "drive-controlled positioning"

  Acceptance of the given command value (position, velocity) by toggling bit 0 of parameter "S-0-0346, Positioning control word"

  → **Toggle mechanism**

- Operation mode "Positioning block mode"

  The positioning block selected via "P-0-4026, Positioning block selection" is accepted via a 0-1 edge of bit 0 of parameter "P-0-4060, Positioning block control word", if the parallel interface is used as master communication or, in the the case of field buses, the I/O mode.

  → **Edge control**

---

☞ When the positioning block mode is used with field buses in the freely configurable operation mode (P-0-4084 = 0xFFFE) or with sercos interface, the toggle mechanism is applied as well **contrarily to the above rule**.

---

**Command Value Acknowledgement**

The command value acceptance is only explicitly acknowledged in the positioning block modes (drive-controlled positioning, positioning block mode).

In this case, a check can be run in the master, whether and when the given command value was accepted by the drive (command value acceptance handshake).

The command value is acknowledged in different ways depending on the positioning mode:

- Operation mode "drive-controlled positioning"

  The drive acknowledges the acceptance of the command value by toggling bit 0 of parameter "S-0-0419, Positioning command acknowledge".

- Operation mode "Positioning block mode"

  The drive acknowledges the command value acceptance by displaying the effective positioning block in parameter "P-0-4051, Positioning block acknowledgment".

---

☞ In the positioning block mode, too, the acceptance of a new positioning block results in toggling of bit 0 of parameter S-0-0419, because here, the positioning command value is processed in an identical way as in the operation mode "drive-controlled positioning".

---

# 6.2 Direct Valve Control

## 6.2.1 Brief Description

Assignment to functional firmware package, see chapter "Supported Operation Modes".

In the "direct valve control" mode, a valve command value is preset for the drive. If required, this value can be directed via a ramp. Optionally, the output of the valve command value generator can also be output directly to the valve controller without control variable adjustment. Direct valve control is an open-loop-controlled mode, i.e. none of the controllers is active. This operation mode is suitable in particular for initial commissioning of the drive or open-loop-controlled manual operation. When the operation mode is activated the diagnostic message is "A0158Direct valve control".

Operation Modes

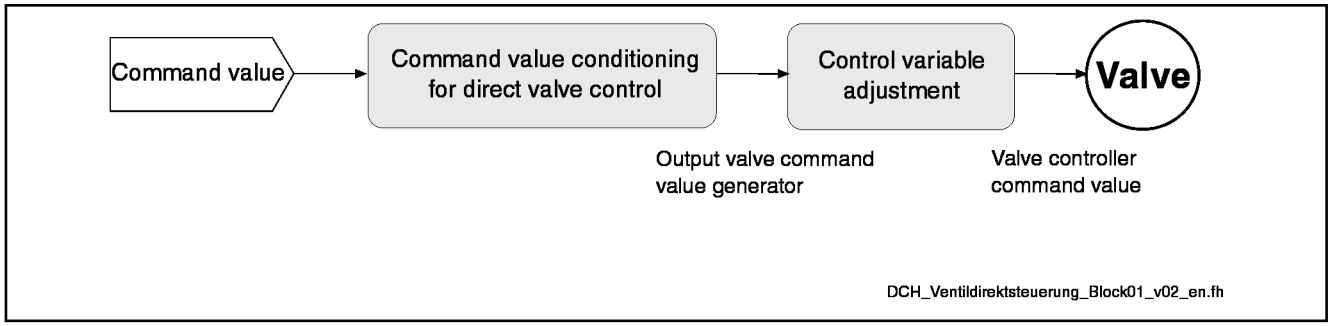



*Fig. 6-2: Block Diagram "Direct Valve Control"*

**Features**

- Output of the sum of the command values preset in parameters "S-0-0860Spool command value" and "S-0-0861Spool command value additive"
- Optional bypassing of control variable adjustment using "P-0-2928.0.1Valve command value control word bit 1"
- Limitation of given command values to limit value that can be parameterized
- To avoid step-like changes, the command value can be fed via a simple ramp or a 4-quadrant ramp, which can be changed over by "P-0-2928.0.1Valve command value control word" bit 0.

**Pertinent Parameters**

- S-0-0860, Spool command value
- S-0-0861, Spool command value additive
- S-0-0864, Bipolar spool limit value
- S-0-0865, Positive spool limit value
- S-0-0866, Negative spool limit value
- S-0-0867, Spool status word
- S-0-0869, Spool ramp time
- P-0-2914, Effective valve command value
- P-0-2928.0.1, Valve command value control word
- P-0-2928.0.3, Output of valve command value generator
- P-0-2928.0.4, Valve command value ramp time positive, acceleration
- P-0-2928.0.5, Valve command value ramp time positive, deceleration
- P-0-2928.0.6, Valve command value ramp time negative, acceleration
- P-0-2928.0.7, Valve command value ramp time negative, deceleration

**Pertinent Diagnostic Messages**

- A0158 Direct valve control

## 6.2.2 Command Value Adjustment for Direct Valve Control

**Command Value Ramp**

The command value provided by "S-0-0860Spool command value" is fed via a ramp to prevent step-like changes. The ramp can either be a simple ramp or a 4-quadrant ramp. Switching between these two options is possible by means of parameter "P-0-2928.0.1Valve command value control word" bit 0.

The simple ramp is determined by "S-0-0869Spool ramp time".

The 4-quadrant ramp is determined by

"P-0-2928.0.4, Valve command value ramp time positive, acceleration"

"P-0-2928.0.5, Valve command value ramp time positive, deceleration"

"P-0-2928.0.6, Valve command value ramp time negative, acceleration"

"P-0-2928.0.7, Valve command value ramp time negative, deceleration"

.

**Additive Valve Command Value**

Moreover, it is possible to feed forward an unfiltered, additive command value via "S-0-0861Spool command value additive". If required, this value can also be cyclically configured.

**Output Variable**

The output variable of command value adjustment for direct valve control is "P-0-2928.0.3Output of valve command value generator".

The output variable can now optionally be output via control variable adjustment or directly to the valve. This can be set via "P-0-2928.0.1Valve command value control word" bit 1.

The control variable that is fed to the valve is "P-0-2914Effective valve command value".

**Block Circuit Diagram**

The graphic below illustrates command value adjustment in the "direct valve control" mode as a block circuit diagram.

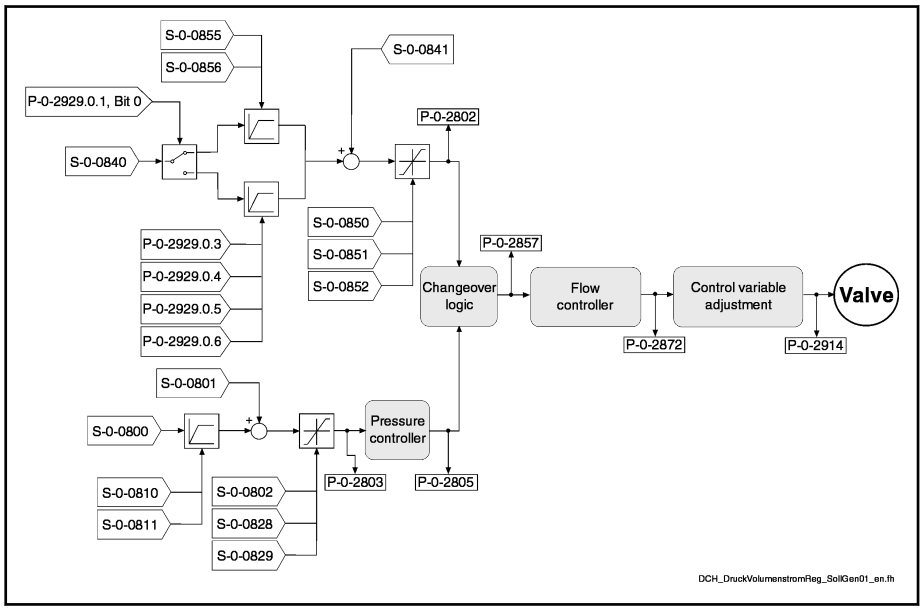



*Fig. 6-3: Command Value Adjustment for Direct Valve Control*

## 6.2.3 Diagnostic Messages and Monitoring Functions

### Diagnostic Status Messages

The activated "direct valve control" mode is indicated by the following diagnostic message:

- A0158 Direct valve control

# 6.3 Torque/Force Control

## 6.3.1 Brief Description

In the "torque/force control" mode, an additive torque/force command value is preset for the drive. If required, this command value can be interpolated with the help of a ramp. In the case of rotary drives, we speak of torque control, with linear drives, we speak of force control. For closed-loop torque/force control, pressure transducers are required. The measured pressure is cconverted into force in the drive via the cylinder dimensions entered. The force can also be sensed directly via a pressure transducer. This operation mode is

used frequently on presses, clamping fixtures, etc. When the operation mode is activated, the diagnostic message is "A0100Torque/Force control".

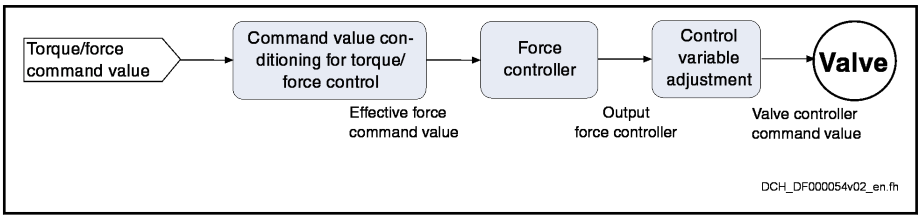



*Fig. 6-4: "Torque/Force Control" Block Circuit Diagram*

**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"
- Limitation of the preset command value to limit value that can be parameterized
- Interpolation of the command value via "S-0-0822, Torque/force ramp" and "S-0-0823, Torque/force ramp time"

**Pertinent Parameters**

- S-0-0080, Torque/force command value
- S-0-0081, Additive torque/force command value
- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0822, Torque/force ramp
- S-0-0823, Torque/force ramp time
- S-0-0824, Status "Torque/force command value attained"
- P-0-0049, Torque/force command value of controller

**Pertinent Diagnostic Messages**

- A0100 Torque/Force control
- E8260 Torque/force command value limit active
- F8079Velocity limit value exceeded

## 6.3.2 Command Value Adjustment in Torque/Force Control

### Principle of Command Value Adjustment

**Command Value Ramp**

The command value preset by "S-0-0080, Torque/force command value" is filtered with the help of a ramp. The ramp can be modified via the setting of "S-0-0822, Torque/force ramp" and "S-0-0823, Torque/force ramp time".

The message "torque/force command value reached" (S-0-0824) signals that the output value of the interpolator has reached the input value (S-0-0080).

**Additive Current Command Value**

Moreover, it is possible to feed forward 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 limit values for torque/force limitation are effective.

**Output Variable**

The output variable for command value adjustment for closed-loop torque/force control is "P-0-0049, Torque/force command value of controller".

**Block Circuit Diagram**

The figure below illustrates command value processing in the "torque/force control" mode as a block diagram.

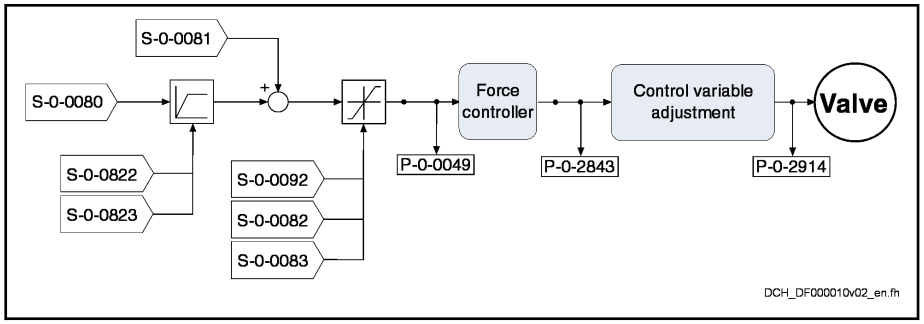



*Fig. 6-5: Command Value Adjustment in Torque/Force Control*

**Velocity Monitor**

In closed-loop torque/force control, the velocity reached by the drive depends on the output of the force controller. Since the velocity of an axis must remain within a permissible range, the actual velocity value is monitored as soon as it is outside the standstill window S-0-0124.

If the value of "S-0-0040, Velocity feedback value" exceeds the 1.125-fold value of "S-0-0091, Bipolar velocity limit value", the drive generates the error message "F8079Velocity limit value exceeded" and switches off with the error reaction that was set.

### Notes on Commissioning for Command Value Limitation

On the user side, the following limitations are available:

- Maximum allowed torque/force (S-0-0092)

See also separate documentation "Parameter Description for HydraulicDrive Controllers"

It is also possible to directly view (in N or Nm) the value of "P-0-0049, Torque/force command value of controller" as intermediate value.

## 6.3.3 Diagnostic Messages and Monitoring Functions

### Diagnostic Status Message

The activated "torque/force control" mode is displayed by the following diagnostic message:

- A0100 Torque/Force control

### Monitoring Functions

Monitoring functions specific to the operation mode:

**Command Value Limit Active**

- If necessary, the drive firmware limits the torque/force command value in dynamic and static form. If such a limitation has been activated, this is signaled by the warning "E8260Torque/force command value limit active".

**Velocity Limit Value Exceeded**

- The value of parameter "S-0-0040, Velocity feedback value" is monitored as soon as it is outside the standstill window S-0-0124. If it exceeds the 1.125-fold value parameterized in "S-0-0091, Bipolar velocity limit value", the error message "F8079Velocity limit value exceeded" is generated.

# 6.4 Closed-Loop Torque/Force Control / Direct Valve Control

## 6.4.1 Brief Description

Assignment to the firmware function package, see "Supported Operation Modes".

In the operation mode "closed-loop torque/force control / direct valve control" a force command value and a valve command value are fed to the drive. If required, these command values can be filtered. The alternating control ensures changing over to closed-loop force control as soon as the set change-over condition if fulfilled. See also Chapter "Alternating Control". When the operation mode is activated the diagnostic message is "A0173Torque/Force control / Direct valve control".

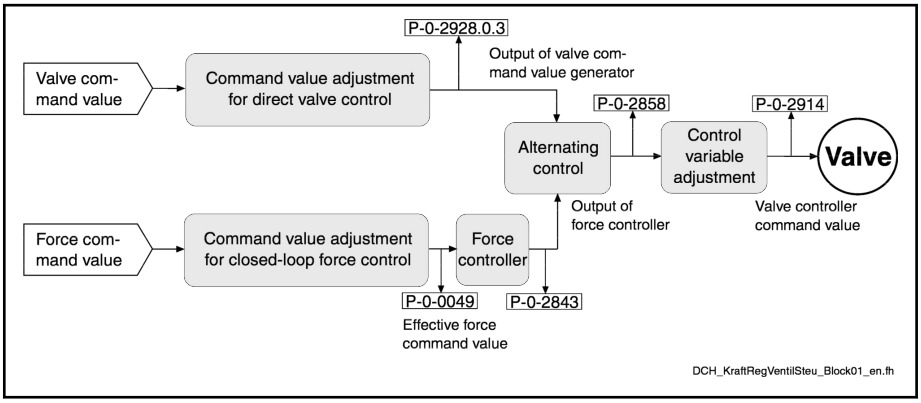



*Fig. 6-6: Block Circuit Diagram "Closed-Loop Force Control / Valve Control"*

**Features**

- Complete command value generators of individual operation modes "direct valve control" and "closed-loop torque/force control"
- Limitation of given command values to limit values that can be parameterized individually
- Complete force controller can be utilized
- Switching between valve control and closed-loop force control with the help of "alternating control"
- Use of control variable adjustment

**Pertinent Parameters**

- S-0-0860 Spool command value
- S-0-0861 Spool command value additive
- S-0-0864 Bipolar spool limit value
- S-0-0865 Positive spool limit value
- S-0-0866 Negative spool limit value
- S-0-0867 Spool status word
- S-0-0869 Spool ramp time
- P-0-2928.0.1 Valve command value control word
- P-0-2928.0.3 Output of valve command value generator
- P-0-2928.0.4 Valve command value ramp time positive, acceleration
- P-0-2928.0.5 Valve command value ramp time positive, deceleration
- P-0-2928.0.6 Valve command value ramp time negative, acceleration
- P-0-2928.0.7 Valve command value ramp time negative, deceleration
- S-0-0049 Positive position limit value
- 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-0-0822 Torque/force ramp
- S-0-0823 Torque/force ramp time
- S-0-0824 Status "Torque/force command value attained"
- P-0-2843 Output of force controller
- P-0-2855 Force controller changeover logic status word
- P-0-2858 Output of position/force changeover logic
- P-0-2914 Effective valve command value

**Pertinent Diagnostic Messages**

- ...A0173 Torque/Force control / Direct valve control

## 6.4.2 Command Value Adjustment in Direct Valve Control

### Direct Valve Control

**Command Value Ramp**

The command value provided by "S-0-0860Spool command value" is fed via a ramp to prevent step-like changes. The ramp can either be a simple ramp or a 4-quadrant ramp. Switching between these two options is possible by means of parameter "P-0-2928.0.1Valve command value control word" bit 0.

The simple ramp is determined by "S-0-0869Spool ramp time".

The 4-quadrant ramp is defined by "P-0-2928.0.4Valve command value ramp time positive, acceleration", "P-0-2928.0.5Valve command value ramp time positive, deceleration", "P-0-2928.0.6Valve command value ramp time negative, acceleration" and "P-0-2928.0.7Valve command value ramp time negative, deceleration".

**Additive Valve Command Value**

Moreover, it is possible to feed forward an unfiltered, additive command value via "S-0-0861, Spool command value additive". If required, this value can also be cyclically configured.

**Output Variable**

The output variable of command value adjustment for direct valve control is "P-0-2928.0.3Output of valve command value generator".

### Command Value Adjustment in Closed-Loop Torque/Force Control

**Filtering the Command Value**

The command value provided by "S-0-0080, Torque/force command value" is filtered. The ramp is defined by "S-0-0822, Torque/force ramp" and "S-0-0823, Torque/force ramp time".

**Additive Force Command Value**

Moreover, it is possible to feed forward an unfiltered, additive command value via "S-0-0081, Additive torque/force command value". If required, this value can also be cyclically configured.

**Output Variable**

The output variable of command value adjustment is "P-0-0049, Torque/force command value of controller". The force controller is connected downstream of it and provides the output variable "P-0-2843Output of force controller". The force controller is described in more detail in the chapter "Drive Control".

### Alternating Control

The behavior of alternating control is described in more detail in the chapter "Drive Control".

The output of alternating control is parameter "P-0-2858Output of position/force changeover logic", which is fed via control variable adjustment to the valve "P-0-2914Effective valve command value".

Operation Modes

**Block Circuit Diagram** The figure below illustrates command value adjustment in the "closed-loop torque/force control / direct valve control" mode as a block circuit diagram.

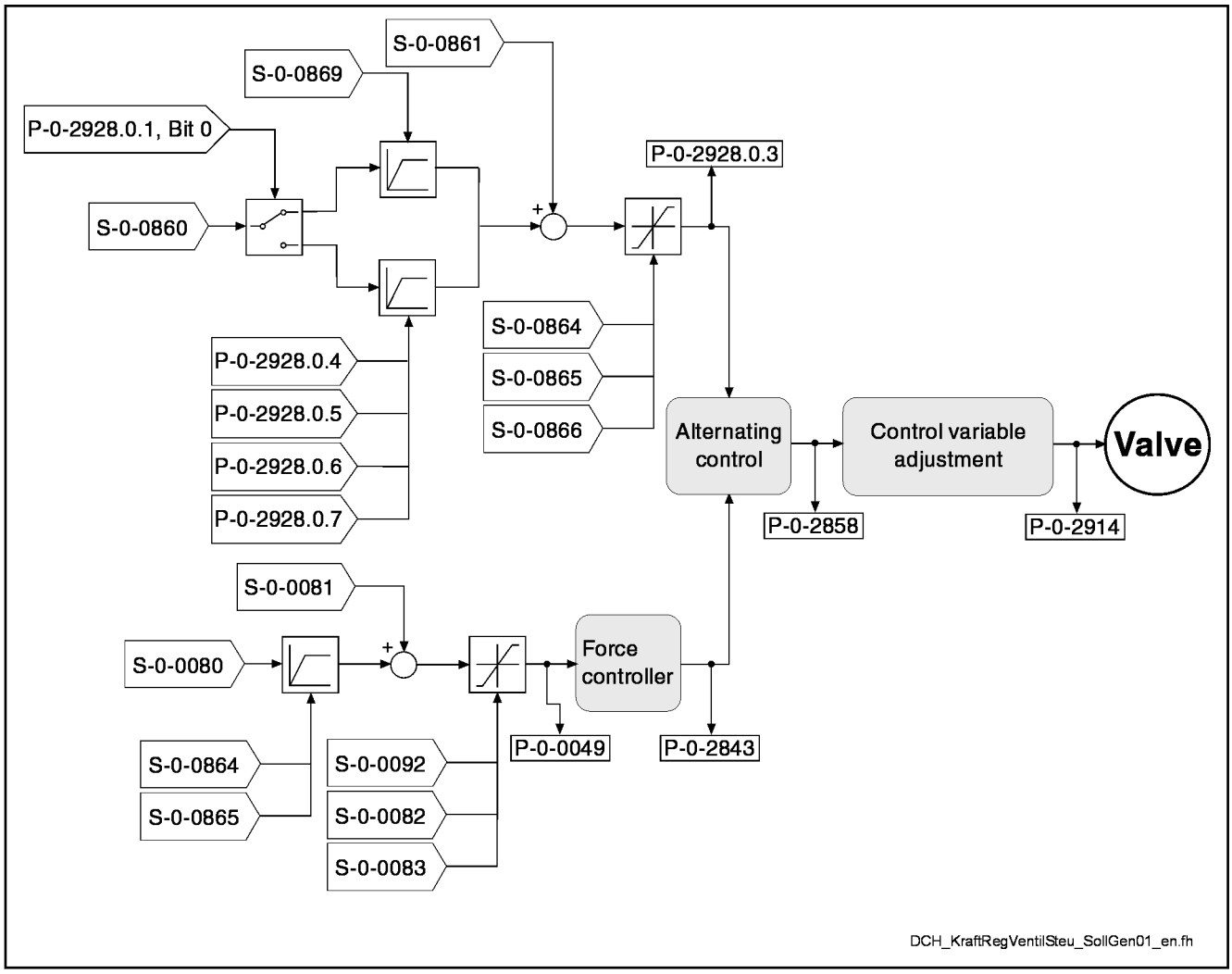



*Fig. 6-7: Command Value Adjustment in Closed-Loop Force Control / Direct Valve Control*

## 6.4.3 Diagnostic Messages and Monitoring Functions

### Diagnostic Status Messages

The activated "closed-loop torque/force control / direct valve control" mode is indicated by the following diagnostic message:

- A0173 Torque/Force control / Direct valve control

# 6.5 Closed-Loop Pressure Control / Direct Valve Control

## 6.5.1 Brief Description

Assignment to the firmware function package, see chapter "Supported Operation Modes".

In the operation mode "closed-loop pressure control / direct valve control" a pressure command value and a valve command value are fed to the drive. Bei Bedarf können diese Sollwerte gefiltert werden. Für diese Betriebsart wird kein Positionsgeber benötigt, aber für die Druckregelung mindestens eine Druckmessdose. Initially, the axis is operated in open loop control. If this

axis gets in contact with the material or any resistance, the changeover logic ensures switching over to closed-loop pressure control as soon as the set changeover condition is fulfilled. See also Chapter “Changeover Logic". With closed-loop pressure control, only the pressure of one chamber is controlled. Changing back to direct valve control takes also place via the set changeover condition. This operation mode allows open-loop-controlled operation of pressure-controlled axes (e.g. lifting, lowering of a paper roll on papermaking machines). When the operation mode is activated the diagnostic message is "A0174Pressure control / Direct valve control (p/Q)".

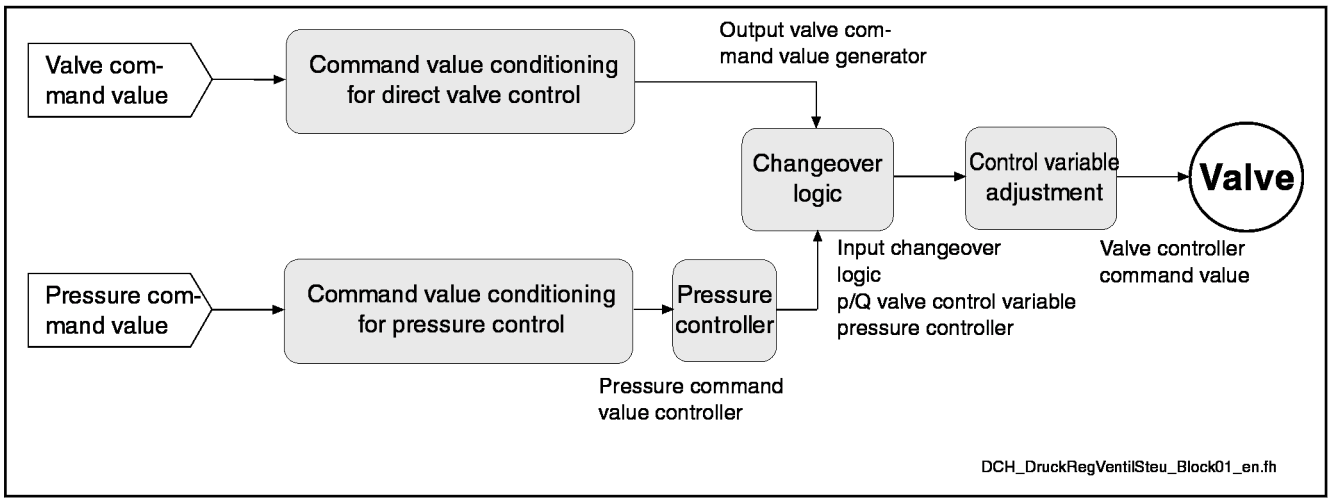



*Fig. 6-8: Block Circuit Diagram "Closed-Loop Pressure Control / Direct Valve Control (p/Q)"*

**Features**

- Command value generators for "direct valve control" and "closed-loop pressure control"
- Limitation of given command values to limit values that can be parameterized individually
- The complete pressure controller can be utilized
- Switching between valve control and closed-loop pressure control with the help of the "changeover logic"
- Use of control variable adjustment

**Pertinent Parameters**

- S–0–0860, Spool command value
- S–0–0861, Spool command value additive
- S–0–0864, Bipolar spool limit value
- S–0–0865, Positive spool limit value
- S–0–0866, Negative spool limit value
- S–0–0867, Spool status word
- S–0–0869, Spool ramp time
- P–0–2928.0.1, Valve command value control word
- P–0–2928.0.3, Output of valve command value generator
- P–0–2928.0.4, Valve command value ramp time positive, acceleration
- P–0–2928.0.5, Valve command value ramp time positive, deceleration
- P–0–2928.0.6, Valve command value ramp time negative, acceleration
- P–0–2928.0.7, Valve command value ramp time negative, deceleration
- S–0–0800, Pressure command value
- S–0–0801, Pressure command value additive

Operation Modes

- S–0–0802, Bipolar pressure limit value
- S–0–0810, Pressure ramp time
- S–0–0811, Pressure ramp reference
- S–0–0828, Positive pressure limit value
- S–0–0829, Negative pressure limit value
- S–0–0830, Pressure status word
- P–0–2803, Pressure command value of controller
- P–0–2805, Output of pressure controller
- P–0–2852.0.11, Correction value: Changeover logic p/Q pressure controller
- P–0–2873.0.16, Control variable adjustment of command value
- P–0–2914, Effective valve command value

**Pertinent Diagnostic Messages**

- ...A0174 Pressure control / Direct valve control (p/Q)

## 6.5.2 Command Value Adjustment with Closed-Loop Pressure Control / Direct Valve Control (p/Q)

### Direct Valve Control

**Filtering the Command Value**

The command value provided by "S-0-0860 Spool command value" is filtered. The filtering effect can be realized either with a simple ramp or the 4-quadrant ramp. Switching between these two options is possible by means of parameter "P-0-2928.0.1 Valve command value control word" bit 0.

The simple ramp is determined by "S-0-0869 Spool ramp time".

The 4-quadrant ramp is preset by "P-0-2928.0.4 Valve command value ramp time positive, acceleration", "P-0-2928.0.5 Valve command value ramp time positive, deceleration", "P-0-2928.0.6, Valve command value ramp time negative, acceleration" and "P-0-2928.0.7 Valve command value ramp time negative, deceleration".

**Additive Valve Command Value**

Moreover, it is possible to feed forward an unfiltered, additive command value via S-0-0861, Spool command value additive. If required, this value can also be cyclically configured.

**Output Variable**

The output variable of command value adjustment for direct valve control is "P-0-2928.0.3 Output of valve command value generator".

### Closed-Loop Pressure Control

**Filtering the Command Value**

The command value provided by "S-0-0800 Pressure command value" is filtered. The ramp is defined by "S-0-0810 Pressure ramp time" and "S-0-0811 Pressure ramp reference".

**Additive Pressure Command Value**

Moreover, it is possible to feed forward an unfiltered, additive command value via S-0-0801, Pressure command value additive. If required, this value can also be cyclically configured.

**Output Variable**

The output variable of command value adjustment is "P-0-2803 Pressure command value of controller". It is connected downstream of the pressure controller and provides the output variable "P-0-2805 Output of pressure controller". The pressure controller is described in more detail in the chapter "Drive Control".

### Changeover Logic

The behavior of the changeover logic is described in more detail in the chapter "Drive Control".

The output of the changeover logic is parameter "P-0-2873.0.16 Control variable adjustment of command value“, which is fed via control variable adjustment to the valve "P-0-2914 Effective valve command value".

**Block Circuit Diagram**

The graphic below illustrates command value adjustment in the "closed-loop pressure control / direct valve control" mode as a block circuit diagram.

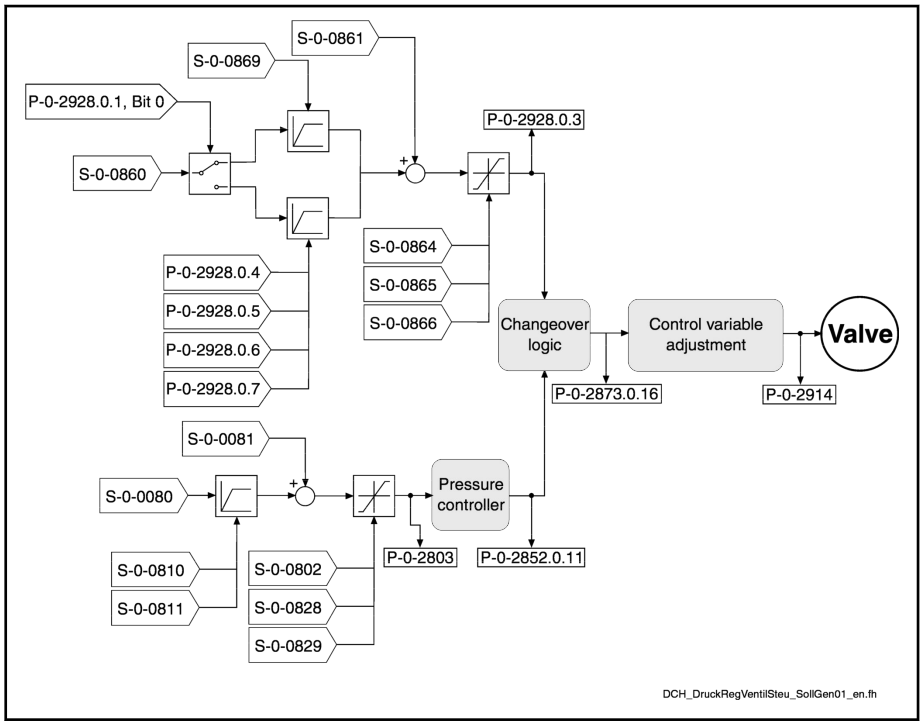



*Fig. 6-9: Command Value Processing with Closed-Loop Pressure Control / Direct Valve Control (p/Q)*

## 6.5.3 Diagnostic Messages and Monitoring Functions

### Diagnostic Status Messages

The activated operation mode "closed-loop pressure control / direct valve control (p/Q)" is indicated by the following diagnostic message:

- A0174 Pressure control / Direct valve control (p/Q)

# 6.6 Closed-Loop Flow Control

## 6.6.1 Brief Description

Assignment to the firmware function package, see chapter "Supported Operation Modes". This operation mode is supported by WRPQ valves only.

In the "closed-loop flow control" mode, a flow command value is preset for the drive. If required, this command value can be filtered. For this operation mode, no position encoder is required. The pressure sensorics integrated in the valve allows closed-loop-controlled operation so that the axis moves at largely constant velocity, even if load and pressure vary. When the operation mode is activated the diagnostic message is “A0171 Flow mode“.

Operation Modes

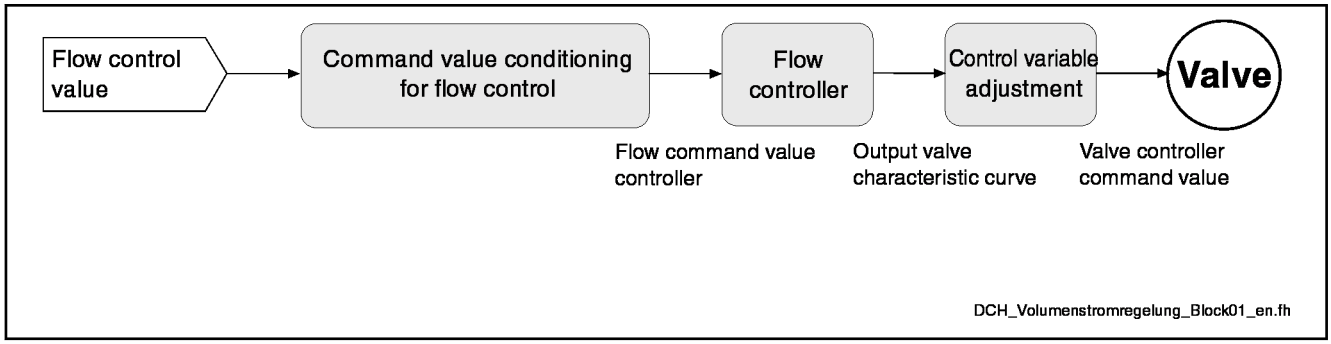



*Fig. 6-10: Block Circuit Diagram "Closed-Loop Flow Control"*

**Features**

- Output of the sum of the command values preset in parameters “S-0-0840 Flow command value“ and “S-0-0841 Flow command value additiv“
- Limitation of given command values to a limit value that can be parameterized
- Filtering of the command value via a simple ramp or via a 4-quadrant ramp; can be changed over by means of "P-0-2929.0.1 Flow control word"

**Pertinent Parameters**

- S-0-0840, Flow command value
- S-0-0841, Flow command value additiv
- S-0-0850, Bipolar flow limit value
- S-0-0851, Positiv flow limit value
- S-0-0852, Negativ flow limit value
- S-0-0855, Flow ramp reference
- S-0-0856, Flow ramp time
- P-0-2802, Flow command value internal
- P-0-2872, Output of valve characteristic curve
- P-0-2914, Effective valve command value
- P-0-2929.0.1, Flow control word
- P-0-2929.0.3, Flow ramp time positive, acceleration
- P-0-2929.0.4, Flow ramp time positive, deceleration
- P-0-2929.0.5, Flow ramp time negative, acceleration
- P-0-2929.0.6, Flow ramp time negative, deceleration

**Pertinent Diagnostic Messages**

- A0171 Flow mode

## 6.6.2 Command Value Adjustment for Closed-Loop Flow Control

**Filtering the Command Value**

The command value provided by "S-0-0840Flow command value" is filtered. The filtering effect can be realized either via a simple ramp or via a 4-quadrant ramp. Switching between these two options is possible by means of parameter "P-0-2929.0.1Flow control word" bit 0.

The simple ramp is determined by "S-0-0855Flow ramp reference" and "S-0-0856Flow ramp time".

The 4-quadrant ramp is defined by "P-0-2929.0.3Flow ramp time positive, acceleration", "P-0-2929.0.4Flow ramp time positive, deceleration", "P-0-2929.0.5Flow ramp time negative, acceleration" and "P-0-2929.0.6Flow ramp time negative, deceleration".

**Additive Flow Command Value**

Moreover, it is possible to feed forward an unfiltered, additive command value via "S-0-0841, Flow command value additiv". If required, this value can also be cyclically configured.

**Output Variable**

The output variable of command value adjustment for flow control is "P-0-2802Flow command value internal". It is connected upstream of the flow controller and provides the output variable "P-0-2872Output of valve characteristic curve ", which is fed via control variable adjustment to the valve "P-0-2914Effective valve command value".

**Block Circuit Diagram**

The figure below illustrates command value processing in the "flow control" mode as a block diagram.

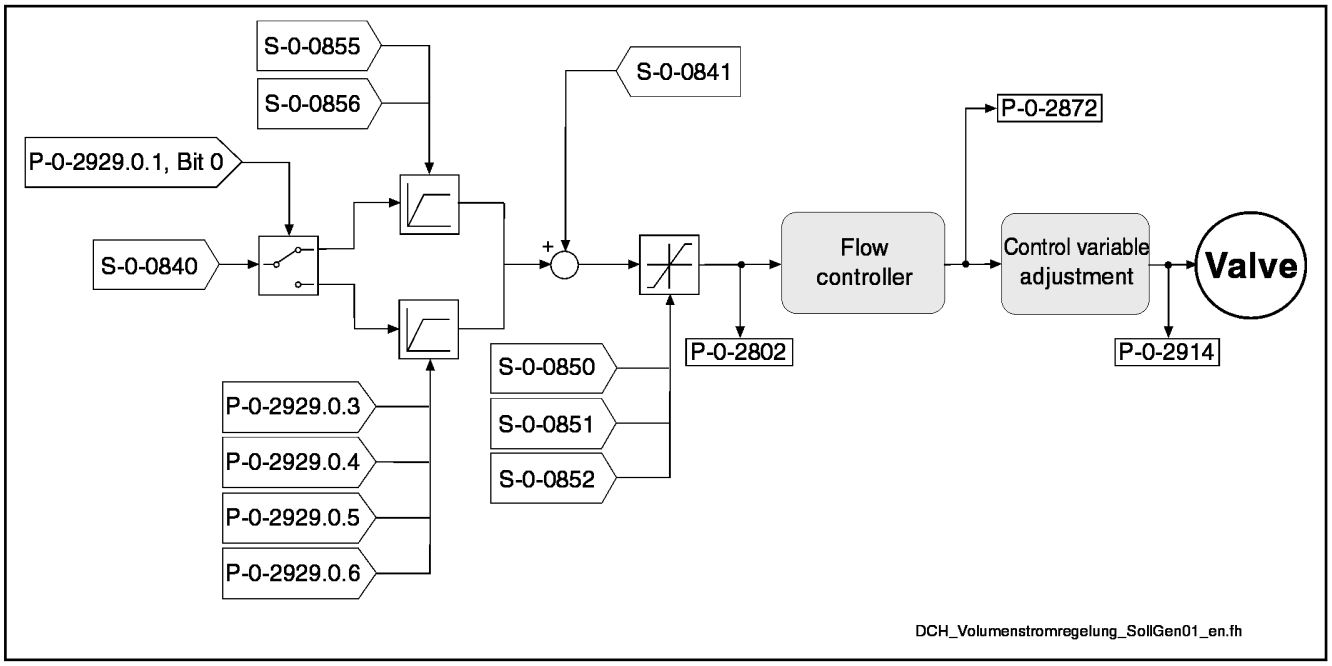



*Fig. 6-11: Command Value Adjustment for Closed-Loop Flow Control*

## 6.6.3 Diagnostic Messages and Monitoring Functions

### Diagnostic Status Messages

The activated "closed-loop flow control" mode is indicated by the following diagnostic message:

- A0171 Flow mode

# 6.7 Closed-Loop Pressure/Flow Control

## 6.7.1 Brief Description

☞ This operation mode is supported by WRPQ valves only.

Assignment to the firmware function package, see chapter "Supported Operation Modes". This operation mode is supported by WRPQ valves only.

In the "closed-loop pressure/flow control" mode, a pressure command value and a flow command value are fed to the drive. If required, these command values can be filtered. For this operation mode, no position encoder or external pressure transducer is required. Initially, the axis is operated in closed-loop flow control. When the axis gets in contact with the material or any resistance, the changeover logic ensures switching over to closed-loop pres-

Operation Modes

sure control as soon as the set changeover condition is fulfilled. See also Chapter “Changeover Logic". With closed-loop pressure control, only the pressure of one chamber is controlled. Changing back to closed-loop flow control also takes place via the set changeover condition. This operation mode allows the flow-controlled operation of pressure-controlled axes (e.g. lifting, lowering of a paper roll on papermaking machines). When the operation mode is activated the diagnostic message is “A0172 Pressure / Flow control“.

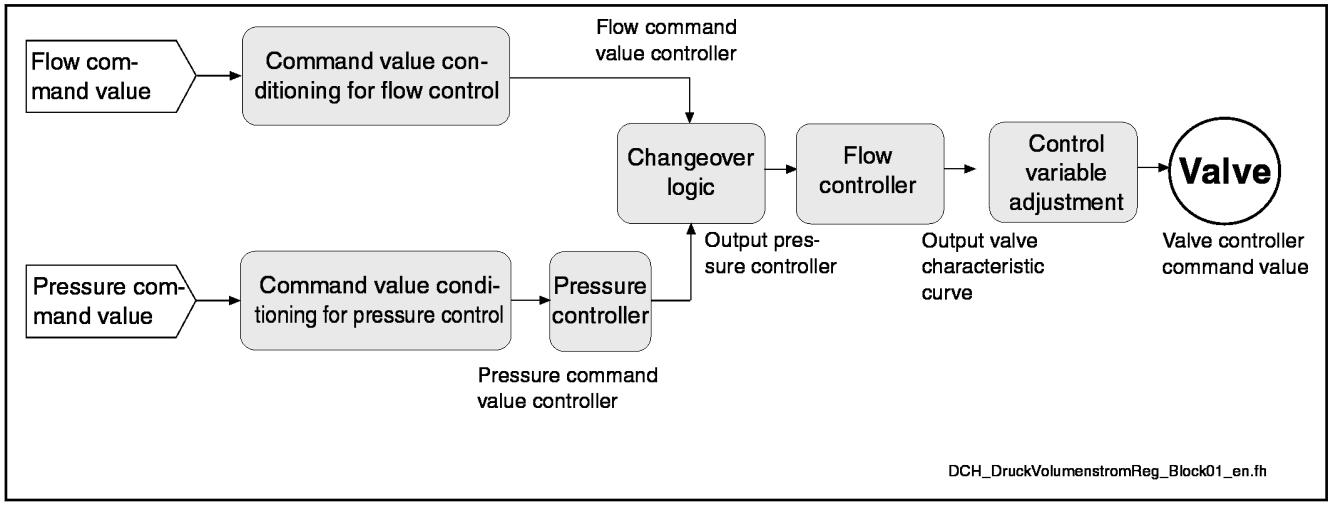



*Fig. 6-12: Block Circuit Diagram "Closed-loop Pressure/Flow Control"*

**Features**

- Command value generators for "closed-loop flow control" and “closed-loop pressure control"
- Limitation of given command values to limit values that can be parameterized individually
- Switching between closed-loop flow control and closed-loop pressure control with the help of the “change-over logic”
- Use of control variable adjustment

**Pertinent Parameters**

- S-0-0800, Pressure command value
- S-0-0801, Pressure command value additive
- S-0-0802, Bipolar pressure limit value
- S-0-0810, Pressure ramp time
- S-0-0811, Pressure ramp reference
- S-0-0828, Positive pressure limit value
- S-0-0829, Negative pressure limit value
- S-0-0830, Pressure status word
- S-0-0840, Flow command value
- S-0-0841, Flow command value additiv
- S-0-0850, Bipolar flow limit value
- S-0-0851, Positiv flow limit value
- S-0-0852, Negativ flow limit value
- S-0-0855, Flow ramp reference
- S-0-0856, Flow ramp time
- P-0-2802, Flow command value internal
- P-0-2803, Pressure command value of controller

- P-0-2805, Output of pressure controller
- P-0-2857, Output of changeover logic p/Q
- P-0-2872, Output of valve characteristic curve
- P-0-2873.0.16, Control variable adjustment of command value
- P-0-2914, Effective valve command value
- P-0-2929.0.1, Flow control word
- P-0-2929.0.3, Flow ramp time positive, acceleration
- P-0-2929.0.4, Flow ramp time positive, deceleration
- P-0-2929.0.5, Flow ramp time negative, acceleration
- P-0-2929.0.6, Flow ramp time negative, deceleration

**Pertinent Diagnostic Messages**

- ...A0172 Pressure / Flow control

## 6.7.2 Command Value Adjustment with Closed-Loop Pressure/Flow Control

### Closed-Loop Flow Control

**Filtering the Command Value**

The command value provided by "S-0-0840Flow command value" is filtered. The filtering effect can be realized either with a simple ramp or the 4-quadrant ramp. Switching between these two options is possible by means of parameter "P-0-2929.0.1Flow control word" bit 0.

The simple ramp is determined by "S-0-0855Flow ramp reference" and "S-0-0856Flow ramp time".

The 4-quadrant ramp is defined by "P-0-2929.0.3Flow ramp time positive, acceleration", "P-0-2929.0.4Flow ramp time positive, deceleration", "P-0-2929.0.5Flow ramp time negative, acceleration" and "P-0-2929.0.6Flow ramp time negative, deceleration".

**Additive Flow Command Value**

Moreover, it is possible to feed forward an unfiltered, additive command value via "S-0-0841, Flow command value additiv". If required, this value can also be cyclically configured.

**Output Variable**

The output variable of command value adjustment for flow control is "P-0-2802Flow command value internal".

### Closed-Loop Pressure Control

**Filtering the Command Value**

The command value provided by "S-0-0800, Pressure command value" is filtered. The ramp is defined by "S-0-0810, Pressure ramp time" and "S-0-0811, Pressure ramp reference".

**Additive Pressure Command Value**

Moreover, it is possible to feed forward an unfiltered, additive command value via "S-0-0801, Pressure command value additive". If required, this value can also be cyclically configured.

**Output Variable**

The output variable of command value adjustment is "P-0-2803, Pressure command value of controller". It is connected downstream of the pressure controller and provides the output variable "P-0-2805Output of pressure controller". The pressure controller is described in more detail in the chapter "Drive Control".

### Changeover Logic

The output variable of command value adjustment for flow control, "P-0-2802Flow command value internal", is compared with the output of the pressure controller "P-0-2805Output of pressure controller".

Parameter "P-0-2801p/Q controller status word" shows, whether the pressure controller branch is currently active. The behavior of the changeover logic is described in more detail in the chapter "Drive Control".

Operation Modes

The output of the changeover logic is parameter "P-0-2857Output of changeover logic p/Q", which is fed via the flow control and control variable adjustment to the valve "P-0-2914Effective valve command value".

**Block Circuit Diagram**

The figure below illustrates command value processing in the "closed-loop pressure/flow control" mode as a block circuit diagram.

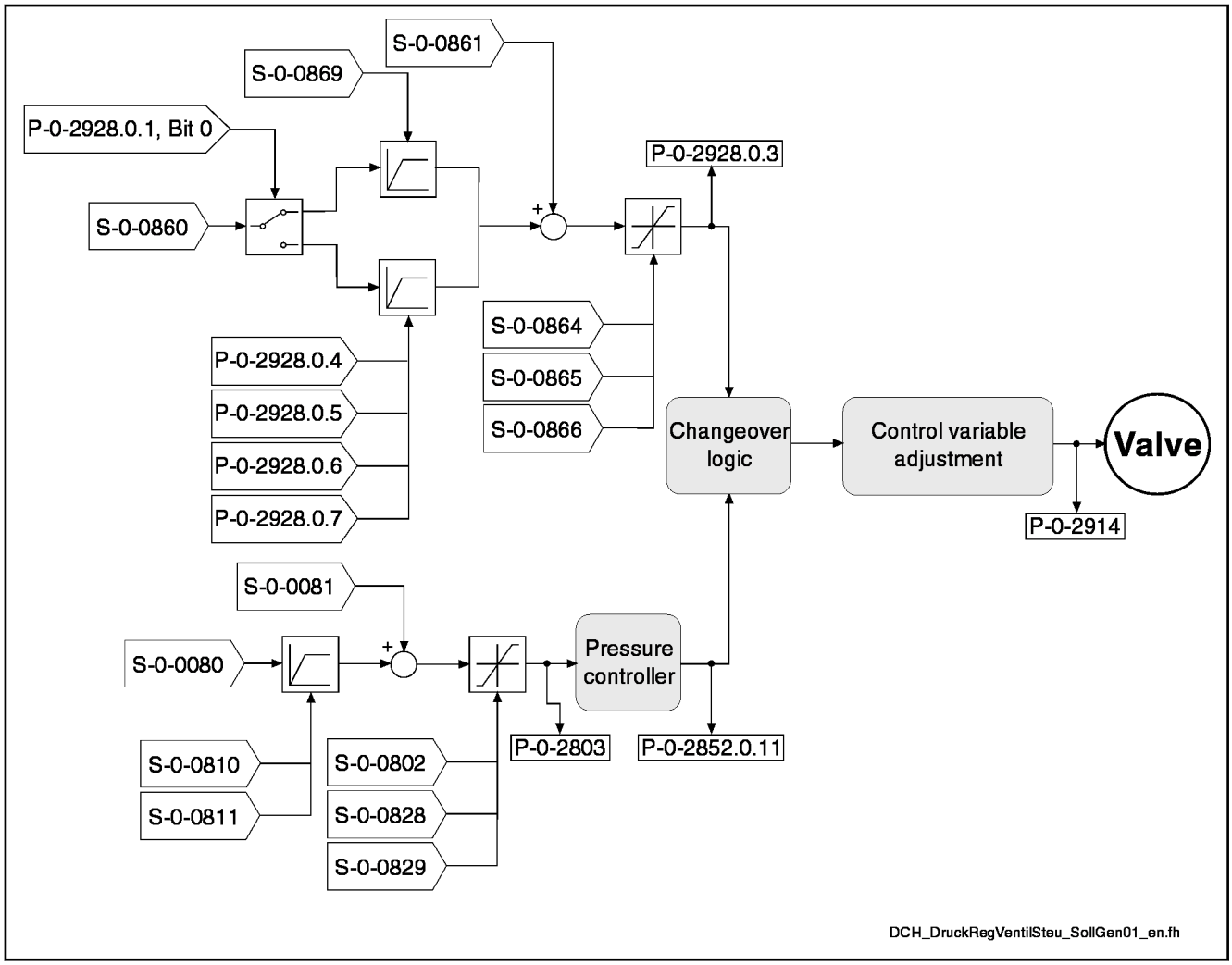



*Fig. 6-13: Command Value Adjustment with Closed-Loop Pressure/Flow Control*

## 6.7.3 Diagnostic Messages and Monitoring Functions

### Diagnostic Status Messages

The activated "closed-loop pressure/flow control" mode is indicated by the following diagnostic message:

- A0172 Pressure / Flow control

# 6.8 Closed-Loop Velocity Control

## 6.8.1 Brief Description

In the "closed-loop velocity control" mode a velocity command value is provided for the drive. The velocity command value is limited by ramps and filters. Closed-loop velocity control is often used for rotary drives. When the operation mode is activated, the diagnostic message is "A0101 Closed-loop velocity control"

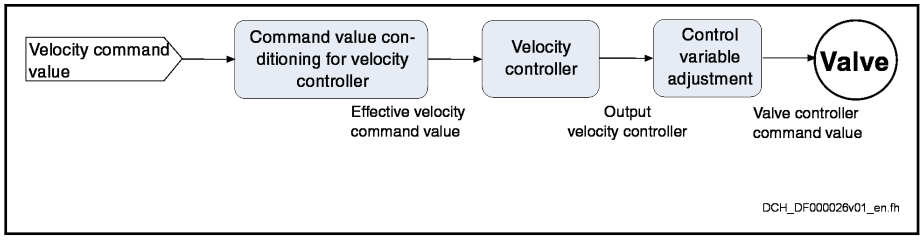



*Fig. 6-14: "Closed-Loop Velocity Control" Block Circuit Diagram*

**Features**

- Command value ramps can be generated by a drive-internal command value generator
- Switching between closed-loop velocity control and closed-loop force control with the help of "alternating control"
- Inversion of the applied velocity command value before it is processed in the ramp-function generator
- Ramp-function generator with separately adjustable, two-stage acceleration and deceleration limits of the preset velocity command value; switching from ramp 1 to ramp 2 is done with selectable velocity and run-up stop that can be parameterized
- Closed-loop velocity control via a digital controller with extensive filtering measures
- Monitoring the command velocity and actual velocity for exceeding parameter "S-0-0091, Bipolar velocity limit value"
- Moreover, monitoring also includes the drive-related limit values "S-0-0113, Maximal-Geschwindigkeit des Antriebs"
- Smoothing of velocity control loop difference via a filter that can be parameterized
- Smoothing of the given command value by means of average value filter (jerk limitation by means of moving average)

**Pertinent Parameters**

- S-0-0036, Velocity command value
- S-0-0037, Additive velocity command value
- S-0-0040, Velocity feedback value
- S-0-0091, Bipolar velocity limit value
- S-0-0113, Maximal-Geschwindigkeit des Antriebs
- S-0-0535, Active velocity feedback value
- P-0-0048, Velocity command value of controller
- P-0-0556, Config word of axis controller
- P-0-1201, Ramp 1 pitch
- P-0-1202, Final speed ramp 1
- P-0-1203, Ramp 2 pitch
- P-0-1211, Deceleration ramp 1
- P-0-1213, Deceleration ramp 2
- P-0-1222, Velocity command filter

**Pertinent Diagnostic Messages**

- A0101 Velocity control
- E2059 Velocity command value limit active
- E2063 Velocity command value > limit value
- E8260 Torque/force command value limit active

- F8079 Velocity limit value exceeded

## 6.8.2 Command Value Adjustment in Closed-Loop Velocity Control

### Overview

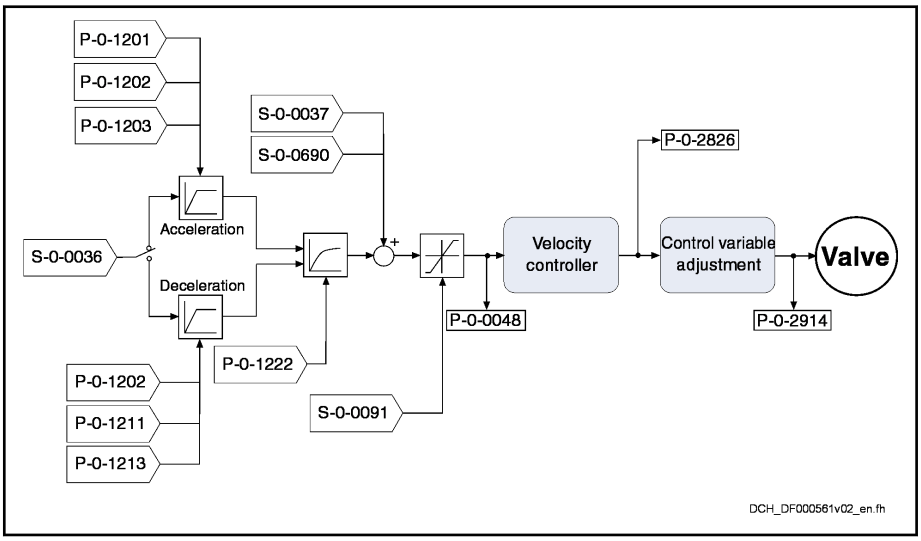



*Fig. 6-15: Command Value Adjustment in Closed-Loop Velocity Control*

☞ The value of "S-0-0037, Additive velocity command value" can be added to "S-0-0036, Velocity command value" directly at the input of the velocity controller.

In the "velocity control" mode velocity command values can be input in the following ways:

- cyclic command value input by means of parameter "S-0-0036, Velocity command value" via master communication (analog interface, sercos, field bus) or IndraMotion MLD

The velocity command value is processed by the so-called ramp generator.

☞ 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"

### Ramp Generator

For the ramp generator, we make the following distinction:

- Cyclic command value provision via S-0-0036

  → 2 ramps (acceleration and deceleration) and a jerk filter take effect

**Command Value Provision via S-0-0036**

The command value provided by parameter "S-0-0036, Velocity command value" can be limited in steps via 2 ramps in terms of increase (acceleration) and deceleration.

- Acceleration process

  → In the first step, the increase in 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 ramp 1", the increase of the command value is limited by the value of "P-0-1203, Ramp 2 pitch" (acceleration ramp 2).

- Deceleration or braking process

  → For decelerating, "P-0-1211, Deceleration ramp 1" and "P-0-1213, Deceleration ramp 2" are used by analogy.

☞ This allows parameterizing different ramps for the acceleration and braking process.

### Jerk Limitation

The velocity command value, the increase and maximum of which are limited, is jerk-limited by means of a 1st order low-pass filter.

For jerk limitation, we make the following distinction:

- Cyclic command value provision via S-0-0036

  → Jerk limitation takes effect as set in parameter P-0-1222

**Command Value Provision via S-0-0036**

The command value preset via "S-0-0036, Velocity command value" is jerk-limited according to the settings in "P-0-1222, Velocity command filter".

### Command Value Limitation

The effective velocity command value (sum of values from S-0-0036 and S-0-0037) is limited to the value specified in parameter "S-0-0091, Bipolar velocity limit value" respectively in the parameters "S-0-0038, Positive velocity limit value" or "S-0-0039, Negative velocity limit value".

☞ When the limitation takes effect, the drive generates the message "E2059Velocity command value limit active".

## 6.8.3 Alternating Control

The output variable of the velocity controller "P-0-2826 Output of velocity/ status controller" is compared with "P-0-2843 Output of force controller".

Parameter "P-0-2855 Force controller changeover logic status word" shows, whether closed-loop velocity or closed-loop force control is currently active. The behavior of alternating control is described in more detail in the chapter "Drive Control". Alternating control has no effect on the generator. This means that when switching back takes place (P-0-0049) is used for the velocity controller.

The output of alternating control is parameter "P-0-2858 Output of position/ force changeover logic“, which is fed via control variable adjustment to the valve "P-0-2914 Effective valve command value".

## 6.8.4 Diagnostic Messages and Monitoring Functions

### Diagnostic Status Messages

**Active Operation Mode**

The activated "velocity control" mode is displayed by the following diagnostic message:

- A0101 Velocity control

### Status of Ramp Generator

**Effective Velocity Command Value**

The currently effective velocity command value at the output of command value adjustment, which is preset for the velocity controller via fine interpolation, is mapped to parameter "P-0-0048, Velocity command value of controller".

**Status of Ramp Generator**

The status of the ramp generators is shown in "P-0-1210 Status word of velocity control mode".

Operation Modes

### Monitoring Functions

Monitoring functions specific to the operation mode:

**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 "E2059Velocity command value limit active".

**Velocity Command Value > Limit Value**

- 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 greater than the value in S-0-0091, the warning "E2063Velocity command value > limit value" is generated.

**Velocity Limit Value Exceeded**

- The value of parameter "S-0-0040, Velocity feedback value" is monitored as soon as it is outside the standstill window S-0-0124. If it exceeds the 1.125-fold value parameterized in "S-0-0091, Bipolar velocity limit value" the error message "F8079Velocity limit value exceeded" is generated.

# 6.9 Closed-Loop Position Control with Cyclic Command Value

## 6.9.1 Brief Description

A prerequisite for the operation mode "closed-loop position control" is a synchronous bus system (sercos, EtherCAT, VARAN). In the "closed-loop position control" mode, a cyclic position command value is made available to the drive within the NC cycle. This command value is fine-interpolated in the drive and, if necessary, jerk-limited via filters before being transmitted to the actual position controller.

To minimize the lag error, a variable velocity feedforward control is available.

There are different forms of the "position control" mode which result in the corresponding diagnostic messages when the operation mode was activated (see below "Pertinent Diagnostic Messages").

**Features**

- Closed-loop position control on the basis of the command value preset in parameter "S-0-0047, Position command value"
- NC-controlled or drive-controlled position control with internal, dynamic synchronization when changing operation modes over
- Time base for cyclic command value provision defined by "S-0-0001, NC cycle time (TNcyc)"
- Switching between closed-loop position control and closed-loop force control with the help of "alternating control"
- Monitoring of the position command value difference for exceeding parameter "S-0-0091, Bipolar velocity limit value"
- Position command values of the control unit smoothed by means of adjustable average value filter; calculation from acceleration and jerk limit values; indication 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 cycle; can be changed over via "P-0-0187, Position command processing mode"
- Adjustable position command value delay in position cycles P-0-0456, Position command value delay), maximum of 32 cycles.
- Closed-loop position control on the basis of position feedback value of encoder 1

- Velocity feedforward through adjustable factor of 0…120 % (default = 100 %)
- Cyclic acceptance of an additive torque/force command value of the control unit (external acceleration feedforward control)

☞ The condition for this operation mode is clock-synchronized communication between the control unit and the drive, as it is the case with sercos interface, for example.

**Pertinent Parameters**

- S-0-0047, Position command value
- S-0-0081, Additive torque/force command value
- S-0-0091, Bipolar velocity limit value
- S-0-0138, Bipolar acceleration limit value
- S-0-0520, Axis control word
- P-0-0010, Excessive position command value
- P-0-0011, Last valid position command value
- P-0-0041, Position command average value filter time constant
- P-0-0042, Current position command average value filter order
- P-0-0047, Position command value control
- P-0-0059, Additive position command value, controller
- P-0-0070, Effective additive torque/force command value
- P-0-0099, Position command smoothing time constant
- P-0-0142, Synchronization acceleration
- P-0-0143, Synchronization velocity
- P-0-0187, Position command processing mode
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0458, Delay of add. command values
- P-0-0556, Config word of axis controller

**Pertinent Diagnostic Messages**

- A0102 Position mode, encoder 1
- A0104 Position mode lagless, encoder 1
- A0154 Position mode drive controlled, encoder 1
- A0156 Position mode lagless, encoder 1 drive controlled
- F2036 Excessive position feedback difference
- F2037 Excessive position command difference

☞ Error message F2037 can also be configured as a warning. In this case, no error reaction takes place on the drive side. The user must initiate a suitable reaction via the control master.

Operation Modes

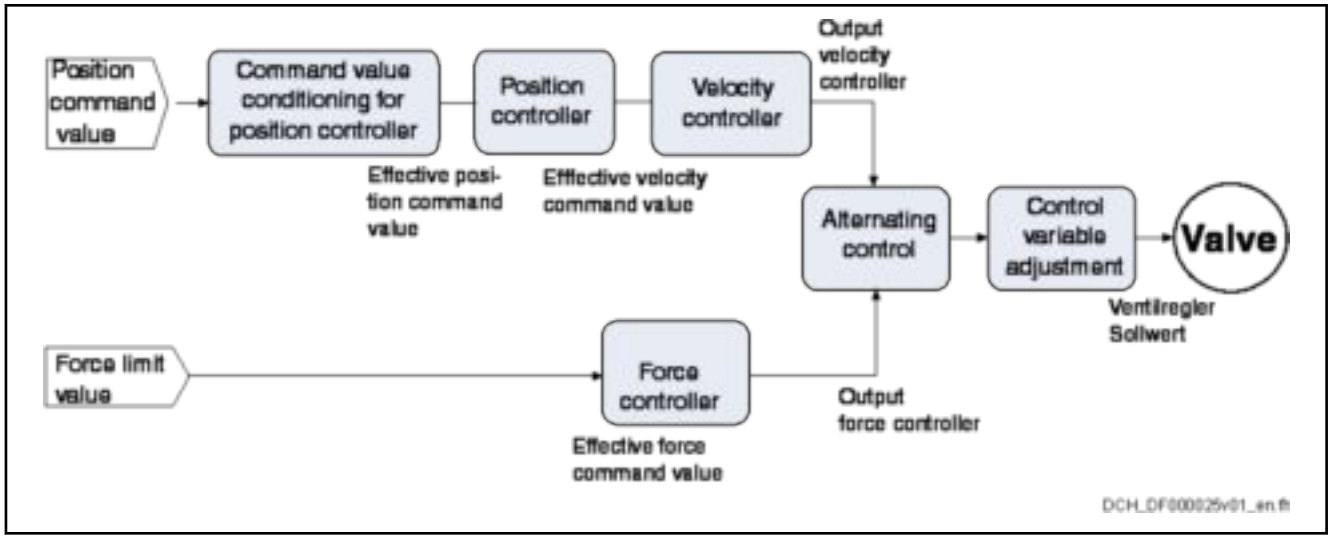



*Fig. 6-16: "Closed-loop Position Control with Cyclic Command Value Input" Block Circuit Diagram*

## 6.9.2 Command Value Adjustment in Closed-Loop Position Control

**NC- or Drive-Controlled Position Control**

We distinguish the following characteristics of the operation mode "closed-loop position control with cyclic command value input":

- **NC-controlled position control** (cf. A0102 to A0105)

  The drive generally follows the position command values which are cyclically provided by the master within the NC cycle.

- **Drive-controlled position control** (cf. A0154 to A0157)

  In the case of a changeover of operation mode to cyclic closed-loop position control, the drive realizes the corresponding synchronization process, i.e. it generates, internally by means of the internal synchronization parameters (P-0-0142, P-0-0143, P-0-0154, P-0-0151), a smooth transition of the internal position command value from the current actual position to the new command value characteristic given by the NC. After the synchronization process has been completed, the drive follows the position command values input by the master in the NC cycle.

☞ The command value cyclically transmitted by the control unit is shown in parameter "P-0-0047, Position command value control".

The internal position command value at the position controller is indicated in parameter "P-0-0434, Position command value of controller". If required, it can also be read out via parameter "S-0-0047, Position command value".

**Command Value Filtering (Jerk Limitation)**

The position command values provided by the control unit can be smoothed via an adjustable average value filter (parameter "P-0-0041, Position command average value filter time constant", moving average filter for a maximum of 64 values). The resulting filtering degree is indicated via "P-0-0042, Current position command average value filter order". This filter can be used for jerk limitation.

In the case of drive-controlled position control, a step-change in the position command value is implemented by a change of the position command average value filter with synchronization movement under closed-loop control.

☞ The PT1 filter for jerk limitation that can be parameterized via "P-0-0099, Position command smoothing time constant" only takes effect with linear fine interpolation.

**Fine Interpolation of the Position Command Value**

The position command value cyclically transmitted in the NC cycle by the control unit can be fine-interpolated in the drive, if necessary.

Via "P-0-0187, Position command processing mode" kit is possible to switch between:

- linear fine interpolator,
- cubic approximator (default setting) or
- cubic fine interpolator (according to contour)

ⓘ See also Parameter Description "P-0-0187, Position command processing mode"

☞ It is recommended to use the cubic fine interpolator according to contour (default setting), because it provides a clearly higher quality of velocity and acceleration feedforward, particularly with lagless position control.

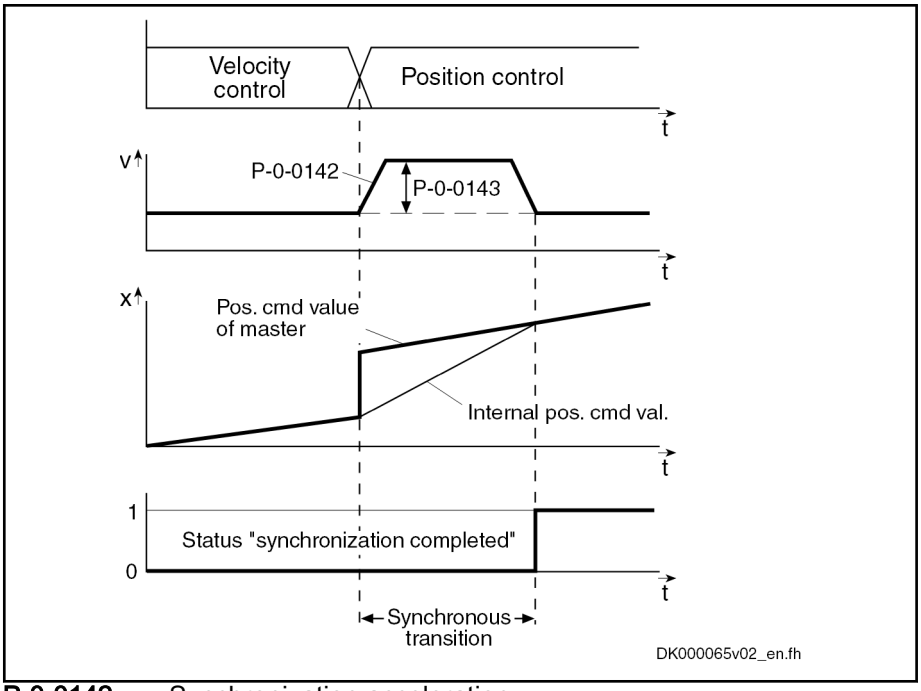
**Position Command Value Delay**

Downstream of the fine interpolator, the position command value can be delayed by a maximum of 32 position cycles, before it is fed to the position controller. This allows a master axis to be controlled synchronously with the controlled slave axis. The number of position cycles is set in the position command value delay (P-0-0456). The undelayed position command value generator (P-0-0457) is entered in a ring buffer, the delayed position command value is then taken over to the position command value controller (P-0-0434).

**Drive-Controlled Change of Operation Mode**

In the case of a drive-controlled change of operation mode, the drive makes sure internally that when the operation mode is changed, the transition is carried out in a synchronized way, even if the command value changes abruptly.

Operation Modes




**P-0-0142** Synchronization acceleration
**P-0-0143** Synchronization velocity

*Fig. 6-17: Time Diagram "Drive-Controlled Change of Operation Mode"*

**Block Circuit Diagram**

The graphic below illustrates command value adjustment in the "closed-loop position control" mode as a block circuit diagram.

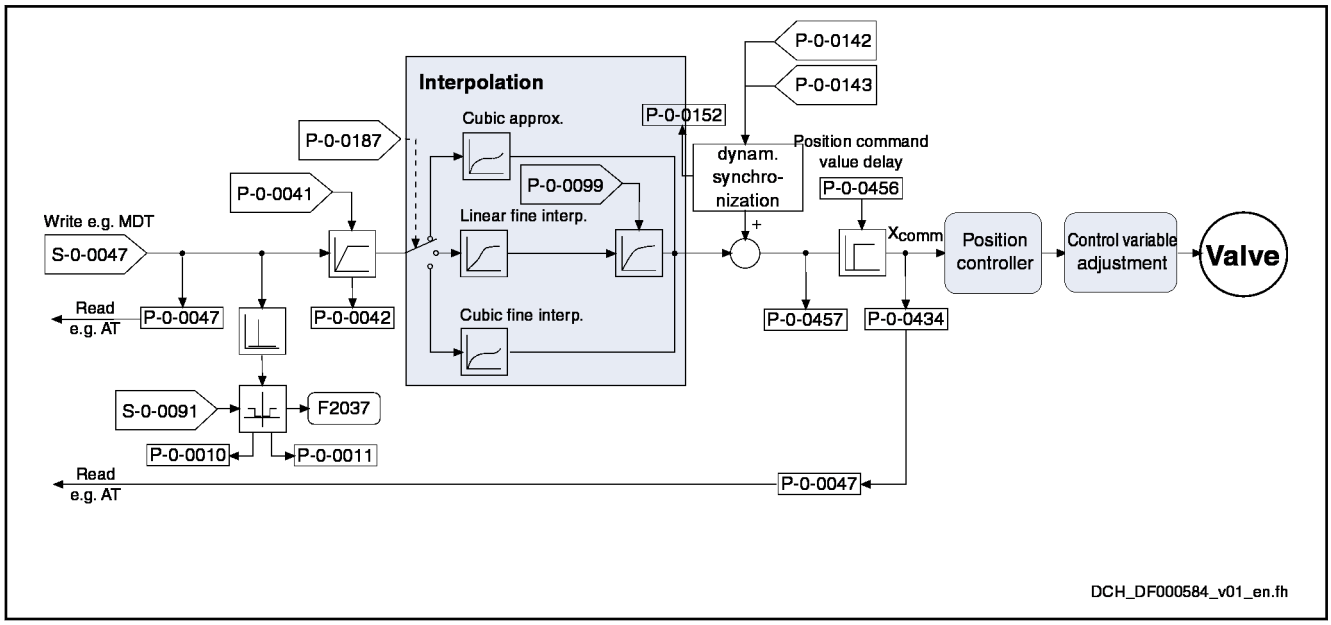



*Fig. 6-18: Command Value Adjustment in Position Control*

## 6.9.3 Alternating Control

The output variable of the velocity controller "P-0-2826 Output of velocity/ status controller" is compared with "P-0-2843 Output of force controller".

Parameter “P-0-2855 Force controller changeover logic status word" shows, whether closed-loop position or closed-loop force control is currently active. The behavior of alternating control is described in more detail in the chapter "Drive Control".

A control must recognize that the force controller is currently active and must react to it. If the control does not react to it, problems may arise during the further control process, because the axis no longer follows the force controller.

The output of alternating control is parameter "P-0-2858 Output of position/ force changeover logic“, which is fed via control variable adjustment to the valve "P-0-2914 Effective valve command value".

## 6.9.4 Position Controller

The position controller is a controller adapted to suit hydraulic requirements.

**Control Loop Performance and Cycle Times**

The position control loop is closed according to the available performance variant.

**Velocity Feedforward**

The type of position control with regard to velocity feedforward control can be set via "S-0-0520, Axis control word"; however, in conjunction with operation modes with firmly assigned encoder (e.g. closed-loop position control, encoder 1), this property is controlled exclusively via a bit of the operation mode parameter.

- Lagless operation (**with** velocity feedforward)
- Operation with lag error (**without** velocity feedforward)

The lag error is the difference between position command value and actual position value. The current value is stored in parameter "S-0-0189, Following distance".

If the mechanical structure and the application permit it, lagless operation should always be selected.

Velocity feedforward control can be variably adjusted by means of P-0-0040, Velocity feedforward evaluation. This allows setting the lag error to a desired percentage value at constant velocity.

In lagless operation and with P-0-0040 = 100 % there is a minimum lag error of "0" at constant velocity.

## 6.9.5 Diagnostic Messages and Monitoring Functions

### Diagnostic Status Messages

The activated "closed-loop position control with cyclic command value input" mode is displayed by one of the following diagnostic messages:

- A0102 Position mode, encoder 1
- A0104 Position mode lagless, encoder 1
- A0154 Position mode drive controlled, encoder 1
- A0156 Position mode lagless, encoder 1 drive controlled

### Monitoring Functions/Diagnostic Messages Specific to Operation Mode

#### Monitoring for Single Position Command Value Failure

**Position Command Value Extrapolation**

In the "position control with cyclic command value input" mode, new position command values are transmitted to the drive in every NC cycle. The difference between the current and the last position command value is determined and checked for plausibility.

Responding of the monitoring function can have the following causes:

- Incorrect command value provision by the control unit

- Command value transmission error

☞ In the case of single command value failure, the position command value is extrapolated.

### Excessive Position Command Value Difference

When the "closed-loop position control" mode was activated, the calculated velocity required for reaching the preset position command value (S-0-0047) is compared with "S-0-0091, Bipolar velocity limit value". The NC cycle time (TNcyc in S-0-0001) is used as the time base for converting the position command value differences into a velocity.

If the command velocity corresponding to the preset position command value exceeds the value in S-0-0091, the error message "F2037Excessive position command difference" is generated. In addition, the two command values involved 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 caused the generation of the error message.

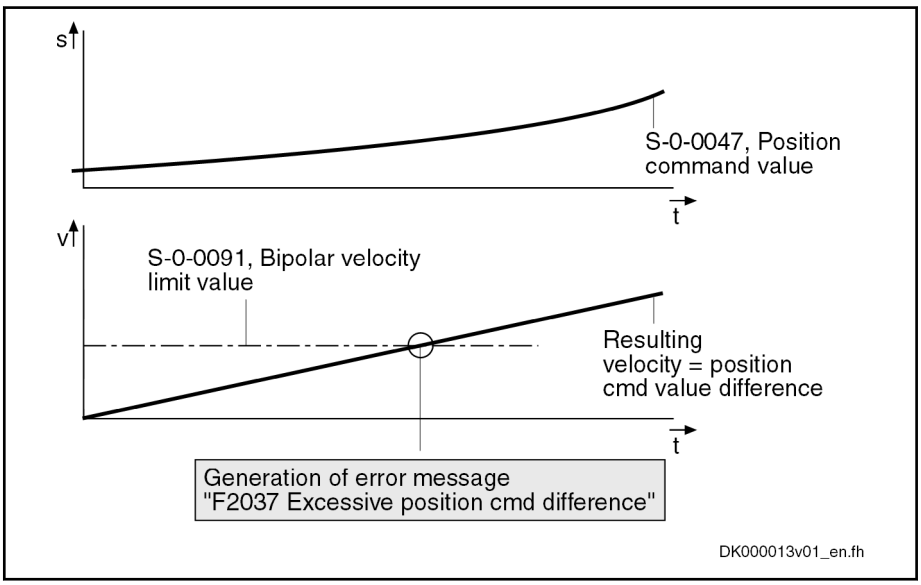



*Fig. 6-19: Monitoring for Error "F2037 Excessive Position Command Difference"*

☞ The value entered in parameter "S-0-0091, Bipolar velocity limit value" should be approximately 5 to 10 % higher than the intended maximum velocity of the axis.

# 6.10 Drive-Internal Interpolation

## 6.10.1 Brief Description

The operation modes "drive-internal interpolation" and "drive-controlled positioning" allow time-optimized positioning of a single axis. The "drive-internal interpolation" mode forms 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) as input value for the position con-

troller from the preset value for the target position taking account of preset positioning data (velocity, acceleration and jerk). New command values (target position, velocity, acceleration and jerk) are accepted directly in the positioning generator. This means that, for example, the velocity can be changed during the positioning process. A new target position is directly accepted as well without the previous target position having to have been reached first.

There are different forms of the "drive-internal interpolation" mode which result in the corresponding diagnostic messages when the operation mode was activated (see below "Pertinent Diagnostic Messages").

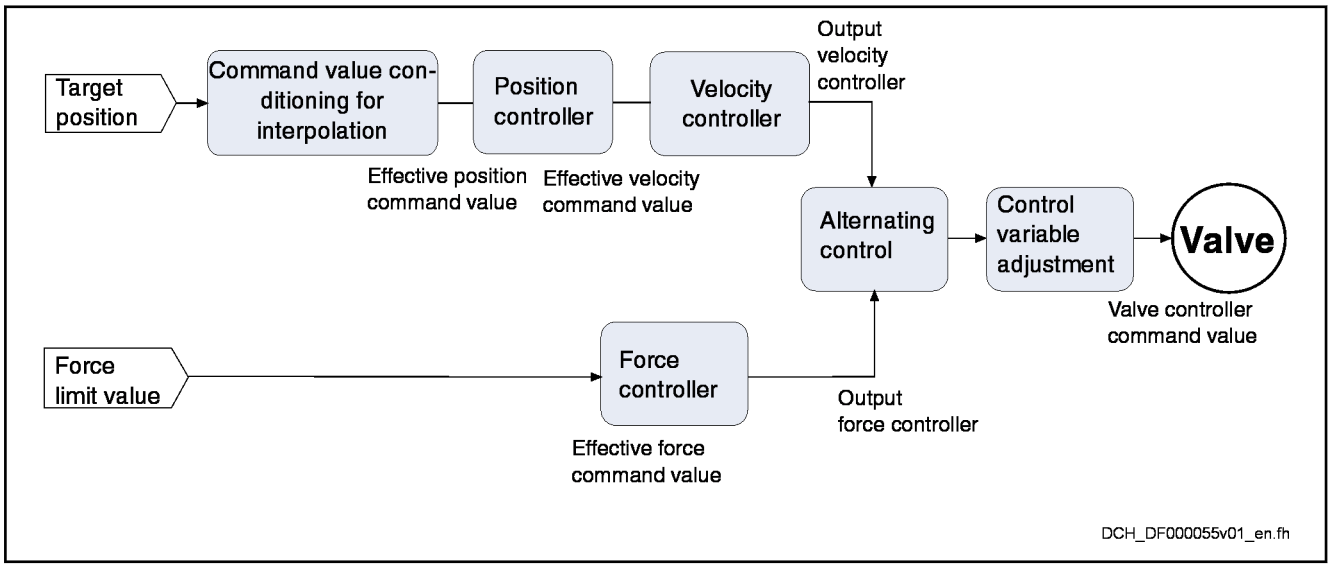



*Fig. 6-20: Block Diagram "Drive-Internal Interpolation"*

**Features**

- Drive-internal generation of a position command value profile to travel to a preset target position (S-0-0258) while maintaining the adjustable positioning velocity (S-0-0259) and positioning acceleration (S-0-0260) or positioning deceleration (S-0-0359); can be set separately
- Switching between closed-loop position control and closed-loop force control with the help of "alternating control"
- The command value is generated within the NC cycle "S-0-0001, NC cycle time (TNcyc)". The transition into the position controller cycle is accomplished by means of cubic fine interpolation.
- Jerk limitation of generated position command value with parameter "S-0-0193, Positioning jerk"
- Setting of the average value filter (jerk limitation) to fixed filter time by means of interpolation cmd value average value filter time constant (P-0-0641)
- Adjustable position command value delay in position cycles (P-0-0456), maximum of 32 cycles.
- Evaluation of the positioning velocity with "S-0-0108, Feedrate override"
- Monitoring of positioning velocity for exceeding the value in parameter "S-0-0091, Bipolar velocity limit value"
- Monitoring of target position for compliance with the position limit values
- Closed-loop position control for "S-0-0051, Position feedback value 1"
- Acceleration and deceleration ramps, can be set separately

Operation Modes

☞ In this operation mode, it is possible to separately parameterize the acceleration and deceleration processes. This allows optimum adjustment to the respective application-specific requirements.

**Pertinent Parameters**

- S-0-0108, Feedrate override
- S-0-0138, Bipolar acceleration limit value
- S-0-0193, Positioning jerk
- S-0-0258, Target position
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0359, Positioning deceleration
- S-0-0430, Effective target position
- S-0-0437, Positioning status
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant

**Pertinent Diagnostic Messages**

- A0106 Drive-internal interpolation, encoder 1
- A0108 Drive controlled interpolation, lagless, encoder 1
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2055 Feedrate override S-0-0108 = 0
- F2057 Target position out of travel range

## 6.10.2 Command Value Adjustment with Drive-Internal Interpolation

The target position can be cyclically preset via parameter "S-0-0258, Target position".

The drive generates the position command value profile necessary to move to the target position, taking account of the requirements defined in the following parameters:

- S-0-0108, Feedrate override
- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0359, Positioning deceleration

☞ The target position preset by the control master is shown in parameter S-0-0430.

The graphic below illustrates command value adjustment in the "drive-internal interpolation" mode as a block circuit diagram.

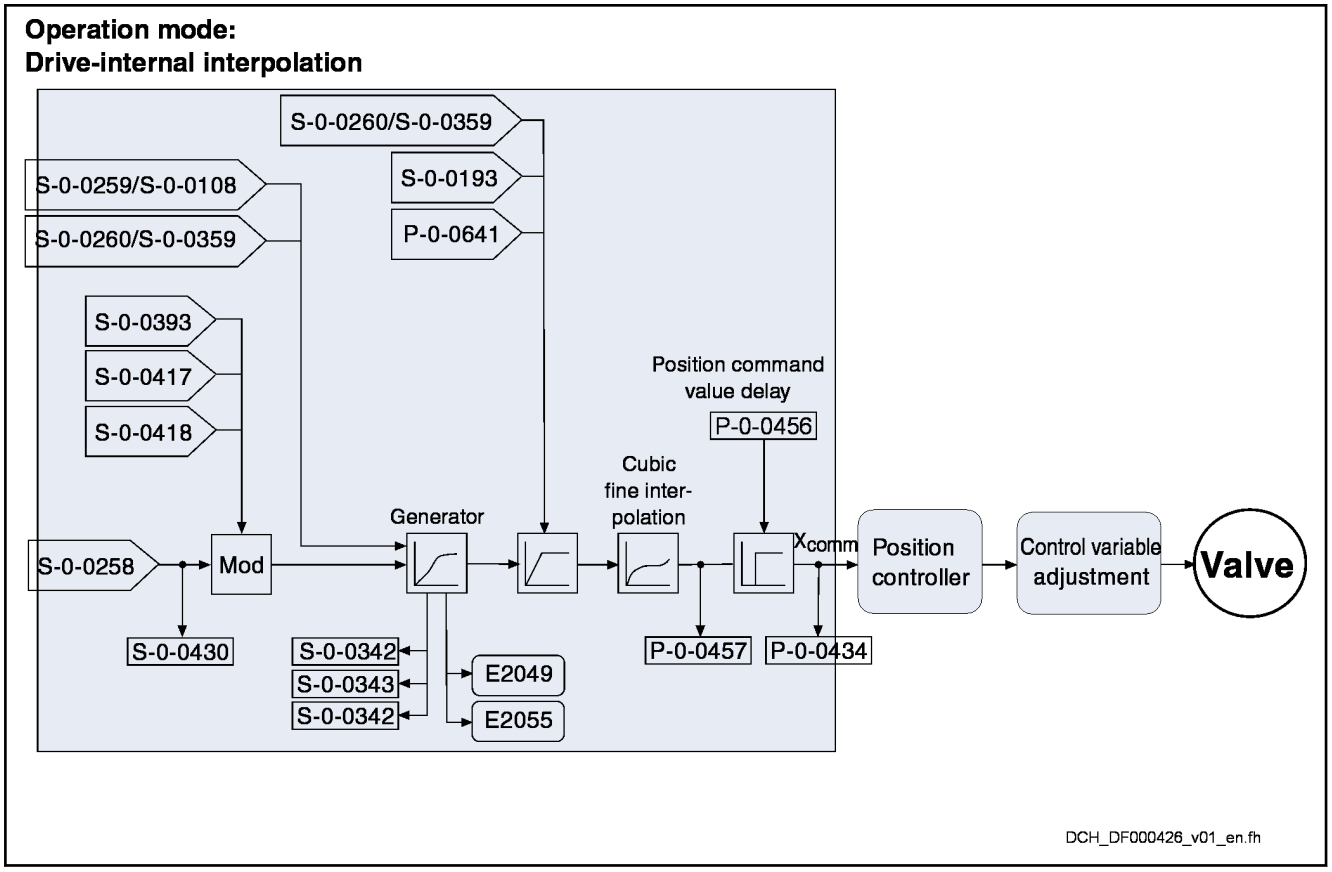



*Fig. 6-21: Command Value Adjustment with "Drive-Internal Interpolation"*

## 6.10.3 Alternating Control

The output variable of the velocity controller "P-0-2826 Output of velocity/ status controller" is compared with "P-0-2843 Output of force controller".

Parameter P-0-2855 Force controller changeover logic status word" shows, whether closed-loop position or closed-loop force control is currently active. The behavior of alternating control is described in more detail in the Chapter "Drive Control".

A control must recognize that the force controller is currently active and must react to it. If the control does not react to it, problems may arise during the further control process, because the axis no longer follows the force controller.

The output of alternating control is parameter "P-0-2858 Output of position/ force changeover logic“, which is fed via control variable adjustment to the valve "P-0-2914 Effective valve command value".

## 6.10.4 Position Controller with Drive-Internal Interpolation

The position command value generated at the output of the command value generator is displayed in parameter "P-0-0434, Position command value of controller" and can be output at the analog output.

In this operation mode, the same information as relevant in the "position control with cyclic command value input" mode applies to the position control loop.

Operation Modes

## 6.10.5 Notes on Commissioning

### Effective Positioning Velocity

The drive reaches its maximum velocity after an acceleration phase with the value set in parameter "S-0-0260, Positioning acceleration".

The maximum velocity during a positioning procedure is the result of:

$$v_{max} = \text{S-0-0259} \times \frac{\text{S-0-0108}}{100\ \%}$$

**S-0-0259** Positioning velocity
**S-0-0108** Feedrate override
*Fig. 6-22: Determining the Maximum Velocity During the Positioning Process*

### Effective Acceleration and Deceleration

The maximum deceleration is defined in parameter "S-0-0359, Positioning deceleration".

If the value in parameter S-0-0359 equals zero, the drive uses the parameter value of "S-0-0260, Positioning acceleration" for deceleration, too.

If the value in parameter S-0-0260 equals zero, too, the parameter value of "S-0-0138, Bipolar acceleration limit value" is used. If this value has also been set to zero, acceleration is not limited. If possible, the drive sets the positioning velocity immediately.

### Smoothing Filter (or Jerk Filter)

In the "drive-internal interpolation" mode the position command value can be filtered at the output of the positioning generator. We distinguish between two cases for setting of the filter order.

**Case 1: Filter order computed from acceleration / jerk**

The filter order of the (moving) average filter available to do this (cf. P-0-0042) is calculated on the basis of the preset positioning acceleration or the positioning jerk.

This means that the parameterized acceleration or deceleration only becomes effective after $t = \text{P-0-0042} \times T_{NCYC}$.

☞ $T_{NCYC}$ is the generator cycle time (S-0-0001).

$$P\text{-}0\text{-}0042 = \frac{S\text{-}0\text{-}0260}{S\text{-}0\text{-}0193}[s] * \frac{10^6}{T_{NCYC}}$$

– or –

$$P\text{-}0\text{-}0042 = \frac{S\text{-}0\text{-}0359}{S\text{-}0\text{-}0193}[s] * \frac{10^6}{T_{NCYC}}$$

**P-0-0042** Current position command average value filter order
**S-0-0260** Positioning acceleration
**S-0-0193** Positioning jerk
**S-0-0359** Positioning deceleration

*Fig. 6-23: Internally Determining the Value of P-0-0042 for Operation Modes with Drive-Internal Interpolation*

☞ The setting S-0-0193 = 0 switches the smoothing filter off; i.e. the desired acceleration or deceleration is immediately reached.

**Case 2: Filter order constant**

The filter order can also be set to a fixed value, which is accomplished using parameter "Interpolation cmd value average value filter time constant" (P-0-0641). The filter order is calculated from the time constant referred to the generator cycle time $T_{NCYC}$, > 0 with an order > 0, the function "filter order constant" is active and the accelerating / jerk calculation is ineffective. A new filter order can only become effective when the operation mode is initialized or when a block change takes place. The current filter order is continued to be shown in P-0-0042.

### Position Command Value Delay

Downstream of the fine interpolator, the position command value can be delayed by a maximum of 32 position cycles, before it is fed to the position controller. This allows a master axis to be controlled synchronously with the controlled slave axis. The number of position cycles is set in the position command value delay (P-0-0456). The undelayed position command value generator (P-0-0457) is entered in a ring buffer, the delayed position command value is then taken over to the position command value controller (P-0-0434).

## 6.10.6 Diagnostic Messages and Monitoring Functions

### Diagnostic Status Messages

The activated "drive-internal interpolation" mode is displayed by one of the following diagnostic messages:

- A0106 Drive-internal interpolation, encoder 1
- A0108 Drive controlled interpolation, lagless, encoder 1

### Monitoring Functions

Monitoring functions specific to the operation mode:

**Target Position out of Travel Range**

- If position limit value monitoring is activated (bit 4 of parameter "S-0-0055, Position polarities" has been set) and the measuring system used for the operation mode has been homed, the parameter"S-0-0258, Target position" is monitored for compliance with the position limit values (S-0-0049 or S-0-0050). If the parameter exceeds these limit val-

ues, either the error message "F2057Target position out of travel range" or the warning "E2053Target position out of travel range" is generated, depending on the determination in "P-0-0090, Travel range limit parameter". If parameterized as warning, positioning refers to the limit switches.

The preset target position will not be accepted.

**Positioning Velocity >= Limit Value**

- If the preset positioning velocity ("S-0-0259, Positioning velocity") exceeds the maximum allowed limit value ("S-0-0091, Bipolar velocity limit value"), the warning "E2049" is generated.

  The drive moves to the new target position at the velocity specified in parameter "S-0-0091, Bipolar velocity limit value".

**Feedrate Override (S-0-0108) = 0**

- If the factor of positioning velocity "S-0-0108, Feedrate override" equals zero, the warning "E2055Feedrate override S-0-0108 = 0" is generated.

## Status Messages

The parameter "S-0-0437, Positioning status" contains all the important status information on the operation mode "drive-internal nterpolation".

See Parameter Description "S-0-0437, Positioning status"

The figures below illustrate the operating principle of the status messages:

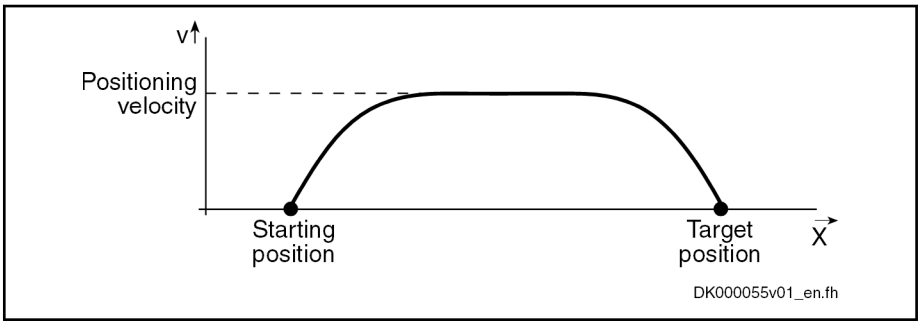



*Fig. 6-24: Travel Profile to Explain how the Interpolation Status Messages Work*

In this example, the drive is at the starting position when the new target position is preset.

The result is the following time diagram:

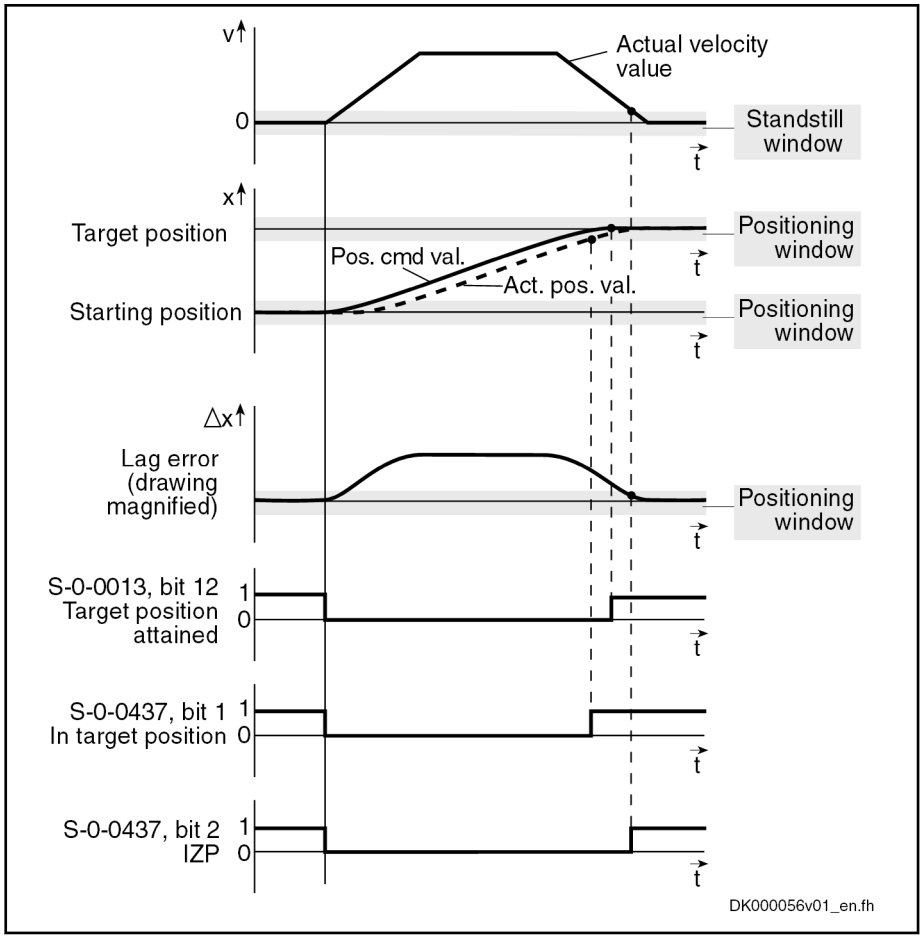



*Fig. 6-25: Generating the Status Bits of the Operation Modes with Drive-Internal Interpolation*

# 6.11 Drive-Controlled Positioning

## 6.11.1 Brief Description

The operation modes "drive-internal interpolation" and "drive-controlled positioning" allow time-optimized positioning of a single axis. The "drive-internal interpolation" mode forms 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 input value for the position loop from the preset positioning data (effective target position, velocity, acceleration and jerk). In contrast to “drive-internal interpolation”, with “drive-controlled positioning” the acceptance of the command values can be controlled via the positioning control word (S-0-0346). It is possible to parameterize different types of position processing (see features).

There are different forms of the "drive-controlled positioning" mode which result in the corresponding diagnostic messages when the operation mode was activated (see "Pertinent Diagnostic Messages" below).

Operation Modes

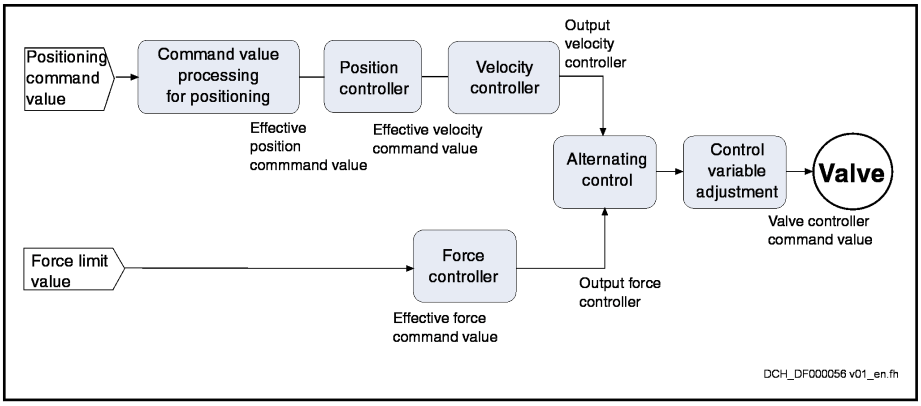



*Fig. 6-26: "Drive-Controlled Positioning" Block Circuit Diagram*

**Features**

- Processing of an absolute target position or a relative travel distance
- Drive-internal generation of a position command value profile to reach the positioning command value (S-0-0282) while maintaining the adjustable positioning velocity (S-0-0259) and positioning acceleration (S-0-0260) or positioning deceleration (S-0-0359); can be set separately
- Switching between closed-loop position control and closed-loop force control with the help of "alternating control"
- The command value is generated within the NC cycle "S-0-0001, NC cycle time (TNcyc)". The transition into the position controller cycle is accomplished by means of cubic fine interpolation.
- Acceptance of the positioning command value via toggle bit (S-0-0346, bit 0)
- Jerk limitation of the generated position command value with parameter "S-0-0193, Positioning jerk"
- Setting of the average value filter (jerk limitation) to fixed filter time by means of interpolation cmd value average value filter time constant (P-0-0641)
- Adjustable position command value delay in position cycles (P-0-0456), maximum of 32 cycles.
- Evaluation of the positioning velocity with parameter "S-0-0108, Feedrate override"
- Monitoring of positioning velocity for exceeding the value in parameter "S-0-0091, Bipolar velocity limit value"
- Monitoring of target position for compliance with position limit values (see "S-0-0049, Positive position limit value", "S-0-0050, Negative position limit value")
- Closed-loop position control for "S-0-0051, Position feedback value 1"
- Acceleration and deceleration ramps can be set separately ("S-0-0260, Positioning acceleration" or "S-0-0359, Positioning deceleration")
- Position limit values taken into account when accepting target position, positioning velocity and positioning acceleration
- Jog mode ("infinite travel" positive/negative; S-0-0346, bits 1 and 2)
- Residual path processing can be activated
- "On-the-fly acceptance" of the new target position or intermediate stop

☞ In this operation mode, it is possible to separately parameterize the acceleration and deceleration processes in order to achieve optimum adjustment to the respective application-specific requirements.

**Pertinent Parameters**

- S-0-0057, Position window
- S-0-0108, Feedrate override
- S-0-0138, Bipolar acceleration limit value
- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0282, Positioning command value
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0346, Positioning control word
- S-0-0359, Positioning deceleration
- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode
- S-0-0419, Positioning command acknowledge
- S-0-0430, Effective target position
- S-0-0437, Positioning status
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant

**Pertinent Diagnostic Messages**

- A0150 Drive-controlled positioning, encoder 1
- A0151 Drive-controlled positioning, encoder 1, lagless
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2055 Feedrate override S-0-0108 = 0
- F2050 Overflow of target position preset memory
- F2057 Target position out of travel range

## 6.11.2 Command Value Adjustment with Drive-Controlled Positioning

### Overview

The figure below illustrates command value processing in the "drive-controlled positioning" mode as a block circuit diagram.

Operation Modes

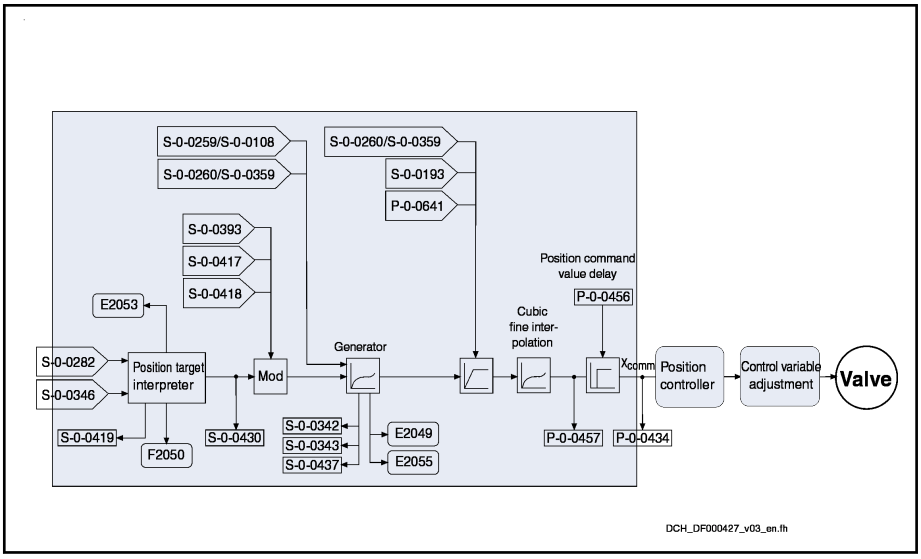



*Fig. 6-27: Command Value Processing With "Drive-Controlled Positioning"*

## 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".

Upon every edge of bit 0 (toggle bit) of S-0-0346, the content of "S-0-0282, Positioning command value", is, depending on bit 3 of S-0-0346,

- **kopiert** to parameter S-0-0430
  (when bit 3 = 0 → absolute **target position**)

- or -

- **added** to the value of parameter S-0-0430
  (when bit 3 = 1 → **travel distance**).

---

☞ If a positioning process is interrupted 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.

---

Via "S-0-0419, Positioning command acknowledge" (bit 0), the drive acknowledges that it has accepted the positioning command value. This allows realizing a data handshake for monitoring the command value acceptance between master and drive.

---

☞ The active target position is displayed in parameter"S-0-0430, Effective target position".

---

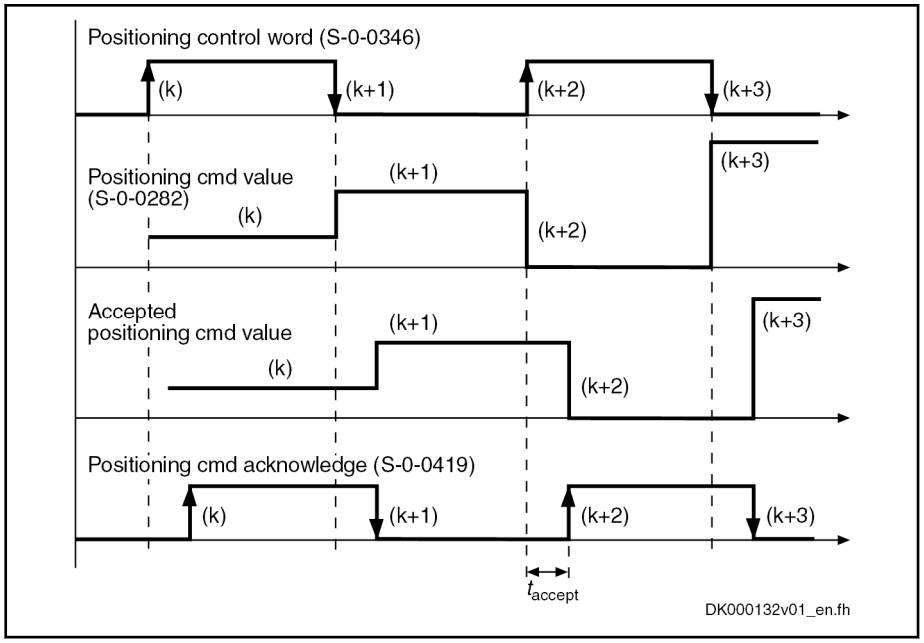



*Fig. 6-28: Positioning Command Value Acceptance and Acknowledgment*

Time $t_{accept}$ (see illustration above) defines the time that passes between status change of the acceptance bit by the control unit and the reception of acknowledgment in the master. The time is made up of the effective transmission time of the command values and actual values and thus depends on the configuration of the interface to the master (e.g. sercos/field bus timing parameter).

---

☞ If the "drive-controlled positioning" mode is not yet active, the acceptance of the new positioning command value is not acknowledged.

If bit 0 ofS-0-0346 is unequal to bit 0 of S-0-0419 while this operation mode is active, the positioning command value from S-0-0282 is immediately accepted and the drive immediately moves to this command value.

---

The acceptance is acknowledged when the new positioning command value is taken over from the intermediate buffer to parameter "S-0-0430, Effective target position" and thus to the position command value generator.

Operation Modes

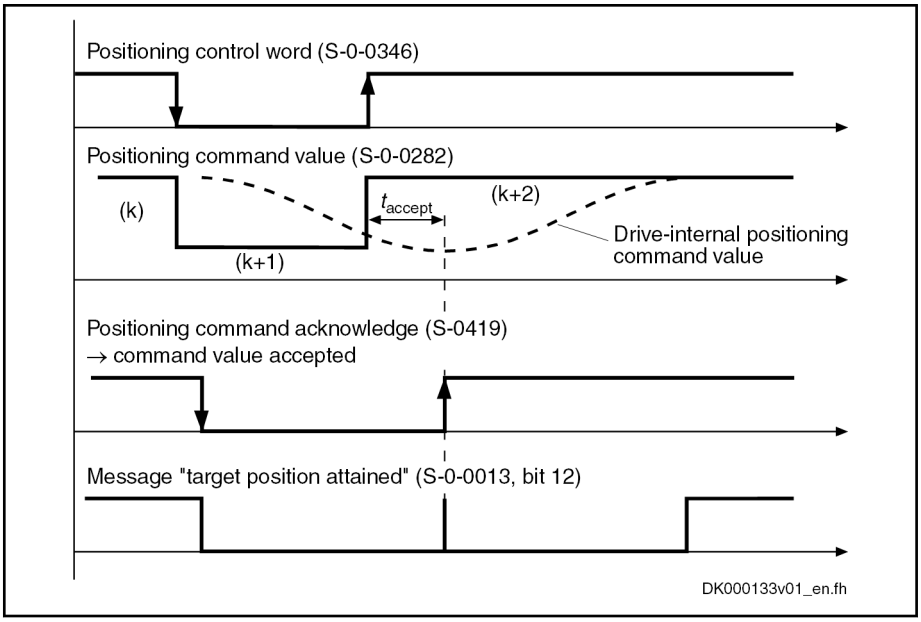



*Fig. 6-29: Acknowledgment of Positioning Command Value Acceptance in Mode "Complete Move to Positioning Command Value (k+2)"*

**Acknowledgment with Error "Overflow of Target Position Preset Memory"**

If, in the "complete move to positioning command value" mode, one tries to preset a new positioning command value by toggling parameter "S-0-0346, Positioning control word", although the preceding positioning command value (k+1) was not accepted (because the drive had not yet moved to the preceding positioning command value (k)), the error message "F2050Overflow of target position preset memory" is generated.

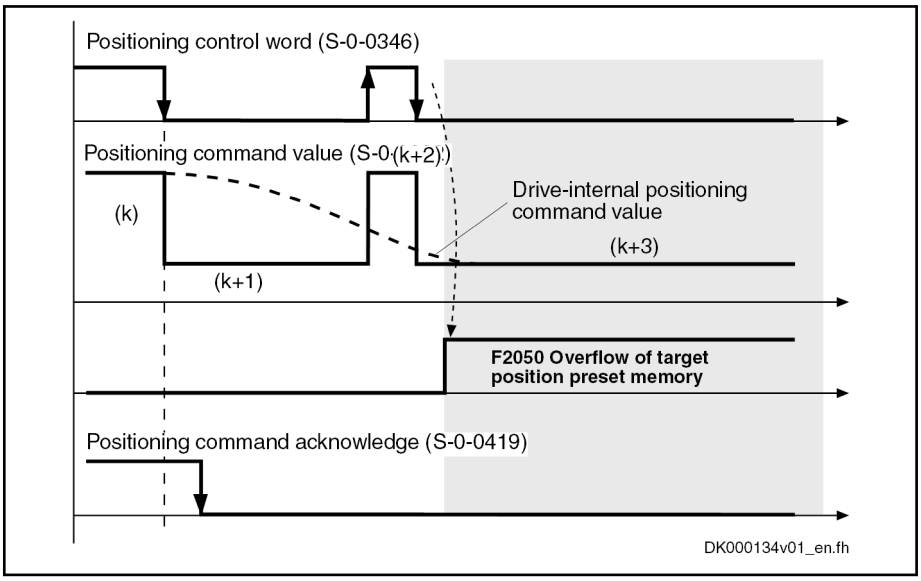



*Fig. 6-30: Acknowledgment with Error "Overflow of Target Position Preset Memory"*

In addition to bit 0 for mere block acceptance, the parameter "S-0-0346, Positioning control word" contains further control bits which are explained below.

**Positioning Modes that can be Selected**

Via bit 1 and bit 2 of S-0-0346 you can determine different positioning modes:

- **"Infinite travel"** (jog positive or negative → **Jog mode**) when:
  - Bit 2/1 = 01 → "Infinite travel" positive

  - Bit 2/1 = 10 → "Infinite travel" negative
- **"Stopping"** (with "S-0-0359, Positioning deceleration"") if:
  - Bit 2/1 = 11

**Reference of Active Target Position**

Via bit 4 of S-0-0346, it is possible to determine the reference of the active target position.

- **Bit 4 = 0** → Reference for positioning is the "old target position", i.e. a residual path that possibly hasn't been traveled yet is traveled before the drive moves to the new target

  → Incremental dimension is maintained in the case of successive positioning procedures
- **Bit 4 = 1** → Reference for positioning is the current actual position value, a possibly existing residual path is not traveled

  → Incremental dimension reference is maintained

Bit 4 takes effect with every new travel job (edge on bit 0). Residual path processing is only carried out during the first positioning process after the operation mode was activated, when the position status has been set and bit 2 = 1 in parameterS-0-0393. In this case the residual path, after the operation mode was activated, is traveled without start edge.

**Reaction to New Target Position Input**

Via bit 5 of S-0-0346, it is possible to determine the time of the reaction to a new target position input:

- **Bit 5= 0** → The drive travels to the last preset target before positioning at the new target. The target is considered to have been reached when the following applies:

  Target position – actual position value < positioning window
- **Bit 5 =1** → The previous target is rejected and the drive immediately travels to the new target.

  → Immediate block change

See also Parameter Description "S-0-0346, Positioning control word"

### Positioning Generator

The drive generates the position command value profile necessary to move to the target position taking account of the boundary 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

## 6.11.3 Alternating Control

The output variable of the velocity controller "P-0-2826 Output of velocity/ status controller" is compared with "P-0-2843 Output of force controller".

Parameter P-0-2855 Force controller changeover logic status word" shows, whether closed-loop position or closed-loop force control is currently active. The behavior of alternating control is described in more detail in the Chapter "Drive Control".

A control must recognize that the force controller is currently active and must react to it. If the control does not react to it, problems may arise during the further control process, because the axis no longer follows the force controller.

The output of alternating control is parameter "P-0-2858 Output of position/ force changeover logic“, which is fed via control variable adjustment to the valve "P-0-2914 Effective valve command value".

## 6.11.4 Position Controller with Drive-Controlled Positioning

The position command value generated at the output of the command value generator is displayed in parameter "P-0-0434, Position command value of controller" and can be output at the analog output.

In this operation mode, the same information as relevant in the "position control with cyclic command value input" mode applies to the position control loop.

## 6.11.5 Jog Mode with Drive-Controlled Positioning ("Jogging")

☞ The jog mode is part of the positioning mode and not an individual operation mode! This means that there aren't any separate parameters for the jog mode, but you have to use the parameters of the "drive-controlled positioning" mode.

**Activating the Jog Mode**

To use the jog mode, make the following settings:

- Activate the "drive-controlled positioning" mode

  - and -

- Select the positioning mode "infinite travel" (jog positive or negative → jog mode) via bits 1 and 2 of parameter "S-0-0346, Positioning control word"

**Parameterizing the Jog Mode**

When jogging, the following parameters are relevant for operation:

- S-0-0108, Feedrate override

  → To achieve, if necessary, a reduction of the jog velocity online by means of a "potentiometer"

- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity

  The positioning velocity becomes effective immediately, also when the jog mode is active.

- S-0-0260, Positioning acceleration
- S-0-0282, Positioning command value
- S-0-0346, Positioning control word

  → To select the jog direction ("Jog+", "Jog-" and "stopping")

- S-0-0359, Positioning deceleration

The parameters for acceleration, deceleration, and jerk are accepted when a jog movement is started and stopped.

During the jog mode, changes of parameters can only become effective by toggling the acceptance bits in the positioning control word (bit 0).

☞ Bits 1 and 2 of parameter S-0-0346 are integral parts of the field bus control word and, if required, can be assigned to the digital inputs.

## 6.11.6 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:

$$v_{max} = S\text{-}0\text{-}0259 \times \frac{S\text{-}0\text{-}0108}{100\ \%}$$

**S-0-0259** Positioning velocity
**S-0-0108** Feedrate override

*Fig. 6-31: Determining the Maximum Velocity During the Positioning Process*

### Effective Acceleration and Deceleration

The maximum deceleration is defined in parameter "S-0-0359, Positioning deceleration".

If the value in parameter S-0-0359 equals zero, the drive uses the parameter value of "S-0-0260, Positioning acceleration" for deceleration, too.

If the value in parameter S-0-0260 equals zero, too, the parameter value of "S-0-0138, Bipolar acceleration limit value" is used. If this value has also been set to zero, acceleration is not limited. If possible, the drive sets the positioning velocity immediately.

### Smoothing Filter (or Jerk Filter)

In the operation mode "drive-controlled positioning" the position command value can be filtered at the output of the positioning generator, with two cases having to be distinguished for setting the filter order.

**Case 1: Filter order calculated from A / R**

The filter order of the (moving) average filter available to do this (cf. P-0-0042) is calculated on the basis of the preset positioning acceleration or the positioning jerk.

This means that the parameterized acceleration or deceleration only becomes effective after t = P-0-0042 × $T_{NCYC}$.

☞ $T_{NCYC}$ is the generator cycle time (S-0-0001).

Operation Modes

$$P\text{-}0\text{-}0042 = \frac{S\text{-}0\text{-}0260}{S\text{-}0\text{-}0193}[s] * \frac{10^6}{T_{NCYC}}$$

– or –

$$P\text{-}0\text{-}0042 = \frac{S\text{-}0\text{-}0359}{S\text{-}0\text{-}0193}[s] * \frac{10^6}{T_{NCYC}}$$

**P-0-0042** Current position command average value filter order
**S-0-0260** Positioning acceleration
**S-0-0193** Positioning jerk
**S-0-0359** Positioning deceleration

*Fig. 6-32: Internally Determining the Value of P-0-0042 for Operation Modes with Drive-Internal Interpolation*

☞ The setting S-0-0193 = 0 switches the smoothing filter off; i.e. the desired acceleration or deceleration is immediately reached.

**Case 2: Filter order constant**

The filter order can also be set to a constant value. This is made via parameter "Interpolation cmd value average value filter time constant" (P-0-0641). The filter order is calculated from the time constant related to the generator cycle time $T_{NCYC}$; with an order > 0, the const. filter order function is active and the A / R calculation is ineffective. A new filter order can only become effective when the operation mode is initialized or when a block change takes place. The current filter order is continued to be shown in P-0-0042.

### Position Command Value Delay

Downstream of the fine interpolator, the position command value can be delayed by a maximum of 32 position cycles, before it is fed to the position controller. This allows a master axis to be controlled synchronously with the controlled slave axis. The number of position cycles is set in the position command value delay (P-0-0456). The undelayed position command value generator (P-0-0457) is entered in a ring buffer, the delayed position command value is then taken over to the position command value controller (P-0-0434).

## 6.11.7 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

### Monitoring Functions

Monitoring functions specific to the operation mode:

**Target Position out of Travel Range**

- If position limit value monitoring is activated (bit 4 of parameter "S-0-0055, Position polarities" has been set) and the measuring system used for the operation mode has been homed, the parameter"S-0-0258, Target position" is monitored for compliance with the position limit values (S-0-0049 or S-0-0050). If the parameter exceeds these limit values, either the error message "F2057Target position out of travel range"

or the warning "E2053Target position out of travel range" is generated, depending on the determination in "P-0-0090, Travel range limit parameter". If parameterized as warning, positioning refers to the limit switches.

The preset target position will not be accepted.

**Positioning Velocity >= Limit Value**

- If the preset positioning velocity ("S-0-0259, Positioning velocity") exceeds the maximum allowed limit value ("S-0-0091, Bipolar velocity limit value"), the warning "E2049Positioning velocity >= limit value" is generated.

  The drive moves to the new target position at the velocity specified in parameter "S-0-0091, Bipolar velocity limit value".

**Feedrate Override (S-0-0108) = 0**

- If the factor of positioning velocity "S-0-0108, Feedrate override" equals zero, the warning "E2055Feedrate override S-0-0108 = 0" is generated.

## Status Messages

The parameter "S-0-0437, Positioning status" contains all the important status information on the operation mode "drive-internal nterpolation".

See Parameter Description "S-0-0437, Positioning status"

The figures below illustrate the operating principle of the status messages:

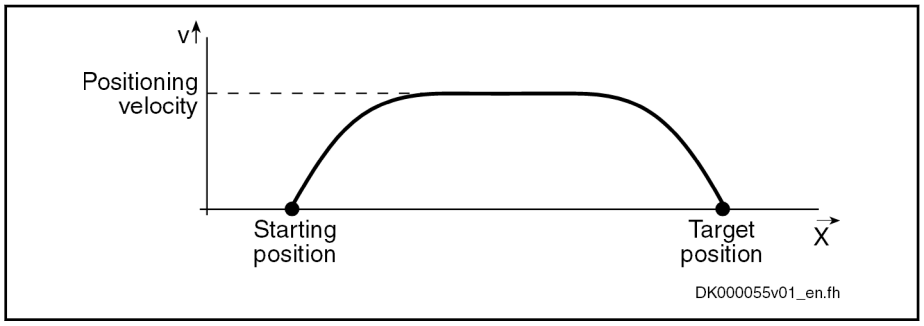



*Fig. 6-33: Travel Profile to Explain how the Interpolation Status Messages Work*

In this example, the drive is at the starting position when the new target position is preset.

The result is the following time diagram:

Operation Modes

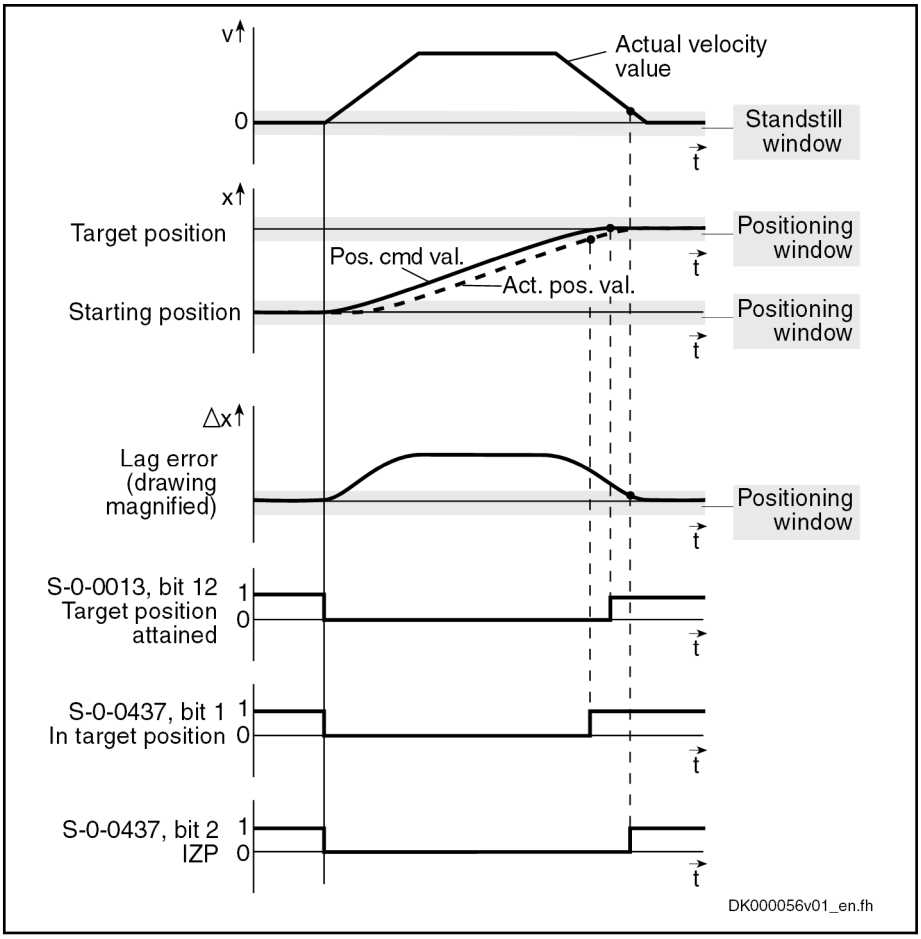



*Fig. 6-34: Generating the Status Bits of the Operation Modes with Drive-Internal Interpolation*

# 6.12 Positioning Block Mode

## 6.12.1 Brief Description

In this operation mode, it is possible to run up to 64 programmed positioning blocks. The drive moves to the target position in position control, while maintaining velocity, acceleration, deceleration and jerk limits as defined in the respective positioning block. This operation mode is ideal for programming simple cyclic programming sequences without a higher-level control using IndraWorks. The positioning block mode can, however, also be used for dislocating positioning processes from the control and merely have commanding of the control word (S-0-0346) carried out by the control.

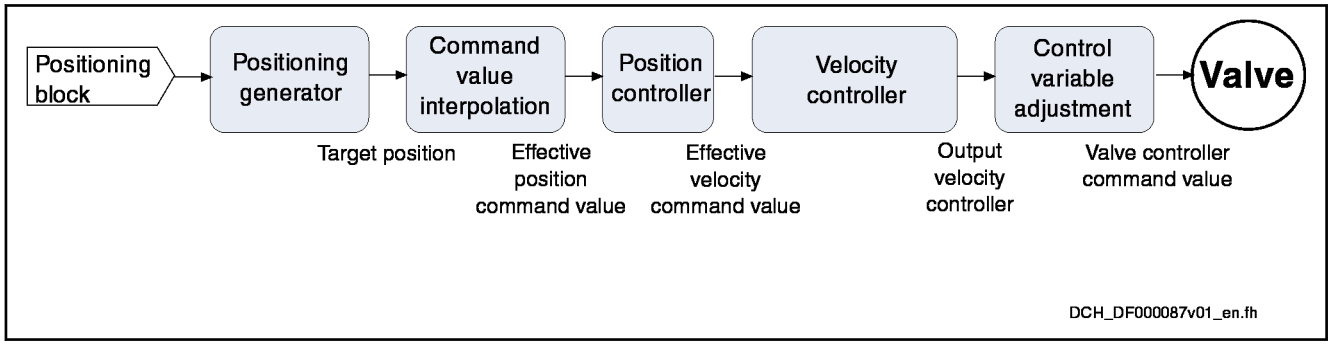



*Fig. 6-35: "Positioning Block Mode" Block Diagram*

**Features**

- Parameterization of up to 64 positioning blocks; each with target position/travel distance, velocity, acceleration, deceleration and jerk
- The command value is generated within the NC cycle "S-0-0001, NC cycle time (TNcyc)". The transition into the position controller cycle is accomplished by means of cubic fine interpolation.
- Jerk limitation of generated position command value with parameter "S-0-4009, Positioning block jerk"
- Setting of the average value filter (jerk limitation) to fixed filter time by means of interpolation cmd value average value filter time constant (P-0-0641)
- Adjustable position command value delay in position cycles (P-0-0456), maximum of 32 cycles.
- Defined block acceptance by toggling bit 0 in S-0-0346 with reaction time $t_{R_strobe} = t_{position}$

  **Note:** An exception to this is the I/O mode with field bus drives. In this case, acceptance takes place by a 0-1 edge of bit 0 in P-0-4060.

  → Block selection and acknowledgment via separate parameters (handshake principle)
- Positioning modes that can be freely parameterized:
  - Relative positioning
  - Absolute Positioning
  - Infinite travel (positive or negative)
- Single-block or sequential block mode with different conditions for advancing:
  - Block advance with switch cams
  - Block advance at defined position value
  - Block transition with "old" or "new" positioning velocity
- In the as-supplied condition, the positioning velocity is limited to 100 for safety reasons.
- Positioning block transition with freely definable delay time (P-0-4018)
- Positioning taking account of command value mode (shortest distance, positive direction, ...)
- Residual path processing can be activated (→ no loss of incremental dimension)
- "Slow travel" mode can be activated (limitation of velocity to auf "S-0-0259, Positioning velocity")
- Adjustable velocity override

**Fields of Application**

Sequential block processing allows executing several positioning blocks in direct succession without having to give a new start signal each time. Typical fields of application are:

- There is no or only a very simple higher-level control unit available and the activation is realized via digital I/Os only or a field bus control word (I/O mode with field bus interface).
- Quick reaction times or block advances are required. The required motion profiles can be represented in the drive by the maximum possible 64 positioning blocks.

Operation Modes

- Positioning processes are 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
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant
- P-0-4006, Positioning block target position
- P-0-4007, Positioning block velocity
- P-0-4008, Positioning block acceleration
- P-0-4009, Positioning block jerk
- P-0-4018, Positioning block delay time
- P-0-4019, Positioning block mode
- P-0-4026, Positioning block selection
- P-0-4051, Positioning block acknowledgment
- P-0-4052, Positioning block, last accepted
- P-0-4053, Positioning block, last active
- P-0-4057, Positioning block, input linked blocks
- P-0-4060, Positioning block control word
- P-0-4061, Positioning block status word
- P-0-4063, Positioning block deceleration

Parameter S-0-0259 is used in the positioning block mode to reduce the positioning velocity (see also "P-0-4060, Positioning block control word").

**Pertinent Diagnostic Messages**

- A0162 Positioning block mode
- A0206 Positioning block mode, encoder 1
- A0207 Positioning block mode lagless, encoder 1
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2054 Not homed
- E2055 Feedrate override S-0-0108 = 0

- E2058 Selected positioning block has not been programmed
- F2028 Excessive deviation

## 6.12.2 Command Value Adjustment with Positioning Block Mode

The figure below illustrates command value processing in the "positioning block mode" mode as a block diagram.

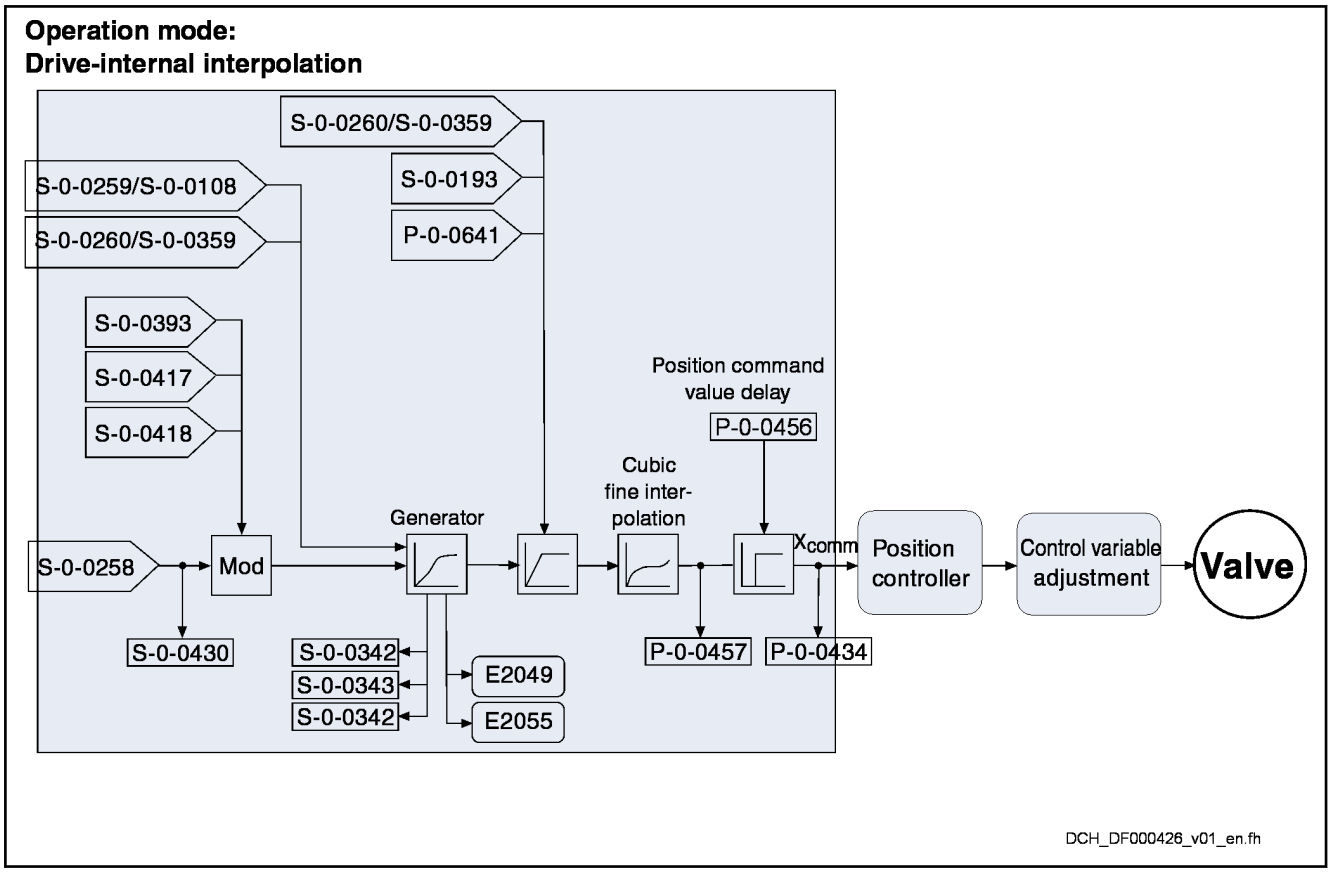



*Fig. 6-36: Command Value Adjustment with Positioning Block Mode*

## 6.12.3 Single-Block Processing

### Description of Basic Function

#### General Information

**Positioning Block Elements**

A positioning block is defined by the values of the following list parameters:

- P-0-4006, Positioning block target position
- P-0-4007, Positioning block velocity
- P-0-4008, Positioning block acceleration
- P-0-4009, Positioning block jerk
- P-0-4018, Positioning block delay time
- P-0-4019, Positioning block mode
- P-0-4063, Positioning block deceleration

☞ Each parameter contains 64 elements, with elements having the same number describing the travel profile of the respective positioning block with this number.

Operation Modes

The drive reaches the relevant positioning block velocity after an acceleration phase with the corresponding positioning block acceleration (P-0-4008).

**Effective Positioning Velocity**

The effective velocity during a positioning process is calculated as follows:

$$v_{max} = \text{P-0-4007} \times \frac{\text{S-0-0108}}{100\ \%}$$

$v_{max}$ Velocity
**P-0-4007** Positioning block velocity
**S-0-0108** Feedrate override
*Fig. 6-37: Effective Velocity During a Positioning Process*

**Effective Acceleration and Deceleration**

The maximum deceleration is specified by parameter "P-0-4063, Positioning block deceleration".

***NOTICE*** **The set target is never reached or passed, if acceleration or deceleration becomes equal to zero, because the drive can no longer decelerate!**

⇒ Set acceleration value > 0!

☞ A further limitation is achieved with the value of parameter "S-0-0138, Bipolar acceleration limit value", because this limit value takes effect in all operation modes with position control.

**Jerk Limitation by Jerk Filter**

In the "drive-internal interpolation" mode the position command value can be filtered at the output of the positioning generator. We distinguish between two cases for setting of the filter order.

**Case 1: Filter order calculated from A / R**

The filter order of the (moving) average filter available to do this (cf. P-0-0042) is calculated on the basis of the preset positioning acceleration or the positioning jerk.

This means that the parameterized acceleration or deceleration only becomes effective after t = P-0-0042 × $T_{NCYC}$.

☞ $T_{NCYC}$ is the generator cycle time (S-0-0001).

$$\text{P-0-0042} = \frac{\text{P-0-4008}}{\text{P-0-4009}}$$

– or –

$$\text{P-0-0042} = \frac{\text{P-0-4063}}{\text{P-0-4009}}$$

**P-0-0042** Current position command average value filter order
**P-0-4008** Positioning block acceleration
**P-0-4063** Positioning block deceleration
**P-0-4009** Positioning block jerk
*Fig. 6-38: Internally Determining the Value of P-0-0042 for Positioning Block Mode*

☞ With a value equal to zero in parameter P-0-4009, the smoothing filter is switched off, i.e. the desired acceleration or deceleration is immediately reached.

**Case 2: Filter order constant**

The filter order can also be set to a constant value. This is made via parameter " (P-0-0641, Interpolation cmd value average value filter time constant".). The filter order is calculated from the time constant referred to the generator cycle time $T_{NCYC}$; with an order > 0, the function of constant filter order is active and the calculation A / R is not effective. A new filter order can only become effective when the operation mode is initialized or when a block change takes place. The current filter order is continued to be shown in P-0-0042.

**Position Command Value Delay**

Downstream of the fine interpolator, the position command value can be delayed by a maximum of 32 position cycles, before it is fed to the position controller. This allows a master axis to be controlled synchronously with the controlled slave axis. The number of position cycles is set in the position command value delay (P-0-0456). The undelayed position command value generator (P-0-0457) is entered in a ring buffer, the delayed position command value is then taken over to the position command value controller (P-0-0434).

**Positioning Block Control Word**

With parameter "P-0-4060, Positioning block control word" (bit 1), the positioning velocity can be limited to the value defined in parameter "S-0-0259, Positioning velocity".

**Position Feedback**

When a positioning block has been completed, bit 4 (end position reached) is set in parameter "P-0-4061, Positioning block status word".

→ |S-0-0430 – S-0-0051| < S-0-0057 && no sequential block

**Interrupting a Positioning Block**

The positioning block mode can be interrupted by:

- Withdrawing the controller enable
- Activating "Drive Halt"
- Changing over the operation mode
- Jogging
- Positioning stop or operational stop (S-0-0346, bit 1 and bit 2 = 1)
- A drive error occurring

**Positioning Block Modes**

Parameter "P-0-4019, Positioning block mode" is used to define the way in which the target position is processed in parameter "P-0-4006, Positioning block target position". There are the following options:

- Absolute positioning
- Relative positioning
- Relative positioning with residual path storage
- Infinite travel in positive/negative direction
- Sequential block processing

See Parameter Description "P-0-4019, Positioning block mode"

☞ It is possible to define an individual positioning mode for each positioning block.

**Command Value Mode (S-0-0393)**

The parameter "S-0-0393, Command value mode" controls the drive behavior in case "modulo format" was set as processing format of the position data.

See also Parameter Description "S-0-0393, Command value mode"

The following modes have to be distinguished:

- Shortest distance
- Positive direction
- Negative direction

The following limiting conditions have to be taken into account:

- If the amount of the current actual velocity is greater than the velocity threshold for positioning in modulo format (S-0-0417), the drive is always operated in the direction of rotation last active.
- If the target position is within the target position window in the modulo format (S-0-0418), positioning is always carried out according to the "shortest distance" principle.

| ***NOTICE*** | **If the velocity threshold for positioning in modulo format was parameterized with very small values that are within the noise level of the actual velocity value, this can cause unpredictable behavior.** |
|---|---|

See also Parameter Description "S-0-0417, Positioning velocity threshold in modulo mode"

See also Parameter Description "S-0-0418, Target position window in modulo mode"

## Activating Positioning Blocks

**Prerequisite** "Positioning block mode" must have been entered as the primary mode of operation.

This is done by the respective selection of the active operation mode in the status word by activating drive enable and by setting "Drive Halt" = 1.

**Command Value Acceptance** Depending on the master communication, a positioning block is started by:

- Toggling of bit 0 in parameter "S-0-0346, Positioning control word"

- or -

- With **field bus interface in IO mode** 0-1 edge of bit 0 in parameter "P-0-4060, Positioning block control word"

The positioning command value is thereby copied (absolute target position) or added (relative position target, travel distance) to the effective target position (S-0-0430).

The block acceptance is confirmed by updating "P-0-4051, Positioning block acknowledgment" and "S-0-0419, Positioning command acknowledge". In addition, with a 0-1 edge of bit 0 of parameter P-0-4060, bit 0 of parameter S-0-0346 is also toggled internally.

Depending on the master communication and profile type, the block acceptance requires different configurations in the cyclic command value channel:

- **sercos interface**
  - "S-0-0346, Positioning control word" has to be configured in the cyclic data channel (MDT)
- **Field bus interface**
  - In the freely configurable mode (profile type P-0-4084 = 0xFFFE), bit 0 of P-0-4077 is mapped to bit 0 of S-0-0346.
  - In the "I/O mode positioning" (profile type P-0-4084 = 0xFF82), bit 3 of P-0-4068 is mapped to bit 0 of "P-0-4060, Positioning block control word".

    As an alternative, starting in the I/O mode is also possible by setting the start signal (P-0-4068, bit 1).

See also "Command Value Acceptance and Acknowledgment" in section "General Information on the Operation Modes"

☞ If bit 0 is different in S-0-0346 and in S-0-0419 when the operation mode is activated, the selected positioning block is immediately accepted and executed.

**Block Selection**

In the positioning block mode, the block is always selected via the content of parameter "P-0-4026, Positioning block selection".

Depending on the master communication, parameter P-0-4026 can be written in different ways:

| Configuration of P-0-4026 | Master Communication | | |
|---|---|---|---|
| | sercos interface | Field bus interface | |
| Via cyclic data channel | ■ | ■ | |
| Via digital inputs | ■ | ■ | |
| Via serial interface | ■ | ■ | |
| Via field bus control word | -- | ■ | |

*Tab. 6-2: Possibilities of Writing Parameter P-0-4026 Depending on Master Communication*

☞ The assignment of P-0-4026 to digital inputs requires, among other things, the parameters "S-0-0144, Signal status word" and "S-0-0145, Signal control word".

## Absolute Positioning

**Parameter Setting**

"P-0-4019, Positioning block mode" = **0000 0000 0000 000X**

**Function**

In an absolute positioning block, the target position is a fixed (absolute) position within the machine coordinate system.

For absolute positioning the drive must have been homed.

**Prerequisite**

Requirements for executing absolute positioning blocks are:

- The drive must have been homed.
- The travel range can be limited with position limit values. Absolute positioning blocks are only executed, if the target position is within the allowed travel range.

Operation Modes

**Example:**

Absolute positioning with target position = 700 (current position = 200)

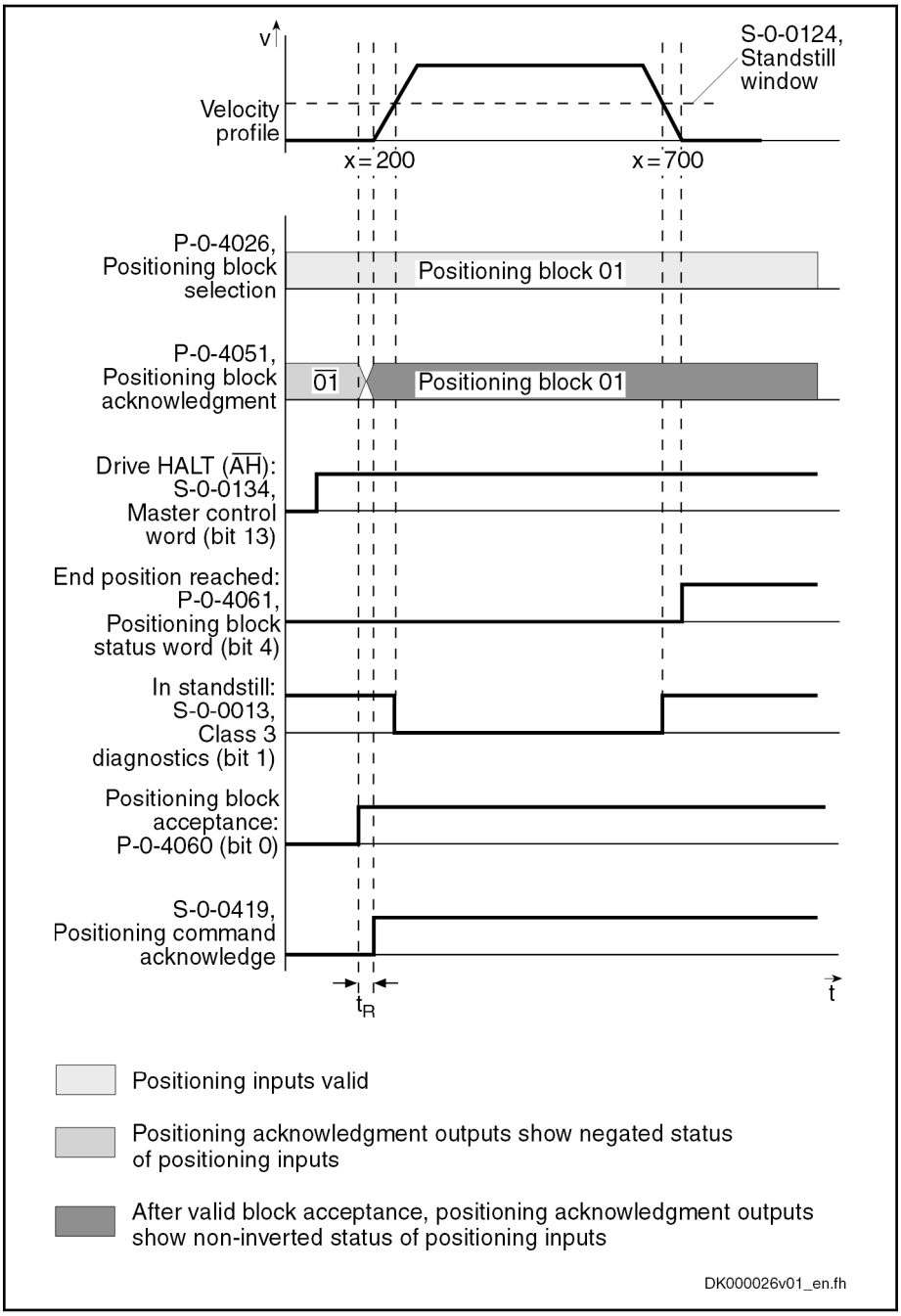



*Fig. 6-39: Absolute Positioning Block*

Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

## Relative Positioning without Residual Path Storage

**Parameter Setting** "P-0-4019, Positioning block mode" = **0000 0000 0000 001X**

**Dedicated Position**

In the case of relative positioning blocks without residual path storage, the target position contained in the positioning block is added to the current position.

Relative positioning blocks are also executed, if the drive has not been homed.

**Incremental Dimension Reference**

By sequencing relative positioning blocks it is possible to position with incremental dimension. If a relative positioning block without residual path storage is interrupted, the incremental dimension reference gets lost.

If the positioning block is completed (i.e. the drive reaches target position and message "end position reached" is active), positioning is possible without losing the incremental dimension reference.

If infinite positioning in either a forward or backward direction is achieved by sequencing relative positioning blocks (conveyor belt), the position data must be scaled in modulo format (modulo value = length of conveyor belt or modulo value = 2 × maximum travel distance).

**Example:**

Relative positioning without residual path storage with travel distance = 700 (current position = 200; target position = 900)

Operation Modes

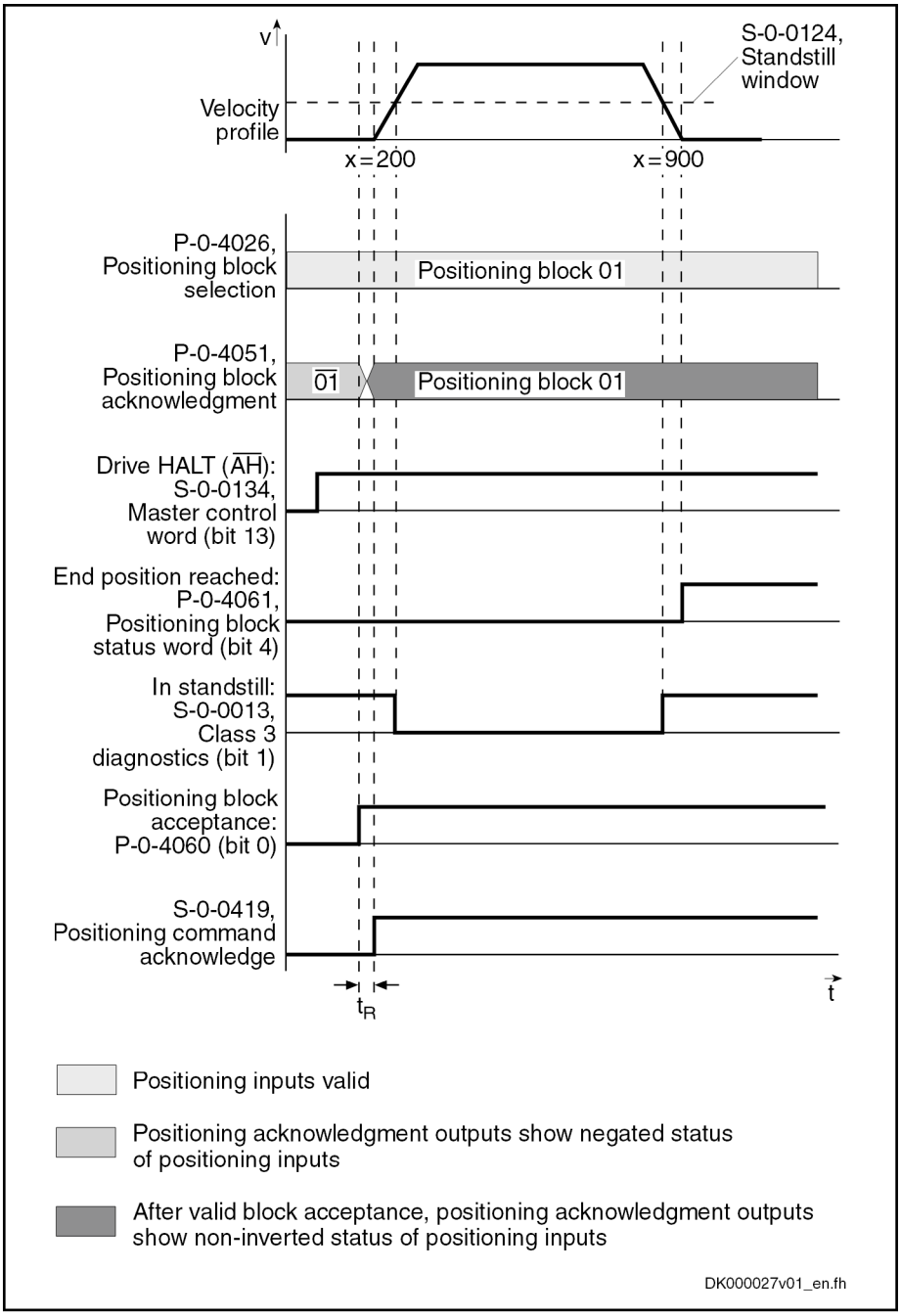



*Fig. 6-40: Relative Positioning Block Without Residual Path Storage*

☞ Depending on the master communication, the positioning block is accepted 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

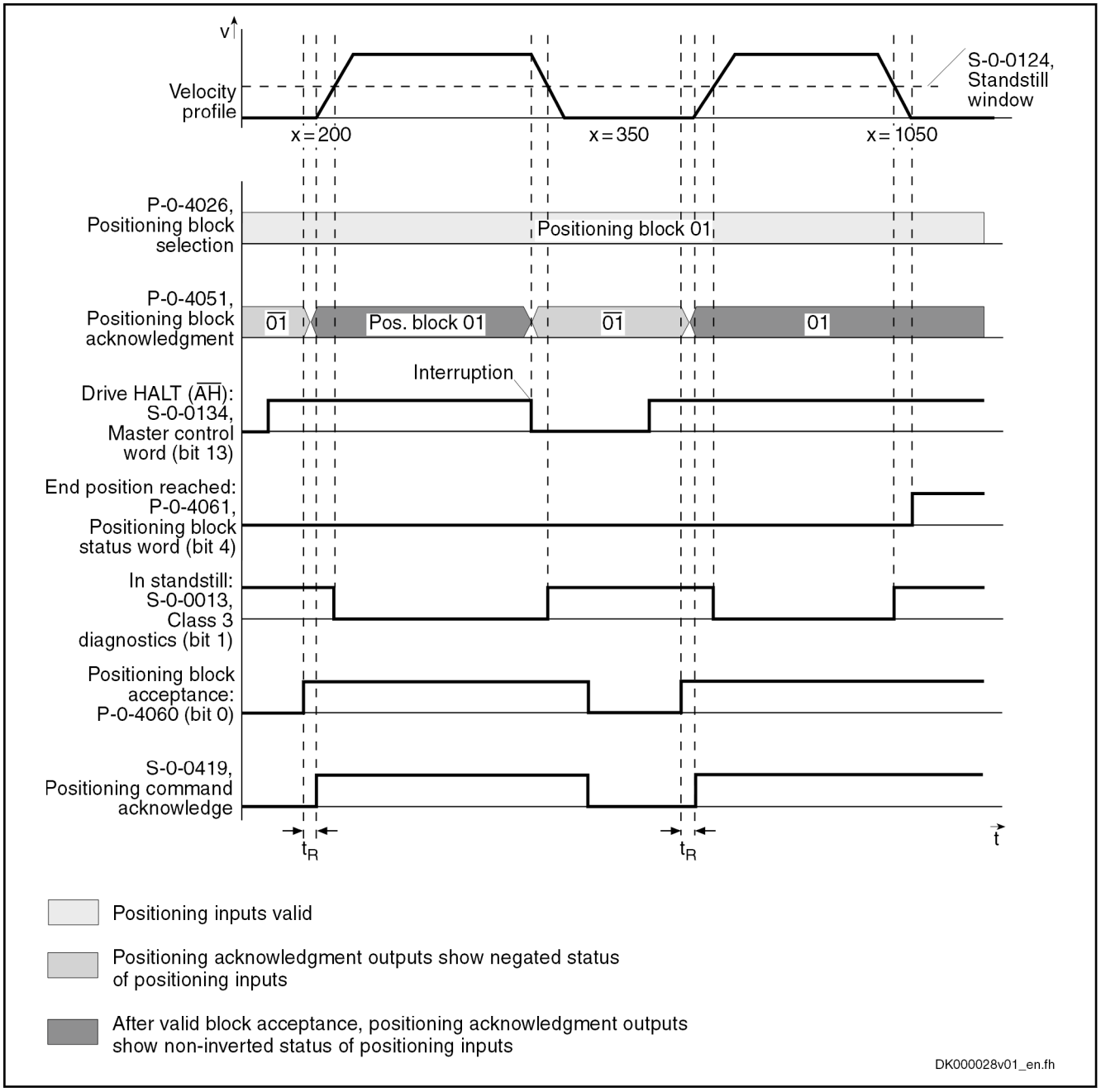



*Fig. 6-41: Interrupting a Relative Positioning Block Without Residual Path Storage*

Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

## Relative Positioning with Residual Path Storage

### Basic Function

**Parameter Setting** "P-0-4019, Positioning block mode" = **0000 0001 0000 001X**

**Residual Path** If positioning blocks are interrupted, there remains a distance still to be traveled up to the target position. This remaining distance is the residual path.

Operation Modes

In a relative positioning block with residual path storage, the target position is a relative distance that relates to the target position at which the message "end position reached"was last active.

Relative positioning blocks with residual path storage are also executed, if the drive has not been homed.

**Incremental Dimension Reference**

By sequencing relative positioning blocks it is possible to position with incremental dimension. If a relative positioning block with residual path storage is interrupted, the incremental dimension reference is retained.

---

☞ If another positioning block is started while such a positioning block is being executed, the residual path is rejected. If this new block is also a relative positioning block with residual path storage, the target position is related **to the current actual position** as a relative distance.

---

**Example:**

- Relative positioning with residual path storage with travel distance = 700 (plus residual path = 20 of positioning block n-1)
- Without interruption
- Current position = 180; new target position = 900

**Dedicated Position**

The last valid target position is used as dedicated position (in the example, position = 200 of positioning block n-1).

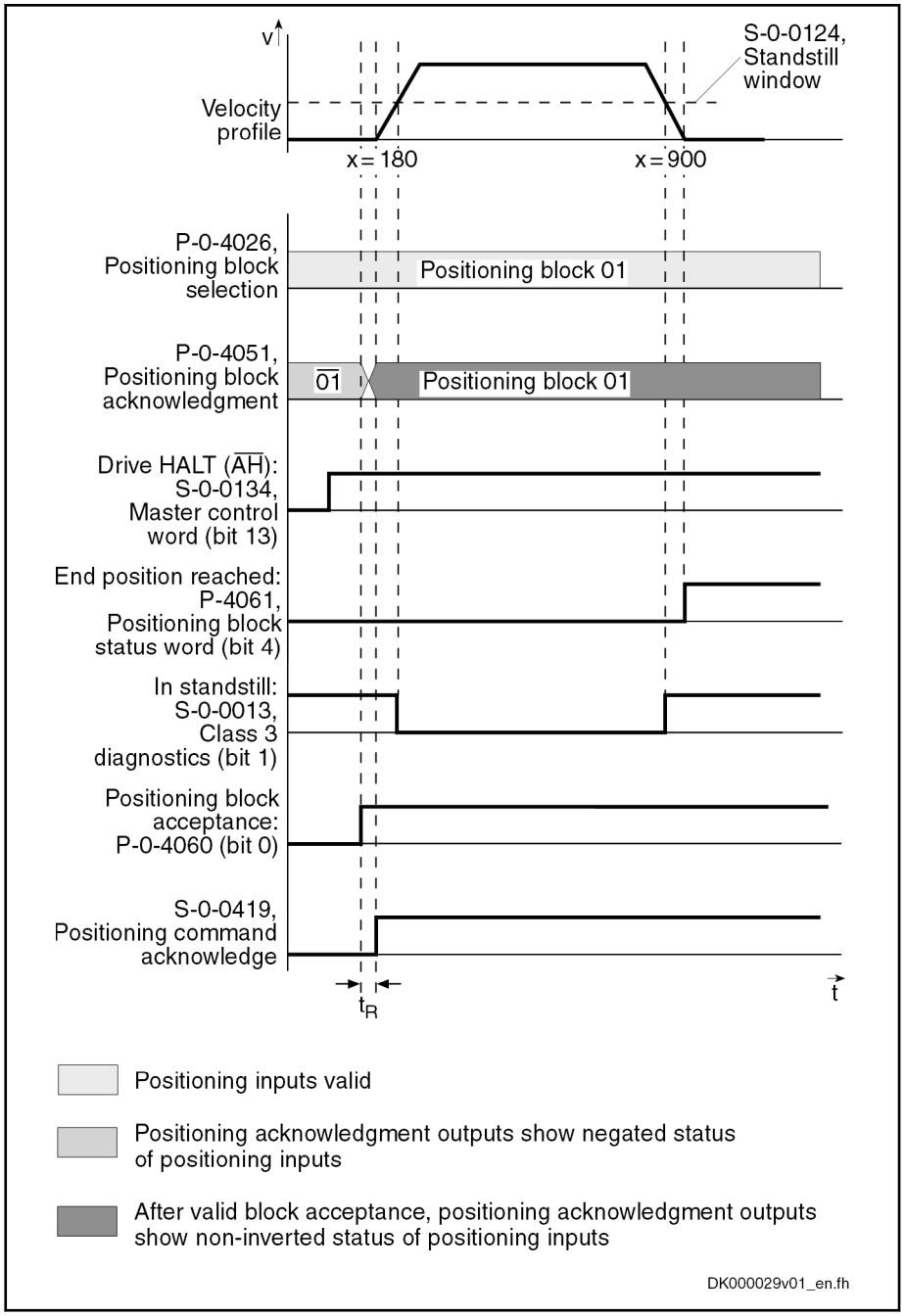



*Fig. 6-42: Relative Positioning Block With Residual Path Storage*

Depending on the master communication, the positioning block is accepted 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).

Operation Modes

**Dedicated Position**

The position command value at the last "end position reached" (position = 200) message is used as the dedicated position.

The incremental dimension reference is ensured.

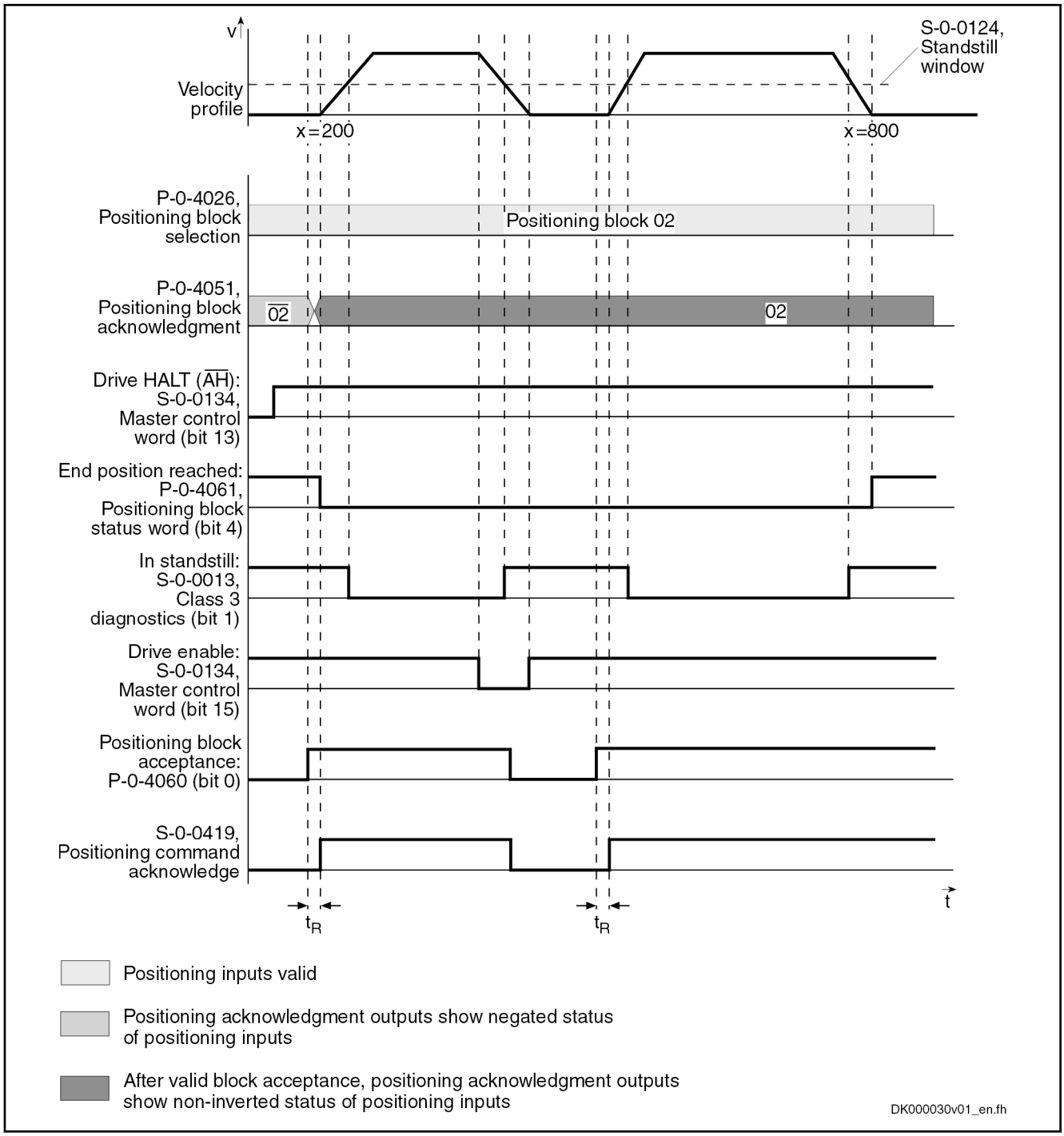



*Fig. 6-43: Relative Positioning Block With Residual Path Storage After Activating Drive Enable*

Depending on the master communication, the positioning block is accepted 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

**Dedicated Position** Positioning is always based on the current actual position value.

**Behavior** An interruption by means of jogging or positioning stop clears the residual path memory.

| ***NOTICE*** | **An interruption by jogging or a positioning stop results in the fact that when the positioning block is started again, not the residual path is traveled, but the positioning block is restarted (complete relative positioning block). The incremental dimension reference is no longer ensured!** |
|---|---|

Operation Modes

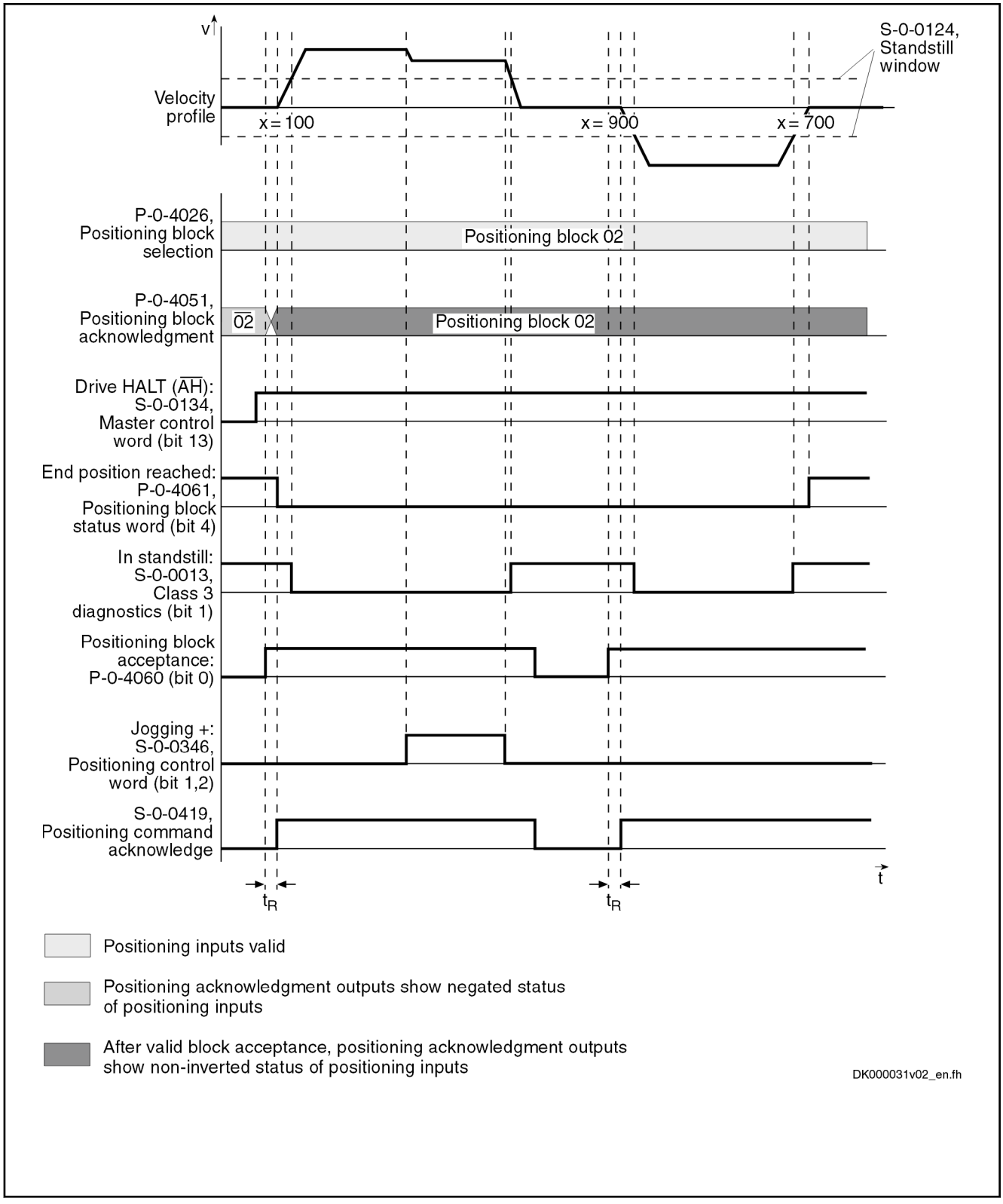



*Fig. 6-44: Relative Positioning Block With Residual Path Storage After Jog Mode*

☞ Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

## 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 withdrawn or one of the position limit values or the travel range limit switch is reached.

The entered target position is irrelevant in this positioning mode.

**Parameter Setting**

- P-0-4019, Positioning block mode = **0000 0000 0000 010X**
  → Travel in positive direction
- "P-0-4019, Positioning block mode" = **0000 0000 0000 100X**
  → Travel in negative direction

Operation Modes

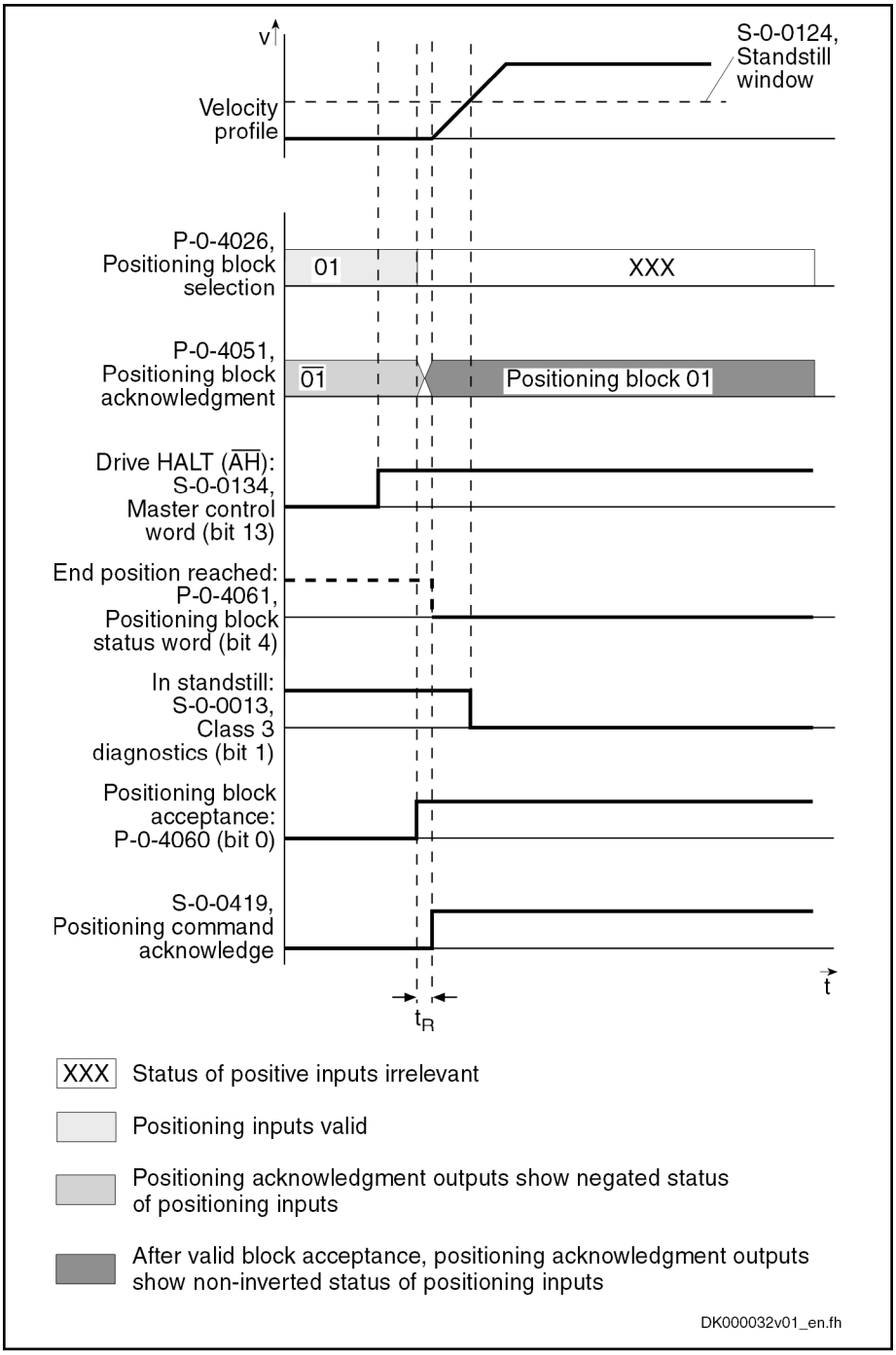



*Fig. 6-45: Example: Infinite Travel in Positive/Negative Direction*

☞ Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

## 6.12.4 Sequential Block Processing

### Basic Function

☞ For sequential block processing, the same basic rules apply as for single-block processing (see description of single-block processing). In addition to mere positioning block functions with defined positioning blocks and block acceptance, there also is a defined block transition to be parameterized.

**Selecting and Activating a Sequential Block**

A positioning block with sequential block is selected and activated in the usual way, with only the first block of the sequential block chain having to be selected. The sequential block is the block with the next higher block number. A sequential block can also have a sequential block so that after a start block up to 63 sequential blocks can be set.

☞ The potential sequential block of the last valid block is block 0.

**Advancing Conditions in Sequential Block Mode**

There are two basically different modes for block advancing, which themselves can be subdivided as follows:

- **Position-dependent block advance**
  - Block transition with old positioning velocity
  - Block transition with new positioning velocity
  - Block transition with intermediate stop and defined delay time (see P-0-4018)
- **Switching signal-dependent block advance**

### Position-Dependent Block Advance

#### General Information

With position-dependent block advance, switching to the sequential block is carried out at the target position of the start block.

There are three different types of block transition:

- Block transition with old positioning velocity (mode 1)
- Block transition with new positioning velocity (mode 2)
- Block transition with intermediate stop and defined delay time

#### Block transition with old positioning velocity (mode 1)

**Parameter Setting**

- "P-0-4019, Positioning block mode" = **0000 0000 0001 000X**
  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0001 001X**
  → Relative block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0001 010X**
  → Infinite block in positive direction with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0001 100X**
  → Infinite block in negative direction with sequential block

**Function**

In this mode, the target position of the start block is passed at the velocity of the start block. Then the positioning velocity is switched to that of the sequential block.

Operation Modes

With relative and absolute positioning blocks with block advance, the drive moves towards the target position. As soon as the target position is overrun, 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, with block n representing the positioning block that is currently being processed.

☞ 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 changeover position.

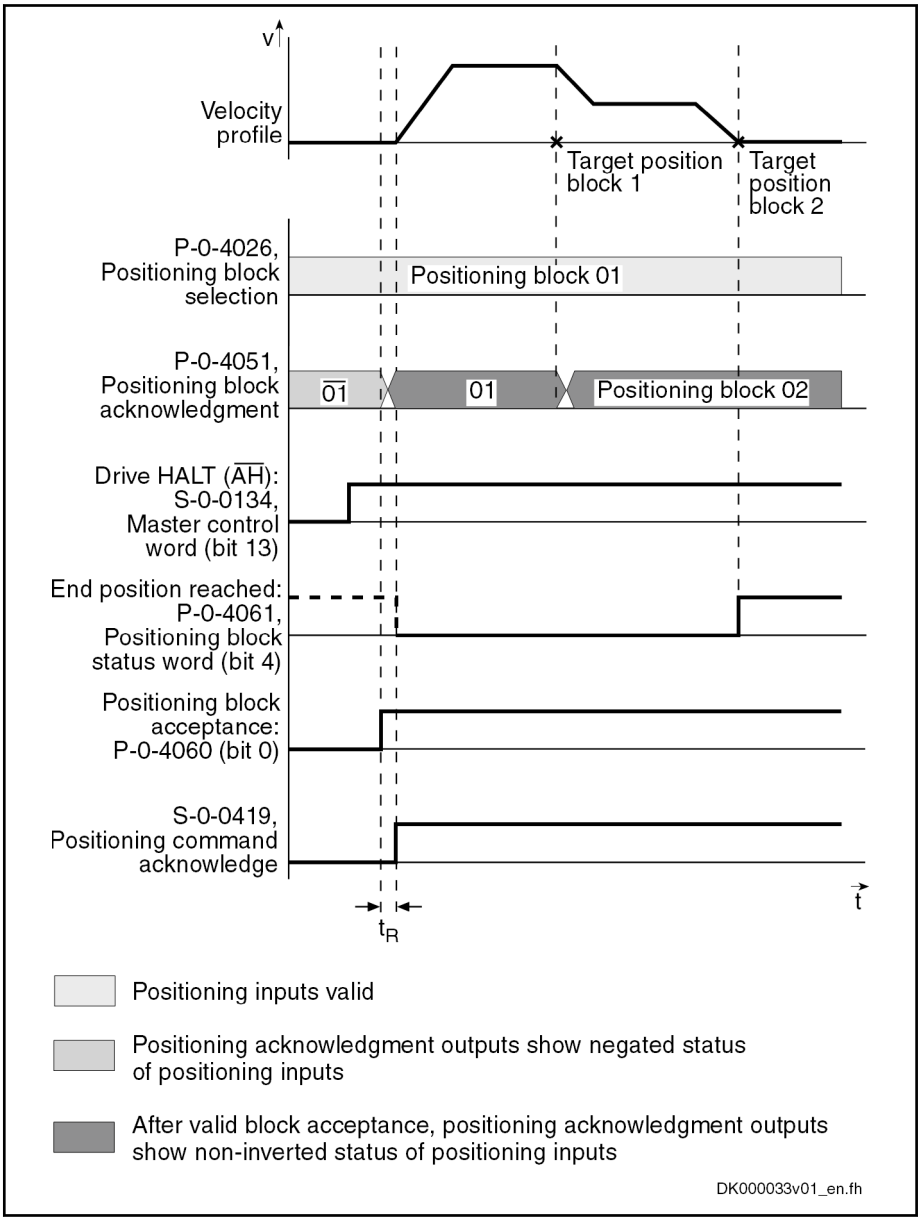



*Fig. 6-46: Example: Position-Dependent Block Advance (Mode 1)*

☞ Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

### Block transition with new positioning velocity (mode 2)

**Parameter Setting**

- "P-0-4019, Positioning block mode" = 0000 0000 0010 000X
  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0010 001X
  → Relative block with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0010 010X
  → Infinite block in positive direction with sequential block
- "P-0-4019, Positioning block mode" = 0000 0000 0010 100X
  → Infinite block in negative direction with sequential block

**Function**

In this mode, the target position of the start block is passed 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 the 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 $x_n$.

Switching to the next positioning block does, however, not occur before the target position is overrun.

Operation Modes

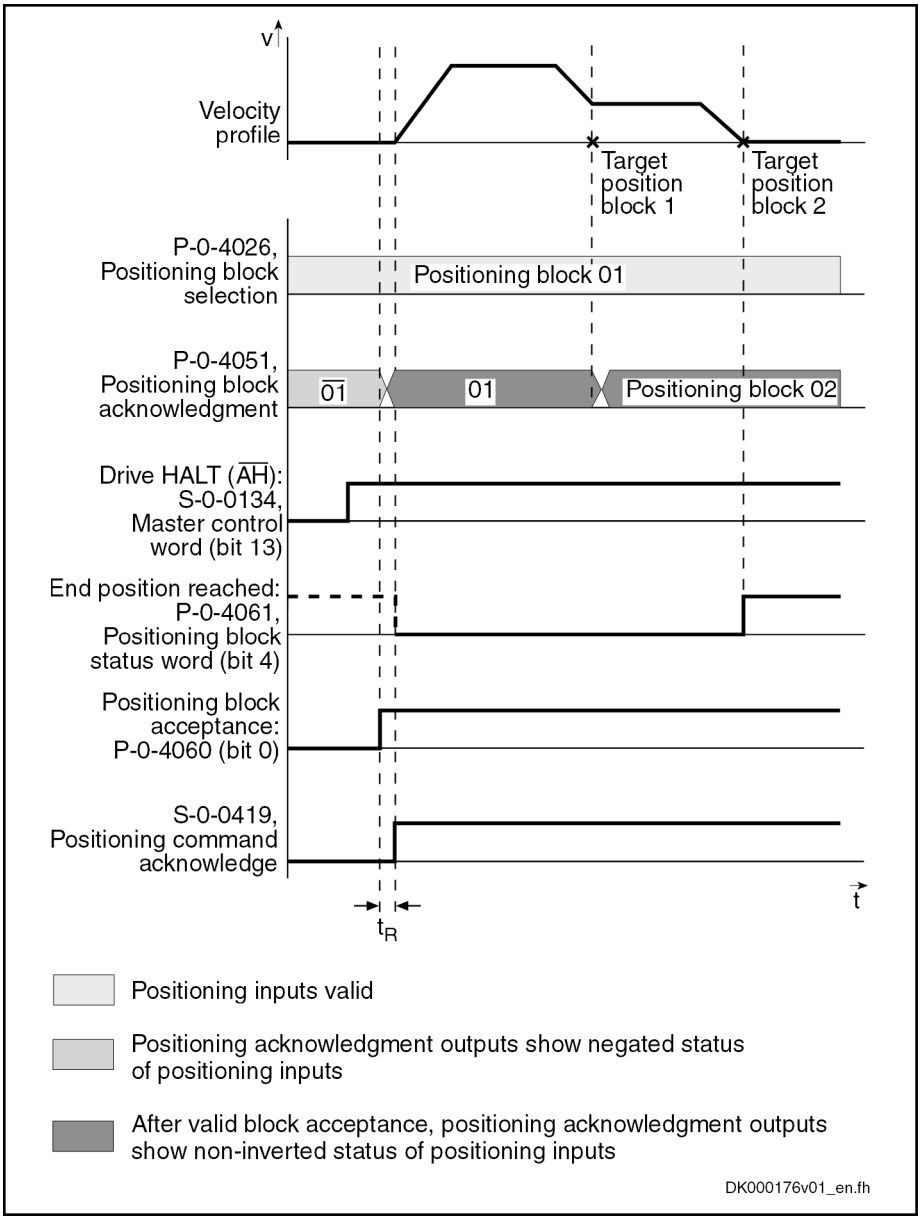



*Fig. 6-47: Example: Position-Dependent Block Advance (Mode 2)*

Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

## Block Transition with Intermediate Stop and Defined Delay Time

**Parameter Setting**

- "P-0-4019, Positioning block mode" = **0000 0000 0100 000X**
  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0100 001X**
  → Relative block with sequential block

**Function**

In this mode, the drive first positions at the target position of the start block. Once the position command value is at the target position, the sequential block is automatically started without a new start signal having been given

externally. If a delay time (P-0-4018) was parameterized for the positioning block, the sequential block is only started when the delay time is over.

Another operation mode is the changeover when overrunning the target position with intermediate stop.

In this case, the drive is decelerated to speed "0" at the target position and then accelerated to the new positioning velocity.

Advancing takes place when the internal command value generator has reached the target position and a possibly parameterized delay time (P-0-4018) has elapsed. With very small jerk values, the resulting dwell time is relatively long.

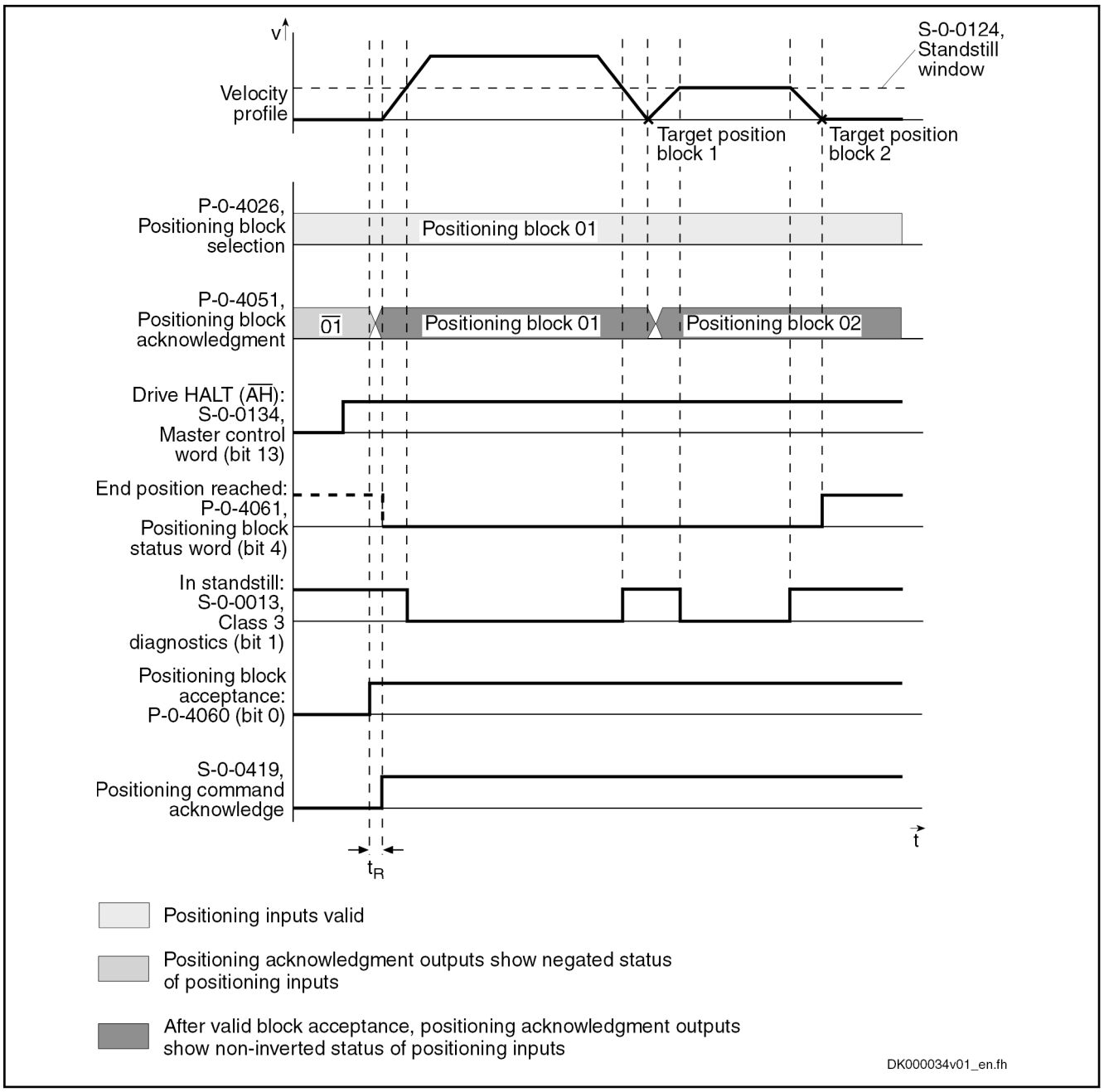



*Fig. 6-48: Example: Sequential Block Advance for Target Position with Intermediate Stop*

Operation Modes

☞ Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

☞ This mode should be used if there is a change in direction in the case of two consecutive sequential blocks within one sequential block chain. Otherwise, the position at which the direction is changed will be inevitably overrun.

## Switching Signal-Dependent Block Advance

For switching signal-dependent block advance, the following positioning modes are possible:

- "P-0-4019, Positioning block mode" = **0000 0000 1000 000X**
  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 1000 001X**
  → Relative block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 1000 010X**
  → Infinite block in positive direction with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 1000 100X**
  → Infinite block in negative direction with sequential block

☞ Advancing to the block with the next higher block number is triggered by an externally applied switching signal.

**Switching with Cams**

The switching signal-dependent block advance allows the transition to a sequential block, triggered by an external switching signal. Two sequential block inputs are available as input for this switching signal.

The status of the hardware signals is displayed in parameter "P-0-4057, Positioning block, input linked blocks".

**Function**

The drive switches to the **next travel block n+1**, as soon as the input for the **sequential block cam 1** changes from "0" to "1". If the target position is not reached, switching to the new positioning block is carried out while traveling.

The drive switches to the **next travel block n+1**, as soon as the input for the **sequential block cam 2** changes from "0" to "1". If a sequential block cam is activated during traveling, the drive switches to the positioning block after the next one.

**Dedicated Position**

A subsequent relative positioning block refers to the position at which the sequential block cam was switched.

☞ The sequential block cams are scanned within the position controller cycle (see "Performance Data"). The precision of position detection therefore strongly depends on the velocity during overrun.

**Assignment Table for Cams**

| Cam 2 | Cam 1 | Drive reaction |
|---|---|---|
| 0 | 0 | Drive moves to target position of block n |
| x | 0 → 1 | Block n+1 is started |
| 0 → 1 | x | Block n+2 is started |

**n** Positioning block preselected via the parallel inputs or parameter "P-0-4026, Positioning block selection"

**x** Not relevant

*Tab. 6-3: Drive Reaction With Different Switching Signal Sequences*

Operation Modes

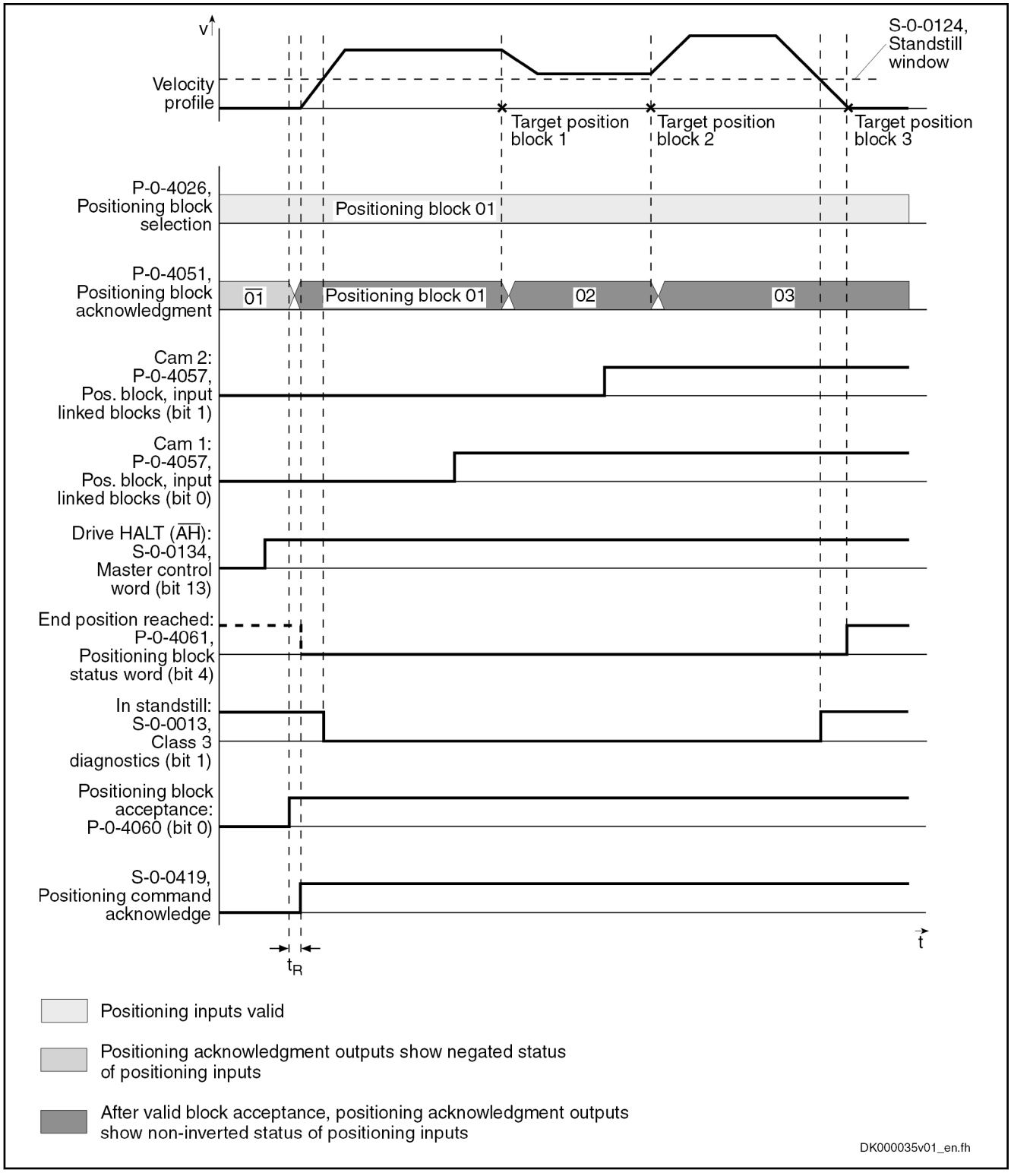



*Fig. 6-49: Example: Switching Signal-Dependent Block Advance*

☞ Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

**Failure of Switching Signal for Block Advance**

If the start block of a switching signal-dependent sequential block is an absolute or relative positioning block, the drive positions at the target position, if the switching 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 switching signal is subsequently applied, the drive will execute the sequential block.

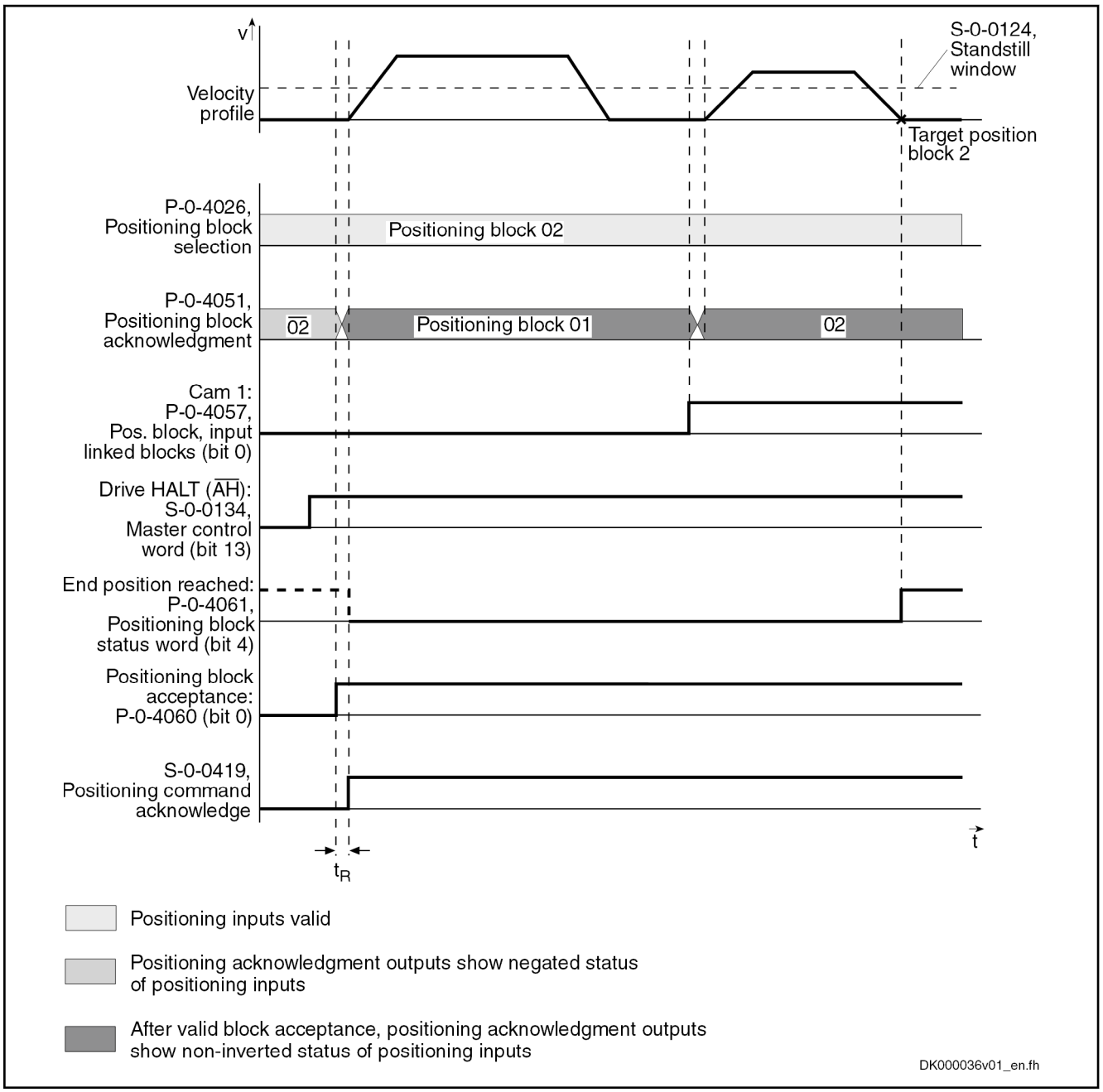



*Fig. 6-50: Example: Switching Signal-Dependent Block Advance (Behavior With Failure of Switching Signal)*

☞ Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Operation Modes

☞ All conditions for advance are constantly queried and evaluated to be able to switch to the correct sequential block, even after the sequential block chain was interrupted. However, only the first condition for advance occurring during an interruption is recognized. All other conditions are ignored!

**Interrupting a Sequential Block Chain**

There are two basically different behaviors when a sequential block chain is interrupted:

- **Residual path is rejected** when interrupted by:
  - Positioning stop (S-0-0346, bit 1 and bit 2 = 1)
  - Jogging +/-
  - Control voltage "Off"

  After interruption with "positioning stop" and "jogging +/-" positioning is always resumed at the current actual position. The sequential block chain interrupted before is not completed, but the currently selected block is executed. Thereby the incremental dimension reference gets lost!
- **Residual path is maintained** when interrupted by:
  - Withdrawing the controller enable
  - Withdrawing the "drive start" signal
  - Changing the operation mode

Depending on the block type of the sequential block chain that was interrupted and the events occurring during this interruption, the sequential block chain is processed differently after a restart.

☞ In sequential block mode, relative positioning blocks **without residual path storage** are **not allowed**, as otherwise the incremental dimension reference would get lost in the case of interruption.

In the case of an interruption, the sequential block chain will be completed upon a restart.

**Dedicated Position**

The dedicated position is the original start position of the sequential block chain.

☞ The incremental dimension reference is retained, as only absolute and relative positioning blocks with residual path storage are used in the sequential block mode!

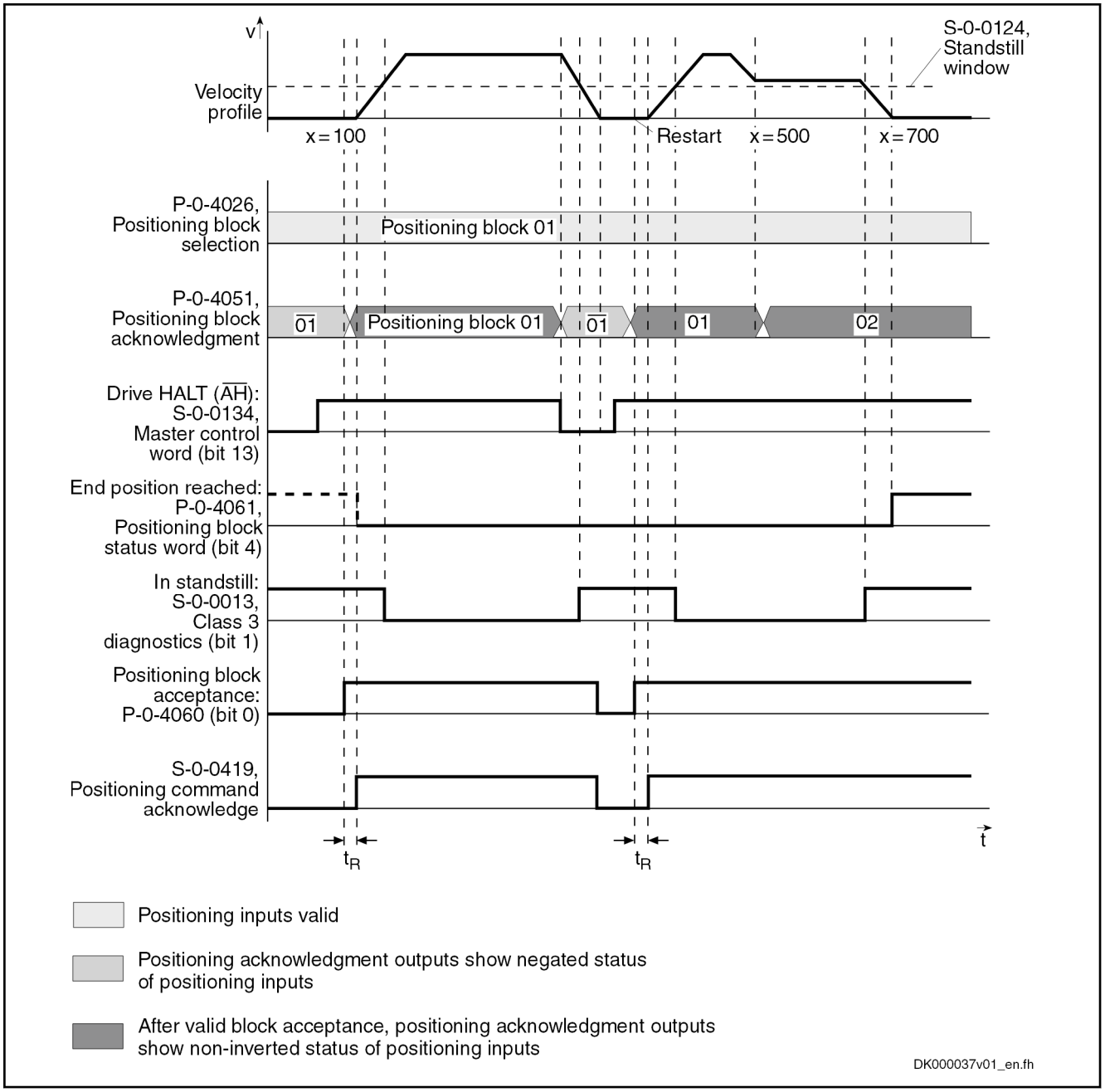



*Fig. 6-51: Example: Sequential Block Interruption With Same Block Selected*

☞ Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

**Changing to Other Operation Mode**

When changing the operating mode during an interruption, the sequential block chain interrupted before is completed upon the restart, if no new block was selected.

In the case of sequential blocks with advance due to target position, only overrunning of the target position of the current positioning block will be detected. Processing of the sequential block is completed from this position.

☞ The advance condition due to switch signals is always detected.

Operation Modes

**Interrupting a Sequential Block Chain with Selection of New Positioning Block**

If a new positioning block is selected during an interruption (e.g. with "Drive Halt", the previously interrupted sequential block chain is not completed upon a restart, but the currently selected block is executed.

**Dedicated Position**

The dedicated position is the current actual position value.

| *NOTICE* | **In the case of an interruption of the sequential block, the incremental dimension reference gets lost and results in the fact that when the positioning block is started again, the residual path is not traveled, but the positioning block is restarted (complete relative positioning block). The incremental dimension reference is no longer ensured!** |
|---|---|

The conditions for the interruption of sequential blocks also apply after the control voltage is switched off, if an absolute encoder is used.

**Interrupting a Sequential Block Chain with Absolute Sequential Blocks**

An interruption with absolute positioning blocks does not cause any problem, as the position data reference is always guaranteed.

When a **new block number** is selected in the case of an interruption, the sequential block interrupted before is not completed when toggling bit 0 in "S-0-0346, Positioning control word" or with a positive edge of bit 0 in "P-0-4060, Positioning block control word", but the currently selected block is executed.

When **no new block number** is selected in the case of an interruption, the sequential block interrupted before is completed when toggling bit 0 in "S-0-0346, Positioning control word" or with a 0-1 edge of bit 0 in "P-0-4060, Positioning block control word".

## 6.12.5 Notes on Commissioning and Parameterization

### Limit Values of the Drive

When parameterizing sequential blocks, the maximum values of the drive must be taken into account. These values are:

- Maximum acceleration capability
- Maximum velocity/revving speed

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 "F2028Excessive deviation" the drive will then signal that it cannot follow the position command value.

### Minimum Values for Acceleration and Jerk

Too low acceleration values can cause problems. Therefore, guideline values according to the formula below are to be preferred when determining positioning blocks:

$$\text{Acceleration} > \frac{(\text{velocity difference})^2}{2 \times \text{target position difference}} \times \frac{(v_{n+1} - v_n)^2}{2 \times (x_{n+1} - x_n)}$$

$v_n$ Velocity of block n
$v_{n+1}$ Velocity of block n+1
$x_n$ Target position of block n
$x_{n+1}$ Target position of block n+1

*Fig. 6-52: Minimum Acceleration Value With Sequential Block Mode (Linear)*

☞ The above relationship applies to an infinitely large jerk which corresponds to a jerk filter that has been switched off (= 0). If a jerk filter is used, the calculated values have to be doubled in a first approximation. The distance to be covered with a block and the associated velocity are in most of the cases determined by the process. If the minimum acceleration value calculated with the above guideline value formula already causes the above-mentioned maximum value to be exceeded, a lower positioning block velocity must be selected.

**Minimum Jerk Value**

If the acceleration values parameterized are too low, this can cause the parameterized velocity not to be reached. In this case, the so-called "triangular mode" is used.

## Directional Change Within a Sequential Block Chain

☞ If a directional change takes place when changing from block n to block n+1 of a sequential block, the mode "switching at target position with halt" should be used for block n to reverse the direction without overshoot.

**Explanation of the Figure Below**

Block n with intermediate stop follows block n-1 with mode 1 (block transition with old positioning velocity), because a change in direction occurs when changing from block n to block n+1. As the direction is reversed, the sign of velocity is changed at target position n. If the acceleration parameterized in block n is too low to decelerate from velocity $v_{n-1}$ to value "0" within the travel distance difference $x_n$-$x_{n-1}$, the parameterized target position $x_n$ is overrun.

This may cause software or hardware limit switches to trigger.

Operation Modes

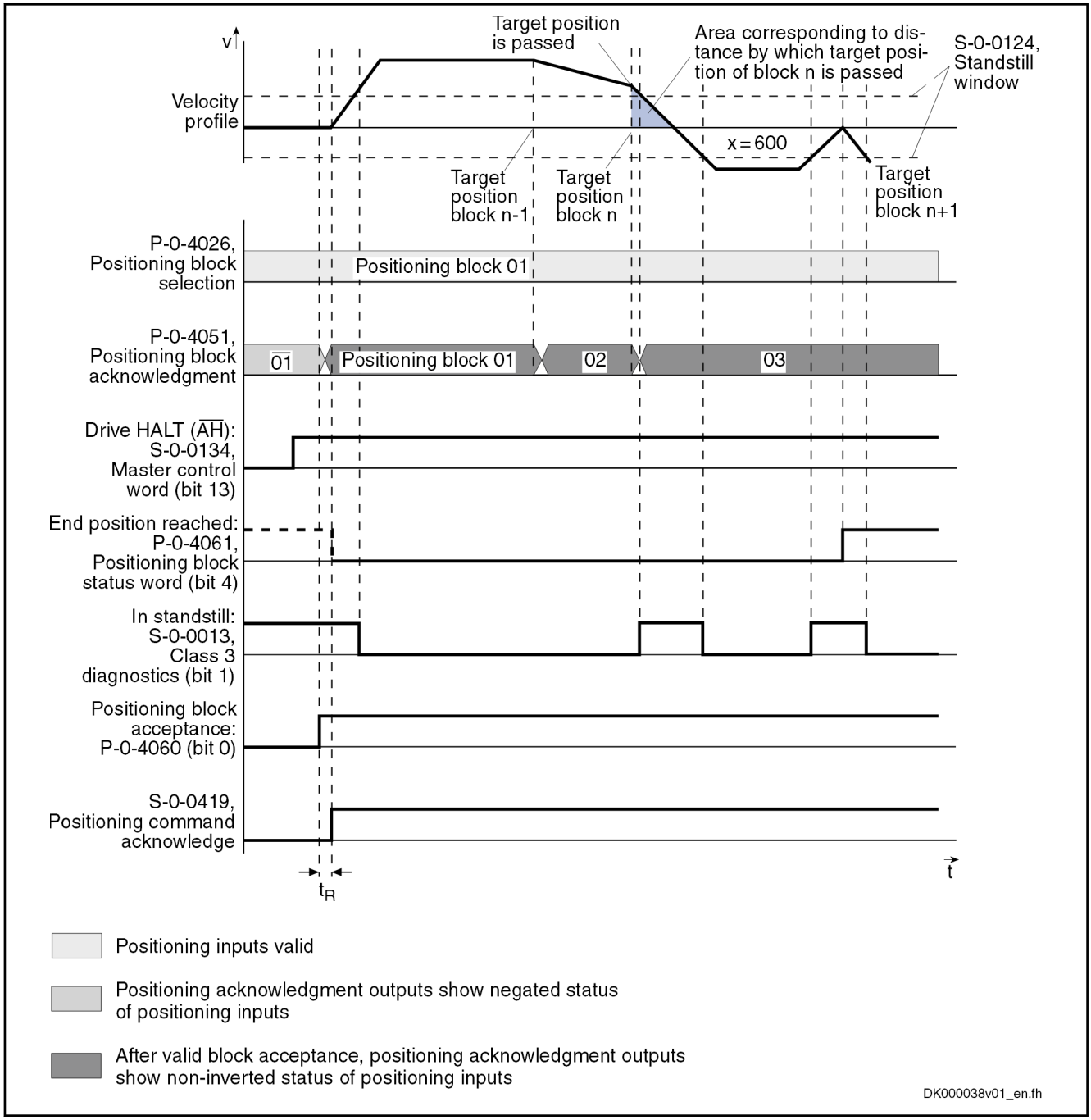



*Fig. 6-53: Parameterizing a Sequential Block With Directional Change*

☞ Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

☞ In the case of a sequential block with directional change, it is necessary to take values according to the above formula for the minimum acceleration value in order to avoid overshooting of position!

## 6.12.6 Diagnostic and Status Messages, Acknowledgments

### 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 when operation is trouble-free, the block number of the positioning block that was started is output. If an error is detected at the start of a positioning block, the faulty positioning block is acknowledged with the complement of the block number. The drive generates a warning and stops.

**Acknowledgement With "Drive Halt"**

If "Drive Halt" is active, the complement of the block number of the selected positioning block is output in parameter "P-0-4051, Positioning block acknowledgment".

**Acknowledgment With Secondary Operation Modes**

The acknowledgment is not affected by secondary operation modes, error reaction and command inputs, i.e. parameter "P-0-4051, Positioning block acknowledgment" retains its value.

**Acknowledgment With Controller Enable Switched Off**

After switching off the controller 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.

Operation Modes

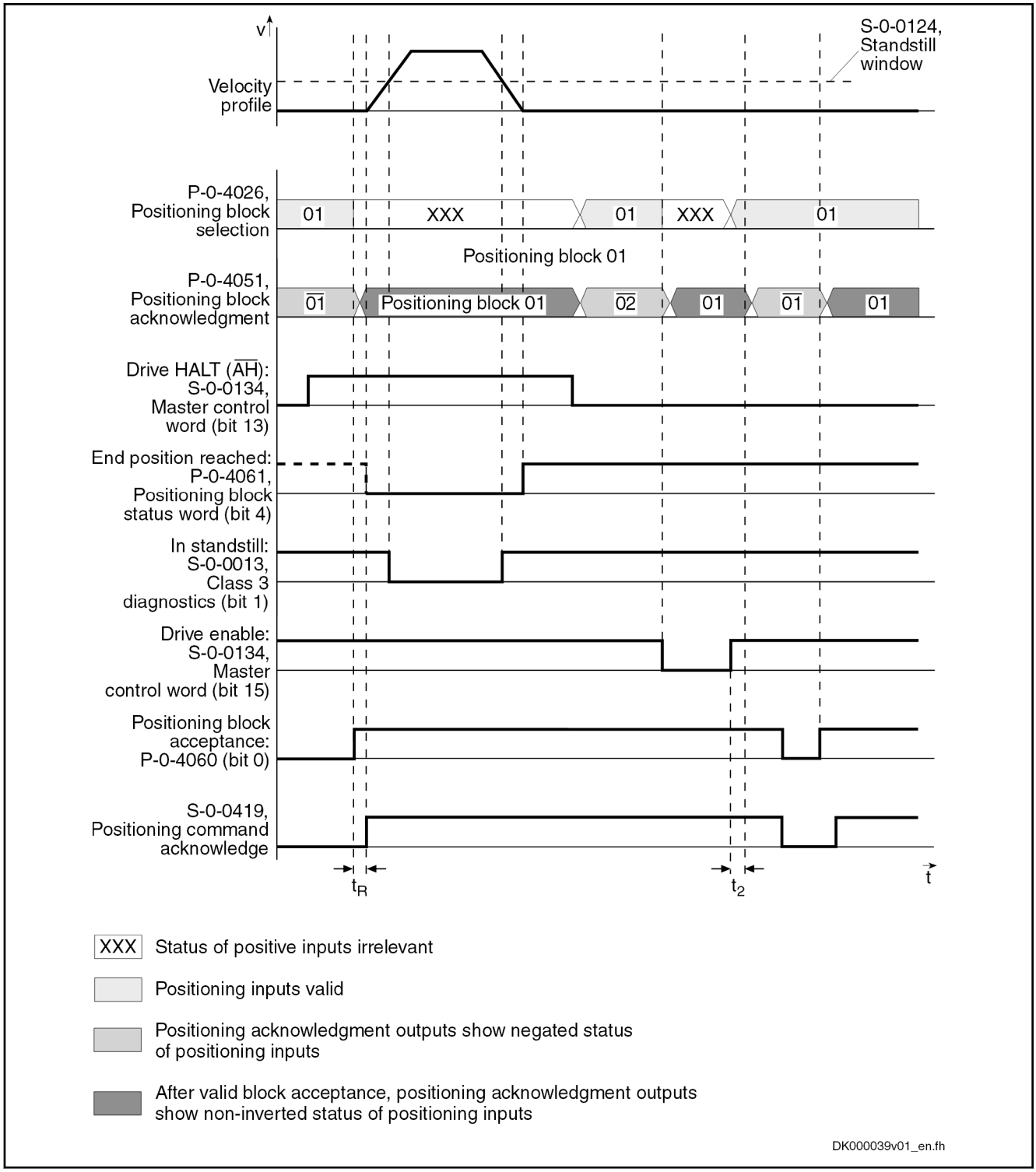



*Fig. 6-54: Acknowledgment and Message "End Position Reached" After Drive Enable Switched Off*

☞ Depending on the master communication, the positioning block is accepted by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

**With Absolute Value Encoder**

If an **absolute value encoder** is used, it is possible to decide, after the control voltage is switched off and on, whether the drive still is at the target position of the last accepted positioning block (end position reached).

The "end position reached" message is generated as soon as the drive is ready for operation again (bb contact closed).

**With Single-Turn Encoder**

If a **single-turn encoder** is used, the "end position reached" message is not clearly defined after a voltage interrupt until the first target position has been moved to or homed.

☞ The "end position reached" message is only retained if the axis has not been moved during the interruption. If the axis is moved into the positioning window during the interruption, the "end position reached" message will also be generated! After activating controller enable, positioning block acknowledge changes as described under "Acknowledgment with Drive Enable Switched Off".

## Status Messages

**Status Bits**

In addition to the status messages during the "drive-internal interpolation" mode, the "end position reached" status message is generated in the "positioning block mode" (bit 4 = 1 in parameter "P-0-4061, Positioning block status word"), if the following applies:

- |S-0-0430 – S-0-0051/S-0-0053| < S-0-0057 (in position)

  - and -

- No sequential block has been selected.

See also Parameter Description "P-0-4061, Positioning block status word"

**Status Parameters**

The following parameters provide further diagnostic options:

- P-0-4051, Positioning block acknowledgment

  → Acknowledgment of the currently accepted and active positioning block

  **Note:** In the case of "Drive Halt", the selected positioning block is returned in negated form (complementary to positioning block selection).

- P-0-4052, Positioning block, last accepted

  → Contains the last accepted positioning block (stored in non-volatile form)

  **Note:** For sequential block chains, this is always the first block of the sequential block chain!

- P-0-4053, Positioning block, last active

  → Contains the last active positioning block (stored in non-volatile form)

  **Note:** For sequential block chains, this is the last active block of the sequential block chain. For single blocks (no sequential block processing), the contents of parameters P-0-4052 and P-0-4053 are always identical!

- P-0-4057, Positioning block, input linked blocks

  → Contains an image of the digital sequential block inputs (switch cam inputs)

## Diagnostic Messages

**Diagnostic status messages:**

- A0162 Positioning block mode
- A0206 Positioning block mode, encoder 1
- A0207 Positioning block mode lagless, encoder 1

**Warnings:**

- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2054 Not homed
- E2055 Feedrate override S-0-0108 = 0
- E2058 Selected positioning block has not been programmed

**Error messages:**

- F2028 Excessive deviation

# 6.13 Pump Control

## 6.13.1 Brief Description

In the operation mode "pump control", a swivel angle command value and a pressure command value are fed to a variable displacement pump. If required, these command values can be directed via a ramp generator.

In this operation mode, swivel angle and pressure controller are simultaneously active, and both generate a control variable. The changeover logic passes the smallest control variable from these two controllers on (function of minimum value comparator). This minimum value comparator ensures that controlling is based on only one of the two variables of swivel angle or pressure and that it is possible to switch dynamically between the two control types. The output variable of the changeover logic can be modified using various characteristic curves and functions in control variable adjustment before it is handed over to the valve controller as valve command value.

When the operation mode is activated the diagnostic message is A0175, Pump control".

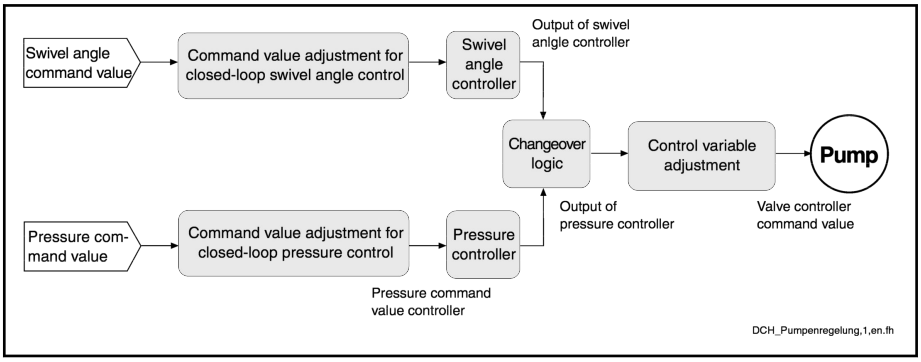



*Fig. 6-55: Overview "Pump Control"*

**Features**

- Command value generators for "closed-loop swivel angle control" and "closed-loop pressure control"
- Limitation of given command values to limit values that can be parameterized individually
- Switching between closed-loop swivel angle control and closed-loop pressure control with the help of the "changeover logic"
- Control variable adjustment

**Pertinent Parameters**

- S-0-0880, Swivel angle command value

- S-0-0881, Swivel angle command value, additive
- S-0-0884, Swivel angle limit value, bipolar
- S-0-0885, Swivel angle limit value, positive
- S-0-0886, Swivel angle limit value, negative
- S-0-0887, Swivel angle status word
- S-0-0888, Swivel angle ramp time
- P-0-2972, Swivel angle command value, Generator
- S-0-0800, Pressure command value
- S-0-0801, Pressure command value additive
- S-0-0802, Bipolar pressure limit value
- S-0-0810, Pressure ramp time
- S-0-0811, Pressure ramp reference
- S-0-0828, Positive pressure limit value
- S-0-0829, Negative pressure limit value
- S-0-0830, Pressure status word
- P-0-2975, Pressure command value (without controller enable)
- P-0-2976, Swivel angle command value (without controller enable)

**Pertinent Diagnostic Messages**

- A0175, Pump control

**Specialties in the Device Behavior / Device State Machine**

Pressure and swivel angle controller are in the state "drive ready (dr)" and active in the event of an error. The following, separate command values are used for this:

P-0-2975, Pressure command value (without controller enable)

P-0-2976, Swivel angle command value (without controller enable)

## 6.13.2 Command Value Processing for Closed-Loop Swivel Angle Control

**Filtering the Command Value**

The command value provided via S-0-0880, Swivel angle command value, is filtered by being directed via a simple ramp.

The ramp is defined by S-0-0888, Swivel angle ramp time, and refers to a change of the swivel angle from 0 % to 100 %.

**Additive Swivel Angle Command Value**

Moreover, it is possible to feed forward an unfiltered, additive command value via S-0-0881, Swivel angle command value, additive. If required, this value can also be cyclically configured.

**Output Variable**

The output value of the swivel angle generator can be limited to maximum values. 3 limit values are provided for this purpose:

S-0-0884, Swivel angle limit value, bipolar

S-0-0885, Swivel angle limit value, positive

S-0-0886, Swivel angle limit value, negative

The output variable of command value adjustment for swivel angle control is P-0-2972, Swivel angle command value, Generator.

## 6.13.3 Command Value Processing for Closed-Loop Pressure Control

**Filtering the Command Value**

The command value provided by S-0-0800, Pressure command value, is filtered. The ramp is defined by S-0-0810, Pressure ramp time, and S-0-0811, Pressure ramp reference.

**Additive Pressure Command Value**

Moreover, it is possible to feed forward an unfiltered, additive command value via S-0-0801, Pressure command value additive. If required, this value can also be cyclically configured.

Operation Modes

**Output Variable**

The output value of the pressure command value generator can be limited to maximum values. 3 limit values are provided for this purpose:

S-0-0802, Bipolar pressure limit value

S-0-0828, Positive pressure limit value

S-0-0829, Negative pressure limit value

The output variable of command value adjustment is P-0-2803, Pressure command value of controller. It is connected upstream of the pressure controller and provides the output variable P-0-2805, Output of pressure controller. The pressure controller is described in more detail under "Pump controller".

## 6.13.4 Block Circuit Diagram

The graphic below illustrates command value processing in the "pump control" mode as a block circuit diagram.

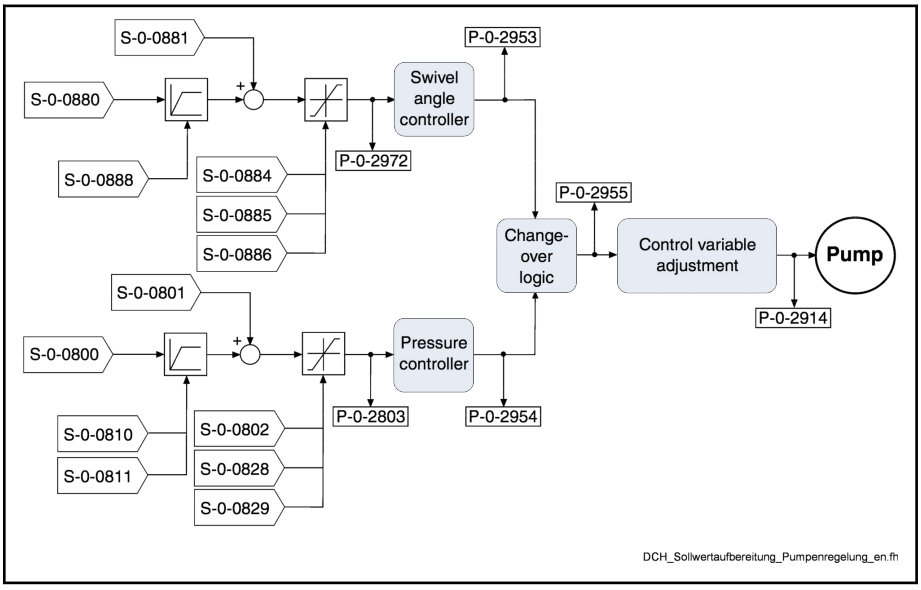



*Fig. 6-56: Command Value Processing for "Pump Control"*

## 6.13.5 Diagnostic Messages and Monitoring Functions

**Diagnostic Status Messages**

The activated "pump control" mode is indicated by the following diagnostic message: A0175, Pump control

# 7 Open and Closed-Loop Drive Control

## 7.1 Overview

### 7.1.1 Basic Principles and Terms

*Depending on the device characteristic, the following principles of drive control are supported:*

- **p/Q Function**

  Generally, no position encoder is available. Depending on the available pressure sonsorics (hardware requirements) it is possible to select open-loop Q control (valve opening) or closed-loop flow control (closed-loop Q control).

- **Open-Loop Axis Control** or **Open-Loop Operation**

  No position encoder available. The valve opening is input in open-loop operation. Optionally, the force can be closed-loop controlled, provided that the relevant sensors are connected.

- **Closed-Loop Axis Control** or **Closed-Loop Operation**

  A position encoder is available, which is used for position feedback (position control). Optionally, the velocity and, provided that the required sensors are connected, force/pressure can be closed-loop-controlled. The selection of the operation mode determines both, the required controllers (position, velocity, and force) and their changeover (alternating control). However, in closed-loop operation, the valve opening may also be input in the open-loop mode.

**The following table gives an overview of which control types are supported by which device variant in which operation mode:**

| Operation mode | Control mode | Firmware derivate | Position encoder available | Sensorics | Required base package |
|---|---|---|---|---|---|
| Direct valve control | Open-loop controlled operation | HDB, HDC | Yes | | Closed-loop |
| | | | No | | Open-loop |
| Closed-loop flow control | Closed-loop flow control | HDB | No | Internal pressure sensors | Open-loop |
| Closed-loop pressure control / direct valve control (p/Q) | Open-loop controlled operation, including changeover logic to closed-loop pressure control | HDB, HDC | No | Pressure sensor | Open-loop |
| Closed-loop pressure / flow control (p/flow) | Closed-loop flow control including changeover logic to closed-loop pressure control | HDB | No | Internal pressure sensors | Open-loop |
| Closed-loop position control | Closed-loop position control, including alternating control (force control) | HDB, HDC | Yes | Pressure sensors or force sensor | Closed-loop |
| Drive-controlled positioning, positioning block mode | Closed-loop position control, including alternating control (force control) | HDB, HDC | Yes | Pressure sensors or force sensor | Closed-loop |

Open and Closed-Loop Drive Control

| Operation mode | Control mode | Firmware derivate | Position encoder available | Sensorics | Required base package |
|---|---|---|---|---|---|
| Closed-loop torque/force control | Closed-loop torque/force control | HDB, HDC | No | Pressure sensors or force sensor | Open-loop |
| | | | Yes | Pressure sensors or force sensor | Closed-loop |
| Closed-loop torque/force control / direct valve control | Closed-loop position control, including alternating control (torque/force control) | HDB HDC | No | Pressure sensors or force sensor | Open-loop |
| Closed-loop velocity control | Closed-loop velocity control, including alternating control (force control) | HDB, HDC | Yes | Pressure sensors or force sensor | Closed-loop |

*Tab. 7-1: Overiew of Operation Modes and Possible Control Types*

☞ The selection of p/Q function or axis control partially depends on the concrete device characteristic. For example, for closed-loop flow control, a specific device with integrated pressure sensor and measured valve characteristic curve is required (WRPQ valve). This must be taken into account when the device is ordered. For certain operation modes it is necessary that pressure sensors and/or a position encoder are present. The changeover between open-loop and closed-loop package is made by selecting the respective function package (HDB and HDC only).

## 7.1.2 Principles of Drive Control

**Overview of p/Q functionality**

The p/Q function allows the input of the valve opening for the open-loop-controlled operation of a drive. With the help of closed-loop flow control, a drive can be operated without the use of a position encoder and without closing the position control loop, comparably with closed-loop velocity control. A precondition for this is that pressure sensors are integrated in the hydraulic valve, which sense the chamber pressures. Moreover, closed-loop pressure control is possible, which is activated or deactivated using a changeover logic.

*The following operation modes are supported:*

- Direct valve control
- Closed-loop flow control
- Closed-loop pressure control / direct valve control (p/Q)
- Closed-loop pressure/flow control

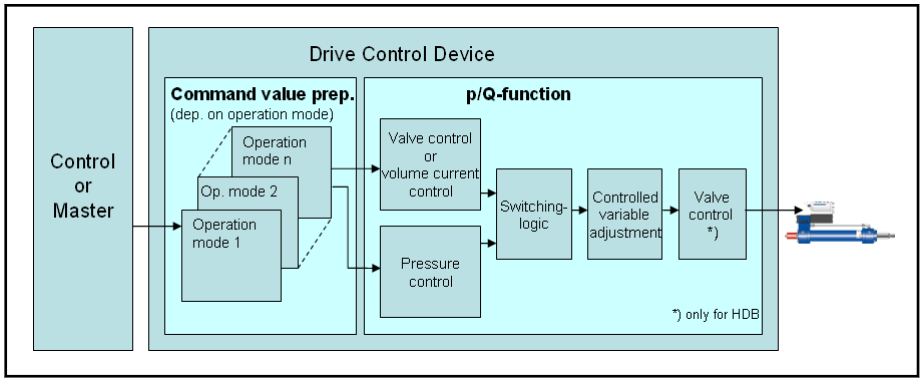



*Fig. 7-1: Principle of the p/Q Function*

**Overview of Open-Loop Axis Control (Open-Loop Operation)**

Open-loop axis control allows open-loop-controlled operation of the drive without position encoder.

HDB: The primary operation mode "direct valve control" is configured.

HDS: In der Auswahl für Geber 1 und Geber 2 wird "kein Geber" konfiguriert.

Closed-loop control (position and velocity) and functions and operation modes depending thereof are not possible. Closed-loop torque/force control can be superimposed ("alternating control").

*The following operation modes are supported:*

- Direct valve control
- Closed-loop torque/force control (additional sensorics required for acquiring the force by means of pressure or force sensors)
- Closed-loop torque/force control / direct valve control
- Closed-loop pressure control / direct valve control

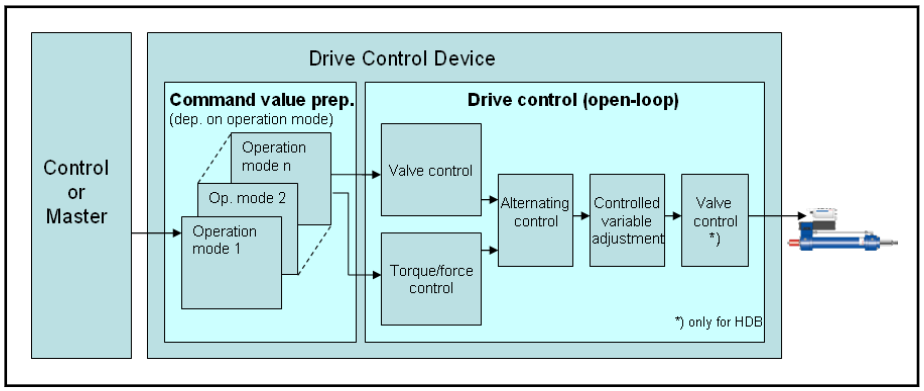



*Fig. 7-2: Principle of Drive Control (Open-Loop Operation)*

**Overview of Axis Control (Closed-Loop Operation)**

Closed-loop axis control allows the drive to be operated in closed-loop control.

The position control loop and, if required, inner-loop velocity controllers, are closed via the encoder feedback.

*Here, the following operation modes are supported:*

- Direct valve control
- Closed-loop position control with cyclic command value input
- Closed-loop velocity control (can also be used for open-loop velocity control)
- Positioning modes (e.g. drive-controlled positioning) (HDB and HDC only)

- Closed-loop torque/force control (additional sensorics required for acquiring the force by means of pressure or force sensors)
- Closed-loop torque/force control / direct valve control
- Closed-loop pressure control / direct valve control

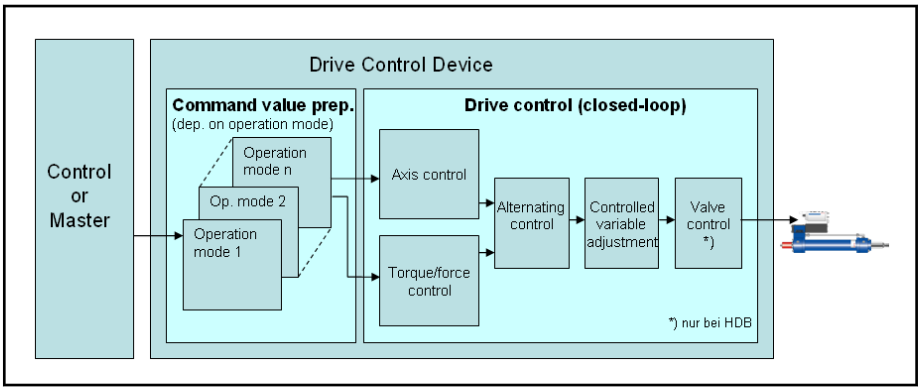



*Fig. 7-3: Principle of Drive Control (Closed-Loop Operation)*

## 7.1.3 Features of the Control Loops

**Performance (Controller Cycle Times)**

*The internal controller cycle times (flow, velocity and position) depend on the following conditions and parameters:*

- Firmware derivate
- Activation of the functional packages
- P-0-0556, Config word of axis controller (Bit 2 and Bit 5)
- P-0-0556, Config word of axis controller (Bit 15) setting of the clock ratio

Depending on these factors, the following cycle times can be achieved:

**With 1:2 timing (P–0–0556, Bit 15 = 0)**

| Bit 2.5: Performance level | Controller cycle time | Base cycle time |
|---|---|---|
| Basic performance | 500 µs | 250 µs |
| Economy performance | 1000 µs | 500 µs |
| Low performance | 2000 µs | 1000 µs |

**With 1:1 timing (P–0–0556, Bit 15 = 1)**

| Bit 2.5: Performance level | Controller cycle time | Base cycle time |
|---|---|---|
| Basic performance | 500 µs | 500 µs |
| Economy performance | 1000 µs | 1000 µs |
| Low performance | 2000 µs | 2000 µs |

**Performance (controller cycle times)**

The presence of the listed controllers as well as the internal controller cycle times depend on the following conditions and parameters:

- Hardware characteristic
- Activation of functional packages (HDB only)
- HDB and HDC: P-0-0556, Config word of axis controller (bits 2 and 5)

  HDS: Performance depends on motion and sercos cycle times (C-0-0400 and C-0-0503)

**Depending on these factors, the following cycle times can be achieved:**

| | HDB | HDC | HDS |
|---|---|---|---|
| Valve controller cycle | 100 µs | 100 µs | - |
| Flow controller cycle | 1 ms | 1 ms | - |
| Pressure controller cycle | 0.5 ms | 0.5 ms | - |
| Controller cycle time | 1 ms | 1 ms | 0.5 ms |
| Velocity controller cycle | 0.5 ms | 0.5 ms | 0.5 ms |
| Torque/force controller cycle | 0.5 ms | 0.5 ms | 0.5 ms |

**Valve Controller**

The valve controller is contained in IAC devices only. These devices are mounted directly to the hydraulic valve and substitute the standard OBE (on-board electronics). Otherwise, the valve command value is usually fed over an analog interface to the standard OBE.

If the valve controller is included, it is matched to the relevant hydraulic valve in the factory and requires no application-specific adjustments.

**Flow Controller**

*The flow controller is characterized by the following features:*

- Calculation of the valve actuating signal by means of flow equation and flow characteristic curve of the valve

**Pressure Controller**

*The pressure controller is characterized by the following features:*

- PI-controller with switchable I-component and associated logic

**Position Controller with Inner-Loop Velocity Controller**

*The position loop is characterized by the following features:*

- Kv with D-component and fine positioning, including associated logic for controlling the I-component
- Velocity feedforward
- Inner-loop velocity controller as PI controller, including associated logic for controlling the I-component
- State feedback (velocity, acceleration or force)

**Torque/Force Controller**

*The force controller is characterized by the following features:*

- Normalization of the control difference to velocity; thus, the controller parameters, controller components and outputs are already referred to velocity
- PI-controller with switchable I-component and associated logic
- Possibility of velocity feedforward
- Quadrant limitation

## 7.1.4 General Notes on Commissioning and Notes for Users

**Additive Command Values and Possibilities of Accessing Outer Control Loops**

In closed-loop operation, it is possible to add command values in addition to the command values available in the control loop. These parameters can be found in the description of the relevant operation mode.

**Notes on Commissioning for Control Loop Setting**

The correct setting of the control loops has a decisive influence on the properties of the hydraulic axis.

**Order of Manual Control Loop Setting**

First, the parameters of control variable adjustment should be adapted to the hydraulic system to be controlled: Valve standard velocity, direction-dependent gain and valve characteristic curve.

For direct valve control (open-loop operation) no further settings are necessary.

With regard to p/Q applications, for devices with flow control, the control variable calculation must be parameterized first, followed by the setting of the pressure controller and changeover logic.

For closed-loop operation, the control variable adjustment must be set, then the position controller must be parameterized. For applications in continuous path controls, the inner-loop velocity controller must be used; otherwise, it needs not to be activated. For stabilizing and increasing the control loop gain, state feedbacks can be activated. Afterwards, force controllers and alternating control can be activated.

**Pertinent Parameters**

- P-0-0556.000.000, Config word of axis controller

# 7.2 Open-Loop Drive Control

## 7.2.1 Overview

### Functional Description

In case that no position sensor is connected to the drive controller, the drive can only be operated under open-loop control (with direct valve control). Depending on the device variant, the following operation modes are possible:

### Devices Without Integrated Pressure Sensorics (Standard)

#### Direct Valve Control

Direct valve control is a mode for open-loop-controlled operation. It allows the axis to be operated without any further settings. The velocity of the axis is not closed-loop-controlled and can therefore change in dependence upon the system pressure. Since, apart from the valve control loop, no further loops are closed, it can be ensured in this way that the axis cannot vibrate. For a description, see operation mode "direct valve control".

#### Closed-Loop Pressure Control / Direct Valve Control

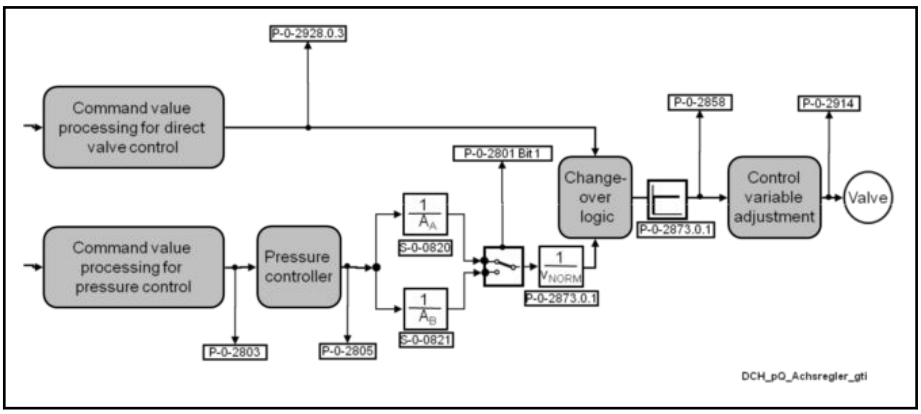



*Fig. 7-4:*

In addition to direct valve control, pressure can be closed-loop-controlled. For this, it is required that at least one external pressure sensor is connected. The output of the pressure controller must be converted into a velocity; to this end, the two cylinder areas must be known. Control variable adjustment must be set accordingly. This is particularly valid for the valve standard velocity, because it contains gain information with reference to the valve and the system pressure. For the description, see operation mode "closed-loop pressure control / direct valve control" as well as "pressure controller", "changeover logic p↔Q or p↔Flow" and "control variable adjustment".

### Closed-Loop Torque/Force Control

A force is closed-loop-controlled. For this, the required sensorics must be connected. For a description, see operation mode "closed-loop torque/force control / direct valve control".

### Closed-Loop Torque/Force Control / Direct Valve Control

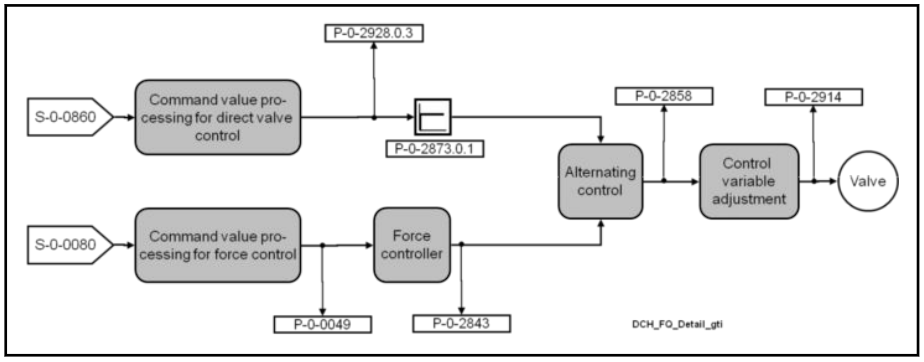



*Fig. 7-5:*

In addition to direct valve control, the force can optionally be closed-loop-controlled. In parallel to the valve command value, the force controller is calculated. The alternating control ensures a change-over to closed-loop force control as soon as the set changeover condition is fulfilled. For a description, see operation mode "closed-loop torque/force control / direct valve control" as well as "force controller", "alternating control" and "control variable adjustment".

## Devices with Integrated Pressure Sensorics (Pressure Compensator Function)

### Pressure Sensorics

In this case, the pressure in the respective valve chambers can be measured by means of the integrated pressure sensors. By establishing the pressure differential across a control land and taking account of the valve's flow characteristic curve it is possible to generate a constant flow.

### Closed-Loop Flow Control

The flow is closed-loop-controlled by the device. This allows traversing of the axis at largely constant velocity. In this case, the velocity of the axis is not directly closed-loop-controlled, but determined via the flow, which is calculated from the system pressure and the chamber pressures. For a description, see operation mode "closed-loop flow control".

### Closed-Loop Pressure/Flow Control

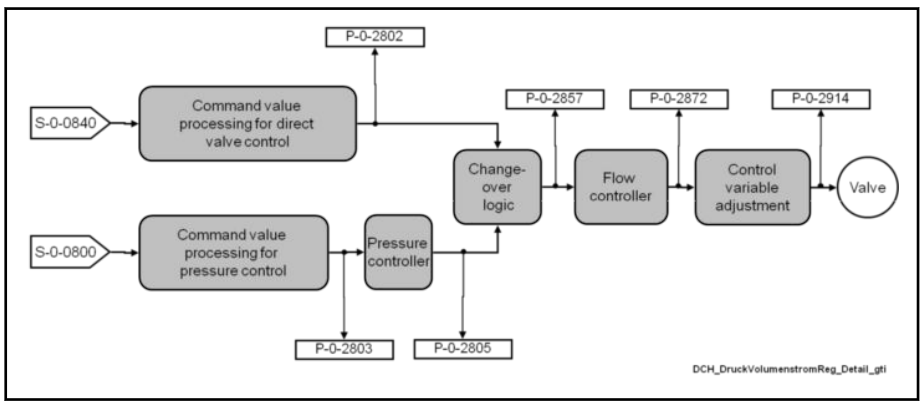



*Fig. 7-6:*

In addition to the flow, the pressure can be closed-loop-controlled. The changeover logic monitors the axis with the set configuration and activates the pressure controller, as soon as the set condition is fulfilled. Switching off also takes place according to the defined criteria. For the description, see operation mode "closed-loop pressure/flow control" as well as "pressure controller", "changeover logic p↔Q or p↔Flow" and "control variable adjustment".

### Closed-Loop Pressure Control / Direct Valve Control

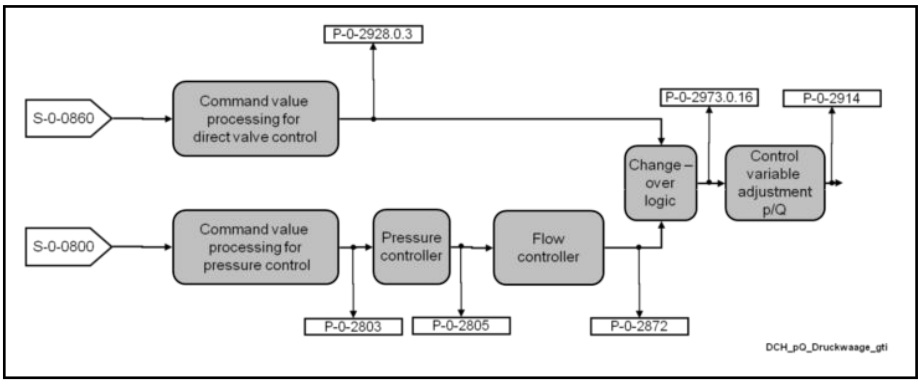



*Fig. 7-7:*

Alternatively, open-loop-controlled operation can be set with direct valve control. This allows the axis to be operated without any further settings. The velocity of the axis is not closed-loop-controlled and can therefore change in dependence upon the system pressure. In addition, the pressure can be closed-loop-controlled. The changeover logic monitors the set configuration and activates the pressure controller as soon as the set condition is fulfilled. Switching off also takes place according to the defined criteria. For the description, see operation mode "closed-loop pressure control / direct valve control" as well as "pressure controller" and "changeover logic p↔Q or p↔Flow".

In the case of p/Q, the axis is traversed with an open-loop-controlled valve control variable and closed-loop-controlled on the basis of a pressure command value. In the case of p/Flow, the flow is additionally closed-loop-controlled, which allows smooth traversing of the axis, even if fluctuations in the system pressure occur. In the case of F/Q, the axis is traversed with an open-loop-controlled valve control variable and closed-loop-controlled on the basis of a force command value.

The changeover to closed-loop pressure or force control and back can be configured and adapted to the application at hand.

p/Flow control can only be used for a valve with pressure compensator. p/Q control can be used in conjunction with a valve with pressure compensator and also with an axis controller. The F/Q control can only be used in conjunction with an axis controller.

The operation modes are composed of three parts: A flow or valve command value is generated, a pressure or a force is closed-loop-controlled, and a changeover logic is calculated. In this way, it is possible to switch between the two command values or controllers within every clock cycle. This allows you to preset limit values in an application, which are adhered to by the IAC. A detailed explanation of the changeover logic is described under "changeover logic p↔Q and p↔Flow“. The pressure controller is described for all devices under "closed-loop pressure control". The operation mode F/Q utilizes the changeover logic of the axis controller. This is described in the Chapter "alternating control". The force controllers are described in detail in "closed-loop force control".

## 7.2.2 Pressure Controller

### Brief Description

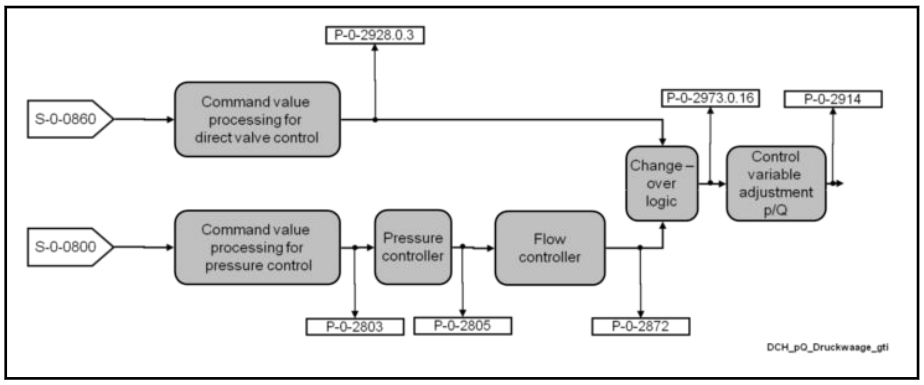



*Fig. 7-8: Overview of p/Q Control With Pressure Compensator*

The valve opening is open-loop-controlled. This allows the axis to be operated without any further settings. The velocity of the axis is not closed-loop-controlled and can therefore change in dependence upon the system pressure. Since, apart from the valve control loop, no further loops are closed, it can in this way be ensured that the axis cannot vibrate. The changeover logic monitors the set configuration and activates the pressure controller as soon as the set condition is fulfilled. Switching off also takes place according to the defined criteria. The pressure controller is required for realizing closed-loop control of pressure.

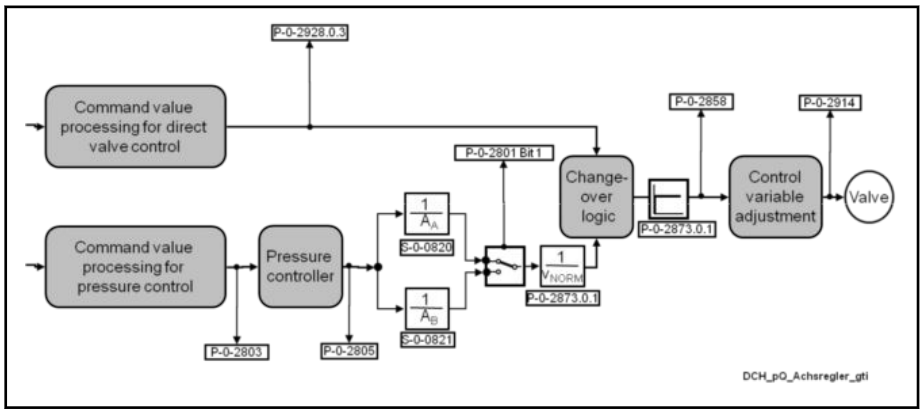



*Fig. 7-9: Overview of p/Q Control with Axis Controller*

The axis controller utilizes the same command values and the same settings as a valve with pressure compensator, but since the flow must be converted into velocity, the two cylinder areas are required. Please note that in the case of the axis controller, the control variable adjustment must be set correctly in order that the pressure controller can work properly. This is also valid for the valve standard velocity, because it contains gain information with reference to the valve and the system pressure.

For control variable adjustment, we also have to distinguish between the two devices, pressure compensator and axis controller. A pressure compensator features only a few setting options, because most of the values are determined by integrated sensors or stored characteristic curves. The axis controller supports complete control variable adjustment and may it require depending on the configuration.

**Pertinent Parameters**

- S-0-0800, Pressure command value
- S-0-0820, Piston area A

Open and Closed-Loop Drive Control

- S-0-0821, Piston area B
- S-0-0860, Spool command value
- P-0-2803, Pressure command value of controller
- P-0-2805, Output of pressure controller
- P-0-2858, Output of position/force changeover logic
- P-0-2873.0.1, Valve standard velocity
- P-0-2914, Effective valve command value
- P-0-2928.0.3, Output of valve command value generator
-

## Closed-Loop Pressure/Flow Control (p/Flow)

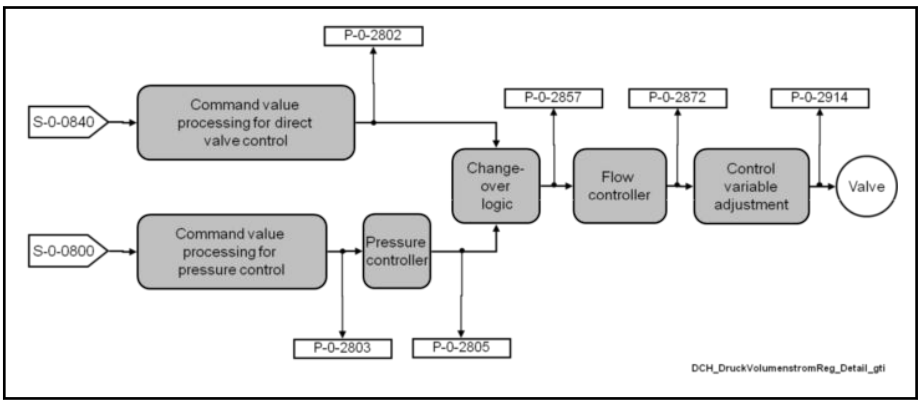



*Fig. 7-10: Overview of p/Flow Control with Pressure Compensator*

☞ This operation mode is available only for a valve with pressure compensator.

The flow is closed-loop-controlled by the device. This allows traversing of the axis at largely constant velocity. The velocity of the axis is not directly closed-loop-controlled, but determined via the flow that results from the system pressure and the chamber pressures.

The changeover logic monitors the axis with the respective set configuration and activates the pressure controller as soon as the set condition is fulfilled. Switching off also takes place according to the defined criteria.

There are only a few setting options, because most of the values are determined by integrated sensors or stored characteristic curves.

**Pertinent Parameters**

- S-0-0800, Pressure command value
- S-0-0840, Flow command value
- P-0-2802, Flow command value internal
- P-0-2803, Pressure command value of controller
- P-0-2805, Output of pressure controller
- P-0-2857, Output of changeover logic p/Q
- P-0-2872, Output of valve characteristic curve
- P-0-2914, Effective valve command value

## Closed-Loop Force Control / Direct Valve Control (F/Q)

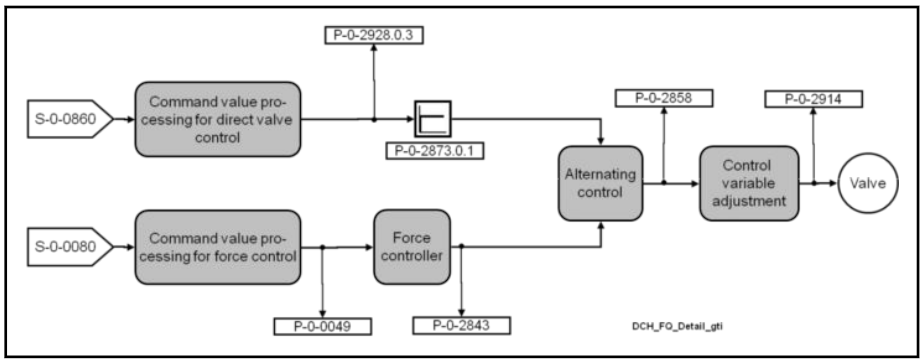



*Fig. 7-11: Overview of p/Q Control with Axis Controller*

This operation mode is available only in conjunction with the axis controller.

The valve opening is open-loop-controlled. This allows the axis to be operated without any further settings. The force controller is calculated in parallel. The alternating control ensures a change-over to closed-loop force control as soon as the set changeover condition is fulfilled. See also Chapter "Alternating Control".

**Pertinent Parameters**

- S-0-0080, Torque/force command value
- S-0-0860, Spool command value
- P-0-0049, Torque/force command value of controller
- P-0-2843, Output of force controller
- P-0-2858, Output of position/force changeover logic
- P-0-2873.0.1, Valve standard velocity
- P-0-2914, Effective valve command value
- P-0-2928.0.3, Output of valve command value generator

## Closed-Loop Pressure Control

The pressure controller can only be used in conjunction with closed-loop pressure control/direct valve control or closed-loop pressure/flow control.

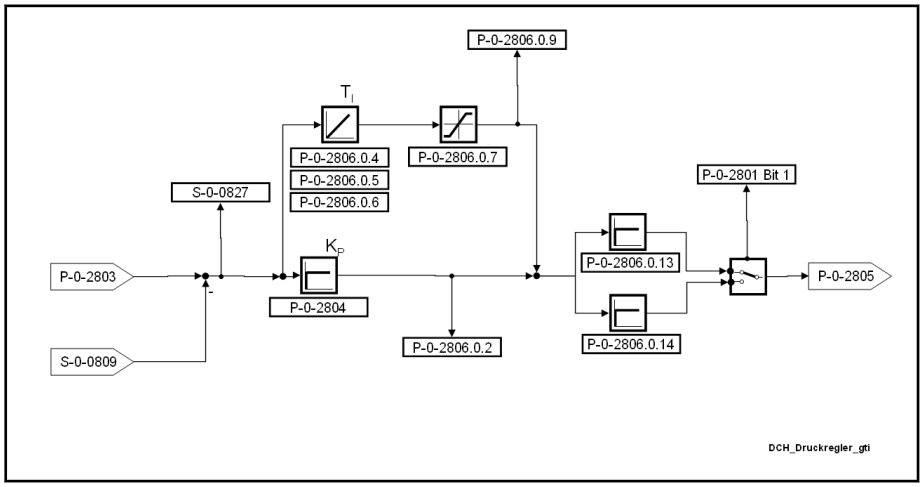



*Fig. 7-12: Structure of Pressure Controller*

The pressure controller controls the respective chamber pressure. This means that the actual pressure value is always referred to the relevant cham-

ber. Since it can be assumed that leakage oil is present, this deviation can be compensated for with the help of the integrator. The enable condition for the integrator is determined by the change in the actual pressure value. This means that when a quasi-steady-state is reached, the integrator is activated and it is switched off again when the accuracy window is reached. The relevant windows must be adapted to the individual application. With regard to the limitation, it must be noted that it determines the maximum change (pressure per time unit). It is therefore possible that the limitation is greater than the system pressure.

If the pressure in chamber B forms the basis for controlling, it must be noted that the two pressures are used internally with a negative sign. This must be taken into account for the control error, because the meaning of the sign changes. If the command and the actual values are negative, a positive sign indicates that the actual pressure is too high, and a negative sign indicates that the actual pressure is too low.

☞ The sign of the pressure command value and actual pressure value are derived from the internal control signal. This control signal defines, whether the pressure in chamber A or B is closed-loop-controlled. A positive value means chamber A, a negative value chamber B.

For the controller, it must additionally be taken into account, which chamber volume the value refers to. The greater the volume in the chamber, the more oil is required for the same change in pressure. If the exact volume is not known, it is recommended that an estimated, somewhat smaller volume be used.

☞ For a pressure compensator, for example, you can determine the volume for a pressure step-change by 100 bar by integrating the actual flow, thus determining the approximate oil quantity that is required to change the pressure. This volume corresponds to about 1 % of the entire volume (leakage oil falsifies the result), because with a modulus of elasticity of 1000 bar, a change in the oil volume by 1 % corresponds to 100 bar.

### Setting the I-Component When Activating the Pressure Controller

When the pressure controller is activated, the I-component is set to zero by default. In certain cases, it may be useful to initialize the I-component with a greater value, e.g. when the drive hits a resistance during its travel movement and is to continue its movement under closed-loop pressure control. This initialization value can be set in dependence upon the pressure change rate when the pressure controller is activated.

The initialization of the I-component of the pressure controller is calculated according to the following formula:

$$I_component = (Q_{comm} - p_{actuating}) * KB_{I-sum} - P_component$$

*Fig. 7-13:*

With

**I_component**

I-component of the pressure controller (corresponds to P-0-2806.0.9)

**$Q_{comm}$**

internal flow command value as input for the changeover logic (see changeover logic p/Q)

**$p_{var}$**

internal pressure control variable as input for the changeover logic (see changeover logic p/Q)

**P_component**

P-component of the pressure controller (corresponds to P-0-2806.0.2)

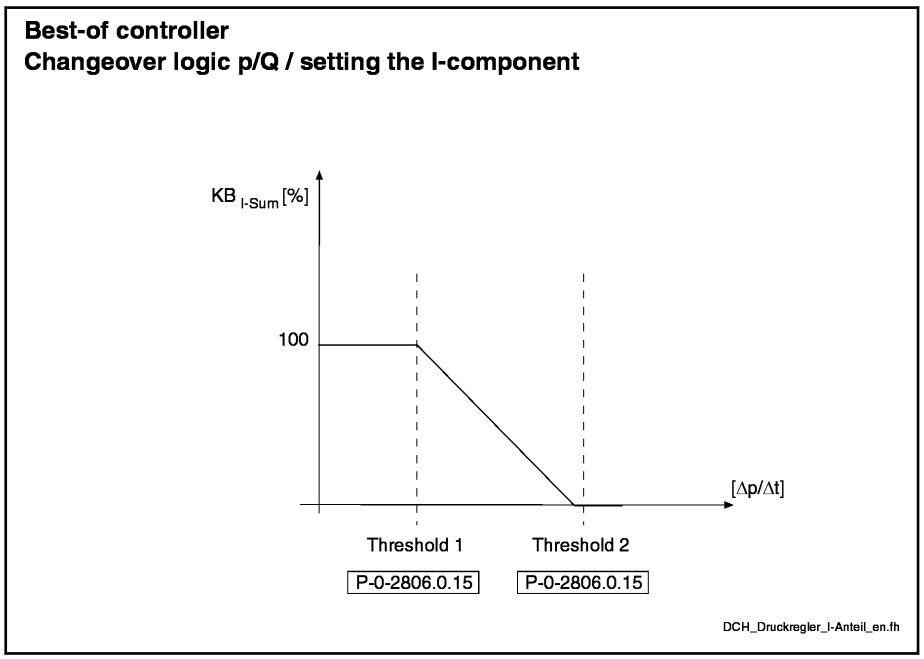



*Fig. 7-14: Determination of the Scaling Factor For Initializing the Pressure Controller I-Component*

☞ High pressure change rates indicate that the drive has hit a positive stop. Traveling further is rather improbable. In this case, the valve opening must be reduced as quickly as possible to avoid overshooting of the actual pressure value. Initializing the I-component with a value >0 would be rather unfavorable. If, when the pressure controller is activated, the pressure change rate is small, it must be expected that the drive hit an obstacle, which can be pushed away. Here, initializing the I-component with a greater value would be useful. In this way, it can be achieved that the drive continues to travel as continuously as possible under closed-loop pressure control.

The output of the pressure controller is converted into a control signal for the valve in dependence on the drive controller.

- S-0-0809, Pressure feedback value
- S-0-0827, Pressure control deviation
- P-0-2803, Pressure command value of controller
- P-0-2804, Pressure controller P-gain
- P-0-2805, Output of pressure controller
- P-0-2806.0.2, Correction value: pressure controller P-gain
- P-0-2806.0.3, Pressure controller integrator enable lowpass filter
- P-0-2806.0.4, Pressure controller integration time constant
- P-0-2806.0.5, Pressure controller integrator enable pressure change window

- P-0-2806.0.6, Pressure controller accuracy window integrator
- P-0-2806.0.7, Pressure controller integrator limit
- P-0-2806.0.9, Correction value: pressure controller integrator
- P-0-2806.0.13, Pressure controller calculation p->Q value side A
- P-0-2806.0.14, Pressure controller calculation p->Q value side B

## 7.2.3 Changeover Logic p↔Q and p↔Flow

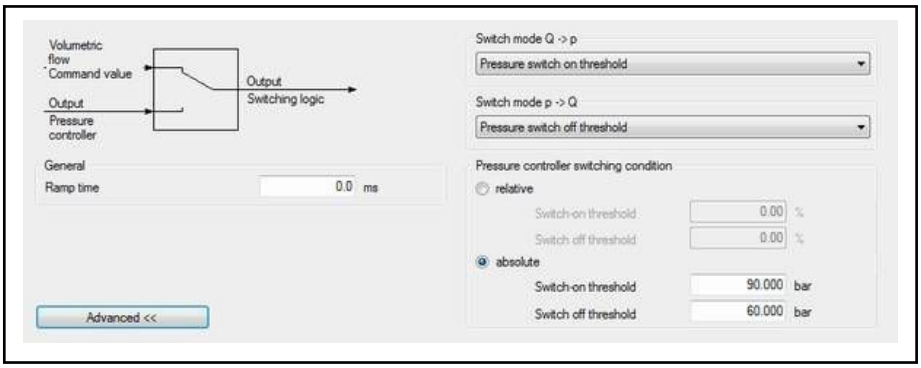



*Fig. 7-15: Overview of Changeover Logic*

The changeover logic switches between closed-loop flow control and closed-loop pressure control or direct valve control. This is checked in every pressure controller cycle. This means that the changeover logic could theoretically switch over in every cycle.

There are several modes for changing over to the pressure controller:

- "No selection": The changeover logic is switched off.
- "Minimum value": Depending on the control signal to be generated for the valve, the controller/the control signal is selected that results in a lower activation.
- "Pressure switch-on threshold": Depending on a defined relative or absolute threshold the changeover logic switches to the pressure controller.
- "Minimum value or pressure switch-on threshold": The criterion that occurs first changes over to the pressure controller.

---

☞ The activation threshold is a reliable changeover criterion for many applications.

---

The following setting options are available for changing from the pressure controller over to direct valve control or the flow controller:

- "No selection": This results in an immediate changeover from the pressure controller.
- "Minimum value": Depending on the control signal to be generated for the valve, the controller/the control signal is selected that results in a lower activation.
- "Pressure switch-off threshold": Depending on a defined relative or absolute threshold the changeover logic switches over from the pressure controller.
- "Pressure switch-off threshold or minimum value": The criterion that occurs first results in switching back.

- "Changeover to Q due to P-0-2800 bit 1": An edge change of bit 1 can be triggered in "P-0-2800, p/Q controller control word", thus forcing switching back from the pressure controller.
- "Changeover of the internal Q command value": If the sign changes, the pressure controller is automatically deactivated and the axis follows the relevant command value.
- "Change of Q sign or minimum value": A combination of these two options.
- "Change of Q sign or pressure switch-off threshold": A combination of these two options.
- "Change of Q sign or pressure switch-off threshold or minimum value": A combination of these three options.
- "Change of Q sign or P-0-2800 bit 1 with a positive edge": A combination of these two options.

The relative threshold refers to the internal pressure command value. Since this value can change via a ramp, depending on the setting, this ramp also has an effect on the relative threshold. In the case of problems, it may be helpful to also have a look at "P-0-2852.x.5, Pressure controller active switch-on threshold" or "P-0-2852.x.8, Pressure controller active switch-off threshold".

**Pertinent Parameters**

- P-0-2800, p/Q controller control word
- P-0-2801, p/Q controller status word
- P-0-2850, p/Q changeover logic control word
- P-0-2851, p/Q changeover logic status word
- P-0-2852.0.3, Pressure controller switch-on threshold, relative
- P-0-2852.0.4, Pressure controller switch-on threshold, absolute
- P-0-2852.0.5, Pressure controller active switch-on threshold
- P-0-2852.0.6, Pressure controller switch-off threshold, relative
- P-0-2852.0.7, Pressure controller switch-off threshold, absolute
- P-0-2852.0.8, Pressure controller active switch-off threshold
- P-0-2852.0.9, Pressure controller changeover logic ramp time
- P-0-2852.0.10, Correction value: pressure controller changeover logic ramp
- P-0-2857, Output of changeover logic p/Q

# 7.3 Closed-Loop Drive Control

## 7.3.1 Overview/Controller Structures

**Control Loop Structure**

The drive controller is a combination of a cascade and parallel structure. The position, velocity and valve controllers are interconnected in cascaded form. In contrast to this, the force controller is connected in parallel to the position/velocity controller cascade and can assume control due to alternating control. Depending on the active operation mode, a combination of controllers is closed in the drive.

Open and Closed-Loop Drive Control

The graphic shows an overview of the structure and the interaction of the control loops (information on the setting and display parameters can be found in the relevant chapters of the individual controllers).

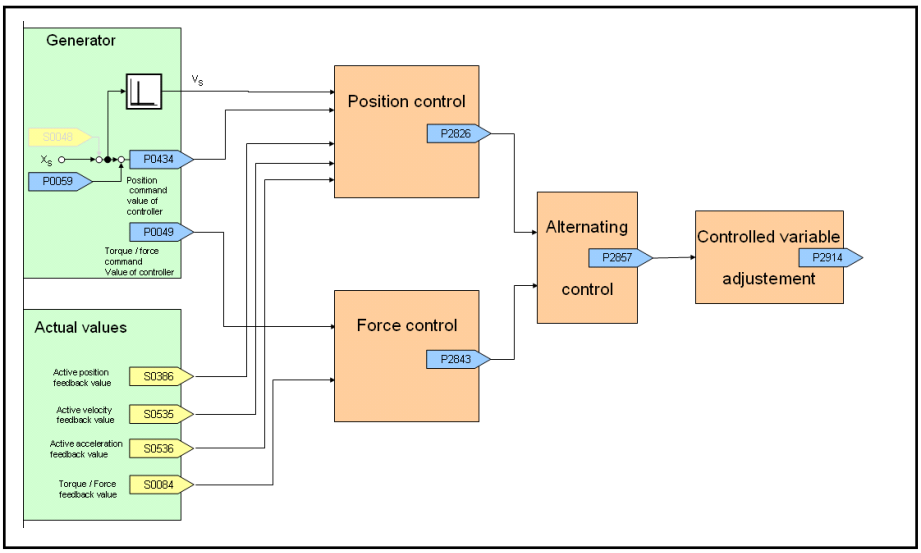



*Fig. 7-16: Overview of Position Controller Structure*

An external master or analog peripherals can provide command values. These are interpolated depending on the selected operation mode and fed to the controllers. The control signal issued by control variable adjustment is passed on to the valve controller. In the case of an IAC this takes place within the axis controller, and with an external motion controller via, for example, an analog interface to the valve.

☞ In the case of an IAC, additional information with regard to the valve command value, the actual valve value and control deviation are constantly available to the user.

## 7.3.2 Closed-Loop Position Control

### Structure

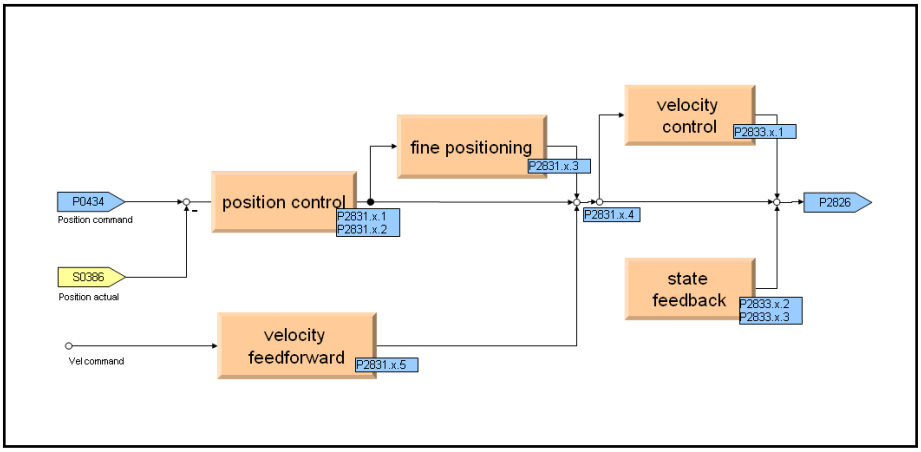



*Fig. 7-17: Structure of the Position Controller*

For closed-loop position control, apart from the position controller itself, further components can be activated: Fine positioning (integrator), velocity feedforward, inner-loop velocity controller and state feedback.

## Position Controller with Velocity Feedforward

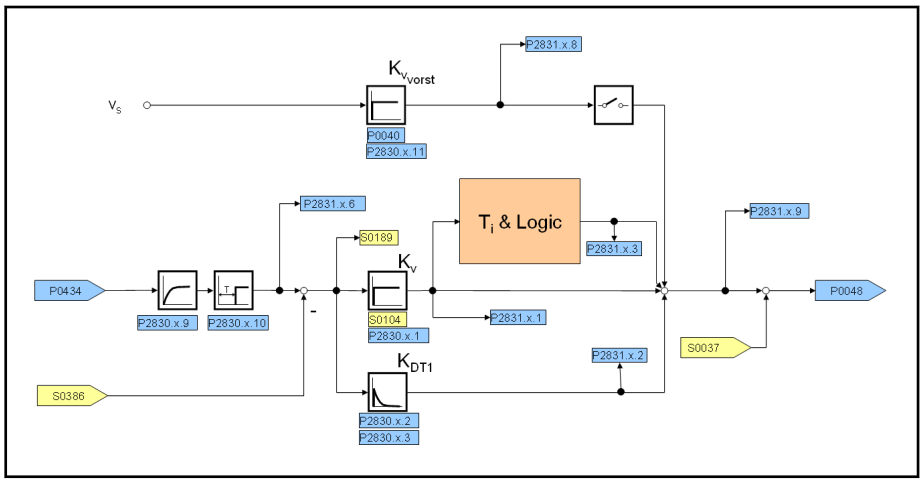



*Fig. 7-18: Detail of Position Controller*

The position command value can be filtered, if required. For this, a T1 filter (P-0-2830.0.9) and a dead time filter (P-0-2830.0.10) are available. The filtered value can then be read off in parameter Position command value of controller, delayed(P-0-2831.6).

**PDT1 Position Controller**

A DT1-component, which is calculated with parameters "Position loop time constant D-component“ (P-0-2830.0.2) and “ Position controller filter time D-compoent“ (P-0-2830.0.3) can be added to the proportional controller ( Position loop Kv-factor, S-0-0104). This may become necessary, if the natural frequency of the cylinder-mass system is higher than the natural frequency of the valve.

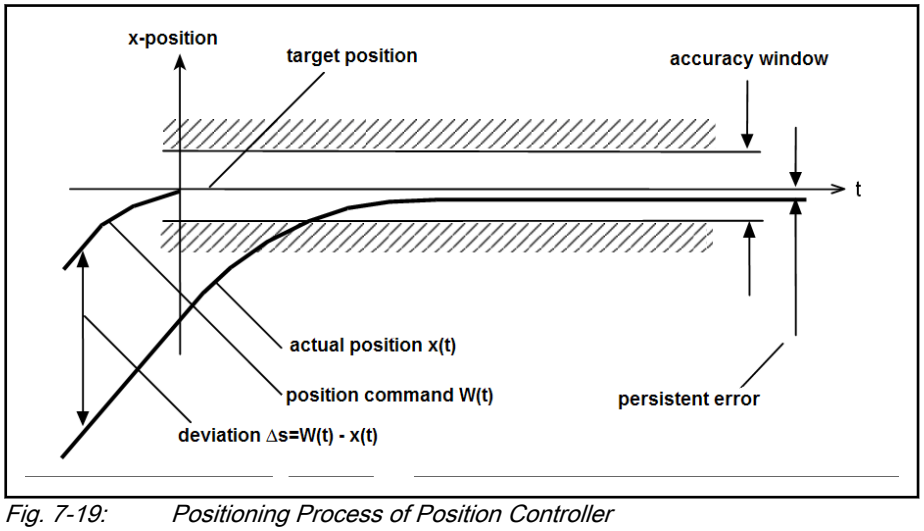



*Fig. 7-19: Positioning Process of Position Controller*

Depending on the controlled system, a permanent control error persists. This can be minimized by means of the fine positioner.

If, while a position operation mode is active, the Kv parameter is changed, the active Kv value is adjusted via a ramp using the parameter Position controller Kv ramp (P-0-2830.0.1). If the Kv change is set to 0, the adjustment is made step-like.

**Feedforward**

With the help of feedforward control (command value feedforward), the command velocity - scaled with a percentage factor (P-0-0040) can be processed in parallel to the position controller. In this way, any following errors can be minimized. Also here, a ramp (P-0-2830.0.11) is used when the scaling is

changed. Feedforward is activated by means of the respective operation mode selection or a feedforward value unequal to 0.

## Fine Positioner

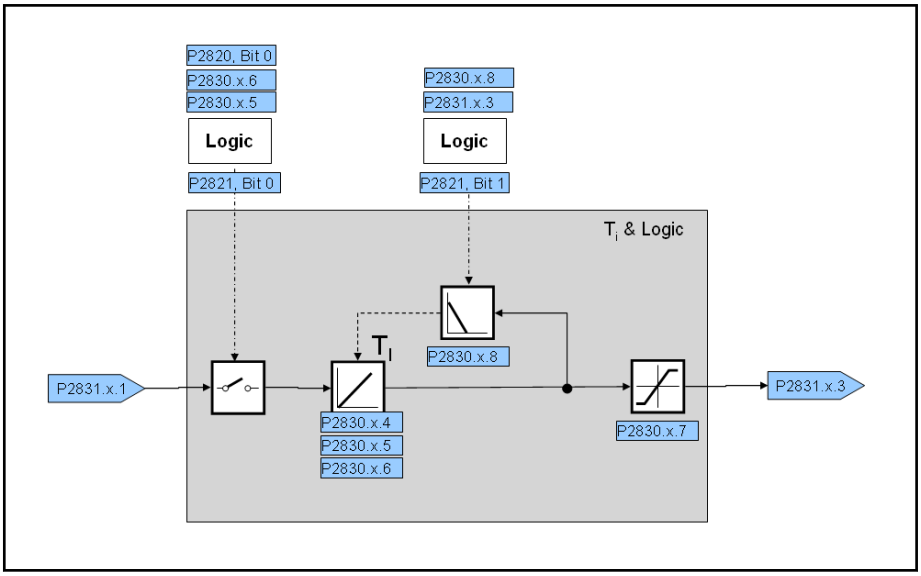



*Fig. 7-20: Detail of Fine Positioner*

**Integrator for Fine Positioning**

For exact positioning of a hydraulic axis, it may be required to activate a special algorithm for fine positioning. Because at higher travel velocities, the integrator has an unfavorable influence on the control behavior, it is only activated at lower travel speeds and close to the target position. The accuracy is specified by the accuracy window (P-0-2830.0.6).

The input of the integrator is parameter Correction value: position controller Kv (P-0-2831.0.1). The slope of the I-component is determined by the integration time constant (P–0–2830.0.4).

Apart from not having reached the accuracy window yet, a switch-on condition for the integrator is a value below that given for the enable velocity of the I-component (P-0-2830.0.5).

When fine positioning is switched off (e.g. by the relevant control bit P-0-2820, Bit 0), the value is ramped down in the integrator (P-0-2830.0.8).

In addition, the output of the fine positioning integrator can be limited (P-0-2830.0.7). This means that the integrator sums up to a maximum of this limit value, which will not be exceeded.

---

☞ If the value "0" is set for the limitation of the I-component, the limitation is switched off.

---

The current value of the integrator can be read out, e.g. for an optimization. (P-0-2831.0.3)

## State Feedback

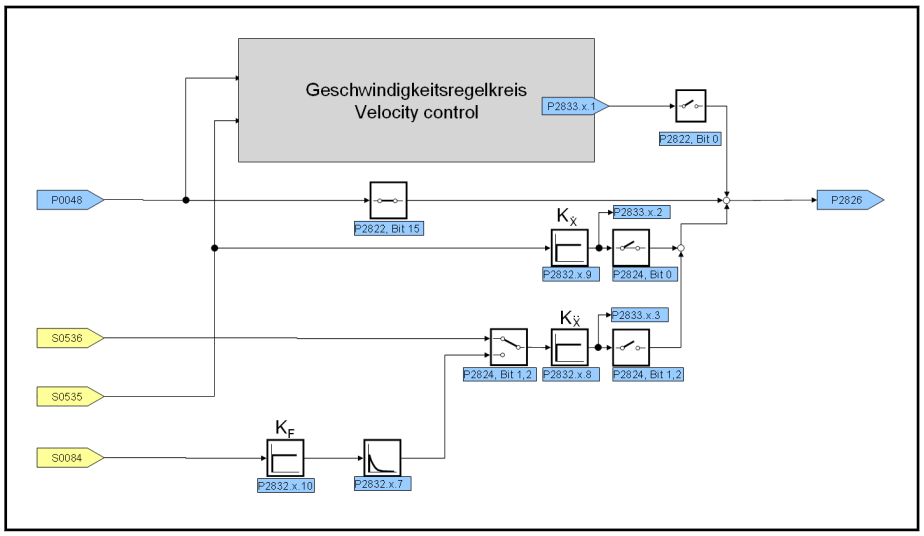



*Fig. 7-21: Detail of State Feedback*

The feedback of state variables can be used to achieve a greater controller gain and thus a better control behavior (reference reaction and error response, faster signal transitions). Especially for systems with a relatively low natural frequency ($f_{system}$ < 15 Hz) state feedback helps to improvement the dynamic behavior. However, a prerequisite is that the valve is "sufficiently" fast compared with the cylinder-mass system. ($f_{valve}$ > 2* $f_{system}$)

**Types of Feedback**

With state feedback, the actual process values of velocity, acceleration or force can be scaled (v: P-0-2832.0.9, a: P-0-2832.0.8, F: P-0-2832.10 and P-0-2832.0.8) and fed back to the control loop. The feedback can be positive or negative, which is determined by the sign of the relevant parameter.

The state controller should not be used together with the inner-loop velocity controller.

The type of feedback is set via the control word P-0-2824.

Either acceleration feedback or force feedback can be used. Both feedback types can be combined with velocity feedback.

## Inner Velocity Control Loop

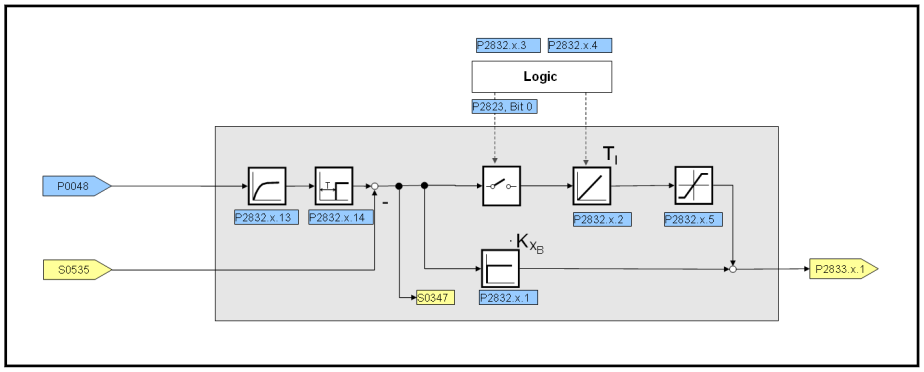



*Fig. 7-22: Detail of Inner-Loop v-Controller*

The inner-loop velocity controller is a PI controller. It is used to correct the velocity deviation between the command and actual value. The P-component results from multiplication by the V-controller proportional gain (P-0-2832.0.1).

Open and Closed-Loop Drive Control

If the absolute control error (S-0-0347) is greater than the V-controller accuracy window (P-0-2832.0.4), and actual acceleration (S-0-0536) is less than the switch-on acceleration (P-0-2832.0.3), the integrator is activated with the V-controller integration time constant (P-0-2832.0.2). This integrator, too, can be limited by means of a parameter (P-0-2832.0.5).

The inner-loop velocity control is switched on in the velocity controller control word (P-0-2822, Bit 0).

## Commissioning / Parameters / Diagnostic and Status Messages

### Parameters Used

| IDN | Alias IDN | Name | Module | DocuObj |
|---|---|---|---|---|
| P-0-0040 | | Velocity feedforward evaluation | XREG | P-0-0040_V1.0.xml |
| P-0-0434 | | Position command value of controller | XREG | P-0-0434_V1.0.xml |
| P-0-0435 | | Control word of position controller | XREG | P-0-0435_V1.0.xml |
| P-0-0454 | | Velocity feedforward actual value | XREG | P-0-0454_V1.0.xml |
| P-0-2820 | | Control word of position controller | XREG | P-0-2820.000.000_VH01.xml |
| P-0-2821 | | Position controller status word | XREG | P-0-2821.000.000_VH01.xml |
| P-0-2830.0.1 | P-0-3408 | Position controller Kv ramp | XREG | P-0-2830.000.001_VH01.xml |
| P-0-2830.0.2 | P-0-3409 | Position loop time constant D-component | XREG | P-0-2830.000.002_VH01.xml |
| P-0-2830.0.3 | P-0-3410 | Position controller filter time D-compoent | XREG | P-0-2830.000.003_VH01.xml |
| P-0-2830.0.4 | P-0-3411 | Position controller integration time | XREG | P-0-2830.000.004_VH01.xml |
| P-0-2830.0.5 | P-0-3412 | Position controller integrator enable velocity window | XREG | P-0-2830.000.005_VH01.xml |
| P-0v2830.0.6 | P-0-3413 | Position controller accuracy window integrator | XREG | P-0-2830.000.006_VH01.xml |
| P-0-2830.0.7 | P-0-3414 | Position controller limitation integrator | XREG | P-0-2830.000.007_VH01.xml |
| P-0v2830.0.8 | P-0-3415 | Position controller deactivation ramp integrator | XREG | P-0-2830.000.008_VH01.xml |
| P-0-2830.0.9 | P-0-3416 | Filter time of position command value | XREG | P-0-2830.000.009_VH01.xml |
| P-0-2830.0.10 | P-0-3417 | Dead time of position command value | XREG | P-0-2830.000.010_VH01.xml |
| P-0-2830.0.11 | P-0-3418 | Velocity feedforward control ramp | XREG | P-0-2830.000.011_VH01.xml |
| P-0-2831.0.1 | | Correction value: position controller Kv | XREG | P-0-2831.000.001_VH01.xml |
| P-0-2831.0.2 | | Correction value: position controller D | XREG | P-0-2831.000.002_VH01.xml |
| P-0-2831.0.3 | | Correction value: position controller integrator | XREG | P-0-2831.000.003_VH01.xml |
| P-0-2831.0.4 | | Output of position controller | XREG | P-0-2831.000.004_VH01.xml |
| P-0-2831.0.5 | | Correction value: velocity feedforward control | XREG | P-0-2831.000.005_VH01.xml |
| P-0-2831.0.6 | | Position command value of controller, delayed | XREG | P-0-2831.000.006_VH01.xml |
| S-0-0104 | | Position loop Kv-factor | XREG | S-0-0104_VH1.0.xml |
| S-0-0189 | | Following distance | XREG | S-0-0189_V1.0.xml |
| P-0-0048 | | Velocity command value of controller | VREG | P-0-0048.000.000_V01.xml |
| P-0-2822 | | Velocity controller control word | VREG | P-0-2822.000.000_VH01.xml |
| P-0-2823 | | Velocity controller status word | VREG | P-0-2823.000.000_VH01.xml |

| | | | | |
|---|---|---|---|---|
| P-0-2824 | | State controller control word | VREG | P-0-2824.000.000_VH01.xml |
| P-0-2825 | | State controller status word | VREG | P-0-2825.000.000_VH01.xml |
| P-0-2826 | | Output of velocity/status controller | VREG | P-0-2826.000.000_VH01.xml |
| P-0-2832.0.1 | P-0-3419 | Velocity controller P-gain | VREG | P-0-2832.000.001_VH01.xml |
| P-0-2832.0.2 | P-0-3420 | Velocity controller integration time | VREG | P-0-2832.000.002_VH01.xml |
| P-0-2832.0.3 | P-0-3421 | Velocity controller integrator enable acceleration window | VREG | P-0-2832.000.003_VH01.xml |
| P-0-2832.0.4 | P-0-3422 | Velocity controller accuracy window integrator | VREG | P-0-2832.000.004_VH01.xml |
| P-0-2832.0.5 | P-0-3423 | Velocity controller integrator limitation | VREG | P-0-2832.000.005_VH01.xml |
| P-0-2832.0.7 | P-0-3424 | State controller force time constant | VREG | P-0-2832.000.007_VH01.xml |
| P-0-2832.0.8 | P-0-3425 | State controller acceleration gain | VREG | P-0-2832.000.008_VH01.xml |
| P-0-2832.0.9 | P-0-3426 | State controller velocity gain | VREG | P-0-2832.000.009_VH01.xml |
| P-0-2832.0.10 | P-0-3427 | State controller force normalization | VREG | P-0-2832.000.010_VH01.xml |
| P-0-2832.0.13 | P-0-3428 | Filter time of velocity command value | VREG | P-0-2832.000.013_VH01.xml |
| P-0-2832.0.14 | P-0-3429 | Dead time of velocity command value | VREG | P-0-2832.000.014_VH01.xml |
| P-0-2833.0.1 | | Correction value: velocity controller | VREG | P-0-2833.000.001_VH01.xml |
| P-0-2833.0.2 | | Correction value: status controller velocity | VREG | P-0-2833.000.002_VH01.xml |
| P-0-2833.0.3 | | Correction value: acceleration/force: status controller | VREG | P-0-2833.000.003_VH01.xml |
| P-0-2833.0.5 | | Velocity command value of controller, delayed | VREG | P-0-2833.000.005_VH01.xml |
| P-0-2833.0.6 | | Correction value: velocity controller P-gain | VREG | P-0-2833.000.006_VH01.xml |
| P-0-2833.0.7 | | Correction value: velocity controller integrator | VREG | P-0-2833.000.007_VH01.xml |
| S-0-0037 | | Additive velocity command value | VREG | S-0-0037.000.000_V01.xml |
| S-0-0038 | | Positive velocity limit value | VREG | S-0-0038_V1.0.xml |
| S-0-0039 | | Negative velocity limit value | VREG | S-0-0039_V1.0.xml |
| S-0-0040 | | Velocity feedback value | VREG | S-0-0040.000.000_V01.xml |
| S-0-0091 | | Bipolar velocity limit value | VREG | S-0-0091_V2.0.xml |
| S-0-0347 | | Velocity error | VREG | S-0-0347.000.000_V01.xml |
| S-0-0535 | | Active velocity feedback value | VREG | S-0—0535.000.000_V01.xml |

## Diagnostic Messages

### Diagnostic Messages Used

| Diagnostic message number | Name | Module | DocuObj |
|---|---|---|---|
| F2028 | Excessive deviation | XREG | F2028_V1.0.xml |
| E2059 | Velocity command value limit active | VREG | E2059_V1.0.xml |
| E2070 | Acceleration limit active | VREG | E2070_V01.xml |
| F8079 | Velocity limit value exceeded | VREG | F8079_V3.0.xml |

Open and Closed-Loop Drive Control

The following monitoring functions are performed in the position controller:

**Excessive Control Deviation**

The following error is monitored by means of a model. The deviation of the actual position value from the model is monitored. This means that model error monitoring may provide a smaller value than the actual following error.

If the deviation from the model is greater than the monitoring window (S-0-0159), the drive apparently cannot follow the given command value and error messageg "F2028Excessive deviation" is generated.

## Interrelationships

Interrelationship of functional packages: Closed Loop

# 7.3.3 Closed-Loop Force Control

## Structure

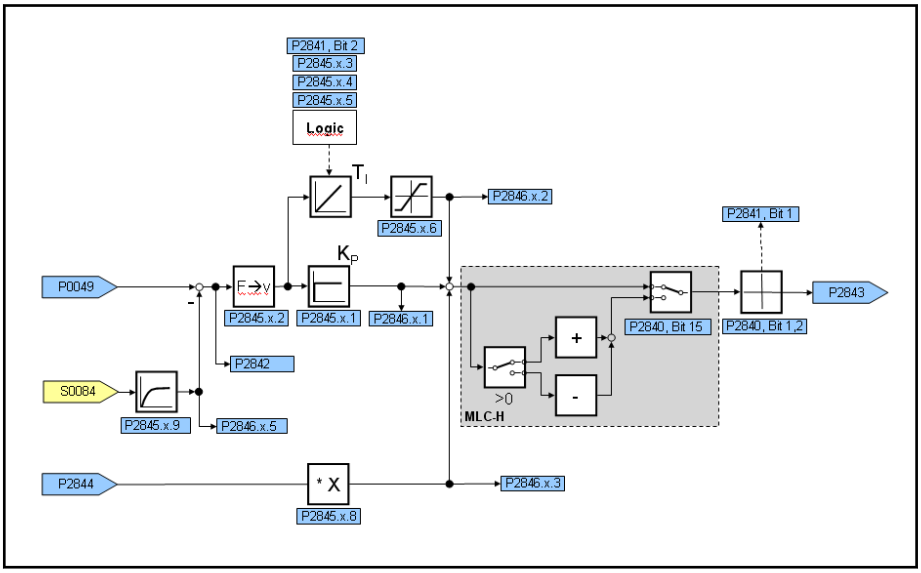



*Fig. 7-23: Detail of Force Controller*

## Description

The force controller is called in operation mode "closed-loop torque/force control" and only controls the force in this mode. In other modes, e.g. "cyclic closed-loop position" or "torque/force control / direct valve control" the force controller is called additionally, if "alternating control" was activated. When the force controller is engaged (for conditions, see Chapter "Alternating control"), **bit 0** of parameter **"P-0-2841, Force controller status word"** is set to "True". The force controller then controls **"S-0-0084, Torque/force feedback value"** on the basis of the set **"P-0-0049, Torque/force command value of controller"**.

**Filter**

A noisy **actual force value** can be smoothed by means of parameter **"P-0-2845.0.9, Filter time of force feedback value"**. If the value 0 is entered, the filter is deactivated. The smoothed actual force value is shown in parameter **"P-0-2846.0.5, Torque/force feedback value, filtered"**.

**Normalization of Force by Velocity**

**"P-0-2842, Force control deviation"** is the difference between **"effective torque/force command value"** and **"torque/force feedback value, filtered"**. With the help of parameter **"P-0-2845.0.2, Normalization of force by velocity"** the **"force control deviation"** is normalized to velocity units, because this unit is used for further calculations within the controllers. This normalization factor is calculated from the entered cylinder geometry data **"S-0-0819, Length of cylinder"** and **"S-0-0820, Piston area A"** and results in the fact that with a

**"P-0-2845.0.1, Force controller P-gain"** of 1, overshoot-free controlling can be realized. This provides a good starting value for further optimization.

In open-loop operation, the normalization factor must be entered, because the cylinder stroke is not available as parameter. To simplify matters, use the following formula for this:

$$P-0-2845.0.2 = \frac{stroke[mm]}{area[mm]} * 1.25$$

*Fig. 7-24:*

**P-Gain**

Parameter **"P-0-2845.0.1, Force controller P-gain"** is used for setting the proportional control action of the controller. Parameter **"P-0-2846.0.1, Correction value: force controller P-gain"** shows the proportional component of the force controller.

**Integrator**

Despite an optimization of the P-gain, a permanent control deviation due to disturbances or offsets may be present. This can be corrected by means of the integrator.

*The integrator can be set with the following parameters:*

- P-0-2845.0.3, Force controller integration time
- P-0-2845.0.4, Force controller integrator enable force change window
- P-0-2845.0.3, Force controller integration time

By specifying **"Force controller integrator enable force change window"** and **"Force controller accuracy window integrator"** you can define the switch-on condition for the integrator. The integrator is only activated when the change of the **actual feedback value** is smaller than the specified enable force change and the **"force control deviation"** is still greater than the **"KForce controller accuracy window integrator"**. As long as the integrator is activated,**bit 2 "enable condition I-controller true"** of the **status word (P-0-2841)** is set to "TRUE".

If the **Control deviation** is within the envisaged accuracy window, the I-component is stopped to prevent the drive from oscillating at values around the command value.

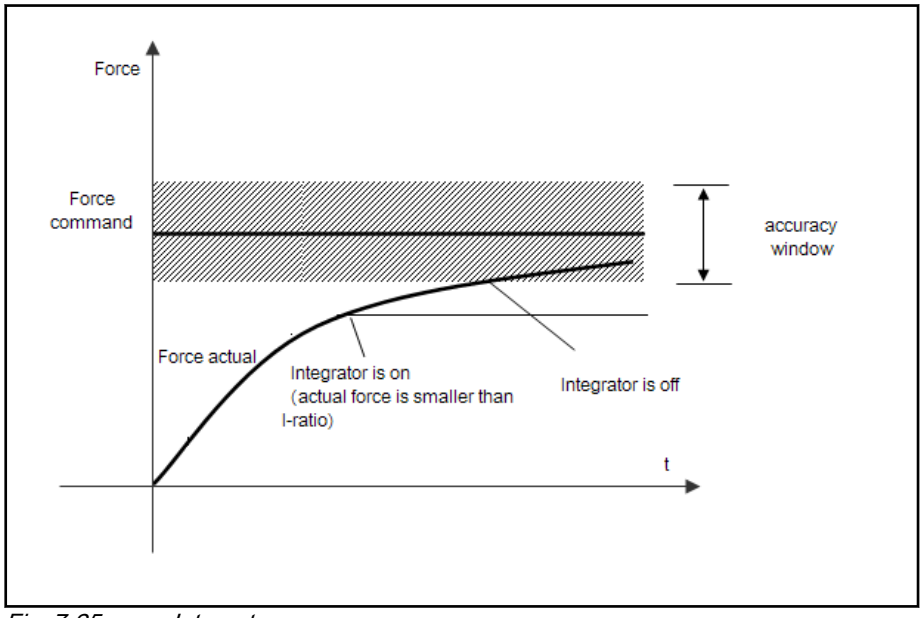



*Fig. 7-25: Integrator*

Open and Closed-Loop Drive Control

**"P-0-2846.0.2, Correction value: force controller integrator"** can be limited by **"P-0-2845.0.6, Force controller limitation integrator"** irrespective of the sign.

**Velocity Feedforward**

**"P-0-2845.0.8, Force controller scaling of velocity feedforward control"** is established by multiplying **"P-0-2844, Force controller velocity feedforward control"** by **"P-0-2845.0.8, Force controller scaling of velocity feedforward control"**. This is applied for drives that are moved at a measurable, impressed velocity. In this case, the measured velocity value is cyclically assigned to **"P-0-2844, Force controller velocity feedforward control"**. The resulting velocity feedforward component is added to the controller output.

**Valve Root Function**

This function is only relevant for the HDS derivate. It takes account of the valve's dependence on load. Load dependence means that with a constant command value of the valve at different load pressures, different amounts of oil flow across the valve. The selection of this function improves the control result when **velocity feedforward** is selected in conjunction with changing force command values. The function is activated by setting **bit 15** in the **control word** of the force controller.

**Quadrant Limitation**

As long as quadrant limitation is active, **bit 1** of the status word (P–0–2841) is set to "TRUE".

## Pertinent Parameters

- S-0-0084, Torque/force feedback value
- P-0-0049, Torque/force command value of controller
- P-0-2840, Force controller control word
- P-0-2841, Force controller status word
- P-0-2842, Force control deviation
- P-0-2843, Output of force controller
- P-0-2844, Force controller velocity feedforward control
- P-0-2845.0.1, Force controller P-gain
- P-0-2845.0.2, Normalization of force by velocity
- P-0-2845.0.3, Force controller integration time
- P-0-2845.0.4, Force controller integrator enable force change window
- P-0-2845.0.5, Force controller accuracy window integrator
- P-0-2845.0.6, Force controller limitation integrator
- P-0-2845.0.8, Force controller scaling of velocity feedforward control
- P-0-2845.0.9, Filter time of force feedback value
- P-0-2846.0.1, Correction value: force controller P-gain
- P-0-2846.0.2, Correction value: force controller integrator
- P-0-2846.0.3, Correction value: force controller velocity feedforward
- P-0-2846.0.5, Torque/force feedback value, filtered

## 7.3.4 Alternating Control

### Structure

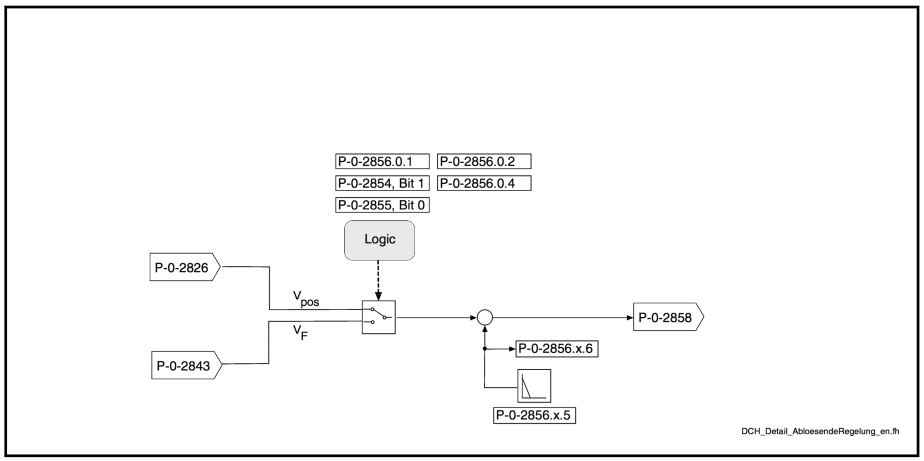



*Fig. 7-26: Detail of alternating control*

### Description

Alternating control can be used for various operation modes:

- All position control modes with force limitation
- Direct valve control with force limitation

If the changeover conditions are fulfilled (see below), the axis automatically switches to force control and is controlled on the basis of the specified **"P-0-0049, Torque/force command value of controller"**. When the switch-back conditions (see below) are fulfilled, force control is deactivated.

**Changeover Condition**

For changing over to force control, you can choose whether the changeover is to take place at a **"P-0-2856.0.1, Force controller changeover threshold"** or a **"P-0-2856.0.2, Force controller relative changeover window"**, referred to the current **"P-0-0049, Torque/force command value of controller"**. The selection between absolute or relative changeover is made by means of **bit 2** in parameter **"P-0-2854, Force controller changeover logic control word"**.

When the **"P-0-2856.0.3, Force controller active changeover threshold"** derived from the entries is reached, the relevant **bit 3** or **bit 4** of parameter **"P-0-2854, Force controller changeover logic control word"** is set and when the adjustable **"P-0-2856.0.4, Force controller switch-on logic delay time"** is exceeded, changing over to force control will take place. The changeover will be realized via an adjustable cross-fade ramp (see below).

☞ Parameter **"P-0-2856.0.4, Force controller switch-on logic delay time"** is used for suppressing pressure peaks to prevent an undesirable premature changeover.

☞ When changing over to force control takes place, the other command value generator is stopped, provided that it is integrated in the device (depending on operation mode).

**Switch-Back Condition**

The force controller is deactivated according to the following condition:

If **"P-0-2826, Output of velocity/status controller"** is less than or greater than **"P-0-2843, Output of force controller"**, the axis moves in the positive or negative direction, and the switch-back interlock is deactivated via **bit 1** in parameter **"P-0-2854, Force controller changeover logic control word"**, the force con-

troller is deactivated. If bit 3 and bit 4 allow only one direction, a changeover from force control will also take place.

**Control Word / Status Word**

By means of **"P-0-2854, Force controller changeover logic control word"** the following settings can be made.

*The relevant function is activated with bit = 1:*

- **Bit 0**: Activate/deactivate alternating control
- **Bit 1**: Activate/deactivate switch-back interlock
- **Bit 2**: Switch-on threshold absolute/switch-on threshold relative
- **Bit 3**: Activate/deactivate alternating control in positive direction
- **Bit 4**: Activate/deactivate alternating control in negative direction

---

☞ For the HDS derivate alternating control cannot be activated via the control word. For this, application blocks are available in the PLC library TechHydrMotion.

---

*In status word "P-0-2855, Force controller changeover logic status word" the following information is provided:*

- **Bit 0**: is 1, if the force controller is active
- **Bit 1**: is 1, as long as the delay time is running

**Cross-Fading Ramp**

While changing over to force control or switching back, control variable step-changes can occur at the controller output. To prevent them, the changeover is realized by fading in to the active controller output with a defined **"P-0-2856.0.5, Force controller changeover logic ramp time"**. The entry is to be made in "ms" referred to the value of **"P-0-2873.0.1, Valve standard velocity"** (corresponds to the maximum control variable). If the ramp time is set to zero, the ramp is deactivated and the changeover takes place immediately.

## Pertinent Parameters

- P-0-2826, Output of velocity/status controller
- P-0-2843, Output of force controller
- P-0-2856.0.1, Force controller changeover threshold
- P-0-2856.0.2, Force controller relative changeover window
- P-0-2854, Force controller changeover logic control word
- P-0-2855, Force controller changeover logic status word
- P-0-2856.0.3, Force controller active changeover threshold
- P-0-2856.0.4, Force controller switch-on logic delay time
- P-0-2856.0.5, Force controller changeover logic ramp time
- P-0-2856.0.6, Correction value: force controller changeover logic ramp
- P-0-2858, Output of position/force changeover logic

## 7.3.5 Control Variable Adjustment

**Structure**

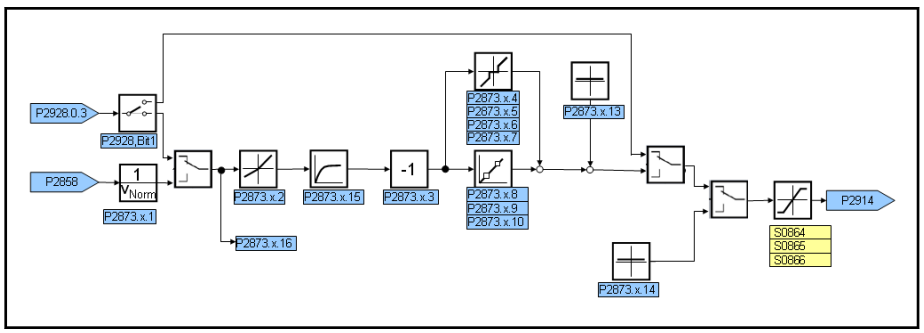



*Fig. 7-27: Detail of Control Variable Adjustment*

**Description**

Control variable adjustment can be used to adjust the control variable, which is fed to the valve or system. The adjustment is independent of the selected operation mode. When the operation mode is changed over, all settings are maintained. Apart from inversion, offset and limitation of the control variable, the non-linearity of the valve can also be compensated for.

The operation mode "direct valve control" can be configured so that control variable adjustment is ineffective except for the limitation function (P-0-2928.0.1, bit 1).

**Valve Standard Velocity**

"P-0-2873.0.1, Valve standard velocity" is the velocity, at which the hydraulic drive can move with maximum valve opening (100 %). Since the valve activation is based on percentage values, the output value of the individual controller is normalized to percent with the help of the valve standard velocity. The normalized value is shown in parameter "P-0-2873.0.16, Control variable adjustment of command value". The required adjustments are made subsequently.

**Forward/Backward Adjustment**

The setting of "P-0-2873.0.2, Direction-dependent gain" takes account of the velocity ratio for the open-loop controlled retracting and extending of the cylinder. In this case, influences are, for example, the area ratio of the cylinder or the load-dependence with vertical axes. This keeps the loop gain constant during extending and retracting.

*The factor can be determined in two ways:*

- The control variable is measured at identical velocity during extending and retracting. Parameter P-0-2873.0.2 results from the quotient of the control variable during retracting and the control variable during extending.
- The actual velocity is measured during extending and retracting while the control variable is identical in terms of the amount. Parameter P-0-2873.0.2 results from the quotient of the velocity during extending and the velocity during retracting.

In the case of a negative control variable, this is corrected by this factor. A factor of 1 means that no adjustment is necessary and the behavior of the axis is independent of the direction This is mostly valid for double-rod cylinders.

Open and Closed-Loop Drive Control

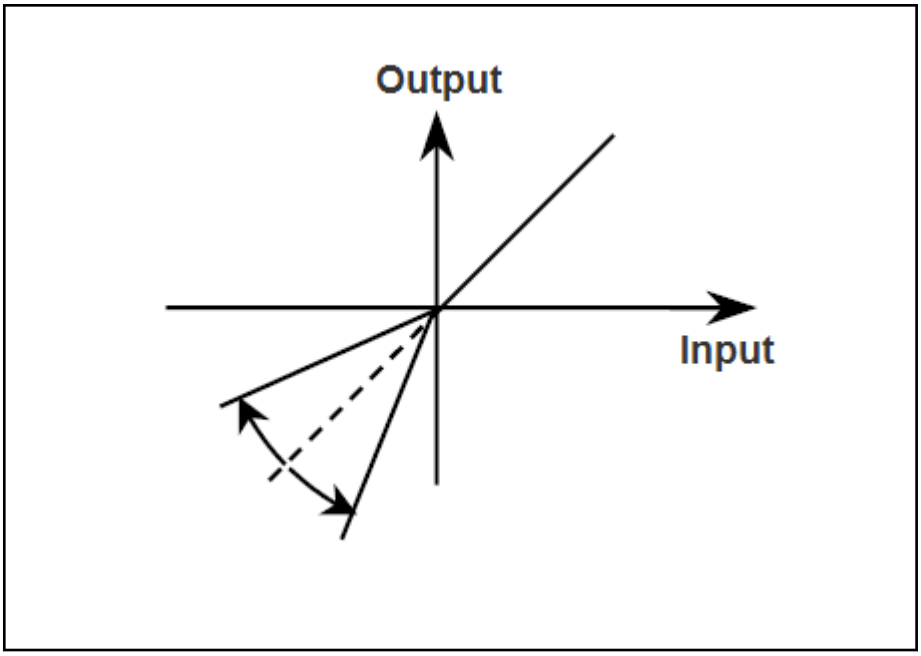



*Fig. 7-28: Direction-Dependent Gain*

**Filter** The control variable adjustment command value can be smoothed using parameter "P-0-2873.0.15, Filter time of valve control variable". If the value 0 is entered, the filter is deactivated. The filter is used, for example, with drives, on which the natural frequency of the valve is significantly greater than that of the hydraulic drive (e.g. cylinder).

**Inversion** The control variable adjustment command value is multiplied by "P-0-2873.0.3, Control variable inversion". If the value -1 is entered here, the control variable adjustment command value is inverted.

**Overlap** This principle compensates the dead band behavior of valves with a positive overlap. As a result, the control variable needs not to pass the dead band of the valve until a reaction becomes effective at the cylinder. With "P-0-2873.0.4, Valve overlap type" you can select one of the two variants "jump compensation" and "linear compensation" or switch off overlap compensation.

*The following parameters are available for both variants:*

- P-0-2873.0.5, Valve overlap A-side
- P-0-2873.0.6, Valve overlap B-side
- P-0-2873.0.7, Valve overlap threshold

The valve overlap threshold determines, from which input value on the value "P-0-2873.0.5, Valve overlap A-side" is output for positive values, and the value "P-0-2873.0.6, Valve overlap B-side" for negative values. Above the valve overlap threshold, the values are linearly extrapolated up to +/-100 %.

If valve overlap type 1 (value = 1) is selected, 0 % is output within the "vavle overlap threshold". Within this range the valve is always in its central position, thus shutting off the hydraulic drive.

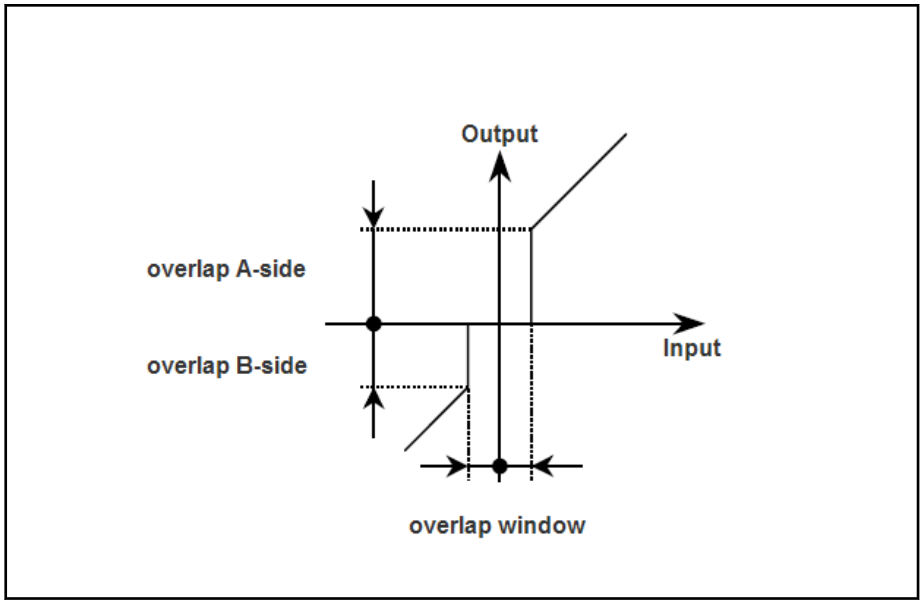



*Fig. 7-29: Valve Overlap Type 1 "Jump“*

If valve overlap type 2 (value = 2) is selected, within the "valve overlap threshold" the values are linearly interpolated between the "valve overlap B-side" and "valve overlap A-side". This variant is selected, if the valve is to be closed-loop controlled around the central position of the valve.

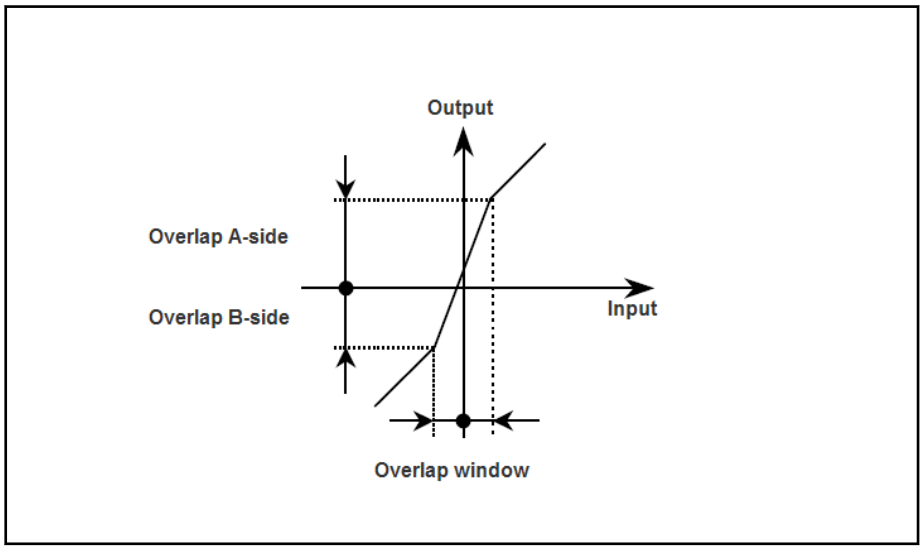



*Fig. 7-30: Valve Overlap Type 2 "Straight"*

Valve overlap type 0 (value = 0) deactivates valve overlap compensation

**Valve Characteristic Curve**

The valve characteristic curve describes the relationship between the command value (control variable) and flow of a valve across a control land at a defined pressure. In most of the cases, valves with linear characteristic curves are selected so that no correction of the valve characteristic curve is required. For some applications, valves with progressive or inflected characteristic curve are selected in order to obtain a higher resolution within the lower velocity range. In order to achieve linear behavior for the upstream controller, the valve characteristic curve is compensated by entering the inverse characteristic curve.

To compensate for the non-linearity, the valve characteristic curve from the data sheet must be mirrored. The two table parameters "P-0-2873.0.9, Valve

characteristic curve input value" and "P-0-2873.0.10, Valve characteristic curve output value" are used to enter the points. IIn this example, the activation is carried out as follows:

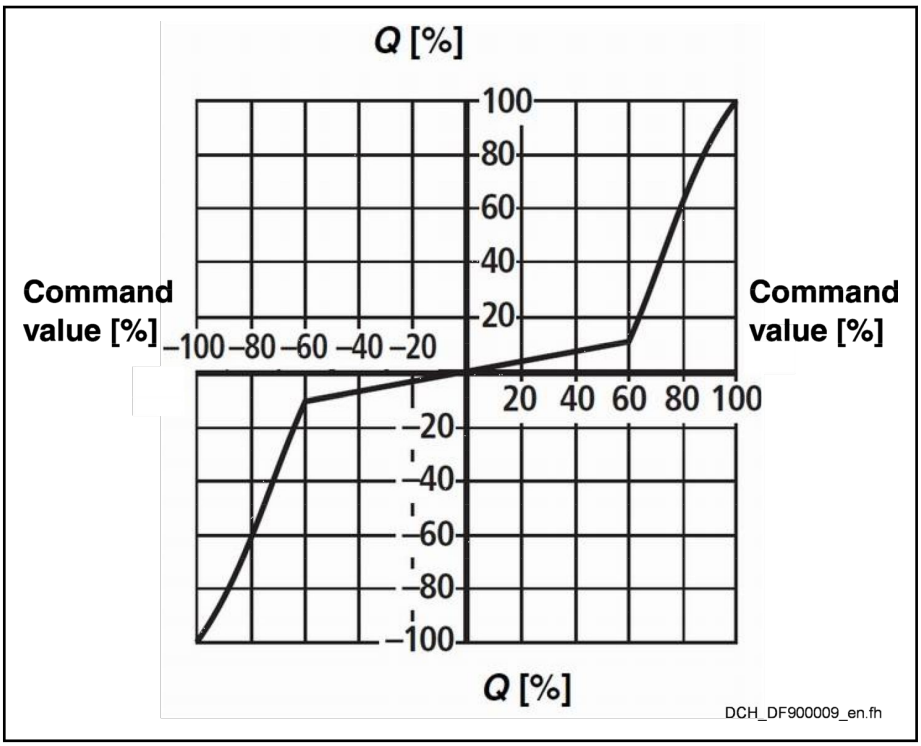



*Fig. 7-31: Representation of a Valve Characteristic Curve to be Entered*

If one has a look at the setting for a symmetric characteristic curve, it becomes apparent that the points "input value" must be set to = 0 %, "output value" to = 0 % as well as "input value" to = 100 % and "output value" to = 100 %. The central point is determined automatically, since with a valve opening of 60 % the flow amounts to 10 %. Consequently, the resulting input value = 10 %, and the output value = 60 %. This corresponds to an inversion of the existing valve characteristic curve. This inversion results in a linear valve activation.

*The following "P-0-2873.0.8, Valve characteristic curve type" can be selected:*

- 0: Valve characteristic curve deactivated.
- -1: Symmetrical; only the positive branch of the input characteristic curve is used. For the negative values, the curve is mirrored to the negative.
- -2: Asymmetrical; both, the positive and the negative branch of the input characteristic curve are used. The curve points start within the maximum negative range and end within the positive maximum range.

☞
- The number of values must be identical in both tables.
- The values of "P-0-2873.0.9" must be entered monotonically increasing.
- The intermediate values of the valve characteristic curve are determined by linear interpolation.

**Valve Control Variable Offset**

Using "P-0-2873.0.13, Valve control variable offset" a constant percentage value can be added to the "valve controller command value".

This can be used to correct a valve zero point deviation or signal-bound offsets.

☞ The "valve control variable offset" is not inverted, because it is effective only after the inversion.

**Valve Control Variable Standstill Value**

"P-0-2873.0.14, Valve control variable standstill value" determines the value, which is used for activating the valve as long as the axis is not in a closed-loop control mode. In particular when high-response valves without overlap are used or in the case of vertical axes, a value unequal to 0 % is required to achieve the standstill of an axis without controller enable.

☞ This parameter does not ensure a shutdown of the drive. To implement machine safety, this can only be ensured by providing additional circuit measures (usually check valves).

☞ Some hydraulic circuits or applications can also require values that significantly deviate from zero, e.g. shut-off valves of the cylinder on one side only or desired retraction of the cylinder.

**Spool Limit Value**

Here, you can preset the limitation of the valve control variable. The limitation can be set separately for the positive and negative range using the parameters "S-0-0866, Negative spool limit value" and "S-0-0865, Positive spool limit value". If symmetrical limitation is desired, you can use parameter "S-0-0864, Bipolar spool limit value". Here, the smaller of the limitation values is effective.

☞ The limitation can be used to avoid undesired fast movements during commissioning.

**Pertinent Parameters**

- P-0-2870, Control variable adjustment control word
- P-0-2871, Control variable adjustment status word
- P-0-2872, Output of valve characteristic curve
- S-0-0864, Bipolar spool limit value
- S-0-0865, Positive spool limit value
- S-0-0866, Negative spool limit value
- P-0-2873.0.1, Valve standard velocity
- P-0-2873.0.2, Direction-dependent gain
- P-0-2873.0.3, Control variable inversion
- P-0-2873.0.4, Valve overlap type
- P-0-2873.0.5, Valve overlap A-side
- P-0-2873.0.6, Valve overlap B-side
- P-0-2873.0.7, Valve overlap threshold
- P-0-2873.0.8, Valve characteristic curve type
- P-0-2873.0.9, Valve characteristic curve input value
- P-0-2873.0.10, Valve characteristic curve output value
- P-0-2873.0.13, Valve control variable offset
- P-0-2873.0.14, Valve control variable standstill value
- P-0-2873.0.15, Filter time of valve control variable
- P-0-2873.0.16, Control variable adjustment of command value

- P-0-2873.0.17, Control variable adjustment of command value, maintenance
- P-0-2914, Effective valve command value

# 7.4 Pump Controller

## 7.4.1 Description of Parallel Structure

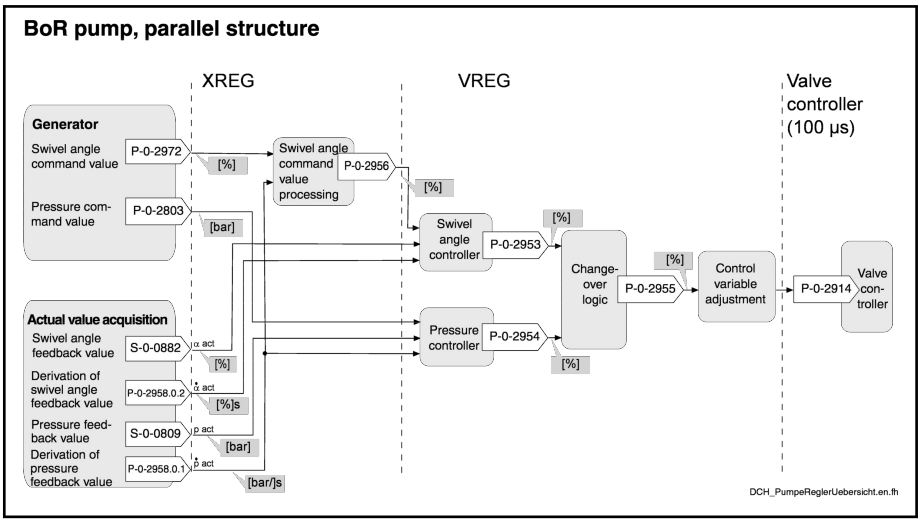



*Fig. 7-32: Pump Controller Overview of Parallel Structure*

The parallel structure with pressure controller and swivel angle controller is called in the operation mode "pump control".

The swivel angle command value from the generator is adjusted in swivel angle command value processing, before it is passed on to the actual swivel angle controller.

In pump control the pressure and the swivel angle controller are simultaneously active and both generate a control variable. In standard cases, the changeover logic passes on the smallest or most negative control value of both controllers (minimum value comparator function). This minimum value generator ensures that always only one of the two variables of pressure or swivel angle is used for controlling and that it is possible to switch between the two control types. The output variable of the changeover logic can be modified using various characteristic curves and functions in control variable adjustment before it is handed over to the valve controller as valve command value.

**Pertinent Parameters**

- P-0-2873.0.2, Direction-dependent gain
- P-0-2873.0.3, Control variable inversion
- P-0-2873.0.8, Valve characteristic curve type
- P-0-2873.0.9, Valve characteristic curve input value
- P-0-2873.0.10, Valve characteristic curve output value
- P-0-2873.0.16, Control variable adjustment of command value
- P-0-2950, Pump controller control word
- P-0-2951, Pump controller status word
- P-0-2952, Torque limitation of pump, relative
- P-0-2953, Output of swivel angle controller
- P-0-2954, Output of pump pressure controller

- P-0-2955, Output of pump changeover logic
- P-0-2956, Effective swivel angle command value
- P-0-2957.0.1, Pressure normalization
- P-0-2957.0.2, Correction value: pressure controller P-gain
- P-0-2957.0.3, Correction value: pressure controller D-component
- P-0-2957.0.4, Correction value: swivel angle feedback
- P-0-2957.0.6, Derivation pressure feedback value
- P-0-2957.0.7, Pressure feedback value, delayed
- P-0-2958.0.1, Derivation swivel angle feedback value
- P-0-2958.0.3, Correction value: torque limitation
- P-0-2958.0.4, Swivel angle command value after leakage compensation
- P-0-2958.0.5, Correction value: p-point feedback
- P-0-2958.0.6, Correction value: leakage compensation offset value
- P-0-2959.0.1, Correction value: control var. adjustment after feedforward
- P-0-2959.0.2, Correction value: valve correction
- P-0-2960, Gate time derivation actual pressure value
- P-0-2961, Filter time
- P-0-2963, Pressure controller P-gain 1 positive
- P-0-2964, Pressure controller P-gain 1 negative
- P-0-2965, Pressure controller P-gain 2 positive
- P-0-2966, Pressure controller P-gain 2 negative
- P-0-2967, Pressure controller control deviation threshold negative
- P-0-2968, Pressure controller control deviation threshold negative
- P-0-2969, Pressure controller time constant D-component positive
- P-0-2970, Pressure controller time constant D-component negative
- P-0-2971, Pressure controller time constant swivel angle feedback
- P-0-2972, Swivel angle command value, Generator
- P-0-2973, p-point feedback filter time
- P-0-2974, p-point feedback time constant
- P-0-2975, Pressure command value (without controller enable)
- P-0-2976, Swivel angle command value (without controller enable)
- P-0-2977, Swivel angle controller P-gain
- P-0-2978, Swivel angle controller time constant D-component
- P-0-2980, Leakage compensation calibration value
- P-0-2981, Valve correction pressure stage
- P-0-2982, Valve correction pressure offset
- P-0-2983, Control variable adjustment, feedforward valve
- P-0-2984, Control variable adjustment, scaling feedforward positive
- P-0-2985, Control variable adjustment, scaling feedforward negative
- P-0-2988, Control variable adjustment, swivel angle minimum value
- S-0-0864, Bipolar spool limit value
- S-0-0865, Positive spool limit value

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- S-0-0866, Negative spool limit value
- S-0-0867, Spool status word
- S-0-0882, Swivel angle actual value
- S-0-0883, Swivel angle controller control deviation

**Pertinent Diagnostic Messages**

At present, none

**Swivel Angle Command Value Processing**

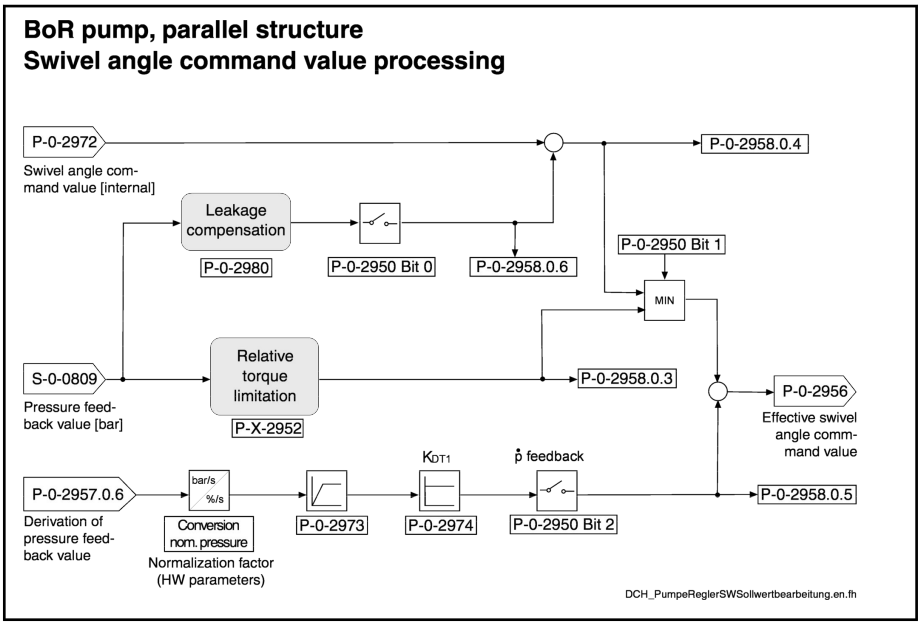



*Fig. 7-33: Swivel Angle Command Value Processing*

**Leakage Compensation**

Leakage compensation can be used to compensate for pressure-related leakage of the pump or the system. For this, the controller computes a compensation value from a linear characteristic curve and the current pressure. Support points for this characteristic curve are 20 bar and 0 % as well as the pressure for pressure normalization $p_{norm}$ (P-0-2957.0.1) with the leakage compensation value (P-0-2980).

Leakage compensation is active, when the actual pressure value $p_{act}$ (S-0-0809) is greater than 20 bar. Leakage compensation can be deactivated via the pump controller control word (P-0-2950 bit 0).

The offset value is shown in the correction value of leakage compensation offset (P-0-2958.0.6).

Offset value = (($p_{act}$ - 20bar ) * P-0-2980 ) / ($p_{norm}$ - 20 bar)

SWA_command_output = SWA_command + offset value

**Relative Torque Limitation**

To protect the drive motor against overloading, the maximum torque of the pump can be limited. The Torque limitation of pump, relative (P-0-2952) is a relative variable in percent and refers to the maximum torque of the pump at 315 bar. The permissible maximum swivel angle command value for the pump is calculated from the current actual pressure value $p_{act}$ and the setting for the relative torque limitation according to the following calculation rule:

Max. permissible swivel angle command value = Torque limitation of pump, relative (P-0-2952) * $p_{norm}$ / $p_{act}$

The max. permissible swivel angle command value is shown in parameter Correction value: torque limitation (P-0-2958.0.3).

The minimum value comparator switches between the permissible maximum swivel angle that results from torque limitation and the swivel angle command

value generator (P-0-2972). By means of the Pump controller control word P-0-2950 the minimum value comparator can be firmly set to P-0-2972, which deactivates the torque limitation function.

**p-Point Feedback**

The p-point feedback is used to add the derivative of the actual pressure value to the swivel angle command value to dampen pressure fluctuations in closed-loop swivel angle control. The derivative of the actual pressure value can be smoothed via a low-pass filter of 1st order (P-0-2973) and multiplied by a factor (P-0-2974).

**Swivel Angle Controller**

In the operation mode "pump control", the swivel angle controller consists of a PD-controller:

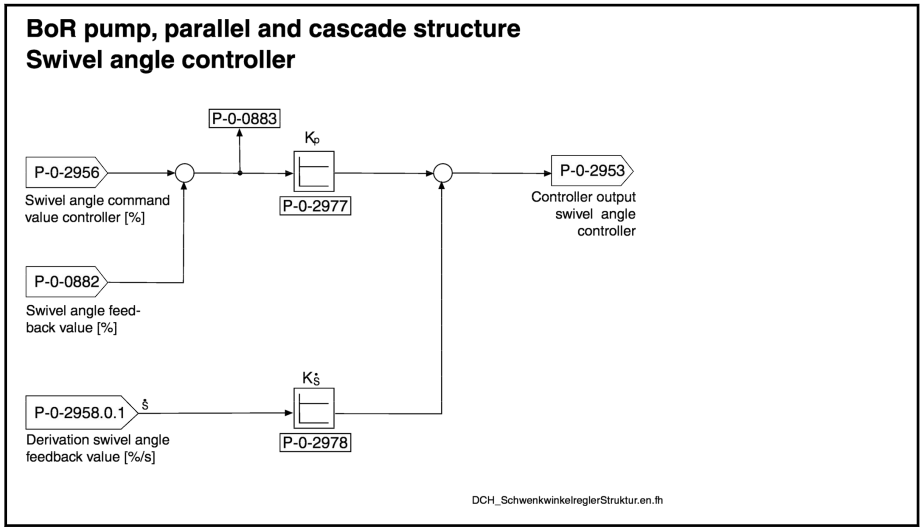



*Fig. 7-34: Swivel Angle Controller Structure*

**Pressure Controller**

In the operation mode "pump control", the pressure controller consists of a PD-controller with additional feedback of the actual swivel angle value. In addition, an inflected characteristic curve can be activated for the P-gain. (Pump controller control word P-0-2950, Bit 3). The inflected characteristic curve provides a second proportional gain for the positive and negative control difference as well as the associated activation threshold for this second proportional gain.

Open and Closed-Loop Drive Control

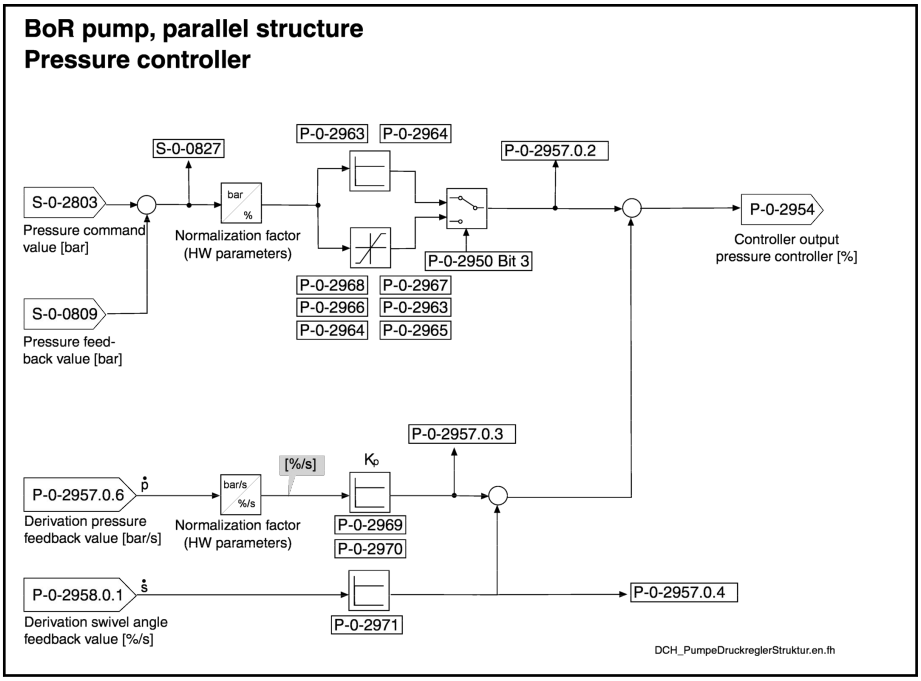



*Fig. 7-35: Pump Pressure Controller Structure*

**Changeover Logic**

A minimum value comparator in the changeover logic compares the control variables of the pressure controller and the swivel angle controller. The smaller of these values is passed on to the controller output. The minimum value comparator can be switched off by means of the pump controller control word P-0-2950 and the operation can be based exclusively on the pressure or the swivel angle controller:

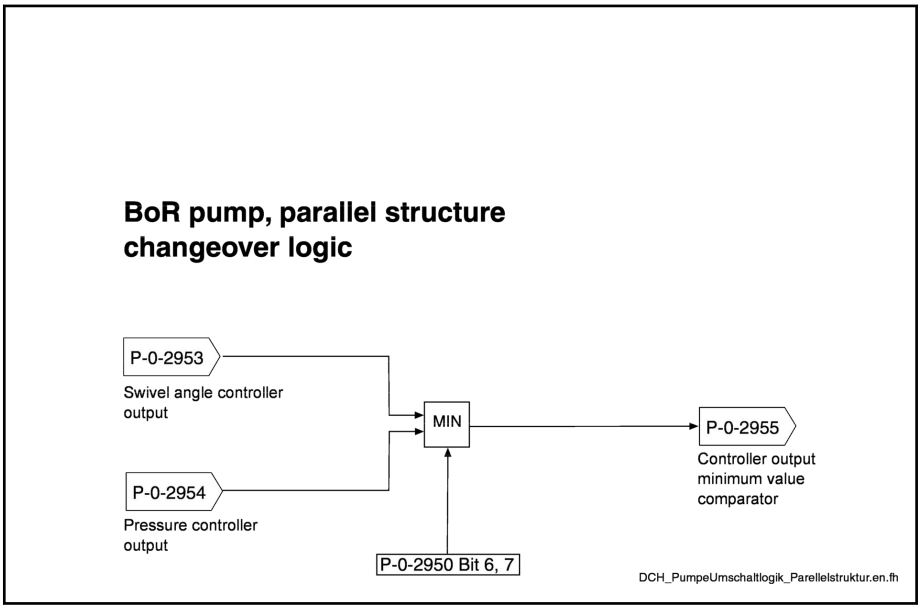



*Fig. 7-36: Pump Changeover Logic Parallel Structure*

**Control Variable Adjustment**

In the control variable adjustment, various values can be added to the valve command value as feedforward values. Moreover, it is possible to limit the minimum swivel angle to a fixed value (P-0-2988). For this, a simplified controller structure of the swivel angle controller is used. The command value for this simplified controller is parameter P-0-2988 (swivel angle minimum value). A maximum value comparator is used to switch between the controller output

of swivel angle limitation and parameter P-0-2959.0.1, Correction value: control var. adjustment after feedforward.

To compensate for zero point deviations of the pilot valve, an offset value for the valve command value is generated from a pressure-related characteristic curve with several calibration values. At the end of control variable adjustment, the valve command value can be limited to a maximum value in a bipolar form or directly to a positive or negative maximum value.

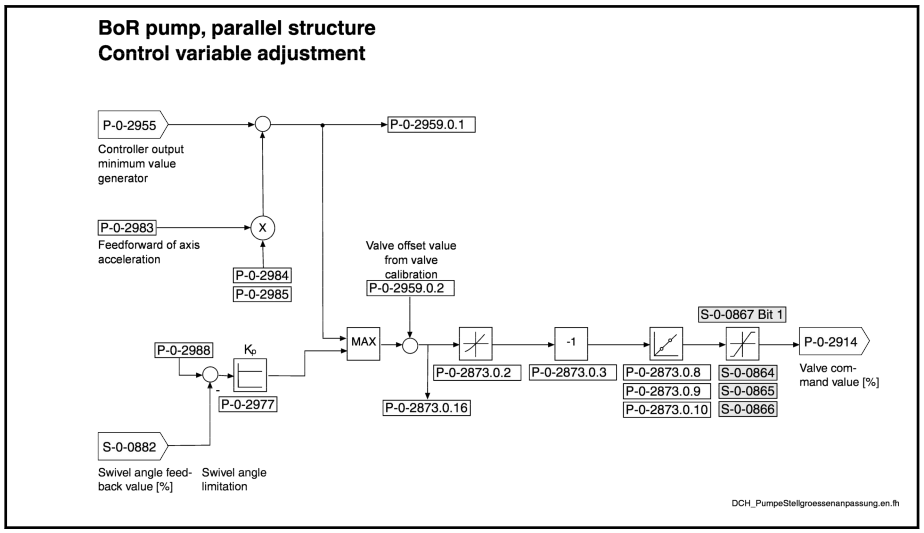



*Fig. 7-37: Pump Control Variable Adjustment*

## 7.4.2 Actual Value Acquisition

**Actual Swivel Angle Value Acquisition**

For the swivel angle feedback, the voltage at the analog input of the main stage is read in and automatically converted into the range from -100 % to 100 %. This value is written to parameter S-0-0882, Swivel angle actual value.

For swivel angle acquisition, a derivative of the actual value is provided. The derivative is filtered though a PT1 filter with adjustable filter time P-0-2961.

**Actual Pressure Value Acquisition**

Filtering the actual pressure values and their derivatives is required to keep faults due to pressure pulsation of the pump to a minimum. In some cases, this pulsation can be aggravated due to unfavorable hose/tube lengths.

The gate time must be set to a multiple of the pressure pulsation period. See calculation fig. 7-38 "Actual Pressure Value Acquisition and Filtering" on page 342.

With the help of the time difference that can be set by means of parameters (gate time → Tgate) (gate time of derivative of actual pressure value), an optimum suppression of pressure pulsations can be achieved in the derivative of the actual pressure value (see Figure).

Open and Closed-Loop Drive Control

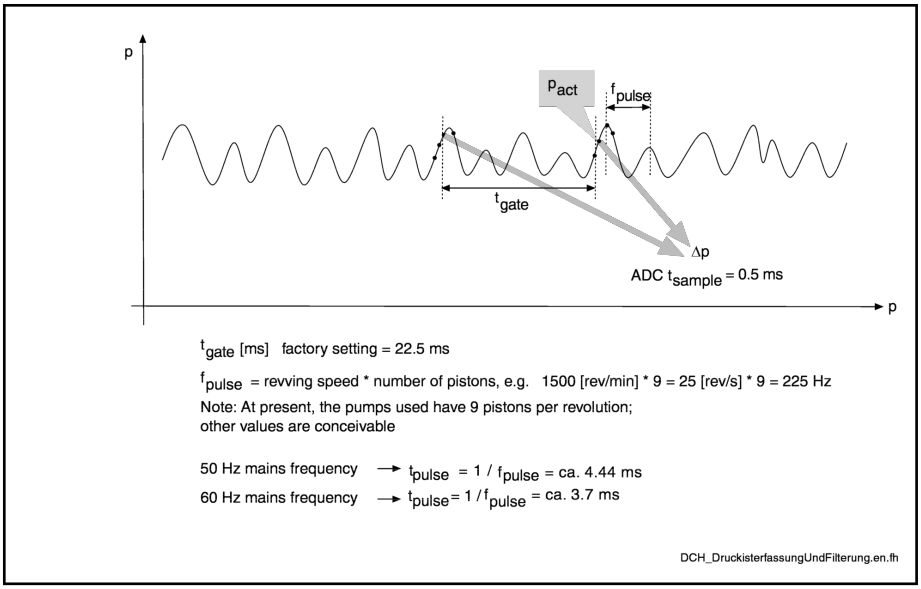



*Fig. 7-38: Actual Pressure Value Acquisition and Filtering*

# 8 Device Functions

## 8.1 Availability of Device Functions

The following overview shows, in which functional packages the individual device functions are available (valid for the firmware derivates HDB und HDC, unless specified otherwise).

| Device function | In functional package ... | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Base package | | | | | Extension package | | |
| | IFB | p/Q | DFE | Axis controller OL | Axis controller CL | Servo [1] | Sync [1] | MLD |
| Drive Halt | | | | | ■ | | | |
| Emergency stop | ■ | ■ | | ■ | ■ | | | |
| Output stage shutdown | ■ | ■ | ■ | ■ | ■ | | | |
| Fast stop | | | | | ■ | | | |
| Return motion | | | | | | ■ | | |
| Reaction on error | ■ | ■ | ■ | ■ | ■ | | | |
| NC reaction on error | ■ | ■ | ■ | ■ | ■ | | | |
| MLD reaction on error | | | | | | | | ■ |
| Quadrant error correction | | | | | | ■ | | |
| Positive stop drive procedure | | | | | ■ | | | |
| Precision axis error correction | | | | | | ■ | | |
| Parameter set changeover | ■ | ■ | ■ | ■ | ■ | | | |
| Set/shift coordinate system | | | | | | ■ | ■ | |
| Parking axis | | | | ■ | ■ | | | |

*Tab. 8-1: Availability of Device Functions*

[1] Only in conjunction with axis controller CL

In order that a functional package can be used, it must have been activated (enabled). The currently enabled functional packages are displayed in parameter "P-0-2004, Active functional packages". See also "Enabling of Functional Packages"" .

Device Functions

# 8.2 Digital Inputs/Outputs

## 8.2.1 Configurable Digital I/O

### General Information

HydraulicDrives are equipped with on-board digital I/Os, which depend on the device type.

These can be used directly in the drive or by a higher-level control after transmission over a cyclic data channel.

### Availability of Digital Inputs/Outputs

- IAC-2x with 11 + PE main connector and digital encoder interface 1Vss, SSI, EnDat 2.2, etc. on the back
  - 4 digital inputs [of which 2 via main plug-in connector]
  - 1 digital output
- IAC-2x with 11 + PE main connector and analog interface on the back
  - 6 digital inputs [of which 2 via main connector]
  - 1 digital output [loadable up to 2 Ampere]
- IAC-2x with 8 + 4 main connector and digital encoder interface 1Vss, SSI, EnDat 2.2, etc. on the back
  - 2 digital inputs
  - 1 digital output
- IAC-2x with 8 + 4 main plug-in connector and analog interface on the back
  - 4 digital inputs
- HMC base card
  - 4 digital inputs
  - 2 digital outputs
- HMC base card plus extension card
  - 8 digital inputs
  - 4 digital outputs

### Processing of Digital Inputs

- Each of the digital inputs is read in over the I/O interface within the position cycle and mapped in P-0-0303. In this case, P-0-0303 could be transmitted to the control over the cyclic data channel.
- The assignment of hardware to P-0-0303 is shown by P-0-0305.
- Each digital input is copied by P-0-0303 to a target IDN, if configured in P-0-0300 and P-0-0301.

Each device-side digital input can be evaluated in every subdevice (multiple evaluation).

### Processing of Digital Outputs

- Every digital output of P-0-0304 is written via reading of a target IDN, if configured in P-0-0310 and P-0-0311.
- The assignment of hardware to P-0-0304 is shown by P-0-0315.

- Only one assignment to a digital output can be made from a drive parameter. Multiple assignments to a digital output from the individual subdevices are therefore not possible.

The IDN of the permitted parameters can be found in the IDN lists of S-0-0398 und S-0-0399.

## Assignment to and Relationship With Hardware

**Inputs**

The digital inputs can be assigned via parameters P-0-0300 and P-0-0301. There is no separate image of the subdevice. Every physical input in every subdevice can be assigned and used. The HydraulicDrive firmware prevents the same bit of a device parameter (parameter that is available only once in the device) from being written by two inputs or by one input via the assignment of two subdevices. In this case, C0203 is issued when changing over from PM to OM takes place.

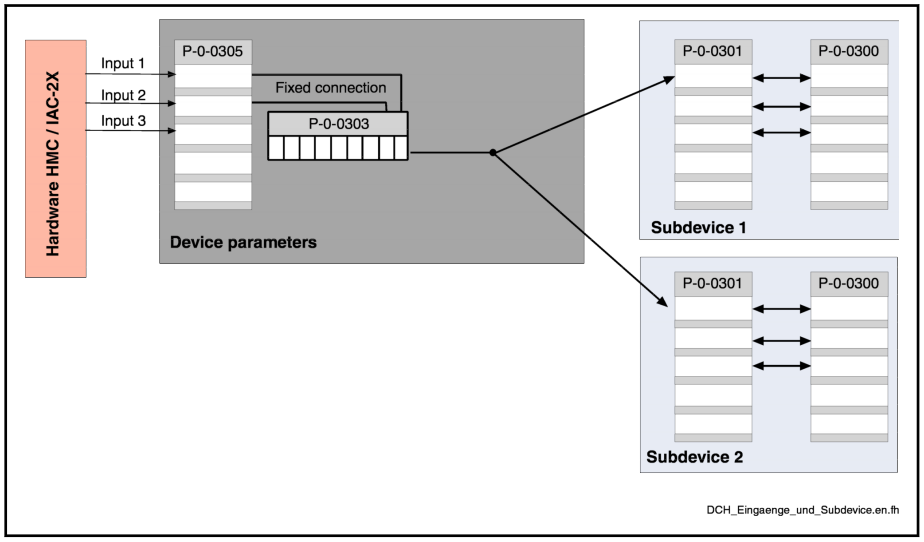



*Fig. 8-1: Interrelationship Between Physical Inputs and Assignment in the Subdevice*

**Outputs**

The digital outputs can be assigned via parameters P-0-0310 und P-0-0311. There is no separate image of the subdevice. The outputs must, however, be assigned to the relevant subdevice. The assignment is made directly by the allocation; this means, by setting a target parameter other than S-0-0000 the assignment is activated. Every physical output from every subdevice can therefore be assigned. The HydraulicDrive firmware runs a check to prevent that the same bit from several subdevices is used. If this is the case, C0203 is issued when changing over from PM to OM takes place.

If a digital output is not used by any of the subdevices, the HydraulicDrive firmware sets this output to the "low“ state.

The digital outputs can be written (set) by a master through inclusion in the master data telegram (sercos) or in the cyclic command value data channel of master communication. The HydraulicDrive firmware supports this only, if it does not utilize the digital outputs itself (P-0-0310 equal to S-0-0000).

Device Functions

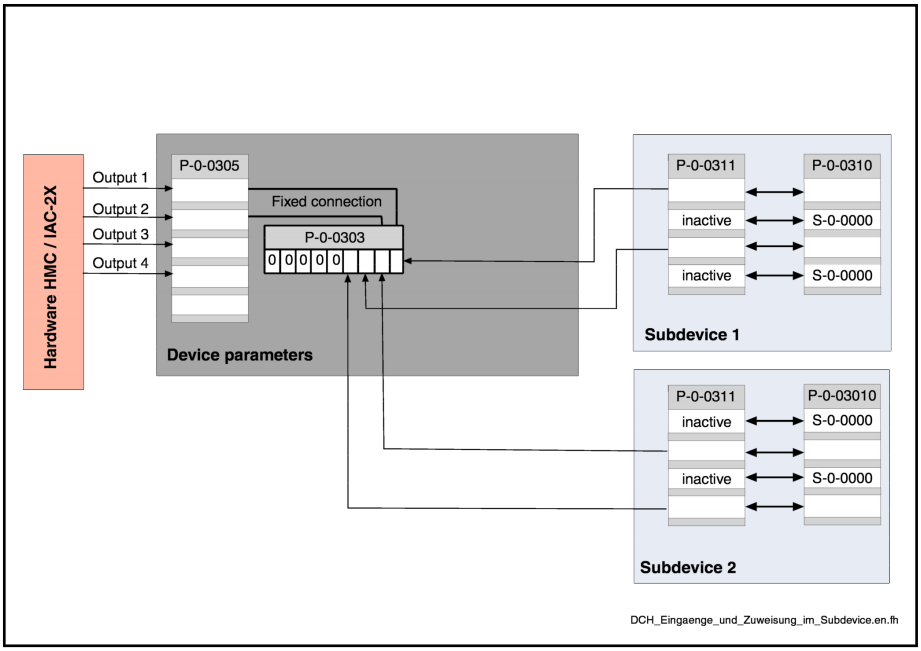



*Fig. 8-2: Interrelationship Between Physical Inputs and Assignment in the Subdevice*

## Pertinent Parameters and Diagnostic Messages

**Parameters**

- P-0-0300, Digital inputs, assignment list
- P-0-0301, Digital inputs, bit numbers
- P-0-0303, Digital inputs, input image of device
- P-0-0304, Digital outputs, output image of device
- P-0-0305, Digital inputs, indication of connector and pin
- P-0-0310, Digital outputs, assignment list
- P-0-0311, Digital outputs, bit numbers
- P-0-0315, Digital outputs, indication of connector and pin

**Diagnostic Messages**

- C0203, Parameter conversion error (->S-0-0423)

## Interrelationships

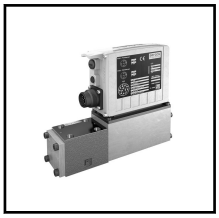
**Dependency on Hardware** The number of digital I/O depends on the hardware, see description above!

# 8.3 Analog Inputs/Outputs

## 8.3.1 Hardware Variants of Analog Peripherals

### Functional Description

The number of analog inputs and outputs depends on the type of drive controller (high-response valve or HMC). The table below illustrates this dependency:

| | Type of Hydraulic-Drive | Number of analog outputs | Voltage/current range |
|---|---|---|---|
|  *Fig. 8-3: IAC* | High-response valve with IAC function | Up to 7 analog inputs<br>0-2 analog outputs | Optional ranges can be defined within the limits:<br>-10...+10 V<br>4...20 mA |
| *Fig. 8-4: HMC* | HMC (Hydraulic Motion Controller) | 4 or 8 analog inputs<br>2 or 4 analog outputs | Optional ranges can be defined within the limits:<br>-10...+10 V<br>4...20 mA |

*Tab. 8-2: Analog inputs or outputs*

The following table provides an overview of the configuration of analog I/O depending on the device type:

| Device | Variant | | Number of analog inputs and outputs | Connector designation | Changeover current/voltage |
|---|---|---|---|---|---|
| | Device connector | Functionality | | | |
| High-response valve with IAC function | 11 + PE | With digital encoder interface (1 Vss/ EnDat 2.2 / SSI) | Analog input 1<br>Analog input 2<br>Analog input 3<br>Analog input 4<br>Analog output | XH2<br>XH2<br>X2M1<br>X2M2<br>XH2 | Analog input 1&2 and analog output together<br>Analog input 3&4 separately |
| High-response valve with IAC function | 11 + PE | With analog interface (p/Q function) | Analog input 1<br>Analog input 2<br>Analog input 3<br>Analog input 4<br>Analog input 5<br>Analog input 6<br>Analog input 7<br>Analog output | XH2<br>XH2<br>X2M1<br>X2M2<br>X2M3<br>X2M3<br>X2M3<br>XH2 | Analog output 1&2 and analog output together<br>Analog input 3&4 separately<br>Analog inputs 5 - 7 are exclusively voltage inputs |
| High-response valve with IAC function | 8 + 4 | p/Q function | Analog input 5<br>Analog input 6<br>Analog input 7 | X2M3<br>X2M3<br>X2M3 | Analog inputs 5 to 7 are exclusively voltage inputs |

Device Functions

| Device | Variant | | Number of analog inputs and outputs | Connector designation | Changeover current/voltage |
|---|---|---|---|---|---|
| | Device connector | Functionality | | | |
| HMC | Single-axis version without extension card | | Analog input 1<br>Analog input 2<br>Analog input 3<br>Analog input 4<br>Analog output 1<br>Analog output 2 | X1<br>X1<br>X1<br>X1<br>X1<br>X1 | Each analog input and output can be changed over separately |
| HMC | Single-axis version with extension card | | Analog input 1<br>Analog input 2<br>Analog input 3<br>Analog input 4<br>Analog input 5<br>Analog input 6<br>Analog input 7<br>Analog input 8<br>Analog output 1<br>Analog output 2<br>Analog output 3<br>Analog output 4 | X1<br>X1<br>X1<br>X1<br>X4<br>X4<br>X4<br>X4<br>X1<br>X1<br>X4<br>X4 | Each analog input and output can be changed over separately |

*Tab. 8-3: Configuration of Analog I/O*

For high-response valves with IAC function the switch-over voltage / current is accomplished with the help of P-0-2918.0.1 and for HMC devices by means of P-0-2918.0.2. The bit assignments are specific to each device type.

If errors occur when the set configuration is checked, the respective parameter is entered in S-0-0423 when switching to OM takes place, and switching over is blocked.

The change-over of value ranges for analog inputs/outputs on the hardware side is not provided.

Information on how many analog inputs and outputs are available on a device is given via parameter P-0-1520 "Control section type"

.

## Location of Connectors on High-Response Valves with IAC Function

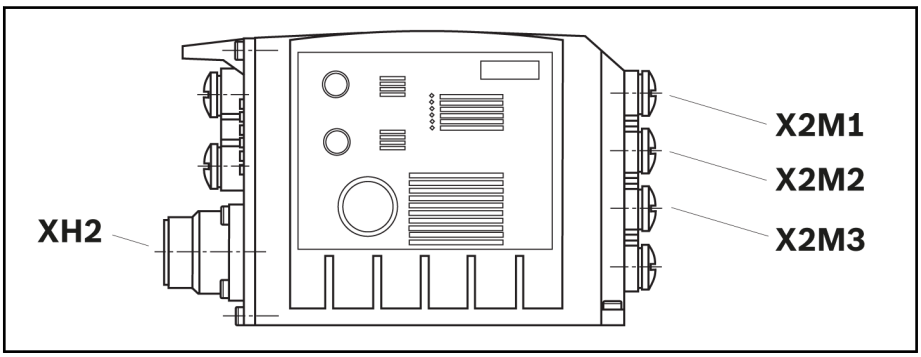



*Fig. 8-5: Location of Connectors on High-Response Valves with IAC Function*

On high-response valves with IAC function, the analog inputs and outputs are distributed to the interfaces XH2, X2M1, X2M2 and X2M3.

## Location of Connectors on HMC Devices

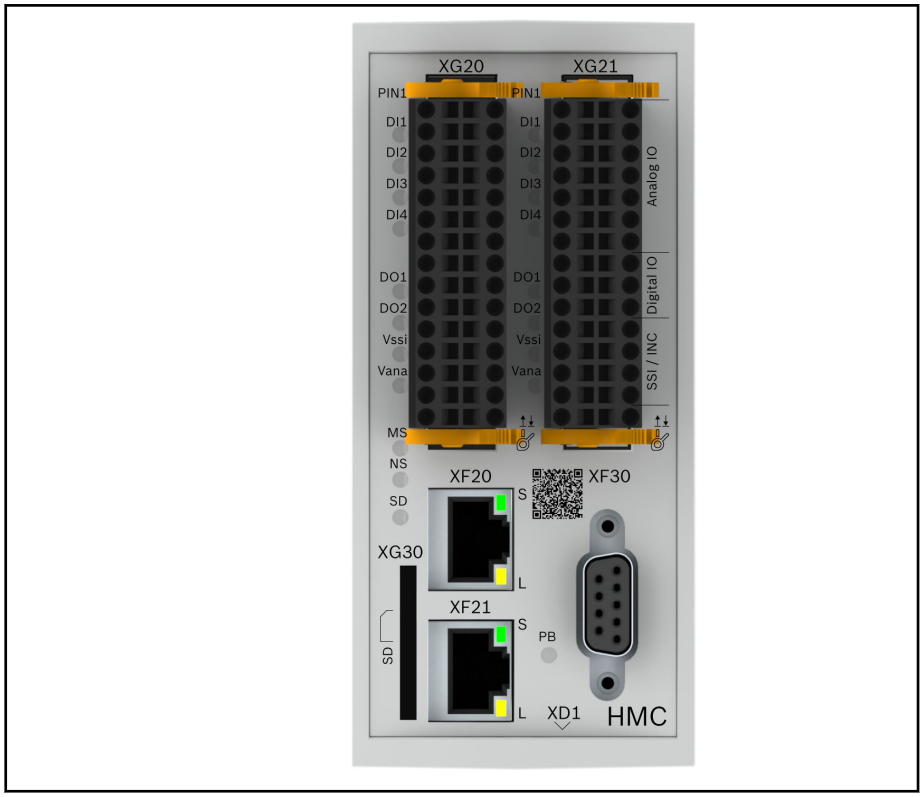



*Fig. 8-6: Location of Connectors on HMC Devices*

On HMC devices 4 inputs and 2 outputs are located on the base card (X1) and further 4 inputs and 2 outputs on the extension card (X4).

## Pertinent Parameters and Diagnostic Messages

**Parameters**

- P-0-2918.0.1, Hardware control word of analog inputs and outputs
- P-0-2918.0.2, Hardware control word of analog inputs and outputs
- P-0-0208, Analog input 5
- P-0-0209, Analog input 6
- P-0-0210, Analog input 1
- P-0-0211, Analog input 2
- P-0-0221, Analog input 7
- P-0-0228, Analog input 3
- P-0-0229, Analog input 4
- P-0-0240, Analog input 8
- P-0-0139, Analog output 1
- P-0-0140, Analog output 2
- P-0-0414, Analog Output 3
- P-0-0415, Analog Output 4

**Diagnostic Messages**

- C0203, Parameter conversion error (->S-0-0423)

Device Functions

## 8.3.2 Assignments of Analog Inputs

### Functional Description

Over the analog inputs, it is possible to read in, for example, analog sensors, but also any other optional voltage and current signals can be reassigned to various drive parameters.

### General Features of Analog Inputs

- Depending on the type of HydraulicDrive up to 8 analog inputs are available
- Updating of analog inputs within the velocity controller clock cycle
- Reading in from various analog sensors
- Reading in of optional voltage and current signals (within defined ranges)
- Filtering of analog input signals
- Wire break monitoring
- Parameterizable signal conversion through offset and nominal value for assignment to internal drive parameters
- Monitoring for double assignment of a drive parameter (e.g. when master communication and an analog input want to write to the same drive parameter)

### Use of Analog Inputs

The analog inputs of the HydraulicDrive can be used in the following two ways:

1. **Use for pressure/force sensing for the controller**

   In this case, the value from an analog output is output to the respective actual pressure or force value in a scaled form.

2. **Free configuration of analog inputs and assignment to drive parameters**

   In this case, the value from an analog output is output to any drive parameter in a scaled form (selection restricted to list P-0-0212).

### Assignment of a Read-in Analog Value to a Drive Parameter

Assigning an analog input works according to the following principle:

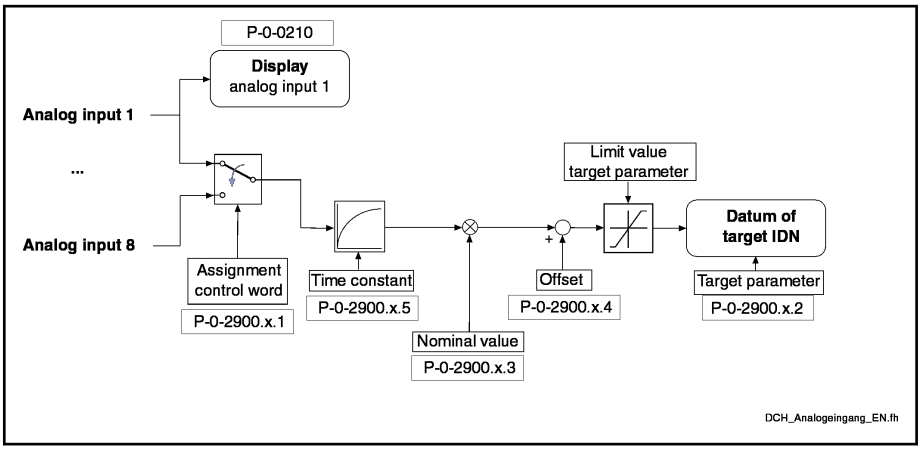



*Fig. 8-7: Assignment of a Read-in Analog Value to a Drive Parameter*

## Meaning of Nominal Value and Offset in the Assignment of the Analog Input

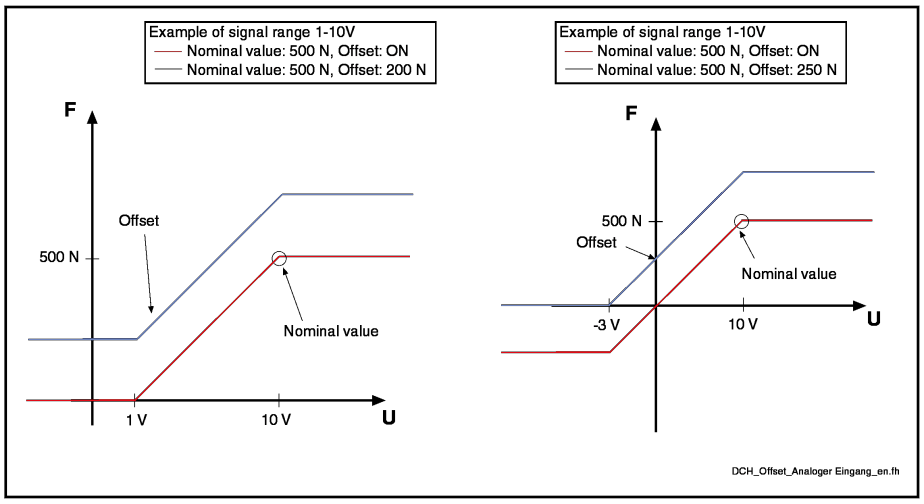
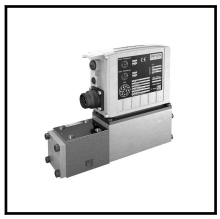



*Fig. 8-8: Meaning of Nominal Value and Offset in the Assignment of the Analog Input*

## Number of Assignments to Drive Parameters

The number of assignments of analog inputs to drive parameters is limited. The same analog input may be assigned to several drive parameters, but for performance reasons, only a maximum of 5 assignments can be used per subdevice.

| | Type of Hydraulic-Drive | Number of analog outputs | Number of assignments |
|---|---|---|---|
|  *Fig. 8-9: IAC* | High-response valve with IAC function | Up to 7 analog inputs | 5 assignments |
| *Fig. 8-10: HMC* | HMC (Hydraulic Motion Controller) | Up to 8 analog inputs | 5 assignments per subdevice |

*Tab. 8-4: Number of Assignments to Drive Parameters*

## List of Assignable Drive Parameters

An analog input is assigned to drive parameters on the basis of a predefined selection list that is contained in parameter "P-0-0212, Analog input, list of assignable parameters". This parameter contains the IDN list of status variables and signals of the axis that can be written via an analog input.

## Assignment Clock Cycle

For the assignments you can define, in which clock cycle these are to be calculated. You can select the valve controller clock cycle, the velocity controller cycle and the position controller clock cycle.

Device Functions

### Wire Break Monitoring

Wire break monitoring is active separately for each assignment, as soon as a signal range was selected, the lower limit of which is greater than 0. Via the extended control word P-0-02900.x.7 the wire break message can be configured as warning or error.

Monitoring responds when the analog input is below half the value of the lower limit.

**Example:** Signal range 4-20 mA --> wire break message in the case of signals of less than 2 mA.

### Pertinent Parameters and Diagnostic Messages

**Parameters**

- P-0-0208, Analog input 5
- P-0-0209, Analog input 6
- P-0-0210, Analog input 1
- P-0-0211, Analog input 2
- P-0-0212, Analog input, list of assignable parameters
- P-0-0221, Analog input 7
- P-0-0228, Analog input 3
- P-0-0229, Analog input 4
- P-0-0256, Analog input 8
- P-0-2900.x.1, Analog input, assignment, control word
- P-0-2900.x.2, Analog input, assignment, target parameter
- P-0-2900.x.3, Analog input, assignment, nominal value
- P-0-2900.x.4, Analoger input, assignment, offset
- P-0-2900.x.5, Analog input, assignment, filter time
- P-0-2900.x.6, Analog input, assignment, status word
- P-0-2900.x.7, Analog input, assignment, extended control word
- P-0-2900.x.8, Analog input, assignment, signal range lower limit
- P-0-2900.x.9, Analog input, assignment, signal range upper limit

**Diagnostic Messages**

- C0242, Multiple configuration of a parameter (->S-0-0423)
- E2270, Analog input, wire break
- F2270, Analog input, wire break

# 8.4 Drive Halt

## 8.4.1 Functional Description

The function “Drive Halt" is used for decelerating an axis by a higher-level control. The drive no longer follows the command values of the active operation mode, but decelerates on its own. The procedure depends on the active functional package.

**Activating the Function “Drive Halt”**

Drive Halt is triggered by:

- withdrawing the Drive Halt bit in the control word of master communication (e.g.: Master control word, S-0-0134, bit 13).
- interrupting a drive control command (e.g.: drive-controlled homing procedure)

**Return to the Operation Mode Active Before**

The operation mode active before and still selected becomes active again, when the Drive Halt bit is set again in the control word of master communication.

With “Drive Halt”, the kind of deceleration depends on the operation mode active before.

## 8.4.2 Drive Halt with Functional Package OL, IFB, or p/Q

Decelerating is accomplished by setting "P-0-2914Effective valve command value" to "0" via the ramp function set in the operation mode “direct valve control”.

For acknowledgement of Drive Halt, see “Drive Halt With Functional Package CL". The actual velocity is calculated from the valve command value with the help of valve standard velocity.

## 8.4.3 Drive Halt with Functional Package DFE

In the case of pump control, the drive is not stopped, but special command values for swivel angle and pressure become effective:

- Swivel angle "P-0-2976Swivel angle command value (without controller enable)"
- Pressure: "P-0-2975Pressure command value (without controller enable)"

Drive Halt is acknowledged immediately.

## 8.4.4 Drive Halt with Functional Package CL

Stopping takes place with defined acceleration and defined jerk.

Drive Halt is carried out as quick stop in closed-loop position control without velocity controller. Position control is activated, if one of the operation modes with position control (S-0-0032...) has been defined (incl. internal PLC operation modes). Otherwise, the “velocity” control mode is active.

**Quick Stop in Position Control**

In closed-loop position control stopping takes place applying the deceleration in "S-0-0372, Drive Halt acceleration bipolar" and jerk in "S-0-0349, Bipolar jerk limit".

☞ If the content of "S-0-0372, Drive Halt acceleration bipolar" is equal to "0", decelerating is based on the value in "S-0-0138, Bipolar acceleration limit value".

☞ If alternating control (see “Alternating Control”) is active, torque/force is limited (minimum of S-0-0092 and S-0-0082 or S-0-0092 and S-0-0083).

If Drive Halt is started from an operation mode with position command value delay, then the delay is also activated for Drive Halt. Downstream of the fine interpolator, the position command value can be delayed by a maximum of 32 position cycles, before it is fed to the position controller. This allows a master axis to be controlled synchronously with the controlled slave axis. The number of position cycles is set in the position command value delay (P-0-0456). The undelayed position command value generator (P-0-0457) is entered in a ring buffer, the delayed position command value is then taken over to the position command value controller (P-0-0434).

Position-controlled stopping is carried out with position control with lag error, if an operation mode that also contained position control with lag error was

active before. Otherwise, the function is executed with lagless position control.

Model monitoring is active (see “closed-loop position control”).

**Quick Stop in Velocity Control**

If the “velocity” control type is selected, stopping takes place in closed-loop velocity using the value in parameter "S-0-0372, Drive Halt acceleration bipolar" and jerk in "S-0-0349, Bipolar jerk limit".

---

☞ If the content of "S-0-0372, Drive Halt acceleration bipolar" is equal to "0", decelerating is based on the value in "S-0-0138, Bipolar acceleration limit value".

---

☞ If alternating control (see “Alternating Control”) is active, torque/force is limited (minimum of S-0-0092 and S-0-0082 or S-0-0092 and S-0-0083).

---

**Acknowledging Drive Halt**

At standstill, i.e. the actual velocity is within the standstill window (S-0-0124), Drive Halt is acknowledged.

- Bit 4 (Drive Halt acknowledgement) in parameter"P-0-0115, Device control: Status word" is set.
- "A0010 Drive Halt" is output in diagnostics (S-0-0095).
- In the diagnostic message number (S-0-0390) "0x000A0010" is output.

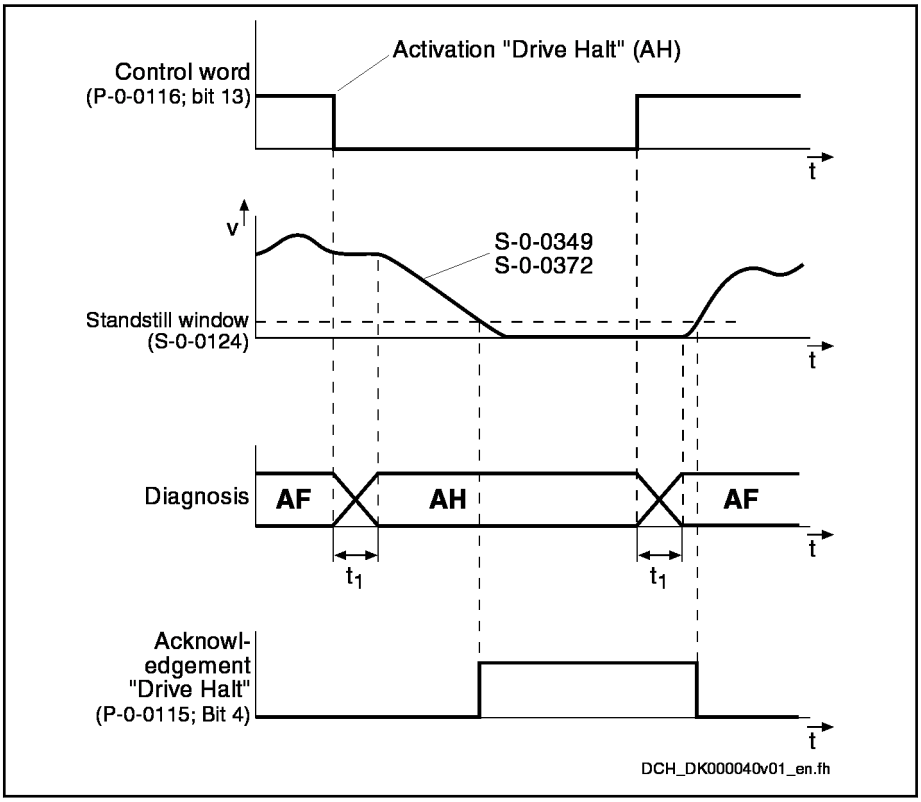



*Fig. 8-11: Principle of “Drive Halt" with quick stop in CL*

## 8.4.5 Pertinent Parameters and Diagnostic Messages

**Parameters**

- P-0-0456, Position command value delay
- P-0-0457, Position command value generator
- S-0-0108, Feedrate override

- S-0-0138, Bipolar acceleration limit value
- S-0-0349, Bipolar jerk limit
- S-0-0372, Drive Halt acceleration bipolar
- S-0-0095, Diagnostic message
- S-0-0390, Diagnostic message number
- S-0-0124, Standstill window
- P-0-0115, Device control: Status word
- P-0-0116, Device control: Control word

**Diagnostic Messages**

- A0010 Drive HALT

# 8.5 Error Reactions

## 8.5.1 Overview of Warning and Error Classes and Reactions

### Functional Description

If a state is recognized that no longer allows proper operation, the drive controller generates an error message or warning depending on the severity of the problem.

### Warning Classes and Warning Reactions

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

| Diagnostic message number | Warning class | Warnings reaction |
|---|---|---|
| E2xxx | Non-fatal warning | Prewarning only, no reaction, operation possible without any restrictions |
| E4xxx | Warning of master communication | Master communication disturbed in part or in whole; operation possible with restrictions only |
| E8xxx | Fatal warning | Operation possible with restrictions only. The reaction of the drive to this warning class is described in conjunction with the respective warning. |

*Tab. 8-5: Warning Classes and Warning Reactions*

In the case of fatal warnings E8029, E8030, E8042, E8043 and E8044 the drive is decelerated using ramp "S-0-0138, Bipolar acceleration limit value" (vcomm=0!), if bit 4-7=4 is configured in parameter P-0-0119. Otherwise, the drive brakes without braking ramp when these warnings occur.

### Error Classes and Error Reactions

Errors are classified in error classes depending on their severity. The error class is indicated by bits 15..12 of the diagnostic message number.

If this axis is in closed-loop control (the controller enable is set) and an error occurs, a drive error reaction is started automatically. This drive error reaction depends on:

- the error class of the error occurred and
- the setting of the following parameters:

– P-0-0117, Activation of control unit reaction on error
– P-0-0119, Best possible deceleration

| Diagnostic message number | Error class | Error reaction |
|---|---|---|
| F2xxx | Non-fatal error | • Control reaction according to P-0-0117, Activation of control unit reaction on error<br>• Drive-side error reaction according to P-0-0119, Best possible deceleration, bits 0...3 |
| F4xxx | Error of master communication | • Drive-side error reaction according to P-0-0119, Best possible deceleration, bits 0...3 |
| F6xxx | Emergency stop error | • Drive-side error reaction according to P-0-0119, Best possible deceleration, bits 4...7 |
| F8xxx | Fatal error | • Activation of valve ramp |

*Tab. 8-6: Error Classes and Error Reactions*

## 8.5.2 Best Possible Deceleration

### Functional Description

#### Setting of Drive-Sided Error Reaction

The sequence of the drive-side error reaction, this is, the way of command value generation and operation mode is set in "P-0-0119, Best possible deceleration".

The reaction to F2...F4 errors is set in bits 0...3:

- "0" - valve ramp
- "1" - output stage shutdown
- "2" - velocity command value reset with ramp and filter (quick stop)
- "3" - return motion
- "4" - valve ramp

The reaction to F6 errors is set in bits 4...7:

- "0" - valve ramp
- "1"- output stage switch-off
- "4" - valve ramp

### Limit Value Parameters During Drive-Sided Error Reaction

| Type of deceleration | Acceleration limit values | | | Jerk limit value | Calculation from filter constant from |
|---|---|---|---|---|---|
| | S-0-0138 | S-0-0429 | S-0-0372 | S-0-0349 | |
| **Emergency halt**<br>Velocity command value reset | X | | | | No filter active |
| **Emergency halt**<br>Velocity command value reset with ramp and filter | X | X | | X | S-0-0349 & S-0-0372 |
| **Quick stop**<br>Velocity command value reset with ramp and filter | X | | X | X | S-0-0349 & S-0-0372 |

*Tab. 8-7: Limit value parameters during drive-side error reaction*

## Fatal System Errors

While the above error classes result from drive-side monitors of control, communication, peripherals, etc. there is also a class of fatal system errors. These are based on errors in drive-internal signal processing with the result that a reaction, which can be handled, is hardly possible. Diagnostics and reaction are shown in the following:

| Diagnostic message number | Error class | Error reaction |
|---|---|---|
| F9xxx / E-xxxx | Fatal system error or "processor exception" | • Immediate switch-off of the output stage<br>• Deactivation of all local digital outputs<br>• Deactivation of all analog outputs |

*Tab. 8-8: Fatal System Error*

## Time Sequence When Switching Off the Drive Enable

After withdrawing the controller enable, the following actions can or have to be carried out:

- Activating the non-return valve with S"S-0-0207, Drive off delay time". During this time the axis is protected against drifting away by a velocity command value reset.

In parameter "S-0-0207, Drive off delay time" you have to enter the time that the non-return valve takes for closing, i.e. the time between the activation of the valve and its actual being closed. During this time, the drive prevents drifting away of the axis by resetting the velocity command value.

When the controller enable is switched off, bit 3 of the drive status changes to 0 ("drive ignores command value input"), and at the end of the delay time S-0-0207, bit 14 and 15 of the drive status (P-0-0115) change to "Ab" = 10b.

A typical switch-off sequence of the drive is shown in the following graphic:

Device Functions

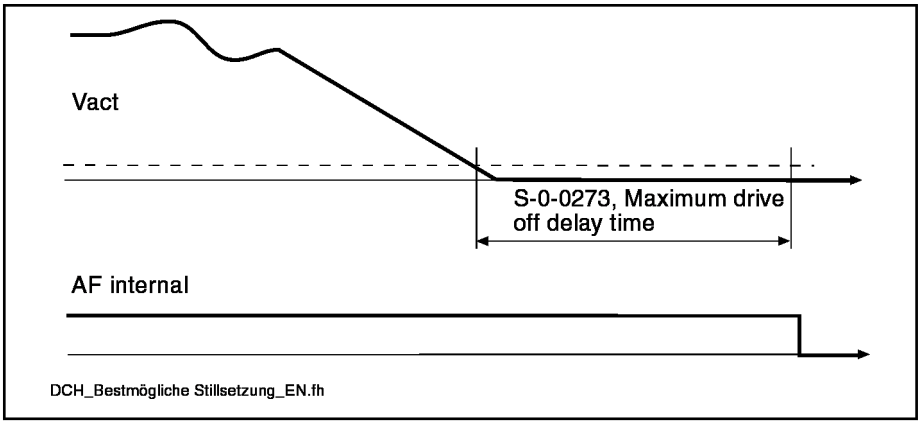



*Fig. 8-12: Operating Principle S-0-0207, Drive Off Delay Time*

**Braking Time < S-0-0273**

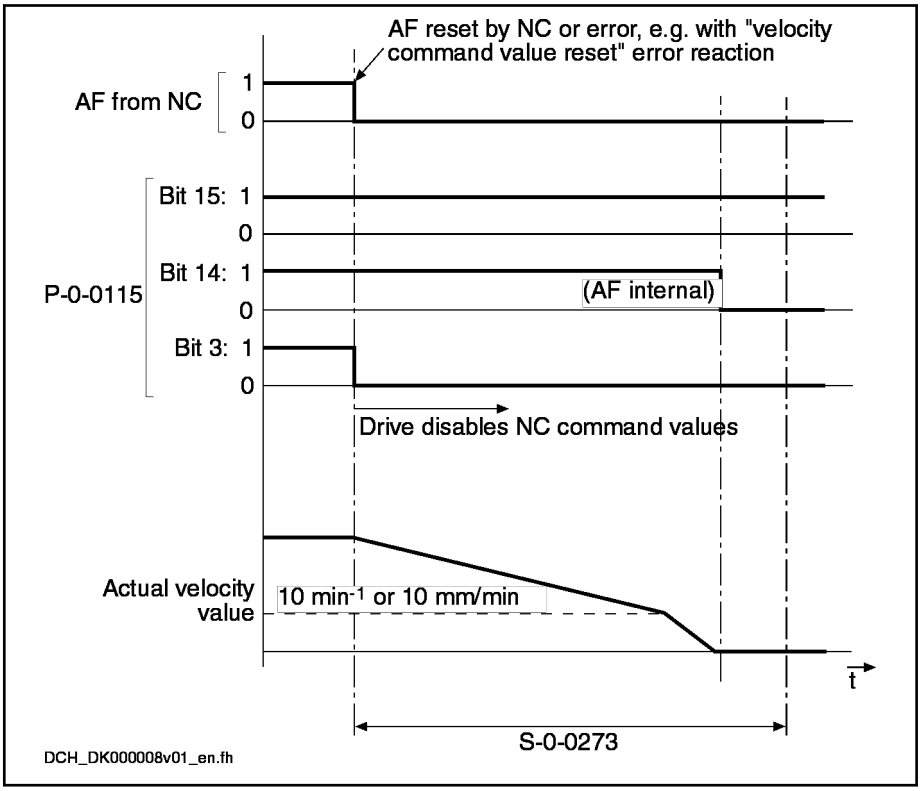



*Fig. 8-13: Braking Time < S-0-0273*

**Braking Time > S-0-0273**

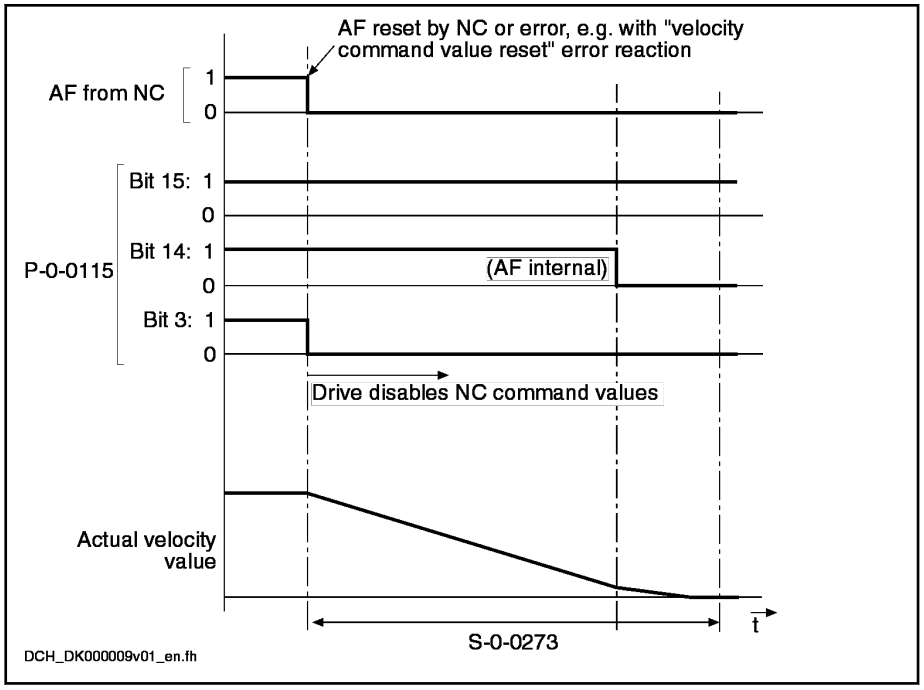



*Fig. 8-14: Braking Time > S-0-0273*

## Velocity Command Value Reset ("Emergency Stop")

Velocity Command Value Reset ("Emergency Stop") is to be used, if best possible deceleration is to be carried out in the event of an error.

**P-0-0119, Bit 0...3 = 0; P-0-0119, Bit 4...7 = 0**

In the event of an error, the controlled drive in closed-loop velocity control is stopped with command value = "0". Parameter "S-0-0138, Bipolar acceleration limit value" is used as acceleration limit value.

## Velocity Command Value Reset With Ramp and Filter ("Emergency Halt")

Velocity command value reset with ramp and filter (emergency halt) is used, if the stopping process is to spare the mechanical system and the quick stop characteristics are to be adhered to.

**P-0-0119, Bit 0...3 = 4; P-0-0119, Bit 4...7 = 4**

In the event of an error, the servo-drive in closed-loop velocity control is stopped using a command value ramp, which is determined by "S-0-0429, Emergency halt deceleration" and the jerk limit value "S-0-0349, Bipolar jerk limit". If the value of S-0-0429 = "0", the value in "S-0-0138, Bipolar acceleration limit value" is effective.

## Velocity Command Value Reset With Filter and Ramp ("Quick Stop")

Velocity command value reset with filter and ramp ("quick stop") is used, if the stopping process is to spare the mechanical system and the quick stop characteristics are to be adhered to.

**P-0-0119, Bit 0...3 = 2**

In the event of an error, the closed-loop-controlled servo drive in velocity control or the open-loop-controlled drive in U/f operation is stopped using a command value ramp, which is determined by "S-0-0372, Drive Halt acceleration bipolar" and the jerk limit value "S-0-0349, Bipolar jerk limit". If the value of S-0-0327 = "0", the value in "S-0-0138, Bipolar acceleration limit value" is effective. A torque/force limitation is derived from parameter P-0-0109.

In open-loop-controlled U/f operation, stopping is carried out taking account of "P-0-0569, Maximum stator frequency slope".

Device Functions

After "S-0-0273, Maximum drive off delay time" has elapsed, the servo-brake is applied, after the drive off delay time from S-0-0207 has elapsed, the drive enable is switched off internally. In the case of a main spindle brake, the brake is applied at a velocity of less than 10 rev/min.

## Output Stage Switch-Off

Output stage switch-off is used, if an axis is to move to the failsafe position of the valve.

**P-0-0119, Bit 0...3 = 1; P-0-0119, Bit 4...7 = 1 or Fatal Errors**

In the event of an error, the valve is brought to the failsafe position as quickly as possible. In this process, the drive may be exposed to some mechanical stress.

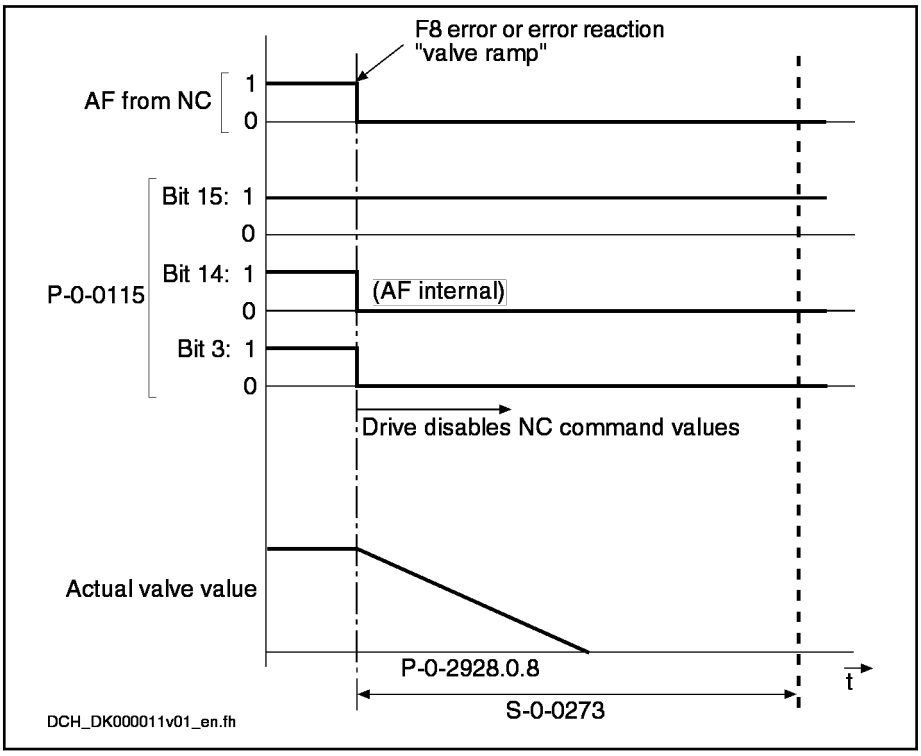



*Fig. 8-15: Output Stage Switch-Off*

## Return Motion

Return motion is used, if in the event of an error a deliberate return of the axis from the machining zone is required.

**P-0-0119, Bit 0...3 = 3**

If "return motion" is set for best possible deceleration, the drive generates a position command value profile to run the desired travel distance in the event of an error. In the case of error, a relative travel distance is therefore activated.

**Generating the Position Command Value Profile**

With the "drive-internal interpolation" mode the command value profile is generated internally by means of predefined travel block data (velocity, acceleration, jerk), see "Drive-Internal Interpolation".

The value of the parameter "P-0-0055, Return distance" depends on the sign, i.e. a positive return distance causes positive motion with reference to the coordinate system selected.

The value of "P-0-0055, Return distance" can be configured and transmitted in the cyclic telegram (MDT).

The velocity profile is generated using the parameter:

- "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, with the order of the average value filter ("P-0-0042, Current position command average value filter order") being calculated from "P-0-0057, Return acceleration" and "P-0-0058, Return jerk".

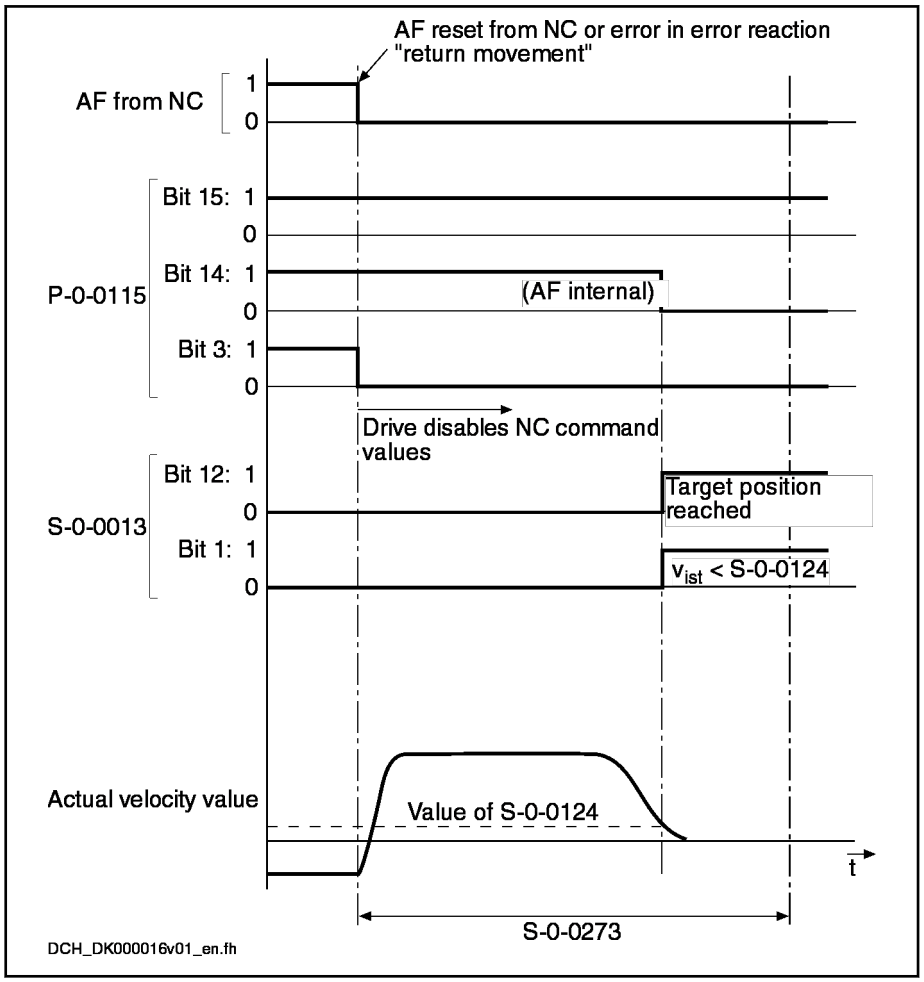



*Fig. 8-16: Return Motion*

## Pertinent Parameters and Diagnostic Messages

**Parameters**

- P-0-0055, Return distance
- P-0-0056, Return velocity
- P-0-0057, Return acceleration
- P-0-0058, Return jerk
- P-0-0109, Torque/force peak limit
- P-0-0117, Activation of control unit reaction on error
- P-0-0119, Best possible deceleration
- P-0-0569, Maximum stator frequency slope
- S-0-0138, Bipolar acceleration limit value
- S-0-0273, Maximum drive off delay time
- S-0-0429, Emergency halt deceleration

- P-0-0372, Drive Halt acceleration bipolar
- P-0-0193, Positioning jerk

**Diagnostic Messages**

- F6024, Maximum braking time exceeded

## 8.5.3 Control Reaction on Error

### NC Reaction on Error

#### Brief Description

To avoid damage to the machine, some applications require that the master (e.g. NC) also retains control over the travel profile of the axes in the case of error and shuts down the machine axes in a coordinated way. For this case, the "NC reaction on error" option was implemented; it can be activated via parameter P-0-0117.

The master is informed of an error in the drive controller via the drive status word (see S-0-0135) so that the master can shut down the machine axes in a coordinated way and therefore avoid possible damage.

☞ An NC reaction on error is only possible with non-fatal errors (diagnostic message F2xxx), otherwise the drive always reacts with an immediate error reaction on the drive side.

**Pertinent Parameters**

- S-0-0135, Drive status word
- P-0-0117, Activation of control unit reaction on error
- P-0-0119, Best possible deceleration

#### Functional Description

In the case of NC reaction on error, the axis reporting the error still is provided with the command values preset by the master and follows them, even in the case of error, for another 30 s. To achieve this, the function has to be activated so that the defined time delay of 30 s becomes effective between the detection of the error and the drive-side reaction.

**Activating the NC Reaction**

The NC reaction in the event of an error is set in "P-0-0117, Activation of control unit reaction on error".

**P-0-0117, bit 0:**

- Bit 0 = "0" → The drive carries out its error reaction **without delay** according to the setting in "P-0-0119, Best possible deceleration" after recognizing the error.
- Bit 0 = "1" → The drive carries out its error reaction according to the setting in parameter P-0-0119 **only 30 s after recognizing the error**. The drive continues following the command values of the master for the duration of 30 s after detection of the error, thus allowing an **NC error reaction**.

  **Note:** In case that after the recognition of the error the error message is deleted within this waiting period, **no** drive reaction as set in parameter P-0-0119 will be executed.

☞ The activation of "NC reaction on error" (P-0-0117, bit 0 = "1") only makes sense for masters that have the respective procedure for the case of error.

# 8.6 E-Stop Function

## 8.6.1 Brief Description

The E-Stop function is used to stop the drive with a selectable drive reaction (see Parameter Description "P-0-0008, Activation E-Stop function") via a digital input of the drive controller.

For using the E-Stop input on the device, parameter P-0-0223 E-Stop input must be assigned to a digital input on the drive via configuration of the digital I/Os.

The following options are available for utilizing the E-Stop function:

- E-Stop as error

  → **Reaction:**

  – Valve control variable reset with ramp→"F6034Emergency-Stop activated"

  – Best possible deceleration (as set in P-0-0119) →"F4034Emergency-Stop activated"

- E-Stop as fatal warning "E8034Emergency-Stop activated"

  → **Reaction:** Best possible deceleration (as set in P-0-0119)

☞ If "E-Stop" is parameterized as warning, it is not necessary to clear the diagnostic message!

**Pertinent Parameters**

- P-0-0008, Activation E-Stop function
- P-0-0223, E-Stop input

**Pertinent Diagnostic Messages**

- E8034 Emergency-Stop activated
- F4034 Emergency-Stop activated
- F6034 Emergency-Stop activated

## 8.6.2 Functional Description

By activating the E-Stop input (P-0-0008, bit 0 = 1) and assigning bit 0 of P-0-0223 to a digital input, the drive is caused to stop by carrying out the reaction defined via P-0-0008 when 0 V is applied at the E-Stop input.

**E-Stop Reaction According to P-0-0008, bit 2**

The reaction firstly depends on the setting of bit 2 in P-0-0008.

If the interpretation as "fatal warning" is parameterized (bit 2 = 1) here, the drive reacts like upon the withdrawal of the external drive enable with the reaction set in "P-0-0119, Best possible deceleration":

- The warning "E8034Emergency-Stop activated" appears. In "S-0-0012, Class 2 diagnostics" bit 15 is set (manufacturer-specific warning).
- At the same time, bit "change bit class 2 diagnostics" is set in the drive status word.

☞ By reading "S-0-0012, Class 2 diagnostics" this change bit is cleared again. Via "S-0-0097, Mask class 2 diagnostics" warnings can be adjusted with regard to their effect on the change bit.

☞ To reactivate the drive, the E-Stop input must be deactivated and **another 0-1 edge has to be applied to the external controller enable**.

If the interpretation is set as error in P-0-0008 (bit 2 = 0), the reaction selected in bit 1 is carried out:

- The diagnostic error message "F4034Emergency-Stop activated" (or "F6034Emergency-Stop activated") appears.
- In "S-0-0011, Class 1 diagnostics" bit 15 is set.
- In the drive status word of the drive telegram, bit 13 (drive lock-out, error in class 1 diagnostics) is set. The error message can be cleared via command "S-0-0099, C0500 Reset class 1 diagnostics", if the E-Stop input is no longer active.

☞ The error reaction is carried out without delay, irrespective of "P-0-0117, Activation of control unit reaction on error".

**E-Stop Reaction According to P-0-0008, bit 1**

If bit 1 = 0 in parameter P-0-0008, the drive is stopped according to the error reaction parameterized via "P-0-0119, Best possible deceleration".

When the E-Stop input is activated, the diagnostic message is "F4034Emergency-Stop activated".

If bit 1 = 0 in parameter P-0-0008, the drive, when the E-Stop triggers, is decelerated to standstill independently of the error reaction determined in P-0-0119 by ramping the valve control variable to zero. The corresponds to the best possible deceleration "emergency halt" with the ramp time set in P-0-2928.0.8.

When the E-Stop input is activated, the diagnostic message is "F6034Emergency-Stop activated".

## 8.6.3 Notes on Commissioning

### Activation and Polarity of the E-Stop Input

**Assigning the Digital Input**

A prerequisite for utilizing the function is the assignment of bit 0 of parameter P-0-0223 to a digital input (see "Digital Inputs/Outputs"). A voltage level at the digital input therefore also has an effect on bit 0 of P-0-0223.

| ***NOTICE*** | **Without this assignment to the digital input, the E-Stop reaction will not be carried out when activated! An exception to this is IndraDrive Mi.** |
|---|---|

**To be noticed with IndraDrive Mi**

If IndraDrive Mi is used and the E-Stop input (P-0-0223) is not configured in the assignment list of the digital inputs (P-0-0300), the E-Stop signal from the hybrid cable is evaluated for the E-Stop function, see also "zone formation" in the separate documentation "Rexroth IndraDrive Mi, Drive Systems With KCU02, KSM02, KMS02, Project Planning Manual", (DOK-INDRV*-KCU02+KSM02-PR01-DE-P; Mat no.: R911335702).

**Activating E-Stop**

Bit 0 of "P-0-0008, Activation E-Stop function" (see also Parameter Description P-0-0008) is used to activate the E-Stop input and select a reaction for decelerating the drive.

**P-0-0008, Bit 0 (E-Stop activation):**

- Bit 0 = 0 → function not activated
- Bit 0 = 1 → function activated

### Selecting the Drive Reaction

**Determining the Reaction**

It can be determined, whether an error message or a warning is to be generated when 0 V is detected at the E-Stop input. Relevant for the determination are bit 1 and bit 2 of "P-0-0008, Activation E-Stop function".

**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 → interpretation as error (see bit 1)
- Bit 2 = 1 → interpretation as fatal warning

☞ The error reaction can be determined in "P-0-0119, Best possible deceleration".

### Connecting the E-Stop Input

See Documentation "Control Sections for Drive Controllers - Project Planning"

☞ The polarity of the input cannot be selected. It is always active when the signal = 0 V; this means that 0 V at the digital input causes the E-Stop to trigger.

## 8.6.4 Diagnostic and Status Messages

### Warnings and Diagnostic Error Messages

The following diagnostic messages are possible in conjunction with the E-Stop function:

- Warning "E8034Emergency-Stop activated"
  → E-Stop with best possible deceleration
- Error "F4034Emergency-Stop activated"
  → E-Stop with best possible deceleration
- Error "F6034Emergency-Stop activated"
  → E-Stop with best possible velocity command value reset

### Status Messages

The status of the E-Stop input can be read out via "P-0-0223, E-Stop input":

- Bit 0 = 0: 0 V at input
  → E-Stop is triggered
- Bit 0 = 1: 24 V at input
  → E-Stop not triggered

Device Functions

# 8.7 Compensation Functions/Corrections

## 8.7.1 Quadrant Error Correction

### Brief Description

Assignment to functional firmware package, see chapter “Availability of the Extended Axis Function”

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.

To compensate for this contour error at the so-called "quadrant transitions" (velocity revisal) HydraulikDrive controllers feature the "quadrant correction" function.

This correction function is useful for such cases when drives are operated in cyclic position control and in circular interpolation by the control master.

**Pertinent Parameters**

- P-0-0100, Position command value extension
- P-0-0435, Control word of position controller
- P-0-0436, Reference radius for quadrant error correction
- P-0-0437, Velocity time range for quadrant error correction
- P-0-0438, Table of path velocities for quadrant error correction
- P-0-0439, Table of velocity pulse for quadrant error correction

### Functional Description

For quadrant error correction, static friction possibly occurring at the reversal points of the direction of motion is compensated by adding an additional, pulse-shaped command value to the velocity command value at the output of the position controller. Due to this velocity feedforward the axis overcomes static friction faster and with less lag error.

**Sinusoidal Position Command Value Profile**

To use quadrant error correction for circular interpolation, it is required that the control master operates two drives in cyclic position control. In this case, the drives are controlled in an interpolating way with sinusoidal position command value profiles with an angular difference, related to the circle, of 90 angular degrees between them. The internally generated velocity command value profiles of the two drives are also sinusoidal and have an offset of 90°.

**Velocity Pulse With Reversal of Direction**

When the direction of motion changes, a triangular velocity pulse with a velocity time range to be set is added to the drive-internal velocity command value.

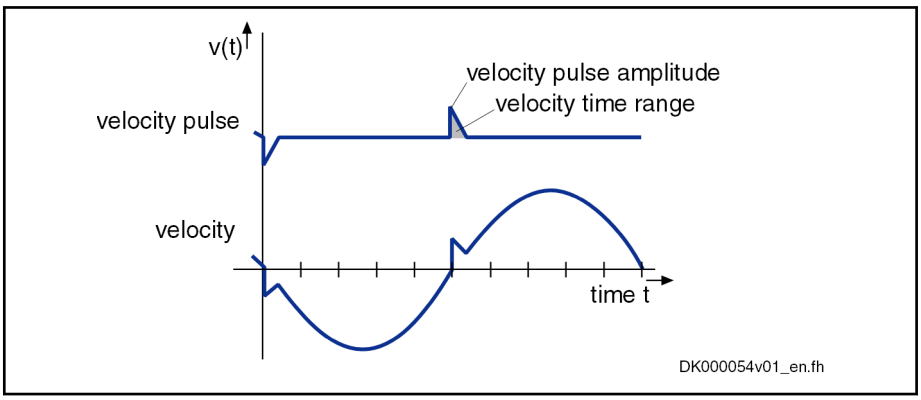



*Fig. 8-17: Schematic Curves of Velocity Pulse and Velocity Command Calue with Quadrant Error Correction*

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. This corresponds to the value entered in "P-0-0437, Velocity time range for quadrant error correction".

**Estimation for the Velocity Time Range**

For the dimensioning of P-0-0437, it is recommended that the required pulse amplitude and the duration of the pulse be estimated. This should be done with regard to the path velocity and the duration for processing the reference circle (P-0-0436):

$$P\text{-}0\text{-}0437 = \frac{1}{2} \times \frac{a}{100\%} \times v_{path} \times \frac{b}{100\%} \times T_{circle}$$

| | |
|---|---|
| **P-0-0437** | Velocity time range for quadrant error correction |
| **a** | percentage of path velocity |
| $v_{path}$ | path velocity |
| **b** | percentage of duration for processing of circular contour |
| $T_{circle}$ | duration for processing the circular contour |

*Fig. 8-18: 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, with the velocities having 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.

Device Functions

☞ Experience has shown that it is absolutely necessary to integrate the extended position command value (P-0-0100) in the cyclic master communication on the control side!

**Activating the Quadrant Error Correction**

The quadrant error correction is activated by the control master by setting the respective bit of "P-0-0435, Control word of position controller". It is only advantageous to use the function when a circular form is to be machined in the part program.

The correction should be activated at the earliest one clock cycle after the start of circular interpolation so that the velocity pulse won't be added when the drive is starting. Otherwise high velocity pulses damaging the contour could be added, due to the mostly high starting accelerations, when the drive is starting.

For machining other contours, the quadrant error correction should be deactivated. To do this, the respective bit of P-0-0435 should be contained in the cyclic master communication and activated depending on the kind of machining.

☞ The quadrant error correction remains without effect when the value "0" is contained in "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 ballbar testing.

**Recommended Commissioning Steps**

The quadrant error correction should be commissioned in the following steps:

1. Make the following presettings:
   - Enter value for "P-0-0436, Reference radius for quadrant error correction"
   - Set quadrant error correction inactive in "P-0-0435, Control word of position controller"
   - Set "P-0-0437, Velocity time range for quadrant error correction" to "0"
   - Write 50 % and 70 % (list lines 1 and 2), for example, of maximum circular velocity to "P-0-0438, Table of path velocities for quadrant error correction"
   - Write the value "0" to the first two list lines in "P-0-0439, Table of velocity pulse for quadrant error correction"
2. Move drive on control side in circular interpolation with 50 % of maximum circular velocity and check quality of circular form with measuring equipment for ballbar testing.
3. Set quadrant error correction inactive in "P-0-0435, Control word of position controller".
4. Write ca. 1 % of the current circular velocity to list line 2 of "P-0-0439, Table of velocity pulse for quadrant error correction".
5. Increase value in parameter "P-0-0437, Velocity time range for quadrant error correction" starting with low values, observe quality of circular form with measuring equipment; increase values until maximum quality of circular form has been reached.

If quality of circular form does not improve, write lower or higher value to list line 2 of P-0-0439, depending on tendency of improvement of circular form quality.

6. After the optimum value was written to P-0-0437, operate drive at other, different circular velocities in order to determine optimum values for P-0-0439.

☞ Observe interpolation data (see above) for the velocity pulse amplitude depending on the current path velocities (P-0-0438 und P-0-0439)!

# 8.8 Positive Stop Drive Procedure

## 8.8.1 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 compressive or pressing forces.

When an axis has moved to a limit stop in a standard situation, the drive should signal a drive error via the monitoring features of the position or velocity control loop and react with a 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 motion monitors and generate the required pressing force, if necessary.

The control master signals this special case to the controller via a command. In response to this command, the drive switches the respective monitors off and issues an acknowledgement, if an axis standstill is recognized and an adjustable force or torque threshold is exceeded.

**Pertinent Parameters**

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0149, C1300 Positive stop drive procedure command
- S-0-0159, Monitoring window
- S-0-0331, Status "n_feedback = 0"

**Pertinent Diagnostic Messages**

- C1300 Positive stop drive procedure command
- C1301 Class 1 diagnostics error at command start

## 8.8.2 Functional Description

Moving a machine axis to a limit stop in closed-loop position control, e.g. for generating a pressing force, is a process specifically provoked on the master side. To do this, the master provides 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 "C1300Positive 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:

- E2059, Velocity command value limit active
- E8260, Torque/force command value limit active
- F2028, Torque/force command value limit active

- F2037, Excessive position command difference

The command is acknowledged on the following conditions:

When the positive stop was recognized.

- Condition 1: Standstill of the drive was recognized ("S-0-0331, Status "n_feedback = 0"")

  - and -

- Condition 2: The force controller is active (S-0-0084 has exceeded the torque/force limit value)

  or

  the following distance (S-0-0189) is greater than the monitoring window (S-0-0159),

The criteria for command acknowledgment can be set axis-specifically.

As command C1300 is reset, the monitors are switched on again!

**NOTICE** **Property damage can be caused by moving to positive stop too rapidly!**

⇒ Reduce approaching velocity and torque/force limit value (S-0-0092) to values that are not causing damage to the mechanical system!

☞ If the drive already signals a class 1 diagnostics error (e.g. has already reached positive stop), the command "positive stop drive procedure" cannot be started!

## 8.8.3 Notes on Commissioning

For acknowledgment of command C1300 it is necessary to set:

- Threshold value for detection of axis standstill in parameter
  - S-0-0124, Standstill window
- Torque/force threshold in the parameters
  - S-0-0082, Torque/force limit value positive
  - S-0-0083, Torque/force limit value negative
  - S-0-0092, Bipolar torque/force limit value

☞ The parameters S-0-0124, S-0-0082, S-0-0083 and S-0-0092 are used for other functions, too. Specific changes of values made for the function "positive stop drive procedure" have to be undone, if necessary!

Before positive stop is reached, start:

- Detection of controller deviation S-0-0159, Monitoring window
- S-0-0149, C1300 Positive stop drive procedure command

After the drive has moved away from the positive stop, reset the command, if necessary!

**Diagnostics** The command has been executed when the "commands change bit" is set in parameter "S-0-0135, Drive status word" and no command error is present.

If a class 1 diagnostics error is present at the start of command C1300 (e.g. because the axis has already reached the positive stop), the command is not executed. The following message is displayed:

- C1301 Class 1 diagnostics error at command start

# 8.9 Parameter Set Changeover

## 8.9.1 Brief Description

HydraulicDrive drives are provided with four parameter sets, which can be switched during operation. One of the switchable parameter sets is always active. Switching takes place upon command of the control master.

**Notes on Application**

By switching parameter sets during operation, the values of specific parameters can be adjusted to the different operating phases or machining processes. This supports the work flow in flexible production facilities.

Application examples of this:

- Adjusting the control loop gains to different load inertias or load masses (e.g. with very different workpieces)
- Changing over ramp times and limitations in generators

**Classification of Switchable Parameters**

The parameters to be switched are subdivided into the following groups taking account of application-related aspects:

- Application parameters
- Control loop parameters

**Pertinent Parameters**

- S-0-0216, C4100 Switch parameter set command
- S-0-0217, Preselect parameter set command
- S-0-0219, IDN-list of parameter set

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☞ List parameters S-**0**-0219 to S-**7**-0219 contain parameter sets no. 0 to no. 3

---

- S-0-0254, Current parameter set
- P-0-2216, Parameter set switching, configuration
- P-0-2217, Parameter set switching, preselection range
- P-0-2218, Parameter set switching, delay time

**Pertinent Diagnostic Messages**

- C4100 Switch parameter set command
- C4101 Switching only possible without AF
- C4103 Preselect parameter set forbidden value
- C4104 Error during parameter set switching (->S-0-0423)

## 8.9.2 Functional Description

### General Information

Parameter set switching is activated:

- by triggering command "C4100Switch parameter set command" (S-0-0216) via the control master

- or -

- in a "drive-controlled" manner by changing parameter "S-0-0217, Preselect parameter set command"

Triggering parameter set switching is determined in parameter "P-0-2216, Parameter set switching, configuration".

The drive firmware then activates the parameter set, which is defined by the value of parameter "S-0-0217, Preselect parameter set command". The parameter set currently active is shown in parameter "S-0-0254, Current parameter set". After switching on, it is always set 0 that is active.

To minimize switching, saving and loading times for the parameter sets of a drive, the switchable parameters are firmly assigned to the following groups:

- **Application** (e.g. parameters for the limit values of torque/force, position, velocity, etc.)
- **Control loop** (e.g. parameters for gain factors of position and velocity controllers, etc.)

Parameter "P-0-2216, Parameter set switching, configuration" determines, which of the parameters groups mentioned are to be switchable. Moreover, in parameter "P-0-2217, Parameter set switching, preselection range" you can determine, how many of the parameter sets are to be used. The parameters provided for parameter set switching are shown in list parameters S-**0**-0219 to S-**7**-0219 (IDN list of the respective parameter set). These list parameters are formed by the drive in dependence upon the determinations in parameters P-0-2216 and P-0-2217.

Parameters from sets or groups that are not configured:

- are not listed in "S-0-0192, IDN-list of all backup operation data".
- are write-protected in the operating mode.

Parameters are addressed via their IDN. For the switchable parameters, the number for the respective parameter set, parameter set number (0 to 3), must be observed.

## Determining Parameter Groups

**Application Parameters**

The following switchable parameters are firmly assigned to the group "Application":

- S-0-0038, Positive velocity limit value
- S-0-0039, Negative velocity limit value
- S-0-0057, Position window
- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0091, Bipolar velocity limit value
- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0125, Velocity threshold nx
- S-0-0126, Torque threshold Tx
- S-0-0138, Bipolar acceleration limit value
- S-0-0157, Velocity window
- S-0-0193, Positioning jerk
- S-0-0261, Coarse position window
- S-0-0349, Bipolar jerk limit
- S-0-0372, Drive Halt acceleration bipolar

- S-0-0446, Ramp reference velocity for acceleration data
- S-0-0822, Torque/force ramp
- S-0-0823, Torque/force ramp time
- P-0-0041, Position command average value filter time constant
- P-0-0641, Interpolation cmd value average value filter time constant
- P-0-1201, Ramp 1 pitch
- P-0-1202, Final speed ramp 1
- P-0-1203, Ramp 2 pitch
- P-0-1211, Deceleration ramp 1
- P-0-1213, Deceleration ramp 2
- P-0-1222, Velocity command filter

**Control Loop Parameters**

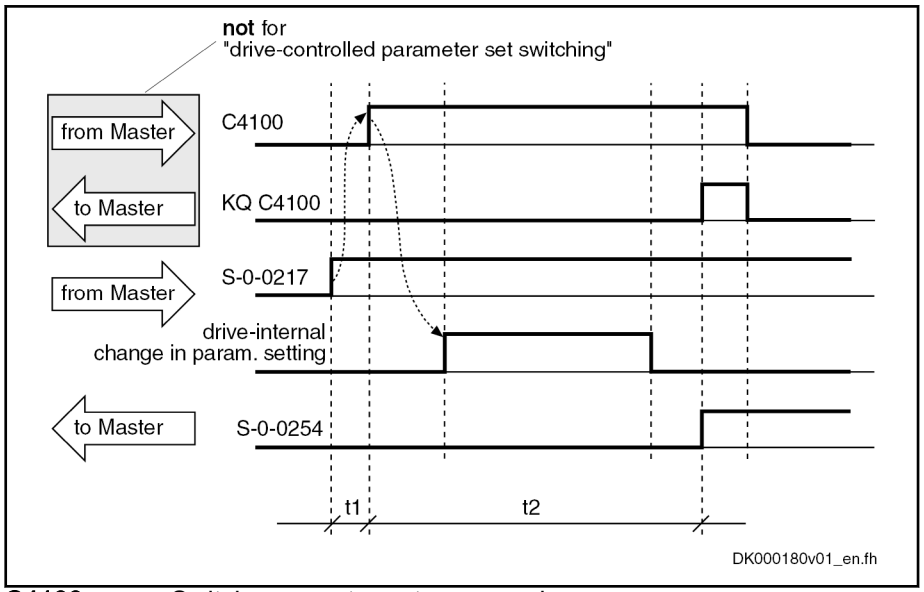
The following switchable parameters are firmly assigned to group "Control loop" (for MPB-17VRS, MPC-17VRS, MPM-17VRS only in the alternative functional packages for servo function, main spindle function and synchronization):

- S-0-0104, Position loop Kv-factor
- S-0-0826, Torque/force window
- P-0-0040, Velocity feedforward evaluation

## Conditions and Timing for Parameter Set Switching

**Parameter Groups "Application" and "Control Loop"**

The parameter sets of application and control loop parameters can be switched during operation, that is, when the drive is enabled ("AF"). For "drive-controlled parameter set switching", the timing is as follows:




| | |
|---|---|
| **C4100** | Switch parameter set command |
| **KQ C4100** | Switch parameter set command acknowledgment |
| **S-0-0217** | Preselect parameter set command |
| **S-0-0254** | Current parameter set |
| **t1** | ca. 6 ms (drive-controlled parameter set switching) |
| **t2** | ca. 5…30 ms |

*Fig. 8-19: Sequence Diagram for Switching Application and Control Loop Parameters*

Device Functions

## 8.9.3 Notes on Commissioning

**Presettings**

Preset the parameter groups to be switched in:

- P-0-2216, Parameter set switching, configuration

Determine the number of parameter sets to be switched in:

- P-0-2217, Parameter set switching, preselection range

If desired, activate "drive-controlled parameter set switching" also in parameter P-0-2216.

**Writing Switchable Parameters**

Depending on the selected presettings, in communication phase 4 those parameters can be written, the IDNs of which are displayed in parameters S-"0"-0219 to S-"7"-0219 (IDN list of respective parameter set).

---

☞ All further parameter sets, which could also be included in parameter set switching (S-1-xxxx to S-7-xxxx or P-0-xxxx to P-0-xxxx), but are not listed in S-x-0219:

- are not listed in "S-0-0192, IDN-list of all backup operation data".
- are write-protected in the operating mode.

---

**Initial State**

After switching on, it is always "parameter set 0" that is active first. Parameter "S-0-0254, Current parameter set" shows "0".

**Carrying Out Parameter Set Switching**

Before the function is activated, the number of the parameter set you wish to switch to must be entered in parameter"S-0-0217, Preselect parameter set command".

Sequence of function:

- Starting of command "C4100Switch parameter set command" (S-0-0216) via the control master
- Successful parameter set switching is checked in parameter "S-0-0254, Current parameter set" (the new parameter set number must have been acknowledged in this parameter)
- Command C4100 is cleared by control master

**Diagnostic Messages**

While the command is being executed, the display of the controllers shows the message "C41".

Possible failures are displayed by the following diagnostic messages:

- C4101 Switching only possible without AF
- C4103 Preselect parameter set forbidden value
- C4104 Error during parameter set switching (->S-0-0423)

# 9 Parameter, Diagnosis and Service Functions

## 9.1 Parameters, Basics

### 9.1.1 Properties/Features of Parameters

#### Brief Description

The controller firmware via data maps the drive to an internal mathematical model. All operating data relevant therefor are mapped to parameters. Each parameter is assigned an identification number (IDN). The IDN allows accessing operating data via

- the engineering interface (TCP/IP)

- or -

- a master communication interface suited for data transfer.

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

#### Functional Description

**Parameter Structure**

Each parameter consists of seven data block elements.

| Element no. | Description | Notes |
|---|---|---|
| 1 | Identification number (IDN) | Parameter identification/ reading of data status |
| 2 | Name | Can be changed by means of language selection |
| 3 | Attribute | Contains decimal places, data length, data type and display format, function |
| 4 | Unit | Can be changed by means of scaling or language selection |
| 5 | Minimum input value | Minimum input value of operating datum |
| 6 | Maximum input value | Maximum input value of operating datum |
| 7 | Operating datum | Parameter value |

*Tab. 9-1: Data Block Elements of a Parameter*

**Writing and Reading a Parameter**

All data block elements can be read via an appropriate interface. Only the operating datum can be written, too.

The operating datum of a parameter can be permanently write-protected or always resp. temporarily be written. The user write access to parameters depends on

- the communication phase

- and -

- the activation of a password.

Parameter, Diagnosis and Service Functions

☞ While reading and writing the operating datum, error messages can occur (see "Terms, Basic Principles: Errors").

**Data Status**

Each parameter has a data status. The data status contains information on:

- Validity/invalidity of the operating datum (parameter value)
- Status of commands (command acknowledgment) for parameters used for activating commands (see "Terms, Basic Principles: Commands").

The controller checks the data status of the parameters for validity of the operating datum when changing from parameter mode to operating mode. When this happens, the operating data (parameter values) of the parameters contained in the following list parameters are checked for validity:

- S-0-0018, IDN-list of operation data for CP2
- S-0-0019, IDN-list of operation data for CP3

The control master can query the IDNs of the parameters with invalid operating data (parameter values) via:

- S-0-0021, IDN-list of invalid operation data for CP2
- S-0-0022, IDN-list of invalid operation data for CP3
- S-0-0423, IDN-list of invalid data for parameterization levels

The data status is signaled when the control master executes a write command to the data block element no. 1 of a parameter. This allows the control master to recognize the status of a command which was started.

See "Basic Functions of Master Communication: Command Processing"

**Language Selection**

In parameter "S-0-0265, Language selection" you can set the language in which parameter names and text in units of parameter values will be displayed.

☞ The language selection made via parameter S-0-0265 will only take effect in parameter "S-0-0095, Diagnostic message", when the diagnostic message changes, too, after language selection.

**Structure of the IDN**

With regard to the IDN we distinguish between

- IDN: 16-bit value
- EIDN: 32-bit value. It can only be used in master communications with 32-bit addressing. To be able to access such parameters also in 16-bit-addressed master communications, alias parameters are available as IDN.

**IDN Structure**

| Bit no. | Value | Description |
|---|---|---|
| 15 | | Standard or product-specific IDN (S or P) |
| | 0 | Standard IDN (S-0-nnnn) |
| | 1 | Product-specific IDN (P-0-nnnn) |
| 14-12 | | Parameter sets |
| | 0-7 | Parameter set |

| Bit no. | Value | Description |
|---|---|---|
| 11-0 | | Data block or function group |
| | 0-4095 | Data block number |

*Tab. 9-2: IDN Structure*

**EIDN Structure**

| Bit no. | Value | Description | Remarks |
|---|---|---|---|
| 31-24 | | Structure instance (SI) | |
| | 0-255 | Number of structure instance (SI) | |
| 23-16 | | Structure element (SE) | |
| | 0-127 (bit 23 = 0) | Standard SE | Defined by sercos (bit 15 = 0) |
| | 128-255 (bit 23 = 1) | Product-specific SE | Defined by manufacturer (bit 15 = 0) |
| 15 | | Standard or product-specific IDN (S or P) | |
| | 0 | Standard IDN (S-0-nnnn) | SE (0-127), SI and data block number determined by sercos |
| | 1 | Product-specific IDN (P-0-nnnn) | Bit 31-0 determined by manufacturer |
| 14-12 | | Parameter sets | |
| | 0-7 | Parameter set | sercos specifies IDNs only for parameter set 0 |
| 11-0 | | Data block or function group | |
| | 0-4095 | Data block number (if SI = SE = 0)<br>Function group (if SI or SE unequal to 0) | |

*Tab. 9-3: EIDN Structure*

## Notes on Commissioning

During the drive-internal check of parameter values carried out when changing from parameter mode to operating mode, the following command errors can be signaled:

- C0201 Invalid parameters (->S-0-0423)
- C0202 Parameter limit error (->S-0-0423)
- C0203 Parameter conversion error (->S-0-0423)

When errors of this category are detected, the IDNs of the parameters with the incorrect operating data are listed in:

- S-0-0021, IDN-list of invalid operation data for CP2
- S-0-0022, IDN-list of invalid operation data for CP3
- S-0-0423, IDN-list of invalid data for parameterization levels

A valid value has to be written to the listed IDNs. The value range limits are contained in the data block elements no. 5 and no. 6. When inputting single parameters, the limits are directly displayed via the "IndraWorks Ds/D/MLD" commissioning tool.

**Language Setting**

The desired display language of parameter names and text in units of parameter values has to be set in parameter

- S-0-0265, Language selection

## 9.1.2 Loading, Storing and Saving Parameters

### Brief Description

**Parameters**

All relevant operating data are mapped to parameters and stored in the controller.

**Data Memory**

HydraulicDrive controllers are provided with

- a non-volatile memory
- 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.

**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 also be stored in the working memory (volatile memory).

**Storing Parameter Values**

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

- After initial commissioning of the machine axis
- Before replacing the controller in the case of repairs (if possible)

Application-specific parameter values can be saved via:

- Commissioning tool "IndraWorks Ds/D/MLD" → Saving of parameter values to external data carrier
- Control master → Saving parameter values on master-side data carrier

**Parameter IDN Lists**

The drive supports saving of parameter values on the master side 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 (loading of default values)
- Serial commissioning of machine axes on series machines (loading the parameter values saved after initial commissioning)
- Restoring of a defined initial state (repeated loading of the parameter values saved after initial commissioning)
- Replacing the controller in the case of a failure (loading the current parameter values saved before the failure)

Possibilities of loading parameter values to the controller:

- Commissioning tool "IndraWorks Ds/D/MLD" → Loading parameter values from an external data carrier
- Control master → Loading of parameter values from master-side data carrier

**Checksum of Parameter Values**

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

**Pertinent Parameters**

- S-0-0017, IDN-list of all operation data
- S-0-0192, IDN-list of all backup operation data
- S-0-0262, C07_x Load defaults procedure command
- S-0-0263, C2300 Load working memory procedure command
- S-0-0264, C2200 Backup working memory procedure command
- S-0-0269, Storage mode
- S-0-0270, IDN-list of selected backup operation data
- S-0-0293, C2400 Selectively backup working memory procedure command
- S-0-0326, Parameter checksum
- S-0-0327, IDN list of checksum parameter
- S-0-0531, Checksum of backup operation data
- P-0-0013, List of all IDNs not corresponding to default value
- P-0-0660.0.1, Configurable factory default values
- P-0-4023, C0400 Communication phase 2 transition
- P-0-4090, Configuration for loading default values

**Pertinent Diagnostic Messages**

Loading default values:

- C0700 Load defaults proced. Command
- C0702 Default parameters not available
- C0703 Default parameters invalid
- C0704 Parameters not copyable
- C0706 Error when reading the controller parameters
- C0730 Load defaults procedure command (MLD)
- C0740 Command Activate field bus profile settings
- C0743 Error in activation of field bus profile settings
- C0750 Load defaults procedure command (factory settings)
- C0751 Parameter default value incorrect (-> S-0-0423)
- C0752 Locked with password
- C0761 Factory default values incorrect (->S-0-0423)
- C0799 An invalid index was set

Backup working memory:

- C2202 Error when writing data to non-volatile memory
- C2200 Backup working memory procedure command

Loading working memory:

- C2300 Load working memory procedure command
- C2301 Error when reading non-volatile memory
- C2302 Error when converting parameters

Selective backup working memory:

- C2400 Selectively backup working memory procedure command
- C2402 Error when saving parameters

Further diagnostic messages:

- F2100 Incorrect access to command value memory

## Functional Description

**Parameter and Operating Mode**

Parameters the operating data of which can be changed, can be written with values in one or possibly several communication phases. We basically distinguish between

- Parameter mode (PM) and
- Operating mode (OM)

As a matter of principle, all parameters that can be changed can be written in the parameter mode.

**Storage Mode**

Depending on "S-0-0269, Storage mode", the application-specific parameter values are stored in the controller in volatile form (in the working memory) or non-volatile form (in the flash memory).

Non-volatile storage is carried out with each write access to the respective operating datum.

Volatile storage of parameter values is recommended when application-specific parameters are cyclically written. Otherwise, the service life of the non-volatile storage media is affected.

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

During the execution of some commands (see description of the respective diagnostic command message; e.g. C0500), data are written to the internal memory (flash), too. This memory, however, only allows a limited number of write accesses. For this reason, it is to be ensured that such write accesses are not carried out too often (a maximum of approx. 100,000 writing cycles).

**Parameter IDN Lists**

For saving the relevant application-specific parameter values the drive makes lists of IDNs available that support the complete storage of the values of parameter groups:

- S-0-0192, IDN-list of all backup operation data
- S-0-0270, IDN-list of selected backup operation data

Parameter S-0-0192 contains a list of IDNs that cannot be modified. Parameter S-0-0270 contains an empty list in which it is possible to enter certain IDNs according to application-specific requirements.

For saving all parameter values, the drive makes available the list of the IDNs of all parameters in

- S-0-0017, IDN-list of all operation data

To identify the parameters the value of which has changed compared to their default value, the drive makes available the parameter

- P-0-0013, List of all IDNs not corresponding to default value

**Command "backup working memory" or "selectively backup working memory"**

If the option "volatile storage" was set in parameter "S-0-0269, Storage mode", the values of the parameters contained in the list parameter S-0-0192 can be saved in the non-volatile flash memory when "S-0-0264, C2200 Backup working memory procedure command" is started.

If the parameter values of the list of S-0-0270 are to be saved, "S-0-0293 , C2400 Selectively backup working memory procedure command" must be activated. Unless the storage mode (S-0-0269) is changed, the values once

saved in the flash memory via the commands C2200 or C2400 remain unchanged.

**Command "Load Working Memory Procedure"**

By means of "S-0-0263, C2300 Load working memory procedure command", the values from the non-volatile flash memory are copied to the volatile working memory.

☞ This only makes sense when volatile storage mode was set (S-0-0269) and parameter values were saved in the controller-internal flash memory!

**Saving Application-Specific Parameter Values**

To save the application-specific parameter values, e.g. after initial commissioning, there are the following possibilities:

- **Commissioning tool "IndraWorks Ds/D/MLD"**

  → 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. This requires an engineering connection to the drive.

- **Control master**

  → The parameter values of the list of S-0-0192 or S-0-0270 and/or other parameters, if necessary, are stored on a master-side data carrier by command of the control master.

**Loading Application-Specific Parameter Values**

To load saved parameter values or transmit axis-specific parameter values to controllers of other axes, there are the following possibilities:

- **Commissioning tool "IndraWorks Ds/D/MLD"**

  → 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. This requires an engineering connection to the drive.

- **Control master**

  → The parameter values of the list of S-0-0192 or S-0-0270 and/or other parameters, if necessary, are loaded from a master-side data carrier to the controller by command of the control master.

**Parameter Checksum via List Parameter S-0-0327**

When reading the parameter "S-0-0326, Parameter checksum", the checksum of all parameter values is generated, the IDNs of which are contained in parameter "S-0-0327, IDN list of checksum parameter". Changes in the parameter settings can be detected by comparing the checksums.

By comparing the checksum of the parameter values currently active in the drive to a checksum value stored at the time of parameter saving, it is possible to determine whether the active application-specific parameter values are correct.

By default, there haven't any IDNs been entered in parameter S-0-0327!

**Parameter Checksum via List Parameter S-0-0192**

When reading the parameter "S-0-0531, Checksum of backup operation data", the checksum of the parameters is generated, the IDNs of which are contained in parameter "S-0-0192, IDN-list of all backup operation data".

☞ In list parameter S-0-0192, the IDNs of those parameters are stored the values of which are axis-specific and have to be loaded to the drive of the respective axis for regular operation.

When the installation has been completely set up, the checksum for each drive can be read via the parameter S-0-0531. The control master can store these values. By comparing the checksum which was saved to the new

checksum which was read, it is possible to find out whether data relevant to operation have changed.

## Notes on Commissioning

**Initial Commissioning**

At the beginning of initial commissioning of 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 or firmware upgrade (see "Firmware Replacement").

**Loading Default Values**

If the desired firmware is available in the controller, load basic parameter values of the firmware by carrying out the following steps:

1. Make determinations in parameter "P-0-4090, Configuration for loading default values"
2. Start "S-0-0262, C07_x Load defaults procedure command"

Associated diagnostic command message:

- C0750 Load defaults procedure command (factory settings)

Associated diagnostic messages in the case of possible command errors:

- C0751 Parameter default value incorrect (-> S-0-0423)
- C0752 Locked with password

See also "Initial Commissioning/Serial Commissioning"

**With Storage Mode "Volatile Storage"**

When the option "volatile storage" was set in parameter "S-0-0269, Storage mode", the parameter values are not automatically stored in the drive-internal flash memory. After complete input, the application-specific parameter values therefore have to be saved drive-internally in the flash memory by

- starting "S-0-0264, C2200 Backup working memory procedure command"

This guarantees that the parameter values suitable for the axis are automatically loaded to the controller's working memory from the flash memory after the drive is switched on again.

Associated diagnostic command message:

- C2200 Backup working memory procedure command

Associated diagnostic messages in the case of possible command errors:

- C2202 Error when writing data to non-volatile memory

After all application-specific parameter values are saved (C2200), it is also possible to only save selected parameter values in the flash memory. These parameters are overwritten with a current value. This is done by

- starting "S-0-0293, C2400 Selectively backup working memory procedure command"

The C2400 command can be used for internally saving a parameter group the values of which have to be optimized again during operation, for example. It is advisable to determine the IDNs of this parameter group by clearing IDNs that are not required from the default setting of the list parameter

- S-0-0270, IDN-list of selected backup operation data

In the case of the "volatile storage" mode, the command C2200 has to be executed at least once before starting the command C2400, because otherwise basic parameter values are maintained for some parameter values in the flash memory.

Associated diagnostic command message:

- C2400 Selectively backup working memory procedure command

Associated diagnostic messages in the case of possible command errors:

- C2402 Error when saving parameters

**Loading and Saving Parameter Values via Control Master or "IndraWorks Ds/D/MLD"**

An appropriate master communication interface or the serial interface can be used for loading and saving parameter values via the control master or "IndraWorks Ds/D/MLD".

## 9.1.3 IDN Lists of Parameters

### General Information

Some of the parameters stored in the drive contain, as their operating data (parameter value), a list of IDNs of drive parameters corresponding to a specific, given criterion. These so-called IDN lists enable the master or a commissioning software to handle drive parameters in a specific way.

### IDN List of All Operation Data (S-0-0017)

The parameter "S-0-0017, IDN-list of all operation data" contains the IDNs of all parameters available in the drive.

### IDN List of Backup Operation Data (S-0-0192)

Parameter "S-0-0192, IDN-list of all backup operation data" contains the IDNs of all parameters that are stored in the non-volatile memory (flash memory). These parameters are required for correct operation of the drive. With the master or a commissioning software, it is possible to use this IDN list for making a backup copy of the drive parameters.

### IDN List of Invalid Operation Data for CP2 (S-0-0021)

In parameter "S-0-0021, IDN-list of invalid operation data for CP2", the IDNs of those parameters are automatically entered which the drive software detects as being invalid when executing the command "S-0-0127, C0100 Communication phase 3 transition check".

Parameters are detected as being invalid, if:

- Their checksum does not match the operating datum [the checksum is stored together with the operating datum in a non-volatile memory (flash memory, amplifier or encoder data memory)]

- or -

- Their operating datum is outside of the minimum or maximum input limits

- or -

- Their operating datum violates specific validation rules.

In any event, the parameters entered in parameter "S-0-0021, IDN-list of invalid operation data for CP2" upon negative acknowledgment of the command "S-0-0127, C0100 Communication phase 3 transition check" must be corrected.

### IDN List of Invalid Operation Data for CP3 (S-0-0022)

In parameter "S-0-0022, IDN-list of invalid operation data for CP3", the IDNs of those parameters are automatically entered which the drive software detects as being invalid or unduly configured when executing the command "S-0-0128, C5200 Communication phase 4 transition check".

Parameters are detected as being invalid, if:

- Their checksum does not match the operating datum [the checksum is stored together with the operating datum in a non-volatile memory (flash memory, amplifier or encoder data memory)]

- or -

- Their operating datum is outside of the minimum or maximum input limits

- or -

- Their operating datum violates specific validation rules.

Parameters are detected as being unduly configured, if

- they were configured more than once for writing by a cyclic interface.

In any event, the parameters entered in parameter "S-0-0022, IDN-list of invalid operation data for CP3" upon negative acknowledgment of the command "S-0-0128, C5200 Communication phase 4 transition check" must be corrected.

## IDN List of Invalid Data for Parameterization Levels (S-0-0423)

When the command "C0200Exit parameterization level procedure command" is executed, the drive parameters are checked and converted. If errors occur during this check, the IDNs of the faulty parameters are written to the list parameter "S-0-0423, IDN-list of invalid data for parameterization levels".

## IDN List of Operation Data for Communication Phase 2 (S-0-0018)

The IDNs that are checked for validity when the command "S-0-0127, C0100 Communication phase 3 transition check" is executed are stored in the operating datum of parameter "S-0-0018, IDN-list of operation data for CP2".

## IDN List of Operation Data for Communication Phase 3 (S-0-0019)

The IDNs that are checked for validity when the command "S-0-0128, C5200 Communication phase 4 transition check" is executed are stored in the operating datum of parameter "S-0-0019, IDN-list of operation data for CP3".

## IDN List of All Command Parameters (S-0-0025)

The operating datum of parameter "S-0-0025, IDN-list of all procedure commands" contains the IDNs of all parameters available in the drive.

## Selected IDN List of Operation Data to Backup (S-0-0270)

The IDNs of those parameters that are to be saved when the command "S-0-0293, C2400 Selectively backup working memory procedure command" is executed are stored in parameter "S-0-0270, IDN-list of selected backup operation data".

## IDN List of Password-Protected Operation Data (S-0-0279)

The parameter "S-0-0279, IDN-list of password-protected operation data" contains the IDNs of those parameters that can be protected by a customer password (S-0-0267). By default, there haven't been any IDNs entered in this parameter.

## IDN List of Checksum Parameter (S-0-0327)

The parameter "S-0-0327, IDN list of checksum parameter" contains the IDNs of those parameters from which the content of parameter "S-0-0326, Parameter checksum" is to be generated. By default, there haven't been any IDNs entered in this parameter.

### IDN List of all Parameter Values not Corresponding to Default Value (P-0-0013)

All parameters the operating datum 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".

## 9.1.4 Password Protection

### Brief Description

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

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

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

- **Customer password**

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

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

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



The customer password can be defined by the customer, the control password and the master password are defined by the manufacturer!

**Pertinent Parameters**

- S-0-0192, IDN-list of all backup operation data
- S-0-0267, Password
- S-0-0279, IDN-list of password-protected operation data
- P-0-4064, Password level

### Functional Description

The activation and deactivation of the write protection for parameter values by the three hierarchically different passwords is carried out by an input in parameter "S-0-0267, Password".

**Customer Password**

By a password defined by the customer, the parameters of a parameter group to be defined can be protected against unauthorized or accidental write access.

The customer password has to comply with the following conditions:

- At least 3 characters long
- A maximum of 10 characters long

- May only 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 contain any IDN. In the list parameter S-0-0279 it is possible to enter parameter IDNs according to application-specific requirements.

☞ The customer password is not obligatory! If it has not been activated, the values of the parameters listed in the list parameter S-0-0279 can still be written.

**Control Password**

After entering the firmware-specific control password defined by the manufacturer, it is also possible to write parameters protected by a customer password. The control password therefore allows the NC control unit to ignore the write protection established by the individual (unknown) customer password.

☞ The control password valid for the respective firmware is only available from the manufacturer on demand!

**Master Password**

The master password is defined by the manufacturer, too, but is exclusively available to development and service staff of Rexroth .

☞ 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" (valve parameters, hardware code parameters, error memory, etc.).

**Activating/Deactivating the Write Protection**

In the condition as supplied, "S-0-0267, Password" contains the value "007". The write protection is activated and deactivated by means of the customer password according to the following procedure:

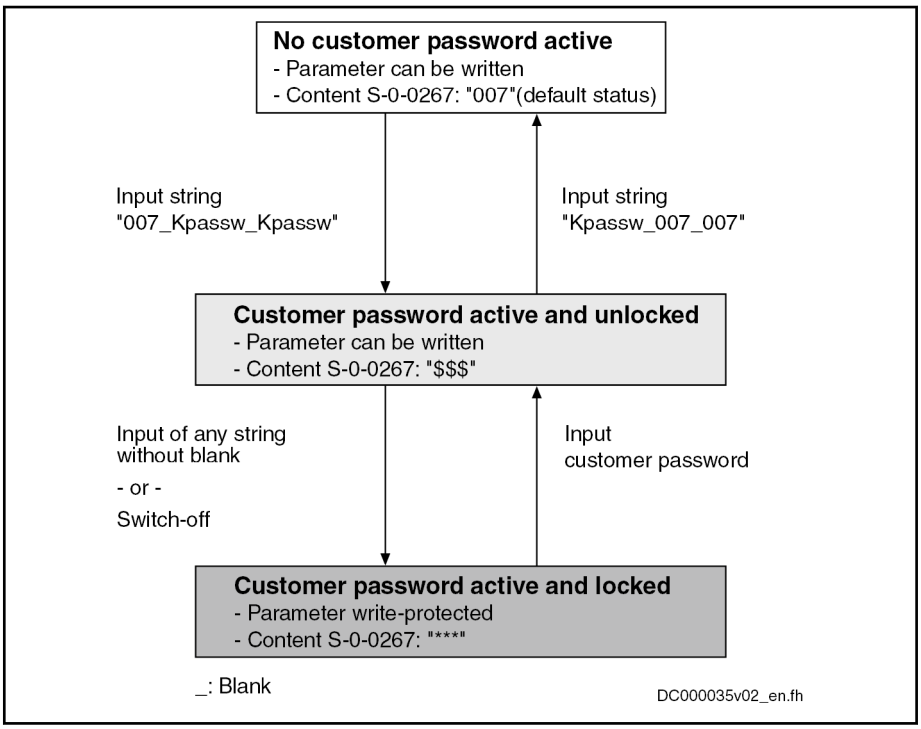



*Fig. 9-1: Activating and Deactivating the Write Protection by Means of the Customer Password*

The write protection activated via customer password is deactivated by means of the control password by entering the control password in S-0-0267. The write protection required by the customer can be activated again by entering any string in S-0-0267.

The write protection for all parameters that can basically be written can only be deactivated by means of the master password and the right to do this is exclusively reserved to the Rexroth development and service staff!

***NOTICE*** **Incorrect control of drives when changing parameter values write-protected on the firmware side ("administration parameters")!**

⇒ The master password mustn't be used on the control unit side or by the customer!

### Notes on Commissioning

Define the IDNs of the group of parameters the values of which are to be write-protected in parameter

- S-0-0279, IDN-list of password-protected operation data

The customer-side write protection via the customer password for the parameters contained in S-0-0279 can be activated and deactivated by writing the parameter

- S-0-0267, Password

☞ Observe the conditions for defining the customer password!

If the active write protection for the parameters defined in S-0-0279 is to be disabled on the master side or without knowledge of the customer password, enter the control password in parameter

- S-0-0267, Password

☞ Ask the manufacturer for the control password!

**Status Query for Write Protection**

The current status of the write protection can be queried via parameter

- P-0-4064, Password level

**Diagnostics**

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.

## 9.1.5 Reset to Default Values

By executing command S-0-0262, "C07_x Load defaults procedure command" a defined initial state of the parameter values can be restored.

The scope of functions of this command can be determined by configuring the parameter P-0-4090 "Configuration for loading default values".

- **Command selection** (bit 0...3):
  - Load default values (factory settings)

    Loading non-volatile parameters to their default values.
  - Load default values (MLD)

Resetting of parameters (incl. boot project) of the PLC integrated in the drive

– Activate field bus profile settings

Field bus-related parameters are activated in dependence on their profile

→ see "Profile Types (with Field Bus Interfaces)"

- **Scaling of command execution** (bit 4...8):

With the command “load default values”, you have the option to load default values for all parameters or to selectively exclude the following groups, for example:

– Master communication parameters
– MLD parameters
– Engineering interface

See also Parameter Description "P-0-4090, Configuration for loading default values"

## 9.1.6 Command Processing

### Overview

Commands are used to control complex functions in the drive. For example, the functions "drive-controlled homing procedure" or "transition check for communication phase 3 to 4" are defined as commands.

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

**Types of Commands**

Three types of commands are distinguished:

- **Drive control commands**
  – can cause automatic drive motion,
  – can only be started when drive enable has been set
  – deactivate the active operation mode while they are executed.
- **Administration commands**
  – carry out administration task,
  – cannot be interrupted

### Command Execution

**General Information**

Observe the following aspects for command execution:

- Belonging to each command there is a parameter with which the command execution can be controlled.
- The higher-level master can start, interrupt or clear commands.
- While the command is being executed, parameter S-0-0390 Diagnostic message number displays the complete command.
- Each command that was started by the master must be actively cleared again.

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

⇒ During the execution of some commands (see description of the respective diagnostic command message; e.g. "C0500Reset class 1 diagnostics, error reset"), data are written to the internal memory (flash), too. This memory, however, only allows a limited number of write accesses. For this reason, it is to be ensured that such write accesses are not carried out too often (a maximum of approx. 100,000 writing cycles).

**Controlling the Command Execution**

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

Commands are started or terminated by:

- Direct writing of the respective command parameter (e.g. "S-0-0099, C0500 Reset class 1 diagnostics" with command "C0500Reset class 1 diagnostics, error reset") via master communication

- or -

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

  See also chapter:

  – "Configurable Signal Control Word"

  – "Digital Inputs/Outputs"

**Possible Command Inputs**

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

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

**Command Acknowledgment**

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

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

**Command Status**

The command status can be:

- **0x0:** Not set and not enabled
- **0x7:** In process
- **0xF:** Error, command execution impossible
- **0x5**: Command execution interrupted
- **0x3:** Command correctly executed

## Command Change Bit

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

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

– Error, command execution impossible (0xF)

- or -

– Command correctly executed (0x3)

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



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

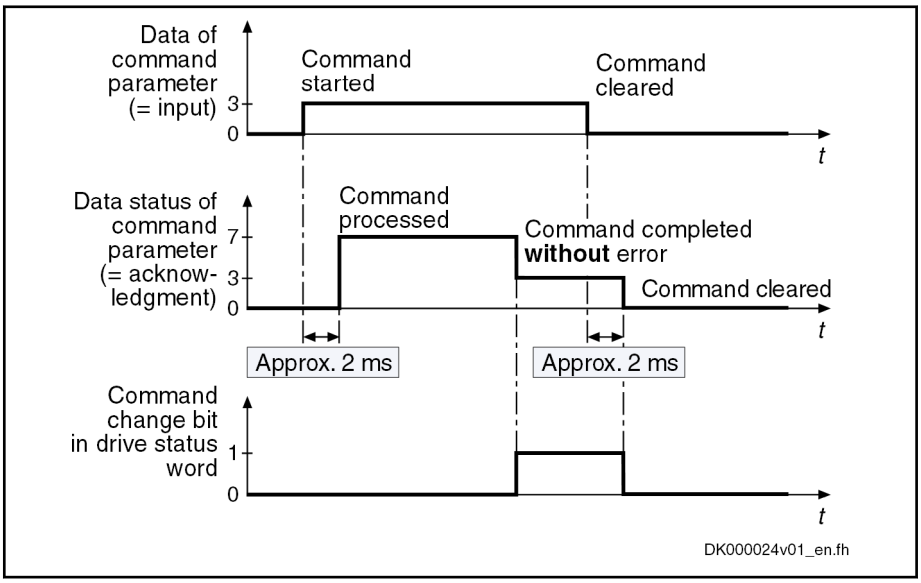



*Fig. 9-2: Input, Acknowledgment and Command Change Bit in the Case of Correct Execution*

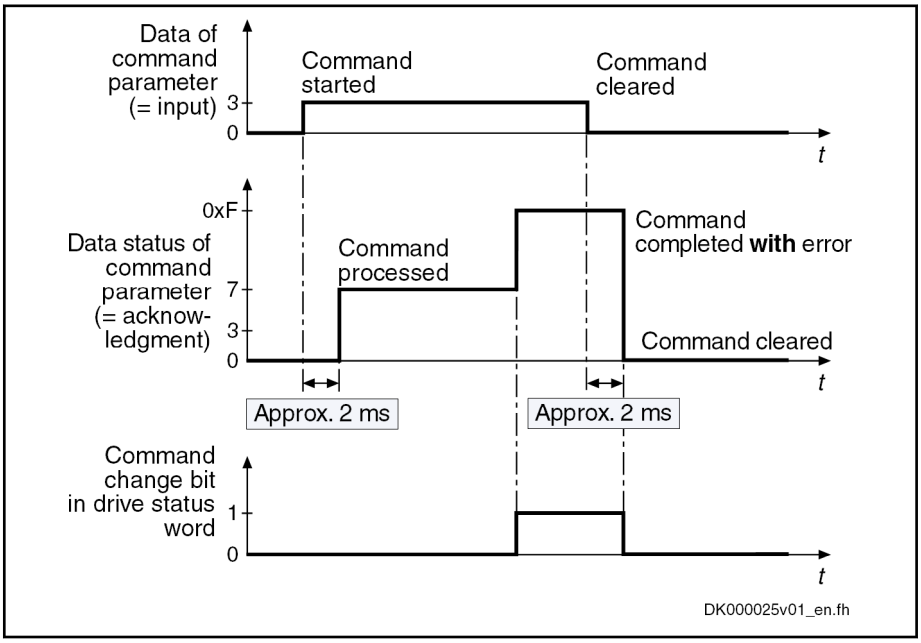



*Fig. 9-3: Input, Acknowledgment and Command Change Bit in the Case of Incorrect Execution*

# 9.2 Diagnostic System

## 9.2.1 Coded Diagnostic Messages of the Drive

### Brief Description

The drive provides a diagnostic system including different options that are basically subdivided into two groups:

- Recognizing and displaying the current drive status by means of drive-internal, priority-dependent generation of diagnostic messages



From HDx18 onwards, the diagnostic message number is generated according to the sercos specification. For this, bits 31-24, too, are written in parameter "S-0-0390, Diagnostic message number". In predecessor versions, these were always "0". In IndraWorks dialogs, these bits are hidden. In these dialogs, the representation remains unchanged.

- Collective messages for various status messages

Moreover, there are parameters for all important operating data, the values of which can be transmitted either via master communication (e.g. sercos) or via a parameter interface.

**Pertinent Parameters**

- S-0-0030, Manufacturer version
- S-0-0095, Diagnostic message
- S-0-0140, Controller type
- S-0-0375, Diagnostic numbers list
- S-0-0390, Diagnostic message number
- S-0-1302.0.3, Application type

  (S-0-0142 is provided only as legacy (or alias) parameter for S-0-1302.0.3.)
- P-0-0478, Logbook event
- P-0-0479, Logbook time stamp

### Drive-Internal Generation of Diagnostic Messages

Operational states, activities and reactions of the drive controller are acquired through drive-internal generation of diagnostic messages. These diagnostic messages can be transferred to a master (control) and displayed and evaluated in service and commissioning software (e.g., "IndraWorks Ds/D/MLD").

We distinguish the following categories of diagnostic messages (kinds of diagnostic messages):

- Error
- Warnings
- Commands/command errors
- Status displays/operational states

Generally, the current diagnostic message with the highest priority is displayed at the following locations in the drive:

- **Parameter "S-0-0095, Diagnostic message"**

  → This parameter contains the currently relevant operational status of the drive in the form of plain text. Preceding the text is the respective content of parameter S-0-0390 in short form.
- **Parameter "S-0-0390, Diagnostic message number"**

→ The number of the diagnostic message is stored in this parameter.

In parameter "S-0-0375, Diagnostic numbers list", the last 50 diagnostic message numbers of parameter S-0-0390 are recorded in chronological order. When reading this list, the number of the diagnostic message that occurred last is displayed as parameter element 0.

## Structure of a Diagnostic Message

### General Information

Every diagnostic message consists of

- Diagnostic message number

  - and -

- diagnostic text.

The diagnostic message for the non-fatal error "F2028, Excessive deviation", for example, has the following structure:

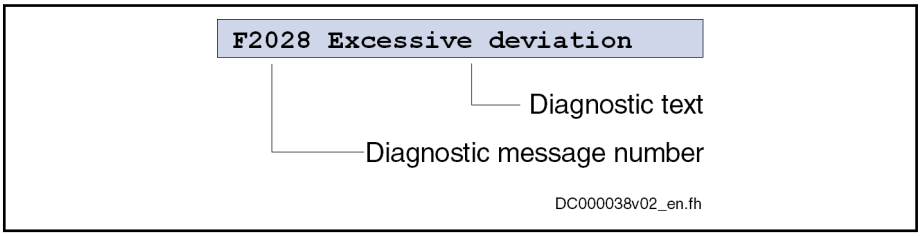



*Fig. 9-4: Structure of a Diagnostic Message*

The diagnostic message number is contained in parameter "S-0-0390, Diagnostic message number" in hexadecimal form (for this example: 0xC00F2028). Parameter "S-0-0095, Diagnostic message" contains the diagnostic message number and the diagnostic text as string "F2028Excessive deviation".

### Diagnostic message in plain text

The diagnostic message in plain text contains the diagnostic message number followed by the diagnostic message text. It can be read via parameter "S-0-0095, Diagnostic message" and directly displayed on an operator interface as a language-dependent description of the drive status.

The diagnostic message in plain text is switched to the selected language via parameter "S-0-0265, Language selection".

### Diagnostic message number

The diagnostic message number contains only the diagnostic number without the diagnostic text. It can be read via parameter "S-0-0390, Diagnostic message number" and is a language-independent possibility of determining and displaying the drive status on an operator interface.

### List of diagnostic message numbers

The last 50 diagnostic message numbers displayed are stored in chronological order in parameter "S-0-0375, Diagnostic numbers list". Every change in the content of "S-0-0390, Diagnostic message number" means that the old content is applied to S-0-0375. When reading parameter S-0-0375, the last transferred diagnostic message number appears in the first element of the parameter, the diagnostic message number transferred before from S-0-0390 in the second element, etc.

### Language Selection

Via parameter "S-0-0265Language selection", it is possible to define or change the language of diagnostic message texts.

See also Parameter Description "S-0-0265, Language selection"

## 9.2.2 Status Classes, Status Displays, Control Parameters

### General Information

In the drive there are many parameters that contain important status information (bit lists). Some of the bits contained in these lists can be used for configuring real-time status bits and additionally can be assigned to digital outputs or to the configurable signal status word.

See "Digital Inputs/Outputs"

See "Configurable Signal Status Word"

The statuses of errors, warnings and messages are distinguished in the drive (diagnostic classes).

Within the drive, there are parameters

- with direct reference to the status of the sequence of various functions (fixed status displays)
- for controlling the drive functions (control parameters)

### Status Classes

#### Brief Description

The drive differentiates between 3 states (error, warning and message) for which there is status information. To make the status information available, there are so-called class diagnostics parameters (S-0-0011, S-0-0012, S-0-0013) which contain the respective status bits.

In addition to these class diagnostics parameters, there are change bits contained in the status word of the field bus (e.g. S-0-0135 in the case of sercos) which display changes in one of the above-mentioned class diagnostics parameters (collective information).

**Features**

- Class diagnostics parameter for **errors** (cf. S-0-0011)
- Class diagnostics parameter for **warnings** (cf. S-0-0012)
- Class diagnostics parameter for **messages** (cf. S-0-0013)
- **Change bits in status word** of master communication (e.g. S-0-0135 in case of sercos)
- Change bits of class 2 and 3 diagnostics (S-0-0097 and S-0-0098) **can be masked** in the status word of master communication (e.g. S-0-0135 in case of sercos) to suppress individual bits or status messages

**Pertinent Parameters**

- S-0-0011, Class 1 diagnostics
- S-0-0012, Class 2 diagnostics
- S-0-0013, Class 3 diagnostics
- S-0-0097, Mask class 2 diagnostics
- S-0-0098, Mask class 3 diagnostics
- S-0-0135, Drive status word

#### Functional Description

**Status Class Parameters**

- **S-0-0011, Class 1 diagnostics** (status parameter for drive errors)

– In case a drive error occurs, the bit assigned to the error is set in parameter S-0-0011. A separate bit is assigned in S-0-0011 to errors defined according to sercos.

  Manufacturer-specific errors cause bit 15 to be set in parameter S-0-0011 (see also Parameter Description "S-0-0011, Class 1 diagnostics").

– In case a drive error occurs, bit 13 (drive lock-out; error in class 1 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in the case of sercos).

---

☞ All bits in class 1 diagnostics are cleared by executing the command C0500 (reset class 1 diagnostics).

See also Parameter Description "S-0-0099, C0500 Reset class 1 diagnostics"

---

- **S-0-0012, Class 2 diagnostics** (status parameter for drive warnings)
  – In case a drive warning occurs, the bit assigned to the warning is set in parameter S-0-0012. A separate bit is assigned in S-0-0012 to warnings defined according to sercos.

    Manufacturer-specific warnings cause bit 15 to be set in parameter S-0-0012 (see also Parameter Description "S-0-0012, Class 2 diagnostics").

  – In case a drive warning occurs, bit 12 (change bit class 2 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in 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 master communication (S-0-0135 in case of sercos) remains, however, set until parameter S-0-0012 has been read once.

---

☞ Via parameter "S-0-0097, Mask class 2 diagnostics", warnings can be masked in terms of their effect on the change bit.

---

- **S-0-0013, Class 3 diagnostics** (status parameter for drive messages)
  – Messages of the drive are listed in parameter S-0-0013. A separate bit is assigned in S-0-0013 to messages defined according to sercos (see also Parameter Description "S-0-0013, Class 3 diagnostics").

  – If a drive message occurs, bit 11 (change bit class 3 diagnostics) is simultaneously set in the status word of the field bus (S-0-0135 in case of sercos).

  – The bits in parameter S-0-0013 are automatically cleared when the message disappears. The change bit in the status word of master communication (S-0-0135 in case of sercos) remains, however, set until parameter S-0-0013 has at least been read once.

---

☞ Each of these messages is stored in a separate parameter (S-0-0330 to S-0-0342).

---

**Change Bits in Drive Status Word**

If the status of a bit in "S-0-0012, Class 2 diagnostics" or "S-0-0013, Class 3 diagnostics" changes, the change bit for class 2 or 3 diagnostics is set in the field bus status word (e.g., S-0-0135 in case of sercos). A change bit in the

status word (bit 11 or 12) is always set due to a change of the parameter content of S-0-0012 or S-0-0013. This enables the master to recognize very quickly whether a change occurred in S-0-0012 or S-0-0013.

A read access to one of the two parameters clears the respective change bit again.

**Masking the Change Bits**

By means of parameters "S-0-0097, Mask class 2 diagnostics" and "S-0-0098, Mask class 3 diagnostics", it is possible to mask certain bits with regard to 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:

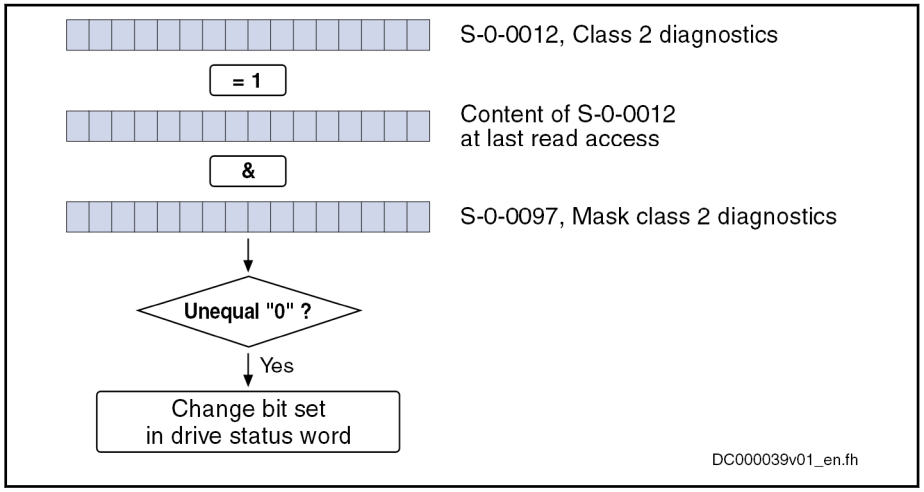



*Fig. 9-5: Generating the Change Bit of Class 2 Diagnostics*

## Notes on Commissioning

The figure below illustrates handling of the change bits in the status word and of the status class parameters:

Parameter, Diagnosis and Service Functions

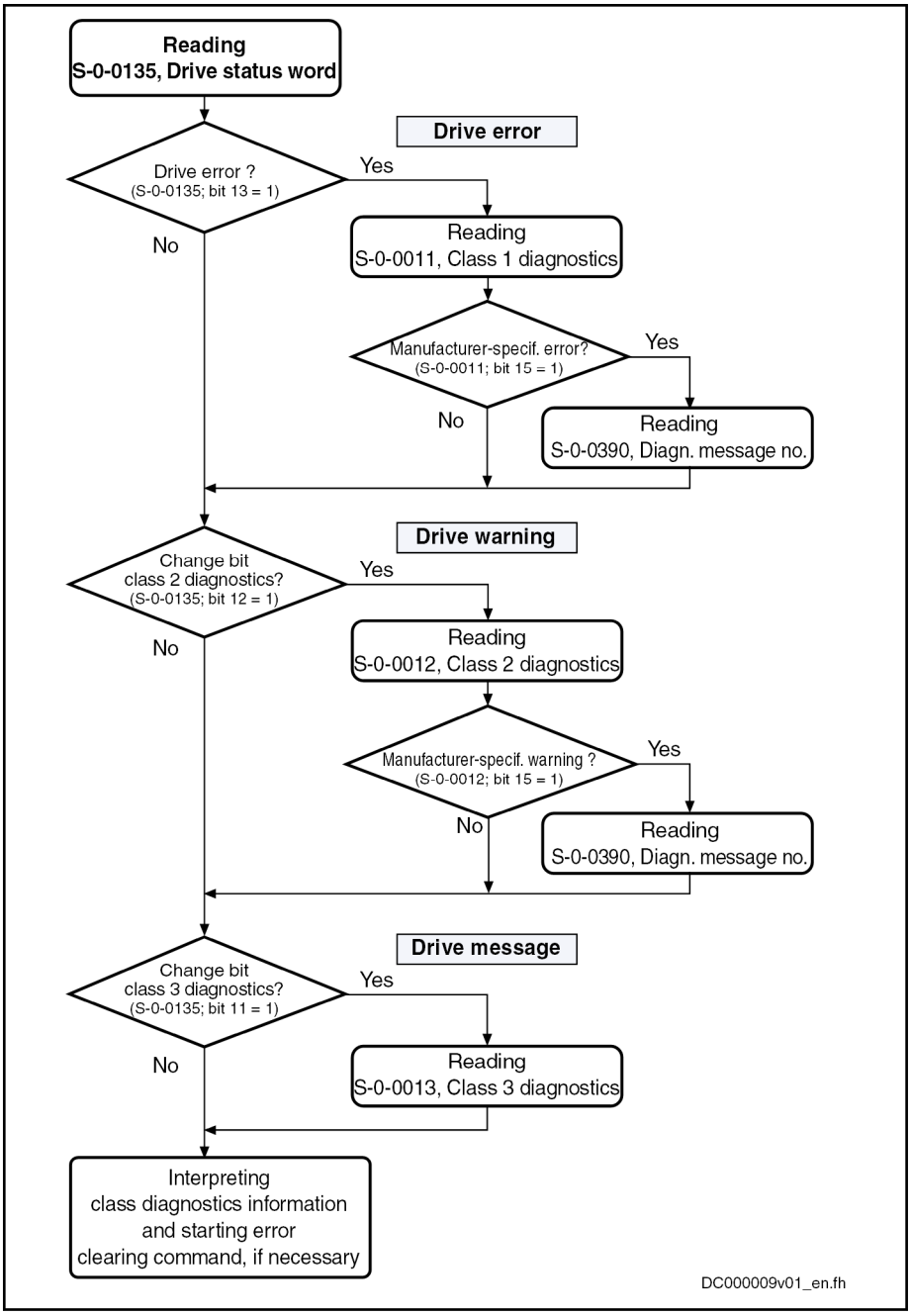



*Fig. 9-6: Handling the Change Bits and Status Class Parameters*

## Fixed Status Displays

### Function-Related Status Parameters

The drive contains parameters the content of which has a direct relation to the status of the sequence of various 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 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-0-0115, Device control: Status word**

  This parameter contains status bits of the device control (see also "Device Control and State Machines").

- **P-0-0222, Travel range limit switch inputs**

  This parameter displays the status of the travel range limit switch inputs.

- **P-0-0223, E-Stop input**

  This parameter displays the status of the E-Stop input.

- **P-0-0555, axis controller messages**

  This parameter displays messages with regard to velocity and limits that have been reached.

- **P-0-4029, Diagnostic report SCSB module**

  Parameter for reading master communication settings and states (with sercos).

- **P-0-4086, Master communication status**

  This parameter displays control information of the master communication for handling the phase switch, drive enable, etc., defined during initialization.

### Status Parameters for Real-Time Status Bits

The following list contains status parameters that only contain one bit and can therefore be used for configuring real-time status bits (see "sercos":

- S-0-0330, Status "n_feedback = n_command"
- S-0-0331, Status "n_feedback = 0"
- S-0-0332, Status "n_feedback < nx"
- S-0-0333, Status "T >= Tx"
- S-0-0334, Status "T >= Tlimit"
- S-0-0335, Status "n_command > n_limit"
- S-0-0336, Status "In position"
- S-0-0341, Status "In coarse position"
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"

## Control Parameters

Apart from the parameters for status display, there are parameters available in the drive that are used to control the drive functions (see also description of the relevant parameter):

- P-0-0556, Config word of axis controller
- P-0-4028, Device control word

Parameter, Diagnosis and Service Functions

## 9.2.3 Operating Hours Counter

### Brief Description

An operating hours counter (P-0-0190) is available in the drive.

**Pertinent Parameters**

- P-0-0190, Operating hours control section

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.

☞ Before the devices are dispatched, the counter is set to a defined value and can therefore indicate the total operating hours of a component in the field.

☞ Every 30 seconds, the operating hours counter is permanently saved in the device. This forms the starting value at the next power-on.

## 9.2.4 Error and Diagnostic Memory

### Brief Description

In the drive, all errors occurred are logged in an error memory on the control section.

☞ When an error occurs, the diagnostic message number and the current count of the operating hours counter are automatically stored.

**Pertinent Parameters**

- S-0-0390, Diagnostic message number
- P-0-0190, Operating hours control section
- P-0-0192, Error memory of diagnostic numbers
- P-0-0193, Error memory operating hours of control 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 is saved in parameter "S-0-0390, Diagnostic message number" (in "hex format"),
- the plain text of the diagnostic message is stored in parameter "S-0-0095, Diagnostic message",
- the content of parameter "P-0-0190, Operating hours control section" at the time the error is detected is stored in parameter "P-0-0193, Error memory operating hours of control section",
- the diagnostic message number belonging to the error according to parameter "S-0-0390, Diagnostic message number" is stored in parameter "P-0-0192, Error memory of diagnostic numbers" in the same order.

The parameters P-0-0192 and P-0-0193 have a stack structure and contain, in chronological order, the diagnostic message numbers or the counts of the operating hours counter of the last **50 errors** that occurred.

☞ The count of the operating hours counter at the time the last error occurred is entered at the top of parameter P-0-0193, and the diagnostic message number of the last error occurred at the top of parameter P-0-0192.

## 9.2.5 Diagnostic LED

### Brief Description

#### General Information

The module status LED indicates the current state of the HDx firmware (e.g. PM, error present) in the form of blinking codes or permanent illumination. The module status LED can light up in the following 3 colors:

- Green
- Red
- Orange

Due to the specifications from the standard of Ethernet/IP, two indicator modes were implemented for the module status LED:

- Indication for Ethernet/IP in conformity with standard
- Extended indication for other bus systems

#### Indication of module status LED

When the bus system Ethernet/IP is active, the indication complies with the stipulations in the standard for module status LEDs. When another bus system is active, an extended indication is active, which also utilizes the color orange. The two indicator modes are summarized in the following table.

| Drive status | Module status LED with Ethernet/IP (indication in conformity with standard) | | | | Module status LED with other bus systems (extended indication) | | | |
|---|---|---|---|---|---|---|---|---|
| De-energized (ENIP: No power) | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF |
| Command active | - - - | - - - | - - - | - - - | GREEN | GREEN | OR | OR |
| Command error | - - - | - - - | - - - | - - - | OR | OFF | OFF | GREEN |
| PM (ENIP: Standby) | GREEN | OFF | GREEN | OFF | GREEN | OFF | GREEN | OFF |
| Bb (drive ready for operation) (ENIP: Standby) | GREEN | OFF | GREEN | OFF | GREEN | OFF | GREEN | OFF |
| Ab (drive ready, power on) (ENIP: Operational) | GREEN | GREEN | GREEN | GREEN | GREEN | GREEN | GREEN | GREEN |
| AH (Drive Halt) (ENIP: Operational) | GREEN | GREEN | GREEN | GREEN | GREEN | GREEN | GREEN | GREEN |
| AF (drive in control) (ENIP: Operational) | GREEN | GREEN | GREEN | GREEN | GREEN | GREEN | GREEN | GREEN |
| F2 non-fatal errors (ENIP: Minor recoverable fault) | RED | OFF | RED | OFF | RED | OFF | RED | OFF |
| F4 communication error (ENIP: Minor recoverable fault) | RED | OFF | RED | OFF | RED | OFF | RED | OFF |
| F6 travel range error (ENIP: Minor recoverable fault) | RED | OFF | RED | OFF | RED | OFF | RED | OFF |
| F8 fatal errors (ENIP: Minor recoverable fault) | RED | OFF | RED | OFF | RED | OFF | RED | OFF |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| F9 fatal system errors (ENIP: Major unrecoverable fault) | RED | RED | RED | RED | RED | RED | RED | RED |
| E2 drive warning | - - - | - - - | - - - | - - - | OR | OFF | OFF | OFF |
| E4 communication warning | - - - | - - - | - - - | - - - | OR | OFF | OFF | OFF |
| E6 travel range warning | - - - | - - - | - - - | - - - | OR | OFF | OFF | OFF |
| E8 fatal warning | - - - | - - - | - - - | - - - | OR | OR | OR | OR |
| Reloading process (LW/FW) (ENIP: Self-test) | GREEN | RED | GREEN | RED | GREEN | RED | GREEN | RED |
| FW update active | GREEN | GREEN | OR | OR | GREEN | GREEN | OR | OR |
| FW update error | RED | OR | RED | OR | RED | OR | RED | OR |
| Boot kernel error | RED | RED | RED | RED | RED | RED | RED | RED |
| | 0.5 s | 0.5 s | 0.5 s | 0.5 s | 0.5 s | 0.5 s | 0.5 s | 0.5 s |

*Tab. 9-4: Indication modes of module status LED*

During EtherNet/IP startup an LED test (green/red flashing) takes place.

# 9.3 Oscilloscope Function

## 9.3.1 Functional Description

The oscilloscope function can be used to record drive-internal and external status variables (parameter contents). This function can be effectively used both for initial commissioning and troubleshooting. Its functionality can be compared to that of an 8-channel oscilloscope.

The total scope of the oscilloscope function is divided into the following function blocks:

- **Measured value recording**

  It is possible to record 8 channels at the same time, with the signals being selected by configuration of signal selection lists (IDN lists).

- **Configuration (basic settings)**

  The control/status block determines the basic functions (start/stop, time resolution, size of memory, operation mode). Generally, 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:

- **Measured value recording**
  - 8 channels, each with a maximum of 8192 measured values (the total number of values must not exceed 32768).
  - Time resolution to be freely selected in steps of the position controller clock cycle (see "Performance Data")
  - In expert mode, shorter time resolutions possible
  - Signal selection by indicating the IDN of the respective parameter
- **Configuration (basic settings)**

  - Multiple-channel display in "IndraWorks Ds/D/MLD"
  - More than 100 different measuring and trigger signals (cf. P-0-0149)
  - Expanded oscilloscope function using patch function
- **Trigger function**
  - Trigger signal selection by indicating 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

Parameter, Diagnosis and Service Functions

## 9.3.2 General Information on the Oscilloscope Function

### Sequence of a Measurement (State Diagram)

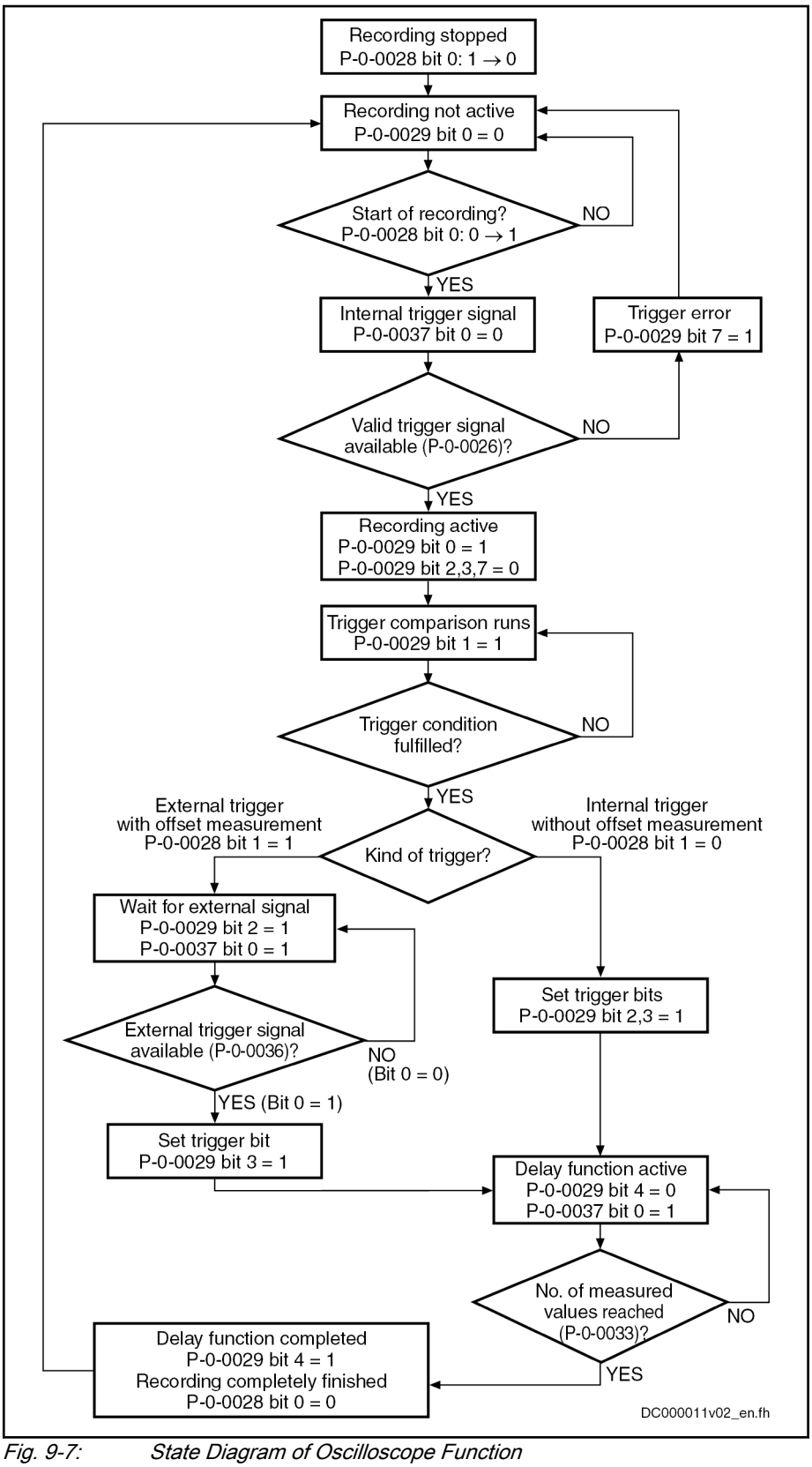



*Fig. 9-7: State Diagram of Oscilloscope Function*

## Configuring the Measured Value Channels

A measured value channel is configured by inputting the IDN of the desired parameter in the respective signal selection parameter:

- P-0-0023, Oscilloscope: Signal selection 1
- P-0-0024, Oscilloscope: Signal selection 2
- P-0-0147, Oscilloscope: Signal selection 3
- P-0-0148, Oscilloscope: Signal selection 4
- P-0-0270, Oscilloscope: Signal selection 5
- P-0-0271, Oscilloscope: Signal selection 6
- P-0-0272, Oscilloscope: Signal selection 7
- P-0-0273, Oscilloscope: Signal selection 8

**Signal Selection List (P-0-0149)**

All IDNs contained in parameter "P-0-0149, Oscilloscope: Signal selection list" can be entered.

P-0-0149 contains all parameters that are suitable as trigger signal (P-0-0026) or as measuring signal (P-0-0023, P-0-0024, P-0-0147, P-0-0148, P-0-0270, P-0-0271, P-0-0272, P-0-0273). By reading P-0-0149 the master recognizes, which signals can be recorded in the drive.

At present, all cyclically configurable parameters (> 100) are contained in the list!

**Example of Signal Selection**

Example of signal selection of the oscilloscope function:

- "S-0-0051, Position feedback value 1" is selected as signal to be recorded
- The actual position value of encoder 1 (S-0-0051) is written to parameter "P-0-0023, Oscilloscope: Signal selection 1"

→ When the limiting conditions occur, actual position value of axis 1 is recorded in the oscilloscope and transmitted to the master.

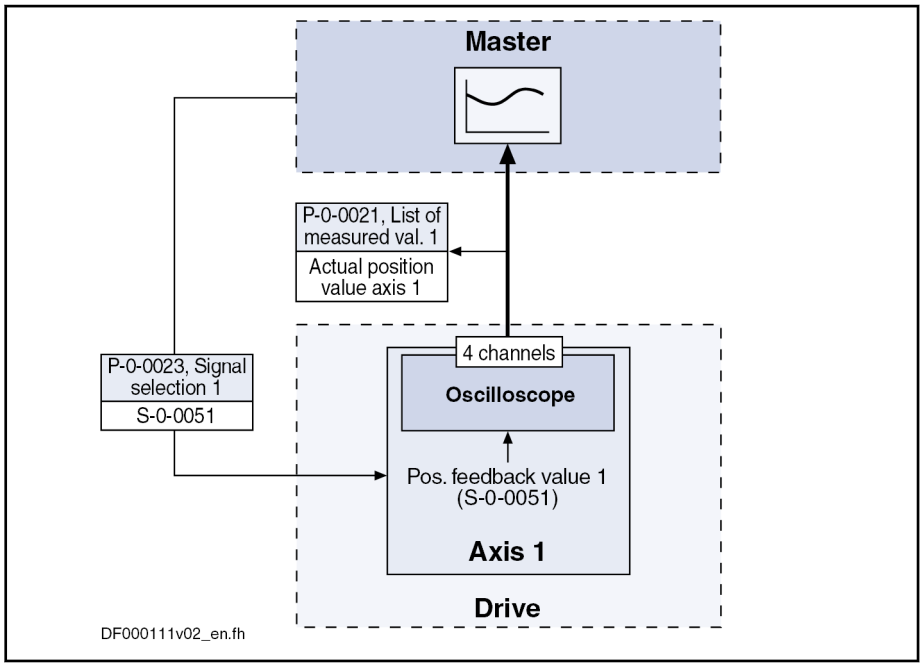



*Fig. 9-8: Example of Signal Selection*

Parameter, Diagnosis and Service Functions

## Expanded Oscilloscope Function (Patch Function)

Besides recording parameter contents via the oscilloscope function, the drive provides the possibility of recording any internal signal, i.e. memory address (patch function).

☞ Using the patch function is only possible with information about the structure of the internal data memory; therefore, this function can be used effectively only by the developers of the IndraDrive firmware.

In order to record internal signals (memory address contents), "P-0-0485, Patch function 1, display" or "P-0-0491, Patch function 2, display" have to be configured in one of the signal selection parameters (P-0-0023, P-0-0024, P-0-0147, P-0-0148, P-0-0270, P-0-0271, P-0-0272, P-0-0273).

☞ The patch function has to be parameterized before the assignment as trigger or measuring signal. After the assignment to the signal selection, the address is copied from the patch function. This means that subsequent changing of the address woks only, if it is newly assigned to the signal parameter.

See also "Patch Function"

## Activating the Oscilloscope Function

The oscilloscope function is activated/deactivated via parameter "P-0-0028, Oscilloscope: Control word".

**P-0-0028, bit 0:**

- Bit 0 = 1 → starts a measurement
- Bit 0 = 0 → stops a measurement

Setting bit 0 in P-0-0028 activates the oscilloscope function, i.e. recording of measured values of the selected signal starts. The oscilloscope function waits for the selected trigger edge or level to occur. Upon detection of a valid edge, the measured values keep being written to the measured value memory, until the number of measured values defined in parameter "P-0-0033, Oscilloscope: Number of measured values after trigger event" has been reached (delay function).

☞ With sercos master communication, start of signal recording and of trigger evaluation are delayed until the next feedback acquisition starting time T4 (S-0-0007 and S-0-1007).

This causes the recording data and the data in the AT telegram to be identical and several drives at one sercos bus to simultaneously start recording within one sercos cycle.

After the defined number of measured values has been recorded, the bit "delay function completed" (bit 4) is set in parameter "P-0-0029, Oscilloscope: Status word". The recording is thus complete and automatically terminated. Bit 0 in parameter P-0-0028 is reset and the list of measured values can be read.

Depending on the parameterization of the size of memory, the time resolution, the number of measured values after the trigger event and the point of time the trigger event occurs, the measured value memory for the current measurement is not always written completely.

This means that there may still be old measured values in the memory that are not valid for the current measurement!

## 9.3.3 Trigger Function

### Trigger Signal Selection

The drive provides extensive and flexible possibilities of triggering.

**Triggering at Standard Signals**

The trigger signal is selected in parameter "P-0-0026, Oscilloscope: Trigger signal selection" by directly inputting parameter IDNs. Only such IDNs are allowed that are contained in the list "P-0-0149, Oscilloscope: Signal selection list".

If, when the oscilloscope function is activated, no valid trigger signal is available, bit 7 for "trigger error" is set in parameter "P-0-0029, Oscilloscope: Status word".

"P-0-0026, Oscilloscope: Trigger signal selection" determines which signal is monitored with regard to the parameterized edge reversal or threshold value.

**Triggering at Any Signal**

Besides the triggering of parameter contents, the drive provides the possibility of recording any internal signal, i.e. memory address (patch function).

Using the patch function is only possible with information about the structure of the internal data memory; therefore, this function can be used effectively only by the developers of the IndraDrive firmware.

**Patch Function**

In order to trigger at internal signals (memory address contents), parameters "P-0-0485, Patch function 1, display" or "P-0-0491, Patch function 2, display have to be configured in " in P-0-0026.

See also "Patch Function"

### Internal or External Trigger

The kind of trigger can be selected in parameter "P-0-0028, Oscilloscope: Control word".

**P-0-0028, bit 1:**

- Bit 1 = 0 → internal trigger without offset measurement
- Bit 1 = 1 → external trigger with offset measurement

**Trigger Event**

The trigger event is the point of time at which trigger signal (P-0-0026) and trigger level (P-0-0027) are matching, taking the determined trigger edge into account (P-0-0030). When the trigger event occurs, the internal trigger is enabled.

**Internal Trigger (Without Offset Measurement)**

When "internal trigger" (P-0-0028; bit 1 = 0) is selected, the external trigger source (P-0-0036 bit 0) is not taken into account. Until the trigger event has been reached, the current state of the comparison "signal/trigger level" is displayed in "P-0-0029, Oscilloscope: Status word".

As the trigger event is reached, bit "internal trigger event" in parameter "P-0-0029, Oscilloscope: Status word" is set and recording is continued until the determined number of measured values after the trigger event (P-0-0033)

is reached. Only then is the bit "delay function completed" set (P-0-0029; bit 4). Setting this bit terminates the complete recording. The bit signals the end of recording irrespective of the trigger source.

When internal trigger source has been selected, the status bit "trigger function completed" (P-0-0029 bit 3) is set simultaneously with the bit for "internal trigger event" (P-0-0029 bit 2) (see state diagram).

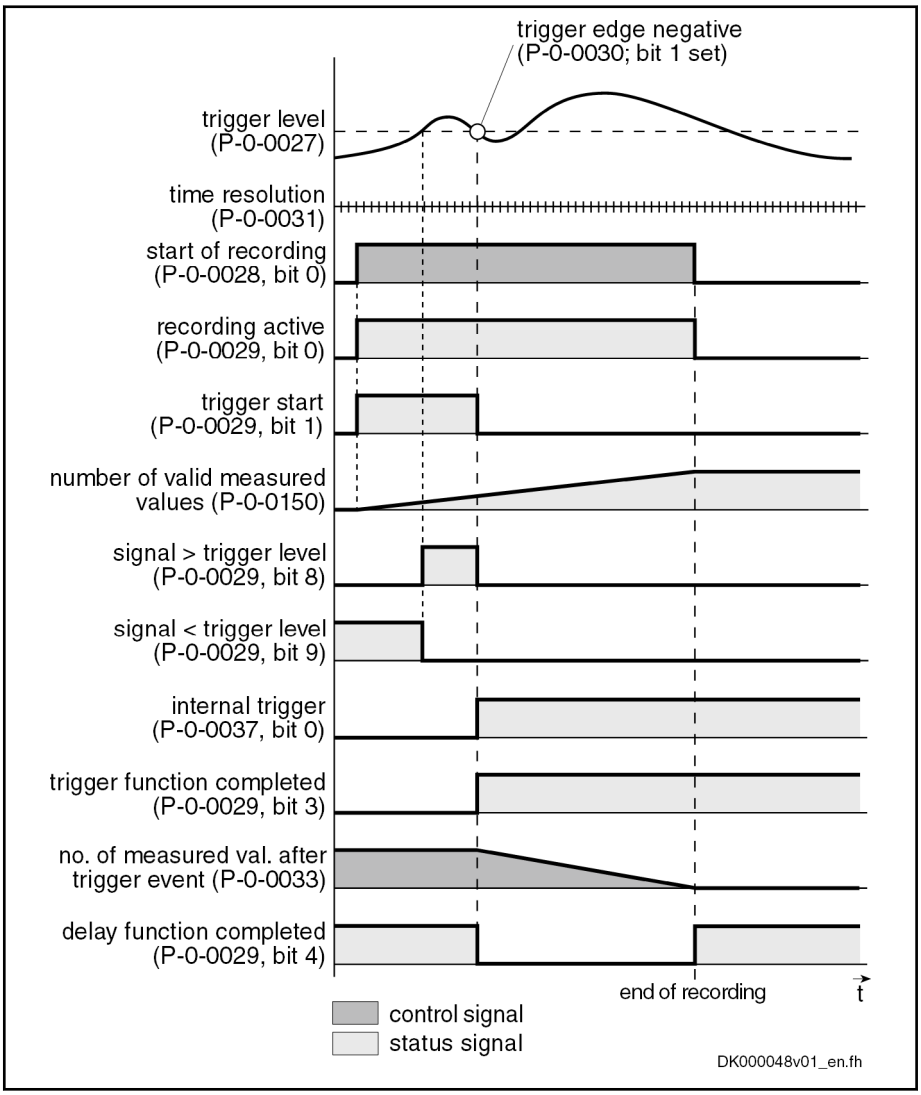



*Fig. 9-9: Internal Trigger Without Offset Measurement (P-0-0028; Bit 1 = 0)*

☞ By parameterizing P-0-0036 (external trigger signal) in "P-0-0026, Oscilloscope: Trigger signal selection" it is possible to enable 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. Afterwards, bit

"trigger function completed" is set in the status word of (P-0-0029; bit 3). The rest of the sequence is the same as in the case of internal trigger source without offset measurement.

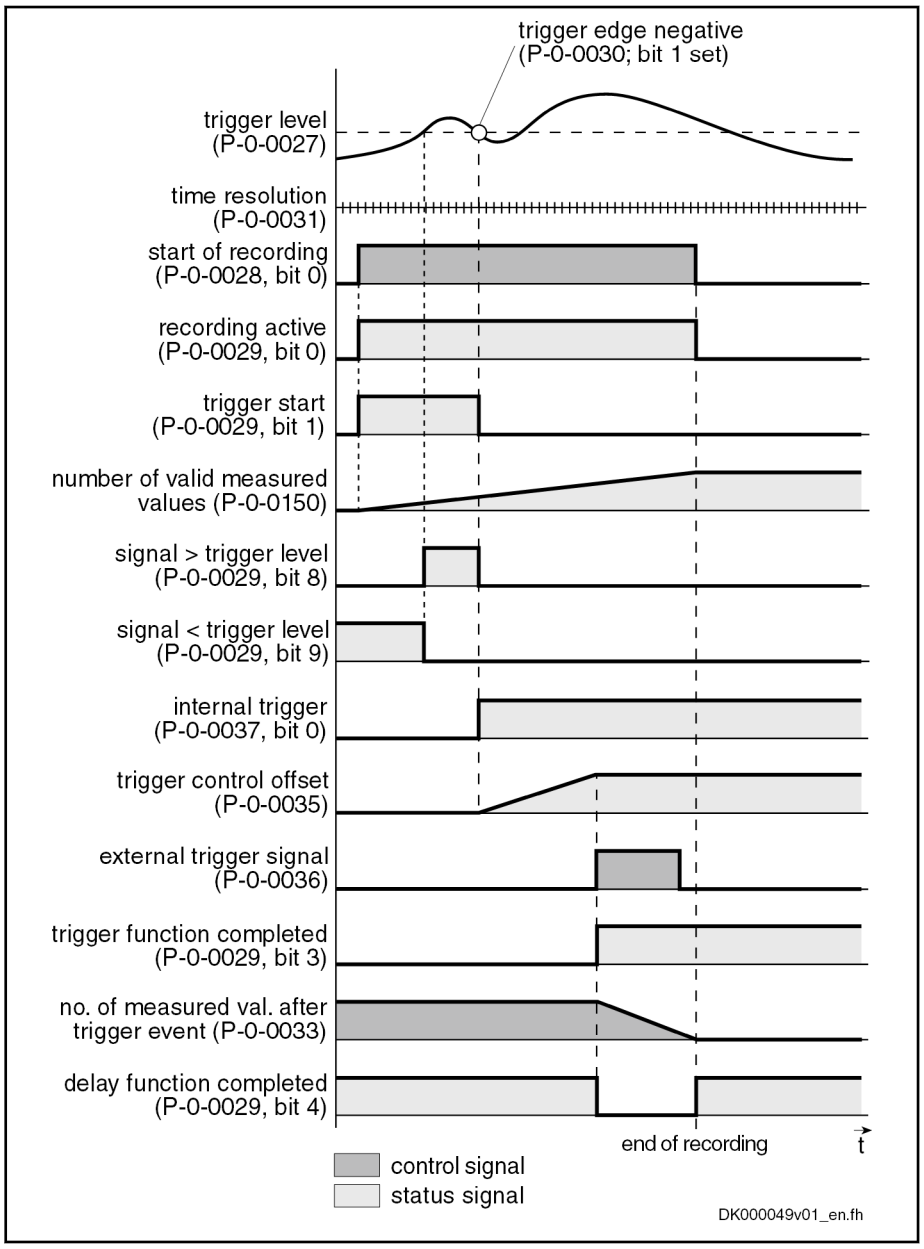



*Fig. 9-10: External Trigger With Offset Measurement (P-0-0028; Bit 1 = 1)*

The use of the external trigger source with trigger offset determination is described in section "Synchronizing the Measuring Signals of Several Axes" (see below).

## Selection of Trigger Edges

**Trigger Edge (P-0-0030)**

In parameter "P-0-0030, Oscilloscope: Trigger edge", you can set at which edge of the trigger signal the internal trigger is released. The following options are available:

- Triggering at the **positive** edge
- Triggering at the **negative** edge

- Triggering at **both** edges
- Triggering when trigger signal **equals** trigger level

☞ Even if both edges are activated, the trigger is only enabled when the value falls below or exceeds the set value. In the case of equal values, the trigger is not enabled.

See Parameter Description "P-0-0030, Oscilloscope: Trigger edge"

## Setting the Trigger Delay

**Trigger Delay Function**

Via "P-0-0033, Oscilloscope: Number of measured values after trigger event"; it is possible to reach a trigger delay independently of the preset trigger source (external/internal). For this purpose, the number of measured values that is to be recorded after the respective trigger event is set in parameter P-0-0033.

☞ It is also possible to record measured values before the trigger event occurs. (Trigger delay function of an oscilloscope).

If "0" is entered in P-0-0033, no data are recorded after the trigger event. The trigger event is the last value in the list of measured values. If the value of parameter P-0-032 is entered, only data available before the trigger event will be recorded. The trigger event is the first value in the list of measured values. The trigger event is therefore also counted. If P-0-0033 consequently takes the value "0" or "1", the trigger result is the last value in the list of measured values.

If the until the trigger event is too short, it may happen that the lists of measured values are not complete. If P-0-033 has the value "0", the list of measured values contains only one value.

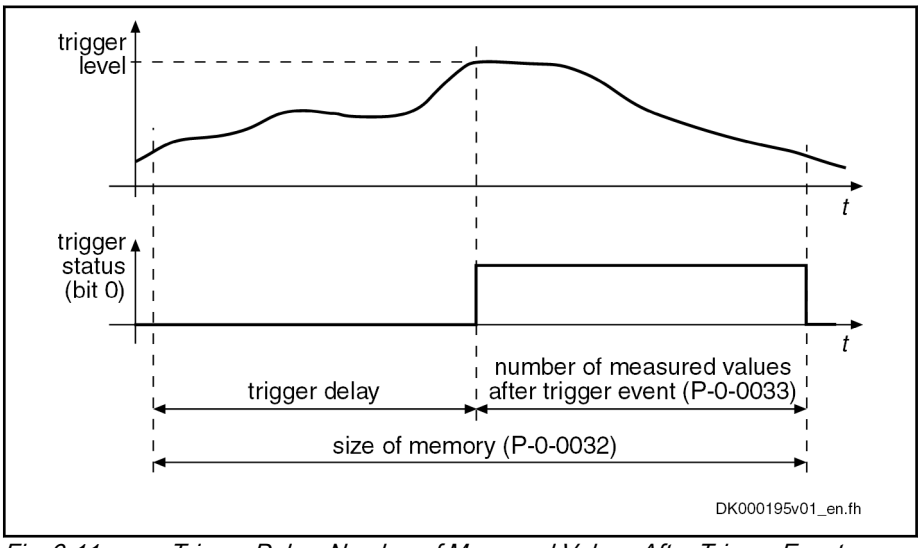



*Fig. 9-11: Trigger Delay: Number of Measured Values After Trigger Event*

## Expanded Trigger Functions

**Trigger Mask (P-0-0025)**

With parameter "P-0-0025, Oscilloscope: Trigger mask", it is possible to trigger at certain events. For trigger signals with the display formats "Bin" and "Hex", it is possible to mask the trigger signal and the trigger level.

See Parameter Description "P-0-0025, Oscilloscope: Trigger mask"

**Trigger Level (P-0-0027)**

The trigger level can be freely set via parameter "P-0-0027, Oscilloscope: Trigger level", with the attribute, unit, etc. being adjusted to the selected trigger signal.

See Parameter Description "P-0-0027, Oscilloscope: Trigger level"

## 9.3.4 Manual Trigger

As manual trigger parameter P-0-0136 should be selected, since P-0-0036 is also used for multiple-device measurement. To this end, it is cyclically configured and can no longer be written by the user. It must be noted that, depending on the edge configuration, exceeding / falling below the value signals the trigger event (not that the trigger level has been reached).

## 9.3.5 Time of Trigger

When the system time is set, P-0-0035.0.1 can be used to read the system time at the time of triggering. In this way, it is possible to determine the time of trigger also at a later point in time. This can be a useful function, if a monitor was configured and the user wishes to see, at which point in time the trigger event occurred.

## 9.3.6 Synchronizing the Measuring Signals of Several Axes

Parameter "P-0-0035, Oscilloscope: Trigger control offset" contains the number of measured values between the occurrence of the internal trigger event (P-0-0029; bit 2) and the external trigger event (P-0-0036; bit 0).

**Trigger Control Offset (P-0-0035)**

The transmission of the trigger event via the master causes a delay between the detection of the trigger event and the release of the trigger. This delay is measured by drive 1 (master drive) and stored in parameter "P-0-0035, Oscilloscope: Trigger control offset". A time-correct display of the signals of several drives can be guaranteed by taking this parameter into account for the visualization of the measured values.

In principle, a slave drive may also be used as triggering axis. It will then behave like the master axis.

See also above "Internal or External Trigger"

Parameter, Diagnosis and Service Functions

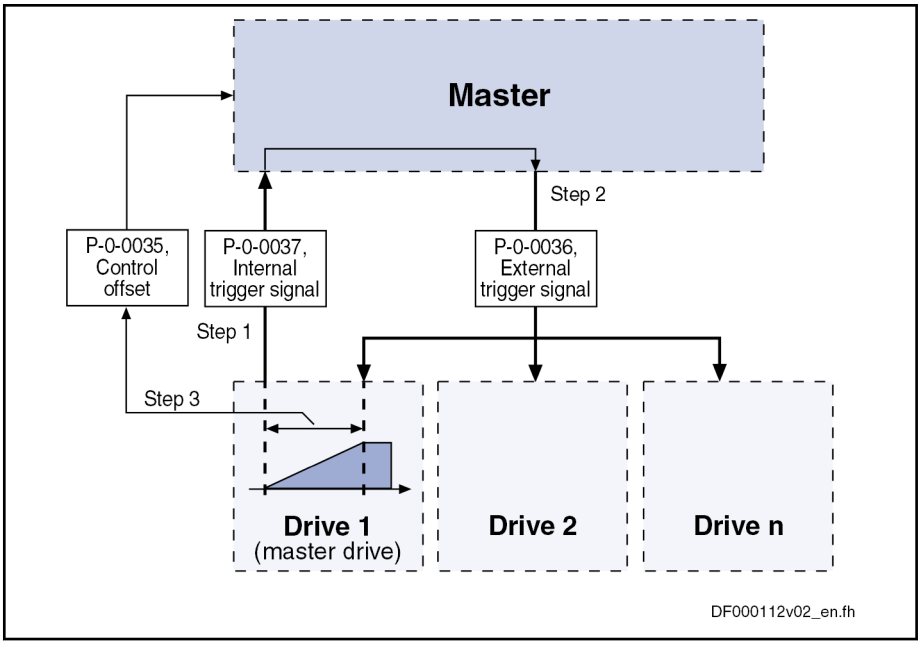



*Fig. 9-12: Application for Trigger Source “External" With Determination of Trigger Offset*

The value in parameter P-0-0035 can be used by the master for synchronizing the measuring signals of several axes with the internal trigger event of the master axis.

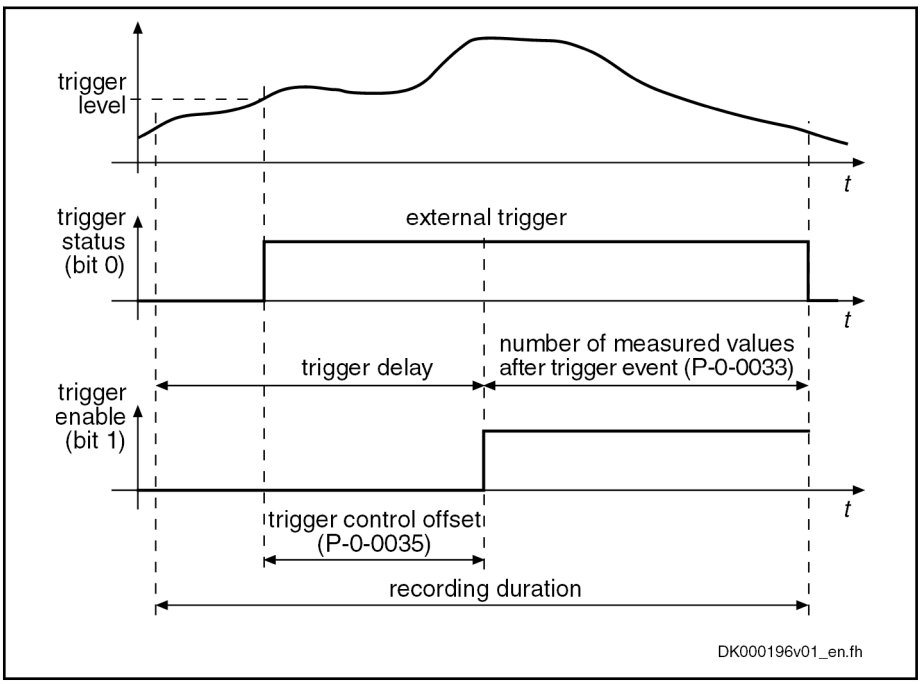



*Fig. 9-13: Trigger Control Offset*

**Status of Internal trigger (P-0-0037)**

Upon successful comparison of trigger signal and trigger condition, bit 0 is set in parameter "P-0-0037, Oscilloscope: Internal trigger signal" (trigger status), but the trigger is not released. It is thereby possible for the master to signal the trigger event via the real-time status bits and real-time control bits to several drives at the same time and to release the trigger.

**External Trigger Signal (P-0-0036)**

"P-0-0036, Oscilloscope: External trigger signal" can be parameterized as real-time control information, both in the real-time channel of the interface and as hardware input. This allows triggering at external signals that are preset via

- master communication of the master

- or -

- an analog or digital input.

## 9.3.7 Parameterizing the Oscilloscope Function

### Recording Duration

The recording duration is determined according to the following relationship:

$$t_A = (\text{P-0-0031}) \times (\text{P-0-0032})$$

$t_A$ Recording duration (in µs)
**P-0-0031** Oscilloscope: Time resolution
**P-0-0032** Oscilloscope: Size of memory
*Fig. 9-14: 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 IDNs are allowed that are contained in the list "P-0-0149, Oscilloscope: Signal selection list".



The selected signal (parameter IDN) defines the unit of the data stored in the list of measured values.

### Parameterizing the Selection of Measured Values

See above "Trigger Function"

### Parameterizing the Time Resolution and the Size of Memory

The recording range or the recording duration can be adjusted to suit the measurement requirements via the following parameters:

- P-0-0031, Oscilloscope: Time resolution
- P-0-0032, Oscilloscope: Size of memory

**Size of Memory of Oscilloscope Function**

The number of measured values is determined via"P-0-0032, Oscilloscope: Size of memory". A maximum of 8192 measured values per channel can be recorded.

**Time Resolution of Oscilloscope Function**

Parameter "P-0-0031, Oscilloscope: Time resolution" determines the time intervals at which measured values are recorded (sampling rate). It is possible to select the time resolution on the time base of the position controller clock cycle ($T_{Osci}$ = N x $T_{A_position}$; N = 1, 2, 3, 4, …).

The value range depends on the selected control performance. The control performance in turn depends on the hardware design of the controller and the setting in parameter P-0-0556.

In the expert mode, the minimum time resolution can be set to the current control clock cycle.

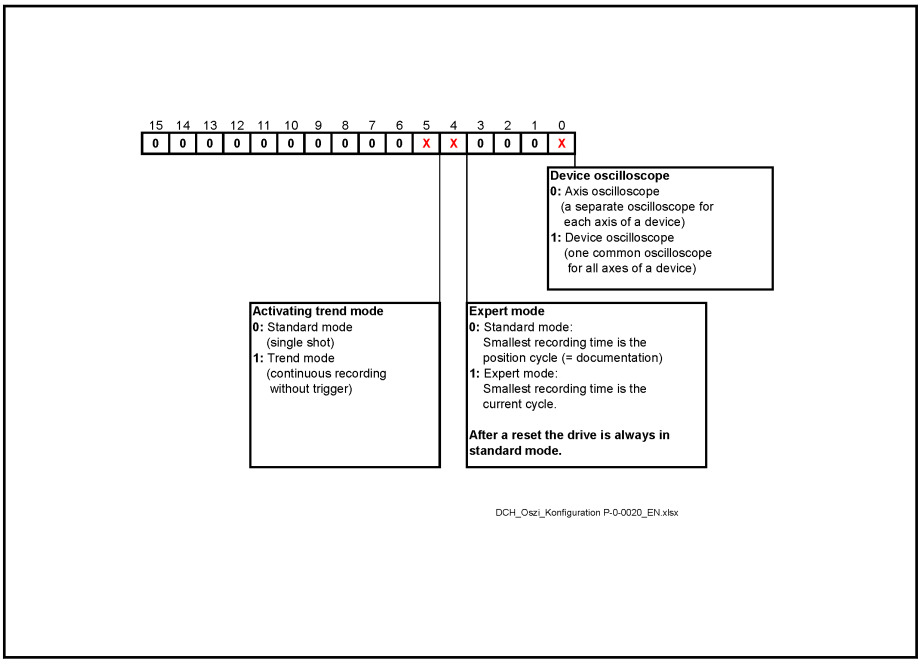



*Fig. 9-15: Configuration of P-0-0020*

The times that can be achieved can be found in the "Performance Data". It must be noted that in the expert mode the trigger is evaluated only in the position controller clock cycle. This means that a trigger event, which is not existent in the position controller clock cycle, cannot be evaluated.

---

☞ Updating of the parameter values is not adapted to the time resolution of recording, i.e. a parameter, which is generated in the firmware in the position controller clock cycle (e.g. S-0-0051) will only change within the time window of the position controller, even if it is measured within, for example, the current controller clock cycle.

---

When the time resolution is set to a value less that the position controller clock cycle and unequal to the velocity or current controller clock cycle, the time resolution is automatically set to the next smaller controller clock cycle (velocity or current controller). The time resolution entered is rounded. The expert mode allows time resolutions, which are greater than or equal to the position controller clock cycle.

---

☞ After a reset the drive is always in the standard mode.

---

Depending on the control section’s utilization of capacity (performance setting, active options, functional packages, MLD program) it may happen that the computing time is not sufficient to call the oscilloscope function in any current controller clock cycle or velocity controller clock cycle. The measurement is not completed before the configured number of measuring points has been recorded. It can therefore not be guaranteed that the time resolution shown in the oscilloscope is correct.

Example: The measurement is configured with 100 measuring points in the current controller (125 µs), and during the measurement the oscilloscope function is active in only every second current controller clock cycle. In the oscilloscope a measurement over 12.5 ms is shown on a time base of 125 µs. The measured values were actually recorded over 25 ms on a time base of 250 µs.

### Parameterizing the Number of Channels

The number of channels can be set using parameter P-0-0269. For reasons of compatibility, the minimum number of 4 channels must be adhered to. The maximum number can be set to 8 channels. In this case, the maximum recording depth is reduced. The sum of all channels must not exceed 32768. This means that the following combinations are possible:

| Number of channels | Recording depth |
|---|---|
| 1-4 | 8192 |
| 5 | 6553 |
| 6 | 5461 |
| 7 | 4681 |
| 8 | 4096 |

*Tab. 9-5: Recording Depth Dependent on Number of Channels*



This parameter is only effective after a restart. Then, the respective parameters become available and the respective recording depth is set.

Depending on the number of channels set, the relevant parameters for signal selection or list of measured values are made available.

## 9.3.8 Diagnostic and Status Messages

### Status of Oscilloscope function

Parameter "P-0-0029, Oscilloscope: Status word" indicates the current state of the oscilloscope function.

P-0-0029 contains, for example, status information on:

- Start/end of recording
- Trigger function
- Status of trigger signal
- Delay function

See also Parameter Description "P-0-0029, Oscilloscope: Status word"

Via parameter "P-0-0037, Oscilloscope: Internal trigger signal" the master is informed about the status of the internal trigger. This parameter can be parameterized as real-time status information, both in the real-time channel of the interface and as hardware output.

### Displaying the Number of Valid Measured Values

After a measurement, the parameter "P-0-0150, Oscilloscope: Number of valid measured values" displays the number of detected measured values in the ring buffer. If the ring buffer has been completely filled with the length de-

termined in parameter "P-0-0032, Oscilloscope: Size of memory", the size of memory is displayed in this parameter.

See also Parameter Description "P-0-0150, Oscilloscope: Number of valid measured values"

## 9.3.9 Trend Mode

The trend mode allows up to 8 channels to be recorded in a cyclical mode. The values are administrated in a buffer storage and called cyclically. IndraWorks can read out and continuingly show this storage. Since the measurement is not necessarily equidistant, it may happen that measured values are missing due to, for example, a slow connection. These values are shown accordingly in the graphic display.

In order that trend mode can be used, the system time must be activated. This time base serves to clearly assign the respective measuring points to a point in time.

The time resolution and the signal selection can only be set while trend mode is switched off. As time resolutions, only times are permitted that are a multiple of 2 ms. If another value is entered, it is rounded down to the next possible value. The signal selection is made using the parameters set before.

The trend mode is activated by setting P-0-0020, bit 5. The mode of the "classic" oscilloscope cannot be used in parallel. Trend recording is then activated via P-0-0028, bit 0. The trend signals its activity also in P-0-0029, bit 0.

After trend mode was activated, the values are recorded in the set time resolution. They are stored in two multi buffers, which means that while one buffer is read, the other can be filled again. Every reading of the parameter (P-0-0280) results in a changeover of the multi buffer. This means also that the data can only be read once. If the parameter is not read and the maximum number of elements has been saved, trend comes to a stop until the parameter is read again. Until reading out, data can no longer be saved and are therefore lost. Considering the current size of the buffers and a 8 channels, it can be assumed that with a minimum time resolution of 2 ms it is possible to record for ca. 400 ms before data are lost. Because these data are to be represented continuously, the request intervals should be issued at significantly shorter time intervals.

Recording always starts with 4-byte information. It always contains the version in the least significant byte. Depending on the version, the other data may be adapted.

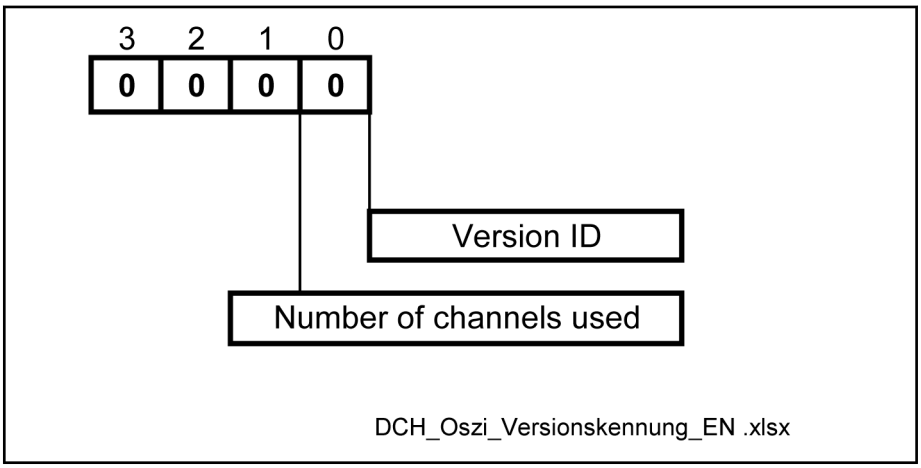



*Fig. 9-16: Version Identification*

Currently, only version 1 is used. This means that the 2nd byte shows the number of channels. The subsequent data are always composed of 2 entries for time (P-0-0197). The high word precedes the low word. They are followed, depending on the number of channels, by the useful data - always in the 4-byte format. 2-byte values are extended with the correct sign. Useful data are interpreted with the same conversion as the selected signals.

## 9.3.10 Pertinent Parameters and Diagnostic Messages

**Parameters**

- P-0-0020, Oscilloscope: Operation mode
- 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-0-0025, Oscilloscope: Trigger mask
- P-0-0026, Oscilloscope: Trigger signal selection
- P-0-0027, Oscilloscope: Trigger level
- P-0-0028, Oscilloscope: Control word
- P-0-0029, Oscilloscope: Status word
- P-0-0030, Oscilloscope: Trigger edge
- P-0-0031, Oscilloscope: Time resolution
- P-0-0032, Oscilloscope: Size of memory
- P-0-0033, Oscilloscope: Number of measured values after trigger event
- P-0-0035, Oscilloscope: Trigger control offset
- P-0-0036, Oscilloscope: External trigger signal
- P-0-0037, Oscilloscope: Internal trigger signal
- P-0-0136, Oscilloscope: Manual trigger signal
- 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
- P-0-0149, Oscilloscope: Signal selection list
- P-0-0150, Oscilloscope: Number of valid measured values
- P-0-0269, Oscilloscope: Channel number setting
- P-0-0270, Oscilloscope: Signal selection 5
- P-0-0271, Oscilloscope: Signal selection 6
- P-0-0272, Oscilloscope: Signal selection 7
- P-0-0273, Oscilloscope: Signal selection 8
- P-0-0274, Oscilloscope: List of measured values 5
- P-0-0275, Oscilloscope: List of measured values 6
- P-0-0276, Oscilloscope: List of measured values 7
- P-0-0277, Oscilloscope: List of measured values 8
- P-0-0279, Oscilloscope: Trend mode, time resolution
- P-0-0280, Oscilloscope: Trend mode, list of measured values

# 9.4 Average Value Filter

### Functional Description

If highly dynamic or actual values generated with high frequency such as currents, torques, accelerations, etc. are to be processed further for visualization purposes, it is often useful to direct these actual values via a smoothing filter. To this end, the function of the average value filter is used.

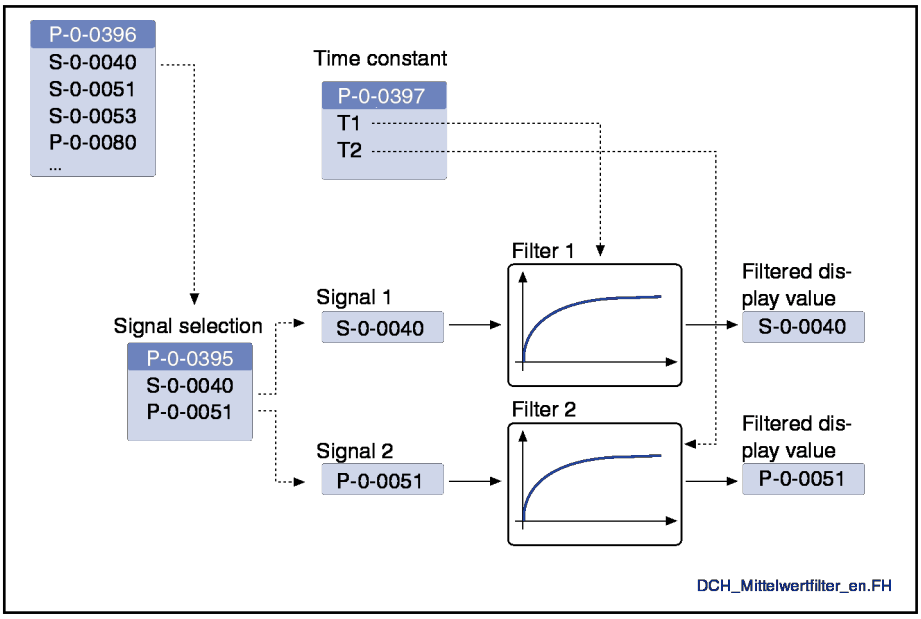



*Fig. 9-17: Average Value Filter*

When selecting the signals, the following points must be observed:

- Only signals from parameter "P-0-0396, Average value filter for display: Signal selection list" can be selected.
- The filter function is deactivated, when "S-0-000" is selected as filter.

### Oscilloscope function and average value filter

It is essential to observe the order of parameterization!

- If the signal for the average value filter for display is preset first and then the same signal is selected as measuring signal in the oscilloscope, the filtered value is recorded in the oscilloscope.
- In the case of reverse order, the non-filtered value is recorded.

If the signal for the average value for display is changed or cleared, automatic switching does not take place with the oscilloscope function. The signal has to be selected again as measuring signal.

### Pertinent Parameters

- P-0-0395, Average value filter for display: Signal selection
- P-0-0396, Average value filter for display: Signal selection list
- P-0-0397, Average value filter for display: Time constant

# 9.5 Firmware Replacement

## 9.5.1 Brief Description

### Basic Principles

**Definition of Terms** The following cases are distinguished for firmware replacement:

- **Release update**

  An old firmware release (e.g. HDB17**V12**) contained in the device is replaced by a new firmware release (e.g. HDB17**V14**).

- **Version upgrade**

  The older firmware version contained in the device is replaced by a new firmware version (example: HDB**17**V14 is replaced by HDB**18**V10).

**Replacement**

Firmware can be replaced using the following hardware and software:

- Computer with software "IndraWorks" or
- Computer with TFTP client

The "IndraWorks" commissioning software can be ordered from Rexroth .

The scope of supply of "IndraWorks" contains a documentation which describes the operation of the program.

**To be Noticed**

After every firmware replacement (release update and version upgrade), check the following parameters for validity:

- P-0-2003, Selection of functional packages
- P-0-4089.0.1, Master communication: Protocol

It might be necessary that you set them valid manually during the first run-up after the firmware replacement.

## Preparations and Boundary Conditions for Firmware Replacement

**Preparations for Replacing Firmware**

You have to make the following preparations for firmware replacement:

1. Drive controller must be on (24 V supply).
2. The drive controller **must not** be in operating mode (communication phase 4) (cf. P-0-0115).
3. It is recommended that you save the required parameters before replacing the firmware.

**General Notes on How to Carry Out Firmware Replacement**

You have to observe the following points when carrying out the firmware replacement:

- For the firmware replacement via IndraWorks, Ethernet communication to the drive must be possible.
- Do not switch off the 24 V control voltage while replacing the firmware.
- The firmware must always be replaced completely.

**Communication Types**

The engineering communication works in different ways, depending on the activated bus system (cf. P-0-4089.0.1). Make the settings and comply with the requirements in accordance with the bus system used. For further information, see chapter "TCP/IP Communication".

After you have changed the IP settings, the device must be restarted for activating the settings. If several devices have been connected via the master communication bus, you have to make sure that an unequivocal IP address is assigned to each node.

**IP Settings on the Computer**

See Microsoft help, keyword "LAN connection"

Parameter, Diagnosis and Service Functions

## 9.5.2 Firmware Release Update

### General Information

Before you update the firmware release, it is recommended that you save the backup parameters of the drive!

### Firmware Release Update With Computer

1. Connect drive to computer (recommended: Cat5e Ethernet cables)
2. Load firmware

   There are two possibilities of performing a firmware release update using a computer:

   - By means of IndraWorks or
   - with a TFTP client

   1. *Firmware release update with IndraWorks*

      1.1 Open "IndraWorks Suite or IndraWorks Ds".

      1.2 IndraWorks Suite: Load project for relevant axis or create new project; to do this, address axis over Ethernet.

      1.3 IndraWorks Suite: Switch project "online".

      IndraWorks Ds: Establish connection with the controller via the dialog "Connection Selection".

      1.4 IndraWorks Suite: Select/highlight controller and call "Firmware Management" in context menu.

      IndraWorks Ds: Call menu item **Diagnosis/Service ▸ Firmware Management...**.

      A new window opens and drive firmware currently available in the drive is displayed.

      1.5 Highlight new firmware (*.ibf file) in upper part of dialog and start firmware download by clicking "Download" button.

      The firmware download runs automatically and all required firmware components are loaded to the drive.

      1.6 After the firmware download has been completed, close the "Firmware Management" window.

   2. *Firmware release update using a TFTP client*

      2.1 Firmware update service is made available via a TFTP server. Command for sending the firmware is "put" command.

---

☞ It is possible with any TFTP client supporting this command (e.g. Windows command line program "tftp.exe") to carry out a firmware release update **without IndraWorks**.

**Example** (with "Microsoft Windows consoles TFTP client"):

To carry out a firmware release update, only a "put" request is transmitted. Do not use an optional alternative name for the file on the target system. For the host, the IP address of the device is to be specified (standard is 192.168.0.1): `tftp -i 192.168.0.1 put FWA-HYDRV_-HDB-18V10-D5.ibf`

---

See also Functional Description "Firmware Download via TFTP Server"

3. Restart drive
4. Put machine into ready-for-operation status again according to the machine manufacturer's instructions.
5. Check functions of drive.

## 9.5.3 Firmware Version Upgrade

### General Information

When firmware in a drive controller is replaced by firmware of a **more recent version**, this is called firmware version upgrade (e.g., FWA-HYDRV*-HDB-**17**V12-D5 replaced by FWA-HYDRV*-HDB-**18**V10-D5).

**Before** carrying out the firmware version upgrade, you must save all parameters (e.g., with "IndraWorks"). **After** firmware replacement, the parameters must be restored, because the command "C07_1 Load defaults procedure command (factory settings)" is carried out automatically. After the desired parameter file was loaded, the drive controller is ready for operation again.

### Saving Parameter Values

Before the firmware upgrade, all application-specific parameter values must be saved on a data carrier. The parameter backup can be carried out by means of:

- **Commissioning software "IndraWorks"**

  → Saving parameter values on external data carrier

- or -

- **Control master**

  → Saving parameter values on master-side data carrier

### Version Upgrade With "IndraWorks"

**Requirements**

The following requirements should have been met in order that a firmware version upgrade with "IndraWorks" makes sense:

- Existing Ethernet connection between PC and drive controller
- Current parameter setting of axis was saved.

When upgrading from HDB17VRS to HDB18VRS, the error F8100 is sometimes generated during the drive controller's first start-up. This error can be cleared via the display and will not occur again during the next booting process.

**Firmware Upgrade With "IndraWorks"**

Carrying out the firmware version upgrade with "IndraWorks" requires the following steps:

1. **Load firmware**

   1.1 Open "IndraWorks Suite or IndraWorks Ds".

   1.2 IndraWorks Suite: Load project for relevant axis or create new project; to do this, address axis over Ethernet.

   1.3 IndraWorks Suite: Switch project "online".

   IndraWorks Ds: Establish connection with the controller via the dialog "Connection Selection".

   1.4 IndraWorks Suite: Select/highlight controller and call "Firmware Management" in context menu.

IndraWorks Ds: Call menu item **Diagnosis/Service ▸ Firmware Management...**.

A new window opens and drive firmware currently available in the drive is displayed.

1.5 Highlight new firmware (*.ibf file) in upper part of dialog and start firmware download by clicking "Download" button.

The firmware download runs automatically and all required firmware components are loaded to the drive.

1.6 After the firmware download has been completed, close the "Firmware Management" window.

1.7 Reboot drive controller

2. **Put drive into ready-for-operation state**

⇒ Switch project "online".

After project has been switched "online", a message sometimes signals that "IndraWorks" could not establish communication to drive via Ethernet interface, as drive-internal settings for Ethernet communication were reset.

⇒ In this case, reconfigure communication via button "Search for devices"!

⇒ As the firmware in the drive no longer complies with the version stored in the project, a corresponding message is displayed. Select desired option in the dialog to make the drive available in the project again and allow reestablishing communication with the device.

⇒ Set functional package and master communication protocol manually via corresponding parameters.

⇒ Activate command "C07_1 Load defaults procedure command (factory settings)". All buffered parameters are thereby set to their default values.

3. **Load parameter values**

⇒ Load saved parameter file!

⇒ Switch off drive and re-start so that the parameterization becomes active.

4. **Put machine into ready-for-operation state**

⇒ Put machine into ready-for-operation status again according to the machine manufacturer's instructions.

⇒ Check functions of drive.

## 9.5.4 Upgrade To HDB18V08

As of version HDB18V08, the firmware download is carried out exclusively via the TFTP protocol. With the predecessor versions HDB18V06 and HDB17V16 the SIS protocol is active.

For the upgrade, an intermediate step is necessary, i.e. the FWA file (version HDB18V08) is loaded twice. In a first step, the TFTP loader is activated. In a second step, the respective, complete FWA version is loaded via the activated loader.

The description refers to the IndraWorks Ds 13V10 operator interface used.

## 9.5.5 Upgrade From HDB17/18 (SIS) To 18V08 (TFTP)

Upgrading must be carried out in the following sequence:

1. Call →Service→Firmware administration in IndraWorks

2. Select file name **FWA-HDB18V08.ibf**
3. Start download

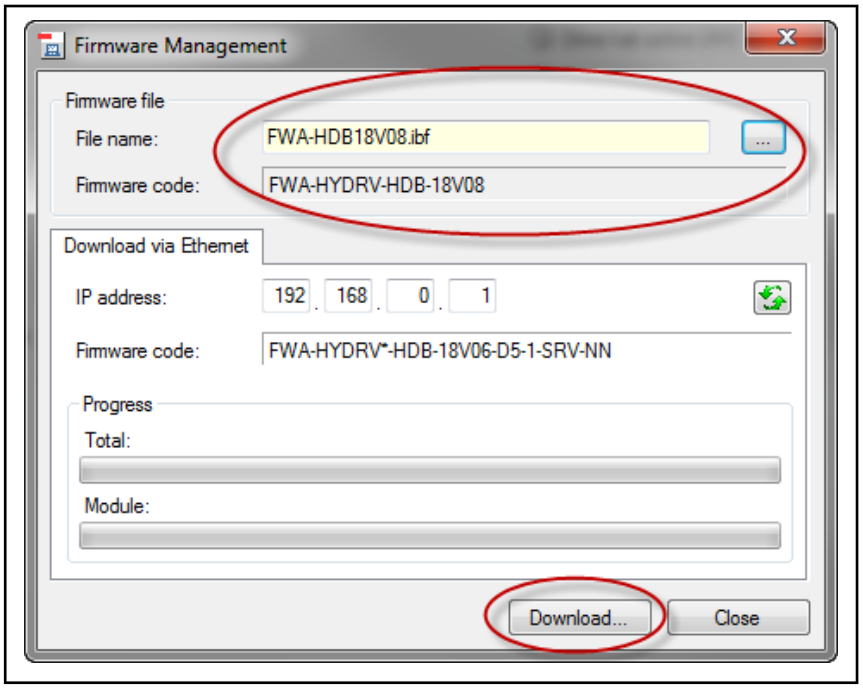



*Fig. 9-18: Upgrade To HDB18V08*

4. The following safety warning must be observed and, if necessary, confirmed by clicking **Yes**.

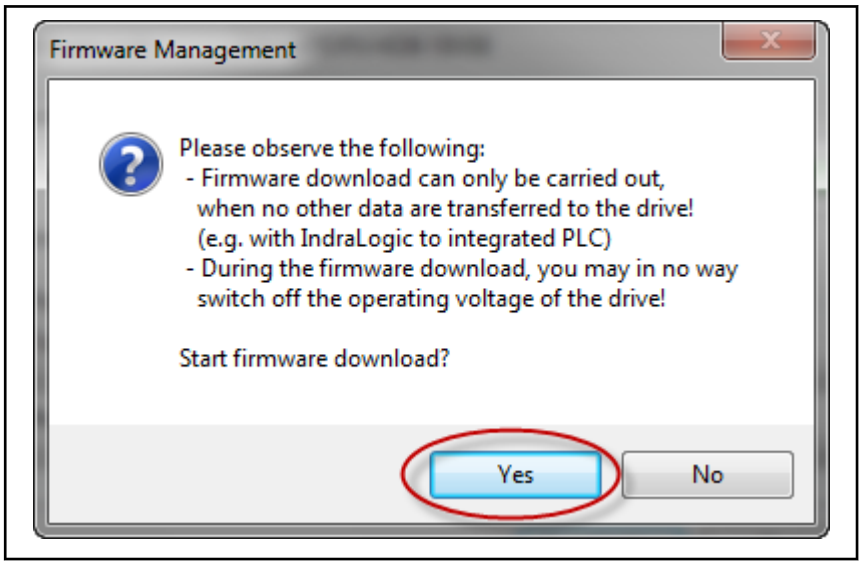



*Fig. 9-19: Upgrade To HDB18V08*

☞ The download is started now.

Parameter, Diagnosis and Service Functions

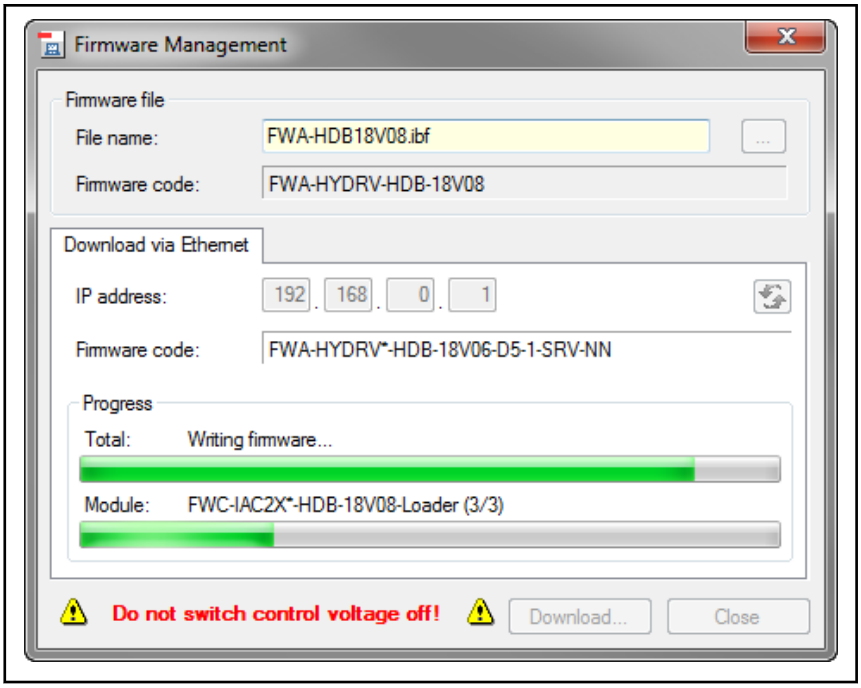



*Fig. 9-20: Upgrade To HDB18V08*

☞ A successful download is confirmed by the subsequent information window.

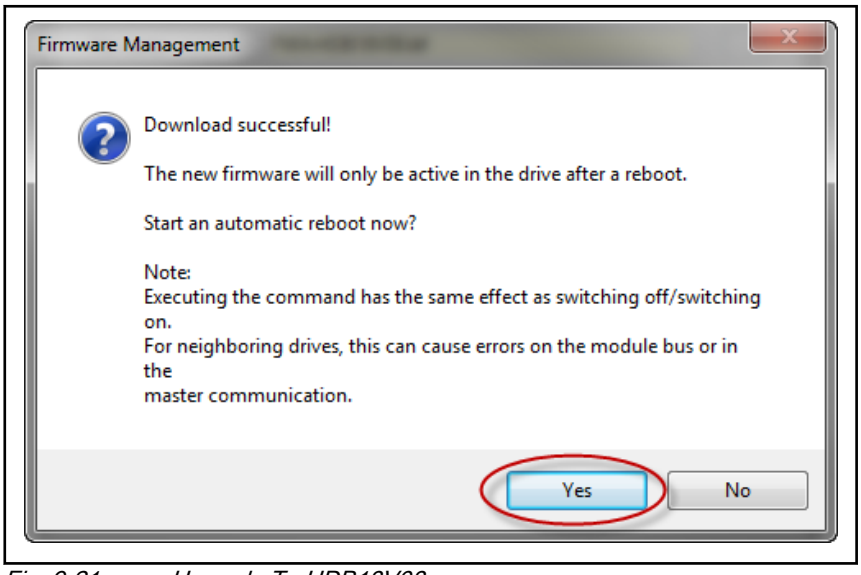



*Fig. 9-21: Upgrade To HDB18V08*

5. A restart is required. It is executed after clicking **YES**. The device can also be booted manually.

☞ Following the restart, the TFTP loader is now active.

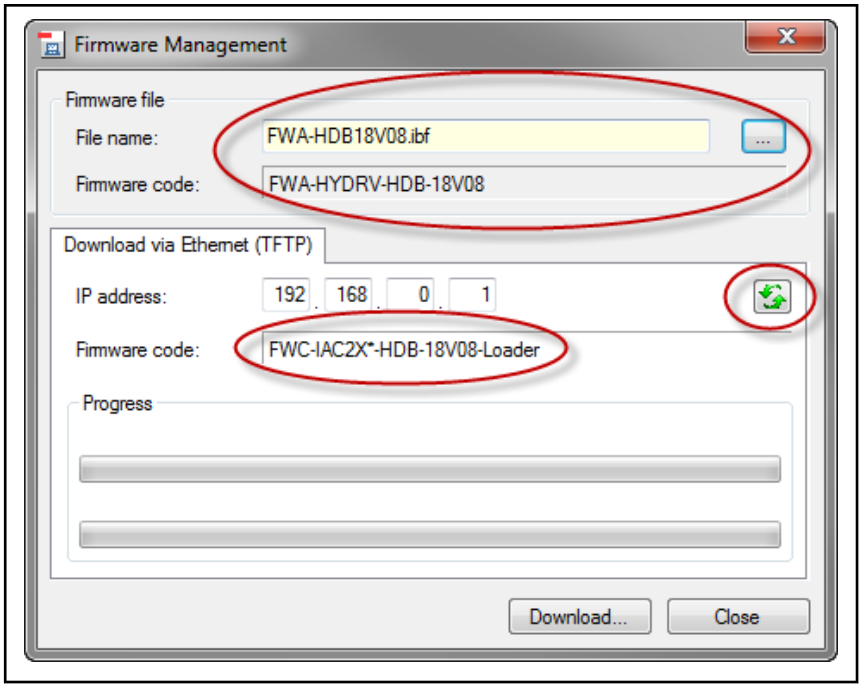



*Fig. 9-22: Upgrade to HDB18V08*

6. The download must be started again.

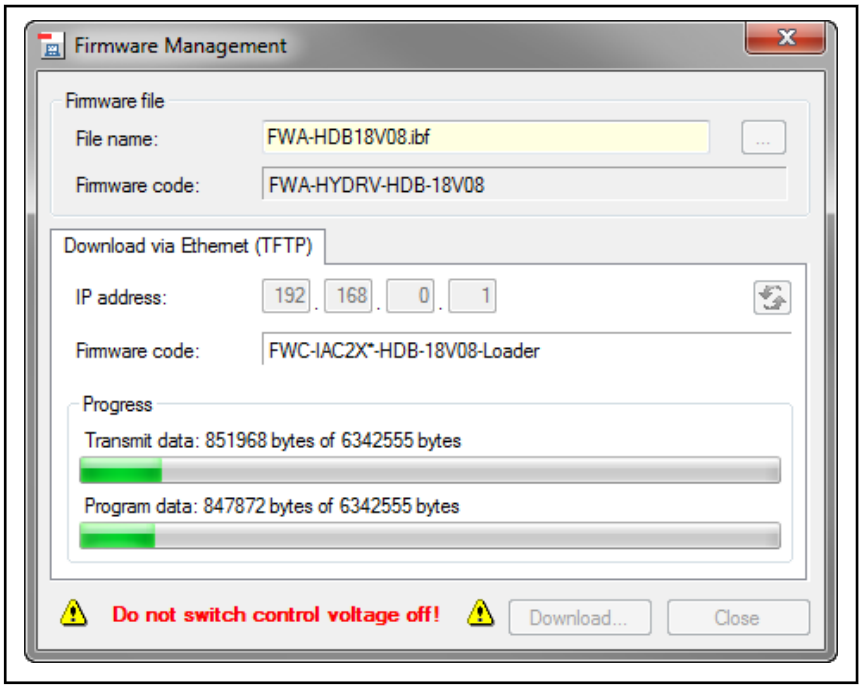



*Fig. 9-23: Upgrade to HDB18V08*

☞ A successful download is confirmed by an information window.

7. A restart is required. It is executed after clicking **YES**. The device can also be booted manually.

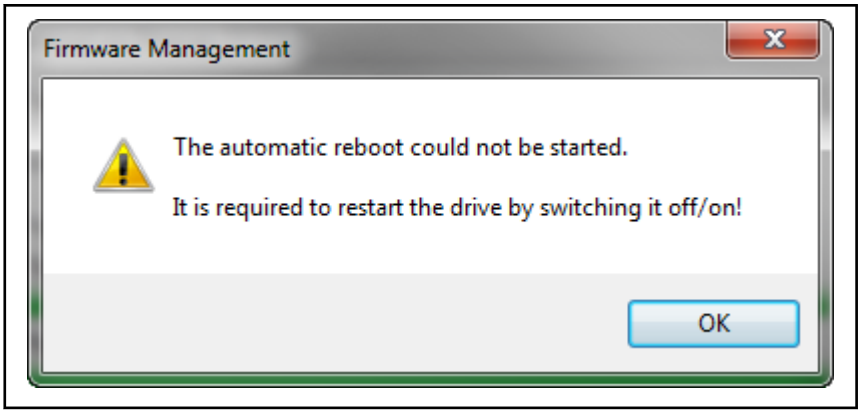



*Fig. 9-24: Upgrade to HDB18V08*

☞ After a restart was carried out, re-copying processes take place, which are signaled by red/green flashing of the ModulStateLED. Then, the new version (HDB18V08) is active.

## 9.5.6 Possible Problems Arising During Firmware Replacement

**General Information**

After an incomplete firmware update, the drive controller might no longer be operable.

Firmware replacement is carried out incompletely, if one of the following situations occurs during the sequence of firmware replacement:

- 24 V supply of control section is switched off
- Connection to drive is interrupted (e.g. defective interface cable)
- Crash of update software / of computer

If there isn't any valid firmware available in the control section, the loader is started. With the loader, it is possible to replace the firmware of the control section.

☞ Upon successful firmware replacement in the control section, a restart has to be carried out.

**Firmware Replacement in the Control Section in the Event of an Error**

The following steps are required for loading the firmware to the control section in the case of error:

1. Open "IndraWorks Suite or IndraWorks Ds".
2. IndraWorks Suite: In the menu, call firmware management under **Tools ▸ Drive ▸ Firmware Management**.

   IndraWorks Ds: In the menu, call firmware management under **Diagnosis/Service ▸ Firmware Management**.

   A new window opens in which the firmware file last used is displayed on the PC.
3. Select "Download via Ethernet" tab.
4. Set IP address "192.168.0.1".
5. Highlight desired firmware (*.ibf file) and start firmware download via **Download** button.
6. The firmware download runs automatically and all required firmware components are loaded to the drive.

7. After the firmware download has been completed, close the "Firmware Management" window.
8. Restart drive.

## 9.5.7 Reboot Command

**Functional Description**

Various, fundamental changes in the configuration of the drive will not become effective before the system is rebooted such as

- Loading of new firmware to firmware
- Changeover of functional package
- Changeover of Multi-Ethernet protocol

To avoid that the control voltage of the device concerned and possibly other devices that may be supplied with the same control voltage need to be switched off and on completely, the "S-0-1350, C6400 reboot command" is implemented.

**Sequence of the Reboot Command**

Upon the start of the command, retain data are saved. Then, a fixed delay time of 2 sec has to elapse before the reboot process is initiated. The delay time allows starting of the command at several drives of a system in parallel without resulting in a breakdown of the sercos communication immediately after the start of the command due to the drive boot process. During the delay time, the command signals "in process".

For safety reasons, the command can only be started in parameter mode (PM).

# 10 Engineering/Diagnostic Interfaces

## 10.1 TCP/IP Communication

### 10.1.1 Brief Description

☞ The chapter "TCP/IP Communication" describes all information required for standard Ethernet communication. In addition to TCP/IP communication, communication via UDP/IP is also possible.

To avoid any confusion with the control communication "EtherNet/IP™ interface" we will not use the term "Ethernet communication". Instead, we use the term " IP communication".

It is possible to communicate with a controller via standard Ethernet telegrams. These Ethernet telegrams contain TCP/IP or UDP/IP telegrams for application-side connection. For communication with the device, the CSMA/CD access method is used. Connection possibilities are interfaces that allow for TCP/IP communication. This may be a free port (e.g. sercos or EtherNet/IP™) or a separate Engineering Port (if available).

**Example of sercos Control Communication**

For sercos, in addition to the time-controlled transmission of sercos-type Ethernet telegrams (MDT and AT), an NRT channel (NonRealTime or IP channel) exists, where telegrams are sent in a specially reserved time slot.

Therefore, in addition to the existing service channel another option for asynchronous data transmission is available for sercos that is very well suitable for large data volumes due to the maximum lengths of user data of approx. 1500 bytes.

**Possible Applications**

With TCP/IP communication in the drive, different application options become available, which are summarized in the following table.

| Connection | Server application | Example client applications |
|---|---|---|
| SIP protocol | Parameter access | IndraWorks parameter application |
| TFTP | Firmware update service | Updating the firmware |
| FTP | Fileserver | File access to the optional memory card (only available if the optional memory card is connected during the booting process) |

*Tab. 10-1: Overview of the Possible Applications*

**Pertinent Parameters**

- S-0-1019, Master comm. engineering over IP: MAC address
- S-0-1020, Master comm. engineering over IP: IP address
- S-0-1021, Master comm. engineering over IP: Network mask
- S-0-1022, Master comm. engineering over IP: Gateway address
- P-0-1044, Master comm. engineering over IP: Status IP communication
- P-0-1530, Engineering: MAC address
- P-0-1531, Engineering: IP address
- P-0-1532, Engineering: Network mask
- P-0-1533, Engineering: Gateway address
- P-0-1534, C6100 Command Activate IP settings
- P-0-1544, Engineering: Status IP communication

**Pertinent Diagnostic Messages**

- C6101 Incorrect IP settings

- F2190 Incorrect Ethernet configuration

## 10.1.2 Functional Description

### Basic Information on the Function

**Components for TCP/IP Communication**

Every device has an interface for MultiEthernet control communication. This interface enables direct IP communication. Depending on the existing hardware or the enabled control communication, this interface is called "Engineering via IP" or "Engineering Port".

The interface is called "Engineering via IP" with:

- sercos
- EtherNet/IP™
- PROFINET® RT
- EtherCAT®

  With IndraWorks and TwinCAT, connection establishment is possible via the ADS interface or the EoE profile.
- VARAN

  With IndraWorks, connection establishment is possible via the EoV profile.

The interface is called "Engineering Port" with:

- Profibus DP

  For Profibus DP, an additional interface option is required.

**Configuration**

For IP communication, at least the IP address and network mask have to be set in each drive.

In addition, a gateway address can be set.

| Interface | IP address | Network mask | Gateway address |
|---|---|---|---|
| Engineering via IP | S-0-1020 | S-0-1021 | S-0-1022 |
| Engineering port | P-0-1531 | P-0-1532 | P-0-1533 |

*Tab. 10-2: Parameters for IP Configuration Setting*

Changes become effective when the drive is restarted or the drive command "C6100Command Activate IP settings" is executed.

**Structure of the IP address**

The IP address of a communication node always comprises a network address (network ID) and a host address (host ID).

In a class C network (network mask 255.255.255.0), the network ID corresponds to the first three bytes of the IP address. The host ID is the fourth byte of the IP address.

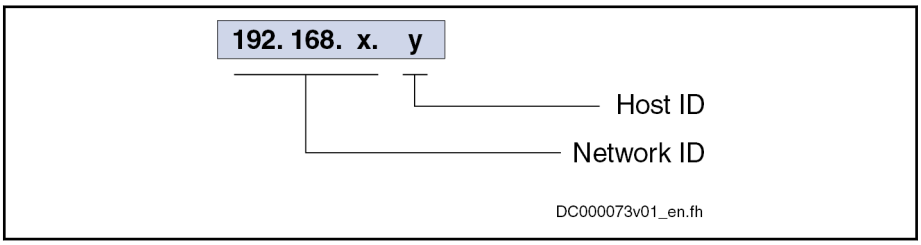



*Fig. 10-1: Structure of the IP Address*

Always use a "private" area as address range of the IP communication with the drive. The defined areas of the following networks are available

- Class A networks (10.x.x.x),

- Class B networks (172.16.x.x.x) or
- Class C networks (192,168.x.x.x).

The private class C networks (192.168.x.x) are recommended and set as default for the IP address area or as default setting.

| Interface | IP address | Network mask | Gateway address |
|---|---|---|---|
| Engineering via IP | 192.168.0.<FKM address> | 255.255.255.0 | 192.168.0.254 |
| Engineering port | 192.168.1.<FKM address> | 255.255.255.0 | No default value |

*Tab. 10-3: Default Values of the IP Configuration*

Use "Load basic parameters (factory settings)" to restore the default values of the IP configuration (see table).

The IP communication configuration can be maintained by selecting this in loading "Load basic parameters".

Select the option "without Engineering interface" to maintain the Engineering port settings unchanged. Select the option "without control communication parameters" to maintain the "Engineering IP" settings unchanged.

### Automatic Settings

**IP Address of the Control Communication Interface**

This IP-configuration is pre-set automatically:

- **IP address:** 192.168.0.<FKM address>
- **Network mask:** 255.255.255.0
- **Gateway address:** 192.168.0.254

If required, change the settings as needed. This may be done using the control via an active connection to the drive.

### IP Port List

The following table provides an overview of the IP ports used in the drive and if they are configurable:

| Communication | Port | Protocol | Port configurable? |
|---|---|---|---|
| IndraWorks drive programming | 5002 | TCP | No |
| EtherNet/IP™ | 44.818 | TCP/UDP | No |
| EtherNet/IP™ | 2222 | UDP | No |
| TFTP | 69 | UDP | No |
| TFTP - other ports dynamic | 1023 et seqq. | UDP | Yes |
| Telnet | 23 | TCP | No |
| Global port list "well known ports" | http://www.iana.org/assignments/port-numbers | | |

*Tab. 10-4: IP Port List*

# 10.2 S/IP Protocol

## 10.2.1 Brief Description

### Fields of Application

S/IP allows for simple access to all drive parameters.

Engineering/Diagnostic Interfaces

Typical fields of application are:

- Communication with the drive for engineering via IndraWorks
- Replacement for cyclic bus communication for the control of simple axis applications without real-time requirements, e.g. positioning block operation or with drive-controlled positioning

### Overview of Functions

### Features

- TCP/IP-based protocol
- The protocol focuses on data exchange; only a very small administration overhead is required.
- User-defined busy timeout (time until the drive sends a defined answer)
- User-defined lease timeout (time when the connection is re-enabled if no new requests are received)
- Dedicated service for read-out of all parameter information in a request
- Up to 2 simultaneous connections possible

### Pertinent Diagnostic Messages

The following error messages are defined and returned directly in a dedicated service by the drive:

| Name | Value in the telegram | Significance |
|---|---|---|
| CONNECTION_ERROR | 1 | Error during connection set-up |
| ABORTED | 2 | The process was aborted |
| UNKNOWN_MESSAGE_TYPE | 3 | Unknown MessageType in the header |
| SERVICE_SPECIFIC | 4 | Service-specific error, e.g. "data is write-protected" |

*Tab. 10-5: S/IP Error Classes*

## 10.2.2 Functional Description

### General Information

S/IP is short for sercos internet protocol.

The following sections contain an overview of the services available in the S/IP protocol and explain the individual services. Example requests and responses are described in the commissioning instructions.

A service always consists of a request and a response. The request is always sent by the client. The server (drive) can answer a request with various responses. If the request can be processed and replied to immediately, the drive directly sends the corresponding response to the request (usually: response service number = request service number +1). If the drive is processing another request, it may also send a busy response (service number: 68). If the telegram has the wrong format, if the service is not supported or if another error occurred, an exception response is sent (service number: 67).

Each telegram consists of a static and a service-specific part. In the static part, a package number can be assigned to allocate the request to the response. In addition, it states the service executed with this telegram.

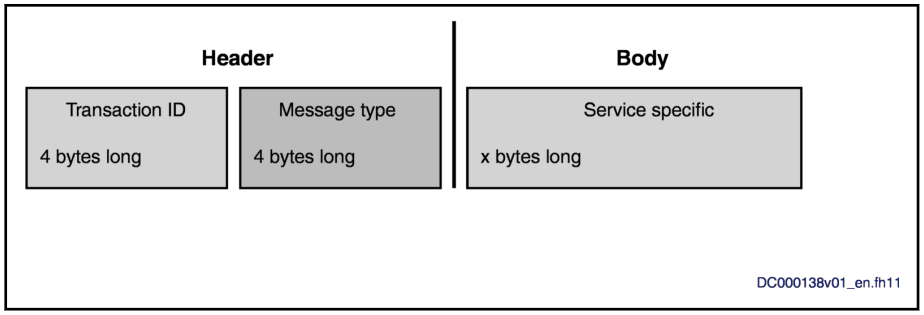



*Fig. 10-2: Basic Set-up of a S/IP Telegram*

The header consists of 8 bytes:

- Bytes 1 to 4 form the "TransactionID", an identification which defines this request. This number is stated in a response.
- Bytes 5 to 8 define the "MessageType". The MessageType is the service number (for a list of services supported by the drive, see below). As currently only services with 1 byte in length are used, the low byte is relevant.

**Variable Definitions**

The services "ReadEverything-Response" and "ReadDescription-Response" send the data and a 2-byte value that states which elements are valid in the response. This value called "ValidElements" consists of the following:

| Bit | Description |
|---|---|
| 0x01 | Data status is valid |
| 0x02 | The description (Description) and description length (DescriptionLength) are valid |
| 0x04 | The attribute is valid |
| 0x08 | The unit (Unit) and unit length (UnitLength) are valid |
| 0x10 | The minimum value is valid |
| 0x20 | The maximum value is valid |
| 0x40 | The value (Value) and value length (ValueLength) are valid |

*Tab. 10-6: Valid Elements*

For the services "ReadEverything-Request", "ReadOnlyData-Request", "ReadOnlyDescription-Request", "ReadDataStatus-Request", "WriteData-Request" and "WriteDataBits-Request", specify for which parameter the action is to be carried out.

For this purpose, a 4-byte value is passed to the drive. The following figure illustrates its set-up.

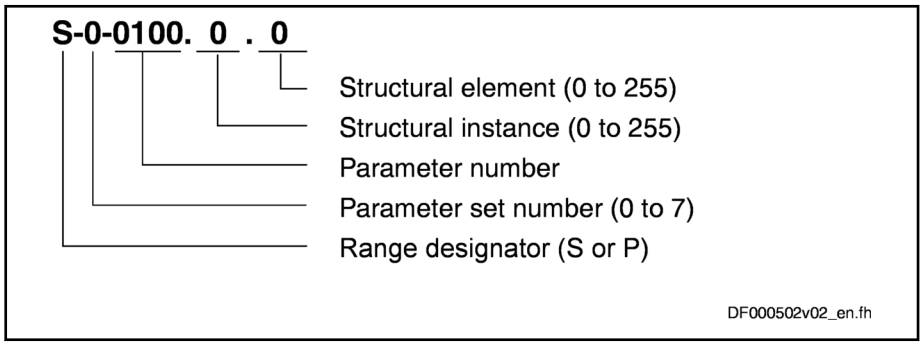



*Fig. 10-3: Example of a 4-byte IDN*

Engineering/Diagnostic Interfaces

| Bit no. | Description | | Value range | Notes |
|---|---|---|---|---|
| 31-24 | Parameter instance/structure instance (SI) | | 0-255 | |
| 23-16 | Parameter element/ structure element (SE) | sercos-defined SE | 0-127 | Defined by sercos (bit 15 = 0) |
| | | Product-specific SE | 128-255 | Not in use |
| 15 | sercos-specified or product-specific IDN (S or P) | Standard IDN (S-0-nnnn) | 0 | SE (0-127), SI and parameter number are defined via sercos |
| | | Product-specific IDN (P-0-nnnn) | 1 | Product-specific parameter |
| 14-12 | Parameter set | | 0-7 | See also "Parameter set switching" |
| 11-0 | Parameter number | | 0-4095 | |

*Tab. 10-7: Set-up of the 4-byte Value*

**Supported Services**

The following table gives an overview of the services supported by the drive and the corresponding "MessageTypes" for the request and response.

| Service name | Service number | |
|---|---|---|
| | Request | Response |
| Connect | 63 | 64 |
| Ping | 65 | 66 |
| Exception | - | 67 |
| Busy | - | 68 |
| ReadEverything | 69 | 70 |
| ReadOnlyData | 71 | 72 |
| ReadDescription | 73 | 74 |
| ReadDataStatus | 87 | 88 |
| WriteData | 83 | 84 |
| WriteDataBits | 85 | 86 |
| Nameplate | 89 | 90 |

*Tab. 10-8: Supported IndraDrive S/IP Services*

## Connect

**Request**

Set-up:

The client connects to the drive using the Connect service. For this purpose, MessageType "63" is sent. Furthermore, the client suggests the busy timeout and the lease timeout times in this telegram.

- **Busy timeout:** States the time that may pass until a response telegram to a request is received.
- **Lease timeout:** States the time until the drive terminates the connection automatically if there are no new requests.

In addition the S/IP protocol version used for communication is stated. The drive supports specification 1.0. Accordingly, the "Version" field has to contain the value "1".

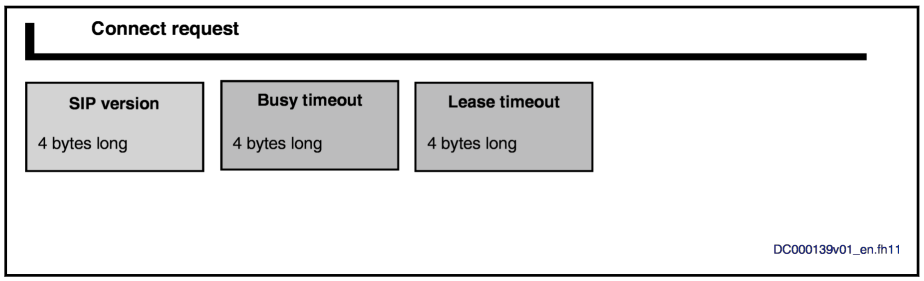



*Fig. 10-4: Representation of a Connect Request*

**Response**

The Connect response is sent as a reply to a Connect request if the connection was established successfully. The service has service number "64" and provides information on the connection:

- What busy timeout is actually used
- What lease timeout is actually used
- What protocol version is actually used
- An array of all supported services (requests) of the drive

| Byte offset | Length (in bytes) | Name | Significance | Example |
|---|---|---|---|---|
| 0 | 4 | Version | Drive protocol version used | 1 |
| 4 | 4 | BusyTimeout | Drive busy timeout used | 500 |
| 8 | 4 | LeaseTimeout | Drive lease timeout used | 15.000 |
| 12 | 4 | NumberMessageTypes | Number of services supported by the drive | 12 |
| 16 | NumberMessageTypes * 4 | MessageTypes | Array consisting of 4-byte values that contain the available drive services | - |

*Tab. 10-9: Structure of Connect-Response*

## Ping

**Ping Request**

The Ping request is identified by service number "65". This is an empty telegram, i.e. the telegram contains 0 bytes of user data. The service can be used to:

- maintain the connection as the drive terminates the connection when the lease timeout has expired
- measure the minimum time required by a response of the drive

**Ping Response**

The Ping response is sent as a reply to a Ping request. The telegram contains no user data.

## Busy & Exception

The services "Busy" and "Exception" are special services. They may be sent to reply to any request.

**Busy Response**

The Busy response is sent if the response telegram cannot be sent when the Busy timeout expires. Die Busy response contains no data. Set the Busy timeout to great values to virtually suppress this response. However, even great values do not guarantee that no Busy response is sent.

Engineering/Diagnostic Interfaces

**Exception Response**

The Exception response is sent if a general communication error occurred. There are several causes for an Exception response.

## ReadEverything

**ReadEverything Request**

With the ReadEverything request all data of a parameter can be requested at once. The service is identified by service number "69". In addition, the Slave-Index and SlaveExtension are required. Furthermore, the parameter to be read is transmitted.

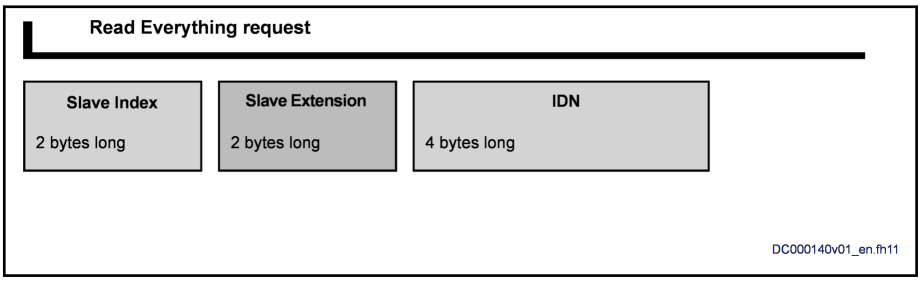



*Fig. 10-5: Representation of a ReadEverything Request*

| Byte offset | Length (in bytes) | Name | Significance | Example |
|---|---|---|---|---|
| 0 | 2 | SlaveIndex | Only relevant with multi-axis devices (HCQ/HCT/CDB)<br>0: Access to 1. Axis<br>1: Access to 2. Axis<br>etc. | 0 |
| 2 | 2 | SlaveExtension | Reserved - always 0 | 0 |
| 4 | 4 | IDN | Parameter to be read | 0x30 |

*Tab. 10-10: Structure of a ReadEverything Request*

**ReadEverything Response**

The ReadEverything response contains the data for the "ReadEverything request". The service is identified by service number "70".

The following values are transmitted:

- Data status
- Attribute
- Minimum and maximum
- Maximum length of the list in bytes (if list parameter)
- Current length of the parameter data in bytes
- Current length of the parameter unit in bytes
- Current length of the name in bytes
- Parameter data in binary format
- Parameter unit as string
- Parameter name as string

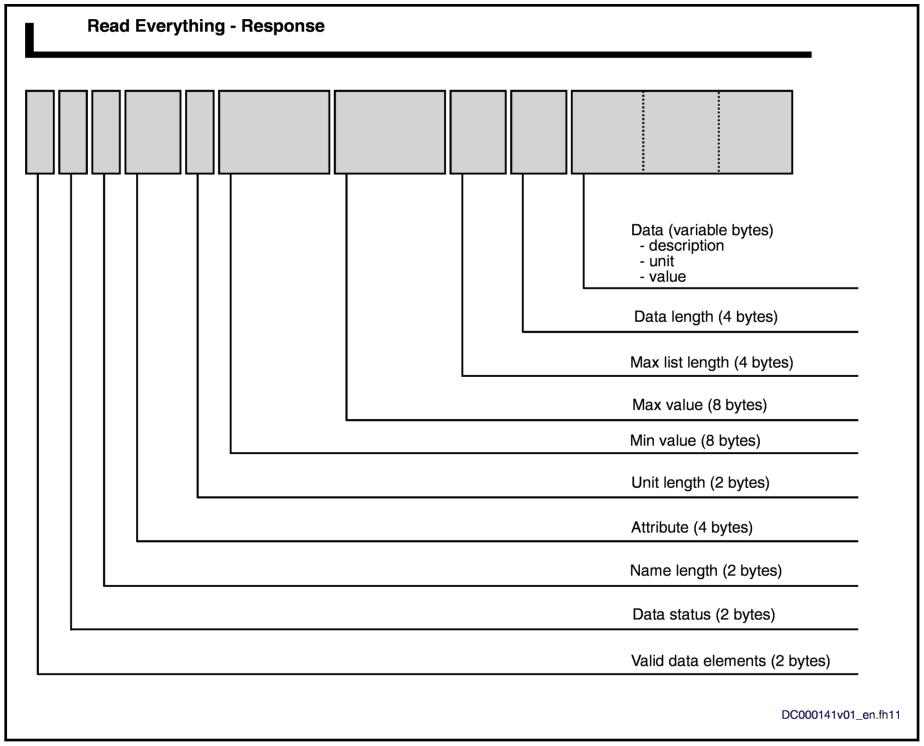



*Fig. 10-6: Representation of a ReadEverything Response*

| Byte offset | Length (in bytes) | Name | Significance | Example |
|---|---|---|---|---|
| 0 | 2 | ValidElements | Bit string that encodes the valid elements | 0b0000.0000.0100.1111 |
| 2 | 2 | DataStatus | Data status of the parameter (valid/invalid) and/or command status of command parameters | 1 |
| 4 | 2 | NameLength | Length of the string that contains the parameter name in the language set in S-0-0265 | 0x20 |
| 6 | 4 | Attribute | The attribute of the parameter contains information on decimal places, display format, maximum length, write protection and whether the parameter is a command parameter. | 0x77560000 |
| 10 | 2 | UnitLength | Length of the string that contains the parameter unit (scaling-dependent) | 6 |
| 12 | 8 | Min | Lower input limit of this parameter | - |
| 20 | 8 | Max | Upper input limit of this parameter | - |
| 28 | 4 | MaxListLength | Maximum length of the list parameter in bytes (only valid with list parameters) | 8196 |
| 32 | 4 | DataLength | Current length of the parameter | 38 |
| 36 | NameLength | Name | Name of the parameter | "Firmware Version" |

Engineering/Diagnostic Interfaces

| Byte offset | Length (in bytes) | Name | Significance | Example |
|---|---|---|---|---|
| 36 + Name-Length | UnitLength | Unit | Unit of the parameter | "" |
| 36 + Name-Length + UnitLength | DataLength | Data | Value of the parameter | "FWA-INDRV****" |

*Tab. 10-11: Structure of a ReadEverything Response*

## ReadOnlyData

**ReadOnlyData Request**

The "ReadOnlyData request" reads out the data. The "ReadOnlyData" request is identical with the "ReadEverything request". Here, service number "71" is sent in the header.

**ReadOnlyData Response**

The "ReadOnlyData response" is identified by service number "72" The following data are transmitted:

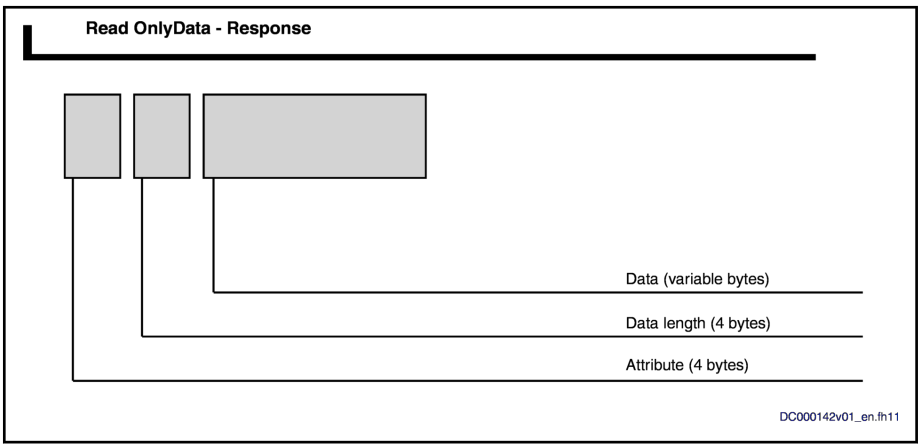



*Fig. 10-7: Representation of the ReadOnlyData Response*

| Byte offset | Length (in bytes) | Name | Significance | Example |
|---|---|---|---|---|
| 0 | 4 | Attribute | Attribute of parameter | 0x77560000 |
| 4 | 4 | Length | Length of the data array in bytes | 2 |
| 4 | Length | Data | Data of the parameter | 0x1345 |

*Tab. 10-12: Structure of a ReadOnlyData Response*

## ReadDescription

**ReadDescription Request**

The "ReadDescription request" queries all information on the parameter, excluding the operating datum. The "ReadDescription" request is completely identical with the "ReadEverything request". However, service number "73" is used.

**ReadDescription Response**

The "ReadDescription response" is identified by service number "74". The following data are transmitted:

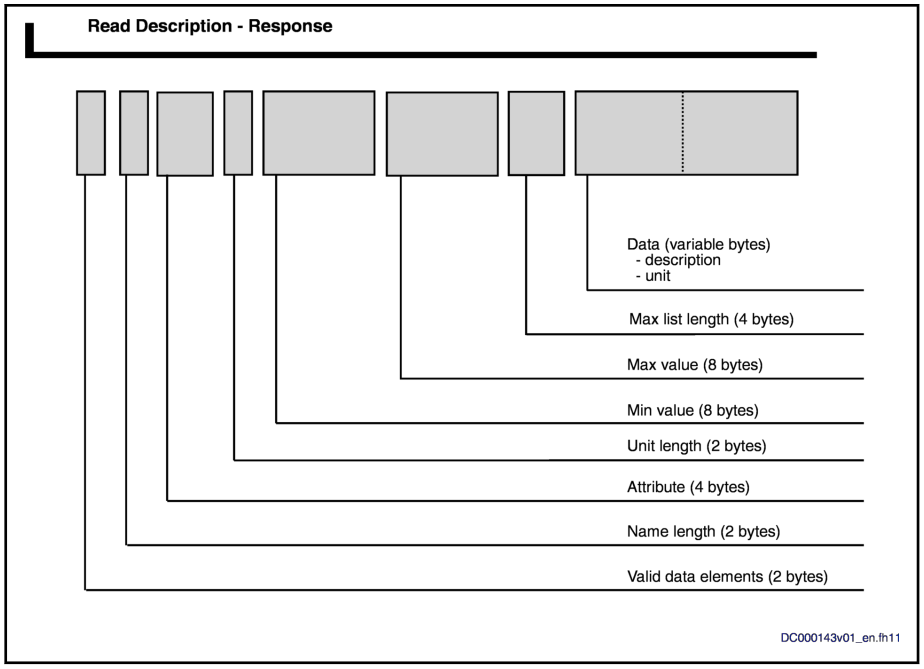



*Fig. 10-8: Representation of the ReadDescription Response*

| Byte offset | Length (in bytes) | Name | Significance | Example |
|---|---|---|---|---|
| 0 | 2 | ValidElements | Bit string that encodes the valid elements | 0b0000.0000.0100.1111 |
| 2 | 2 | NameLength | Length of the string that contains the parameter name in the language set in S-0-0265 | 0x20 |
| 4 | 4 | Attribute | The attribute of the parameter contains information on decimal places, display format, maximum length, write protection and whether the parameter is a command parameter. | 0x77560000 |
| 8 | 2 | UnitLength | Length of the string that contains the parameter unit (scaling-dependent) | 6 |
| 10 | 8 | Min | Lower input limit of this parameter | - |
| 18 | 8 | Max | Upper input limit of this parameter | - |
| 22 | 4 | MaxListLength | Maximum length of the list parameter in bytes (only valid with list parameters) | 8196 |
| 26 | 4 | DataLength | Current length of the parameter | 38 |
| 30 | NameLength | Name | Name of the parameter | "Firmware Version" |
| 30 + Name-Length | UnitLength | Unit | Unit of the parameter | "" |

*Tab. 10-13: Structure of a ReadDescription Response*

## ReadDataStatus

**ReadDataStatus Request**

Use the "ReadDataStatus request" to read out the data status directly. The "ReadDataStatus" request is identical with the "ReadEverything request". Here, service number "87" is used.

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**ReadDataStatus response**

The "ReadDataStatus response" is identified by service number "88". The following data are transmitted:

| Byte offset | Length (in bytes) | Name | Significance | Example |
|---|---|---|---|---|
| 0 | 2 | DataStatus | Data status of the requested parameter | 1 |

*Tab. 10-14: Structure of a ReadDataStatus Response*

## WriteData

**WriteData Request**

"WriteData" reads out the data. Here, service number "83" is used.

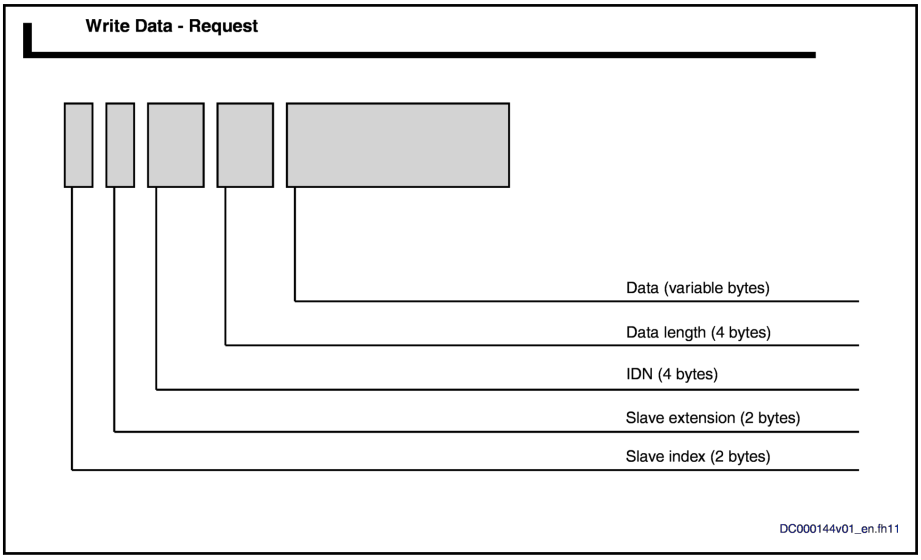


*Fig. 10-9: Representation of the WriteData Request*

| Byte offset | Length (in bytes) | Name | Significance | Example |
|---|---|---|---|---|
| 0 | 2 | SlaveIndex | Reserved - always 0 | 0 |
| 2 | 2 | SlaveExtension | Reserved - always 0 | 0 |
| 4 | 4 | IDN | Parameter to be read | 0x30 |
| 4 | 4 | DataLength | Length of the data to be transmitted | 2 |
| 8 | DataLength | Data | The operating data to be transmitted | 0x1234 |

*Tab. 10-15: Structure of a WriteData Request*

**WriteData Response**

The "WriteData response" is identified by service number "84". No data are transmitted.

## WriteDataBits

**WriteDataBits request**

Use the "WriteDataBits request" to write individual bits of a parameter. The "WriteData" request is identified by service number "85".

Any number of bits of a parameter value can be written in a request. The DataMask, which is part of the request, determines what bits are written. It is therefore possible to change an individual bit in any place in the parameter or to write all bits. The bits to be written have to be selected in the "DataMask" in the respective position. If bit 7 is to be written, set bit 7 in the "DataMask" to 1.

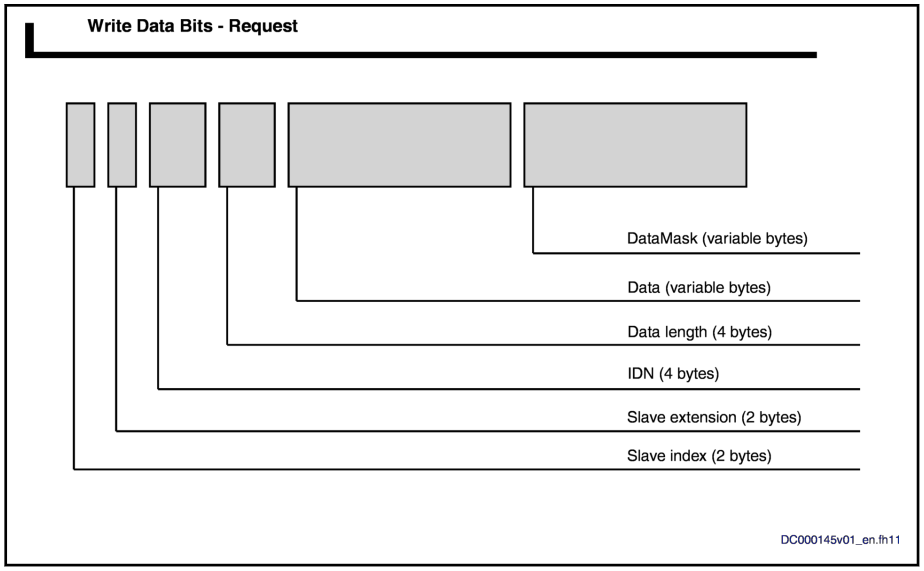


*Fig. 10-10: Representation of the WriteDataBits Request*

| Byte offset | Length (in bytes) | Name | Significance | Example |
|---|---|---|---|---|
| 0 | 2 | SlaveIndex | Reserved - always 0 | 0 |
| 2 | 2 | SlaveExtension | Reserved - always 0 | 0 |
| 4 | 4 | IDN | Parameter to be read | 0x30 |
| 4 | 4 | DataLength | Length of the data to be transmitted | 2 |
| 8 | DataLength | Data | Operating datum to be transmitted | 0x1234 |
| 8 + DataLength | DataLength | DataMask | Bits to be updated | |

*Tab. 10-16: Structure of a WriteDataBits Request*

**WriteDataBits Response** The "WriteDataBits response" is identified by service number "86". No user data are transmitted. In case of error, a "Exception response" is returned instead of the WriteData response.

### Nameplate

**Nameplate Request** In preparation

**Nameplate Response** In preparation

# 10.3 Firmware Download via TFTP Server

## 10.3.1 Brief Description

### Fields of Application

A TFTP server is available for firmware downloads. It is possible to download new firmware to the device.

### Overview of Functions

**Identifying Firmware** Using a special "ReadRequest" the firmware installed in the device can be identified. For this purpose, the string "Firmware" is transmitted during "ReadRequest".

The response telegram contains a data package which contains the manufacturer version (see S-0-0030.0.0).

Engineering/Diagnostic Interfaces

**Firmware Download**

A WriteRequest starts the download process. For this purpose, the drive has to be in PM. Additionally, the "WriteRequest" also establishes a connection to the TFTP server.

Afterwards, the firmware is downloaded to the device via "DataRequests". The device carries out several checks:

- Can the new firmware file be used for the device (compatibility check)?
- Was the correct number of data transmitted (data integrity check)?
- Was the firmware file transmitted correctly and validly (validity check)?

**Error Diagnosis**

All errors occurring in this process are sent back via ErrorFrame in TFTP. The error text is available as plain text.

## Features

The TFTP server of a HydraulicDrive device has the following features:

- A TFTP connection does not know authentication
- There are the following 5 package types with a TFTP connection:
  - "ReadRequest" (starts reading files from the server/drive)
  - "WriteRequest" (starts writing files to the server/drive)
  - "Data" (data transmission)
  - "Acknowledge" (acknowledgement of data packages)
  - "Error" (any kind of error messages)
- Each data package has to be confirmed using "Acknowledge" before the next data package is sent.

## Pertinent Diagnostic Messages

Any errors that occur are converted into plain text using "TFTP ErrorFrame".

# 11 Commissioning

## 11.1 Introduction

The options described here are used for commissioning a hydraulic drive (in the following, referred to as “Hydraulic Drive”).

In these instructions, it is assumed that the hydraulic drive is commissioned using the Easy Startup mode. This allows complete commissioning of the axis without involvement of a control and thus without use of master communication. There is no restriction with regard to operation modes.

It is also possible to carry out commissioning with a control or to change over to the Easy Startup mode at any time.

## 11.2 Easy Startup Mode

After activation of the Easy Startup mode, the hydraulic drive is in direct valve control.

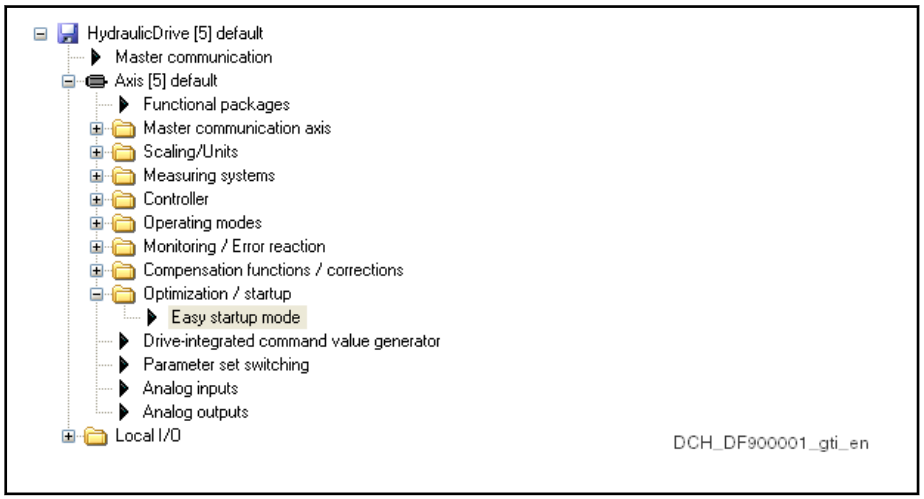


*Fig. 11-1: Menu to Activate the Easy Startup mode*

To be able to set the controller enable, the HW input "Enable" must be set for the hydraulic drive. After the software enable was activated, the hydraulic drive can be operated. In addition, the position, pressures and forces can be read out, if already parameterized.

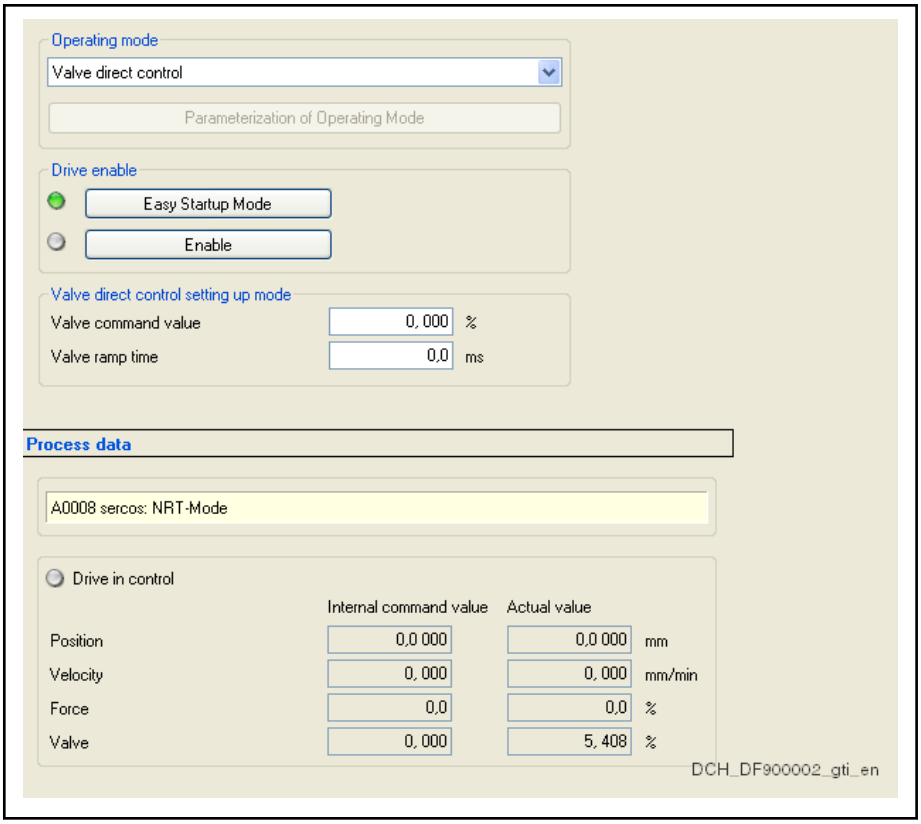


*Fig. 11-2: Easy Startup Mode Dialog*

# 11.3 Commissioning an Axis Control

## 11.3.1 Setting the Encoders

In a next step the position encoder **(P-0-0074)** must be selected. Depending on the encoder type, further settings must be made; for an SSI position encoder, for example, the number of bits and the communication speed must be selected in the SSI control parameter **(P-0-0910)**. Then, you have to set the maximum travel range **(S-0-0278)**. This should be about twice as great as the actual travel range. Depending on the encoder's type of counting, inverting may be required to match the direction of the encoder with that of the controller.

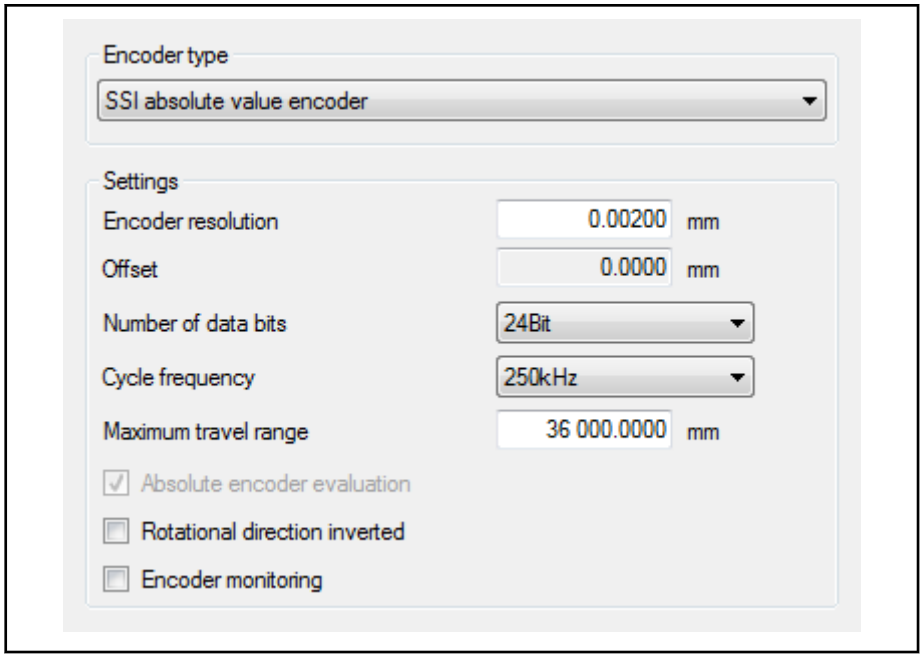


*Fig. 11-3: "Position Setting" Dialog*

The direction of the encoder and the controller should now be checked at low system pressure. Two possibilities are provided for this. You can either select the operation mode “Direct valve control" to control the valve directly, or you can temporarily provide a control variable in control variable adjustment without controller enable via the valve control value standstill value **(P-0-2873.0.17)**.

Extending is to take place in the positive direction using a positive control variable. If this is not the case, the valve control variable or the direction of the position encoder can be inverted. For the control loop it is essential that these settings are correct, since otherwise, a positive feedback occurs and the axis can move in an uncontrolled way up to its maximum velocity.

Commissioning

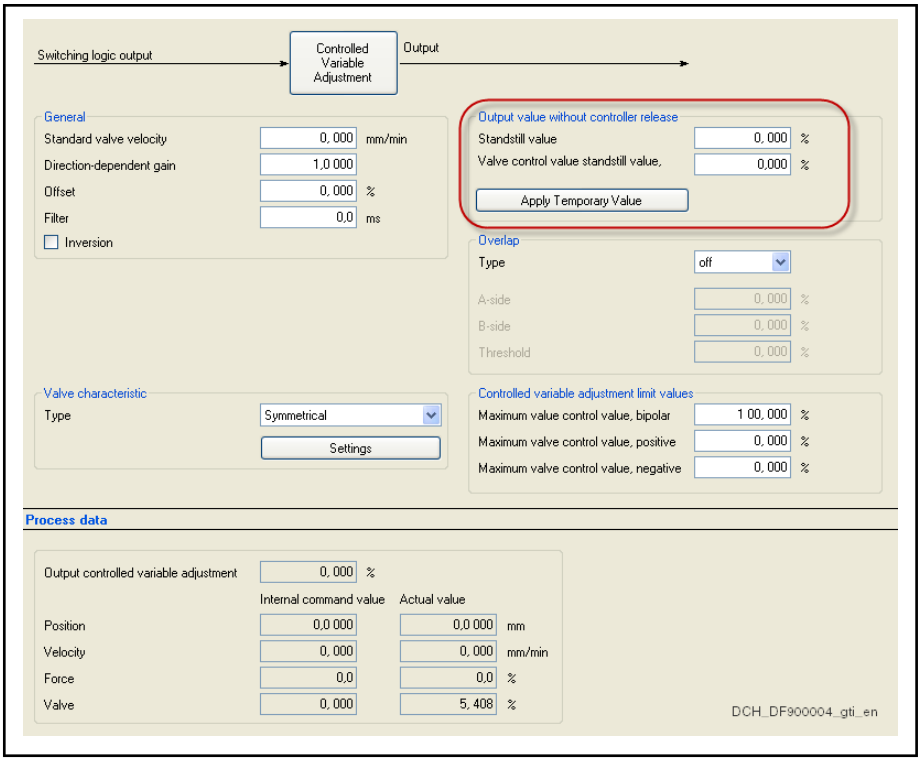


*Fig. 11-4: "Control Variable Adjustment" Dialog*

After you checked the direction of the encoder, you have to determine the 0 mm position at a defined place (useful would be the retracted condition). You can make this selection in the "Establishing position data reference" dialog.

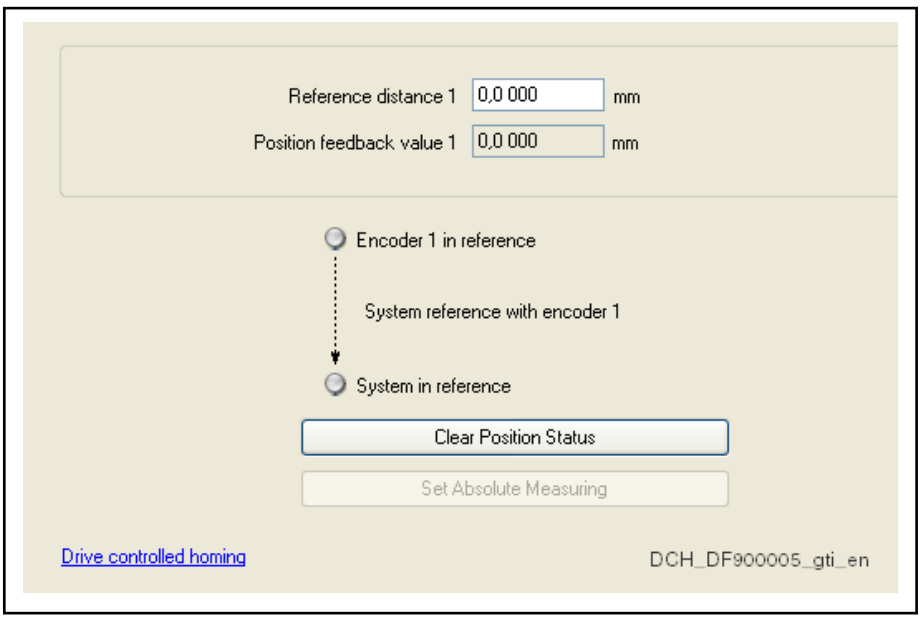


*Fig. 11-5: Position Data Reference Encoder 1*

## 11.3.2 Closed-Loop Position Control

For setting the controller parameters, it is useful to extend and retract the cylinder periodically. For this, it is helpful to use the "positioning block mode, lagless" operation mode. In this operation mode you can enter up to 64 process blocks, which allows the realization also of quite complex movements. For commissioning, two blocks are sufficient, which contain the desired posi-

tions with the related velocities and accelerations. Select realistic values for these movements in order that the axis can actually perform them.

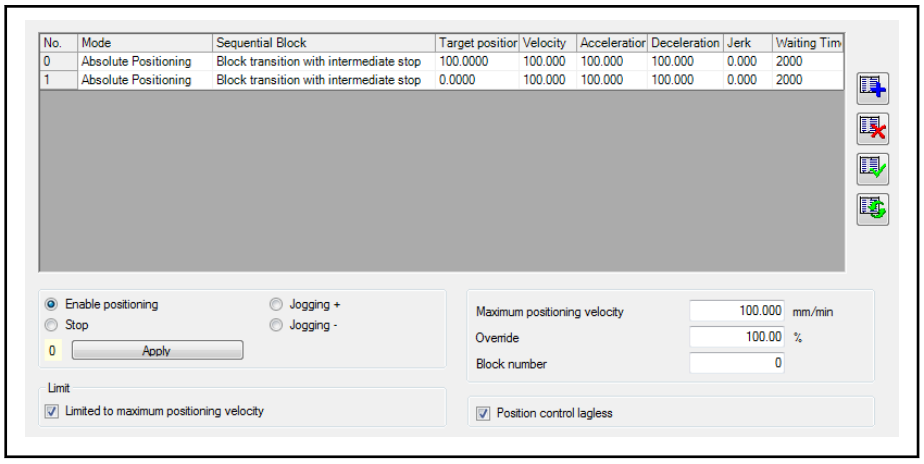


*Fig. 11-6: "Positioning Block Mode" Dialog*

## 11.3.3 Setting the Valve

With the help of "control variable adjustment", the control variable is adapted to the connected valve.

**Valve Standard Velocity**

With the help of valve standard velocity, the controller output is converted into a corresponding valve command value. The velocity entered here corresponds to 100%.

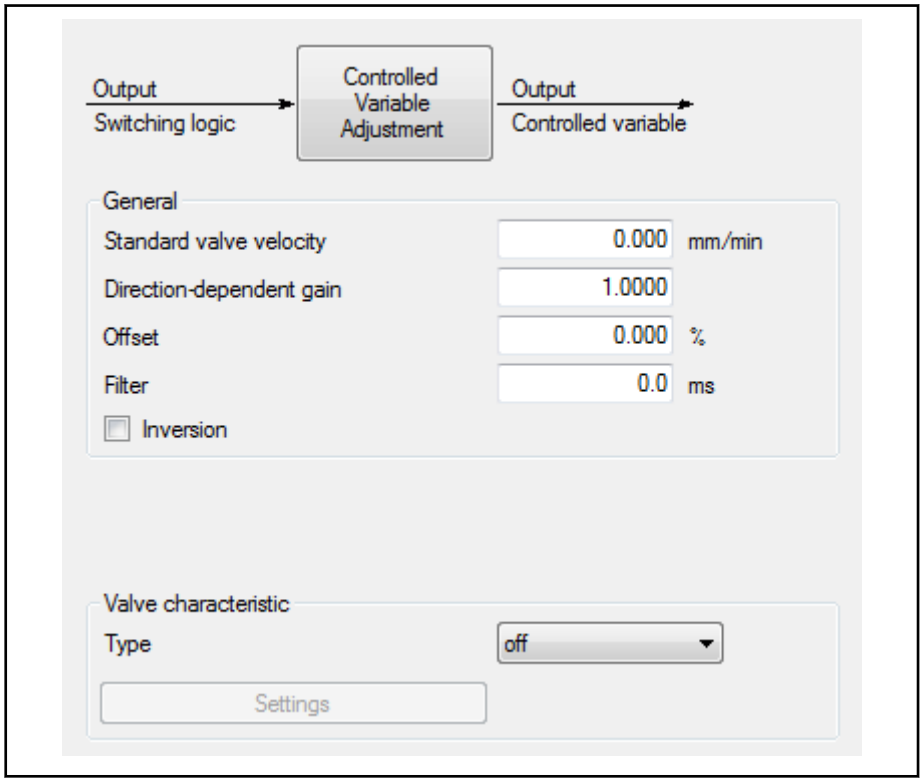


*Fig. 11-7: "Control Variable Adjustment" Dialog*

The valve standard velocity can be established in 2 ways.



The valve standard velocity is a reciprocal value, which means, the smaller it is, the greater is the gain.

Commissioning

**Calculating the Valve Standard Velocity**

The valve standard velocity can be calculated with the help of the system pressure and the area of the spool side:

$$v = Q_N \frac{1}{A} 10^6 \sqrt{\frac{p_s}{p_N}}$$

*Fig. 11-8: Calculating the Valve Standard Velocity*

It must be noted here that the system pressure ($p_S$) must be entered in bar, area of side A (A) in $mm^2$ and the rated flow of the valve ($Q_N$) in l/min. The unit of the result is “mm/min“. For $p_N$ take the differential pressure at nominal flow from the valve data sheet.

**Measuring the Valve Standard Velocity**

Alternatively, the valve standard velocity can be established by measuring the travel velocity. To this end, it is necessary to set the working pressure to the pressure required for the application. Set a temporary valve opening with the help of control variable adjustment of command value, maintenance **(P-0-2873.0.17)**, and acquire the resulting travel velocity. Depending on the application at hand, it may be useful or necessary to preset a valve opening « 100% (10...20%). The valve standard velocity is determined according to the following formula:

$$\text{Standard valve velocity}\,[mm/\text{min}] = \frac{100\%}{\text{Valve control variable}\,[\%]} * \text{travel speed}\,[mm/\text{min}]$$

*Fig. 11-9: Establishing the Valve Standard Velocity*

In a first step, the valve standard velocity **(P-0-2873.0.1)** can be set to the 10-fold value of the calculated or established value. In this way, it can be reliably prevented that the gain becomes too great. Adjustments to the correct value will have to be made later (see "Adjusting the Gain").

It must be noted that the system may become instable, especially at low velocities, because in this case, the gain is in general too great.

## 11.3.4 Valve Characteristic Curves

The valve characteristic must be set, if a valve with a non-linear, e.g. inflected, characteristic curve is used.

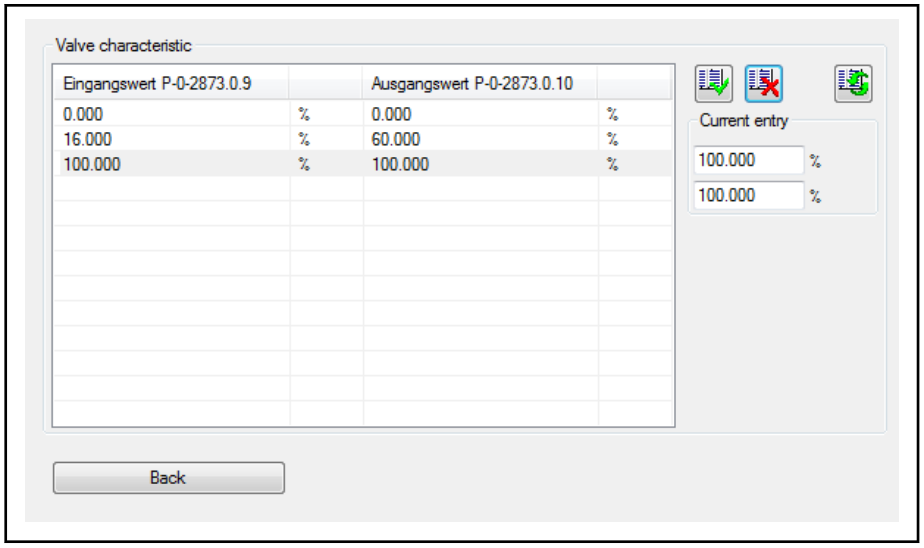


*Fig. 11-10: Valve Characteristic Dialog*

The inflected characteristic curve can in most of the cases be found in the valve data sheet and must be entered in the relevant table **(P-0-2873.0.9, P-0-2873.0.10)** or converted. It must be observed that for fine positioning, a corresponding range with a "flatter" characteristic curve is usually available, which can be utilized due to its greater internal gain.

The example is to illustrate, how the characteristic curve table can be established for a valve. To this end, the inverted characteristic curve is determined. This is shown in the figure below.

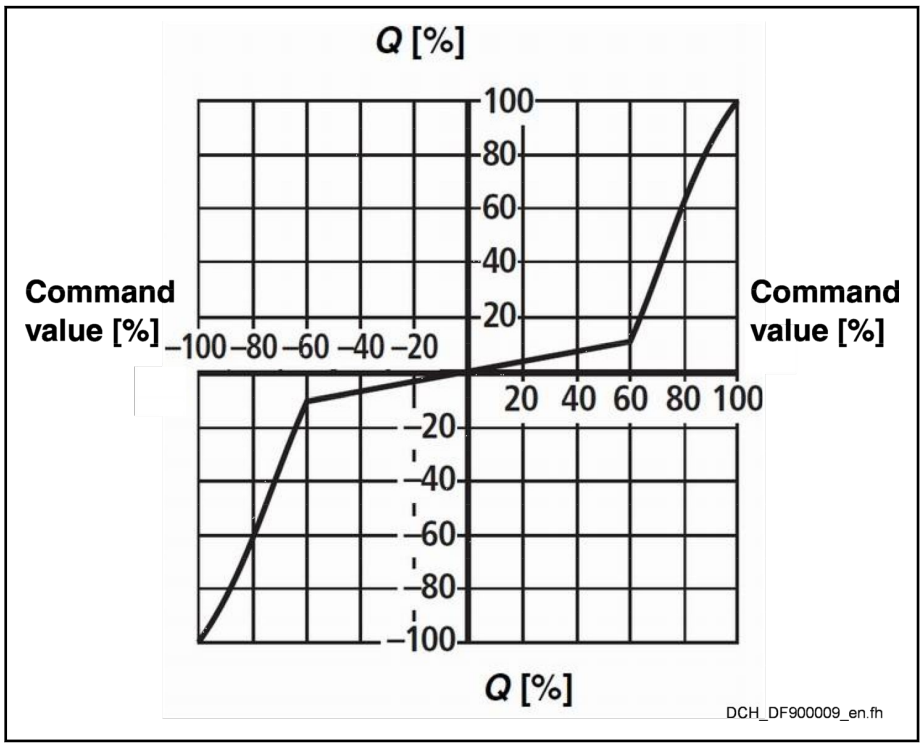


*Fig. 11-11: Characteristic Curve of a Valve*

In this case, the flow in percent and the command value in percent are read from the curve. Based on these inflection points, the inverse characteristic curve can be established. It is recommended that also the zero point be indicated to ensure that also the calculated inverse characteristic curve goes through zero.

| Input value (in %) | Output value (in %) |
|---:|---:|
| -100 | -100 |
| -10 | -60 |
| 0 | 0 |
| 10 | 60 |
| 100 | 100 |

*Tab. 11-1: Characteristic Curve*

Another application for utilizing a characteristic curve is control variable limitation (also in combination). It can be used to limit the maximum control variable in dependence upon the direction.

| Input value (in %) | Output value (in %) |
|---:|---:|
| -100 | -80 |
| -80 | -80 |
| -10 | -60 |
| 0 | 0 |
| 10 | 60 |
| 80 | 80 |
| 100 | 80 |

*Tab. 11-2: Limited Characteristic Curve*

The example shows that the control signal is limited to 80 %. The existing inflection remains unchanged.

This characteristic curve suggests itself in the case of some valve- or application-specific requirements; e.g. a valve with "inflected characteristic curve", which allows fast traveling within one range and exact positioning in another.

**Overlap**

If the valve features an overlap, you can set this overlap using the parameters of valve overlap type **(P-0-2873.0.4)** and A-side **(P-0-2873.0.5)**, B-side **(P-0-2873.0.6)**, threshold **(P-0-2873.0.7)**.

If the axis should still drift, this can be eliminated by means of the valve control variable offset (P-0-2873.0.13).

## 11.3.5 Adjusting the Gain

As mentioned at the beginning, only one working point of velocity is considered for this commissioning procedure. At this point, the control is ready for operation for this working point. For further proceeding, the working pressure must now be set to the pressure necessary for the application.

Firstly, velocity feedforward control **(P-0-0040 = 0)** is to be switched off and the cylinder extended and retracted periodically. This time, attention must be paid to the lag **(S-0-0189)**. This must be set with the help of the valve standard velocity to:

$$\frac{V_{comm}}{K_V} = \text{calculated lag}$$

*Fig. 11-12: Calculating the Lag*

It must be noted that the Kv is defined in 1000/min. Accordingly, in the example, at a Kv of "1“ and a $v_{comm}$ of "2000 mm/min“, a lag of "2 mm“ is to be envisaged. If the gain is so high that vibrations become noticeable the Kv can also be reduced; in this case, the lag must be calculated accordingly.

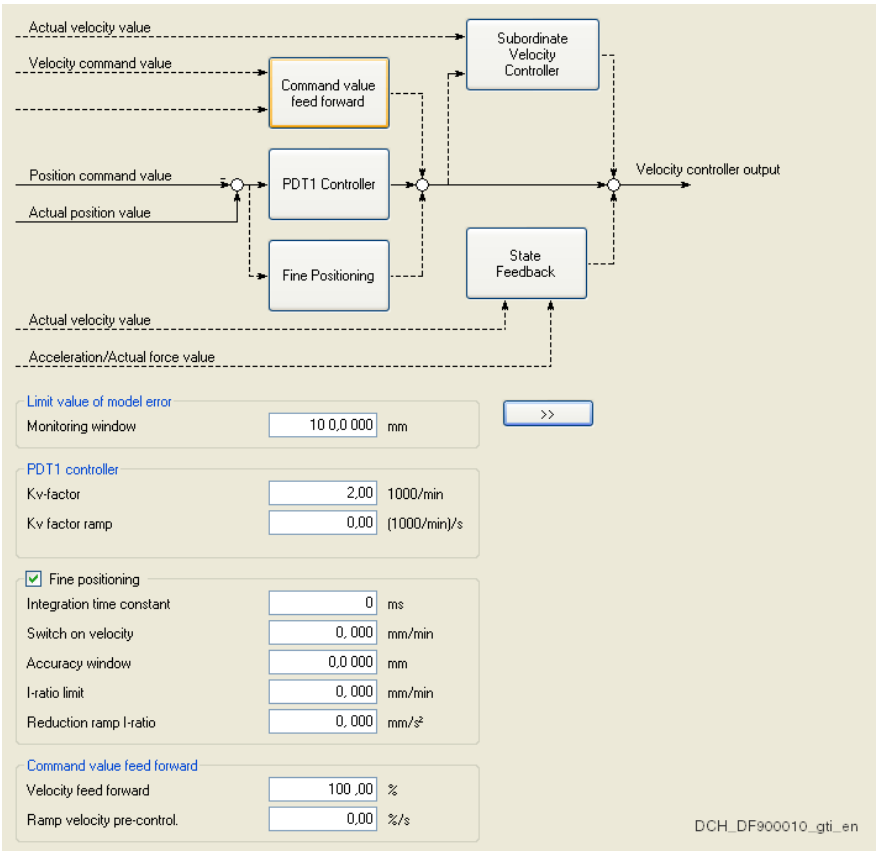


*Fig. 11-13: "Position Controller – PDT1 and Fine Positioning" Dialog*

In a first step, observe the lag for extending the cylinder (positive direction). This means that the valve standard velocity is iteratively adjusted until it is close to the calculated lag. How accurate this value must be, depends on the application. The following iteration steps are useful:

$$\text{old standard valve velocity} * \frac{\text{calculated lag}}{\text{lag}} = \text{new standard valve velocity}$$

*Fig. 11-14: Determining the Valve Standard Velocity*

After having set the forward movement, the negative direction can be adjusted with the help of direction-dependent gain (P-0-2873.0.2). This will not result in a change in the valve standard velocity! This can be carried out in a similar way as for the valve standard velocity:

$$\text{old V/R adjustment} * \frac{\text{lag}}{\text{calculated lag}} = \text{new V/R adjustment}$$

*Fig. 11-15: Establishing Direction-Dependent Gain*

When this is completed, velocity feedforward control should again be set to 100%. Then, the lag is close to "0 mm“.

☞ The lag is reduced at a smaller valve standard velocity.

## 11.3.6 Subordinate Velocity Controller

The subordinate velocity controller allows a so-called $K_V$ constancy. This is required, for example, for traveling along a circular path or under load. In this way, a constant gain is achieved even under varying conditions.

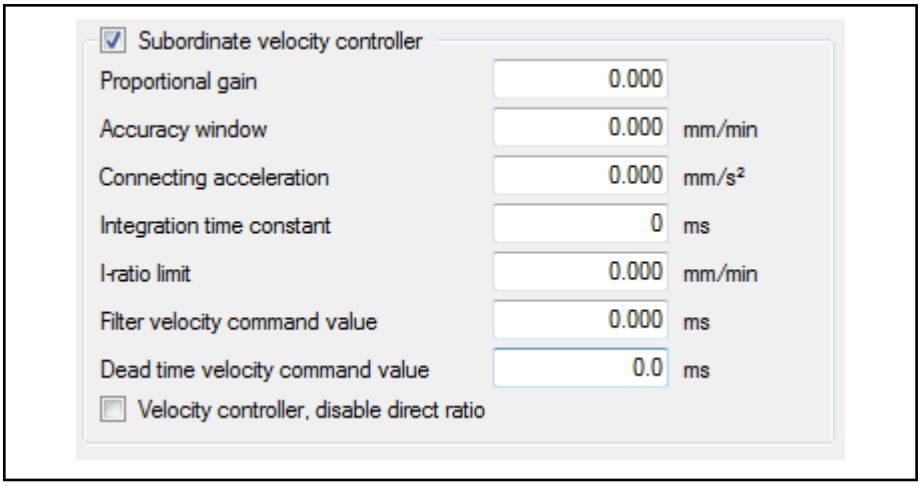


*Fig. 11-16: "Position Controller Extended – Subordinate Velocity Controller" Dialog*

For this, first the proportional gain **(P-0-2832.0.1)** has to be increased to a level, where the axis has not yet started to vibrate. Then, the I-component should be activated in order to further compensate for load-dependencies. Select a very small value or zero as accuracy window **(P-0-2832.0.4)**. As connection acceleration **(P-0-2832.0.3)** a value should be selected, which can be reached by the axis also under load. If the value is too great, the deviation can be taken into account for integrating in the acceleration phase, and this can lead to overshoots. For a start, select a great value (e.g. 1000 ms) for the time constant **(P-0-2832.0.2)**. Times in the order of only a few ms are possible, but depend on the application and the individual system.

## 11.3.7 State Feedback

State feedback is utilized to allow a greater gain. It must be noted that positive and negative feedback can be realized. To this end, it must first be tested, in which direction an improvement can be achieved.

In general, a force feedback is always proportional to an acceleration feedback. If the actual force value is available (pressure sensors or force sensor present), force feedback should be preferred. Provided that the encoder feedback value is of a sufficient quality, acceleration feedback may be used (alternatively).

It is useful to adjust $K_V$ and the feedback alternatingly in order that the gain limit can be reached. It is impossible to indicate, which limit is reasonable for the individual application.

With asynchronous SSI encoders, acceleration is in most of the cases not suitable for state feedback. In the case of force measurement, the force feedback value suggests itself.

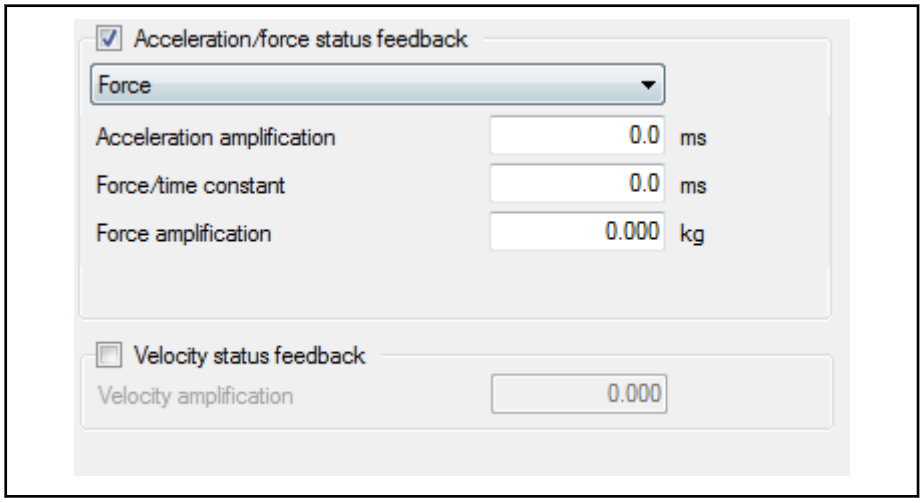


*Fig. 11-17: "Position Controller Extended - Status Feedback" Dialog*

## 11.3.8 Force Setting

First, the cylinder areas should be entered. This can be done by entering the individual diameters or directly the areas **(S-0-0820 and S-0-0821)**. The conversion buttons can be used to convert the pairs of values to correspond to each other.

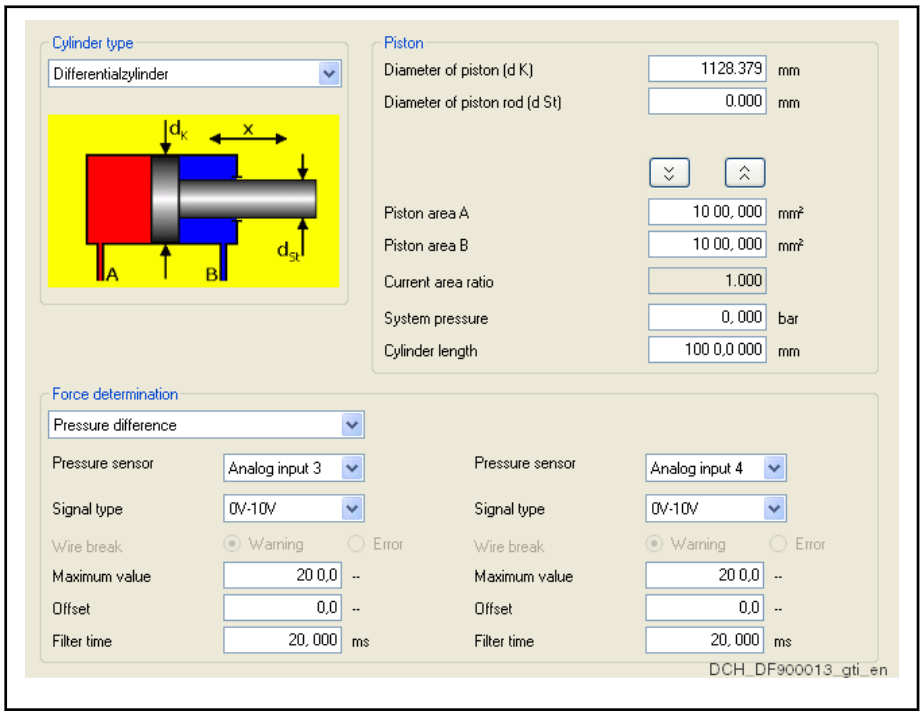


*Fig. 11-18: "Force Setting" Dialog*

The actual force value can be acquired in different ways: Individual pressure measurement in chamber A or in chamber B, taking account of the individual areas, establishment of the differential pressure or differential force of the two sides or direct establishment of the actual force value by means of a force sensor.

The required settings can be made in the dialogs "Analog inputs" and "Force setting", but are not described in more detail here.

## 11.3.9 Closed-Loop Force Control

First of all, a useful value should be set for the nominal force **(S-0-0534)**. If this value is less than 32 kN, preferred scaling can be used for indicating the force. In this case, merely scaling of the force must be set to Newton (N). In the case of increasing force values, it is useful to set scaling to "user-defined". The relevant range can be set via "exponent". The display switches over automatically, e.g. to kN.

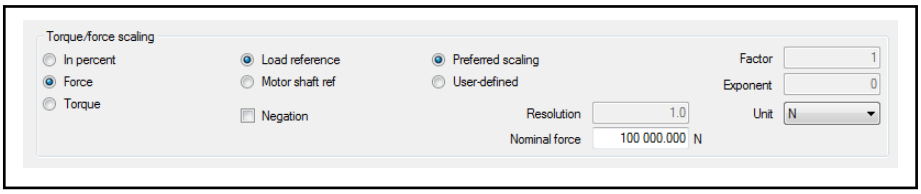


*Fig. 11-19: "Force Scaling" Dialog*

The factor for normalizing the force into a velocity **(P-0-2845.0.2)** is calculated internally from the cylinder geometry. (The parameter has to be entered directly only in the case of OL.) In a next step, you have to set the proportional gain **(P-0-2845.0.1)**. This setting must be determined according to the application and must not excite the system to generate oscillation.

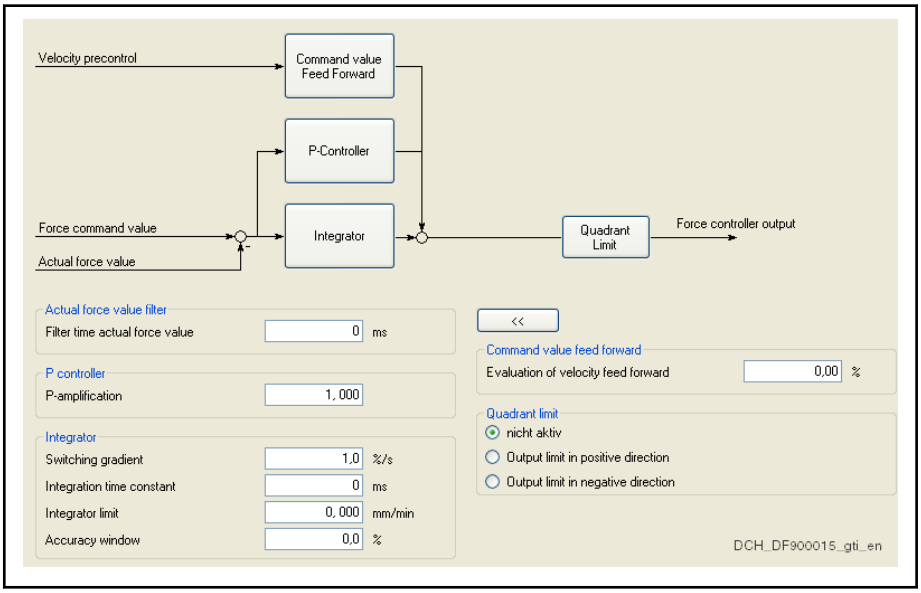


*Fig. 11-20: "Force Controller Extended" Dialog*

## 11.3.10 Alternating Control

All position operation modes support the possibility of limiting the force through alternating control. In this case, position control is superseded by force control, if required, to prevent the maximum force from being exceeded. A typical application is traveling to a positive stop, followed by pressing with a precisely defined force. Alternating control can be parameterized in the related dialog.

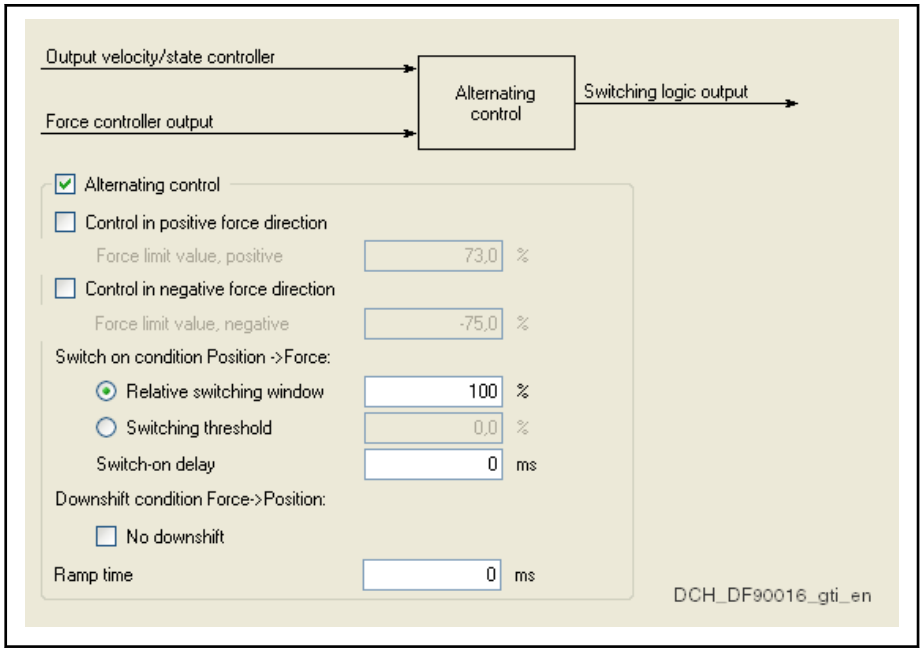


*Fig. 11-21: "Alternating Control" Dialog*

Alternating control must be explicitly activated here.

The ramp time **(P-0-2856.0.5)** defines, within which time a control variable difference at the time of changeover is to be corrected. Switching from position control to force control or switching back to position control always takes place according to the minimum value principle. In addition, relevant changeover conditions must be fulfilled:

**Position -> force:** Alternating control can be permitted or prevented in dependence upon a direction. The actual force value must first exceed the switch-on threshold. This threshold is preset either as absolute value **(P-0-2856.0.1)** or as a percentage-based value **(P-0-2856.0.2)** of the current force command value. The value used is shown in the active changeover threshold **(P-0-2856.0.3)**. In addition, a switch-on delay **(P-0-2856.0.4)** can be set, which further delays the changeover to force control.

**Force -> Position:** Here, you can generally prevent switching back to position control by activating the "No downshift" checkbox.

# 12 Service and Support

**Contact for repairs**

Bosch Rexroth AG
Service industrial hydraulics
Buergermeister-Dr.-Nebel-Strasse 8
97816 Lohr am Main
Phone +49 (93 52) 40 50 60
Germany

E-mail: service@boschrexroth.de
Internet: http://www.boschrexroth.com/service

**Contact for support**

Bosch Rexroth AG
Zum Eisengiesser 1
97816 Lohr am Main
Germany

Phone: **+49 9352 18 1132**
E-mail: support.nc-system@boschrexroth.de

**Helpful Information**

For quick and efficient help please have the following information ready:

- Detailed description of the fault and the circumstances
- Information on the nameplate of the affected products, especially type codes and serial numbers
- Your contact data (phone, fax number and e-mail address)

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# Notes

The Drive & Control Company

Rexroth
Bosch Group

Bosch Rexroth AG
Hydraulics
Zum Eisengießer 1
97816 Lohr, Germany
info@boschrexroth.de
www.boschrexroth.com

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