Rexroth Bosch Group

Rexroth IndraDrive MPx-16 Version Notes

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Release Notes

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1 System Overview

1.1 General Information

1.1.1 About This Documentation

Means of Representation in This Documentation

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

What?	How?	For example...
Important facts which are to be highlighted in continuous text	Boldface	Transmission of freely configurable external **process data** (command values and actual values of the external control unit)
Parameter names, diagnostic message names, function designations	Quotation marks	...the function "set/shift coordinate system" for the firmware MPx16...

Fig. 1-1: Conventions of Notation

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

DANGER

...

DANGER indicates a hazardous situation which, if not avoided, will result in death or serious injury.

WARNING

...

WARNING indicates a hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION

...

CAUTION indicates a hazardous situation which, if not avoided, could result in injury or property damage.

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

This symbol highlights useful tips and tricks.

Your Feedback

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

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

Dokusupport@boschrexroth.de

We need the following information to handle your feedback:

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

1.1.2 How to Use This Documentation

Structure of the Functional Description

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

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

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

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

Brief Description

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

Functional Description

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

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

The detailed description of the diagnostic messages, their causes and measures for remedy is contained in the separate documentation "Rexroth IndraDrive, Troubleshooting Guide" (description of diagnostic messages).

Notes on Commissioning

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

Diagnostic and Status Messages, Monitoring Functions

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

The detailed description of the diagnostic messages, their causes and measures for remedy is contained in the separate documentation "Rexroth IndraDrive, Troubleshooting Guide" (description of diagnostic messages).

Markers and Terms

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

The descriptions of the master communication, the drive functions and the 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 **range** e.g. IndraDrive
- Firmware **design** single-axis; multi-axis
- Firmware **variant** e.g. MP**B**, MP**E**
- Firmware **version** e.g. MPM-**16**VRS
- Firmware **characteristic** open-loop/closed-loop
- Firmware **performance** Basic/Economy
- Firmware **type** complete firmware type designation

Cross References

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

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

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

Reference Documentations

Drive Systems, System Components

Title Rexroth IndraDrive …	Kind of documentation	Document typecode[1)] DOK-INDRV*-…	Part number R911…
Cs Drive Systems	Project Planning Manual	HCS01******-PRxx-EN-P	322210
Drive Controllers HCQ02	Project Planning Manual	HCQ-T+HMQ-T-PRxx-EN-P	324185
Additional Components and Accesso-ries	Project Planning Manual	ADDCOMP****-PRxx-EN-P	306140

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

Fig. 1-2: Documentations – Drive Systems, System Components

Motors

Title Rexroth IndraDyn …	Kind of documentation	Document typecode[1)] DOK-MOTOR*-…	Part number R911…
A Series Asynchronous Motors	Project Planning Manual	MAD/MAF****-PRxx-EN-P	295781
H Frameless Synchronous Spindle Motors	Project Planning Manual	MBS-H******-PRxx-EN-P	297895
L Synchronous Linear Motors	Project Planning Manual	MLF********-PRxx-EN-P	293635
S MSK Synchronous Motors	Project Planning Manual	MSK********-PRxx-EN-P	296289
S Synchronous Motors MSK for Poten-tially Explosive Areas	Project Planning Manual	MSK*EXGIIK3-PRxx-EN-P	312709
T Synchronous Torque Motors	Project Planning Manual	MBT********-PRxx-EN-P	298798

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

Fig. 1-3: Documentations – Motors

Cables

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

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

Fig. 1-4: Documentations – Cables

Firmware

Title Rexroth IndraDrive …	Kind of documentation	Document typecode[1)] DOK-INDRV*-…	Part number R911…
MPB-16, MPM-16, MPE-16 Functions	Application Manual	MP*-16VRS**-APxx-EN-P	326767
MPx-16 Parameters	Reference Book	GEN1-PARA**-RE01-EN-P	328651
MPx-16 Diagnostic Messages	Reference Book	GEN1-DIAG**-RE01-EN-P	326738

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

Fig. 1-5: Documentations – Firmware

1.1.3 Overview of Drive Firmware

Firmware Variants

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

- **MPx**: Drives for general automation (incl. machine tool applications) with SERCOS interface, field bus interfaces, parallel and analog interface (the variants of design are **MPB**, **MPM** and **MPE**; see below)

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

- **MP:** "Multi Purpose" → Drives for general automation (incl. machine tool applications) with SERCOS interface, field bus interfaces as well as parallel and analog interface (drive profile according to SERCOS)

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

- **B**: **Single-axis** firmware with **Basic** performance and functionality
- **M**: **Multi-axis** firmware with **Basic** performance and functionality
- **E**: **Economy** firmware with **Economy** performance and functionality

---

This documentation describes the functionality of the following firmware types:

- **FWA-INDRV*-MPB-16VRS-D5**
- **FWA-INDRV*-MPM-16VRS-D5**
- **FWA-INDRV*-MPE-16VRS-D5**

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

Organization of the Firmware

For application-specific definition of drive functionality, the firmware functions are divided into different "functional packages". There are a **generally available**

base package and various **additional functional packages** that can be optionally activated.

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

1.1.4 Terms, Basic Principles

Parameters

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

Parameters are used for:

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

All operating data are mapped to parameters!

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

Data Storage and Parameter Handling

Data Memory

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

- In the controller
- In the motor encoder (depending on motor type)

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

Condition as Supplied

Condition as supplied of the Rexroth drive components:

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

Storing the Application-Specific Parameter Values

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

Storing of Parameter Values

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

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

Application-specific parameter values can be saved via:

- "IndraWorks Ds/D/MLD" commissioning tool → saving the parameter values on external data carrier
- Control master → saving the parameter values on master-side data carrier

Parameter IDN Lists

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

Loading of Parameter Values

Loading parameter values is required in the following cases:

- Initial commissioning of the motor (loading basic parameter values and motor-specific parameter values)
- Serial commissioning of machine axes at series machines (loading the values saved after initial commissioning)
- Reestablishing a defined initial status (repeated loading of the values saved after initial commissioning)
- Replacing the controller for servicing (loading the current parameter values saved before servicing)

Possibilities of loading parameter values to the controller:

- Motor encoder data memory → loading the parameter values by command or via the control panel during initial motor commissioning
- "IndraWorks Ds/D/MLD" commissioning tool → loading the parameter values from external data carrier
- Control master → loading the parameter values from master-side data carrier

Checksum of Parameter Values

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

Password

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

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

Kinds of Passwords

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

- **Customer Password**

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

  Parameters protected by a customer password can be written; "administration parameters" remain read-only.
- **Master Password**

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

Commands

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

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

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

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

Kinds of Commands

There are 3 different kinds of commands:

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

See also section "Command Processing"

Operating Modes

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

One of the four or eight (for SERCOS) operating modes that are defined in parameters is always active if the conditions below are fulfilled:

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

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

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

See also chapter "Operation Modes"

Warnings

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

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

Classes of Warnings

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

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

The following classes of warnings are distinguished:

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

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

Errors

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

Error Classes

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

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

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

Fig. 1-6: Overview of Error Classes

☞ Apart from the mentioned error classes that can occur during operation, errors can occur when the devices are booted and during firmware download. These errors are not displayed at the control panel with a diagnostic message number of the "Fxxxx" pattern, but with a short diagnostic message text. Booting and firmware download errors are described in the separate documentation "Troubleshooting Guide" (description of diagnostic messages).

Error Reactions of the Drive

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

The drive reaction in the case of interface errors and non-fatal errors is determined in parameter "P-0-0119, Best possible deceleration". At the end of each error reaction, the drive goes torque-free.

See also "Error Reactions"

Clearing an Error Message

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

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

- or -

- Actuating the "Esc" key on the control panel

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

Clearing Error Messages when Drive Enable was set

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

To reactivate the drive:

- Clear the error message and
- Input a positive edge for drive enable again.

Error Memory

The diagnostic message numbers of occurring errors are written to an error memory. This memory contains the diagnostic message numbers of the last 50 errors that occurred and the time when they occurred. Errors caused by a shutdown of the control voltage (e.g. "F8070 +24Volt DC error") are not stored in the error memory.

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

1.2 Drive Controllers

1.2.1 Overview

Standard Design of the IndraDrive Controllers

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

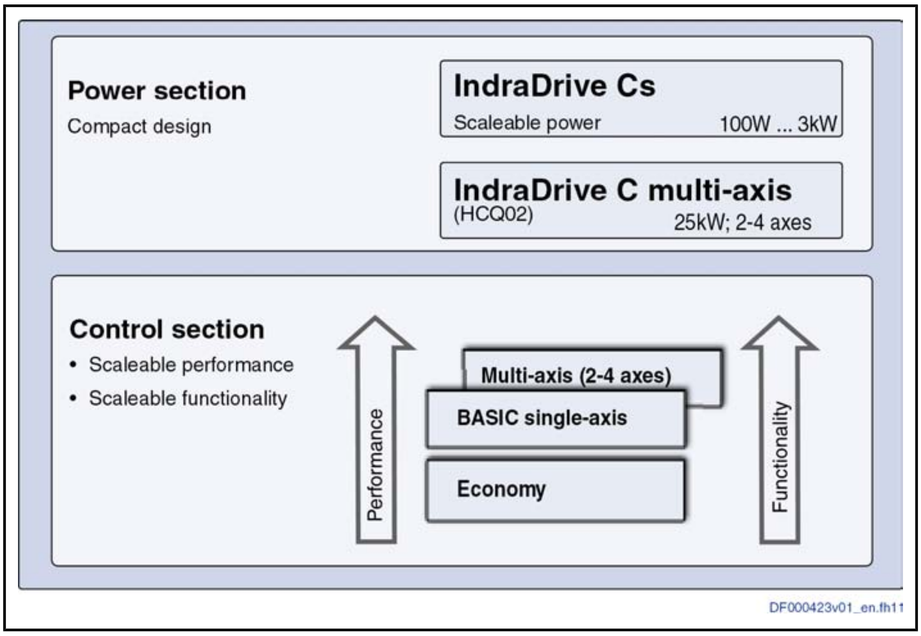


Fig. 1-7: Design of the IndraDrive Controllers

Power Section

The following are connected to the power section:

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

☞ The designs of the power sections are in each case described in separate documentations (see "Reference Documentations").

1.2.2 Power Section

The following power sections for the standard design of IndraDrive controllers can be operated with the firmware **MPx-16VRS**:

IndraDrive Cs Single-axis converter	IndraDrive C Multi-axis converter
HCS01.1	HCQ
	HCT
	Multi-axis inverter
	HMQ
	HMD

Fig. 1-8: Power Section Platform for IndraDrive Firmware

1.2.3 Control Sections

Supported Control Section Cards

The following overview contains the **supported configurations** of the control section cards as regards the support by the **MPx-16VRS** firmware.

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

Control section type →		HCS01.1 Basic	HCS01.1 Multi-axis	HSC01.1 Economy
Firmware variant →		**MPB-16VRS**	**MPM-16VRS**	**MPE-16VRS**
Optional modules for master communication				
ET	MultiEthernet	■	-	-
PB	PROFIBUS-DP	■	-	-
S3	SERCOS III	■	■	■
Optional modules for encoder evaluation and I/O extension				
EC	Encoder interface for EnDat, 1Vpp sine and TTL signals, HIPER-FACE®	■	-	-

Fig. 1-9: Supported Control Section Configurations

1.3 Supported Motors and Measuring Systems

1.3.1 Supported Motors

The following table contains an overview of the Rexroth motors which are supported by this firmware:

Rexroth housing motors		Rexroth kit motors	
Synchronous	**Asynchronous**	**Synchronous**	**Asynchronous**
MSK (IndraDyn S) MSP MSM	MAD (IndraDyn A) MAF (IndraDyn A) MAL	MLF (IndraDyn L) MBS (Standard) MBSxx2 (IndraDyn H) MBT (IndraDyn T)	1MB

Fig. 1-10: Appropriate Rexroth Motors for IndraDrive

1.3.2 Supported Measuring Systems

Motor Encoder and External Optional Encoders

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

- Encoders with sine signals and EnDat2.1 interface (1 Vpp)
- Encoders with sine signals (1 Vpp)
- Encoders with square-wave signals (TTL)
- Encoders with sine signals and HIPERFACE® interface (1 Vpp)
- MSM encoder (only motor encoder)
- Resolver

1.4 Overview of Master Communication

The firmware **MPx-16VRS** supports the following interfaces for master communication:

Firmware variant → Master communication ↓	MPB	MPM	MPE
SERCOS III	■	■	■
PROFIBUS-DP	■	-	-
EtherNet/IP interface	■	-	-
Parallel interface	■	-	-
Analog interface	■	-	■
EtherCAT	■	-	-

Fig. 1-11: Supported Interfaces for the Master Communication

1.5 Overview of Functions/Functional Packages

1.5.1 Overview

General Information

The application-specific scope of usable functions of the **FWA-INDRV*-MP*-16VRS** drive firmware depends on

- the available device configuration

- and -

- the licensed functional firmware packages.

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

Scaling the Drive Functionality

Firmware Scaling by Control Section Configuration

IndraDrive controllers have maximally 2 slots for optional cards. Depending on the available optional cards, it is possible to activate certain functions (incl. corresponding parameters), e.g. master communication (profibus).

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

See also section "Drive Controllers"

Firmware Scaling by Functional Packages

The firmware functionality is divided into the following package groups:

- **Base packages** (open-loop or closed-loop)
- Optional **expansion packages**:
  – Alternative functional packages (expansion packages for servo function, main spindle function, synchronization)

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

System Overview

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

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

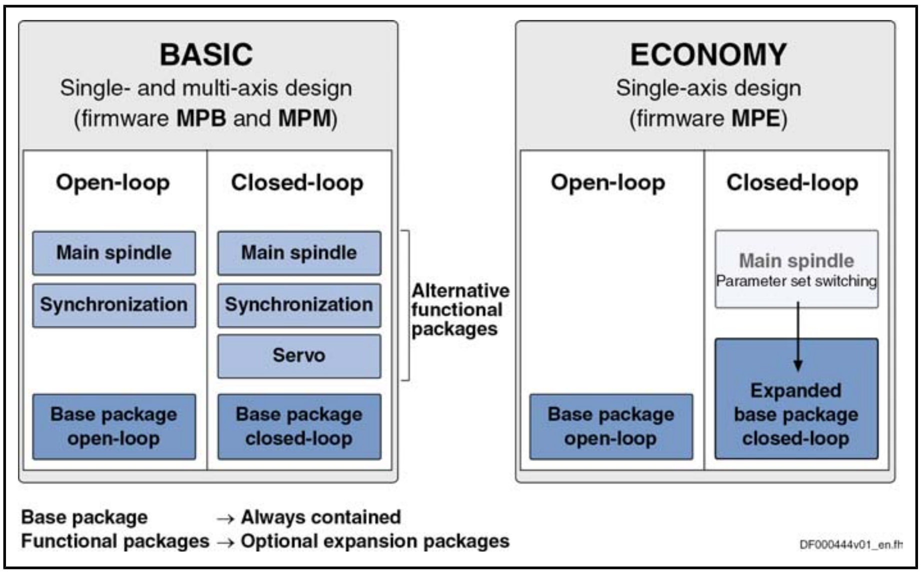


Fig. 1-12: Functional Packages of IndraDrive Firmware MPx16 Depending on Control Performance

Brief Description of the Functional Packages

The overall functionality of an IndraDrive device is divided into groups of functions, the so-called "functional packages". The firmware **FWA-INDRV*-MP*-16VRS** supports the functional packages listed below.

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

Base Packages

The following base packages are available:

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

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

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

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

Alternative functional packages

The following alternative functional packages are available:

- **Servo functions** 1)

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

- **Synchronization** [1)]

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

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

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

☞ 1)...These functional packages cannot be activated simultaneously (only individually)! → **Alternative functional packages**

Overview of Dependencies

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

		Firmware variant →	MPB		MPM		MPE[1)]	
		Control section range ↓	**OL**	**CL**	**OL**	**CL**	**OL**	**CL**
Base package	Basic functions		■	■	■	■	■	■
	Base package "open-loop"	BASIC	■	■	■	■	–	–
	Base package "closed-loop"	BASIC	■	■	■	■	■	■
Alternative functional packages	Servo function	BASIC	–	■	–	■	–	–
	Synchronization	BASIC	■	■	■	■	–	–
	Main spindle	BASIC	■	■	■	■	–	2)

MPB	Single-axis firmware with Basic performance
MPM	Multi-axis firmware with Basic performance
MPE	Economy firmware with Economy performance
OL	Open-loop characteristic
CL	Closed-loop characteristic
1)	With Economy firmware MPE, only an extended basic package is available
2)	The extended basic package contains the function "parameter set switching" from the alternative functional package "main spindle"

Fig. 1-13: Dependence of Functional Packages on Hardware and Firmware Variant

Firmware Types

Structure of the Firmware Type Designation

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

	IndraDrive firmware	Base package of variant (depending on control section)	Version	Release	Language	OL/CL	Alternative expansion packages
Basic single-axis	FWA-INDRV*	-MP**B**-	16	VRS-	D5-	x-	xxx-
Basic multi-axis	FWA-INDRV*	-MP**M**-	16	VRS-	D5-	x-	xxx-
Economy single-axis	FWA-INDRV*	-MP**E**-	16	VRS-	D5-	x-	xxx-

OL Open-loop characteristic
CL Closed-loop characteristic
Fig. 1-14: Basic Structure of the Firmware Type Designation

Function-Specific Abbreviations in Type Designation of IndraDrive Firmware

Base package (application and performance):

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

Firmware characteristic:

- **0** → Open-loop
- **1** → Closed-loop

Alternative expansion packages:

- **NNN** → Without alternative expansion package
- **SRV** → Functional package "Servo function"
- **SNC** → Functional package "synchronization"
- **MSP** → Functional package "main spindle"
- **ALL** → All alternative expansion packages

1.5.2 Base Packages

General Information

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

Basic Functions

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

- Extensive diagnostic functions:
  - Drive-internal generation of diagnostic messages
  - Monitoring function
  - Patch function
  - Status displays, status classes
  - Oscilloscope function
  - Code of optional card
  - Parameter value check

  – Operating hours counter, logbook function, error memory
- Undervoltage monitor
- Output of control signals
- Limitations that can be parameterized

Scope of Functions of Base Packages

Apart from the basic functions, there are other functions available in the base package of the firmware. Their scope depends on the firmware variant and its characteristic ("open-loop" or "closed-loop"). The "set/shift coordinate system" function is, for example, available for the firmware MPx16 in the basic package with the "closed loop" characteristic.

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

See "Availability of the Extended Axis Functions"

See "Availability of the Optional Device Functions"

1.5.3 Alternative Functional Packages

General Information

Apart from the basic packages that are always available, we offer alternative function packages as optional expansion packages. From these functional packages, only one package can be activated at a time (alternative activation).

The following alternative extension packages are available:

- Expanded servo function
- Synchronization
- Main spindle function

Servo Function

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

Firmware variant →	MPB		MPM		MPE	
Functions of the expansion package "servo function"	**OL**	**CL**	**OL**	**CL**	**OL**	**CL**
Precision axis error correction	–	■	–	–	–	–
Temperature error correction	–	■	–	■	–	–
Quadrant error correction	–	■	–	■	–	–
Cogging torque compensation	–	■	–	■	–	–
Programmable position switch	–	■	–	–	–	–

OL Open-loop characteristic
CL Closed-loop characteristic
Fig. 1-15: Overview of "Servo Function" Expansion Package

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

Synchronization

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

Firmware variant →	MPB		MPM		MPE	
Functions of the expansion package "synchronization"	**OL**	**CL**	**OL**	**CL**	**OL**	**CL**
Velocity synchronization	■	■	■	■	–	–
Phase synchronization	–	■	–	■	–	–
Electronic cam	–	■	–	■	–	–
Electronic motion profile	–	■	–	■	–	–
Cogging torque compensation	–	■	–	■	–	–
Measuring wheel mode	–	■	–	■	–	–
Programmable position switch	–	■	–	–	–	–
Measuring encoder	■		–	■	–	–

OL Open-loop characteristic
CL Closed-loop characteristic
Fig. 1-16: Overview of "Synchronization" Expansion Package

Main Spindle Function

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

Firmware variant →	MPB		MPM		MPE	
Functions of the expansion package "main spindle"	**OL**	**CL**	**OL**	**CL**	**OL**	**CL**
Spindle positioning	–	■	–	■	–	–
Parameter set switching	■	■	■	■	–	■ [1)]
Drive-controlled oscillation	■	■	■	■	–	–

OL Open-loop characteristic
CL Closed-loop characteristic
1) Contained for MPE in the extended basic package
Fig. 1-17: Overview of "Main Spindle" Expansion Package

1.6 Performance Data

1.6.1 Overview

Levels of Control Performance

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

- **Basic** performance

  → Standard control performance by medium internal clock rates for the control loops and the signal processing of inputs/outputs

- **Economy** performance

  → Low control performance by reduced clock rates for the control loops and the signal processing of inputs/outputs.

Performance and Clock Rates

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

- Current loop clock $T_{A\_current}$
- Velocity loop clock $T_{A\_velocity}$
- Position loop clock $T_{A\_position}$
- Cycle time of master communication $T_{MastCom}$

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

Performance	$T_{A\_current}$	$T_{A\_velocity}$	$T_{A\_position}$	$T_{MastCom}$
Basic	62.5 to 125	250	500	500
Economy	125	500	1000	1000 1)

1) With half the quantity of cyclic data

Fig. 1-18: Clock Rates (in µs)

☞ The control performance is not identical with the control section design as it is determined by several factors.

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

- **Device configuration** and the related drive **firmware** (MPB, MPM, and MPE)
- **Activation of functional packages** (cf. P-0-2004)
- Switching frequency in "P-0-0001, Switching frequency of the power output stage"

See also "Overview of Drive Control"

1.6.2 Control Section Design and Performance

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

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

Control section/firmware	Performance level	f_{PWM} 1)	PWM switching	$T_{A\_current}$	$T_{A\_velocity}$	$T_{A\_position}$	$T_{MastCom}$
IndraDrive-Cs with **MPB**	Basic	2 kHz 2)	Yes	250 µs	250 µs	500 µs	500 µs
	Basic	4 kHz	Yes	125 µs	250 µs	500 µs	500 µs
	Basic	8 kHz	Yes	125 µs	250 µs	500 µs	500 µs
	Basic	12 kHz	Yes	83.3 µs	250 µs	500 µs	500 µs
	Basic	16 kHz	Yes	62.5 µs	250 µs	500 µs	500 µs
IndraDrive C multi-axis (HCQ02) with **MPM**	Basic	4 kHz	No	125 µs	250 µs	500 µs	500 µs
	Basic	8 kHz	No	125 µs	250 µs	500 µs	500 µs

Control section/firmware	Perform-ance level	f_{PWM} 1)	PWM switching	$T_{A\_current}$	$T_{A\_velocity}$	$T_{A\_position}$	$T_{MastCom}$
IndraDrive-Cs with **MPE**	Economy	4 kHz	No	125 µs	500 µs	1000 µs	2000 µs
	Economy	8 kHz	No	125 µs	500 µs	1000 µs	2000 µs

1) Switching frequency of the power output stage (can be set via P-0-0001)

2) PWM frequency reduction depending on load or PWM switching depending on the velocity

Fig.1-19: Performance Depending on the Control Section Design

1.6.3 PWM Frequency Reduction Depending on Load

For switching frequencies of 12 kHz or 16 kHz and respective setting in parameter "P-0-0556, Config word of axis controller", there is a possibility of reducing the switching frequency in dependence of the thermal load of the controller.

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

See "Current Limitation: Dynamic Current Limitation"

2 Important Directions for Use

2.1 Appropriate Use

2.1.1 Introduction

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

WARNING

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

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

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

Before using Rexroth products, make sure that all the pre-requisites for an appropriate use of the products are satisfied:

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

2.1.2 Areas of Use and Application

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

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

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

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

Drive controllers have to be programmed before commissioning, making it possible for the motor to execute the specific functions of an application.

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

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

Typical applications include, for example:

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

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

2.2 Inappropriate Use

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

Drive controllers must not be used, if ...

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

3 Safety Instructions for Electric Drives and Controls

3.1 Definitions of Terms

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

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

Control System Several interconnected control components placed on the market as a single functional unit.

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

Drive System A group of components consisting of electric motor(s), motor encoder(s) and cable(s), supply units and drive controllers, as well as possible auxiliary and additional components, such as mains filter, mains choke, etc.

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

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

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

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

Product Produced device, component, part, system, software, firmware, among other things.

Project Planning Manual Part of the application documentation used to support the dimensioning and planning of systems, machines or installations.

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

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

- to be trained or instructed to maintain and use adequate safety equipment,
- to attend a course of instruction in first aid.

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

3.2 General Information

3.2.1 Using the Safety Instructions and Passing Them on to Others

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

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

WARNING

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

Observe the safety instructions!

3.2.2 Requirements for Safe Use

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

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

this is not the case, they are excluded. Safety-relevant are all such applications which can cause danger to persons and property damage.

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

  The machine and installation manufacturer must

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

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

National regulations which the user must take into account

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

3.2.3 Hazards by Improper Use

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

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

3.2.4 Explanation of Safety Symbols and Hazard Classification

The safety instructions describe the following hazard classification. The hazard classification informs about the consequences resulting from non-compliance with the safety instructions:

Safety symbol	Signal word	Hazard classification according to ANSI Z535.4-2002
	Danger	Death or serious injury **will** occur.
	Warning	Death or serious injury **could** occur.
	Caution	Minor or moderate injury or property damage may occur.

Fig.3-1: Hazard Classification (According to ANSI Z535.4-2002)

3.3 Instructions with Regard to Specific Dangers

3.3.1 Protection Against Contact with Electrical Parts and Housings

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

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

WARNING

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

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

  Always wait **30 minutes** after switching off power to allow live capacitors to discharge before accessing an electric component. Measure the electrical voltage of live parts before beginning to work to make sure that the equipment is safe to touch.
- Install the covers and guards provided for this purpose before switching on.
- Never touch electrical connection points of the components while power is turned on.
- Do not remove or plug in connectors when the component has been powered.
- As a basic principle, residual-current-operated circuit-breakers cannot be used for electric drives to prevent direct contact.
- Secure built-in devices from penetrating foreign objects and water, as well as from direct contact, by providing an external housing, for example a control cabinet.

WARNING

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 drive and control system to the equipment grounding conductor at the grounding points.
- Connect the equipment grounding conductor of the components of the drive and control system permanently to the main power supply at all times. The leakage current is greater than 3.5 mA.
- Establish an equipment grounding connection with a copper wire of a cross section of at least 10 mm^2 (8 AWG) or additionally run a second equipment grounding conductor of the same cross section as the original equipment grounding conductor.

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 volts at the components of the Rexroth drive and control system 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.

WARNING

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

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

3.3.3 Protection Against Dangerous Movements

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

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

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

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

WARNING

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

To avoid accidents, injury and/or property damage:

- Keep free and clear of the machine's range of motion and moving machine parts. Prevent personnel from accidentally entering the machine's range of motion by using, for example:
  - Safety fences
  - Safety guards
  - Protective coverings
  - Light barriers
- Make sure the safety fences and protective coverings are strong enough to resist maximum possible kinetic energy.
- Mount emergency 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 an emergency stop circuit or use a safe starting lockout.
- Make sure that the drives are brought to a safe standstill before accessing or entering the danger zone.
- Additionally secure vertical axes against falling or dropping after switching off the motor power by, for example,
  - mechanically securing the vertical axes,
  - adding an external braking/arrester/clamping mechanism or
  - ensuring sufficient equilibration of the vertical axes.
- The standard equipment **motor holding brake** or an external holding brake controlled by the drive controller is **not sufficient to guarantee personal safety**!
- Disconnect electrical power to the components of the drive and control system using the master switch and secure them from reconnection for:
  - Maintenance and repair work
  - Cleaning of equipment
  - Long periods of discontinued equipment use
- Prevent the operation of high-frequency, remote control and radio equipment near electric/electronic components of the drive and control system and their supply leads. If the use of these devices cannot be avoided, check the machine or installation, before initial commissioning of the drive and control system, for possible malfunctions when operating such high-frequency, remote control and radio equipment in its possible positions of normal use. It might possibly be necessary to perform a special electromagnetic compatibility (EMC) test.

3.3.4 Protection Against Magnetic and Electromagnetic Fields During Operation and Mounting

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

WARNING

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

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

3.3.5 Protection Against Contact with Hot Parts

CAUTION

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

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

3.3.6 Protection During Handling and Mounting

CAUTION

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

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

3.3.7 Battery Safety

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

CAUTION

Risk of injury by improper handling!

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

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

3.3.8 Protection Against Pressurized Systems

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

WARNING

Risk of injury by improper handling of pressurized lines!

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

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

4 Master Communication

4.1 Basic Functions of Master Communication

4.1.1 Brief Description

General Information

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

Features

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

- **Address assignment**

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

  → Drive commands to be externally activated (via master communication, serial and control panel)
- **Device control** (state machine)

  → Individual state machines for master communication and device
  - According to the variant of master communication, the master communication state machine has different functionality and complexity. The communication-specific states are distinguished and mapped to the status words of the corresponding master communication (e.g. for SERCOS: S-0-0014, S-0-0135).
  - The device state machine is independent of the variant of master communication and maps the device-specific states to parameter "S-0-0424, Status parameterization level". We always distinguish operating mode (OM) and parameter mode (PM).
- **Extended possibilities of control**
  - Signal control word (S-0-0145) and signal status word (S-0-0144)
  - Multiplex channel

  See section "Control Options / Additional Functions"

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

Pertinent Parameters

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

Parameters for State Machine and Phase Switch

- S-0-0011, Class 1 diagnostics
- S-0-0012, Class 2 diagnostics
- S-0-0013, Class 3 diagnostics
- S-0-0014, Interface status

- S-0-0420, C0400 Activate parameterization level 1 procedure command
- S-0-0422, C0200 Exit parameterization level procedure command
- S-0-0423, IDN-list of invalid data for parameterization levels
- S-0-0424, Status parameterization level
- P-0-4086, Master communication status
- P-0-4088, Master communication: Drive configuration

Operating Mode Parameters

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

Device-Specific Control and Status Words

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

SERCOS-Specific Parameters

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

- S-0-0021, IDN-list of invalid operation data for CP2
- S-0-0022, IDN-list of invalid operation data for CP3
- S-0-0127, C0100 Communication phase 3 transition check
- S-0-0128, C5200 Communication phase 4 transition check
- S-0-0134, Master control word
- S-0-0135, Drive status word

Field-Bus-Specific Parameters

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

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

Specific Parameters for Parallel/ Analog Interface

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

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

Pertinent Diagnostic Messages

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

4.1.2 Setting the Axis Address

Overview

Each drive is identified by its own address.

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

The drive address can be set in the following ways:

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

- or -

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

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

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

Address Setting via Standard Control Panel

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

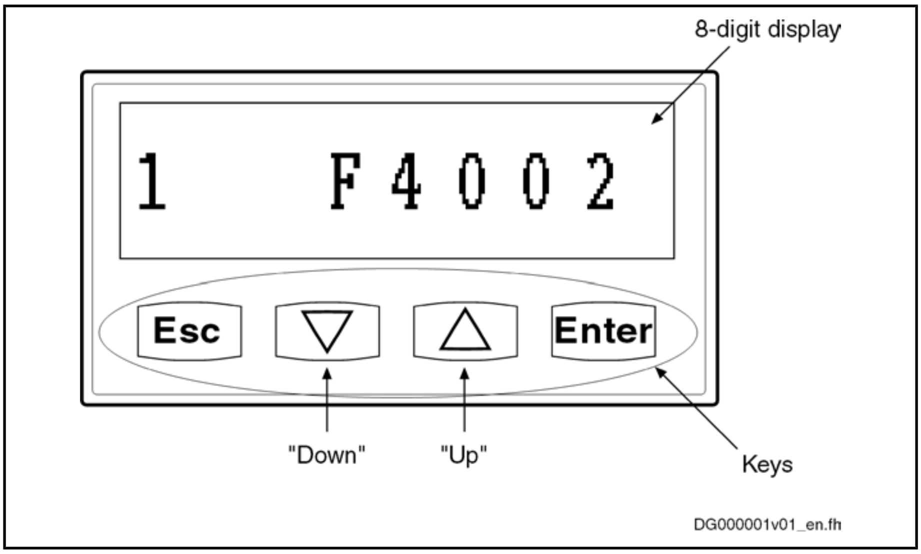


Fig.4-1: Standard Control Panel (Example of Display)

The address is set via the control panel as follows:

1. Change to "Commands/settings" mode

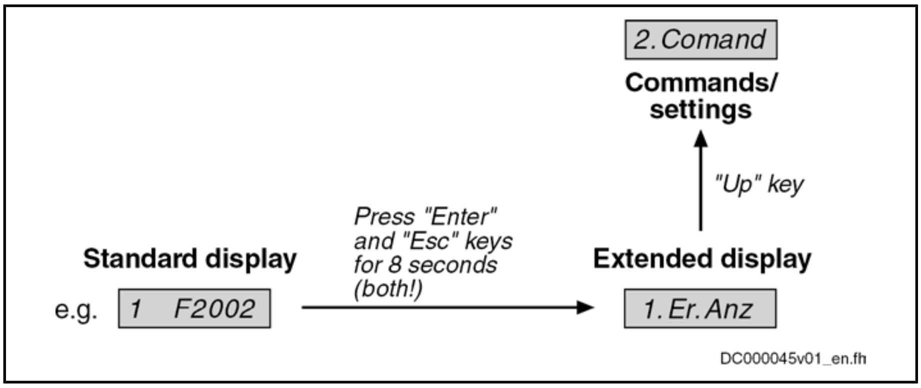


Fig.4-2: Activating the "Commands/Settings" Mode

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

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

     → The display reads "2.1.2 drive address"

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

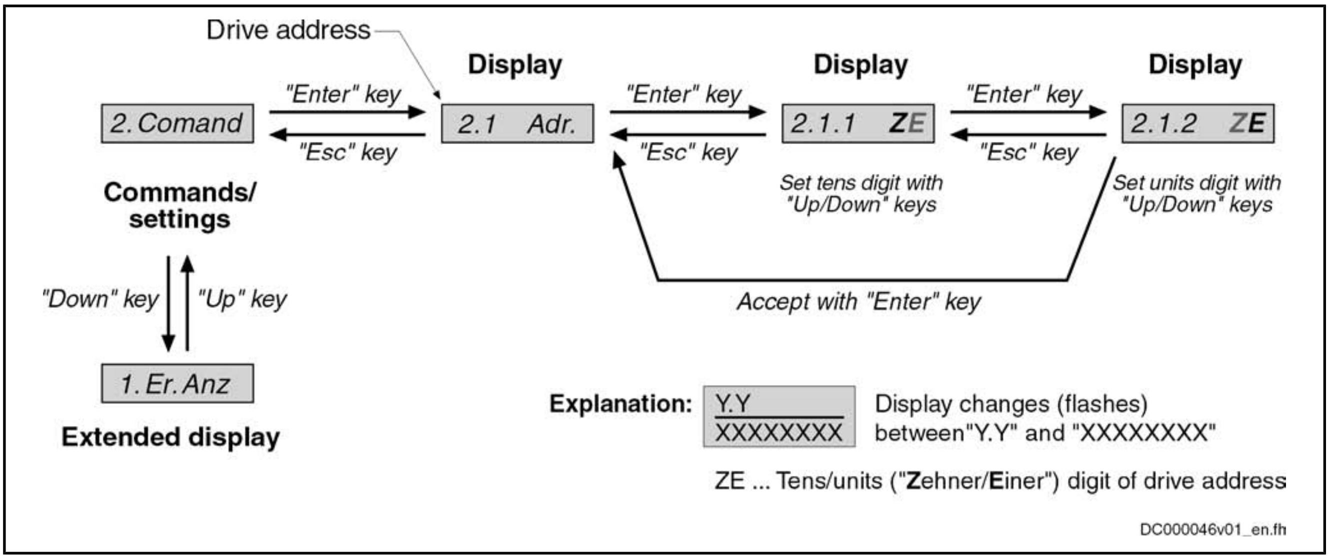


Fig.4-3: Selecting and Setting the Drive Address

Address Setting via Parameter Access

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

In this connection see "Notes on How to Replace the Devices"

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

4.1.3 Command Processing

Overview

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

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

Kinds of Commands

We distinguish 3 kinds of commands:

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

Command Execution

General Information

Observe the following aspects for command execution:

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

CAUTION

Damage to the internal memory (flash) caused by cyclic command execution (write access to the flash)!

⇒ During the execution of some commands (see Description of the Respective Diagnostic Command Message; e.g. "C0500 Reset class 1 diagnostics, error reset"), data are written to the internal memory (flash), too. This memory, however, only allows a limited number of write access. For this reason, you should make sure that such write access is not carried out too often.

Controlling the Command Execution

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

Commands are started or terminated by:

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

"C0500 Reset class 1 diagnostics, error reset") via serial interface of master communication

- or -

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

  See also the following sections:

  – "Configurable Signal Control Word"

  – "Parallel Interface"

  – "Digital Inputs/Outputs"

Possible Command Inputs

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

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

Command Acknowledgment

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

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

Command Status

The command status can be:

- **0x0:** Not set and not enabled
- **0x7:** In process
- **0xF:** Error, command execution impossible
- **0x5**: Command execution interrupted
- **0x3:** Command correctly executed

Command Change Bit

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

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

  - or -

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

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

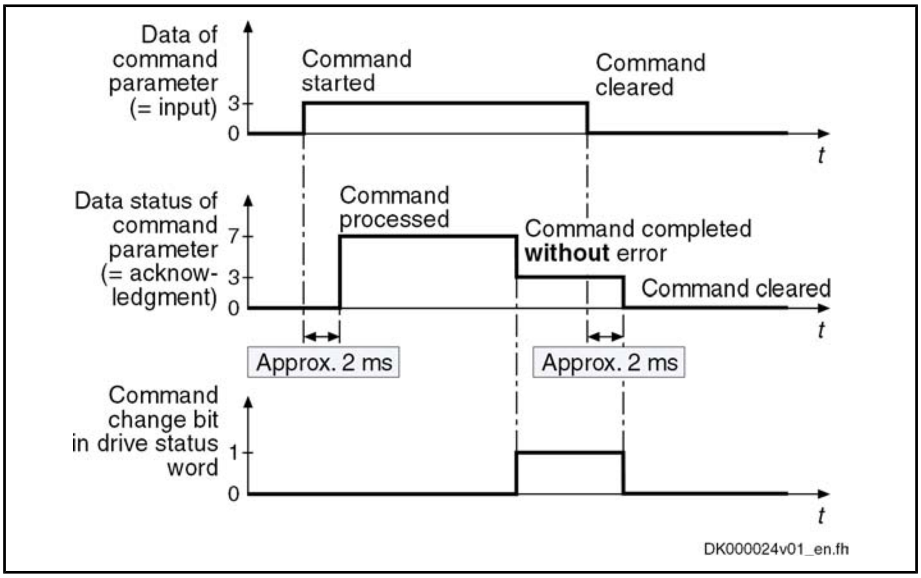


Fig.4-4: Input, Acknowledgment and Command Change Bit in the Case of Correct Execution

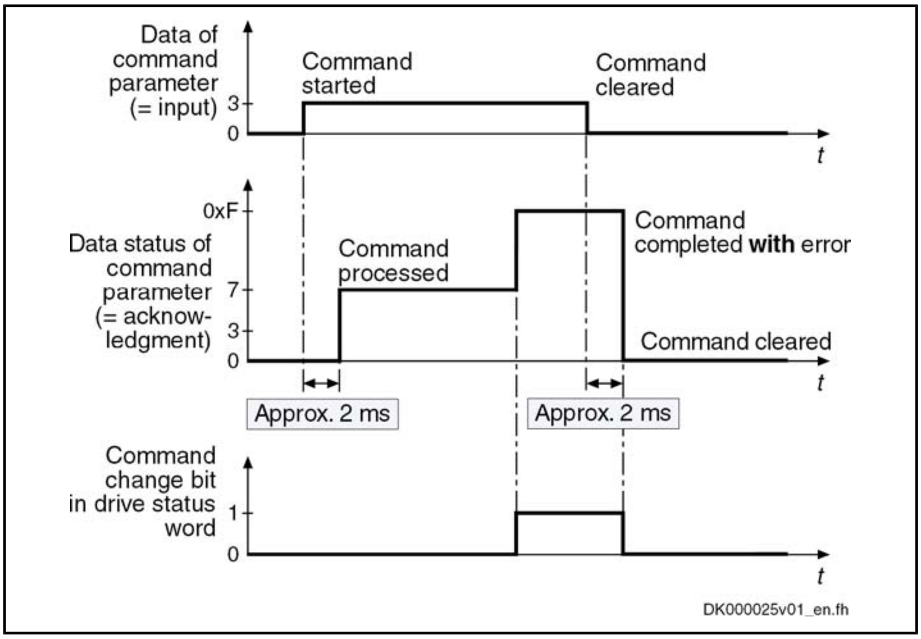


Fig.4-5: Input, Acknowledgment and Command Change Bit in the Case of Incorrect Execution

4.1.4 Device Control and State Machines

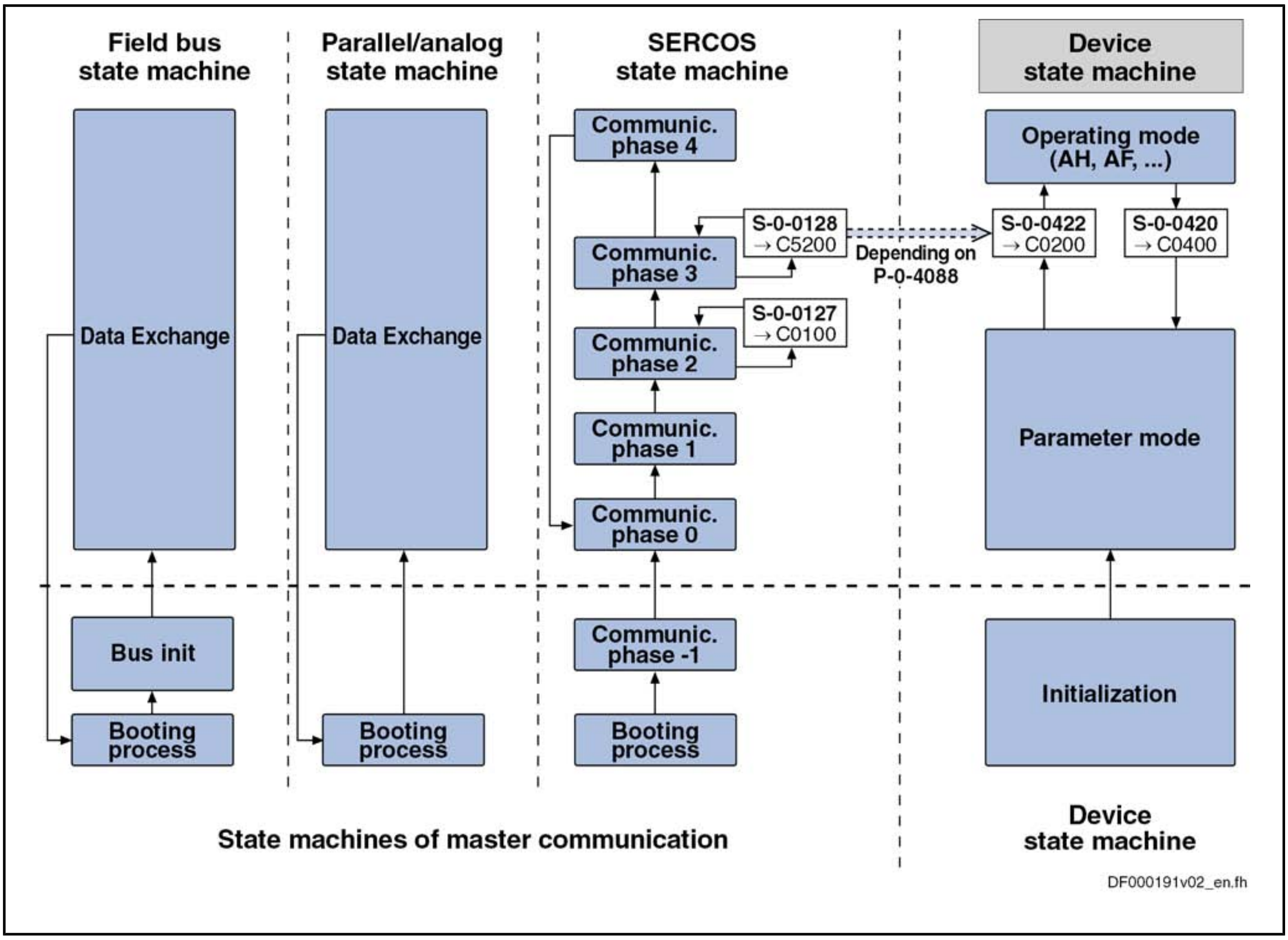
Overview

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

We distinguish between:

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

Master Communication



S-0-0127, C0100 Communication phase 3 transition check
S-0-0128, C5200 Communication phase 4 transition check
S-0-0420, C0400 Activate parameterization level 1 procedure command
S-0-0422, C0200 Exit parameterization level procedure command
P-0-4088, Master communication: drive configuration
Fig.4-6: Overview: State Machines of Master Communications and Device

Device-Internal State Machine

Parameter Mode/Operating Mode

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

- **Parameter mode (PM)**

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

- **Operating mode (OM)**

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

Switching

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

- S-0-0420, C0400 Activate parameterization level 1 procedure command
- S-0-0422, C0200 Exit parameterization level procedure command

Observe the following aspects for switching:

- Switching is generally possible by direct execution of the transition commands S-0-0420 or S-0-0422.

- For field bus devices, switching can additionally take place in the freely configurable operating mode (P-0-4084 = 0xFFFE or 0xFFFD) by presetting the desired mode via bit 1 in "P-0-4077, Field bus: Control word"
- In the case of the "SERCOS interface", the state machine of the master communication is connected to the device-internal state machine. This means that when master communication is switched (communication phase 2 → communication phase 4 or back), the device-internal state machine is switched, too. Via the parameter "P-0-4088, Master communication: Drive configuration", this dependence can be deactivated.
- In the case of master communication other than SERCOS interface, the device-internal state machine changes to the operating mode after the booting process. This behavior, too, can be set via the parameter "P-0-4088, Master communication: Drive configuration".

Control Word and Status Word

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

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

State Machine of Master Communication

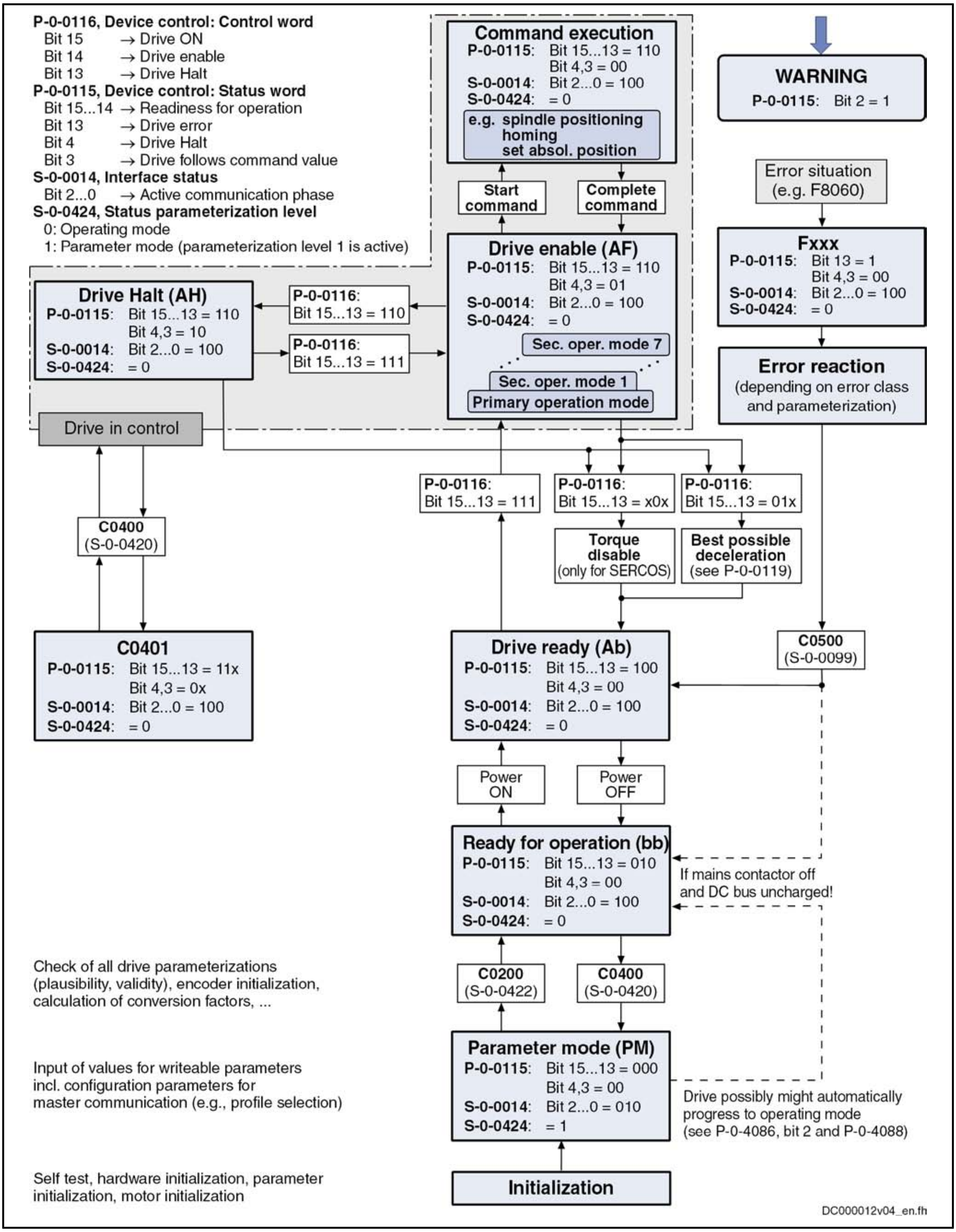


Fig.4-7: Device Control (General State Machine)

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

- SERCOS State Machine
- Field Bus State Machine
- Parallel/analog state machine

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

SERCOS State Machine

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

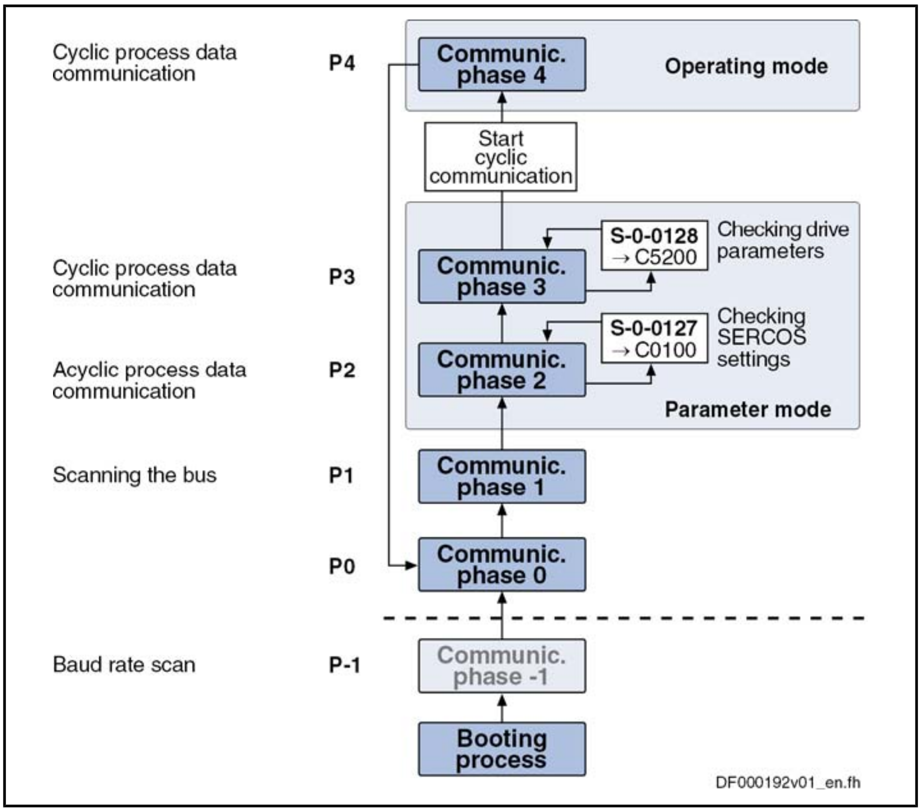


Fig.4-8: State Machine of the Communication Phases of the Drive According to SERCOS Specification

See also "SERCOS interface"

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

Field Bus State Machine

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

Master Communication

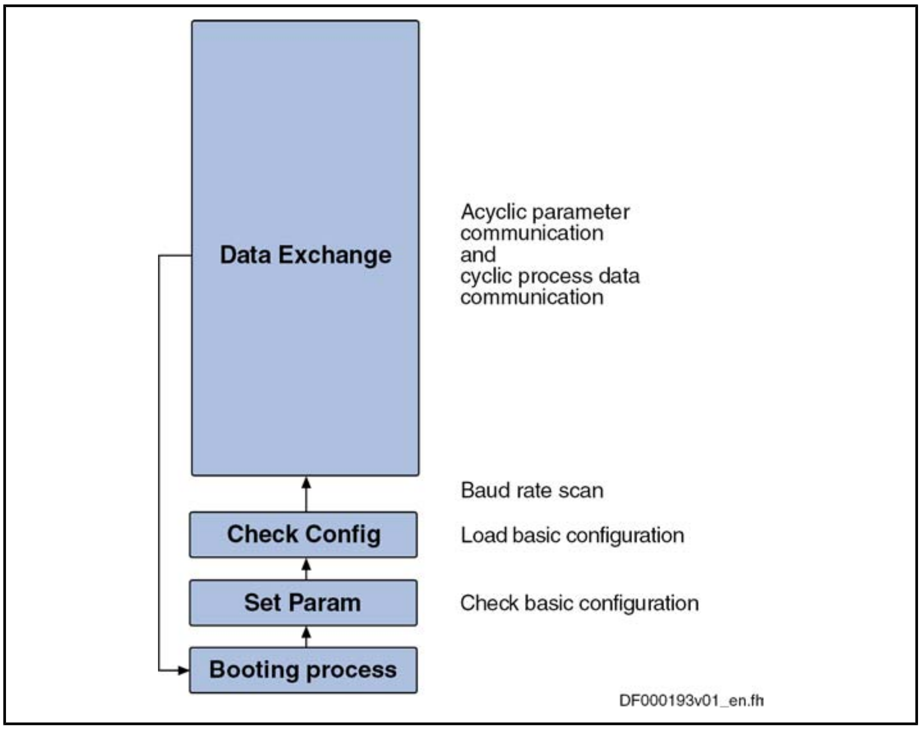


Fig.4-9: State Machine for Field Bus Interfaces

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

Communication Phases of Master Communication

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

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

Communication Phases According to SERCOS Specification

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

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

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

  – Communication parameters (according to SERCOS)

  – Configuration of axis control (sampling times)

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

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

  In phase 3, the following parameters can be changed:
  - Parameters for operating mode configuration
  - Error reaction settings
  - Motor configuration parameters, holding brake parameters
  - Encoder configuration parameters
  - Mechanical transmission elements (gear, feed constant)
  - Scaling and polarity parameters, position data format, modulo value
  - Configuration of analog and digital inputs/outputs
  - Configuration of switch-on / switch-off sequence of drive enable (waiting times, ...)

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

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

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

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

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

Communication Phases for Field Bus Interface

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

- Parameter mode
- Operating mode

Communication Phases for Parallel or Analog Interface

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

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

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

Control Words and Status Words of Master Communication

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

Depending on the master communication, different parameters are used:

- SERCOS interface:
  - S-0-0134, Master control word
  - S-0-0135, Drive status word
- Field bus interface (e.g. PROFIBUS)
  - P-0-4077, Field bus: Control word

    - or -

    P-0-4068,
  - P-0-4078, Field bus: Status word

    - or -

    S-0-0144, Signal status word
- Analog/parallel interface (analog mode):
  - P-0-4028, Device control word
  - P-0-0115, Device control: Status word

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

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

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

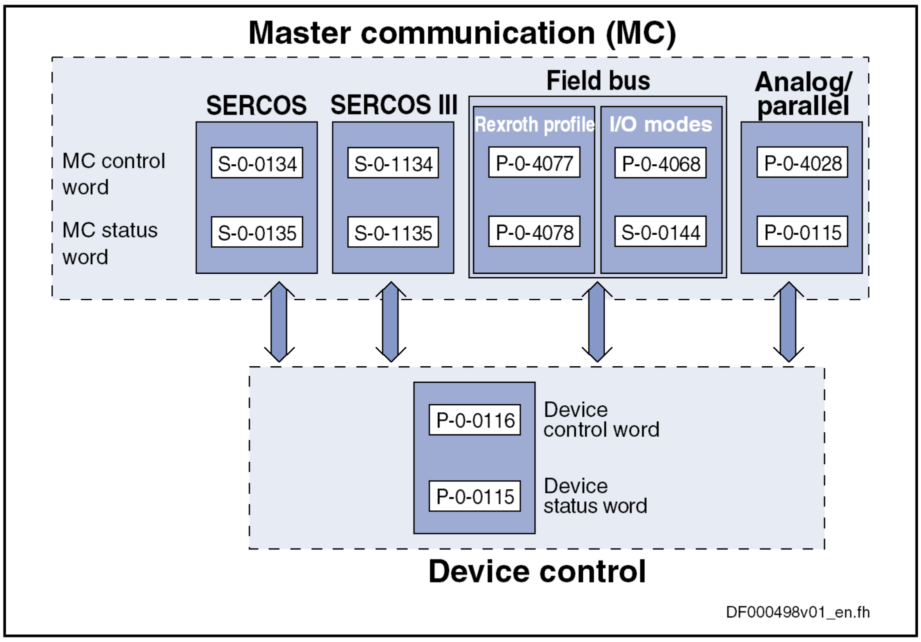
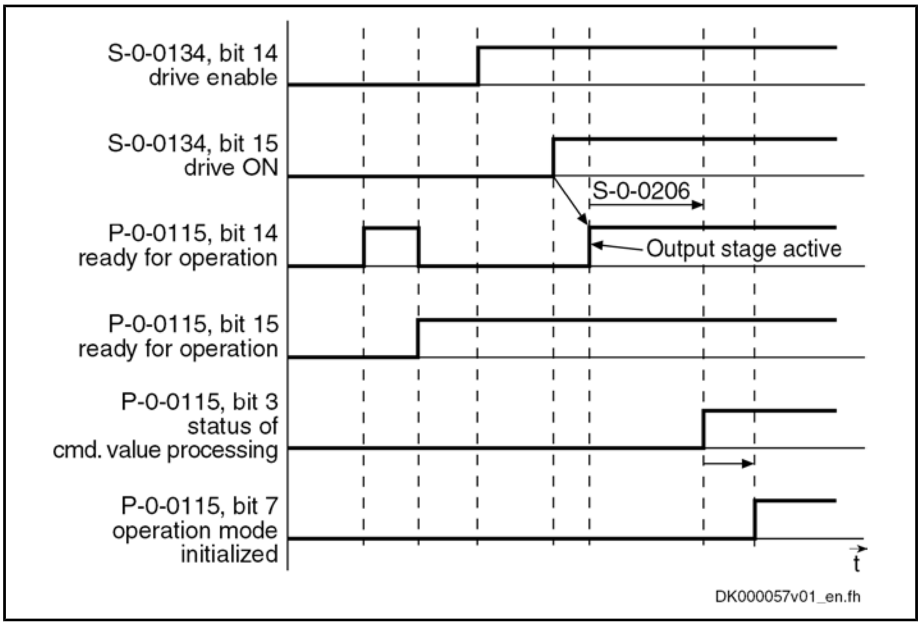


Fig.4-10: Interaction of the Available Control and Status Words

Timing Diagrams for Device Control

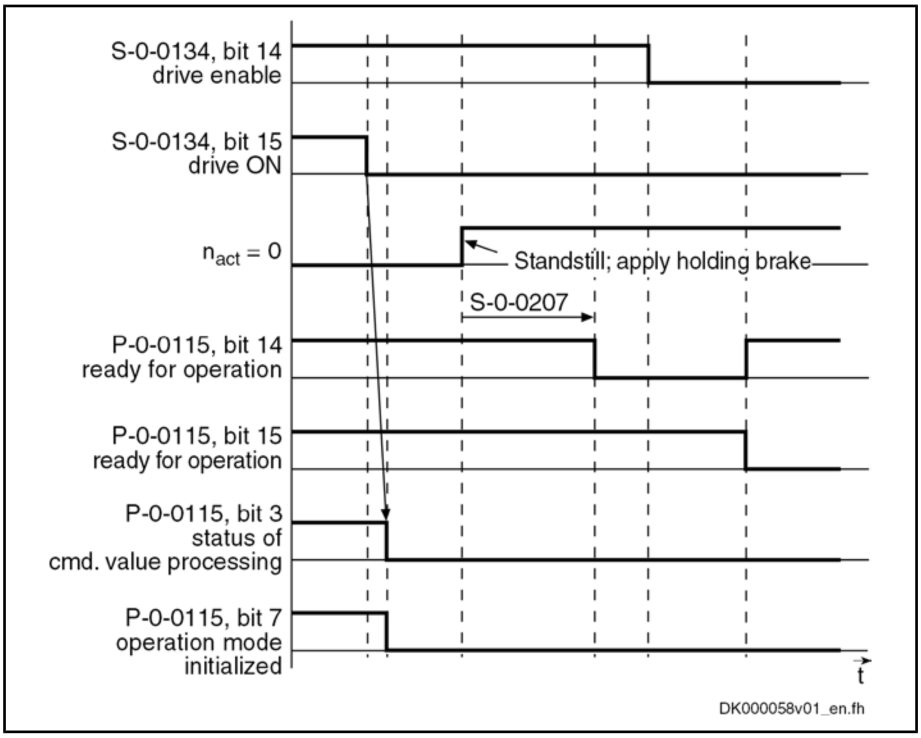
Bit Sequence During Switch-On Process



S-0-0206 Drive on delay time

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

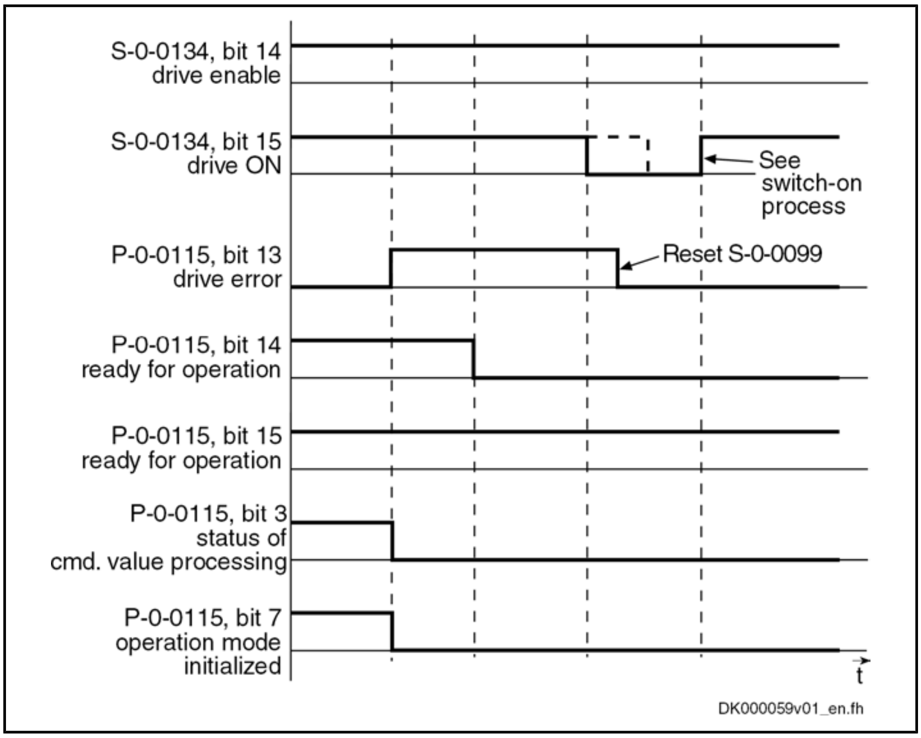
Bit Sequence During Switch-Off Process



S-0-0207 Drive off delay time

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

Bit Sequence During Error Reaction



S-0-0099 C0500 Reset class 1 diagnostics

Fig.4-13: Bit Sequence During Error Reaction

Bit Sequence During Change of Operation Modes

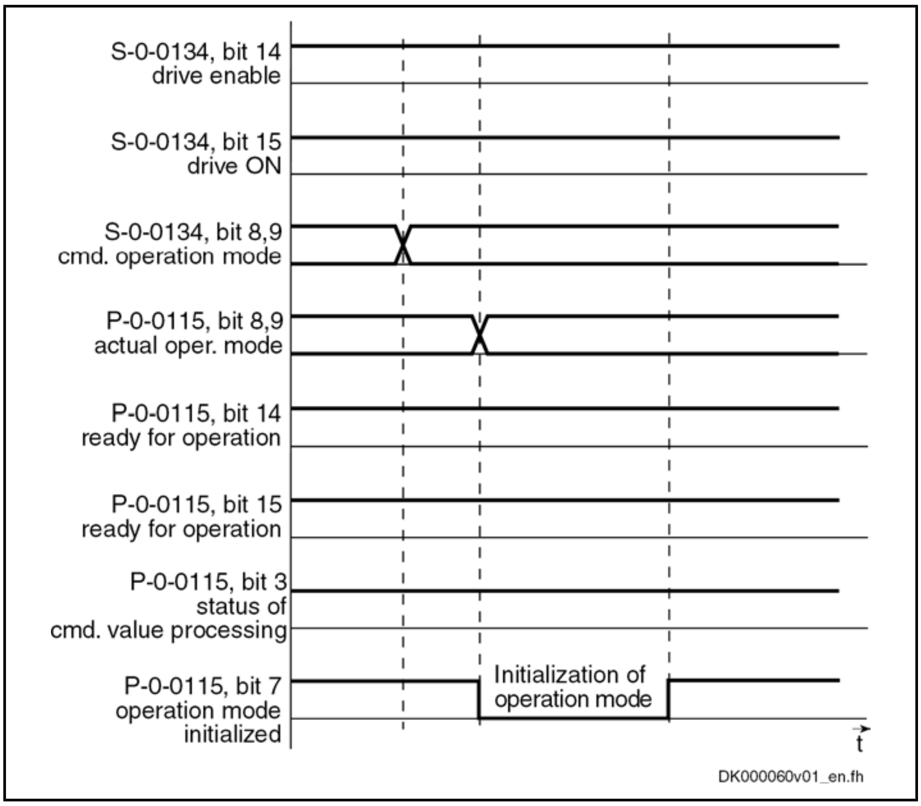


Fig.4-14: Bit Sequence During Change of Operation Modes

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 1 procedure command
  - S-0-0422, C0200 Exit parameterization level procedure command
- Commands for transition check to communication phases 3 and 4 (only with SERCOS!):
  - S-0-0127, C0100 Communication phase 3 transition check
  - S-0-0128, C5200 Communication phase 4 transition check

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

Communication Phase 3 Transition Check

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

- Checking validity of parameters required for switching to phase 3

  If one of these parameters has never been written or the backup was carried out incorrectly, the error message "C0101 Invalid 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.
  - C0101 Invalid parameters (-> S-0-0021)
- Checking device configuration
  - C0132 Invalid settings for controller cycle times
- Checking telegram configuration, especially in the case of configured telegrams

  In this case a check is run to find out whether the parameters selected for the configurable data block in the cyclic command value channel (MDT) or actual value channel (AT) may be configured and whether the allowed length of the configurable data blocks is complied with.
  - C0104 Config. IDN for MDT not configurable
  - C0105 Maximum length for MDT exceeded
  - C0106 Config. IDNs for AT not configurable
  - C0107 Maximum length for AT exceeded
- If necessary, checking timing parameters for SERCOS communication in phases 3 and 4 for validity and compliance with requirements
  - C0108 Time slot parameter > Sercos cycle time
  - C0109 Telegram offset unsuitable
  - C0110 Length of MDT (S-0-0010) odd
  - C0111 ID9 + Record length - 1 > length MDT (S-0-0010)
  - C0112 TNcyc (S-0-0001) or TScyc (S-0-0002) error
  - C0113 Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error
  - C0114 T4 > TScyc (S-0-0002) - T4min (S-0-0005)

- C0115 T2 too small
- C0116 T3 (S-0-0008) within MDT (S-0-0089 + S-0-0010)
- C0139 T2 (S-0-0089)+length MDT (S-0-0010)>TScyc (S-0-0002)

- Limit value check of communication parameters and system
  - C0102 Limit error in parameter (-> S-0-0021)
  - C0103 Parameter conversion error (->S-0-0021)
  -

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

With the "S-0-0128, C5200 Communication phase 4 transition check" or "S-0-0422, C0200 Exit parameterization level procedure command" 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 motor and encoder configuration
  - C0210 Feedback 2 required (->S-0-0423)
  - C0219 Max. travel range too large
  - C0270 Error when reading encoder data => motor encoder
  - C0271 Incorrect parameterization of motor encoder (hardware)
  - C0272 Incorr. parameteriz. of motor enc. (mechanical system)
  - C0273 Modulo value for motor encoder cannot be displayed
  - C0274 Motor encoder unknown
  - C0275 Error when reading encoder data => optional encoder
  - C0276 Incorrect parameterization of optional enc. (hardware)
  - C0277 Incorr. parameteriz. of opt. enc. (mechanical system)

  - C0278 Modulo value for optional encoder cannot be displayed
  - C0279 Optional encoder unknown
  - C0280 Maximum travel range cannot be displayed internally
  - C0284 Invalid motor data in encoder memory (->S-0-0423)
  - C0285 Type of construction of motor P-0-4014 incorrect
  - C0286 Several motor encoders connected
  - C0287 Error during initialization of motor data (->S-0-0423)
  - C0288 Rotary scaling not allowed
  - C0289 Error at init. of synchr. motor with reluctance torque
  - C0290 Error when reading encoder data => measuring encoder
  - C0291 Incorr. prarmeterization of measuring enc. (hardware)
  - C0292 Measuring encoder unknown
  - C0293 Modulo value for measuring encoder cannot be displayed
  - C0294 Incorrect measuring encoder configuration
- Checking modulo range
  - C0244 Act. modulo value cycle greater than max. travel range
- Checks during encoder initialization
  - C0220 Error when initializing position of encoder 1
  - C0221 Initialization velocity encoder 1 too high
  - C0224 Error when initializing position of encoder 2
  - C0225 Initialization velocity encoder 2 too high
  - C0227 Error when initializing position of measuring encoder
  - C0228 Initialization velocity measuring encoder too high
- Initializing optional additional functions (digital I/Os)
  - C0243 Brake check function not possible
  - C0250 Probe inputs incorrectly configured
-
- 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.

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

Examples of Use

This functionality can be used, for example,

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

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

Pertinent Parameters

- S-0-0027, Configuration list 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

4.2.2 Configurable Signal Status Word

Brief Description

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

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

Pertinent Parameters

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

4.2.3 Multiplex Channel

Brief Description

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

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

Features

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

Possible Applications

By means of the multiplex channel it is possible:

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

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

Pertinent Parameters

Parameters for command value channel:

- S-0-0362, Data container A: List index command values
- S-0-0368, Data container A: Addressing
- S-0-0360, Data container A: 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

4.3 Operating Modes of Master Communication

4.3.1 Introduction and Overview

Overview of Operating Modes and Possibilities of Command Triggering

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

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

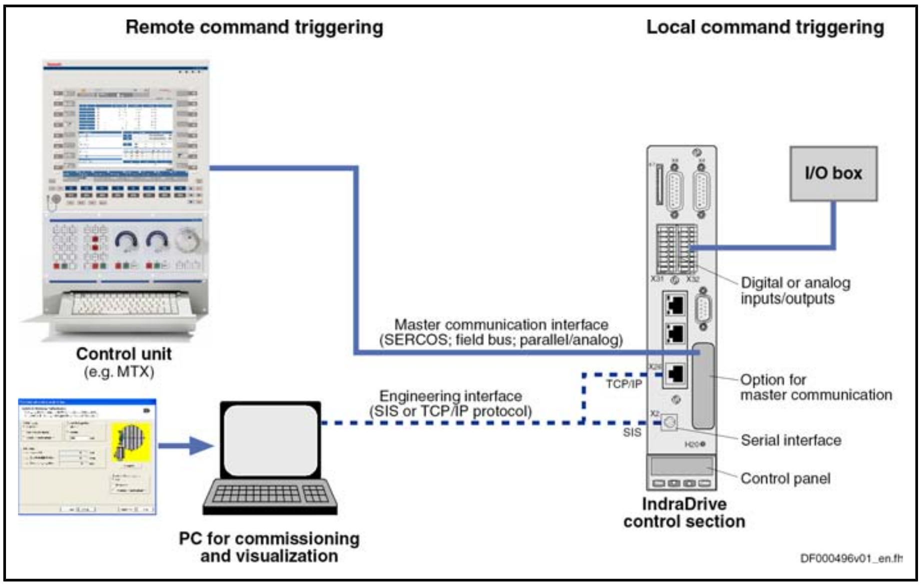


Fig.4-15: Overview of Possibilities of Command Triggering for an IndraDrive Device

Operating Modes and Changes of States

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

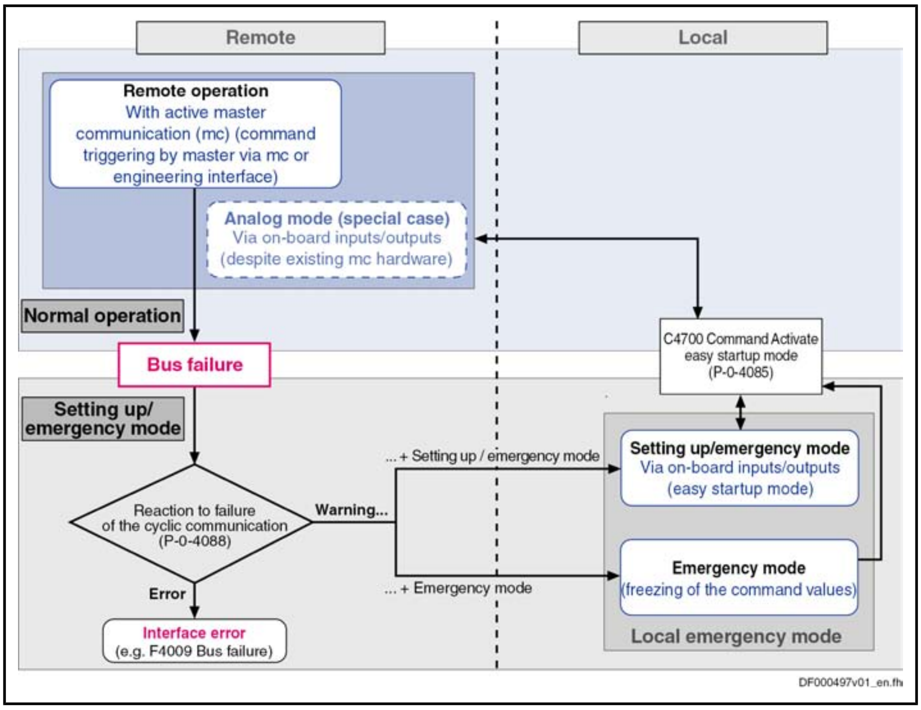


Fig.4-16: Operating States and Operating Modes of Master Communication

Device Control and State Machine

According to the 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 section "Device Control and State Machines" !

Normal Operation (via Internal or External Control Unit)

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

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

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

  Special cases (respective configuration via "P-0-4088, Master communication: Drive configuration"):

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

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

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

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

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

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

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

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

4.3.2 Normal Mode (Remote or Local)

Remote Mode With External Control Unit and Active Master Communication

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

See Description of the Respective Master Communication:

- SERCOS interface
- SERCOS III
- PROFIBUS-DP
- EtherNet/IP interface
- Parallel interface
- Analog interface

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

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

4.3.3 Local Mode

Overview

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

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

Emergency Mode (When Master Communication has Failed)

Behavior in the Case of Bus Failure

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

- **Bus failure as error**

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

- **Bus failure as warning**

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

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

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

CAUTION

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

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

Status Display

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

4.4 Profile Types (With Field Bus Interfaces)

4.4.1 Supported Profile Types

Overview

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

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

The tables below contain an overview of the most important properties and features of these three profile types with master communication **PROFIBUS**:

Profile type	Content of "P-0-4084, Field bus: Profile type"	Features
I/O mode **positioning**	0xFF82	- up to 64 positioning blocks can be controlled via field bus - apart from control and status word, other real-time data can be configured (in P-0-4080 and P-0-4081) - bits can be freely defined in signal status word via function "configurable signal status word"
I/O mode **preset velocity**	0xFF92	- fixed velocity command values can be controlled and ramp-function generator can be operated via field bus - apart from control and status word, other real-time data can be configured (in P-0-4080 and P-0-4081) - bits can be freely defined in signal status word via function "configurable signal status word"

Profile type	Content of "P-0-4084, Field bus: Profile type"	Features
Freely configurable mode (Default assignment is "drive-controlled positioning" with corresponding required cyclic data)	**0xFFFE**	- possible use of complete drive functionality by free configuration of real-time data and operating mode selection - control word and status word have a Rexroth-specific structure - selection suited for operation with analog command values in commissioning phase
	0xFFFD	Like profile 0xFFFE, however reduced field bus control word

Fig.4-17: Profile Types, Field Bus or Drive Type

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,
- P-0-4071,
- P-0-4074, Field bus: Data format
- P-0-4077, Field bus: Control word
- P-0-4078, Field bus: Status word
- P-0-4080, Field bus: Config. list of cyclic actual value data ch.
- P-0-4081, Field bus: Config. list of cyclic command value data ch.
- P-0-4082, Field bus: length of cyclic actual value data channel
- P-0-4083, Field bus: Length of parameter channel
- P-0-4084, Field bus: Profile type

Basic Principles and Terms

Drive Profile

The drive profile defines

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

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

State Machine

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

Abbreviations

- **i16**: 16-bit variable with sign (1 word) in Intel format

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

4.4.2 I/O Mode (Positioning and Preset Velocity)

Brief Description

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

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

General Features

The I/O mode has the following features:

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

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

    → 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 operating mode which takes effect:
  - In the **I/O modes** there is a determined relationship between profile type (P-0-4084) and predefined primary operation mode (S-0-0032).
  - The **freely configurable mode** allows free selection of the operating modes (S-0-0032, S-0-0033, …).

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

Structure of the Real-Time Channel

Data direction	Word1	Format
Master → Slave	P-0-4068,	u16 (1 word)
Slave → Master	S-0-0144, Signal status word	u16 (1 word)

Fig.4-18: Structure of the Real-Time Channel for the I/O Modes

Features of "I/O Mode Positioning"

Specific features of "I/O mode positioning":

- The drive is operated in "positioning block mode, lagless, encoder 1" (see also description of the operating mode "Positioning Block Mode").
- In this operating mode, 64 programmable positioning blocks can be selected and started via 6 bits (in the 16 bit wide control word).

- The jog function can be activated in "P-0-4068, ". "Drive-controlled positioning" was set as the 1st secondary operating mode (see also description of the operating mode "Drive-Controlled Positioning").

Features of "I/O Mode Preset Velocity"

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

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

State Machine in I/O Mode

Interaction of control and status bits (state machine):

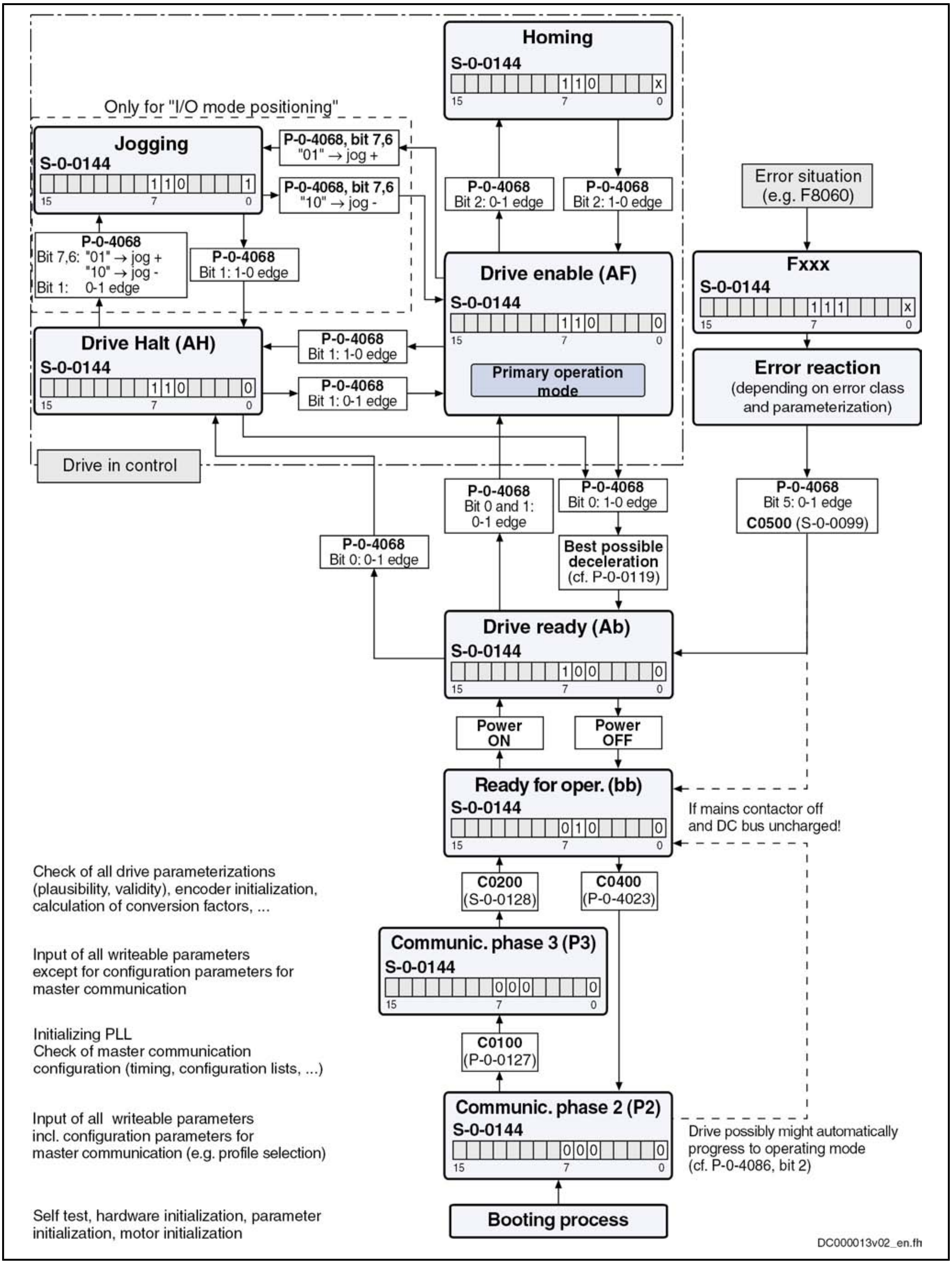


Fig.4-19: Device Control of Variants of I/O Mode (State Machine)

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

DANGER

Automatic restart after bus failure!

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

Field Bus Control Word in I/O Mode

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

See Parameter Description "P-0-4068, "

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

Signal Status Word in I/O Mode

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

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

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

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

Fig.4-20: Default Assignment of Parameter "S-0-0144, Signal Status Word" for "I/O Mode Positioning" (P-0-4084 = 0xFF82)

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

Fig.4-21: 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"

4.4.3 Freely Configurable Mode (IndraDrive Profile Type)

Brief Description

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

Features

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

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

Real-Time Channel

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

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

Fig.4-22: Structure of the Real-Time Channel in the Freely Configurable Mode

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

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

Fig.4-23: Content and Order of Data in Real-Time Channel in the Freely Configurable Mode

4.5 SERCOS interface

4.5.1 Brief Description

General Features

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

Firmware-Specific Features

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

The number of configurable bytes in the MDT/AT depends on the relation of the position cycle time (P-0-0556, bit 2) to the SERCOS cycle time.

SERCOS cycle time = position cycle time → max. length 24 bytes

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

For more detailed information, see SERCOS specification.

Pertinent Parameters

- S-0-0001,
- S-0-0002,
- S-0-0003, Minimum AT transmit starting time (T1min)
- S-0-0004, Transmit/receive transition time (TATMT)
- S-0-0005, Minimum feedback acquisition time (T4min)
- S-0-0006, AT Transmission starting time (T1)
- S-0-0007, Feedback acquisition starting time (T4)
- S-0-0008, Command value valid time (T3)
- S-0-0009, Position of data record in MDT
- S-0-0010, Length of master data telegram
- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0016, Configuration list of AT
- S-0-0024, Configuration list of MDT
- S-0-0028, MST error counter

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

Pertinent Diagnostic Messages

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

- F4004 Error during phase progression
- F4005 Error during phase regression
- F4006 Phase switching without ready signal

4.6 PROFIBUS-DP

4.6.1 Brief Description

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

Cyclic data channel (PROFIBUS-DP)

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

The cyclic data channel is divided as follows:

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

☞ The **device-specific parameter channel** does not fulfill any "real-time characteristics"!

- One (optional) **safety related, axis-specific process data channel** (PROFIsafe).

☞ The **safety related, axis-specific process data channel** is not available in the MPx16VRS. For the configuration you must, however, integrate the "F module not used" module!

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

Fig.4-24: Overview of Cyclic Data Channel

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

Features

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

- Support of **RS485 interfaces according to IEC 61158-2**

- Support of all **data rates according to IEC 61158-2**, with exclusive use of PROFIBUS-DP (9.6 kBaud, 19.2 kBaud, 45.45 kBaud, 93.75 kBaud, 187.5 kBaud, 500 kBaud,1.5 MBaud, 3 MBaud, 6 MBaud, 12 Mbaud)
- Automatic baud rate detection
- Configurable cyclic data up to 15 parameters (incl. field bus control word and field bus status word) in both data directions (max. 48 bytes or 24 words)
- Additional optional parameter channel in the cyclic channel with up to 16 bytes (8 words)

Min. cycle time	Max. quantity of process data ↔ setting P-0-4076	Notes
0,5 ms (T_{A_pos})	16 bytes → P-4076 = 0.5 ms 32 bytes → P-4076 = 1 ms 48 Bytes → P-4076 > 1 ms	Additionally a maximum of 16 bytes parameter channel for PROFIBUS and PROFINET

Fig.4-25: Quantity of Cyclic Data Depending on P-0-4076

Valid values for "P-0-4076, Field bus: Cycle time (Tcyc)": 0.5 ms, 1 ms, 2 ms, 3 ms, 4 ms, 5 ms, …

- Monitoring of the cyclical data exchange (watchdog function)
- LED for diagnosing the PROFIBUS interface
- Supported DPV0 services:
  – Slave_Diag (read diagnostic data)
  – Get_Cfg (read configuration data)
  – Set_Prm (send parameterization data)
  – Chk_Cfg (check configuration data)
  – Data Exchange (transfer I/O data)
  – Global Control (synchronization)
  – RD_Outp (read output data)
  – RD_Inp (read input data)
- Supported DPV1 class 1 services
  – DDLM_Initiate (establishment of connection)
  – DDLM_Read (acyclic read access)
  – DDLM_Write (acyclic write access)
  – DDLM_Abort (abortion of connection)
  – DDLM_Idle (connection monitoring)
- Support of up to two DPV1-class-2 connections
- TCI (Tool Calling Interface) support
- Supported field bus profiles:
  – 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 "operating mode neutral"
  – 0xFFFE: Freely configurable mode

Hardware Requirements

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

- Single-axis BASIC UNIVERSAL (HCS01.1-W00xx-X-0X-B-ET-EC-**PB**-NN-NN-NN-FW)

Pertinent Parameters

Communication parameters

Specific parameters for communication via PROFIBUS-DP:

- P-0-4069,

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: Cycle time (Tcyc)
- P-0-4079, Field bus: Baud rate

Profile type parameters

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

See "Profile Types (With Field Bus Interfaces)"

Parameters for extended communication

We use additional parameters for extended communication.

See following sections:

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

Pertinent Diagnostic Messages

- 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

4.7 Parallel Interface

4.7.1 Brief Description

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

Features

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

Pertinent Parameters

- S-0-0026, Configuration list for signal status word

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

4.8 Analog Interface

4.8.1 Brief Description

Overview

Apart from the digital master communication interfaces (SERCOS, PROFIBUS…), the drive controllers of the IndraDrive range provide an interface for analog master communication (analog interface). This allows assigning an analog command value to a drive parameter (e.g. "S-0-0036, Velocity command value").

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

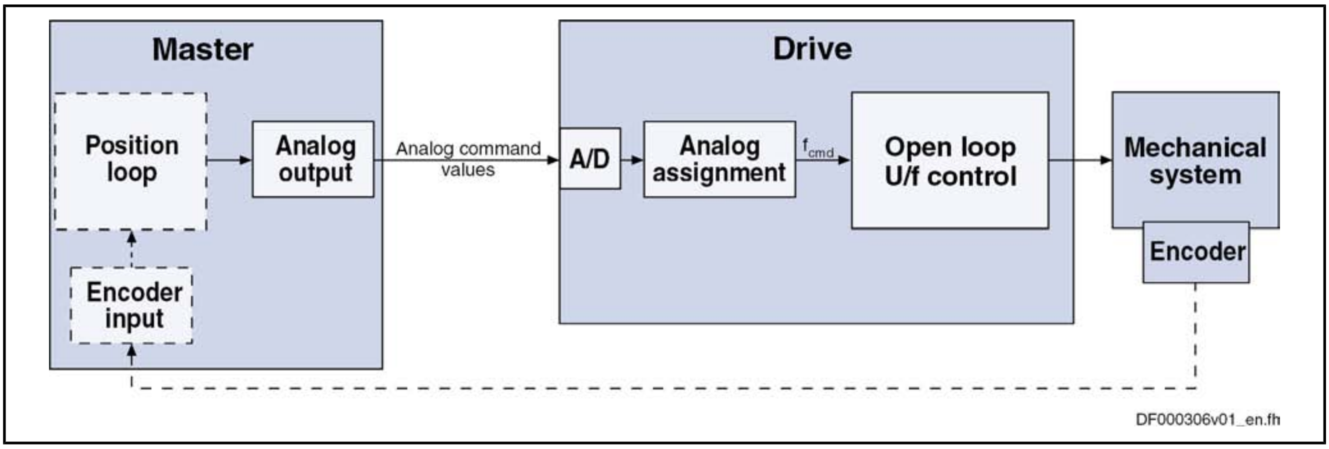


Fig.4-26: Open-Loop Operation With Analog Interface (With Optional Position Feedback to Open-Loop Control)

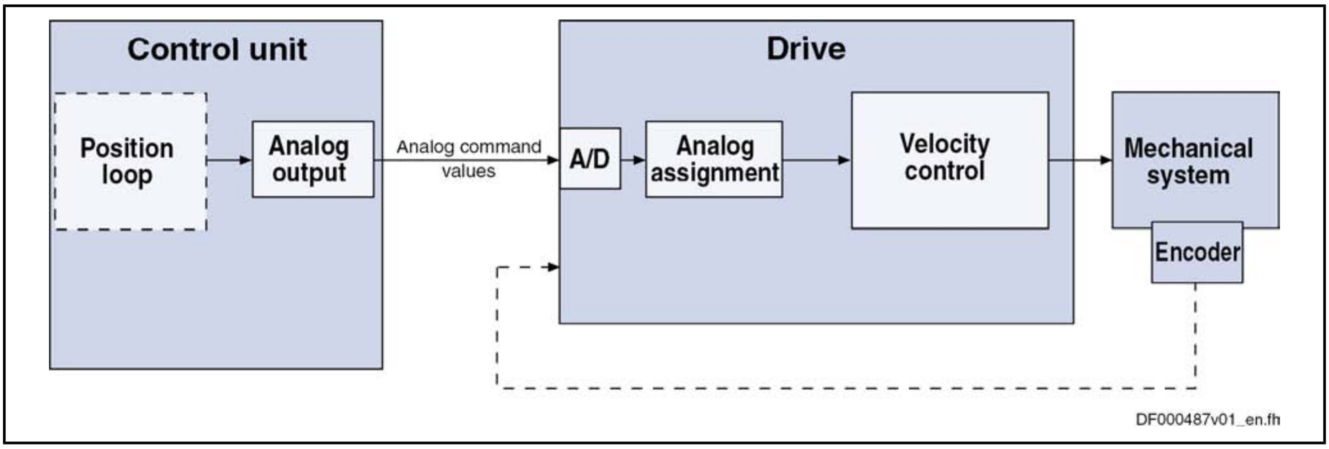


Fig.4-27: Closed-Loop Operation With Analog Interface (With Analog Command Value Input and SSI Emulation)

This section describes the basic functions of the analog interface and contains notes on commissioning and parameterization. The individual function "analog inputs" used is described separately.

See also "Analog Inputs"

Features

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

Features of the **analog inputs**:

- Analog inputs (14 bit) which can be assigned to parameters, with smoothing to be set (number of analog inputs depending on control section design)
- Sampling of the analog inputs in the position loop clock $T_{position}$ (see "Performance Data"

Features of the **analog assignment**:

- Two assignments to parameters are possible; offset and scaling of the analog input can be set for each assignment
- Sampling rates for analog input assignment:
  - Assignment channel A → assignment in position loop clock $T_{position}$
  - Assignment channel B → assignment in clock of 2 ms

Features of the **digital inputs/outputs**:

- Digital control and status information determined via configuration of the digital inputs of the control section:
  - **Digital control inputs** for analog master communication:
    - Signals "drive enable" and "Drive Halt"
    - Zero switch, limit switch (+/-); clearing errors and E-Stop
  - **Digital status outputs** for analog master communication:
    - Ready and warning output
    - Relay output for readiness for operation

Hardware Requirements

Master communication with analog interface is possible via the following control sections or control section designs:

- Analog command value input **for open-loop operation** (also for closed-loop operation)

Pertinent Parameters

Control and status parameters:

- P-0-0115, Device control: Status word
- P-0-0116, Device control: Control word
- P-0-4028, Device control word

Digital inputs/outputs:

- P-0-0300, Digital I/Os, assignment list
- P-0-0301, Digital I/Os, bit numbers
- P-0-0303, Digital I/Os, status display
- P-0-0304, Digital I/Os, outputs
- P-0-0306, Digital inputs, assignment connector and pin
- P-0-0307, Digital inputs, input image sub-device
- P-0-0310, Digital outputs, assignment list
- P-0-0311, Digital outputs, bit numbers
- P-0-0312, Digital outputs, assignment sub-device
- P-0-0313, Digital outputs, output image sub-device
- P-0-0316, Digital outputs, assignment connector and pin

Analog inputs:

- P-0-0210, Analog input 1
- P-0-0212, Analog input, list of assignable parameters
- P-0-0213, Analog input, assignment A, target parameter
- P-0-0214, Analog input, assignment A, scaling per 10V full scale
- P-0-0215, Analog input, assignment A, signal value at 0V
- P-0-0216, Analog input, assignment A, dead zone
- P-0-0217, Analog input 1, time constant input filter
- P-0-0218, Analog input, control parameter
- P-0-0219, Analog input, maximum value for adjustment
- P-0-0220, C2800 Analog input adjustment command
- P-0-0236, Analog input, assignment B, target parameter
- P-0-0237, Analog input, assignment B, scaling per 10V full scale
- P-0-0238, Analog input, assignment B, signal value at 0V
- P-0-0239, Analog input, assignment B, dead zone
- P-0-3901, Adjustment values of control section

4.9 MultiEthernet

4.9.1 Brief Description, Basic Function

General Information

IndraDrive controllers can be operated with a MultiEthernet interface. Thus, the following master communications can be operated:

- SERCOS III
- EtherCAT®
- PROFINET®
- EtherNet/IP™

The protocol is selected or deactivated via "P-0-4089.0.1, Master communication: Protocol". The change will only take effect after a the device has been restarted.

IP engineering (TC/IP communication) can also be carried out via MultiEthernet interface. This function is also maintained after master communication switch-off. With activated EtherCAT® protocol, an IP engineering (TC/IP communication) cannot be carried out as this is not supported by EtherCAT®.

Features

- Protocol selection via control panel or "P-0-4089.0.1, Master communication: Protocol"
- SERCOS III, EtherCAT®, PROFINET®, EtherNet/IP™ protocols are supported
- IP engineering (TC/IP communication) is supported depending on the protocol
- Master comm. engineering is supported depending on the protocol

Hardware Requirements

In the type code, the MultiEthernet interface has the designation ET.

(For example, HCS01.1-W00xx-X-0X-B-**ET**-EC-NN-NN-NN-NN-FW)

Pertinent Parameters

☞ For controls that are not able to access 32-bit EIDN parameters, some relevant parameters have been mapped to 16-bit IDN parameters; the assignment is shown in the following table of the parameters involved.

32-bit EIDN parameters	16-bit 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
P-0-4089.0.11, Master communication: MAC address Port1	P-0-2313, Master communication: MAC address Port1
P-0-4089.0.12, Master communication: MAC address Port2	P-0-2314, Master communication: MAC address Port2
P-0-4089.0.13, Master communication: IP address	P-0-2315, Master communication: IP address
P-0-4089.0.14, Master communication: Network mask	P-0-2316, Master communication: Network mask
P-0-4089.0.15, Master communication: Gateway address	P-0-2317, Master communication: Gateway address

Fig.4-28: Pertinent Parameters

Pertinent Diagnostic Messages

- C0299 Configuration changed. Restart

4.9.2 EtherCAT®

Brief Description

IndraDrive controllers with MultiEthernet interface (ET) can be operated as EtherCAT® master communication. Via these modules, it is possible to exchange real-time data with an EtherCAT® master. "Servo Drive Profile over EtherCAT®" is supported, which is based on the SERCOS II profile.

The following communication channels are distinguished:

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

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

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

  → Transmission of Ethernet telegrams via an EtherCAT® mailbox method (is currently not supported, yet)

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
- Cyclical data exchange of command and actual values
- Free configuration of telegram contents
- Max. length of the configurable MDT/AT data 15 IDNs with max. 48 bytes; with bus cycle = position cycle, the max. length is halved to 24 bytes
- Cycle time: Min. 500 µs (multiples of the position cycle can be set)
- "Distributed clock synchronization" (exact adjustment of distributed clocks)
- Synchronization between time command value takes effect and measurement starting time of the actual values for all drives on a ring
- Overall synchronization of all connected drives to the master
- No support of "CAN over EtherCAT®" (CoE)
- Currently only released in connection with "Beckhoff TwinCAT"

Hardware Requirements

Using the "EtherCAT®" master communication requires the following control section design:

- Single-axis BASIC UNIVERSAL (HCS01.1-W00xx-X-0X-B-**ET**-EC-NN-NN-NN-NN-FW)

Pertinent Parameters

- S-0-0001,
- S-0-0002,
- S-0-0005, Minimum feedback acquisition time (T4min)
- S-0-0006, AT Transmission starting time (T1)
- S-0-0007, Feedback acquisition starting time (T4)
- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0016, Configuration list of AT
- S-0-0024, Configuration list of MDT
- S-0-0028, MST error counter
- S-0-0089, MDT Transmit starting time (T2)

- 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 Double MDT failure shutdown
- F4009 Bus failure

4.9.3 PROFINET

Brief Description

IndraDrive controllers with MultiEthernet interface (ET) can be operated as PROFINET master communication. Via this module it is possible to exchange real-time data with a PROFINET controller.

The field bus provides data containers in which useful data can be cyclically transmitted. This section is referred to as **cyclic data channel** (PROFINET).

The cyclic data channel is divided as follows:

- One (optional) **device-specific parameter channel** for reading and writing of all IndraDrive parameters via PROFINET.

> The **device-specific parameter channel** does not fulfill any "real-time characteristics"!

- One (optional) **safety related, axis-specific process data channel** (PROFIsafe).

> The **safety related, axis-specific process data channel** is not available in the MPx16VRS. For the configuration you must, however, integrate the "F module not used" module!

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

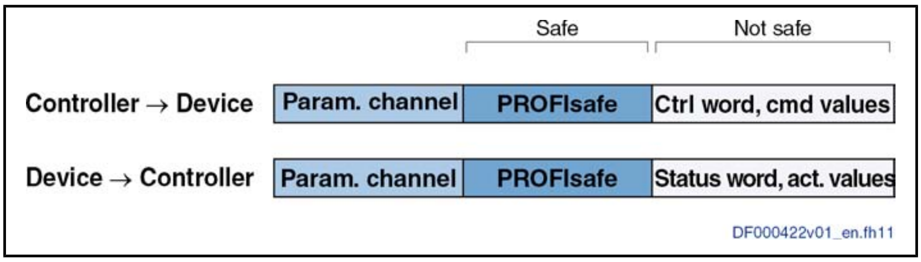


Fig.4-29: Overview of Cyclic Data Channel

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

Features The PROFINET device circuit with MultiEthernet interfaces has the following functional features:

- Ethernet according to IEEE 802.3 and priorization according to IEEE 802.1Q
- Transmission rate 100 Mbit/s
- Data transmission via Ethernet cable (CAT5e copper)
- Allocation of the IT addresses via DCP protocol (**D**iscovery and **B**asic **C**onfiguration)
- 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)

Min. cycle time	Max. quantity of process data/setting P-0-4076	Notes
0,5 ms (T_{A_pos})	16 bytes → P-4076 = 0.5 ms 32 bytes → P-4076 = 1 ms 48 Bytes → P-4076 > 1 ms	Additionally a maximum of 16 bytes parameter channel for PROFINET

Fig.4-30: Quantity of Cyclic Data Depending on P-0-4076

Valid values for P-0-4076: 0.5 ms, 1 ms, 2 ms, 3 ms, 4 ms, 5 ms, …

- Additional optional parameter channel in the cyclic channel with up to 16 bytes (8 words)

- LED for diagnosing the PROFINET status (network status)
- LEDs for displaying the link/activity status
- For reasons of compatibility with IndraDrive controllers with PROFIBUS master communication module, the use of diagnostic messages and alarms is omitted
- PROFINET IRT is not supported. In networks with PROFINET IRT communication, the IndraDrive device cannot be used.
- Supported field bus profiles:
  - 0xFF82: I/O mode "positioning" with configurable real-time data
  - 0xFF92: I/O mode "preset velocity" with configurable real-time data
  - 0xFFFD: Freely configurable mode "operating mode neutral"
  - 0xFFFE: Freely configurable mode

Hardware Requirements

Using the "PROFINET" master communication requires the following control section design:

- Single-axis BASIC UNIVERSAL (HCS01.1-W00xx-X-0X-B-**ET**-EC-NN-NN-NN-NN-FW)

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: Cycle time (Tcyc)
- P-0-4079, Field bus: Baud rate
- P-0-4088, Master communication: Drive configuration
- P-0-4089.0.2, Master communication: Device name
- P-0-4089.0.10, Master communication: MAC address device
- P-0-4089.0.13, Master communication: IP address
- P-0-4089.0.14, Master communication: Network mask
- P-0-4089.0.15, Master communication: Gateway address

Profile type parameters

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

See "Profile Types (With Field Bus Interfaces)"

See "Engineering/Diagnosis Interfaces"

We use additional parameters for extended communication.

See 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
- F4009 Bus failure
- F4012 Incorrect I/O length

4.9.4 SERCOS III

Brief Description

It is possible to operate IndraDrive controllers with a MultiEthernet interface (ET) or the option module "SERCOS III" (S3) as SERCOS III master communication. Via these modules, it is possible to exchange real-time data with a SERCOS III master.

The following communication channels are distinguished:

- **Cyclic data channel** (consumer, producer)

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

  → Data container for acyclic transmission of useful data (**service data**).
- **Non-real time channel (NRT channel)**

  → Defined time slot within the cycle time for transmission of standard Ethernet telegrams

General Features

- Transmission rate 100 Mbit/s
- Cyclical data exchange of command 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 drives on a ring
- Overall synchronization of all connected drives to the master

Firmware-Specific Features

			BASIC MPB-16VRS
Position control cycle	$T_{Position}$	µs	**500**
Master comm. cycle time	min	µs	**500**
	Max.	ms	65
MotionData In each case for MDT/AT	$T_{Sercos}=T_{Position}$	Byte	**24**
		IDN	12
	$T_{Sercos}>T_{Position}$	Byte	48
		IDN	16

		BASIC MPB-16VRS
CC connections [incl. 2-byte connection control word (C_Con)]	Byte	10
	IDN	2

Fig.4-31: Characteristic SERCOS IIi Values

- Cycle time: Min. 500 µs, max. 65 ms (multiples of position clock 500 µs can be set)
- SERCOS compatibility class C
- Max. quantity of configurable consumer data: 52 bytes / 16 IDNs
- Max. quantity of configurable producer/consumer data: 52 bytes / 16 IDNs

☞ The number of configurable bytes in consumer/producer connections depends on the relation of the position cycle time (P-0-0556, bit 2) to the SERCOS cycle time:

- SERCOS cycle time = position cycle time → max. length 28 bytes / 12 IDNs
- SERCOS cycle time > position cycle time → max. length 52 bytes / 16 IDNs

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

Hardware Requirements

The optional module with SERCOS III interface is available for the following device:

- Single-axis economy (HCS01.1-W00xx-X-0X-E-**S3**-EC-NN-NN-NN-NN-FW)

The optional module with MultiEthernet interface is available for the following device:

- Single-axis BASIC UNIVERSAL (HCS01.1-W00xx-X-0X-B-**ET**-EC-NN-NN-NN-NN-FW)

Pertinent Parameters

Specific parameters for SERCOS III communication:

- S-0-1000, SERCOS III: SCP Type & Version
- S-0-1002, SERCOS III: Communication Cycle time (tScyc)
- S-0-1005, SERCOS III: Minimum feedback processing time (t5)
- S-0-1006, SERCOS III: AT0 transmission starting time (t1)
- S-0-1007, SERCOS III: Feedback acquisition capture point (t4)
- S-0-1008, SERCOS III: Command value valid time (t3)
- S-0-1009, SERCOS III: Device Control (C-Dev) offset in MDT
- S-0-1010, SERCOS III: Lengths of MDTs
- S-0-1011, SERCOS III: Device Status (S-Dev) offset in AT
- S-0-1012, SERCOS III: Length of ATs
- S-0-1013, SERCOS III: SVC offset in MDT
- S-0-1014, SERCOS III: SVC offset in AT
- S-0-1015, SERCOS III: Ring delay
- S-0-1016, SERCOS III: Slave delay (P/S)
- S-0-1017, SERCOS III: NRT transmission time

- S-0-1019, Master comm. engineering over IP: MAC address
- S-0-1020, Master comm. engineering over IP: IP address
- S-0-1021, Master comm. engineering over IP: Network mask
- S-0-1022, Master comm. engineering over IP: Gateway address
- S-0-1023, SERCOS III: SYNC jitter
- S-0-1024, C5300 SERCOS III: SYNC delay measuring procedure command
- S-0-1026, SERCOS III: Version of communication hardware
- S-0-1027.0.1, SERCOS III: Requested MTU
- S-0-1027.0.2, SERCOS III: Effective MTU
- S-0-1031, SERCOS III: Signal assignment TSx
- S-0-1035, SERCOS III: Error counter Port1 & Port2
- S-0-1041, SERCOS III: AT Command value valid time (t9)
- S-0-1044, SERCOS III: Device Control (C-Dev)
- S-0-1045, SERCOS III: Device Status (S-Dev)
- S-0-1046, SERCOS III: List of SERCOS addresses in device
- S-0-1050.x.1, SIII-Connection: Connection setup
- S-0-1050.x.2, SIII-Connection: Connection number
- S-0-1050.x.3, SIII-Connection: Telegram assignment
- S-0-1050.x.4, SIII-Connection: Max. length of connection
- S-0-1050.x.5, SIII-Connection: Current length of connection
- S-0-1050.x.6, SIII-Connection: Configuration list
- S-0-1050.x.8, SIII-Connection: Connection control (C-Con)
- S-0-1050.x.10, SIII-Connection: Producer cycle time
- S-0-1050.x.11, SIII-Connection: Allowed data losses
- S-0-1050.x.12, SIII-Connection: Error counter data losses
- S-0-1050.x.20, SIII-Connection: IDN allocation of real-time bit
- S-0-1050.x.21, SIII-Connection: Bit allocation of real-time bit
- S-0-1051, SIII-Connection: Image of connection setups

Additional pertinent parameters according to "SERCOS interface":

- S-0-0014, Interface status
- S-0-0015, Telegram type parameter
- S-0-0097, Mask class 2 diagnostics
- S-0-0134, Master control word
- S-0-0135, Drive status word
- S-0-0187, List of configurable data in the AT
- S-0-0188, List of configurable data in the MDT
- P-0-1044, Master comm. engineering over IP: Status IP communication

Pertinent Diagnostic Messages

- C0108 Time slot parameter > Sercos cycle time
- C0109 Telegram offset unsuitable
- C0112 TNcyc (S-0-0001) or TScyc (S-0-0002) error
- C0113 Relation TNcyc (S-0-0001) to TScyc (S-0-0002) error

- C0170 Config. IDNs for connection not configurable
- C0171 Maximum length for connections exceeded
- C0172 Delay measurement (S-0-1024) not carried out
- C0173 Connections (number) not configurable
- C0174 Connection configuration not allowed
- C0175 Producer cycle time of a connection not correct
- C5301 SERCOS III: Delay measurement failed
- E4001 Double MST failure shutdown
- E4005 No command value input via master communication
- E4007 SERCOS III: Consumer connection failed
- E4010 Slave not scanned or address 0
- F4001 Double MST failure shutdown
- F4002 Double MDT failure shutdown
- F4003 Invalid communication phase shutdown
- F4004 Error during phase progression
- F4005 Error during phase regression
- F4006 Phase switching without ready signal
- F4017 S-III: Incorrect sequence during phase switch

5 Motor, Mechanical Axis System, Measuring Systems

5.1 General Information on Operation of Motors With IndraDrive

5.1.1 Basics on the Motors to be Controlled

Brief Description

With the controllers of the IndraDrive range it is possible to control both synchronous motors and asynchronous motors.

Types of Construction

The following types of construction are possible:

- Rotary motors
- Linear motors

Both types can be used in housing design (motor with an output shaft that includes the bearing) or in kit design (stator and rotor as individual components).

Thermal Monitoring

When IndraDrive is used, the controlled motors are protected against thermal damage when they are provided with a temperature sensor connected to the controller. The controllers are equipped for evaluating the following temperature sensors:

- NTC thermistor K227 (manufacturer: Siemens)
- PTC thermistor KTY84 (manufacturer: Siemens)
- Thermal switch SNM150DK (manufacturer: Thermik)

In addition, it is possible to evaluate temperature sensors not listed above, but their specific resistance characteristics have to be entered manually!

Diagnostic Data of Motor Operation

The firmware provides the option to collect dynamic operating data of the motor and store them (operating hours counter, thermal and mechanical operating data, operational performance).

Adjusting Motor/Controller

The IndraDrive controllers are adjusted to the motor to be controlled by providing or inputting the motor-specific data.

- In the case of **Rexroth motors**, this can be done without any problem, because the manufacturer provides a specific data set for adjusting each motor type. The data are documented by the manufacturer as parameter values, stored and made available in motor-specific parameters.
- In the case of **third-party motors**, it is necessary to check, by means of the motor data and the data of the possibly available motor encoder, whether they are basically suited for operation with IndraDrive. The parameter values for adjusting the controller have to be specifically determined for each motor.

☞ Rexroth motors, by motor-specific parameter values made available and temperature evaluation adjusted in an optimum way, guarantee easy commissioning, full drive performance and a high degree of operational safety!

Motor Holding Brakes

IndraDrive allows controlling and monitoring holding brakes that are mechanically connected to the motor:

- Electrically releasing brakes (self-holding)
- Electrically holding brakes (self-releasing)

Hardware Data

For the electrical connection of the motors to the controller, see the Project Planning Manuals for the IndraDrive controllers. A complete connection diagram for the use of Rexroth motors is contained in the respective Project Planning Manual.

Pertinent Parameters

Motor parameters:

- S-0-0109, Motor peak current
- S-0-0111, Motor current at standstill
- S-0-0113, Maximum motor speed
- S-0-0141, Motor type
- P-0-0018, Number of pole pairs/pole pair distance
- P-0-0051, Torque/force constant
- P-0-0510, Rotor inertia
- P-0-0640, Cooling type
- P-0-4014, Type of construction of motor
- P-0-4048, Stator resistance

Synchronous motor parameters:

- P-0-4016, Direct-axis inductance of motor
- P-0-4002, Charact. of quadrature-axis induct. of motor, inductances
- P-0-4003, Charact. of quadrature-axis inductance of motor, currents
- P-0-4005, Flux-generating current, limit value
- P-0-4013, Current limit value of demagnetizationCurrent limit value of demagnetization

Asynchronous motor parameters:

- P-0-0532, Premagnetization factor
- P-0-4004, Magnetizing current
- P-0-0529, Scaling of stall current limit
- P-0-0530, Slip increase
- P-0-4039, Stator leakage inductance
- P-0-4040, Rotor leakage inductance
- P-0-4041, Motor magnetizing inductance
- P-0-4042, Characteristic of motor magnetizing inductance
- P-0-4043, Rotor time constant

Field-weakening range parameters:

- P-0-0533, Voltage loop proportional gain
- P-0-0534, Voltage loop integral action time
- P-0-0535, Motor voltage at no load
- P-0-0536, Maximum motor voltage

Other Motor-Relevant Parameters

In connection with the motor, there are other important parameters of the following parameter groups:

- Measuring system parameters
- Motor holding brake parameters
- Temperature sensor parameters
- Motor temperature model parameters
- Default control loop parameters

5.1.2 Motor Temperature Monitoring

Brief Description

See "Basics on the Motors to be Controlled"

Pertinent Parameters

- S-0-0201, Motor warning temperature
- S-0-0204, Motor shutdown temperature
- S-0-0383, Motor temperature
- P-0-0512, Temperature sensor
- P-0-0513, Temperature sensor characteristic

Pertinent Diagnostic Messages

- E2021 Motor temperature outside of measuring range
- E2051 Motor overtemp. prewarning
- F2019 Motor overtemperature shutdown
- F2021 Motor temperature monitor defective

5.2 Rexroth Motors

5.2.1 Basics on Rexroth Motors

Brief Description

Classification

Bosch Rexroth's "Electric Drives and Controls" technology field offers a wide range of motors for equipping machines and installations with drives.

Due to their types of construction, Rexroth electric motors can be divided into:

- Housing motors with output shaft and flange or mounting supports
- Kit motors to be installed in machines and installations; consisting of individual components that are mounted to a moving and a static part of the mechanical system

Adjusting Motor/Controller

The controllers can be adjusted to Rexroth motors without any problem because the manufacturer provides the respective data set for each motor type. These data are available as parameter values.

- In the case of housing motors with data memory in the motor encoder, the parameter values are delivered as an integral part of the motor. At the initial commissioning they are automatically loaded to the controller.
- In the case of kit motors (individual components) and housing motors without data memory in the motor encoder, the respective motor parameters are not delivered with the motor. They can be easily loaded to the controller, however, from a database in the "IndraWorks Ds/D/MLD" commissioning tool.

The motor parameter values determined by the manufacturer guarantee that the motor can be loaded in accordance with its operating characteristic, if the required current and the corresponding power are provided by controller and supply unit.

The motor-specific parameter values of Rexroth motors can be loaded into the controller in different ways:

- Automatically in case of housing motors with encoder data memory
- In a database-supported form in case of kit motors, using the commissioning tool "IndraWorks Ds/D/MLD"
- In a file-supported form by loading a drive parameter set
- Manually, by entering the parameter values by means of a motor-specific data list

In case of automatic, database-supported and file-supported loading, the motor-specific parameter values are written to a memory range of the controller recording the data in an unchanged form, similar to a usual "type plate". From this "type plate" memory range, the data is copied into the parameters active for control, converted in a scaling-dependent form if necessary. In case of manual data input, the parameters of the "type plate" memory range should be written.

Thermal Motor Monitoring

Rexroth motors are thermally monitored by the controller and protected against overheating. To do this the current motor temperature is determined by thermo sensors installed in the motor winding. Depending on temperature thresholds that can be set, the controller generates a warning or switches the motor off.

☞ Rexroth motors, by motor parameters made available and temperature evaluation adjusted in an optimum way, guarantee easy commissioning, full drive performance and a high degree of operational safety!

Measuring System

As a standard, Rexroth housing motors are equipped with a position measuring system. The individual motor series have different measuring systems which allows offering cost-efficient motors depending on the application.

The following measuring systems of Rexroth housing motors are supported by this firmware

- Encoders with sine signals and HIPERFACE® interface (1 Vpp)
- Encoders with sine signals and EnDat2.1 interface (1 Vpp)
- Encoders with sine signals (1 Vpp)
- Encoders of MSM motors with digital interface

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

- Encoders with sine signals and EnDat2.1 interface, 1Vpp, Heidenhain standard
- Encoders with sine signals and HIPERFACE® interface (1 Vpp), if the encoder is released by Rexroth (see FAQ_IndraDrive_HIPERFACEGeber)
- Encoder with sine signals, 1Vpp, Heidenhain standard
- Encoder with square-wave signals, TTL, Heidenhain standard

Pertinent Parameters

The "type plate" memory range contains amongst others the parameters listed below. Converted in a scaling-dependent form, if necessary, they are automatically copied into the parameters active for control (see "Pertinent Parameters" under "Basics on the Motors to be Controlled").

General motor parameters:

- P-0-2109, Motor peak current, type plate
- P-0-2111, Motor current at standstill, type plate
- P-0-2113, Maximum velocity of motor, type plate
- P-0-2141, Motor type, type plate
- P-0-3000, Module code of motor, type plate
- P-0-3002, Number of pole pairs/pole pair distance, type plate
- P-0-3003, Rotor inertia, type plate
- P-0-3005, Torque/force constant, type plate
- P-0-3007, Stator resistance, type plate
- P-0-3008, Commutation offset, type plate
- P-0-3050,

Synchronous motor parameters

- P-0-3016, Direct-axis inductance of motor, type plate
- P-0-3017, Quadrature-axis inductance of motor, type plate
- P-0-3018, Charact. quadr.-axis induct. of motor, induct., type plate
- P-0-3019, Charact. quadr.-axis induct. of motor, currents, type plate
- P-0-3015, Flux-generating current, limit value, type plate
- P-0-3023, Current limit value of demagnetization, type plate
- P-0-3008, Commutation offset, type plate

Asynchronous motor parameters

- P-0-3032, Premagnetization factor, type plate
- P-0-3014, Magnetizing current, type plate
- P-0-3029, Scaling of stall current limit, type plate
- P-0-3039, Stator leakage inductance, type plate
- P-0-3040, Rotor leakage inductance, type plate
- P-0-3041, Motor magnetizing inductance, type plate
- P-0-3042, Characteristic of motor magnetizing inductance, type plate
- P-0-3043, Rotor time constant, type plate

Field-weakening range parameters

- P-0-3033, Voltage loop proportional gain, type plate
- P-0-3034, Voltage loop intergral action time, type plate
- P-0-3035, Motor voltage at no load, type plate
- P-0-3036, Maximum motor voltage, type plate

Parameters for measuring system:

- P-0-1000, Kind of encoder 1, encoder memory
- P-0-1001, Encoder 1 resolution, encoder memory

Only for absolute encoders (multi-turn):

- P-0-1002, Absolute encoder offset 1, encoder memory

Parameter for motor holding brake (if available):

- P-0-3010, Torque of motor holding brake, type plate

Default control loop parameters:

- P-0-2100, Velocity loop proportional gain, type plate
- P-0-2101, Velocity loop integral-action time, type plate
- P-0-2104, Position loop Kv-factor, type plate
- P-0-2106, Current loop proportional gain 1, type plate
- P-0-2107, Current loop integral-action time 1, type plate
- P-0-3004, Speed controller smoothing time constant, type plate

☞ At a command, default control loop parameters can be loaded to the controller. They are useful starting values for further control loop optimization.

Pertinent Diagnostic Messages

- C0700 Load defaults procedure com. (load controller param.)
- C0702 Default parameters not available
- C0703 Default parameters invalid

- C0704 Parameters not copyable
- C0706 Error when reading the controller parameters
- F2008 RL The motor type has changed.
- F2104 Commutation offset invalid

5.2.2 Rexroth Housing Motors

Rexroth Housing Motors With Encoder Data Memory

Motor Lines

The following Rexroth housing motors supported by this firmware are equipped with encoder data memory:

- MSK, MSP, MSM
- MAD, MAF

☞ The Bosch motor with the type designation "SF..." that can be controlled with IndraDrive controllers is equipped with an encoder data memory, too. As regards commissioning and parameters, SF motors are also supported by this firmware and have the same behavior as Rexroth housing motors with encoder data memory!

Brief Description

See section "Basics on Rexroth Motors"

Pertinent Parameters See "Pertinent Parameters" in section "Basics on Rexroth Motors"

For the parameters mentioned above, there are also parameters for the data transfer from the encoder data memory into the parameter memory of the controller (administration parameters, cannot be interpreted by users, number depends on the number of available encoder interfaces):

- P-0-1031, Content of encoder memory optional slot 1
- P-0-1032, Content of encoder memory optional slot 2
- P-0-1033, Content of encoder memory optional slot 3
- P-0-1034, Content of encoder memory optional slot 4

Pertinent Diagnostic Messages See "Pertinent Diagnostic Messages" in section "Basics on Rexroth Motors"

Rexroth Housing Motors Without Encoder Data Memory

Motor Lines

The following Rexroth housing motor supported by this firmware does not have an encoder data memory:

- MAL

Brief Description

See section "Basics on Rexroth Motors"

Pertinent Parameters See "Pertinent Parameters" in section "Basics on Rexroth Motors"

Pertinent Diagnostic Messages See "Pertinent Diagnostic Messages" in section "Basics on Rexroth Motors"

For more details see section "Basics on Rexroth Motors"

5.2.3 Rexroth Kit Motors

General Information

Kit motors consist of individual components that are mounted to a moving and as static part of the machine's mechanical system and functionally put together to form a motor.

A kit motor consists of the following components:

- Electrically active part with thermo sensor
- Electrically passive part
- Measuring System
- Storage

The electrical parts of the kit motor are supplied by Rexroth, the measuring system and the bearing are provided on the machine side.

Rexroth kit motors are manufactured according to the "asynchronous motor" or "synchronous motor" functional principles. With regard to control, the functional principles have different requirements:

- In the case of synchronous motors, the current in the windings of the stator must have a fixed allocation to the permanent magnetic field of the rotor so that the maximum torque or the maximum force is generated.
- In the case of asynchronous motors there is no fixed allocation between stator and rotor required in order to generate the maximum torque or the maximum force.

Rexroth Kit Motors, Synchronous

Brief Description

The following Rexroth kit motors are manufactured according to the functional principle "synchronous motor":

- Linear motor MLF
- Rotary motors MBS and MBT

As the motor is assembled in the machine, stator, rotor and measuring system can only be put together on site. The electric-magnetic-mechanical allocation of the synchronous motor is therefore only to be made on site. This is done by determining and setting the commutation offset.

☞ The measuring system should be realized with high resolution and as a motor encoder to be evaluated in absolute form (see also "Absolute Measuring Systems"). If it is necessary to use an incremental measuring system the use of encoders with square-wave signals should be avoided!

Determining the Commutation Offset

The commutation offset can be determined with different methods. The method is chosen in accordance with the axis geometry, the practicability and the chances of success of the respective method depending on the mechanical axis system:

- **Measuring method** for motor encoders that can be evaluated in absolute form

  → Distance measurement, currentless (only possible for Rexroth linear kit motors)
- **Saturation method** (axis needs to be blocked or at standstill)

→ With current (possible with all types of construction in combination with motor encoders that can be evaluated in absolute form or with relative motor encoders)

- **Sine-wave method** (requires unrestricted movement of axis)

  → With current (possible with all types of construction in combination with motor encoders that can be evaluated in absolute form or with relative motor encoders)

☞ In the case of absolute measuring systems, the commutation offset only has to be determined once (at initial commissioning), in the case of incremental measuring systems this has to be done each time the drive is switched on again!

Description of the method for commutation setting, see "Drive Control: Commutation Setting"

Pertinent Parameters See "Pertinent Parameters" in section "Basics on Rexroth Motors"

Pertinent Diagnostic Messages See "Pertinent Diagnostic Messages" in section "Basics on Rexroth Motors"

For more details see section Basics on Rexroth Motors

Rexroth Kit Motors, Asynchronous

Brief Description

The following Rexroth kit motors are manufactured according to the functional principle "asynchronous motor":

- Rotary motors 1 MB

As the motor is assembled in the machine, stator, rotor and measuring system can only be put together on site. After loading the specific parameter values for motor and measuring system the assembled motor can be put into operation independent of rotor position and allocation of the measuring system.

☞ The measuring system should be realized with high resolution! Avoid using encoders with square-wave signals!

Pertinent Parameters See "Pertinent Parameters" in section "Basics on Rexroth Motors"

Pertinent Diagnostic Messages See "Pertinent Diagnostic Messages" in section "Basics on Rexroth Motors"

For more details see section Basics on Rexroth Motors

5.3 Third-Party Motors at IndraDrive Controllers

5.3.1 General Information on Third-Party Motors

Today, machine axes are mainly moved with electric drives. Motors of standard design are used in most cases, as this is the most cost-efficient solution.

Special Requirements Due to special requirements at machine axes, constructional or safety-related aspects, it may be necessary for the machine manufacturer to use a motor construction diverging from the standard.

Motor Design not Included in Product Range For these cases there is the demand on the drive supplier to realize, apart from the deliverable standard drive consisting of (standard) motor, controller, cable and, if required, machine control unit, drives with motors that are not included in his own product range due to the special design.

With Rexroth controllers of the IndraDrive range, it is also possible to control third-party motors.

Checking Whether Third-Party Motors Can be Controlled

For successfully and fail-safely controlling a third-party motor, it is necessary to check beforehand

- whether the third-party motor to be controlled meets the requirements of the controller,
- whether the third-party motor has the required minimum inductance,
- whether the mounted position measuring system can be evaluated by the controller or which position measuring system can be selected for kit motors,
- whether the motor can be protected against inadmissible temperature rise in the case of overload,
- which controller, including supply, is suitable due to the motor power to be delivered.

How to do Project Planning?

The requirements relevant in the system combination are documented in the Project Planning Manual of the drive system.

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

How to Commission?

The motor parameter values have to be determined first (see section "Determining the Parameter Values for Motor and Motor Control"). The parameter values of motor control are calculated by command internally in the firmware.

It is advisable to document the determined motor parameter values in the forms contained in the section "Forms for Parameter Values".

5.3.2 General Information on Controlling Third-Party Motors

Pertinent Parameters and Diagnostic Messages

See "Automatic Setting of Motor Control"

Hardware Data

For the electrical connection of the motors to the controller, see the Project Planning Manuals for the IndraDrive controllers. A complete connection diagram for the use of Rexroth motors is contained in the respective Project Planning Manual.

5.3.3 Determining the Parameter Values of Third-Party Motors

General Information on How to Determine the Parameter Values

As Bosch Rexroth cannot make available parameter values for motor control of third-party motors, these values have to be determined before or during the commissioning of the third-party motor. The determination of these parameter values is supported by the following commands:

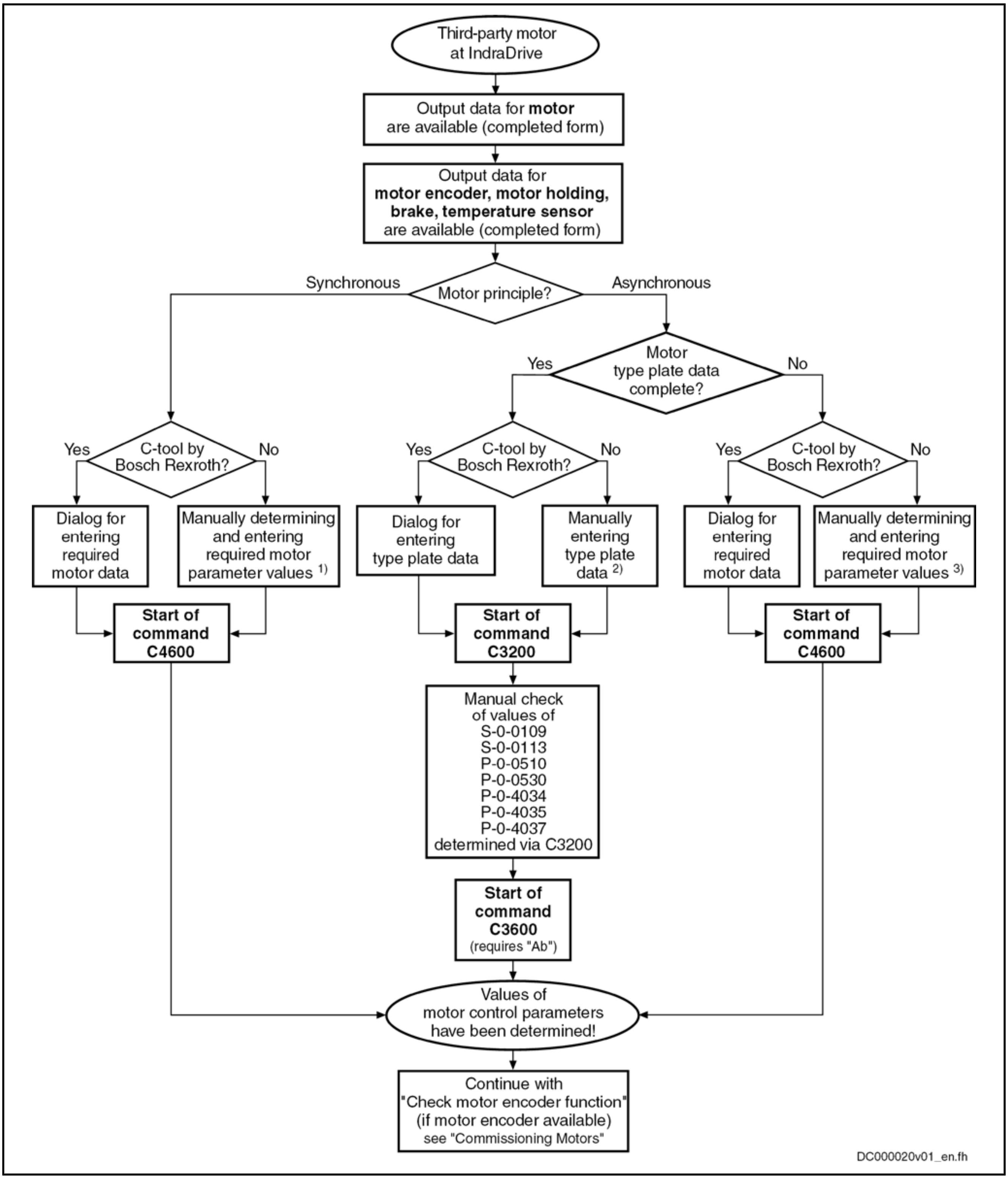
- **C3200 Command Calculate motor data**

  → For asynchronous motors, drive-internal calculation of the values for the motor control parameters from the data on the type plate
- **C3600 Command Motor data identification**

  → For asynchronous motors, drive-internal optimization of the motor control parameter values calculated by means of the command C3200
- **C4600 Command Calculate motor control parameters**

  → Calculating the motor control parameter values from the motor-specific data for synchronous motors and, if necessary, also for asynchronous motors (after manual input of motor-specific data in addition to the data from the type plate)

The specific motor data have to be made available by the motor manufacturer. To collect all required manufacturer-side data of the motor, use the appropriate forms to copy below.



1)	According to form "Motor Parameters for Synchronous Motors"
2)	In parameter "P-0-4032, Motor type plate data"
3)	According to form "Motor Parameters for Asynchronous Motors"
C-tool	Commissioning tool (e.g. IndraWorks Ds/D/MLD)

Fig.5-1: Determining the Values for the Motor Control Parameters

For detailed explanations on the scope of functions of the mentioned commands see "Automatic Setting of Motor Control"!

5.4 Motor Holding Brake

5.4.1 Monitoring the Braking Current

Brief Description

Fields of Application

Base package of all firmware variants in **open-loop and closed-loop** characteristic

Background

The reliable function of a holding brake is of elementary importance for the operational reliability of a machine, particularly in case of vertical servo axes. By means of the "function check of the motor holding brake", the holding brake can be checked for wear and corrosion. Utilization of this function check is, however, left to the user.

Even with cyclic function tests, a wire break occurring between two tests would lead to the unwanted application and possibly the destruction of the brake before it would be possible to recognize the failure within the scope of the next function test. Between the function test intervals, the permanently active monitoring of the braking current recognizes failures in the holding brake control and immediately signals them.

Overview of Functions

Operating Principle

The controller monitors the current lead via the terminals on the controller side for activating the brake. The braking current monitoring recognizes the following conditions:

- Wire break (braking current smaller than 100 mA)
- Braking current ok
- Short circuit

In case of "wire break" and "short circuit", the error message "F2068, Brake error" is generated. The monitoring is active as soon as an existing holding brake has been entered in "P-0-0525, Holding brake control word".

The wire break monitoring can be deactivated, e.g. due to brake control via relay.

The status of the holding brake current monitoring is displayed in "P-0-0539, Holding brake status word"; with IndraDrive Cs, the measured holding brake current is displayed in "P-0-0527, de: Haltebremsen-Iststrom".

With HCQ, a holding brake current output is not possible!

Hardware Requirements

For using the "braking current monitoring", no special hardware is required!

Rexroth motors with encoder data memory automatically recognize the existence of a motor holding brake, the braking current monitoring is automatically activated. In case of third party motors and motors with external holding brake, the existence of a holding brake must be entered in the holding brake control word for activating the function.

Pertinent Parameters

- P-0-0525, Holding brake control word
- P-0-0539, Holding brake status word

- P-0-0527, de: Haltebremsen-Iststrom

Pertinent Diagnostic Messages

- F2068, Brake error

5.4.2 Operating Behavior of the Motor Holding Brake

Brief Description

Motor holding brakes are used to hold axes with drive enable having been switched off. This is particularly important for non-equilibrated vertical axes. With IndraDrive controllers it is possible to control and monitor motor holding brakes in a wear-resistant way.

☞ Holding brakes at Rexroth motors normally aren't designed for decelerating when in operation. Increased wear caused by deceleration in operation can destroy the holding brake at an early stage!

The following motor holding brake types are possible:

- Electrically releasing brakes (self-holding) for servo drives
- Electrically holding brakes (self-releasing) for main drives

The motor holding brake can be directly mounted on the motor shaft, e.g. in the case of Rexroth housing motors, or directly connected to the mechanical axis system, e.g. in the case of linear kit motors.

IndraDrive controllers include application-specific controls of the holding brake in order to minimize wear of the brake in the case of error. The following two functional principles of holding brake control are supported:

- Control of holding brake **for servo drives**
- Control of holding brake **for main drives**

Control of the holding brake is linked with drive enable, considering holding and releasing delays. In special cases it may be appropriate to avoid this programmed link and release or apply the holding brake independently. This, too, is possible with IndraDrive!

Hardware Requirements

The motor holding brake is controlled via a controller-internal relay contact. Power supply is realized by the controller via the 24V control voltage. The holding brake must be suited for the voltage that is output, the holding brake current mustn't exceed the allowed maximum value of the respective device (see documentation "Supply Units and Power Sections; Project Planning Manual for Controllers"). If necessary the holding brake has to be controlled separately.

☞ The optionally available holding brakes of Rexroth motors can be directly controlled via the controller!

Pertinent Parameters

- S-0-0206, Drive on delay time
- S-0-0207, Drive off delay time
- S-0-0273, Maximum drive off delay time
- P-0-0525, Holding brake control word
- P-0-0539, Holding brake status word
- P-0-0540, Torque of holding brake
- P-0-0542, C2000 Command Release holding brake
- P-0-0543, C3800 Command Apply holding brake

Pertinent Diagnostic Messages

- C2000 Command Release motor holding brake
- C2001 Command not enabled
- C3800 Command Apply motor holding brake
- F6024 Maximum braking time exceeded

5.4.3 Function Check of Motor Holding Brake, Drive-Controlled

Brief Description

If the brake torque of holding brakes is too low due to wear and corrosion, this can interrupt the service and endanger safety in machines and installations. IndraDrive controllers have the advantage of monitoring the effectiveness of the holding brake for a command of the control master and recording the monitoring intervals.

This allows cyclic brake check according to EN-954-1, cat. 2 or dynamization/check of one of two redundant holding systems according to EN-954-1, cat. 3.

In the case of corrosion, the effectiveness of the holding brake can be re-established by a drive-controlled "resurfacing procedure"

Pertinent Parameters

- P-0-0525, Holding brake control word
- P-0-0539, Holding brake status word
- P-0-0540, Torque of holding brake
- P-0-0541, C2100 Holding system check command
- P-0-0544, C3900 Command Holding brake resurfacing
- P-0-0545, Test torque for releasing holding system
- P-0-0546, Starting torque for releasing holding system
- P-0-0547, Nominal load of holding system
- P-0-0549, Oper. hours control sec. at last succ. holding system check
- P-0-0550, Time interval holding system check
- P-0-0554, Current torque value of the motor holding brake
- S-0-0084, Torque/force feedback value
- S-0-0135, Drive status word

Pertinent Diagnostic Messages

- C2100 Brake check command
- C2101 Brake check only possible with drive enable
- C2103 Holding brake torque too low
- C2104 Command execution impossible
- C2105 Load of holding system greater than test torque
- C2106 Test torque of holding system not reached
- C3900 Command Brake resurfacing
- C3901 Resurfacing of brake only possible with drive enable
- C3902 Error during resurfacing of brake
- C3903 Command execution impossible
- E3115 Prewarning, end of brake check time interval
- F3115 Error, brake check time interval exceeded

5.5 Measuring Systems

5.5.1 Basics on Measuring Systems, Resolution

Brief Description

Control Loops and Measuring Systems

Operating drives in the closed control loop requires measuring systems in order to metrologically acquire the current status of the physical value to be controlled, the so-called actual value.

The following drive control loops are distinguished:

- Torque/force control loop

  → Actual value by evaluating the current measuring system and converting the value
- Velocity control loop

  → Actual value by evaluating the position measuring system and time-derivation
- Position control loop

  → Actual value by evaluating the position measuring system

The actual value of the torque/force control loop is generated by means of the internal current measurement. The measuring system is inaccessible for the user and has a fixed configuration.

Possibilities of Position Measuring

For acquiring the actual values of the velocity and position control loop there are position measuring systems available that provide the user possibilities of configuration. Position measurement can be carried out:

- At the motor only (measurement via motor encoder)

- or -

- Both at the motor and at the mechanical axis system (measurement via motor encoder and "external" or "optional" encoder).

☞ Position measurement via motor encoder is always required, measurement at the mechanical axis system is optional, the encoder at the mechanical axis system is therefore called "optional encoder". It is also called "external encoder" because this encoder is not installed internally at the motor, but externally at the axis.

Types of Position Measuring Systems

Position measuring systems are available for the different kinds of motion in adapted types of construction:

- Rotary encoders
- Linear encoders

With the appropriate signal specification, encoders in both types of construction can be evaluated by IndraDrive controllers.

Evaluating Position Measurement

Depending on their design and the mechanical arrangement at the axis, the position encoders can be evaluated as

- Relative encoders (incremental encoders)
- Absolute encoders (absolute value encoders).

The position information of the encoder may take the form of

- Two analog voltage signals with sine-shaped curve with constant velocity and 90° phase offset ("analog encoders")
- One digital encoder signal with defined number of increments per encoder revolution ("digital encoders")

Relative Position Measurement

In the case of relative position measurement, only position differences can be evaluated by means of the measuring system. The actual position values signaled by the measuring system refer to the (mostly undefined) position at the time the drive is switched on. To operate the drive within a limited travel range a position reference must be established ("homing") after each time the drive is switched on again.

Absolute Position Measurement

In the case of absolute position measurement, the encoder signals actual position values with a fixed encoder-dependent reference point to the controller. After each time the drive is switched on the correct actual position value is immediately available with each axis position. Due to the mostly undefined mounting situation of the encoder to motor or mechanical axis system, it is necessary to determine the position offset ("setting the absolute value") once at the initial commissioning.

Precision, Resolution

The precision of the position measurement depends on:

- the resolution of the measuring system (division periods (DP) with analog encoders; increments/revolution with digital encoders)
- The absolute encoder precision
- The digitalization quality for analog encoder signals
- The dimension of the travel range of the axis

Monitoring Functions

Correct position information is of fundamental importance for reliable drive behavior and motion according to contour. The encoder signals are therefore monitored for validity and compliance with the allowed tolerances.

In addition, it is possible to monitor drives with an encoder that can be evaluated in absolute form for compliance with the position when switching on compared to the last time the drive was switched off.

It is also possible to monitor the difference between the actual position values of motor encoder and external encoder.

See also "Monitoring the Measuring Systems"

Hardware Requirements

For connecting the measuring systems to the controller, there are two optional interfaces available. Parameters "P-0-0077, Assignment motor encoder->optional slot" and "P-0-0078, Assignment optional encoder->optional slot" are used to determine the interface to which the respective encoder is connected.

See also documentation "Rexroth IndraDrive Cs, Drive Systems" and "Rexroth IndraDrive HCQ, Drive Systems"

☞ The following points apply to the parameters P-0-0077 and P-0-0078:

- In the case of motors with motor encoder data memory , the value for parameter P-0-0077 is automatically set correctly.
- In the case of motors without motor encoder data memory (e.g. Rexroth kit motors), the value for parameter P-0-0077 must be set manually.
- In the case of optional encoders, the value for parameter P-0-0078 has to be set manually, too.

Pertinent Parameters

- S-0-0051, Position feedback value 1
- S-0-0053, Position feedback value 2
- S-0-0115, Position feedback 2 type
- S-0-0116, Resolution of feedback 1

- S-0-0117, Resolution of feedback 2
- S-0-0256, Multiplication 1 (motor encoder)
- S-0-0257, Multiplication 2 (optional encoder)
- S-0-0277, Position feedback 1 type
- S-0-0278, Maximum travel range
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0075, Encoder type 2 (optional encoder)
- P-0-0129, Internal position data format

5.5.2 Monitoring the Measuring Systems

Brief Description

Monitoring the Encoder Signals

Correct position information is the prerequisite for reliable drive behavior and motion according to contour. In order to guarantee best possible position evaluation the encoder signals are therefore monitored for validity and compliance with the allowed tolerances.

Monitoring the encoder signals allows detecting faulty states, such as:

- Encoder is dirty
- Noise injection in the case of inappropriate wire routing or wire design
- Exceeding the max. allowed encoder velocity (limit frequency of the encoder signals)
- Wire break or short circuit on wire

Monitoring the Axis Position When Switching On

In addition it is possible to monitor drives with an encoder that can be evaluated in absolute form for compliance with the position when switching on compared to the last time the drive was switched off. This allows detecting, for example, whether a vertical axis moved down after the machine was switched off or whether an axis was moved away from the position it had when the machine stopped.

Monitoring Mechanical Transfer Elements

It is also possible to monitor the difference between the actual position values of motor encoder and external encoder. This allows, for example, detecting slip due to wear in mechanical transfer elements between motor and axis at an early stage.

Monitoring the Position Data Reference

If the loss of the position data reference of absolute encoders (motor encoder or optional encoder) is detected due to changes in parameter values, e.g. of the mechanical drive system, the drive will signal this faulty status.

Pertinent Parameters

- S-0-0391, Monitoring window feedback 2
- P-0-0095, Absolute encoder monitoring window for motor encoder
- P-0-0096, Absolute encoder monitoring window for opt. encoder
- P-0-0177, Absolute encoder buffer 1 (motor encoder)
- P-0-0178, Absolute encoder buffer 2 (optional encoder)
- P-0-0185, Control word of encoder 2 (optional encoder)
- P-0-0391, Actual position value difference encoder1 - encoder2

Pertinent Diagnostic Messages

- E2074 Encoder 1: Encoder signals disturbed
- E2075 Encoder 2: Encoder signals disturbed
- F2036 Excessive position feedback difference
- F2042 Encoder 2: Encoder signals incorrect
- F2048 Low battery voltage

- F2074 Actual pos. value 1 outside absolute encoder window
- F2075 Actual pos. value 2 outside absolute encoder window
- F2174 Loss of motor encoder reference
- F2175 Loss of optional encoder reference
- F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)

5.5.3 Absolute Measuring Systems

Brief Description

Evaluating Position Measurement

Depending on their design and the mechanical arrangement at the axis, position encoders can be evaluated by IndraDrive controllers as

- Relative encoders (incremental encoders)

- or -

- absolute encoders (absolute value encoders)

if they have the required signal specification.

Rexroth position encoders and motor encoders of Rexroth housing motors are available in one of the two designs:

- Single-turn encoders (absolute actual position values over one encoder shaft revolution)
- Multi-turn encoders (absolute actual position values over 4096 encoder shaft revolutions).

These encoders can be evaluated as absolute encoders if the travel range of the axis can be represented within the absolute actual position value range of the encoder:

- In the case of single-turn encoders within one encoder shaft revolution
- In the case of multi-turn encoders within 4096 encoder shaft revolutions

Encoders of Rexroth Housing Motors

As a standard, Rexroth housing motors are equipped with a position measuring system. The individual motor series have different measuring systems which allows offering cost-efficient motors depending on the application.

The following measuring systems are supported by this firmware:

- Motor encoder option S1 or M1: HIPERFACE® encoder (only such types authorized by Rexroth) single- or multi-turn design,
- Motor encoder option S2 or M2 EnDat2.1 encoder, single- or multi-turn design,

Absolute Encoders for Kit Motors and External Encoders

For kit motors or directly at the mechanical axis system, the following measuring systems, that can be evaluated in absolute form, can be used:

- EnDat linear encoders (Heidenhain) or HIPERFACE® linear encoders (Stegmannn, only such types authorized by Rexroth) for linear motors or linear axes
- Rotary EnDat encoders (Heidenhain) or rotary HIPERFACE® (Stegmannn, only such types authorized by Rexroth) for rotary kit motors or rotary axes

Establishing Axis-Related Absolute Distance

The actual position values of an absolute encoder first only relate to the encoder itself. Due to the mostly undefined mounting situation of the encoder to motor or mechanical axis system, it is necessary to determine the position offset between encoder and axis zero point once at the initial commissioning (see also "Establishing the Position Data Reference: Establishing Position Data Reference for Absolute Measuring Systems").

Hardware Requirements

For the signal specification of third-party encoders for position and homing signals with regard to amplitude and phase angle, see the "Drive Controllers, Control Sections; Project Planning Manual".

☞ Rexroth encoders correspond to the required signal specification!

Pertinent Parameters

- S-0-0115, Position feedback 2 type
- S-0-0277, Position feedback 1 type
- S-0-0278, Maximum travel range
- S-0-0378, Absolute encoder range of motor encoder
- S-0-0379, Absolute encoder range of optional encoder
- P-0-0019, Initial position value

5.5.4 Relative Measuring Systems

Brief Description

Evaluating Position Measurement

IndraDrive controllers can evaluate the signals of both absolute and relative measuring systems, if the encoder signals correspond to the specification.

The **disadvantages** of relative encoders as opposed to encoders that can be evaluated in absolute form are as follows:

- Axes with relative position encoder must go through a homing procedure after switching on so that they can be operated in position control.
- Relative encoders are unsuitable as motor encoders for synchronous motors because each time the drive is restarted it has to go through a procedure for setting the commutation offset. Therefore, the immediate readiness for operation is not guaranteed for synchronous motors!

The **advantages** of relative encoders as opposed to encoders that can be evaluated in absolute form are as follows:

- Longer travel distances are possible for linear encoders.
- The costs of the encoder are mostly lower given equal absolute precision and number of lines or division period length.

Aspects of Use

Due to the above disadvantages, relative measuring systems are not used as motor encoders for synchronous Rexroth housing motors. For asynchronous motors there aren't any disadvantages when using relative motor encoders.

For kit motors it can be necessary, however, to use relative encoders as motor encoders if absolute encoders of the required design are not available:

- Great encoder lengths for long travel distances in the case of linear motors
- Hollow-shaft encoders with special bore diameters or encoders for high maximum speeds in the case of rotary kit motors

Establishing Axis-Related Absolute Distance

The actual position values of relative encoders first do not have any position reference. In any axis position the actual position value of the respective relative encoder, when switching the drive on, is written with the so-called initial position value, if no other encoder being in reference has been connected.

There are two ways to establish the axis-related absolute distance:

- Moving to a defined axis position with reproducible precision.

- or -

- Detecting a defined axis position by "passing" two distance-coded reference marks of the encoder.

At a defined position, the actual position value of the encoder to be homed is written with the corresponding absolute value of the axis (see "Establishing the

Position Data Reference: Establishing Position Data Reference for Relative Measuring Systems").

Hardware Requirements

For the signal specification for position and homing signals with regard to amplitude and phase angle, see the documentation "Drive Controllers, Control Sections; Project Planning Manual".

Pertinent Parameters

- S-0-0115, Position feedback 2 type
- S-0-0116, Resolution of feedback 1
- S-0-0117, Resolution of feedback 2
- S-0-0165, Distance-coded reference offset A
- S-0-0166, Distance-coded reference offset B
- S-0-0277, Position feedback 1 type
- P-0-0019, Initial position value

5.5.5 Establishing the Position Data Reference

General Information on Establishing the Position Data Reference

Brief Description

During the initial commissioning of a drive the actual position values transmitted by the measuring systems do not yet have any reference to the machine axis. This applies to

- Relative measuring systems and
- Absolute measuring systems.

For more detailed information on relative and absolute evaluation of measuring systems, see "Absolute Measuring Systems".

Relative Measuring Systems

The position data reference of a relative measuring system to the axis has to be reestablished after each time the drive is switched on or after the position data reference is lost. For this it is necessary to move to a defined axis position and the actual position value is set to an axis-related value in a defined position (exception: For relative encoders with distance-coded reference marks movement is only required via two marks!)

Absolute Measuring Systems

The position data reference of an absolute measuring system to the axis has to be established once during initial commissioning after replacing the motor or encoder (motor encoder or external encoder) and changes in the mechanical axis system. The position data reference still is maintained and the actual position values are axis-related immediately after the drive is switched on.

Establishing the Position Data Reference, Drive-Controlled

For establishing the position data reference in a drive-controlled way, the position data reference is automatically established by the drive by master-side triggering of a command. The procedure depends on the kind of measuring system:

- In the case of a relative measuring system without distance-coded reference marks, the axis moves to the reference point or to a dedicated point and then automatically switches to axis-related actual position values.
- In the case of a relative measuring system with distance-coded reference marks, the axis moves between two reference marks and then automatically switches to axis-related actual position values.
- In the case of an absolute measuring system, the automatic switching to the axis-related actual position value is carried out with the axis in standstill.

The presettings for establishing the position data reference are made via assigned parameters.

Establishing the Position Data Reference, NC-Controlled

For establishing the position data reference in an NC-controlled way, the drive makes available three commands to the master. The master has to generate the travel motion for searching the mark:

- The master starts the command "NC-controlled homing" and for searching the reference point or dedicated point of the axis has to move the axis by inputting command values.
- To calculate the offset and switch to axis-related actual position values it is necessary to start further commands.

The presettings for establishing the position data reference are made via assigned parameters.

Displaying the Position Data Reference

A position status parameter shows whether the position data reference of a measuring system evaluated by the controller has been established.

Motor Encoder and External Encoders

In addition to the motor encoder an external (optional) encoder can be available. Both encoders, in any combination of relative and absolute measuring systems, can

- have position data reference to the axis independently of each other (both encoders have different actual position values)

- or -

- have position data reference to the axis depending on each other (both encoders have the same actual position values).

This is configured via parameters and realized with the commands for establishing the position data reference.

Actual Position Value Offset

The difference of the actual position value before and after establishing the position data reference is displayed, related to the motor encoder or external encoder, in one parameter respectively.

See also the following sections:

- "Establishing Position Data Reference for Absolute Measuring Systems"
- "Establishing Position Data Reference for Relative Measuring Systems"

Pertinent Parameters

- S-0-0115, Position feedback 2 type
- S-0-0175, Offset parameter 1
- S-0-0176, Offset parameter 2
- S-0-0277, Position feedback 1 type
- S-0-0403, Position feedback value status
- P-0-0074, Encoder type 1 (motor encoder)
- P-0-0075, Encoder type 2 (optional encoder)

Establishing Position Data Reference for Absolute Measuring Systems

Brief Description

Base package of all variants in **closed-loop** characteristic.

See also section "General Information on Establishing the Position Data Reference"

The position data reference of an absolute measuring system to the axis has to be established once during initial commissioning, after replacing the motor or encoder (motor encoder or external encoder) and changes in the mechanical axis system.

Establishing Position Data Reference via Drive Commands

In the case of measuring systems to be evaluated in absolute form, the position data reference can be automatically established by the drive by starting the command

- "C0300 Set absolute position procedure command"

- or -

- "C0600 Drive-controlled homing procedure command".

The position data reference once established is maintained until one of the two commands is started again. The actual position values therefore are axis-related ("homed") immediately after the drive is switched on.

Motor Encoder and External Encoder

If two absolute measuring systems have been connected to the controller, the position data reference can be separately established for both measuring systems. If the position data reference was only set for one of the measuring systems, both actual position values are equal at the position at which the position data reference was established.

☞ If the position data reference was only set for one encoder, the actual position values of both encoders remain equal as long as mechanical axis system and encoder systems are mechanically connected without slip (slip control is possible!).

"Set Absolute Position Procedure" Command

It is recommended to start the "set absolute position" command when the axis is in standstill without drive enable. In the cases in which the axis, for establishing the position data reference, is to be brought to a defined position on the master side and be held in this position by the drive, "set absolute position" can also be executed with active drive.

"Drive-Controlled Homing Procedure" Command

When starting the command "C0600 Drive-controlled homing procedure command" without available reference, the drive moves the axis independently as defined in parameter "S-0-0147, Homing parameter" and establishes the position data reference. If when starting the command "C0600 Drive-controlled homing procedure command", the position system of the drive has already reference, the reference point that has already been determined is approached and the command is positively acknowledged.

For absolute encoders, the command "drive-controlled homing procedure" can be advantageously used after loss of position data reference after:

- encoder replacement in conjunction with a home switch or
- encoder error with peripheral causes in the case of modulo-scaled axes (e.g. encoder cable damage).

☞ "Active drive" means the drive that is in control. Drive enable ("AF") has been set.

Assigning the Axis-Related Actual Position Value With "Set Absolute Position"

By starting the 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 -

- the positioning of the axis at a "striking" axis position (e.g. value "0")

The required assignments and configurations for "setting absolute position" are realized via parameter settings.

Assigning the Axis-Related Actual Position Value With "Drive-Controlled Homing Procedure"

By starting the command "drive-controlled homing procedure", the previous actual position value of an encoder at a dedicated position of the axis is set to a new value. This value is the current axis position related to the coordinate system of the machine.

The required assignments and configurations for "drive-controlled homing" are realized via parameter settings (see information on "Drive-Controlled Homing Procedure" in section "Establishing Position Data Reference for Relative Measuring Systems").

Pertinent Parameters

- S-0-0052, Reference distance 1
- S-0-0054, Reference distance 2
- S-0-0148, C0600 Drive-controlled homing procedure command
- S-0-0447, C0300 Set absolute position procedure command
- S-0-0448, Set absolute position control
- P-0-0177, Absolute encoder buffer 1 (motor encoder)
- P-0-0178, Absolute encoder buffer 2 (optional encoder)
- P-0-1002, Absolute encoder offset 1, encoder memory
- P-0-1012, Absolute encoder offset 2, encoder memory

Pertinent Diagnostic Messages

- C0300 Set absolute position procedure command
- C0301 Measuring system unavailable
- C0302 Absolute evaluation of measuring system impossible
- C0303 Absolute encoder offset cannot be saved
- C0304 Command cannot be executed under drive enable
- C0600 Drive-controlled homing procedure command
- C0601 Homing only possible with drive enable
- C0602 Distance home switch - reference mark erroneous
- C0603 Homing impossible with optional encoder
- C0606 Reference mark not detected
- C0607 Reference cam input not assigned
- C0608 Pos. stop a. HW lim. switch not allowed f. modulo axes
- C0609 Different travel directions parameterized
- C0610 Absolute encoder offset could not be saved

Establishing Position Data Reference for Relative Measuring Systems (Homing)

Brief Description

Base package of all firmware variants in **closed-loop** characteristic.

See also section "General Information on Establishing the Position Data Reference"

Actual Position Value of Relative Measuring Systems when Switching On

After the drive is switched on the actual position values signaled by relative measuring systems do not yet have any reference to the machine axis. Measuring systems can be installed at the motor (motor encoder) and directly at the mechanical axis system (external or optional encoder).

For information on encoder arrangement and mechanical axis system see also "Mechanical Axis System and Arrangement of Measuring Systems"

The position data reference of relative measuring systems to the axis has to be established again each time after the drive was switched on or after all procedures that cause the position data reference to get lost (homing procedure).

Establishing the Position Data Reference, Drive-Controlled

After start of the respective command by the master, the drive can automatically establish the position data reference.

To do this, the drive moves the axis until the controller can detect a dedicated point. The actual position values then are automatically switched to axis reference. The presettings for the sequence for establishing the position data reference are made via assigned parameters.

Establishing the Position Data Reference, NC-Controlled

As an alternative to establishing the position data reference in a drive-controlled way, the NC ("master") can control the homing procedure.

In this case the master inputs the command values for moving the axis to the reference point and controls the homing procedure via commands and assigned parameters.

The NC-controlled homing procedure can be advantageous for drives with a rigid mechanical connection (e.g. for Gantry axes), because the master can input coordinated command values for the drives for the homing motion.

Dedicated Point for Establishing the Position Data Reference

The dedicated point for establishing the position data reference, in the case of linear axes, is at one end of the travel range. This allows finding the dedicated point from any axis position (situation when switched on) by moving in a defined direction. Rotary axes do not have an axis end position, the dedicated point is at a defined position within the travel range.

Reference Mark for Relative Measuring Systems

The precision with which this dedicated point is detected considerably influences the absolute precision of the axis. Apart from the signals for position detection, relative measuring systems therefore also provide a signal for exact determination of a dedicated point. This signal is called "reference mark". Depending on their type, relative measuring systems have one or several reference marks over the range of measurement.

Reference Mark and Home Switch

Especially in the case of rotary measuring systems (e.g. motor encoder) at axes moved in a linear way, the reference mark of the encoder can occur several times over the entire travel range. In this case it is required, by axis-side activation of a switch contact at the end of the travel range, to identify **one** reference mark signal. This defines an unequivocal dedicated point that can be found with reproducible precision. This switch contact is called "home switch". A possibly available travel range limit switch can be used like a home switch, too.

In addition, a reference mark signal can be identified by detecting axis blocking when positive stop at the end of the axis has been reached.

Independent of the number of reference marks over the travel range, an axis-side additional device (home switch or travel range limit switches or positive stop), is indispensable for linear axes for detecting the axis end position!

If only one reference mark occurs over the travel range in the case of rotary axes, the home switch in most cases is not required!

Dedicated Point and Reference Point of an Axis

The dedicated point identified by an encoder reference mark and, if necessary, by a home switch, in most cases is not identical to the reference point of the axis. The distance between reference point and zero point normally is determined on the machine side. Especially in the case of serial machines, this distance should be equal for axes of the same kind. The position of the dedicated point, however, is influenced by the kind of encoder arrangement and therefore differs from axis to axis.

Reference Offset

The position difference between dedicated point and reference point of the axis can be compensated by an offset value (reference offset).

See also section "General Information on Establishing the Position Data Reference"

Pertinent Parameters

Parameters for relative measuring systems:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- S-0-0052, Reference distance 1
- S-0-0054, Reference distance 2
- S-0-0108, Feedrate override
- S-0-0147, Homing parameter
- S-0-0148, C0600 Drive-controlled homing procedure command
- S-0-0150, Reference offset 1
- S-0-0151, Reference offset 2
- S-0-0173, Marker position A
- S-0-0174, Marker position B
- S-0-0191, C1500 Cancel reference point procedure command
- S-0-0298, Reference cam shift
- S-0-0299, Home switch offset
- S-0-0349, Bipolar jerk limit
- S-0-0400, Home switch
- S-0-0403, Position feedback value status
- P-0-0153, Optimum distance home switch-reference mark

Parameters for NC-controlled homing:

- S-0-0146 C4300 NC-controlled homing procedure command
- S-0-0171, C4400 Calculate displacement procedure command
- S-0-0172, C4500 Displacement to referenced system procedure command
- S-0-0175, Offset parameter 1
- S-0-0176, Offset parameter 2
- S-0-0404, Position command value status
- S-0-0407, Homing enable
- S-0-0408, Reference marker pulse registered

Parameters for relative measuring systems, distance-coded:

- S-0-0165, Distance-coded reference offset A
- S-0-0166, Distance-coded reference offset B
- S-0-0177, Absolute offset 1
- S-0-0178, Absolute offset 2

Parameters for homing at travel range limit switches:

- P-0-0090, Travel range limit parameter
- P-0-0222, Travel range limit switch inputs

Parameters for homing at positive stop:

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative

- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0331, Status "n_feedback = 0"
- S-0-0333, Status "T >= Tx"

Pertinent Diagnostic Messages

Diagnostic messages for drive-controlled homing:

- C0600 Drive-controlled homing procedure command
- C0601 Homing only possible with drive enable
- C0602 Distance home switch - reference mark erroneous
- C0604 Homing impossible with absolute encoder
- C0606 Reference mark not detected
- C0607 Reference cam input not assigned

Diagnostic messages for NC-controlled homing:

- C4302 Distance home switch - reference mark erroneous
- C4304 Homing impossible with absolute encoder
- C4306 Reference mark not detected
- C4307 Reference cam input not assigned
- C4308 Pos. stop a. HW lim. switch not allowed f. modulo axes
- C4400 Calculate displacement procedure command

Drive-Controlled Homing Procedure

General Information

Basic Sequence of "Search for Dedicated Point"

After activation of "S-0-0148, C0600 Drive-controlled homing procedure command", the drive for searching the dedicated point moves the axis according to the reference travel direction set in "S-0-0147, Homing parameter". When the controller has detected the position of the dedicated point, e.g. by reference mark detection of the encoder selected in S-0-0147, the position data reference of the actual position values to the axis can be established.

Determining the homing appropriate procedure for the existing axis type (settings in S-0-0147) ensures that during the search for the dedicated point the axis only moves within the allowed travel range!

For information on the actual position value after establishing the position data reference for motor encoder and external encoder see section "General Information on Establishing the Position Data Reference"

Functional Sequence "Drive-Controlled Homing Procedure"

Command Value Profile for Homing Procedure

After activation of "S-0-0148, C0600 Drive-controlled homing procedure command", the drive moves the axis according to the reference travel direction set in "S-0-0147, Homing parameter". The command value profile generated by the controller depends on:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- S-0-0108, Feedrate override

The controller ignores command values of the control master during the execution of command C0600!

> If the respective encoder, at the start of command C0600, should have already been homed, the reference is cleared first!
>
> See Parameter Description "S-0-0403, Position feedback value status"

Homing Motion

At the start of command C0600, two situations have to be distinguished with regard to the initial position of a linear axis. The moving part of the axis is

- within the travel range, the home switch or travel range limit switch has not been activated,

\- or -

- near the end of the travel range, the home switch or travel range limit switch has been activated, the positive stop, possibly used for homing, is almost reached.

If the switch has not been activated or positive stop has not yet been reached, the drive moves the axis in reference travel direction.

When the home switch has already been activated, the drive moves the axis against the reference travel direction.

In the case of non-distance-coded encoders, the drive reverses the direction of motion for searching the dedicated point as soon as the home switch is detected to be "not activated".

In the case of distance-coded encoders, the search for the dedicated point is carried out against the determined reference travel direction.

When positive stop is used for homing, the search for the dedicated point, after axis blocking has been detected, is always carried out against the reference travel direction!

Jerk Limitation

To limit acceleration jumps it is possible to additionally activate a jerk limit. This is done by entering the value parameter "S-0-0349, Bipolar jerk limit".

Motion Range for Homing

The process for searching the dedicated point requires axis motion. The axis motion to be expected depends on the selected measuring system and on the position of the axis at the start of drive-controlled homing (for information on axis motion see above under the description of the respective paragraph "Identifying the Dedicated Point by Means of ...").

Maximum Velocity

As in the case of all drive-controlled functions, the maximum velocity can be directly influenced with a feedrate factor when executing the homing procedure. The effective maximum velocity then results from the product of the values of "S-0-0041, Homing velocity" and "S-0-0108, Feedrate override".

Shutdown

After the controller has detected the dedicated point of the axis by the homing procedure, the actual position values are switched to axis-related values. The drive then shuts down the axis with the homing acceleration (S-0-0042). Shutdown can be carried out as:

- "Stop"

  → Non-target-oriented immediate braking motion that possibly is of shorter duration

\- or -

- "Positioning"

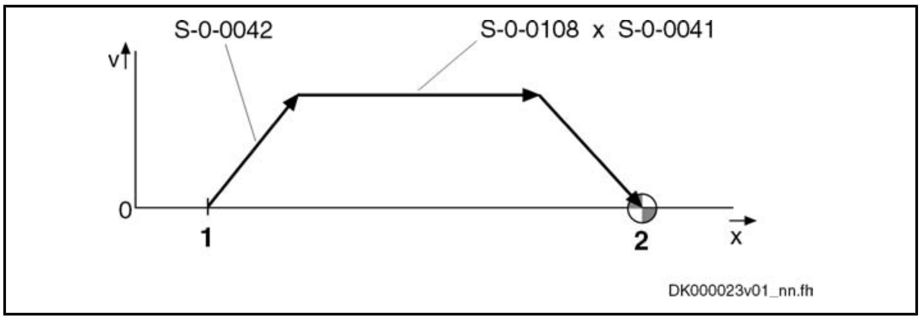
  → Target-oriented motion to the reference point (axis-related value in parameter "S-0-0052, Reference distance 1" or "S-0-0054, Reference distance 2"), if the reference point is within the allowed travel range

\- or -

- "Run path" (only possible for distance-coded encoders!)

  → Moving over a defined path (double reference mark distance), even if the dedicated point had already been detected

The kind of shutdown ("positioning" or "stop" or "run path") is set in "S-0-0147, Homing parameter".



1	Start point
2	Reference point
S-0-0041	Homing velocity
S-0-0042	Homing acceleration
S-0-0108	Feedrate override

Fig.5-2: Command Value Profile for Drive-Controlled Homing With Constant Feedrate Factor and "Positioning" Shutdown

☞ If parameter "S-0-0108, Feedrate override" starts with zero, the warning "E2055 Feedrate override S-0-0108 = 0" is output.

Actions of the Control Unit in the Case of Drive-Controlled Homing

Starting Command C0600

The control master starts the command by writing data to parameter "S-0-0148, C0600 Drive-controlled homing procedure command". The command has to be set and enabled. The command acknowledgment has to be taken from the data status of the same parameter. The command execution is completed when the command change bit in parameter "S-0-0135, Drive status word" has been set and the acknowledgment changes from "in process" to "command executed" or to "command error".

Interrupting Command C0600

If the command is interrupted by the control master during its execution, the drive reacts by activating the "Drive Halt" function. The command execution is continued by removing the interruption.

See also "Drive Halt"

Completing Command C0600

When the control master wants to operate the drive in position control after resetting command C0600, it has to read the drive-internal position command value from "P-0-0047, Position command value control" and preset it as the position command value. By resetting the command the control master takes over the axis without jerk or position offset occurring.

NC-Controlled Homing Procedure

General Information

Sequence of NC-Controlled Homing

For NC-controlled homing the master (NC control unit) controls the homing motion for searching the dedicated point of the axis. To do this the master activates the parameter

- S-0-0146, C4300 NC-controlled homing procedure command

and presets the command value for axis motion, according to the active operating mode.

When the drive has detected the dedicated point, it informs the master of this fact and stores the position of the dedicated point. The master then completes the execution of command C4300 and afterwards activates the parameter

- S-0-0171, C4400 Calculate displacement procedure command.

The required displacement of the actual position values is now calculated in the drive controller, in order to establish the reference of the actual position value to the axis zero point.

When the displacement required for establishing the position data reference has been determined, the master completes the execution of command C4400 and then activates the parameter

- S-0-0172, C4500 Displacement to referenced system procedure command.

Drive-internally the actual position value now is changed by the calculated absolute displacement value and thereby the reference of the actual position value to the axis zero point is established. The master has to adjust its command value input to the changed actual position value, before it completes the NC-controlled homing procedure by deactivating command C4500.

Functional Sequence" NC-Controlled Homing Procedure"

Searching the Dedicated Point, Basic Procedure

After the master has started NC-controlled homing by activating parameter "S-0-0146, C4300 NC-controlled homing procedure command", it has to preset a command value for the drive for the axis motion to identify the dedicated point.

For non-distance-coded encoders, the dedicated point can only be identified, if "S-0-0407, Homing enable" has been set on the master side. If a home switch was connected to the drive controller (setting in parameter S-0-0147), it has to be detected as "activated". For distance-coded encoders, the master-side homing enable (S-0-0407) is not required, because the dedicated point can be unequivocally identified by arbitrary neighboring reference marks.

For details on the search for the dedicated point in the case of NC-controlled homing, see section above "Identifying the Dedicated Point by Means of Reference Mark and Home Switch"!

When the drive has found the dedicated point of the encoder selected in "S-0-0147, Homing parameter", this is displayed in parameter "S-0-0408, Reference marker pulse registered". The position of the dedicated point or the detected reference marks is stored:

- For non-distance-coded encoders, the detected reference position is stored in parameter "S-0-0173, Marker position A".
- For distance-coded encoders, the first detected reference mark is stored in parameter "S-0-0173, Marker position A", the second one in parameter "S-0-0174, Marker position B".

The correct, time-optimized sequence of the execution of command C4300 requires the following assignments:

- Bit "homing enable" (S-0-0407) in real-time control bit of "S-0-0134, Master control word"
- Bit "reference mark detected" (S-0-0408) in real-time status bit of "S-0-0135, Drive status word"

When the bit "reference mark detected" (S-0-0408) has been set, the master can complete the execution of the command C4600.

Drive-Side Calculation of Actual Position Value Displacement for Zero Point Reference

By master-side activation of parameter "S-0-0171, C4400 Calculate displacement procedure command", the actual position value displacement for the encoder selected in "S-0-0147, Homing parameter" is calculated.

Basis for the calculation of displacement:

- For non-distance-coded encoders, the non-homed actual position value at the dedicated point (S-0-0173) and the values of reference distance 1/2 (S-0-0052/S-0-0054) and reference offset 1/2 (S-0-0150/S-0-0151).
- For distance-coded encoders, the non-homed actual position values of the detected reference marks (S-0-0173 and S-0-0174) and the values of "S-0-0177, Absolute offset 1" (motor encoder) or "S-0-0178, Absolute offset 2" (external encoder).

The calculated displacement value is displayed in

- S-0-0175, Offset parameter 1 (motor encoder)

- or -

- S-0-0176, Offset parameter 2 (external encoder).

When the required displacement of the actual position value has been determined, the master can complete the execution of the command C4400.

☞ It would also be possible to calculate the displacement on the master side and directly preset it for the drive via the parameters S-0-0175 or S-0-0176. In this case the execution of command C4400 wouldn't be required!

Displacement of Actual Position Value for Zero Point Reference

To switch the actual position values to axis reference, the master now activates the parameter "S-0-0172, C4500 Displacement to referenced system procedure command". The displacement of the actual position value for the encoder selected in "S-0-0147, Homing parameter" is thereby carried out.

The calculated displacement value (S-0-0175 or S-0-0176) is now added to the non-homed actual position value; the new actual position value is displayed in:

- S-0-0051, Position feedback value 1

- or -

- S-0-0053, Position feedback value 2.

The homing status of the encoders connected to the drive is also displayed in parameter "S-0-0403, Position feedback value status". By means of this parameter the master recognizes when the position command value is to be switched to axis reference. When the switching to the homed position command value was carried out, the master indicates this to the drive in parameter "S-0-0404, Position command value status". The drive then signals the execution of command C4500 to have been completed and the master on its part can complete the execution of command C4500.

The correct, time-optimized execution of the command C4500 requires the following assignments:

- Position command value status bit (S-0-0404) in real-time control bit of "S-0-0134, Master control word"
- Reference encoder status bit (S-0-0403) in real-time status bit of "S-0-0135, Drive status word"

For information on the actual position value after establishing the position data reference for motor encoder and external encoder see section "General Information on Establishing the Position Data Reference"

Shifting the Position Data Reference for Absolute and Relative Measuring Systems (Shift Coordinate System Procedure)

Brief Description

Expansion package **servo function** (order code **SRV**) of all firmware variants in **closed loop** characteristic.

The existing position data reference of the measuring systems to the axis can be shifted if the respective command was activated by the master. It is possible to shift the data reference in standstill or while the axis is moving. This does not affect the position reference of the axis because it is only the actual position values output for the master that are displayed in "shifted" form. Internally the original ("non-shifted") position data reference is maintained.

Shifting the position data reference affects the motor encoder and, if available, the external encoder, independent of which encoder is the active encoder for position control. If different actual position values are valid for the encoders (both encoders possibly have position data reference independent of each other), the actual position values of both measuring systems are shifted by the same difference.

Pertinent Parameters

- S-0-0197, C3300 Set coordinate system procedure command
- S-0-0198, Initial coordinate value
- S-0-0199, C3400 Shift coordinate system procedure command
- 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

Detecting the Marker Position

Brief Description

Base package of all firmware variants in **closed-loop** characteristic.

The "get marker position" function, that is activated via the respective command, can be used for:

- Checking the correct detection of the reference mark of an incremental measuring system

- or -

- Determining the position of the reference mark in case the homing procedure is carried out by the control master. In this case, the coordinate system is switched in the master with the position information of the reference mark.

A possibly available home switch is not evaluated with this function!

Pertinent Parameters

- S-0-0173, Marker position A
- P-0-0014, C1400 Command Get marker position

Pertinent Diagnostic Messages

- C1400 Command Get marker position

5.6 Mechanical Axis System and Arrangement of Measuring Systems

5.6.1 Brief Description

Motor Encoder

Controlled motor activation requires a position measuring system that measures the current rotor position or the position of the moving part as opposed to the static part of the motor.

This position measurement is required for the:

- Current control loop,
- velocity control loop and
- if required, position control loop.

The precision and resolution of the position measurement is decisive for the quality of the actual values, especially in the velocity and position control loop.

External Encoders

Depending on the mechanical properties of the mechanical system between driven motor shaft and machine axis it can be required to carry out the position control by means of an external position encoder (not integrated in the motor) directly at the moving part of the axis, e.g. in the case of

- mechanical system with slip,
- gear play or a low degree of stiffness of the mechanical system, etc.

The external (optional) encoder can also be used as a measuring wheel encoder (frictionally engaged on transported material).

See "Measuring wheel mode"

For information on encoder evaluation and encoder monitoring see also "Basics on Measuring Systems, Resolution" and "Monitoring the Measuring Systems"

Motor Encoders of Rexroth Housing Motors

Rexroth housing motors have integrated position measuring systems:

- EnDat2.1 encoder with 2048 increments for high accuracy requirements
- HIPERFACE® encoder with 128 increments for low accuracy requirements

They are optionally available as

- Relative measuring system ("single-turn motor encoder")

- or -

- Absolute measuring system ("multi-turn motor encoders", range of values ±4096 motor revolutions).

The measuring systems of Rexroth housing motors support the commissioning because the data for encoder type and resolution are stored in the encoder. They are loaded to the controller when the controller is switched on.

Motor Encoders for Rexroth Kit Motors and Third-Party Encoders

Rexroth kit motors are delivered as individual components and assembled in the machine to form the motor. It consists of a moving and a static part, the bearing and the motor encoder.

The following measuring systems can be used as a motor encoder:

- Incremental encoders with sine signals
  (compatible with signal specification of Heidenhain)
- Encoders with EnDat2.1 interface from Heidenhain
- Encoders with HIPERFACE® interface from Stegmann, if the encoder is released by Rexroth (see Automation Portal (registration required): De_FAQ_IndraDrive_HIPERFACEGeber).

- Incremental encoders with square-wave signals (compatible with signal specification of Heidenhain)

Do not use incremental encoders with square-wave signals as motor encoders! Bad drive characteristics are to be expected!

The mentioned measuring systems can be used as motor encoders for third-party kit motors and third-party housing motors.

For synchronous kit motors or synchronous third-party motors it is recommended that you use a measuring system, which can be evaluated in absolute form, as a motor encoder so that you have to determine the commutation offset of the motor only once (during initial commissioning) (see also "Absolute Measuring Systems").

Motor Encoder with Gear

Especially with rotary kit motors it is sometimes impossible to connect the motor encoder directly to the motor shaft. IndraDrive provides the possibility to evaluate a motor encoder connected via a gear.

For synchronous motors in combination with a motor encoder which can be evaluated in absolute form, the advantage of setting the commutation offset only once (see above) can only be used with an encoder gear with i = 1 or when there is no encoder gear available!

External Encoders at Machine Axes

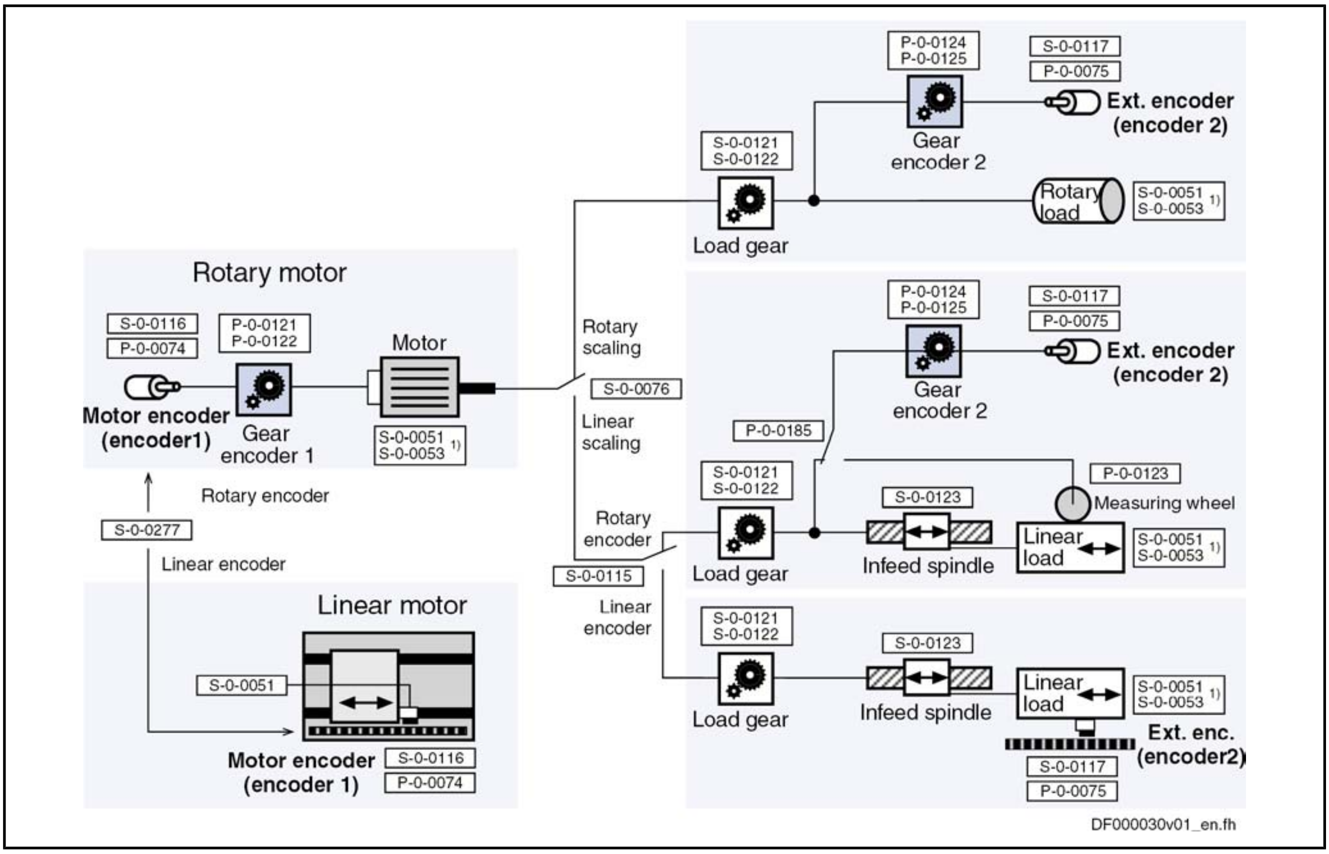
IndraDrive controllers can evaluate the following measuring systems as external encoders:

- Incremental encoders with sine signals
  (compatible with signal specification of Heidenhain)
- Encoders with EnDat2.1 interface from Heidenhain
- Encoders with HIPERFACE® interface from Stegmann, if the encoder is released by Rexroth (see Automation Portal (registration required): De_FAQ_IndraDrive_HIPERFACEGeber).
- Incremental encoders with square-wave signals (compatible with signal specification of Heidenhain)

Possibilities of Arranging Measuring Systems

The figure below shows an overview of arrangement possibilities of mechanical drive system and measuring systems.

Motor, Mechanical Axis System, Measuring Systems



1)	S-0-0051 or S-0-0053, depending on scaling (S-0-0076)
S-0-0051	Position feedback 1 value
S-0-0053	Position feedback 2 value
S-0-0076	Position data scaling type
S-0-0115	Position Feedback 2 Type
S-0-0116	Feedback 1 Resolution
S-0-0117	Feedback 2 Resolution
S-0-0121	Input revolutions of load gear
S-0-0122	Output revolutions of load gear
S-0-0123	Feed constant
S-0-0277	Position Feedback 1 Type
P-0-0074	Encoder type 1 (motor encoder)
P-0-0075	Encoder type 2 (optional encoder)
P-0-0121	Gear 1 motor-side (motor encoder)
P-0-0122	Gear 1 encoder-side (motor encoder)
P-0-0124	Gear 2 load-side (optional encoder)
P-0-0125	Gear 2 encoder-side (optional encoder)
P-0-0123	Feed constant 2 (optional encoder)
P-0-0185	Control word of encoder 2 (optional encoder)

Fig.5-3: Overview of Arrangement Possibilities of Mechanical Drive System and Measuring Systems

Hardware Requirements

For connecting the measuring systems to the controller there are 2 optional interfaces available. By writing parameters "P-0-0077, Assignment motor encoder->optional slot" and "P-0-0078, Assignment optional encoder->optional slot" you can determine the interface to which the respective encoder is connected.

Pertinent Parameters

- S-0-0115, Position feedback 2 type
- S-0-0121, Input revolutions of load gear

- S-0-0122, Output revolutions of load gear
- S-0-0123, Feed constant
- S-0-0277, Position feedback 1 type
- P-0-0121, Gear 1 motor-side (motor encoder)
- P-0-0122, Gear 1 encoder-side (motor encoder)
- P-0-0123, Feed constant 2 (optional encoder)
- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)
- P-0-0185, Control word of encoder 2 (optional encoder)

5.7 Scaling of Physical Data

5.7.1 Brief Description

The controller via data maps the drive to an internal mathematical model. The status variables of the drive are determined on the basis of the following measurements:

- Position Measurement
- Current measurement
- Temperature measurement

The measured values collected in this way are converted into physical data:

- Position, velocity, acceleration and jerk data
- Current data, torque and force data
- Temperature data and load data

The master transmits command values to the drive that are used by the controller for transforming them at the motor output shaft or mechanical axis system. The drive in return registers and transmits actual values, signals operating and command states and, if necessary, generates error messages and warnings.

Communication between drive and master also takes place by exchanging data.

Scaling

An operating data (numeric value) can only be evaluated as a physical value, when the numeric value is connected to a physical unit and the position of the decimal point (decimal places). The data thereby is "scaled" in a qualitative and quantitative way.

Parameters

All data are stored in parameters and transmitted as parameter values (for explanations on parameters see "Parameters, Basics"). The scaling of the parameters containing data of the following physical values can be defined by the customer:

- Position
- Velocity
- Acceleration
- Torque/force
- Temperature

Preferred Scaling/Parameter Scaling

To simplify the scaling definition so-called "preferred scalings" were predefined. But physical data can also be exchanged in the control-internal format, i.e. without specific reference to physical units. To do this, the scaling for certain data can be freely set ("parameter scaling").

Linear and Rotary Data

Depending on the kind of motion of motor or load, the data can be displayed as follows:

- In linear form (linear axis or motor motion)

- or -

- In rotary form (rotary axis or motor motion)

Motor Reference/Load Reference

In the drive firmware there are mechanical transfer elements between motor and load mapped by means of mathematical models. The physical data can thereby be referred to

- the point where the load takes effect (load-side data reference)

- or -

- the point where the force is input (motor-side data reference).

Absolute/Modulo Evaluation

For technical reasons, the value range of the position data the controller can display is limited.

In the case of axes with limited travel range (e.g. linear axes), the current axis position within the controller-side value range can be unequivocally displayed (see "Basics on Measuring Systems, Resolution").

In the case of axes with unlimited travel range (e.g. rotary axes) it is useful to limit the infinite value range of the position data to a finite value. With continuous motion, the value range is recurrently run from minimum to maximum value ("modulo" evaluation of the actual position value).

Pertinent Parameters

- S-0-0043, Velocity polarity parameter
- S-0-0044, Velocity data scaling type
- S-0-0045, Velocity data scaling factor
- S-0-0046, Velocity data scaling exponent
- S-0-0055, Position polarities
- S-0-0076, Position data scaling type
- S-0-0077, Linear position data scaling factor
- S-0-0078, Linear position data scaling exponent
- S-0-0079, Rotational position resolution
- S-0-0085, Torque/force polarity parameter
- S-0-0086, Torque/force data scaling type
- S-0-0093, Torque/force data scaling factor
- S-0-0094, Torque/force data scaling exponent
- S-0-0103, Modulo value
- S-0-0121, Input revolutions of load gear
- S-0-0122, Output revolutions of load gear
- S-0-0123, Feed constant
- S-0-0160, Acceleration data scaling type
- S-0-0161, Acceleration data scaling factor
- S-0-0162, Acceleration data scaling exponent
- S-0-0208, Temperature data scaling type

6 Drive Control

6.1 Overview of Drive Control

6.1.1 Basic Principles and Terms

The IndraDrive firmware supports the following two basic principles of drive control:

- **Open-loop axis control** (U/f control)
  → Open-loop-controlled operation without encoder information
- **Closed-loop axis control** (various methods of control)
  - **With** encoder feedback
    → Closed-loop-controlled operation (position, velocity and current)
  - **Without** encoder feedback
    → Closed-loop-controlled operation with motor model (velocity and current)

When selecting the functional packages, take the desired method of control into account as you have to choose between open-loop and closed-loop base package!

Operating mode / command value adjustment	Control mode	Functional principle of motor	Encoder available	Required base package	Method of control
U/f control with command value adjustment of the velocity control	Voltage-controlled operation	Asynchronous	Yes	Closed-loop	Not relevant
			No	Open-loop	U/f Control
Torque/Force Control	Field-oriented current control	Asynchronous	Yes	Closed-loop	FOC control
			No	--	No procedure available
		Synchronous	Yes	Closed-loop	FOC control
			No	--	No procedure available
Velocity control / velocity synchronization	Velocity control	Asynchronous	Yes	Closed-loop	FOC control
			No	Open-loop	FXC control
		Synchronous	Yes	Closed-loop	FOC control
			No	Closed-loop	FOCsl control
Position control, drive-controlled positioning, positioning block mode, phase synchronization, electronic Cam	position control	Asynchronous	Yes	Closed-loop	FOC control
			No	Closed-loop	FXC control 1)
		Synchronous	Yes	Closed-loop	FOC control
			No	Closed-loop	FOCsl control

1) Only with external encoder

Fig.6-1: Overview: Operating Modes and Available Control Methods

For scaling the drive firmware, we distinguish between the functional base packages with "open-loop" and "closed-loop" characteristic; in this case, however, the meaning is not identical to how the terms are used in conjunction with drive control!

See also section "Overview of Functions/Functional Packages"

6.1.2 Principles of Drive Control

Overview of Open-Loop Axis Control

"Open-loop axis control" allows open-loop-controlled operation of the drive without motor encoder (U/f control).

The primary operation mode "velocity control" is configured, but only the command value processing specific to this operation mode takes effect. Closed-loop control (position and velocity) and functions and operating modes depending thereof are not possible.

See "Voltage-Controlled Open-Loop Operation (U/f Control)"

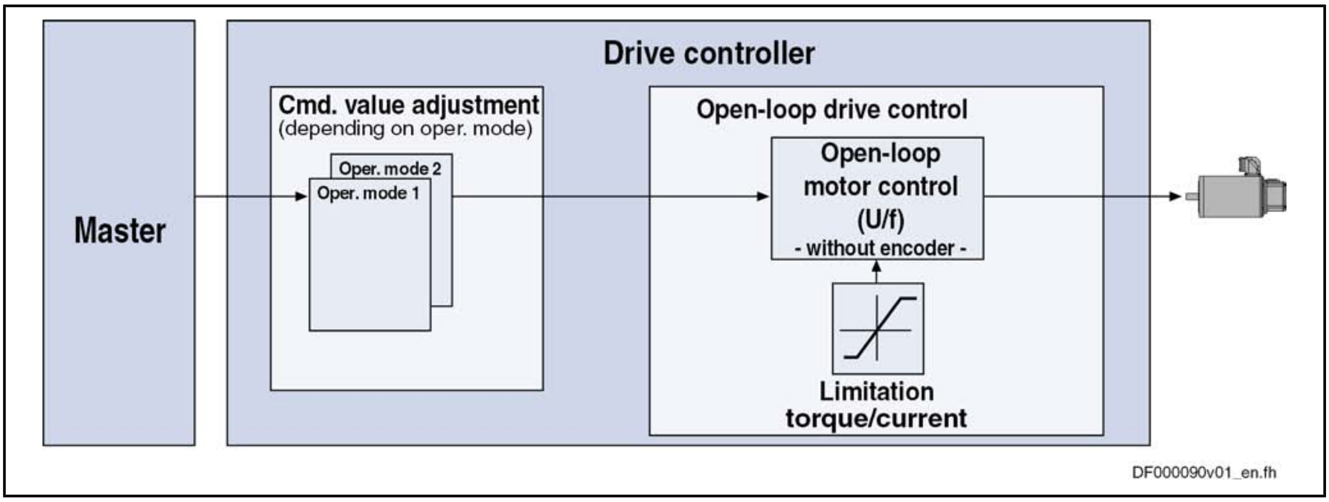


Fig.6-2: Principle of Drive Control (Open-Loop Operation)

See also section "Closed-Loop Axis Control (Closed-Loop Operation)"

See also section "Overview of Functions/Functional Packages"

Overview of Closed-Loop Axis Control

☞ The base package "Closed-Loop" also contains the functions of the base package "Open-Loop".

"Closed-loop axis control" allows closed-loop-controlled operation of the drive; we distinguish between two principles of drive control:

- **Operation with encoder**

  The velocity control loop and the position control loop are closed by means of the encoder feedback so that the following operating modes are supported by field-oriented current control with encoder feedback:

  - Velocity control
  - Position control with cyclic command value input
  - Positioning modes (e.g. drive-controlled positioning)
  - Synchronization modes

- **Operation without encoder**

  The velocity control loop is closed by means of a motor model (monitor) so that field-oriented current control without encoder feedback supports velocity control without encoder.

See section "Field-Oriented Current Control"

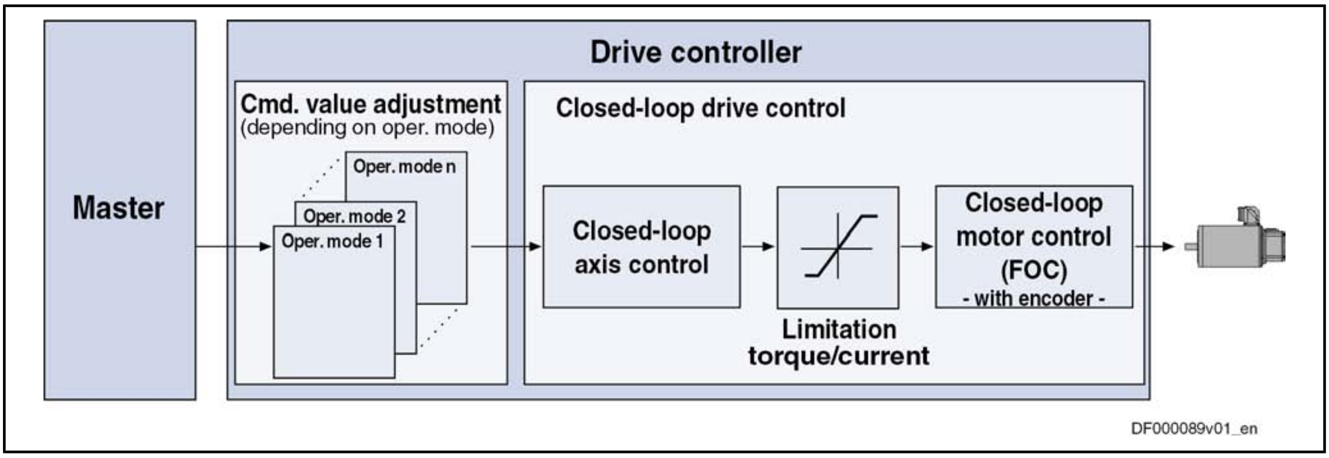


Fig.6-3: Principle of Drive Control (Closed-Loop Operation)

See also section "Open-Loop Axis Control (Open-Loop Operation)"

See also section "Overview of Functions/Functional Packages"

6.1.3 Control Loop Structure

General Information

The drive controller has a so-called cascade structure, i.e. the individual loops (position, velocity and current) are interconnected in cascaded form. Depending on the active operating mode, only the torque/force control loop, the torque/ force control loop and the velocity control loop or, in addition to these two control loops, the position control loop are closed in the drive.

Torque/Force Control

The "torque/force control" mode actually isn't torque or force control but current control. Therefore, only the current control loop is closed in the drive.

See also "Torque/Force Control"

Velocity Control

In the "velocity control" mode, the velocity control loop, apart form the current control loop, is closed in the drive, too.

See also "Velocity Control"

Position Control

For the following position control modes, the position control loop, apart from the current and velocity control loops, is closed internally (in the drive):

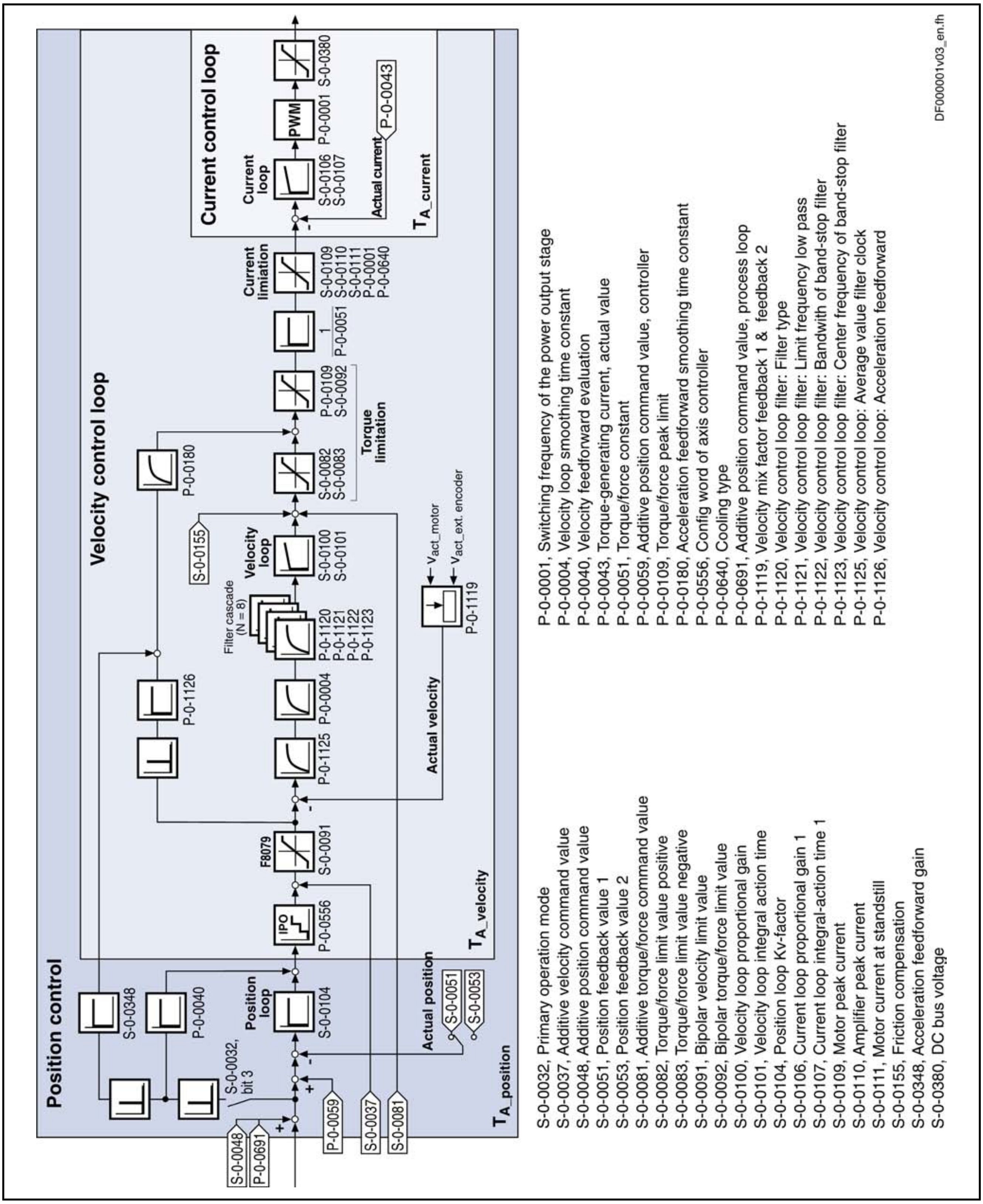
- Position Control With Cyclic Command Value Input
- Drive-Internal Interpolation
- Drive-Controlled Positioning

See also Description of the Respective Operating Mode

The figures in the following two paragraphs contain an overview of the structure and the interaction of the control loops (distinguished according to the illustration of the setting parameters and the display parameters).

Drive Control

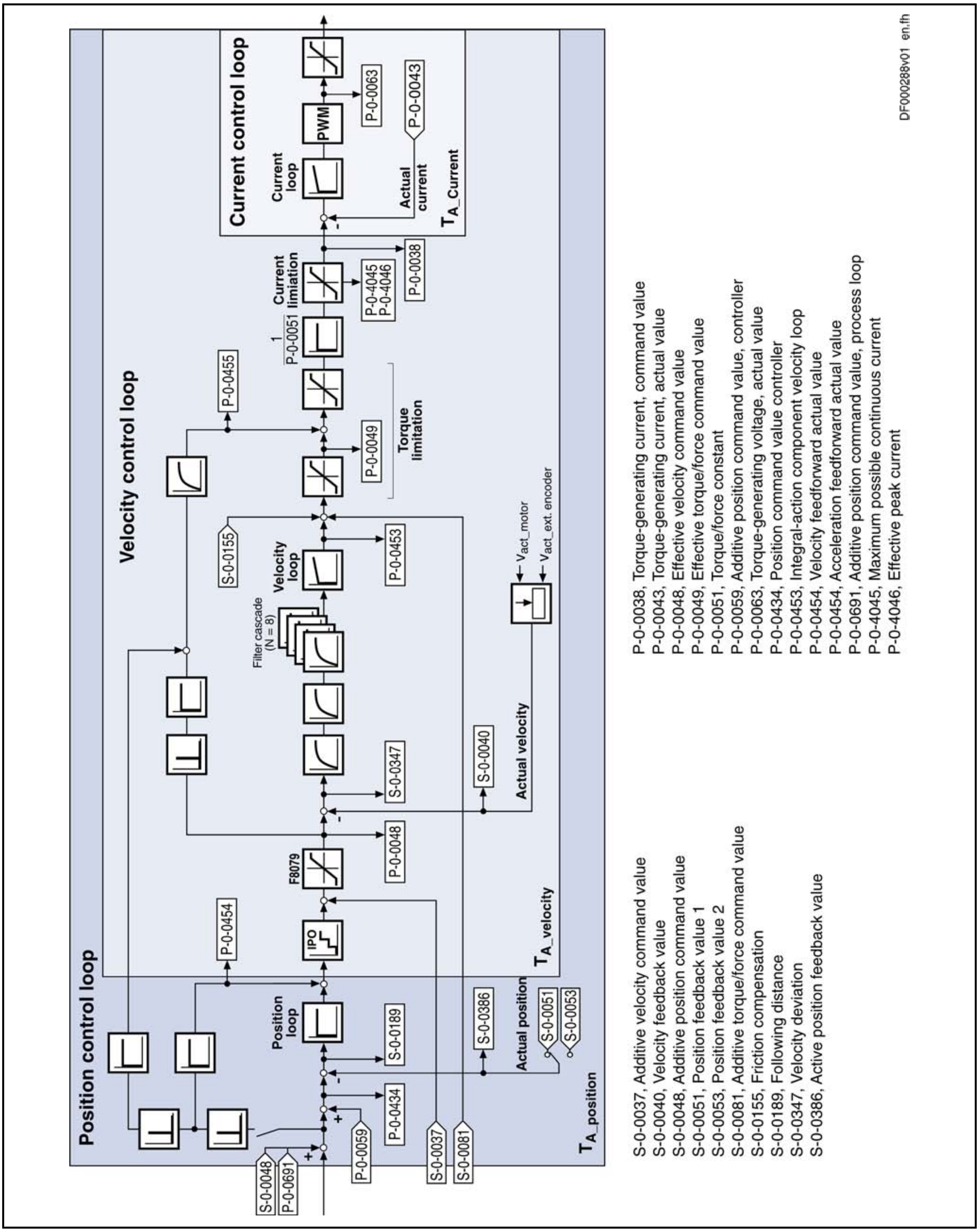
Control Loop Structure With Setting Parameters



T_A Sampling times (see table in the chapter "Features of the Control Loops")

Fig.6-4: Overall Structure of the Control Loops with Points at Which the Setting Parameters Take Effect (Example for Field-oriented Control With Encoder)

Control Loop Structure With Display Parameters



T_A Sampling times (see table in the chapter "Features of the Control Loops")

Fig.6-5: Overall Structure of the Control Loops With Display Parameters (Exam-

ple)

6.1.4 Features of the Control Loops

Performance (Controller Cycle Times)

The internal controller cycle times (current, velocity and position) depend on the following conditions and parameters:

- Activation of the functional packages
- P-0-0001, Switching frequency of the power output stage
- P-0-0556, Config word of axis controller (bit 2 and 5)

Depending on these factors, the following cycle and switching times can be achieved:

	MPE	MPB	MPM
PWM switching frequency	max. 8 kHz	max. 16 kHz	max. 8 kHz
Position loop clock ($T_{A\_position}$)	1000 µs	500 µs	500 µs
Velocity loop clock ($T_{A\_velocity}$)	500 µs	250 µs	250 µs
Current loop clock ($T_{A\_current}$)	125 µs	125 µs	125 µs

Fig.6-6: Cycle and Switching Times to be Achieved With IndraDrive

☞ All performance data are listed under "System Overview: Performance Data" .

Current Loop

The current loop is characterized by the following features:

- PI loop for for d-axis and q-axis of the field-oriented d-q coordinate system (S-0-0106, S-0-0107)
- Inductance feedforward for decoupling d-axis and q-axis (P-0-4017, P-0-4016) for synchronous motors
- Inductance characteristic for adjusting the current loop parameters in the case of saturation phenomena
- Precontrol of e.m.f.

Velocity Loop

The velocity loop is characterized by the following features:

- Standardization of the output value at the velocity loop to Newton (N) or Newton meter (Nm); therefore, depending on the motor type, the following unit results for the parameter "S-0-0100, Velocity loop proportional gain":
  - Rotary motor → Nm * s/rad
  - Linear motor → N * min/mm
- Possibility of extending the filter options for filtering resonance frequencies (4 filters of 2nd degree available; settings via parameters P-0-1120, P-0-1121, P-0-1122 and P-0-1123)
- Limitation of acceleration in velocity control by setting in parameter "S-0-0138, "

Position Loop

The position loop is characterized by the following features:

- Jerk limitation can be set in operating mode "Cyclic position control" in parameter "S-0-0349, Bipolar jerk limit"; filter degree of smoothing filter (moving average) can be set in parameter "P-0-0042, Current position command average value filter order"
- Velocity feedforward (degree of feedforward) can be set in parameter "P-0-0040, Velocity feedforward evaluation" (0% ... 100%)
- Input value for the parameter "S-0-0348, Acceleration feedforward gain":
  – Inertia in kg*m^2 (for rotary motors)

  - or -

  – Mass in kg (for linear motors)

6.2 Motor Control

6.2.1 General Information on Motor Control

Overview of Motor Control Methods

Classification of Motor Control Methods

There are different methods available to control the motor; the main difference between these methods is the fact whether a motor encoder is required or not.

Motor Control With Motor Encoder

Motor control with position feedback via a motor encoder (field-oriented current control → FOC) is the highest-quality method of motor control providing the best control performance. It can be used for synchronous and asynchronous motors and, within the precision and performance of motor and controller determined by the hardware, allows unrestricted motor operation in the following operating modes:

- Position control modes
- Velocity control
- Torque/force control

Motor Control Without Motor Encoder

For sensorless motor control, there are different model-based methods available for synchronous and asynchronous motors.

- For asynchronous motors:
  – Voltage-controlled open-loop operation (U/f control)
  – Flux-controlled operation ("FluX Control" → FXC)
- For synchronous motors:
  – Current-controlled closed-loop operation with indirect rotor position detection (field-oriented current control, sensorless → FOCsl)

Regarding the possible operating modes when using these methods, observe the following restrictions:

- Position control modes ("positioning") can only be used with sensorless synchronous motors, or with asynchronous motors only in flux-controlled operation (FXC) and with an external encoder. In these cases, generally take the performance losses into account!
- Velocity control, too, can only be used with performance losses!

☞ Torque/force control cannot be used for motor control without motor encoder!

Motor Control Method and Functional Principle of Motor

Set the motor control method in parameter "P-0-0045, Control word of current controller". Make sure that the requirements regarding functional principle of motor and motor encoder have been fulfilled for specified motor control mode. The table below contains an overview for selecting the method.

Motor encoder?	Functional principle of motor	Motor control method	Specific information for use	Possible operating modes
With Motor Encoder	Synchronous motor Asynchronous motor	FOC	Parallel operation of linear motors MLF is possible!	Position control modes Velocity control Torque/Force Control
Without Motor Encoder	Synchronous motor	FOCsl	Difference in inductance between d- and q-axis is required!	Position control modes Velocity control
	Asynchronous motor	FXC	Only single-motor operation!	
		U/f Control	Parallel operation of motors is possible!	Velocity control

Fig.6-7: Overview of Motor Operation With and Without Motor Encoder

See also "Overview of Drive Control"

Pertinent Parameters

- P-0-0001, Switching frequency of the power output stage
- P-0-0045, Control word of current controller
- P-0-0556, Config word of axis controller

Field-Oriented Current Control With Motor Encoder (FOC)

Features and Use

Field-oriented current control with position feedback via motor encoder (FOC) is characterized by the following features:

- Highest-quality method of motor control

  → To be used when there are high demands on the quality of control and the dynamic response!
- Can be used for synchronous and asynchronous motors

Operating Modes With FOC

Within the hardware-side precision and performance of motor and controller, field-oriented current control with position feedback via motor encoder allows unrestricted motor operation in the following operating modes:

- Position control modes
- Velocity control
- Torque/force control

See main section "Field-Oriented Current Control (FOC Control)"

Model-Based Current Control Without Motor Encoder (FXC, FOCsl)

Features and Use

Model-based current control without motor encoder is characterized by the following features:

- Cost-saving motors, compared to the FOC method, can be used, as no motor encoder is required (however, performance losses)
- With asynchronous motors → flux-controlled method (FXC) can be used without motor-specific restrictions
- For synchronous motors → FOCsl method; only applicable with motors that have a difference in inductance between d- and q-axis (few sizes of the MSK motor range)

Operating Modes With FXC and FOCsl

Current control without motor encoder allows using the following operating modes:

- Velocity control (only suited for single motors, parallel operation of motors is not possible)
- Position control modes depending on functional principle of motor
  - With synchronous motors, actual position value detection is possible without encoder
  - With asynchronous motors, actual position value detection via external encoder is required

> ☞ Torque/force control cannot be used for sensorless (model-based) motor control!

See main section "Motor Operation Without Encoder, Flux-Controlled (FXC Control)"

Voltage-Controlled Open-Loop Operation (U/f Control)

Features and Use

Voltage-controlled motor operation without motor encoder is characterized by the following features:

- Cost-saving motors, compared to the FOC method, can be used, as no motor encoder is required (however, performance losses)
- Can only be used for asynchronous motors
- Linear or square U/f characteristic can be selected

Operating Mode With U/f Control

For voltage-controlled operation without motor encoder, you can only use the "velocity control" mode with the following features:

- Parallel operation of motors is possible
- Adjustment of motor control to velocity-proportional increase in load (e.g. with blowers) by adjusted ("square") U/f characteristic to reduce the motor losses
- Performance losses compared to velocity control with motor encoder

> ☞ Torque/force control and position control modes cannot be used for voltage-controlled operation without motor encoder!

See main section "Voltage-Controlled Open-Loop Operation (U/f Control)"

Notes on Selection of Motor Control Method

Motor Control Performance

The performance of motor control significantly depends on the type of control section including the corresponding firmware, as well as on the PWM frequency of the power output stage which has been set.

> ☞ An overview of the performance to be achieved and the clock rates depending on control section design and parameter settings is contained in section "Performance Data" .

Selecting the Motor Control Method

Set the motor control method in parameter "P-0-0045, Control word of current controller". By means of a dialog, the commissioning tool "IndraWorks Ds/D/MLD" supports the assignment of the motor control method.

Selection Criteria

The following criteria have to be taken into account when selecting the appropriate motor control method:

Drive Control

Motor type	Motor encoder available?	Parallel connection of motors?	Motor control method	Notes on use
Synchronous motor without reluctance torque	Yes	Rotary: no Linear: Yes 1)	Field-oriented current control	For standard applications with high demands on quality of control and dynamic response
Synchronous motor with reluctance torque	No	No	Field-oriented current control	Only allowed with approval by the drive development department
	Yes	Rotary: no Linear: Yes 1)		For standard applications with high demands on quality of control and dynamic response
Asynchronous motor	No	No	Flux-controlled current control	For standard applications with medium demands on quality of control and dynamic response
		Yes	U/f Control	For standard applications with low demands on quality of control and dynamic response
	Yes	No	Field-oriented current control	For standard applications with high demands on quality of control and dynamic response

1) observe mechanical setup according to motor data

Fig.6-8: Basic Selection Criteria for the Motor Control Method

See also "Overview of Drive Control"

Operating Properties for Control of Synchronous Motors

Observe the following differences for controlling synchronous motors in operation with and without motor encoder:

Motor characteristic		Control with encoder	Control without encoder
Speed working ranges	Basic Speed Range	Yes	Yes (with reduced maximum speed)
	Field weakening range	Yes	No (no field weakening range)
Supported Operation Modes	Torque/Force Control	Yes	No
	Velocity control (incl. synchronization)	Yes	Yes (with restrictions)
	Position control/positioning (incl. synchronization)	Yes	Yes (with restrictions)
Torque limitation		Yes	Yes
Maximum torque		High	Medium
Dynamic response		High	Low to medium
Running smoothness/speed quality		High (depending on measuring system, motor type, mechanical system)	Medium
Torque ripple		low (< ± 5%)	High
Required precision of the motor parameters		Low	High

Motor characteristic	Control with encoder	Control without encoder
Robustness	High	Low
Sensitivity against disturbances	Low	High
Validity (availability) of the position information	Absolute encoder: in PM + OM Relative encoder: in OM	Only when motor supplied with current ("AF" in OM)

PM Parameter mode
OM Operating mode
Fig.6-9: Comparison of Motor Control Without Encoder and With Encoder for Synchronous Motors

Operating Properties for Control of Asynchronous Motors

Observe the following differences for controlling asynchronous motors as regards operation with and without encoder:

Motor characteristic		Control with encoder	Control without encoder	U/f Control
Speed working ranges	Basic Speed Range	Yes	Yes	Yes
	Field weakening range	Yes	Yes	Yes
Supported operation modes	Torque/force control	Yes	No	No
	Velocity control (incl. synchronization)	Yes	Yes (with restrictions)	Yes (with restrictions)
	Position control/positioning (incl. synchronization)	Yes	Only with external position encoder	No
Torque limitation		Yes	Yes	No (only stall protection loop)
Maximum torque		High	Medium	Low
Dynamic response		High	medium	Low
Running smoothness/speed quality		high (depending on measuring system, motor type, mechanical system)	Medium	Low
Torque ripple		Low (< ± 5%)	High	High
required Accuracy of the motor parameters		Low	Low	High, if high performance must be reached
Robustness		High	Medium	Low
Sensitivity against disturbances		Low	High	High
Validity (availability) of the position information		Absolute encoder: in PM + OM relative encoder: only in OM	Depending on load-side encoder type used	Not available

PM Parameter mode
OM Operating mode
Fig.6-10: Comparison of Motor Control Without Encoder and With Encoder for Asynchronous Motors

6.2.2 Voltage-Controlled Open-Loop Operation (U/f Control)

Brief Description

The drive function "voltage-controlled open-loop operation of asynchronous motors without encoder in U/f control" is made available in the base package "open-loop" in the "velocity control" mode. When the expansion package "synchronization" has been enabled, the operating mode "velocity synchronization with real/virtual master axis" is additionally available.

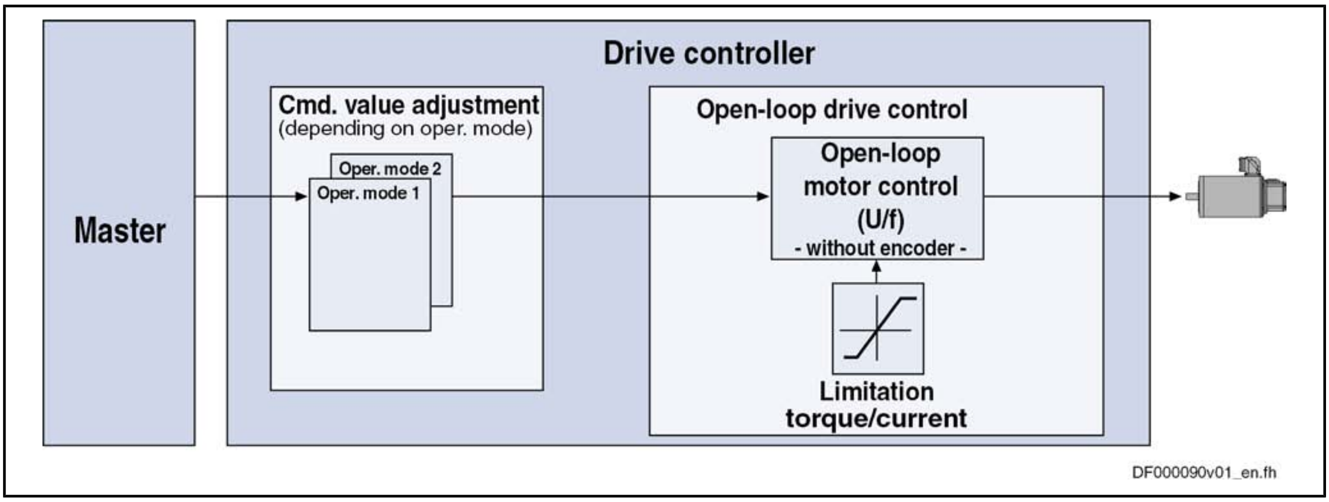


Fig.6-11: Principle of U/f Control

U/f motor control is characterized by the following features or core functions:

Features

- Monitoring and **limitation** of the maximum **stator frequency slope** that results from the command velocity change
- **Stall protection loop** (PI loop that can be optionally activated to prevent breakdown of the machine when the torque limits are attained)
- **Slip compensation** (feedforward of estimated slip of the machine by means of slip compensation factor)
- Calculation of output voltage by means of **U/f characteristic** based on motor model data
- Subsequent trimming of magnetization via premagnetization factor, as well as linear or square characteristic to be selected
- **IxR boost** (adjustable load-dependent feedforward of the output voltage due to the voltage drop on the motor winding resistance)
- **Oscillation damping** (adjustable load-dependent feedforward to prevent velocity oscillations in the partial load and idling ranges)
- **D.C. braking** to reach standstill more quickly
- User-side **torque/force limitation** via enabled stall protection loop

Pertinent Parameters

- S-0-0040, Velocity feedback value
- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- P-0-0043, Torque-generating current, actual value
- P-0-0044, Flux-generating current, actual value
- P-0-0045, Control word of current controller
- P-0-0046, Status word of current controller

- P-0-0048, Effective velocity command value
- P-0-0063, Torque-generating voltage, actual value
- P-0-0064, Flux-generating voltage, actual value
- P-0-0065, Absolute voltage value, actual value
- P-0-0440, Actual output current value (absolute value)
- P-0-0442, Actual value torque limit positive (stationary)
- P-0-0443, Actual value torque limit negative (stationary)
- P-0-0532, Premagnetization factor
- P-0-0556, Config word of axis controller
- P-0-0568, Voltage boost
- P-0-0569, Maximum stator frequency slope
- P-0-0570, Stall protection loop proportional gain
- P-0-0571, Stall protection loop integral action time
- P-0-0572, Slip compensation factor
- P-0-0573, IxR boost factor
- P-0-0574, Oscillation damping factor
- P-0-0577, Square characteristic: Lowering factor
- P-0-0578, Current for deceleration, absolute value
- P-0-0579, Current for deceleration, time period
- P-0-4036, Rated motor speed
- P-0-4046, Effective peak current

Pertinent Diagnostic Messages

- E8040 Torque/force actual value limit active
- E8041 Current limit active
- E8260 Torque/force command value limit active

6.2.3 Field-Oriented Current Control (FOC Control)

Brief Description

Base package of all firmware variants in **closed-loop** characteristic

The current loop was preset for all motors by Bosch Rexroth and the parameter values have been stored in the motor encoder data memory or in the commissioning tool ("IndraWorks Ds/D/MLD", "DriveTop").

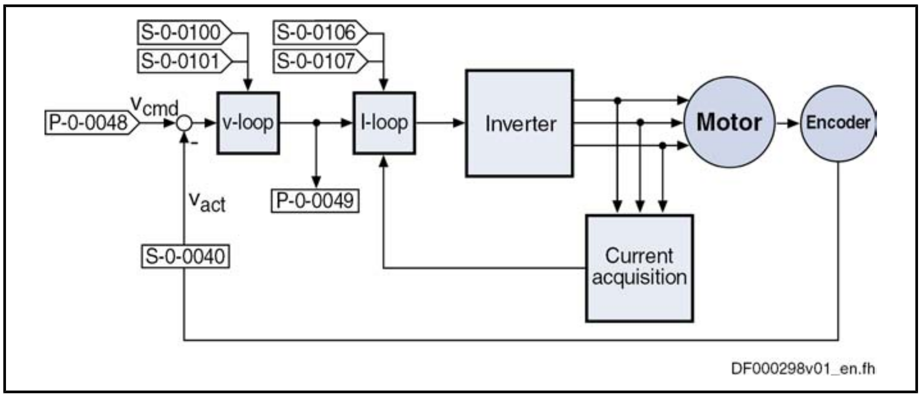
For notes on how to commission the current loop for third-party motors, see "Third-Party Motors at IndraDrive Controllers"!

Principle of Field-Oriented Current Control

In the case of field-oriented current control, the internal control task consists in generating the transformed currents I_d and I_q in controlled form:

- I_d (flux-generating current) → PI loop for I_d
- I_q (torque-generating current) → PI loop for I_q

The figure below illustrates the principle of field-oriented current control for operation with motor encoder:



v-loop Velocity Loop
I-loop Current Loop
Fig.6-12: Simplified Schematic Diagram for Field-Oriented Current Control With Higher-Level Velocity Control

Working Ranges

Field-oriented current control of asynchronous and synchronous motors allows operation in the entire speed range.

The speed range is divided into the following working ranges:

- Basic speed range → **constant torque**
- Field weakening range 1 → **constant power**
- Field weakening range 2 → **power limit range**

General Features

Field-oriented current control has the following general features:

- Control of the motor current according to the principle of field orientation, i.e. separate control of the torque-generating current and the flux-generating current
- Compensation of the cross coupling of the d and q axes to increase dynamics
- Voltage loop for operation in the field weakening range
- Activation of the optimum current loop proportional gain value, depending on the current PWM frequency during the load defaults procedure

Features of Synchronous Motor Control

In the case of **synchronous motors**, field-oriented current control additionally has the following features:

- Limitation of the I_q command value at the voltage limit for protection against too little control margin
- Utilization of the reluctance effect to increase the available torque in the basic speed range
- Support of synchronous motors with reluctance torque, i.e. motors with significantly different inductances in the d and q axes

Features of Asynchronous Motor Control

In the case of **asynchronous motors**, field-oriented current control has the following features in addition to the general features:

- Optimum torque linearity, even in the field weakening range, by:
  - Permanent correction of the torque constant and the slip factor by means of the currently calculated rotor flux
  - Rotor flux model taking temperature and saturation behavior of the magnetizing inductance into account
- Improved dynamic behavior by:
  - Voltage- and load-dependent flux feedforward

  - Voltage loop for correcting the flux feedforward
  - Flux loop for dynamically generating the rotor flux
- Possibility of reducing the magnetizing current for low-loss operation at no load or in partial load range

Pertinent Parameters

Current loop setting:

- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- P-0-0001, Switching frequency of the power output stage
- P-0-0045, Control word of current controller
- P-0-4002, Charact. of quadrature-axis induct. of motor, inductances
- P-0-4003, Charact. of quadrature-axis inductance of motor, currents

Voltage loop setting:

- P-0-0533, Voltage loop proportional gain
- P-0-0534, Voltage loop integral action time
- P-0-0535, Motor voltage at no load
- P-0-0536, Maximum motor voltage

Rotor flux control for asynchronous motors:

- P-0-0528, Flux control loop proportional gain
- P-0-0529, Scaling of stall current limit
- P-0-0530, Slip increase
- P-0-0532, Premagnetization factor

Power monitoring:

- S-0-0158, Power threshold Px
- S-0-0337, Status "P >= Px"
- S-0-0382, DC bus power

Display parameters:

- S-0-0380, DC bus voltage
- P-0-0046, Status word of current controller
- P-0-0063, Torque-generating voltage, actual value
- P-0-0064, Flux-generating voltage, actual value
- P-0-0065, Absolute voltage value, actual value

Pertinent Diagnostic Messages

- C0132 Invalid settings for controller cycle times
- E8025 Overvoltage in power section
- E8028 Overcurrent in power section
- F2077 Current measurement trim wrong
- F8060 Overcurrent in power section

General Function of Field-Oriented Current Control

Torque/Force Control

In contrast to the functional principle mentioned in the "torque/force control" mode, this actually is current control, as the actual current value is measured and not the force or the motor torque. This means that open-loop control of torque/force takes place, the torque or the force being directly connected with the torque-/force-generating current via the torque/force constant:

$$M_i = K_M \times I_q$$

The so-called torque/force constant "K_M" is, however, no statistic value, it is changed by:

- Amount of the actually flowing current: Reduction in currents larger $I_{nominal}$
- Temperature change of motor winding and rotor: Reduction in case of increasing temperature

This causes deviations of the torque at the motor shaft compared with the value shown on the drive side. In case of torque/force scaling in the physical units "Nm" and/or "N", the value on the drive side differs from the actual effect of the motor, in case of percentage scaling, the displayed value is only current for the current ratio.

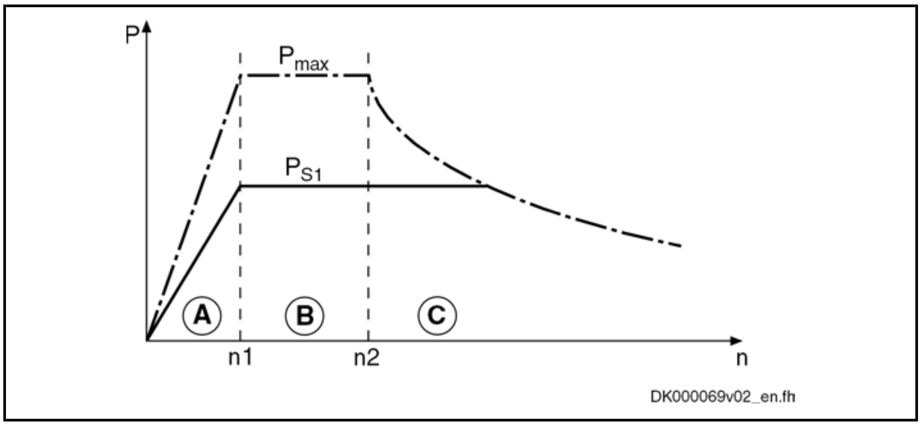
With synchronous motors, the specified influencing factors can be corrected on the drive side so that a precise torque/force constant is effective for the torque/force calculation. (Cross reference to the documentation on "Compensation functions / correction of the torque/force constant")

In the case of asynchronous motors, the torque constant is only corrected according to the active rotor flux.

Field Weakening Operation

With the firmware, it is possible to operate asynchronous and synchronous motors in the entire speed range (including field weakening range).

We basically distinguish 3 working ranges that are illustrated in the following figure and described below.



A	Basic Speed Range
B	Field weakening range 1
C	Field Weakening Range 2 (Power Limit Range)
Fig.6-13:	*Three Working Ranges of the Speed Range*

Basic Speed Range

The basic speed range is characterized by constant torque and speed-independent torque/force constant (P-0-0051).

In the case of asynchronous motors, the programmed, effective magnetizing current flows in no-load operation. The motor voltage is less than the maximum controller output voltage. The corner speed n1 is directly proportional to the DC bus voltage.

Field Weakening Range 1 (Constant Power)

The field weakening range 1 is characterized by constant power, the motor voltage is kept constant. In the case of asynchronous motors, the no-load current is reduced as the speed increases. This reduces the magnetization and the torque constant, the slip increases accordingly. The adjustment of magnetizing current and slip is automatically carried out by the voltage loop.

Field Weakening Range 2 (Power Limit Range)

The field weakening range 2 is the range of decreasing peak power. An asynchronous motor works at the stall current limit in this range, through vector control, the current is maintained at an efficient and stable level. The peak current is reduced in such a way that the point of maximum power is not exceeded. Further increase in current would only lead to increased power dissipation and less shaft output. The peak power in range 3 is proportional to the square of the DC bus voltage. It is ensured that the maximum possible power is reached for each DC bus voltage without parameter adjustment.

☞ Due to this causal connection, it is clear that the power in range 3 cannot be increased by using a more powerful controller. In this section, performance can only be increased by increasing the voltage of the DC bus!

In the following sections, we distinguish control of synchronous machines (with motor encoder) and asynchronous machines (with and without motor encoder).

Field-Oriented Current Control of a Synchronous Machine

☞ For synchronous motors, field-oriented current control is only possible with motor encoder (with closed-loop base package)!

Synchronous motors with a motor encoder in field-oriented current control can be operated in all available operating modes. The figure below illustrates the control loop structure and the points at which the individual parameters take effect for a synchronous machine.

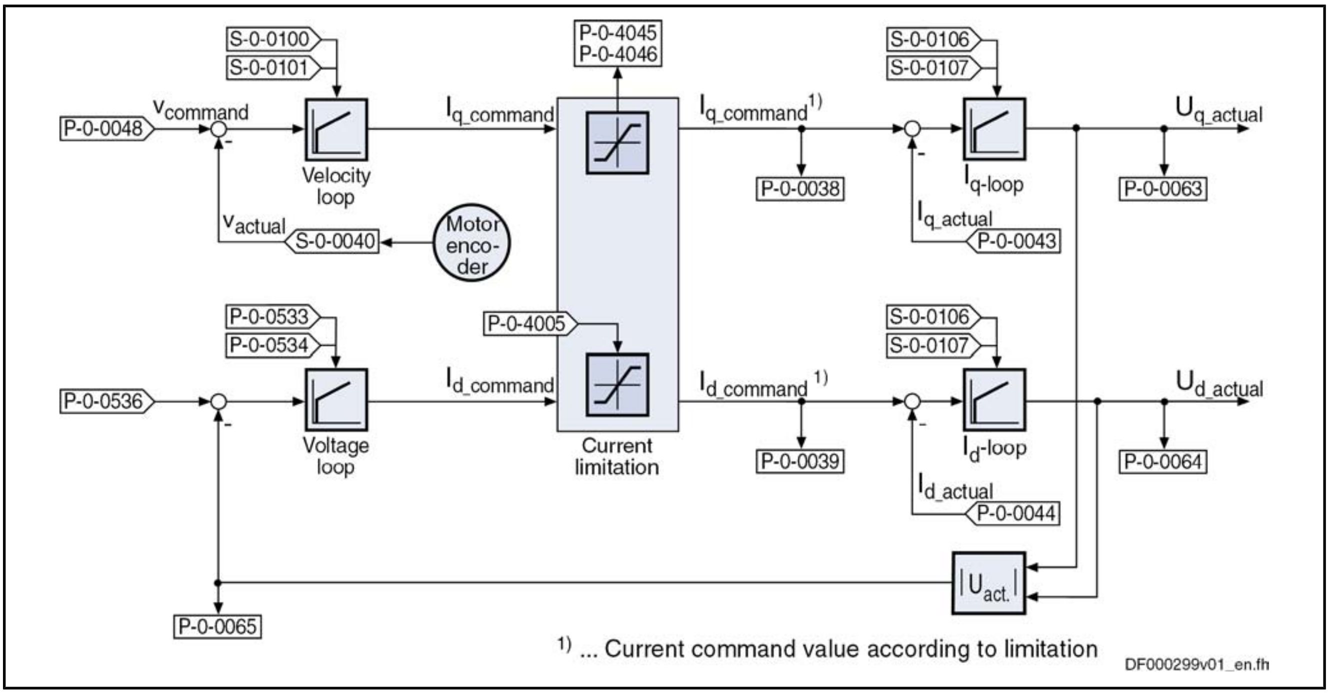


Fig.6-14: Simplified Schematic Diagram of the Current Control Loop for a Synchronous Machine

Voltage Loop for Synchronous Motors

For field control (or voltage control), a voltage loop designed as a PI loop is used that can be set via the following parameters:

- P-0-0533, Voltage loop proportional gain
- P-0-0534, Voltage loop integral action time

☞ The command value of the voltage loop is preset by parameter "P-0-0536, Maximum motor voltage".

The voltage loop becomes active when the current loop output exceeds a defined absolute voltage value (cf. "P-0-0536, Maximum motor voltage"). By generating a field counteracting the permanent field-linked direct-axis flux (→ negative I_d command value), the reduction of the output voltage can be obtained.

☞ The output value of the voltage loop is the command value for the field-generating component of the subsequent current loop (see figure "chapter "Field-Oriented Current Control of a Synchronous Machine" on page 147").

Field Weakening of Synchronous Motors

In the case of synchronous motors with field weakening, a command value of I_{d_cmd} = 0 is run in the basic speed range, as in the case of synchronous motors without field weakening.

When entering the field weakening, I_{d_cmd} is increased towards negative values and therefore allows higher motor velocities.

Closed-Loop Control of Synchronous Motors With Distinctive Reluctance Torque

Closed-loop control of synchronous motors with reluctance torque, i.e. motors with significantly different inductances in the d and q axes, requires the separate input of L_d and L_q in the respective parameters:

- P-0-4016, Direct-axis inductance of motor
- P-0-4017, Quadrature-axis inductance of motor

☞ Utilization of the reluctance effect allows increasing the available torque in the basic speed range.

Field-Oriented Current Control of an Asynchronous Machine

Field-oriented control of the asynchronous machine differs from control of the synchronous machine in the additional function blocks "flux feedforward" and "flux loop incl. field model".

The figure below illustrates the control loop structure of field-oriented current control:

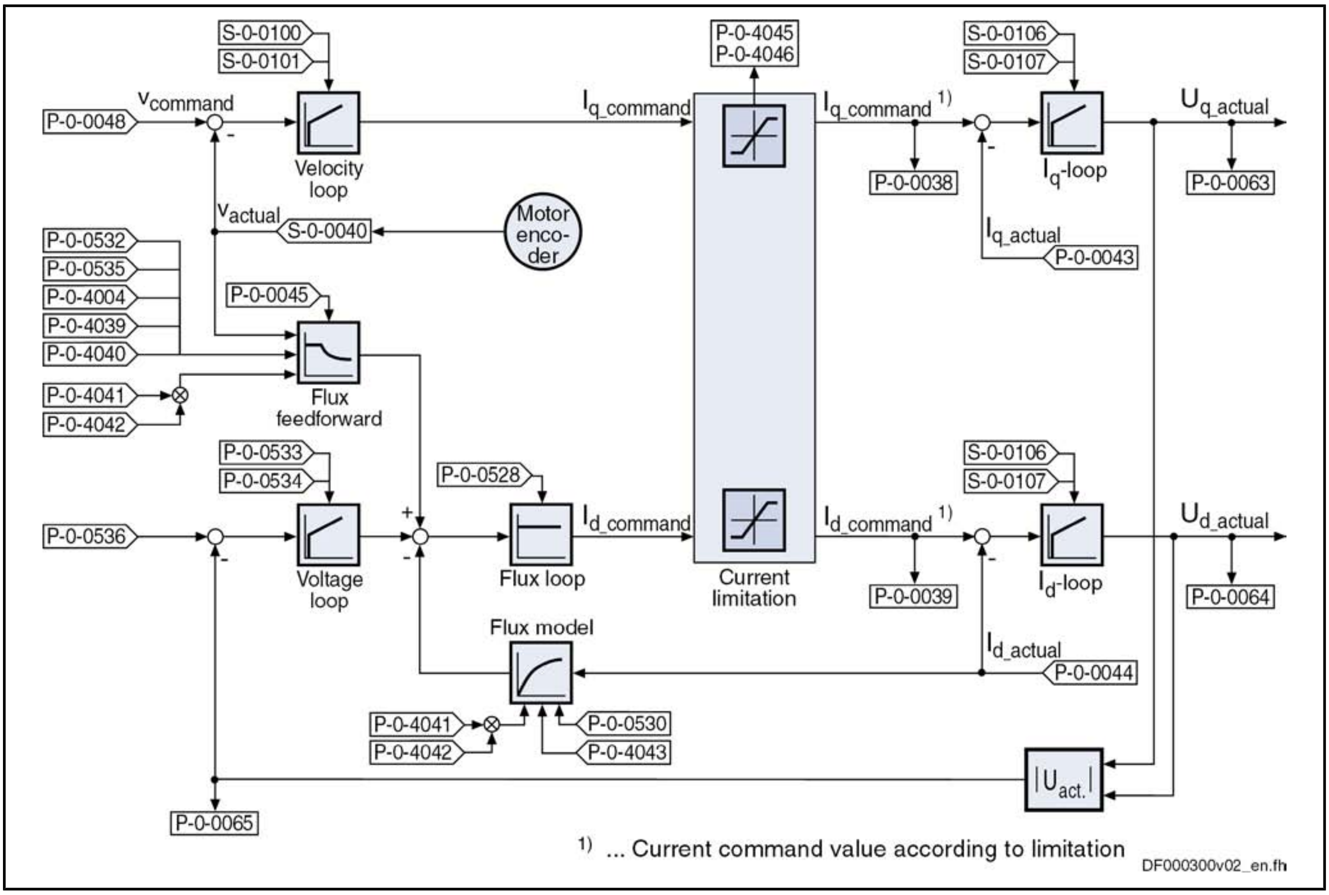


Fig.6-15: Simplified Schematic Diagram of the Current Control Loop for an Asynchronous Machine

Flux Feedforward and Flux Model

The flux feedforward calculates the optimum rotor flux command value for each working point of the machine. The limiting variable is the motor voltage that increases with the speed. The flux feedforward uses the value in parameter "P-0-0535, Motor voltage at no load" as limit value.

In addition, the following motor data have an influence on flux feedforward and flux model:

- P-0-4004, Magnetizing current
- P-0-4039, Stator leakage inductance
- P-0-4040, Rotor leakage inductance
- P-0-4041, Motor magnetizing inductance
- P-0-4042, Characteristic of motor magnetizing inductance
- P-0-4043, Rotor time constant

On the basis of the above motor data and the active value of the flux-generating current I_d, the flux model calculates the actual value of the rotor flux. This value is used as actual value for the flux loop (see below) and additionally determines the torque constant and the slip frequency of the asynchronous machine required for generating the torque.

Voltage Loop

The voltage loop works as a PI loop and in the absolute value limits the voltage output by the current loop to a maximum value. The setting is made via the following parameters:

- P-0-0533, Voltage loop proportional gain

- P-0-0534, Voltage loop integral action time
- P-0-0536, Maximum motor voltage

When the maximum motor voltage is exceeded, the output of the voltage loop interferes in a corrective way in the output value of the flux feedforward.

Flux Loop

The flux loop works as a P-loop with command value feedforward. It compares the actual value from the rotor flux model to the command value from flux feedforward and voltage loop and by the corresponding input of the flux-generating current component $I_{d\text{-}cmd}$ provides for rapid rotor flux generation. This is of importance for applications with dynamic speed response (field weakening range). The gain can be set in "P-0-0528, Flux control loop proportional gain".

In the case of asynchronous motors, the field or rotor flux control has a decisive influence on the torque generation and dynamic response of the machine, particularly in the field weakening range.

For Rexroth motors the corresponding value is stored in the "DriveBase" database.

Stall Current Limit

The stall current limit only takes effect in the power limit range of the field weakening range (C). The maximum allowed torque-generating current is calculated by means of the active rotor flux and the motor data. This absolute limit value can be relatively changed via the setting in "P-0-0529, Scaling of stall current limit" (in percent).

When operating a motor without field weakening it is only the effective magnetizing current that is applied as command value for the field-generating current component.

Determining the Rotor Flux Angle

For field-oriented control of an asynchronous motor, the current rotor flux angle is continuously required. This angle is generated from the position information of the motor encoder.

6.2.4 Sensorless Motor Operation, Flux-Controlled (FXC Control)

Brief Description

Base package of all firmware variants in **open-loop and closed-loop** characteristic

---

For asynchronous and synchronous motors, flux-controlled, sensorless motor operation is available in the base packages "open-loop" and "closed-loop" of all firmware variants and can be used in the "velocity control" mode and in position-controlled operation modes which use position encoder 2 (external encoder).

When using the firmware expansion package "synchronization", you can also run the operation mode "velocity synchronization with real/virtual master axis".

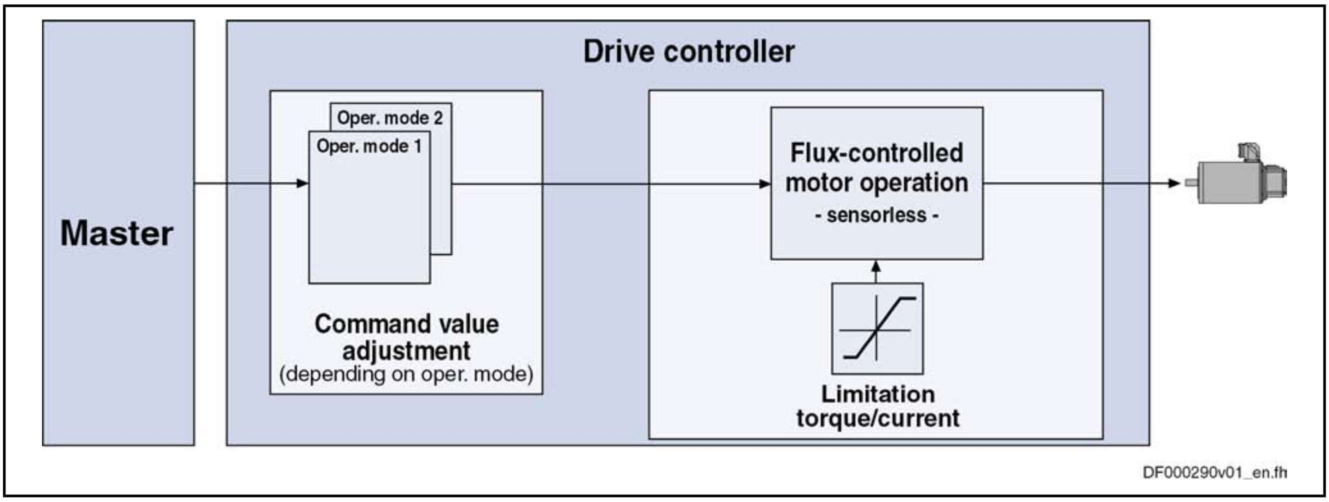


Fig.6-16: Principle of Sensorless, Flux-Controlled Motor Operation

Features

- Limitation of the maximum **stator frequency slope** that results from the command velocity change
- "Stable" motor operation

  → To maintain the maximum possible torque
- **Slip compensation** for asynchronous motors (estimated motor slip taken into account for calculating actual velocity value)

  → To minimize the stationary speed deviations, due to slip, from the command value when the asynchronous motor is loaded
- Motor speed does not tend to oscillation in operation at partial load and no-load operation
- **Velocity search mode** of a coasting asynchronous motor after switching drive enable on
- Possibility of taking user-side **torque/force limitation** into account

Pertinent Parameters

Motor control parameters of sensorless, flux-controlled motor operation:

- P-0-4033, C3200 Command Calculate motor data
- P-0-0532, Premagnetization factor
- P-0-0565, C3600 Command Motor data identification
- P-0-0578, Current for deceleration, absolute value
- P-0-0579, Current for deceleration, time period
- P-0-0580,
- P-0-0593,
- P-0-0594,
- P-0-0595,
- P-0-0596,
- P-0-0597,
- P-0-0598,
- P-0-0599,
- P-0-0600,
- P-0-0602,

Motor data parameters:

- P-0-0510, Rotor inertia

- P-0-4004, Magnetizing current
- P-0-4032, Motor type plate data

Axis data parameters:

- P-0-4010, Load inertia

Control parameters:

- P-0-0045, Control word of current controller
- P-0-0601,

6.2.5 Automatic Setting of Motor Control

Brief Description

Base package of all firmware variants in **open-loop and closed-loop** characteristic

For operating motors, it is necessary to collect the values for motor parameters (resistance values, inductances, ...), in order to determine the motor control parameters (flux loop, voltage loop, current loop, ...) with these values.

Depending on the manufacturer and type of the motor to be controlled, the values for motor parameters and motor control parameters are made available to the controller in different ways.

Motors by Bosch Rexroth

For Rexroth motors, the values for the motor and motor control parameters are optimized and made available by the manufacturer. The automatic setting of the motor control parameters by the drive firmware is not required and not allowed for Rexroth motors!

- For motors **with motor encoder data memory**:

  → Parameters loaded automatically when drive is switched on (see "Default Settings in the Motor Encoder Data Memory ("Load Defaults Procedure")")
- For motors **without motor encoder data memory**:
  – Parameters loaded via the commissioning tool "IndraWorks Ds/D/MLD" from the motor data base (DriveBase)

    - or -
  – Individual parameters manually written via the serial interface or the master communication interface by means of a motor parameter list.

Third-party motors

For third-party motors, the drive firmware possesses commands by means of which the values for the motor and motor control parameters are generated depending on the available output data and the functional principle of the motor.

The following commands are available for calculating values for the motor and motor control parameters:

- C3200 Command Calculate motor data
  1. Calculating the motor parameter values for asynchronous motors from the **data on the type plate**
  2. Calculating the values to be set for the motor control parameters
- C3600 Command Motor data identification
  1. Identifying (or optimizing) the motor parameter values for asynchronous motors

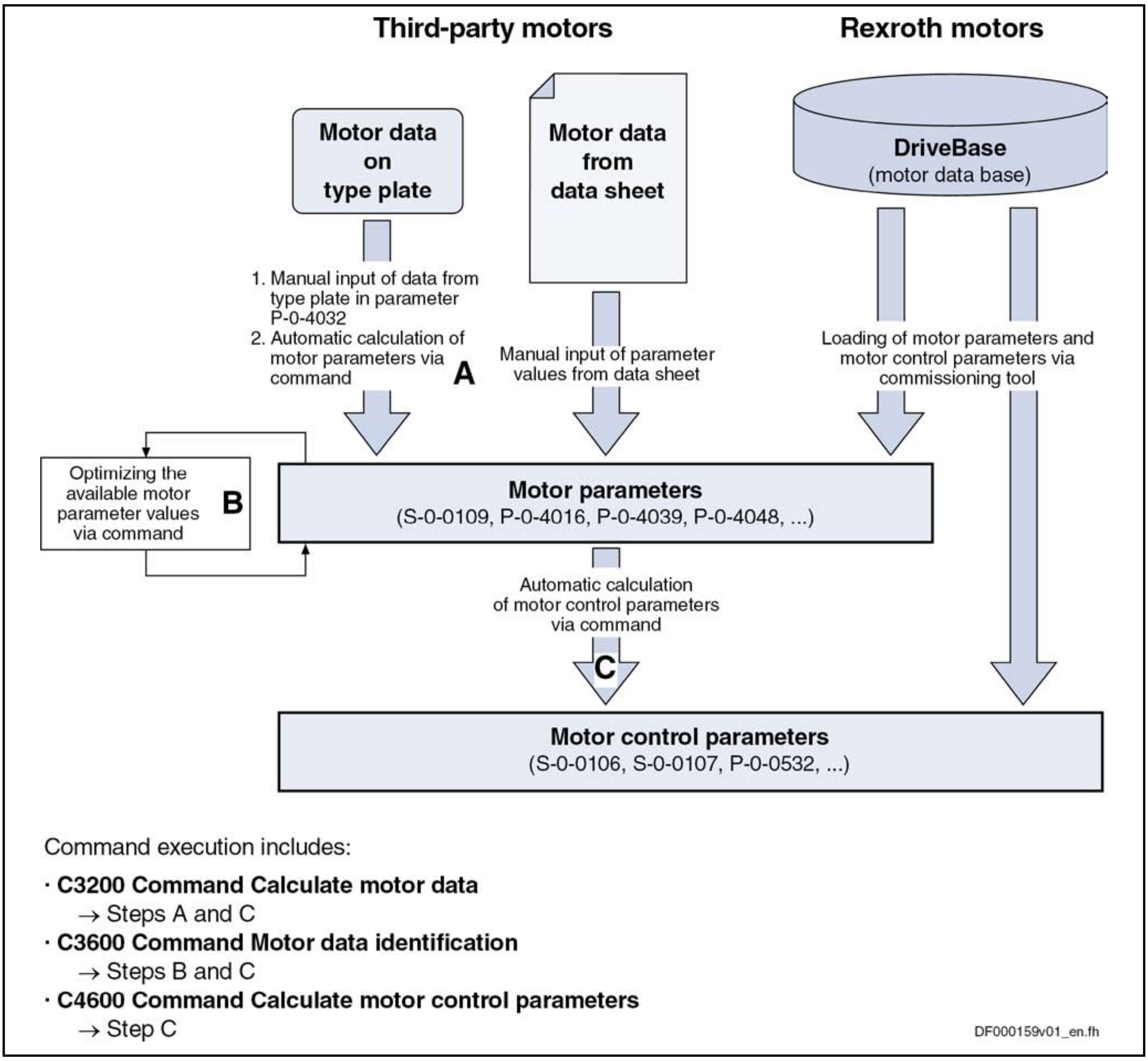
     Note: Appropriate start values already have to be available!
  2. Calculating the values of the motor control parameters

- C4600 Command Calculate motor control parameters

  Calculating the values of the motor control parameters from the motor parameters for synchronous motors and, if necessary, for asynchronous motors (after manual input of motor data in motor parameters)

☞ Basically, the prerequisite is the form "Manufacturer-Side Data of Synchronous Motors" or "Manufacturer-Side Data of Asynchronous Motors" in the section "Third-Party Motors at IndraDrive Controllers" to be completed by the motor manufacturer!

Overview The figure below illustrates an overview of the possibilities of determining the motor and motor control parameters for motors without motor encoder data memory:



P-0-4032 Motor type plate data

Fig.6-17: Determining Motor and Motor Control Parameters for Motors Without Motor Encoder Data Memory

In addition to collecting or determining the motor and motor control parameters, further data on measuring system, temperature sensor, motor temperature model, motor holding brake and, if necessary, position and velocity loop are required.

See "Closed-Loop Axis Control (Closed-Loop Operation)"

See "Notes on Commissioning" in section "Third-Party Motors at IndraDrive Controllers"

Pertinent Parameters

- P-0-0565, C3600 Command Motor data identification
- P-0-0566, C4600 Command Calculate motor control parameters
- P-0-4032, Motor type plate data
- P-0-4033, C3200 Command Calculate motor data

Pertinent Diagnostic Messages

- C3200 Command Calculate motor data
- C3201 Incorrect input for current
- C3202 Incorrect input for voltage
- C3203 Incorrect input for frequency
- C3204 Incorrect input for speed
- C3205 Incorrect input for power factor
- C3206 Incorrect input for power
- C3207 Type plate list incomplete
- C3208 Error when writing parameters (->S-0-0423)
- C3600 Command Motor data identification
- C3601 Motor not or not correctly connected
- C3602 Determined values invalid
- C3603 Device current limit too low
- C3604 Error when writing parameters (->S-0-0423)
- C3605 Motor turning
- C3606 Type of construction of motor not allowed
- C4600 Command Calculate motor control parameters
- C4601 Error when writing parameters (->S-0-0423)

Overview of Motor and Motor Control Parameters

Motor Parameters

The table below contains an overview of the motor parameters for synchronous and asynchronous motors:

Motor parameters	
Synchronous motor	**Asynchronous motor**
P-0-4014, Type of construction of motor	P-0-4014, Type of construction of motor
S-0-0109, Motor peak current	S-0-0109, Motor peak current
S-0-0111, Motor current at standstill	S-0-0111, Motor current at standstill
S-0-0113, Maximum motor speed	S-0-0113, Maximum motor speed
P-0-0018, Number of pole pairs/pole pair distance	P-0-0018, Number of pole pairs/pole pair distance
P-0-0051, Torque/force constant	P-0-0051, Torque/force constant
P-0-0510, Rotor inertia	P-0-0510, Rotor inertia

Motor parameters	
Synchronous motor	**Asynchronous motor**
P-0-4048, Stator resistance	P-0-4048, Stator resistance
P-0-4013, Current limit value of demagnetization	P-0-0530, Slip increase
P-0-4016, Direct-axis inductance of motor	P-0-4004, Magnetizing current
P-0-4017, Quadrature-axis inductance of motor	P-0-4036, Rated motor speed
P-0-4002, Charact. of quadrature-axis induct. of motor, inductances	P-0-4039, Stator leakage inductance
P-0-4003, Charact. of quadrature-axis inductance of motor, currents	P-0-4040, Rotor leakage inductance
P-0-4005, Flux-generating current, limit value	P-0-4041, Motor magnetizing inductance
	P-0-4042, Characteristic of motor magnetizing inductance
	P-0-4043, Rotor time constant

Fig.6-18: Overview of Motor Parameters for Synchronous and Asynchronous Motors

Motor Control Parameters

The following tables contain an overview of the motor control parameters for synchronous and asynchronous motors that are used for field-oriented current control (with and without encoder) and voltage-controlled operation:

Motor control parameters for voltage-controlled operation (U/f)	
Synchronous motor	**Asynchronous motor**
	S-0-0106, Current loop proportional gain 1
	S-0-0107, Current loop integral action time 1
	P-0-0532, Premagnetization factor
	P-0-0568, Voltage boost
	P-0-0569, Maximum stator frequency slope
	P-0-0570, Stall protection loop proportional gain
	P-0-0571, Stall protection loop integral action time
	P-0-0572, Slip compensation factor
	P-0-0573, IxR boost factor
	P-0-0574, Oscillation damping factor
	P-0-0575, Search mode: Search current factor
	P-0-0576, Search mode: Finding point slip factor
	P-0-0577, Square characteristic: Lowering factor

Fig.6-19: Overview of Motor Control Parameters for Synchronous and Asynchronous Motors and Voltage-Controlled Operation (U/f)

Motor control parameters for field-oriented current control (FOC)	
Synchronous motor	**Asynchronous motor**
S-0-0106, Current loop proportional gain 1	S-0-0106, Current loop proportional gain 1
S-0-0107, Current loop integral action time 1	S-0-0107, Current loop integral action time 1

Motor control parameters for field-oriented current control (FOC)	
Synchronous motor	**Asynchronous motor**
P-0-0533, Voltage loop proportional gain	P-0-0533, Voltage loop proportional gain
P-0-0534, Voltage loop integral action time	P-0-0534, Voltage loop integral action time
P-0-0535, Motor voltage at no load	P-0-0535, Motor voltage at no load
P-0-0536, Maximum motor voltage	P-0-0536, Maximum motor voltage
	P-0-0528, Flux control loop proportional gain
	P-0-0529, Scaling of stall current limit
	P-0-0532, Premagnetization factor

Fig.6-20: Overview of Motor Control Parameters for Synchronous and Asynchronous Motors and Field-Oriented Current Control (FOC)

Motor control parameters for sensorless motor operation, flux-controlled (FXC)	
Synchronous motor	**Asynchronous motor**
	P-0-0532, Premagnetization factor
	P-0-0578, Current for deceleration, absolute value
	P-0-0579, Current for deceleration, time period
	P-0-0593,
	P-0-0594,
	P-0-0595,
	P-0-0596,
	P-0-0597,
	P-0-0598,
	P-0-0599,
	P-0-0600,

Fig.6-21: Overview of Motor Control Parameters for Synchronous and Asynchronous Motors and Sensorless, Flux-Controlled Motor Operation (FXC)

Determining the Parameter Values by Means of Type Plate Data

"Calculate Motor Data" Command (C3200)

For asynchronous motors, it is possible via "C3200 Command Calculate motor data" to calculate the values for motor parameters from the type plate data and then the values of the motor control parameters. The activation of C3200 first requires manual input of the motor data from the type plate of the asynchronous motor in "P-0-4032, Motor type plate data".

See Description of "P-0-4032, Motor type plate data"

The command C3200 can only be used for asynchronous motors and can only be activated in communication phases "P2" or "P3"!

The figure below illustrates the scope of functions of the command C3200:

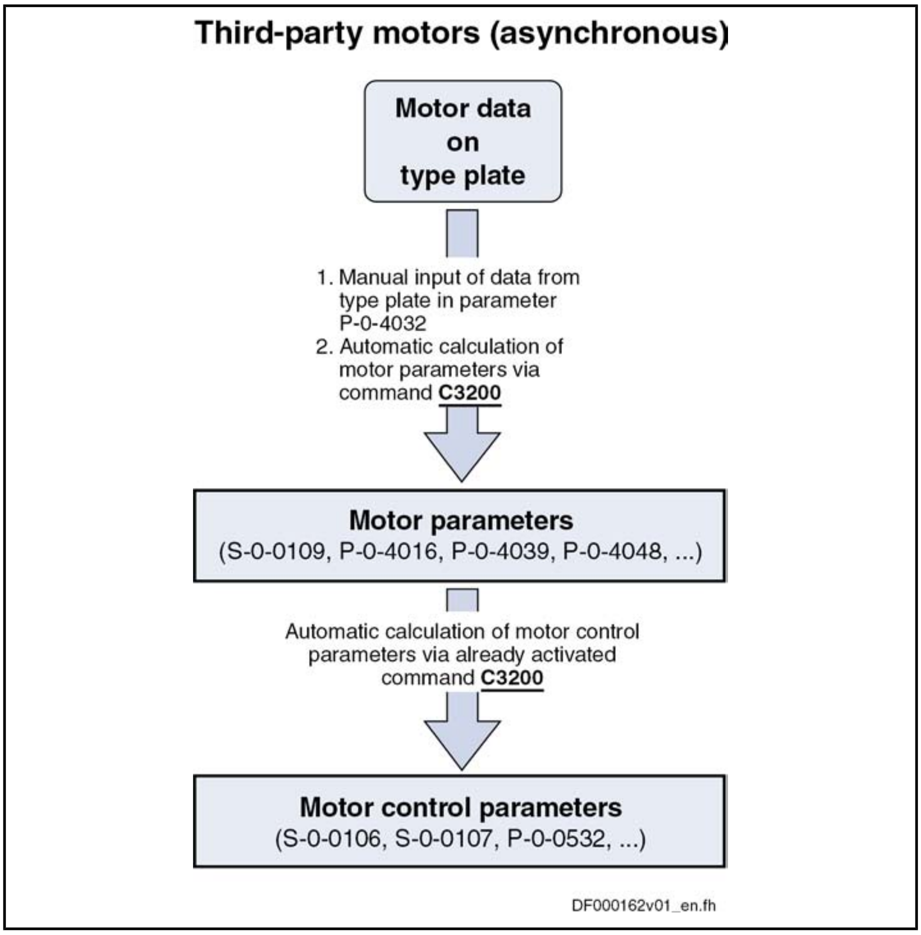


Fig.6-22: Functions of "C3200 Command Calculate Motor Data"

☞ The type plate does not contain the complete information required for safe operation of the third-party motor!

All required data are part of the form of manufacturer-side motor data which has to be available in completed form. The additional data, however, are not required for executing the command C3200.

Internally Calculated Parameter Values

By activating the command C3200 (P-0-4033), the following parameter values are calculated from the data of the asynchronous motor entered in list parameter P-0-4032:

- Motor parameters
  - Motor parameters, general
  - Specific motor parameters for asynchronous motors
- Motor control parameters
  - Motor control parameters for voltage-controlled operation (U/f) of sensorless asynchronous motors
  - Motor control parameters for field-oriented current control (FOC) of asynchronous motors
  - Motor control parameters for flux-controlled operation (FXC) of asynchronous motors without encoder

Notes on Operating Principle

As regards the operating principle of the command C3200, observe the following points:

- Input in P-0-4032 is irrelevant unless the command C3200 has been started.
- When the command was processed without error, the calculated values of motor and motor control parameters are operational.

Identifying and Optimizing the Motor Parameter Values

"Motor Data Identification" Command (C3600)

For asynchronous motors, it is possible via "C3600 Command Motor data identification" to automatically identify and optimize the optimum motor and motor control parameters on the basis of appropriate start values.

☞ The command C3600 can only be used for asynchronous motors and can only be activated in the operating mode (communication phase "P4")!

The figure below illustrates the scope of functions of the command C3600:

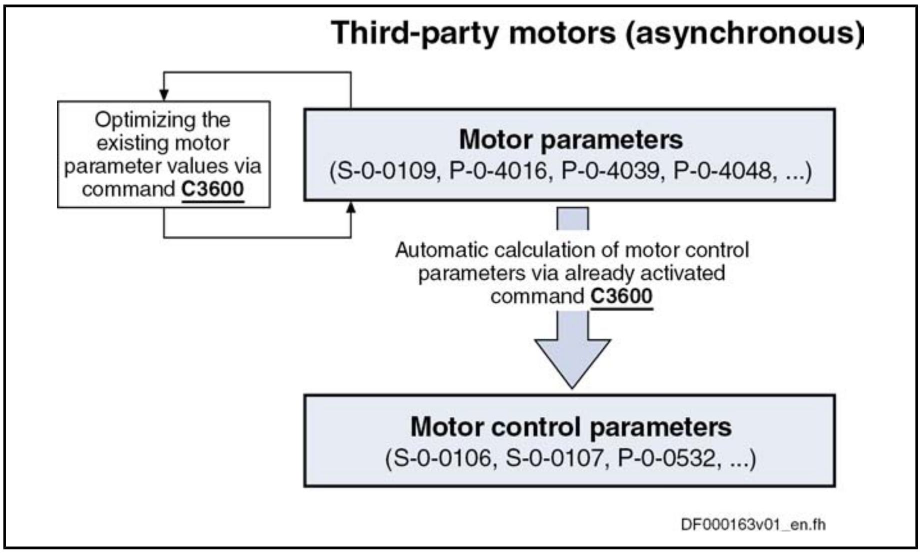


Fig.6-23: Functions of "C3600 Command Motor Data Identification"

Requirements

To execute the command C3600, the following requirements must have been fulfilled:

- manual input of the motor data from the type plate in "P-0-4032, Motor type plate data" and subsequent execution of "C3200 Command Calculate motor data"

  \- or -
- Manual input of all motor data in the motor parameters according to manufacturer's specification in completed motor data form

Procedure

In status "ready for power output" ("Ab"), current and voltage test signals are transmitted to the motor with the execution of command C3600. In this way, the motor parameters for asynchronous motors (see above) are checked and, if necessary, optimized.

A possibly available holding brake continues remaining in the status of control, as existing in the operating status "Ab".

After having successfully completed the command execution, the motor and motor control parameters have been optimized and stored.

The following parameters have been recalculated:

- Motor control parameters for voltage-controlled operation (U/f) of sensorless asynchronous motors

- Motor control parameters for field-oriented current control (FOC) of asynchronous motors
- Motor control parameters for flux-controlled operation (FXC) of asynchronous motors without encoder

Notes on Operating Principle

As regards the operating principle of the command C3600, observe the following points:

- Motor motion is not required; the motor holding brake possibly applied at "Ab" remains applied. The motor does not generate torque. With little friction and inertial mass, little motion can however occur!
- When the command was processed without error, the calculated values of motor and motor control parameters are operational. If the command execution is aborted during the measurement, all motor and motor control parameters remain unchanged.

Calculating the Motor Control Parameters From the Motor Parameters

"Calculate Motor Control Parameters" Command (C4600)

For synchronous motors and in special cases (see "Requirements" below) for asynchronous motors, it is possible via "C4600 Command Calculate motor control parameters" to calculate the motor control parameters from the motor parameters.

☞ The command C4600 can only be activated in the operating mode (OM)!

→ Communication phase P4 ("bb" or "Ab")

The figure below illustrates the scope of functions of the command C4600:

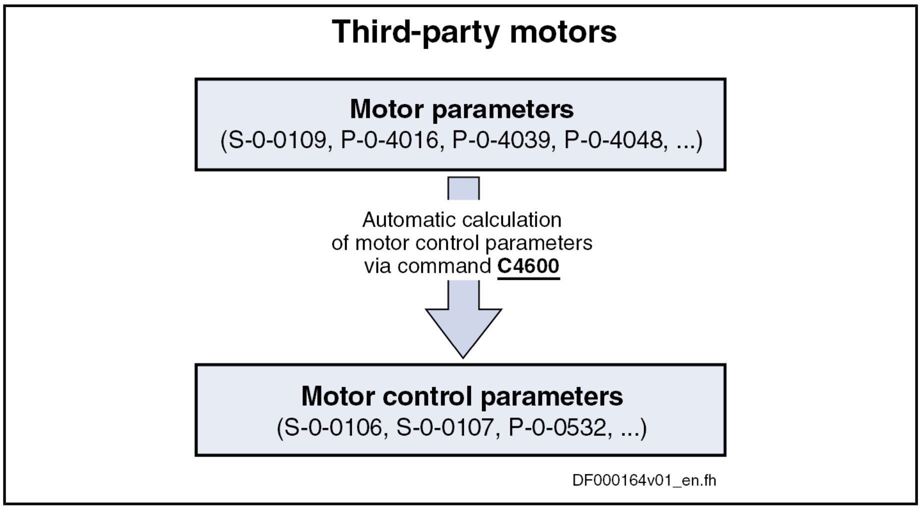


Fig.6-24: Function of "C4600 Command Calculate Motor Control Parameters"

Requirements

To execute the command C4600, the following requirements must have been fulfilled:

- **Synchronous third-party motors** require manual input of the motor data in the motor parameters (see "Third-Party Motors at IndraDrive Controllers").
- For **asynchronous third-party motors**, the command C4600 is only useful, if the motor control parameters are to be generated from specific, manually input motor parameters (e.g. from equivalent circuit diagram data, see "Third-Party Motors at IndraDrive Controllers"). The calculated values for the motor control parameters thereby might possibly be more exact! It is easier, however, to use the commands C3200 and C3600 (see above) for asynchronous motors.

Notes on Operating Principle

As regards the operating principle of the command C4600, observe the following points:

- When the command was processed without error, the calculated values of motor and motor control parameters are operational.

6.3 Open-Loop Axis Control (Open-Loop Operation)

6.3.1 Brief Description

In sensorless operation (open-loop operation), the velocity control loop is not closed in the drive, but the drive is operated in a velocity-controlled way (without feedback) via open-loop U/f control.

☞ The method of open-loop/closed-loop motor control can be selected via bit 14 of parameter "P-0-0045, Control word of current controller".

See also section "Motor Control"

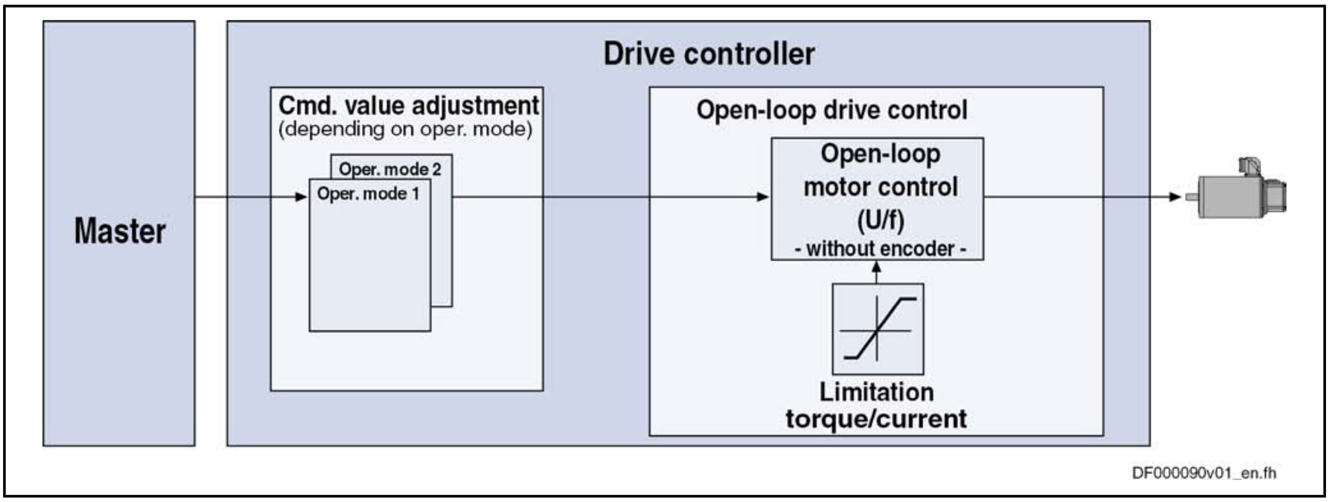


Fig.6-25: Principle of Drive Control in Open-Loop Operation

Features

The velocity control has the following features:

- Fine interpolation of the velocity command value (can be switched off)
- Monitoring of the velocity control loop is possible (can be switched off via P-0-0556; bit 1)
- Parameterizable filtering of the actual velocity value
- Additive velocity command value (S-0-0037)
- Display of the resulting command value (in P-0-0048)
- Monitoring and **limitation** of the maximum stator frequency slope that results from the command velocity change
- **Stall protection loop** (PI loop that can be optionally activated to prevent breakdown of the machine when the torque limits are attained)
- **Slip compensation** (feedforward of estimated slip of the machine by means of rotor time constant and slip compensation factor)
- Calculation of output voltage by means of **U/f characteristic** based on motor model data
- Subsequent trimming of magnetization via premagnetization factor (linear or square characteristic to be selected)

- **IxR boost** (adjustable load-dependent feedforward of the output voltage due to the voltage drop on the motor winding resistance
- **Oscillation damping** (adjustable load-dependent feedforward to prevent velocity oscillations in the partial load and idling ranges)
- **Current limitation loop** to protect the output stage
- **Velocity search mode** of a coasting machine after switching drive enable on (can be set for one or both rotational directions)

Pertinent Parameters

- S-0-0037, Additive velocity command value
- S-0-0040, Velocity feedback value
- S-0-0091, Bipolar velocity limit value
- P-0-0048, Effective velocity command value
- P-0-0049, Effective torque/force command value
- P-0-0555, Status word of axis controller
- P-0-0556, Config word of axis controller

Pertinent Diagnostic Messages S-0-0091 Exceeded

- F8079 Velocity limit value exceeded (S-0-0091)

6.4 Closed-Loop Axis Control (Closed-Loop Operation)

6.4.1 General Information on Closed-Loop Axis Control

Control Loop Structure

The drive controller has a so-called cascade structure, i.e. the individual loops (position, velocity and current) are interconnected. Depending on the operating mode there are different control loop structures with different points of input and paths of the command values. Depending on the active mode of operation, only the torque control loop, the torque control loop and the velocity control loop or, in addition to these two control loops the position control loop can be closed in the drive.

The structure and the interaction of the control loops are illustrated in the two graphics in the section "Overview of Drive Control" (see "Control Loop Structure with Setting Parameters" or "Control Loop Structure with Display Parameters").

Features of the Control Loops

For the simplification of the parameterization of the control loops and for an increase in performance, a number of standardizations and structural changes have been carried out.

Performance (Controller Cycle Times)

The internal controller cycle times (current, velocity and position) depend on the following conditions and parameters:

- Activation of the functional packages
- P-0-0001, Switching frequency of the power output stage
- P-0-0556, Config word of axis controller (bit 2 and 5)

Depending on these factors, the following cycle and switching times can be achieved:

	BASIC control sections
PWM switching frequency	max. 16 kHz
Current loop clock ($T_{A\_current}$)	125 µs

	BASIC control sections
Velocity loop clock ($T_{A\_velocity}$)	250 µs
Position loop clock ($T_{A\_position}$)	500 µs

Fig.6-26: Cycle and Switching Times to be Achieved With IndraDrive

☞ All data about performance are summarized in the section "Performance Data" .

Position Loop

- Jerk limitation in the "cyclic position control" mode by introducing the "S-0-0349, Bipolar jerk limit". The filtering degree of the smoothing filter (moving average value) can be set in the parameter "P-0-0042, Current position command average value filter order".
- Velocity feedforward, i.e. degree of feedforward, to be set in the parameter "P-0-0040, Velocity feedforward evaluation" (0% ... 100%)
- Input value for the parameter "S-0-0348, Acceleration feedforward gain" can be the respective inertia in kg*m^2 (for rotary motors) or the mass in kg (for linear motors)

Velocity Loop

- Standardization of the output value at the velocity loop to Newton (N) or Nowton meter (Nm). Therefore, depending on the motor type, the following unit is obtained for the parameter S-0-0100 in IndraDrive:
- Rotary motor → Nm * s/rad
- Linear motor → N * min/mm
- Possibility of extending the filter options for filtering the resonance frequencies. 4 filters of 2nd order are available, that can be set via the parameters P-0-1120, P-0-1121, P-0-1122 and P-0-1123.
- Limitation of acceleration in velocity control by setting in parameter "S-0-0138, "

Possibilities of Access to Included Control Loops

For operation in a higher-level mode of operation, it is possible to access an included control loop. Depending on the basic mode of operation, the following parameters are available:

In position control:

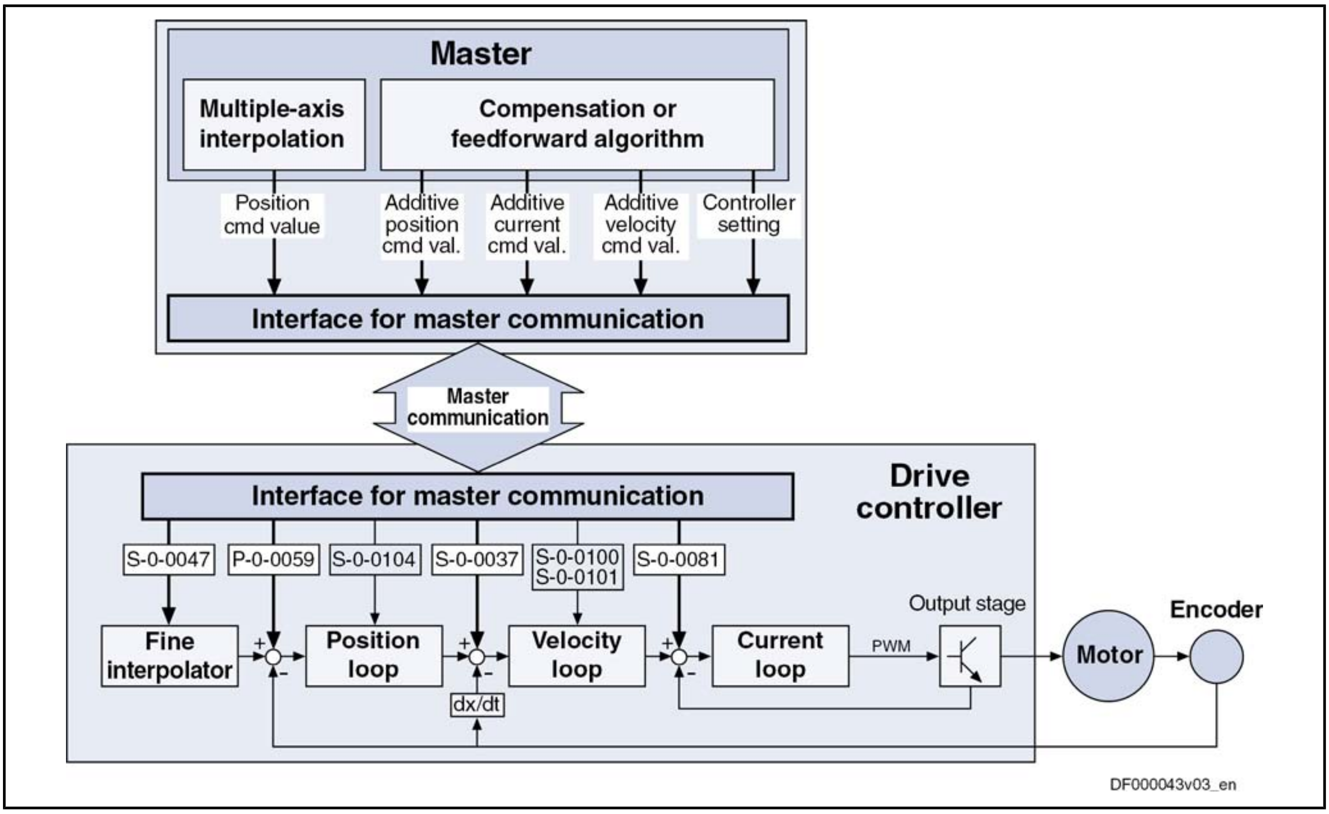
- P-0-0059, Additive position command value, controller
- S-0-0037, Additive velocity command value
- S-0-0081, Additive torque/force command value

In velocity control:

- S-0-0037, Additive velocity command value
- S-0-0081, Additive torque/force command value

In current control:

- S-0-0081, Additive torque/force command value



S-0-0037	Additive velocity command value
S-0-0047	Position command value
S-0-0081	Additive torque/force command value
S-0-0100	Velocity loop proportional gain
S-0-0101	Velocity loop integral action time
S-0-0104	Position loop Kv-factor
P-0-0059	Additive position command value, controller

Fig.6-27: Structural Overview With Access Options

Command Value Processing Depending on Operating Mode

Position Control

For the following modes of operation, the position control loop is closed internally (in the drive) in addition to the velocity and the current control loops:

- Position Control With Cyclic Command Value Input
- Drive-Internal Interpolation
- Drive-Controlled Positioning

See also Description of the Respective Mode of Operation

Velocity Control

In the "velocity control" mode, the velocity control loop, apart form the current control loop, is closed in the drive, too.

See also "Velocity Control"

Torque/Force Control

The "torque/force control" mode actually isn't torque or force control but current control. Therefore, only the current control loop is closed in the drive.

See also "Torque/Force Control"

Default Settings in the Motor Encoder Data Memory ("Load Defaults Procedure")

"Load Defaults Procedure" Command

For all Rexroth motors of the lines with motor encoder data memory (e.g. MKE, MSK and possibly MAD and MAF), the basic settings for the controllers are stored and can be loaded to the drive by executing the "Load defaults procedure" command (S-0-0262).

There are two ways to activate the parameter "S-0-0262, C07_x Load defaults procedure command":

- Automatically when running up the drive by recognizing that the motor type (cf. parameter S-0-0141) has changed. The display then reads "RL" and the "Load defaults procedure" command is internally started by pressing the "Esc" button on the control panel, unless this was deactivated in "P-0-0556, Config word of axis controller".
- Starting the command by writing "11b" to parameter S-0-0262.

See also "Loading, Storing and Saving Parameters"

> ☞ In order to start the "Load defaults procedure" command, the value "0" (default setting) must have been set in parameter "P-0-4090, Configuration for loading default values".

During the load defaults procedure, the following control loop parameters are set to their default values optimized for the respective motor:

- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- S-0-0104, Position loop Kv-factor
- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- P-0-0004, Velocity loop smoothing time constant

> ☞ The default settings for the current loop (cf. S-0-0106 and S-0-0107) are automatically adjusted to the currently parameterized PWM frequency (cf. P-0-0001) and performance setting (cf. P-0-0556)!

In addition, during loading default procedure, the following control loop parameter is set to its firmware default value, although there are no default values stored in the motor data memory:

- S-0-0348, Acceleration feedforward gain

> ☞ In the majority of cases, the controller settings stored in the motor encoder data memory provide a useful and reliable control loop setting. In exceptional cases, however, it may be necessary to make the settings with regard to the specific application.

6.4.2 Automatic Setting of Closed-Loop Axis Control

Brief Description

To facilitate drive parameterization, the IndraDrive firmware provides automatic control loop setting in closed-loop operation. Using "P-0-0163, Damping factor for autom. controller setting" and "P-0-0164, Application for autom. controller setting", the result of the control loop setting (achieved control loop dynamics) can be influenced.

> ☞ To carry out the automatic control loop setting, it is necessary to move the drive. The velocity and position control loops are optimized.

Features

- Definition of a travel range for movement control for the automatic control loop setting by

  - Absolute position limits for the travel range

  - or -

  - Entering a travel distance based on the current actual position
- Use of drive-internal interpolation and its parameters
- Possible settings in "P-0-0165, Drive optimization, control word" for:
  - Velocity loop
  - Position loop
  - Acceleration feedforward
  - Determination of the load inertia
  - Determination of the maximum acceleration
  - Oscillation movement / unipolar movement
  - Absolute travel limits / relative movement around start position

Pertinent Parameters

- P-0-0162, C1800 Command Drive optimization / command value box
- P-0-0163, Damping factor for autom. controller setting
- P-0-0164, Application for autom. controller setting
- P-0-0165, Drive optimization, control word
- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive
- P-0-0168, Maximum acceleration to be parameterized
- P-0-0169, Drive optimization, travel distance

Pertinent Diagnostic Messages

- C1800 Command automatic control loop setting
- C1801 Start requires drive enable
- C1802 Motor feedback data not valid
- C1803 Inertia detection failed
- C1804 Automatic controller setting failed
- C1805 Travel range invalid
- C1806 Travel range exceeded
- C1807 Determining travel range only via travel distance
- E2049 Positioning velocity >= limit value (S-0-0091)
- E2055 Feedrate override S-0-0108 = 0

6.4.3 Velocity Loop (Including the Respective Filters)

Brief Description

In closed-loop operation, in addition to the field-oriented current controller, the velocity control loop is also closed in the drive by means of the drive software (PI cascade structure).

The controlled-loop operation (current and velocity) can be carried with encoder for all types of motors and for asynchronous motors also without encoders.

☞ The motor control type is selected by means of "P-0-0048, Control word of current controller" (Bit 14, 15)

Drive Control

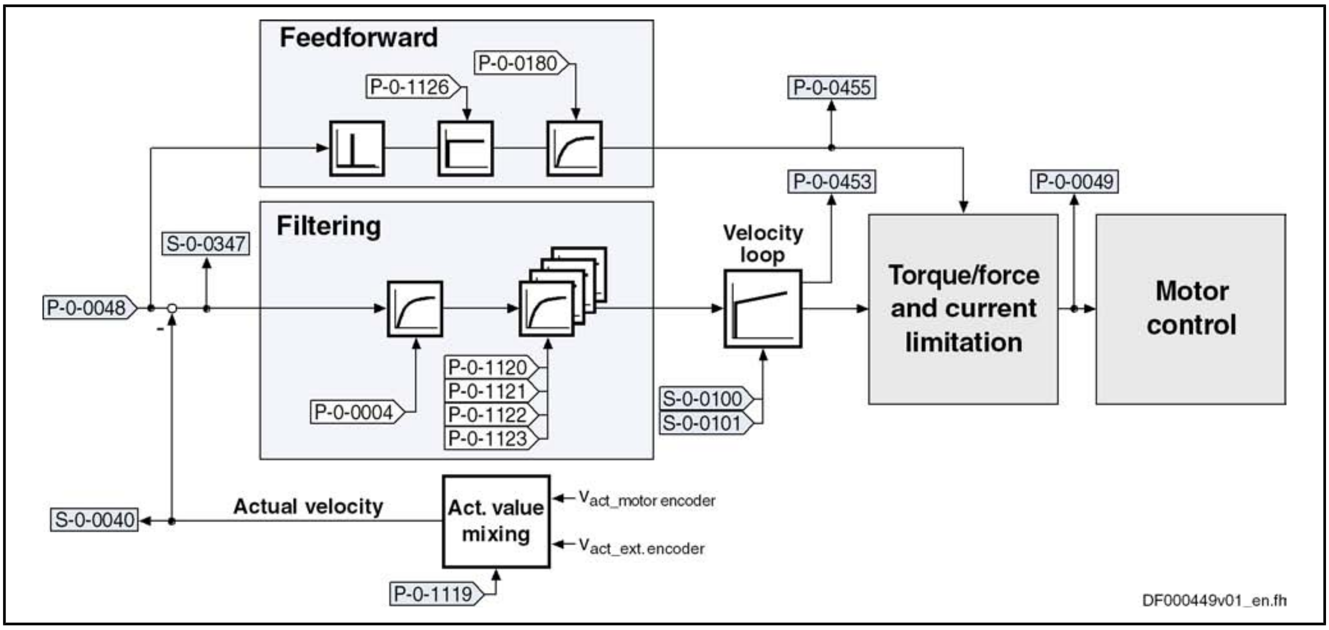


Fig.6-28: Structure of the Velocity Loop

☞ The following description is restricted to the velocity loop including the respective options of filtration and feedforward. The processing of the velocity command value is described within the operating mode "Velocity control" .

Features

- Digital PI controller with anti-windup function, can be set by means of the following parameters:
  – S-0-0100, Velocity loop proportional gain
  – S-0-0101, Velocity loop integral action time
- Setting can be carried out by
  – Executing the function "load defaults procedure" once
  - or -
  – Manual optimization (see description below)
  - or -
  – Automatic parameterization of the axis controller (see "Automatic Setting of Axis Control").
- Depending on the control performance which has been set, the cycle time $T_{A\_velocity}$ is used for velocity loop calculations (see "Performance Data").
- Possibility of mixing the velocities of motor encoder and optional encoder
- 4 freely configurable filters of 2nd order (e.g. band-stop filters) for filtering resonance frequencies
- Moving average filter of the control loop deviation for a maximum of 16 controller clocks (as a "feedback filter", in the case of low-resolution motor measuring systems)
- Low-pass filter to attenuate interference frequencies, to be set via P-0-0004 (VZ1)
- Fine interpolation of the command values of the position loop (can be switched on by P-0-0556, Bit 0)

- Monitoring of the velocity control loop (can be switched off by P-0-0556; Bit 1)
- Optional acceleration feedforward from the torque command value (with filtering option)

Pertinent Parameters

- S-0-0037, Additive velocity command value
- S-0-0040, Velocity feedback value
- S-0-0081, Additive torque/force command value
- S-0-0084, Torque/force feedback value
- S-0-0091, Bipolar velocity limit value
- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- S-0-0149, C1300 Positive stop drive procedure command
- S-0-0155, Friction compensation
- S-0-0164, Acceleration feedback value 1
- S-0-0347, Velocity error
- P-0-0004, Velocity loop smoothing time constant
- P-0-0048, Effective velocity command value
- P-0-0049, Effective torque/force command value
- P-0-0180, Acceleration feedforward smoothing time constant
- P-0-0451, Actual acceleration torque/force value
- P-0-0452, Actual process torque/force value
- P-0-0555, Status word of axis controller
- P-0-0556, Config word of axis controller
- P-0-1119, Velocity mix factor feedback 1 & 2
- P-0-1120, Velocity control loop filter: Filter type
- P-0-1121, Velocity control loop filter: Limit frequency of low pass
- P-0-1122, Velocity control loop filter: Bandwidth of band-stop filter
- P-0-1123, Vel. cont. loop filter: Center frequency of band-stop filter
- P-0-1126, Velocity control loop: Acceleration feedforward
- P-0-2100, Velocity loop proportional gain, type plate
- P-0-2101, Velocity loop integral-action time, type plate
- P-0-3004, Speed controller smoothing time constant, type plate

Pertinent Diagnostic Messages

- E2059 Velocity command value limit active
- E8260 Torque/force command value limit active
- F8078 Speed loop error

6.4.4 Position Loop (With Respective Feedforward Functions and Actual Value Adjustment)

Brief Description

The following section only describes the position loop with the respective feedforward possibilities (velocity and acceleration feedforward).

Drive Control

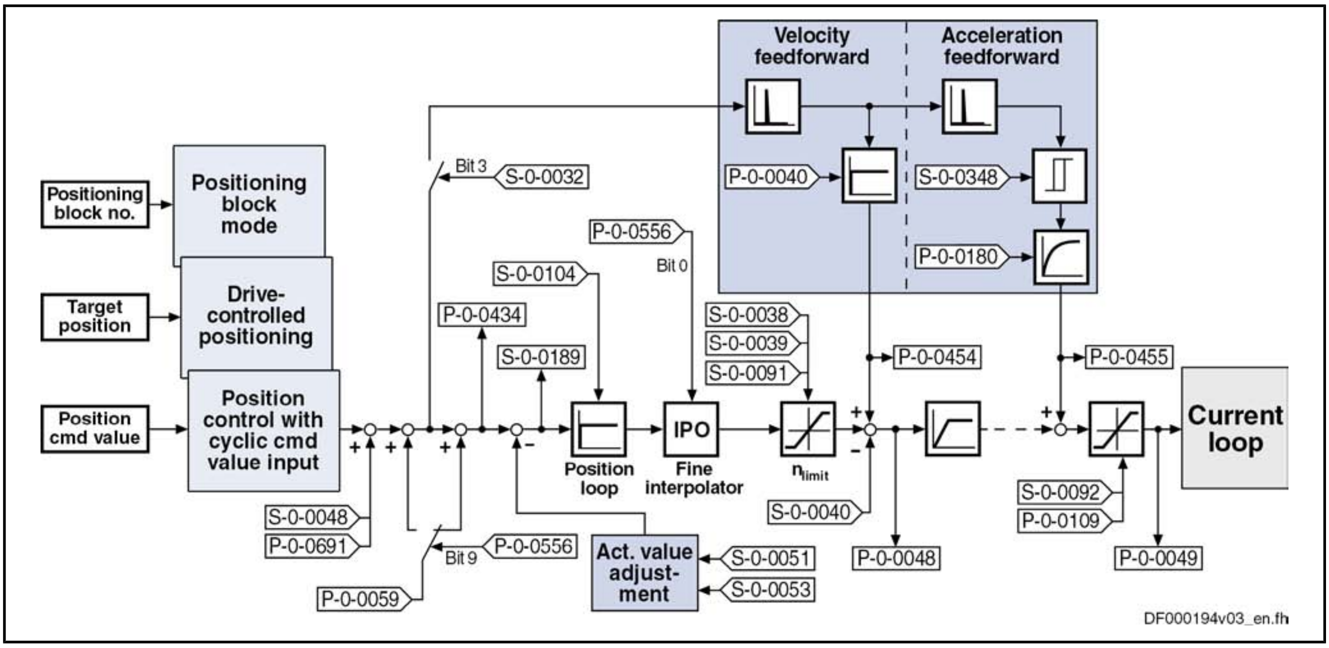


Fig.6-29: Structure of the Position Loop

☞ The preprocessing of the position command value (command value adjustment) is described in the corresponding section of the position control mode (e.g. position control with cyclic command value input, positioning block mode, ...).

Features

- Digital proportional loop, can be set via the following parameter:
  – S-0-0104, Position loop Kv-factor
- Lag error is minimized by:
  – Variable velocity feedforward (see P-0-0040)
  - and -
  – Variable acceleration feedforward (see S-0-0348), including smoothing filter
- Depending on the control performance which has been set, the cycle time $T_{A\_position}$ is used for position loop calculations (see "Performance Data").
- With lag error or lagless, i.e. with velocity feedforward
- Model monitor for the lag error (see also F2028)
- Possibility of evaluating a "hybrid actual position value" from motor encoder and external position control encoder (up to now only motor encoder and measuring wheel encoder)

Pertinent Parameters

- S-0-0032, Primary operation mode
  → Bit 3 = 1 → Activation of lagless operation
- S-0-0038, Positive velocity limit value
- S-0-0039, Negative velocity limit value
- S-0-0040, Velocity feedback value
- S-0-0048, Additive position command value
- S-0-0051, Position feedback value 1
- S-0-0053, Position feedback value 2

- S-0-0091, Bipolar velocity limit value
- S-0-0092, Bipolar torque/force limit value
- S-0-0104, Position loop Kv-factor
- S-0-0189, Following distance
- S-0-0348, Acceleration feedforward gain
- S-0-0386,
- S-0-0520, Control word of axis controller
- -0-0521, Status word of position loop
- P-0-0040, Velocity feedforward evaluation
- P-0-0048, Effective velocity command value
- P-0-0049, Effective torque/force command value
- P-0-0059, Additive position command value, controller
- P-0-0109, Torque/force peak limit
- P-0-0180, Acceleration feedforward smoothing time constant
- P-0-0241,
- P-0-0434, Position command value of controller
- P-0-0454, Velocity feedforward actual value
- P-0-0455, Acceleration feedforward actual value
- P-0-0556, Config word of axis controller
- P-0-0691, Additive position command value, process loop

Pertinent Diagnostic Messages

- F2028 Excessive deviation
- F2036 Excessive position feedback difference
- F2037 Excessive position command difference

6.5 Commutation Setting

6.5.1 Basics on Commutation Setting

Brief Description

The following Rexroth kit motors are manufactured according to the functional principle "synchronous motor":

- Linear motors LSF, MLF
- Rotary motors MBS and MBT

As the motor is assembled in the machine, stator, rotor and measuring system cannot be put together by the manufacturer. The customer will make the electric-magnetic-mechanical allocation of the synchronous motor on site by determining and setting the commutation offset.

The same applies for the Rexroth housing motor MSP.

Measuring Systems for Synchronous Rexroth Motors

Absolute measuring systems should ideally be used for synchronous Rexroth kit motors. The advantage in this case is the absolute position detection of the rotor position which immediately ensures, when drive enable is set, the correct assignment of current in the primary part to the magnetic field in the secondary part. This is realized by the commutation offset stored at initial commissioning.

For some applications it is necessary to use relative measuring systems, because the available length of absolute measuring systems is limited, for example. The disadvantage in this case is that absolute detection of the rotor position is impossible. It is therefore necessary, after each time the drive is switched on again or after having changed the communication phase from "P2" to "P4" ("bb" or "Ab"), to set the commutation offset again. For linear motors, this disadvantage can be removed by using the Hall sensor box SHL01.1, because with regard to commutation setting the relative motor encoder then behaves like an absolute measuring system.

☞ If you use a relative motor encoder, using the Hall sensor box SHL01.1 is absolutely recommended for linear motors! In this way, you achieve highest safety with regard to correct motor function and compliance with the power data!

Measuring Systems for Synchronous Third-Party Motors

Concerning operationally reliable drives with synchronous third-party motors and IndraDrive controllers, there are, with regard to the selected measuring system, the same principles applying as to synchronous Rexroth kit motors (see above); the Hall sensor box SHL, however, cannot be used for linear third-party motors!

Overview of the Synchronous Motors to be Used for Motor Measuring Systems

Motor measuring system	Synchronous Rexroth kit motor (rotary, linear)	Synchronous Rexroth kit motor (linear) with SHL01.1	Synchronous third-party motor
Absolute	+	--	+
Relative	o	+	o

+ Advantageous combination
o Combination possible, initial commissioning might possibly require especially trained staff
-- Combination not useful

Fig.6-30: Possible Combinations of Motor Measuring System and Synchronous Motors for Which Commutation Setting is Required

☞ The measuring system should be realized with high resolution and as a motor encoder to be evaluated in absolute form. If it is necessary to use a relative measuring system, you should avoid using encoders with square-wave signals!

For synchronous motors in combination with a motor encoder which can be evaluated in absolute form, the advantage of setting the commutation offset only once (see above) can only be used with an encoder gear with i = 1 or when there is no encoder gear available!

Ab MPx16V04

In special cases, the one-time setting of the commutation offset can also be used by a motor encoder with encoder gear (only rotary encoders).

In this connection, you distinguish between 2 cases:

- Case 1:

  One encoder revolution results in N motor revolutions (N integer).
- Case 2:

  One motor revolution results in M encoder revolutions (M integer). The encoder is a multi-turn encoder, the multi-turn revolutions are an integral multiple of the gear ratio M.

See also "Absolute Measuring Systems" and "Mechanical Axis System and Arrangement of Measuring Systems"

Pertinent Parameters

Apart from the motor parameters (see Overview of Parameters in "Basics on the Motors to be Controlled), " there are further parameters available for commutation setting:

- P-0-0506, Amplitude for angle acquisition
- P-0-0507, Test frequency for angle acquisition
- P-0-0508, Commutation offset
- P-0-0517, Commutation: Required harmonics component
- P-0-0518, C5600 Command subsequent optimization of commutation offset
- P-0-0521, Effective commutation offset
- P-0-0522, Control word for commutation setting
- P-0-0523, Commutation setting measured value
- P-0-0524, C1200 Commutation offset setting command
- P-0-3008, Commutation offset, type plate

Pertinent Diagnostic Messages

- C1200 Commutation offset setting command
- C1204 Error in offset calculation
- C1208 No adjustment with asynchronous motor
- C1209 Proceed to phase 4
- C1211 Commutation offset could not be determined.
- C1214 Command only possible with linear synchronous motor
- C1215 Command only possible in 'bb'
- C1216 Commutation determination not selected
- C1217 Setting only possible in 'Ab'
- C1218 Automatic commutation: Current too low
- C1219 Automatic commutation: Overcurrent
- C1220 Automatic commutation: Timeout
- C1221 Automatic commutation: Iteration without result
- C1222 Error when writing offset parameters
- C5600 Command subsequent optimization of commutation offset
- C5601 Command requires drive enable
- C5602 Axis blocked
- C5603 Timeout: Axis in motion
- F2032 Validation error during commutation fine adjustment
- F8010 Autom. commutation: Max. motion range when moving back
- F8011 Commutation offset could not be determined
- F8012 Autom. commutation: Max. motion range
- F8013 Automatic commutation: Current too low
- F8014 Automatic commutation: Overcurrent
- F8015 Automatic commutation: Timeout
- F8016 Automatic commutation: Iteration without result

Overview of Methods for Determining the Commutation Offset

Methods for Determining the Commutation Offset

The commutation offset can be determined with different methods. The method is chosen in accordance with the axis geometry, the practicability and the chances of success of the respective method depending on motor and mechanical axis system.

The following methods are possible:

- **Calculation method**

  → For relative motor encoder when using the Hall sensor box (distance measurement, currentless → only possible with Rexroth linear kit motors, see documentation "Hall Sensor Box SHL01.1")

- **Measuring method**

  → For motor encoder that can be evaluated in absolute form (distance measurement, currentless → only possible with Rexroth linear kit motors)

- **Saturation method** (axis needs to be blocked or at standstill, with current)

  → Possible with all types of construction in combination with motor encoders that can be evaluated in absolute form and with relative motor encoders; but see "Restrictions for Saturation Method" in table below

- **Sine-wave method** (requires unrestricted movement of axis, with current)

  → Possible with all types of construction in combination with motor encoders that can be evaluated in absolute form and with relative motor encoders; but see "Restrictions for Sine-Wave Method" in table below

Recommendations for selecting the determination method:

		Determination method			
		Calculation method (with Hall sensor box)	Measuring method	Saturation Method	Sine-Wave Method
Motor type	**Measuring system used →**	**Relative, linear**	**Absolute, linear**	**Absolute/relative**	**Absolute/relative**
MBSxx0		--	--	+	o
MBSxx2 (high speed)		--	--	o	+
MBTxx0		--	--	+	o
MBTxx1		--	--	o	+
LSF		+	+	+	o
MLF		+	+	+	o
MSP		--	--	+	o

\+ Recommended method
o Method not recommended
-- Method not possible

Fig.6-31: Recommendations for Selecting Determination Method for Commutation Offset Depending on Motor Type (for Rexroth Motors)

☞ The sine-wave method (generally requires unrestricted movement of axis) should only be used if the saturation method cannot be used!

Restrictions for Saturation Method

Applications of synchronous motors	Restrictions for saturation method
Third-party motors without or with only little saturation effects	Saturation method cannot be used for determining commutation offset!
Applications with relative measuring system (without using the optimum commutation offset value with regard to the reference point)	Max. torque/force can be reduced by approx. 15% compared to the optimum value (autom. determination of the commutation offset for "AF")!
Applications with relative measuring system that are using the optimum commutation offset value with regard to the reference point	Max. torque/force until reference mark is passed can be reduced by approx. 15%!
Drives that can be in motion during the determination of the commutation offset, e.g. coasting spindles, printing roller drives etc.	Saturation method only possible for motors in standstill!
Drives with a low degree of overload capacity	Saturation method only possible if amplifier current is sufficiently high (2...4-fold continuous motor current required)!

Fig.6-32: Typical Applications and Restrictions for Saturation Method

Restrictions for Sine-Wave Method

Applications of synchronous motors	Restrictions for sine-wave method
Linear axis with single motor or parallel motor	Only balanced (e.g. horizontal) axes with little friction!
Linear axes in Gantry arrangement	Only balanced (e.g. horizontal) axes with little friction! In addition, both drives have to carry out sequential commutation settings, "AF" in this case mustn't be active at the other drive!
Rotary axes with single drive	Only balanced axes with little friction; high inertia can cause problems!
Rotary axes, mechanically connected	See above "Linear Axes in Gantry Arrangement"!

Fig.6-33: Typical Applications and Restrictions for Sine-Wave Method

Significance of Commutation Offset

A synchronous motor can only generate the torque or the force specified according to motor data, when the commutation offset is correct. If the value for the commutation offset is incorrect, lower action torque / force is to be expected; a highly incorrect value implies the danger of the motor having a "runaway effect".

Therefore, the parameter "P-0-0521, Effective commutation offset" is read-only. For initial commissioning of Rexroth kit motors, however, it is required to allow writing parameter P-0-0521 in order to set and optimize the value, if necessary. An initial commissioning mode must be activated for this purpose (see "P-0-0522, Control word for commutation setting"). During the initial commissioning of the motor, you have to determine the commutation offset value with due diligence.

☞ For synchronous Rexroth motors with integrated motor encoder (MSK, MHD, MKD, MKE motors), it is not necessary to set the commutation offset! The correct value is provided in the motor encoder data memory and is automatically activated.

Depending on the motor encoder used, you have to determine the commutation offset for the following situations:

- With absolute motor encoder only during initial commissioning of the drive
- With relative motor encoder both during initial commissioning and each time the drive has been switched on (recommissioned)

☞ Deviating values when determined again (recommissioning with relative motor encoder) can occur, this can cause deviating drive behavior (remedy: "Optimum commutation offset with regard to reference point", see below)!

6.5.2 Commutation Setting for Rexroth Motors MLF, LSF

Brief Description

Linear Rexroth kit motors of the MLF and LSF lines are manufactured according to the functional principle "synchronous motor". For kit motors, the motor components stator, rotor and measuring system are finally assembled on the customer side in the machine.

With Absolute Motor Encoder

The electric-magnetic-mechanical allocation of the synchronous motor therefore can only be made on site by determining and setting the commutation offset. This is done once during initial commissioning of the motor, if it has been equipped with a motor encoder to be evaluated in absolute form.

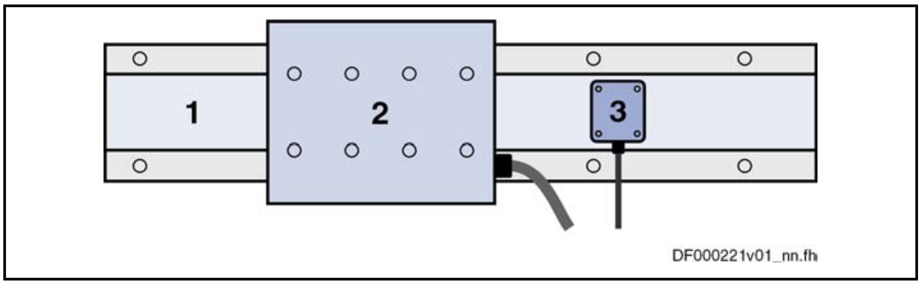
With Relative Motor Encoder

When a relative motor encoder is used, it is necessary to determine the commutation offset again each time after the drive was switched off.

Deviating commutation offset values when determined again (recommissioning with relative motor encoder) can occur, this can cause deviating drive behavior. To avoid this, it is recommended that you use the Hall sensor box SHL01.1 which was developed for linear Rexroth motors.

Hall Sensor Box SHL01.1

The Hall sensor box SHL01.1 is an absolute measuring system within one pole pair distance of linear Rexroth motors. Via the signals of the Hall sensors, the controller detects the position of the motor windings compared to the magnetic field of the motor; therefore, the commutation setting is only required during initial commissioning. When the drive is recommissioned, the correct commutation offset is already available at drive enable ("AF").



1 secondary part
2 Primary part
3 Hall sensor box SHL

Fig.6-34: Linear Rexroth Motor With Hall Sensor Box SHL

For information on mounting and connection see the documentation on Hall Sensor Box SHL01.1.

6.5.3 Saturation Method

Brief Description

For rotary synchronous Rexroth kit motors, IndraDrive controllers only provide methods with current to determine the commutation offset. The saturation method is one of these methods; when it is used, "motor standstill" is necessary. A possibly available holding brake should remain applied!

☞ For synchronous Rexroth motors with integrated motor encoder (MSK, MHD, MKD, MKE motors), it is not necessary to set the commutation offset! The correct value is provided in the motor encoder data memory and is automatically activated.

The saturation method can also be used for linear synchronous Rexroth kit motors, if they have only been equipped with a relative measuring system (without Hall sensor box SHL), and for motors with an absolute measuring system for which distance measurement at the axis is impossible due to the mounting.

As a prerequisite for successful application of the saturation method, the iron material of the motor must be magnetically saturated when current is supplied, i.e. the controller must be able to provide sufficiently high current to the motor. For synchronous motors which are not magnetically saturated at maximum allowed current, this method is unsuited for determining the commutation offset!

☞ If the saturation method cannot be used, the controller provides the sine-wave method (works with current, too) for determining the commutation offset.

When the requirements have been fulfilled, the saturation method can be used both for initial commissioning and for recommissioning.

☞ The restrictions to be observed when using the saturation method are described in section "Basics on Commutation Setting". This section outlines the different methods which can be used for determining the commutation offset.

6.5.4 Sine-Wave Method

Brief Description

For synchronous motors, IndraDrive controllers, in addition to the saturation method, provide the sine-wave method, also with current, to determine the commutation offset. When this method is used, "unrestricted movement of axis is required". The axis must be able to move easily and freely!

Before using the sine-wave method, carefully check whether it is possible to use the saturation method, because unrestricted movement of the axis generally causes problems. For the saturation method movement of axis is not necessary, it should be blocked, if possible.

When the requirements have been fulfilled, the sine-wave method is suited to only a limited extent for initial commissioning and for recommissioning.

☞ The restrictions to be observed when using the sine-wave method are described in section "Basics on Commutation Setting". This section outlines the different methods which can be used for determining the commutation offset.

6.6 Limitations

6.6.1 Overview of Limitations

To protect the mechanical axis system, the controllers and the motors against overload, IndraDrive devices have different possibilities of limitation:

- Torque/force limitation
  - Axis-side torque/force limit values, depending on the preceding sign
  - Axis-side torque/force limit values, related to the absolute value (independent of the preceding sign)
- Current limitation
  - Absolute current limit values, depending on controller or motor
  - Dynamic current limitation, depending on the thermal load of controller or motor
- Velocity limitation
  - Motor-side velocity limit values
  - Axis-side velocity limit values
- Position limitation
  - Evaluation of axis-side travel range limit switches
  - Firmware-side travel range limit values

The existing limiting facilities are active depending on the method of motor control.

Voltage-Controlled Open-Loop Operation (U/f Control)

With voltage-controlled, sensorless operation, the following limitations are available to protect the device or motor:

- Torque/force limitation via stall protection loop
- Current limitation via current limitation loop
- Position limitation by
  - Travel range limit switches
  - Software limit switches

Closed-Loop Operation of Motors (FXC, FOC, FOCsl)

In closed-loop operation (flux-controlled or current-controlled), there are the following parameterizable limitations to protect the device or motor:

- Torque/force limitation
- Current limitation
- Velocity limitation
- Position limitation by
  - Travel range limit switches
  - Software limit switches

6.6.2 Current and Torque/Force Limitation

Brief Description

Current limitation and torque/force limitation avoid mechanical overload of the axis and thermal overload of motor and controller.

Torque/force limit values due to axis conditions and processing take effect statically as positive and negative limits of the torque/force command value. The thermal overload protection might possibly reduce these limits dynamically, depending on the current thermal load of motor and controller.

Features

- User-side limit values for torque/force (drive-internally converted to current limit values):
  – Bipolar limit values (S-0-0092, P-0-0109)
  – Unipolar limit values (S-0-0082, S-0-0083)
- Display of the current torque/force command value in parameter "P-0-0049, Effective torque/force command value"
- Display of the process torque or process force in parameter "S-0-0084, Torque/force feedback value"
- Drive-side, absolute current limit values in the parameters "S-0-0110, Amplifier peak current" and "S-0-0109, Motor peak current"
- Dynamic current limitation depending on work load reduces maximum current to the thermally allowed continuous current on the basis of motor and amplifier temperature model (depending on motor type and possibly selected cooling type, as well as on PWM frequency and amplifier type); currently available maximum current and thermally possible continuous current displayed in the parameters:
  – P-0-4045, Maximum possible continuous current
  – P-0-4046, Effective peak current
- Resulting torque/force limit values from the user-side torque/force limitations and the (dynamic) current limitation depending on work load are displayed in the parameters:
  – P-0-0442, Actual value torque limit positive (stationary)
  – P-0-0443, Actual value torque limit negative (stationary)
  – P-0-0444, Actual value peak torque limit
- Status word for analysis of the currently active torque/current limitation (P-0-0445)
- Display of effective torque-generating current command value ("limited" current command value) in parameter
  – P-0-0038, Torque-generating current, command value
- Display of actual current values in the parameters
  – P-0-0440, Actual output current value (absolute value)
  – P-0-0043, Torque-generating current, actual value
  – P-0-0044, Flux-generating current, actual value

Pertinent Parameters

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0109, Motor peak current
- S-0-0110, Amplifier peak current
- S-0-0111, Motor current at standstill
- S-0-0112, Amplifier nominal current
- S-0-0384, Amplifier temperature
- P-0-0001, Switching frequency of the power output stage
- P-0-0038, Torque-generating current, command value
- P-0-0049, Effective torque/force command value
- P-0-0051, Torque/force constant

- P-0-0109, Torque/force peak limit
- P-0-0141, Thermal drive load
- P-0-0440, Actual output current value (absolute value)
- P-0-0441, Overload warning
- P-0-0442, Actual value torque limit positive (stationary)
- P-0-0443, Actual value torque limit negative (stationary)
- P-0-0444, Actual value peak torque limit
- P-0-0445, Status word torque/current limit
- P-0-0556, Config word of axis controller
- P-0-0640, Cooling type
- P-0-4034, Thermal time constant of winding
- P-0-4035, Thermal time constant of motor
- P-0-4037, Thermal short-time overload of winding
- P-0-4045, Maximum possible continuous current
- P-0-4046, Effective peak current
- P-0-4058, Amplifier type data
- P-0-4059, Electric type data of power section

Pertinent Diagnostic Messages

- E2050 Device overtemp. prewarning
- E2051 Motor overtemp. prewarning
- E2056 Torque limit = 0
- E2061 Device overload prewarning
- E8055 Motor overload, current limit active
- E8057 Device overload, current limit active
- F2018 Device overtemperature shutdown
- F2019 Motor overtemperature shutdown
- F2021 Motor temperature monitor defective
- F2022 Device temperature monitor defective

Torque/Force Limitation

The torque/force limit can be freely parameterized by the user and provides bipolar and unipolar limits.

Parameters for bipolar limits:

- S-0-0092, Bipolar torque/force limit value
- P-0-0109, Torque/force peak limit

Parameters for unipolar limits:

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative

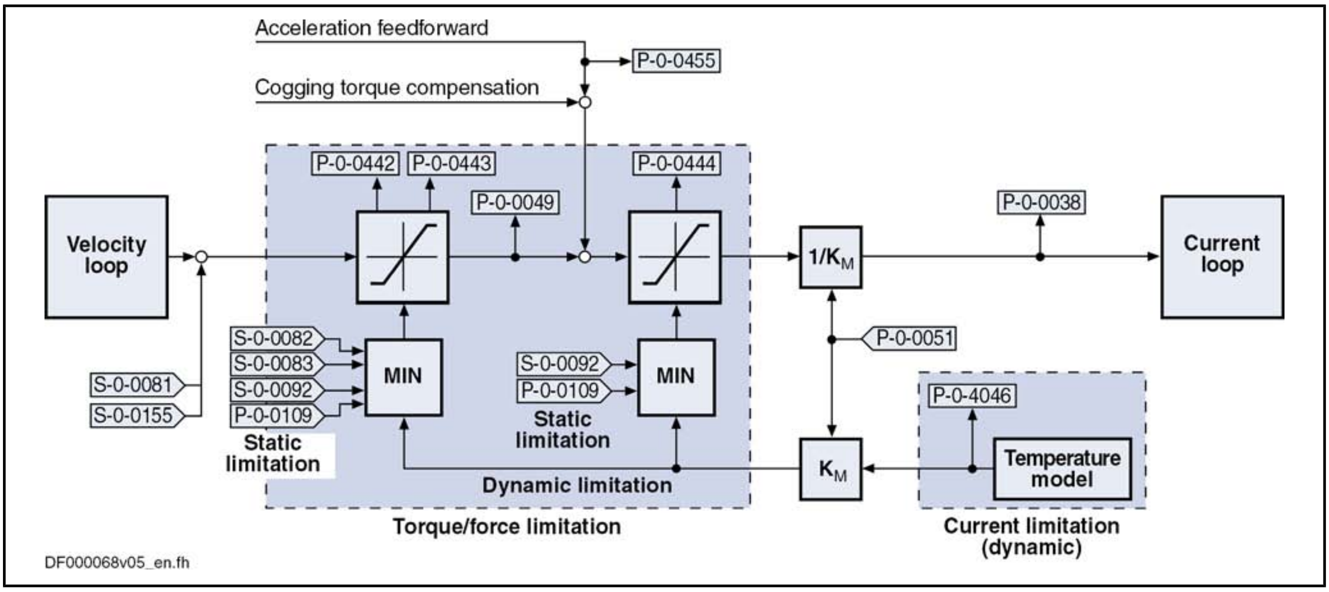
☞ It is always the lowest value of the torque/force limit values entered in the parameters S-0-0082, S-0-0083, S-0-0092 or P-0-0109 that takes effect!

Depending on the method of motor control, the torque/force limitation influences the control of the motor in different ways.

Motor Control Methods FOC, FOCsl, FXC

In closed-loop motor operation, the unipolar torque limitation takes effect on the torque command value output by the velocity loop. The bipolar torque/force limitation takes effect on the value limited in unipolar form, including possibly added feedforward values.

In addition to the user-side static limit values, the current limitation takes effect dynamically, via "P-0-4046, Effective peak current", on the resulting torque/force limit values (converted via "P-0-0051, Torque/force constant").



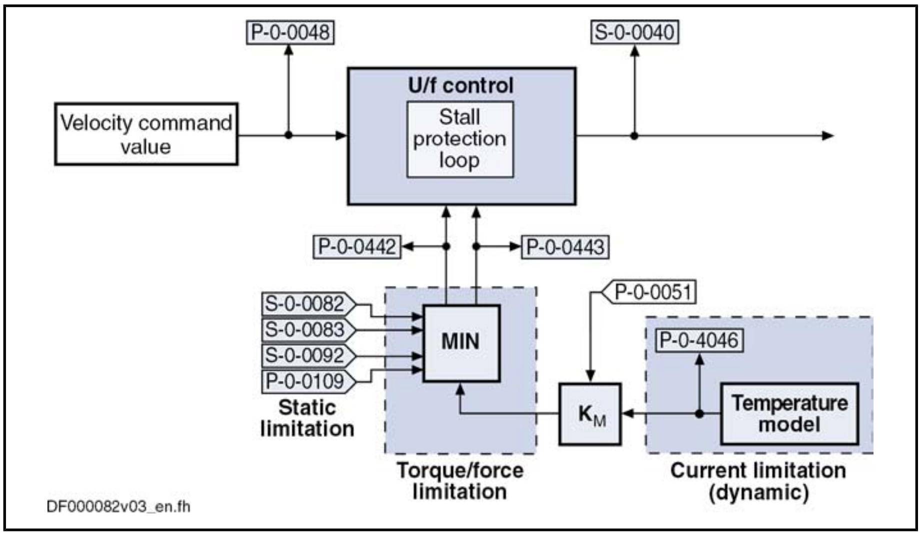
S-0-0081	Additive torque/force command value
S-0-0082	Torque/force limit value positive
S-0-0083	Torque/force limit value negative
S-0-0092	Bipolar torque/force limit value
S-0-0155	Friction compensation
P-0-0038	Torque-generating current, command value
P-0-0049	Effective torque/force command value
P-0-0051	Torque/force constant
P-0-0109	Torque/force peak limit
P-0-0442	Actual value torque limit positive (stationary)
P-0-0443	Actual value torque limit negative (stationary)
P-0-0444	Actual value peak torque limit
P-0-0455	Acceleration feedforward actual value
P-0-4046	Effective peak current

Fig.6-35: Torque/Force Limitation With the Motor Control Methods FOC, FOCsl and FXC

U/f Control

In voltage-controlled, sensorless motor operation (U/f), the torque limitation only takes effect on the stall protection loop. The static negative and positive torque limit values are generated from the lowest values of the torque/force limit values entered in the parameters S-0-0082, S-0-0083, S-0-0092 or P-0-0109.

In addition to the user-side static limit values, the current limitation takes effect dynamically, via "P-0-4046, Effective peak current", on the resulting torque/force limit values (converted via "P-0-0051, Torque/force constant").



S-0-0040	Velocity feedback value
P-0-0048	Effective velocity command value
P-0-0051	Torque/Force Constant
P-0-0442	Actual value torque limit positive (stationary)
P-0-0443	Actual value torque limit negative (stationary)
P-0-4046	Effective peak current

Fig.6-36: Torque/Force Limitation in Sensorless U/f Operation of the Motor

Current Limitation

Principles of Current Limitation

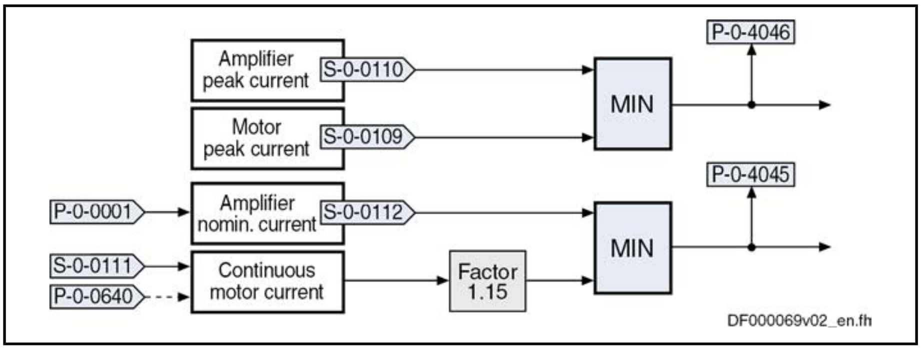
☞ The current limitation cannot be parameterized by the user; it takes effect automatically and protects the motor and the amplifier against inadmissible load.

We basically distinguish the following principles of current limitation:

- **absolute current limitation** (depending on maximum possible peak currents and continuous currents of motor and drive controller)
- **dynamic peak current limitation** (depending on work load, realized by motor and amplifier temperature models)

Absolute Current Limitation

The figure below illustrates the generation of the maximum values for continuous current and peak current from the motor- and controller-specific current data (without thermal load of motor and controller).



S-0-0111	Motor current at standstill
P-0-0001	Switching frequency of the power output stage
P-0-0640	Cooling type
P-0-4045	Maximum possible continuous current
P-0-4046	Effective peak current

Fig.6-37: Generating the Maximum Values for Continuous Current and Peak Current

Maximum Possible Continuous Current (P-0-4045)

The maximum possible continuous current (P-0-4045) is the minimum value from the maximum allowed continuous current of the controller and the motor, with the following dependencies:

- The continuous current of the controller depends on the switching frequency of the power output stage (P-0-0001).
- The continuous current of the motor depends on the motor current at standstill (S-0-0111); for motor with variable cooling type (MSK, MHD, MKD), it additionally depends on the realized cooling type and the corresponding setting in parameter "P-0-0640, Cooling type".

Continuous Current of the Controller

The continuous current of the controller basically depends on the switching frequency of the power section. With a setting of 12 kHz or 16 kHz in parameter P-0-0001, the currently effective switching frequency can be reduced depending on the work load. This increases the allowed continuous current compared to the value at higher switching frequency (see below "Continuous Current of Controller Depending on Work Load at PWM of 12 kHz or 16 kHz").

Continuous Current of the Motor

The continuous motor current is internally calculated from the value of the parameter "S-0-0111, Motor current at standstill" and the "cooling type factor". This factor is selected in parameter "P-0-0640, Cooling type" by a characteristic value, depending on the motor type and possibly of the selected cooling type.

$$\text{Continuous motor current} = \text{cooling type factor} \times (\text{S-0-0111})$$

Cooling type factor	see Parameter Description "P-0-0640, Cooling type"
S-0-0111	Motor current at standstill

Fig.6-38: Internal Calculation of the Continuous Motor Current

The maximum possible continuous current (P-0-4045) is the 1.15-fold value of the continuous motor current, if the continuous current of the controller (power section) allows this.

Effective Peak Current (P-0-4046)

The output current of the controller us dynamically limited, depending on the thermal load of the motor or controller. The current limit value is displayed in parameter "P-0-4046, Effective peak current". The maximum value results from the minimum of the values of "S-0-0109, Motor peak current" and "S-0-0110, Amplifier peak current".

Dynamic Current Limitation

With dynamic current limitation, the thermal load of controller and motor is determined by means of temperature model calculation, depending on the value in parameter "P-0-0440, Actual output current value (absolute value)" and the duration of effectiveness of this current. Due to the current load, the maximum possible amplifier current or motor current can be limited to the continuously possible current (continuous current):

- **Limitation of amplifier current**

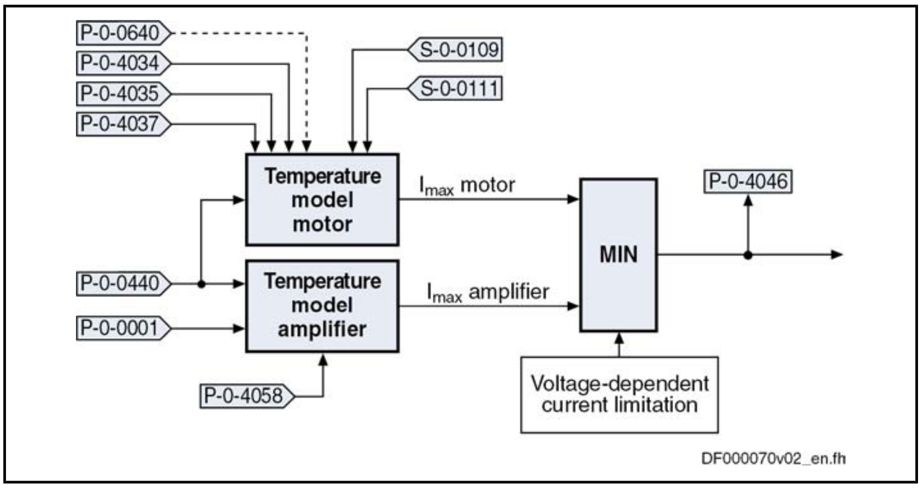
  It is used to protect the drive controller against overload. The firmware-side temperature model calculation takes place on the basis of the amplifier type data determined by the hardware.

  Note: The amplifier type data is determined at the factory and stored in parameter "P-0-4058, Amplifier type data" on the power section.

- **Limitation of motor current**

  It is used for overload protection of the motor with peak load and short-time overload operation. The firmware-side temperature model calculation takes place on the basis of motor-specific temperature model data.

  Note: In addition, the temperature sensor of the motor might possibly support thermal overload protection (continuous current, rms current).



S-0-0109	Motor peak current
S-0-0111	Motor current at standstill
P-0-0001	Switching frequency of the power output stage
P-0-0440	Actual output current value (absolute value)
P-0-0640	Cooling type
P-0-4034	Thermal time constant of winding
P-0-4035	Thermal time constant of motor
P-0-4037	Thermal short-time overload of winding
P-0-4046	Effective peak current
P-0-4058	Amplifier type data

Fig.6-39: Generating the Dynamic Peak Current Limit Value (Temperature Model)

Properties

Basic properties of dynamic current limitation:

- The value taking effect is always the lowest value resulting from motor current or amplifier current limitation.
- The current, maximum possible continuous current is displayed in parameter P-0-4045, the effective peak current in parameter P-0-4046.

Depending on the method of motor control, the current limitation influences the control of the motor in different ways.

Motor Control Methods FOC, FOCsl, FXC

In closed-loop motor operation, the current limitation, via the value of parameter "P-0-4046, Effective peak current", possibly takes a reducing effect on the user-side, static torque/force limit values. The dynamic torque/force limit value resulting from the value of P-0-4046 is determined via the parameter "P-0-0051, Torque/force constant".

The current (limited) torque/force command value is displayed in parameter P-0-0049, the corresponding torque-generating command current in parameter P-0-0038.

U/f Control

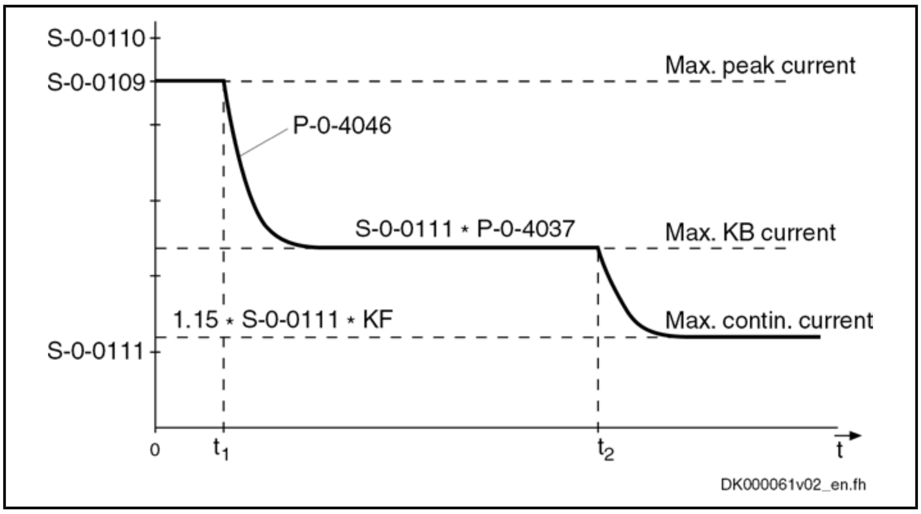
In voltage-controlled, sensorless motor operation (U/f), the current limitation takes effect on the current limitation loop and the stall protection loop:

- For the **current limitation loop**, the effective peak current (P-0-4046) is the limit value to which the actual output current value (P-0-0440) is limited by reducing the motor voltage by means of a control process.
- For the **stall protection loop**, the current limitation, in addition to the user-side static limit values, takes effect dynamically via the effective peak current (P-0-4046) on the resulting positive and negative torque/force limit values (P-0-0442, P-0-0443) (converted via "P-0-0051, Torque/force constant").

The static negative and positive torque limit values are generated from the lowest values of the torque/force limit values entered in the parameters S-0-0082, S-0-0083, S-0-0092 or P-0-0109.

Motor Temperature Model

The value of parameter "P-0-4046, Effective peak current" is only generated by the motor temperature model, if the controller has been sufficiently dimensioned compared to the motor. When the motor has not been thermally preloaded, the following curve results at full motor load:



S-0-0109	Motor peak current
S-0-0110	Amplifier peak current
S-0-0111	Motor current at standstill
P-0-4037	Thermal short-time overload of winding
P-0-4046	Effective peak current
t_1	max. duration after which the motor temperature model reduces to the max. KB current
t_2	max. duration after which the motor temperature model reduces to the max. continuous current
KB	Short-time operation (KB = "Kurzzeitbetrieb")
KF	Cooling type factor (see note below)

Fig.6-40: Curve of Effective Peak Current (P-0-4046) at Motor Load, Generated by Motor Temperature Model

Depending on the load current of the motor, the times t_1 or t_2 can be determined. They apply to motors which have not been thermally loaded and therefore are theoretical maximum values. In motor operation, t_1 and t_2 depend on the following factors:

- Motor-controller combination
- Thermal preload of drive
- Load cycle

The time t_1 applies to load currents greater than, the time t_2 to load currents smaller than the maximum allowed short-time operation current. The values are determined according to the following formula:

$$t_1 = -\ln\left[1-\left(\frac{(\text{P-0-4037}) \times (\text{S-0-0111})}{I_{L1}}\right)^2\right] \times (\text{P-0-4034})$$

$$t_2 = -\ln\left[1-\left(\frac{1{,}15 \times \text{KF} \times (\text{S-0-0111})}{I_{L2}}\right)^2\right] \times \frac{(\text{P-0-4035})}{\text{KF}}$$

t_1	Max. duration after which the motor temperature model reduces to the max. KB current
t_2	Max. duration after which the motor temperature model reduces to the max. continuous current
I_{L1}	Assumed load current (> max. KB current)
I_{L2}	Assumed load current (max. continuous current < I_L2 < max. KB current)
S-0-0111	Motor current at standstill
P-0-4034	Thermal time constant of winding
P-0-4035	Thermal time constant of motor
P-0-4037	Thermal short-time overload of winding
KF	Cooling type factor (see note below)

Fig.6-41: Calculating the Time for the Effective Peak Current (at Starting Condition "Motor has not been Thermally Loaded")

☞ The **cooling type factor** depends on the cooling type and the resulting setting of parameter "P-0-0640, Cooling type" (see also Parameter Description):

- 1.0 → For standard cooling (AD, MAF, MBT, MBS, LSF, MLF) and for non-ventilated motors MHD, MSK, MKD, MKE
- 1.5 → For ventilation (only MHD, MSK, MKD, MKE)
- 1.9 → For liquid cooling (only MHD, MSK, MKD, MKE)

Amplifier Temperature Model

In addition to the motor temperature model, the value of parameter "P-0-4046, Effective peak current" is limited by the amplifier temperature model. The variables of the model calculation are:

- Time behavior of "P-0-0440, Actual output current value (absolute value))"
- P-0-4058, Amplifier type data
- P-0-0001, Switching frequency of the power output stage
- Output frequency of the motor voltage

The value of "S-0-0112, Amplifier nominal current" (maximum continuous current of controller) depends on the setting in parameter "P-0-0001, Switching frequency of the power output stage". At motor standstill (below an output frequency threshold), however, the allowed continuous current value is reduced, compared to the value of S-0-0112, by the temperature model calculation (dynamic reduction of continuous current at motor standstill). At the corresponding motor load, the value of parameter "P-0-4046, Effective peak current" falls below the value of S-0-0112 (unless the motor is the current-limiting component!).

The current data of the amplifiers (power sections of the IndraDrive controllers) for continuous and cyclic load are contained in the separate documentation "Supply Units and Power Sections; Project Planning" .

> The physical data of motor-controller combinations for servo, main drive and S1 print applications can be retrieved via the selection list program "DriveSelect" (Intranet). "DriveSelect" takes the influence of the motor and amplifier temperature models into account!

Continuous Current of Controller Depending on Work Load at PWM of 12 kHz or 16 kHz

The continuous current of the controller is reduced as the switching frequency of the power output stage (PWM frequency) is increased. When the value in parameter "P-0-0001, Switching frequency of the power output stage" has been set to 12 kHz or 16 kHz, it is possible, however, to reduce the switching frequency depending on the thermal load of the controller. This reduces the thermal load of the power output stage and increases the allowed continuous current of the controller. Make the corresponding setting in parameter "P-0-0556, Config word of axis controller". This causes the following behavior:

- When the value of "P-0-0141, Thermal drive load" increases to the value set in parameter "P-0-0441, Overload warning", the switching frequency is internally reduced to 8 kHz. The display "E2061 Device overload prewarning" is generated.
- When the value of "P-0-0141, Thermal drive load" falls below a controller-specific threshold, the value of the switching frequency entered in parameter P-0-0001 takes effect again. The display "E2061 Device overload prewarning" disappears.

> The reduction of the switching frequency depending on the work load only influences the allowed continuous current of the controller. The maximum output current remains at the value belonging to the switching frequency set in parameter P-0-0001! The respective documentation of the power sections contains the current data related to the controller (see "Supply Units and Power Sections; Project Planning").

When the default values for the control loop parameters are loaded ("RL" or command C07_0), the values of the current loop parameters, which have been stored in the encoder data memories of the motors and relate to the PWM frequency of 4 kHz, are converted to the value set in parameter P-0-0001. When the option "reduction of switching frequency depending on work load" has been activated, conversion to the reduced switching frequency takes place!

> In the case of manual optimization of the current loop parameters, select the lower switching frequency (PWM). For this purpose, enter the value "0" in parameter "P-0-0441, Overload warning" before optimization!

6.6.3 Velocity Limitation

Brief Description

A unipolar velocity limitation was implemented in the drive that allows limiting the velocity command value to a positive and negative threshold freely definable and differing with regard to the absolute value.

Features

- Unipolar velocity limit values (S-0-0038, S-0-0039)
- Cyclically configurable, bipolar velocity limit value (S-0-0091)

Pertinent Parameters

- S-0-0036, Velocity command value
- S-0-0037, Additive velocity command value
- S-0-0038, Positive velocity limit value
- S-0-0039, Negative velocity limit value
- S-0-0091, Bipolar velocity limit value

Pertinent Diagnostic Messages

- E2059 Velocity command value limit active
- E2063 Velocity command value > limit value
- F8079 Velocity limit value exceeded

6.7 Power Supply

6.7.1 Power Supply Possibilities

Brief Description

The following IndraDrive devices are supported by this firmware:

- Single-axis converter devices of the IndraDrive Cs device family (HCS01.1 controllers)
- Multi-axis converter devices (HCQ, HCT controllers)

Converter devices contain supply and inverter sections. They are suitable for the direct mains connection can, however, in single-axis design (HCS01.1) also be used as a DC bus-coupled modular drive system.

Pertinent Parameters

- S-0-0380, DC bus voltage
- P-0-0114, Undervoltage threshold
- P-0-0118, Power supply, configuration
- P-0-0119, Best possible deceleration
- P-0-0460, Module group, control word
- P-0-0461, Module group, status word
- P-0-0806, Current mains voltage crest value
- P-0-0809, Properties of charging circuit
- P-0-0810, Minimum mains crest value
- P-0-0815, Nominal mains voltage crest value
- P-0-0816, Amplifier temperature 2
- P-0-0819, Energy counter
- P-0-0833, Braking resistor threshold
- P-0-0844, Braking resistor load
- P-0-0858, Data of external braking resistor
- P-0-0859, Data of internal braking resistor

- P-0-0860, Converter configuration
- P-0-0861, Power supply status word

Pertinent Diagnostic Messages

- E2026 Undervoltage in power section
- E2040 Device overtemperature 2 prewarning
- E2050 Device overtemp. prewarning
- E2061 Device overload prewarning
- E2086 Prewarning supply module overload
- E2802 HW control of braking resistor
- E2810 Drive system not ready for operation
- E2814 Undervoltage in mains
- E2816 Undervoltage in power section
- E2819 Mains failure
- E2820 Braking resistor overload prewarning
- E2829 Not ready for power on
- E8025 Overvoltage in power section
- E8028 Overcurrent in power section
- E8057 Device overload, current limit active
- E8058 Drive system not ready for operation
- F2026 Undervoltage in power section
- F2086 Error supply module
- F2087 Module group communication error
- F2816 Softstart fault power supply unit
- F2818 Phase failure
- F2819 Mains failure
- F2820 Braking resistor overload
- F2821 Error in control of braking resistor
- F2825 Switch-on threshold braking resistor too low
- F2836 DC bus balancing monitor error
- F8838 Overcurrent external braking resistor

Possible Device Combinations and Mains Connection

☞ The possible device combinations are only described in principle for the purpose of explanation. As regards combinations of device types actually possible and specific facts to be observed, see separate documentation "Rexroth IndraDrive Cs – Drive System, Project Planning Manual" (DOK-INDRV*-HCS01******-PR01; part no.: R911322210).

Central Supply

The figure below illustrates the principle of central supply:

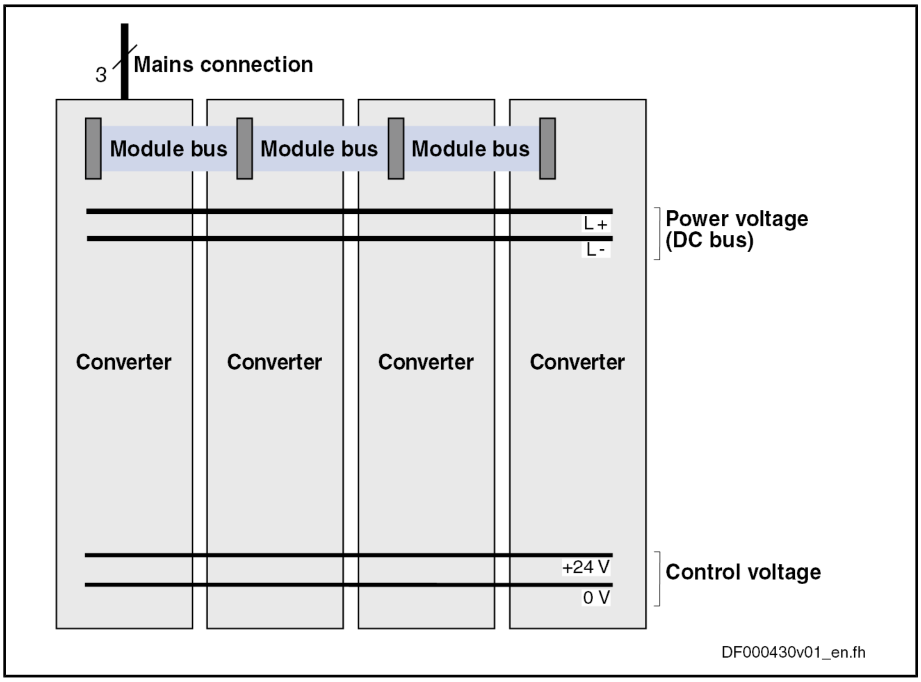


Fig.6-42: Mains Supply via Converter

Group Supply

The figure below illustrates the principle of group supply:

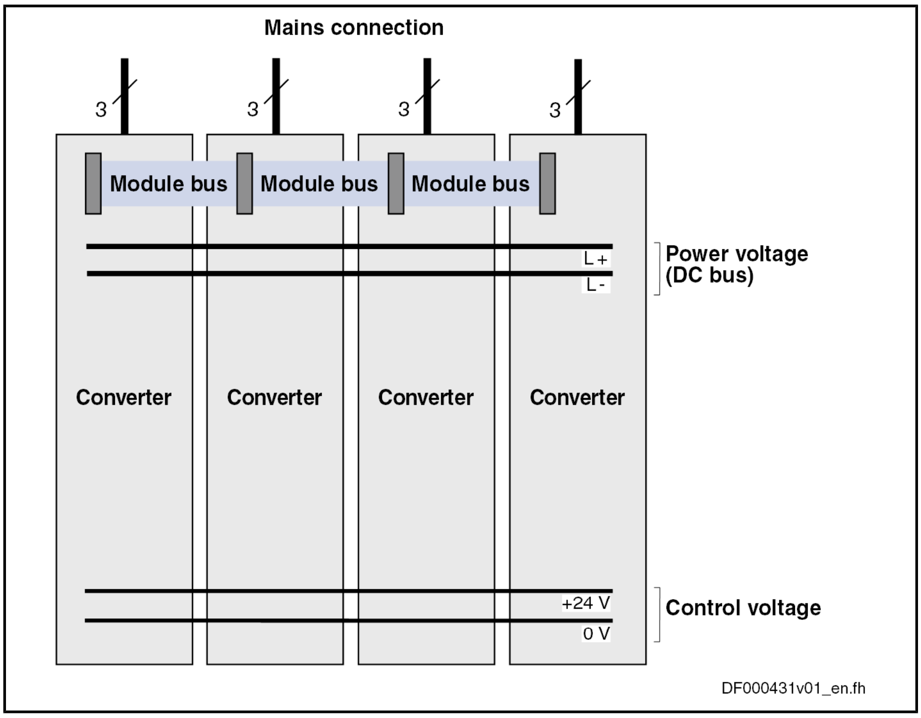


Fig.6-43: Mains Supply via all Devices

Communication in Drive Group

Depending on the task of a drive system or of several drives cooperating in a process, it can be appropriate to rapidly carry out a common reaction to certain events. This requires the exchange of signals (communication) between the cooperating devices:

- Multi-axis converter devices have an internal communication between supply section and the axis inverters

- Single-axis converter devices (IndraDrive Cs) are interconnected via the module bus

Information on IndraDriveCs Single-Axis Converter Devices

A single-axis converter device combines supply unit and inverter in one device. In a "drive system" (several drives the DC buses and module buses of which are interconnected), a converter can fulfill the following functions:

- Supply of an integrated inverter and more inverters and/or converter devices operated as such

- or -

- Operation only as inverter on a DC bus

Information on Multi-Axis Converter Devices

A multi-axis converter device combines a supply unit and several inverters in one device. It always works as "drive system" (several drives the DC buses and module buses of which are interconnected). Supply of more external converters or inverters or external module bus connection is not possible!

Regenerated Energy

In the case of regenerative operation (e.g. deceleration mode) of the motors connected to a single-axis or multi-axis device, the regenerated energy is first absorbed by the DC bus. If the energy absorption capacity is exhausted, the absorbed energy is converted into heat via the braking resistance.

Braking Resistor

The braking resistor is connected on the DC bus side. Depending on the device line, an internal braking resistor is available or an external braking resistor can be connected.

Module Bus

As regards hardware, connections and signals, the module bus is described in the documentations of the devices (Project Planning Manuals).

7 Operation Modes

7.1 General Information on the Operation Modes

7.1.1 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 illustrates by which base package or functional package the respective operation mode is supported, and applies to the two firmware variants MPB and MPM. The MPE firmware variant is only supported by an extended base package.

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

OL Open-loop characteristic
CL Closed-loop characteristic
Fig.7-1: Supported Operating Modes

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

See also "Enabling of Functional Packages"

7.1.2 Operating Mode Handling

Selecting the Operating Mode

It is possible to configure up to 8 different operating modes in the drive (depending on "S-0-0292, List of 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 "F2007 Switching to non-initialized operation mode" error message is generated when this operating mode is activated.

Activating the Operating Mode

The operating mode is activated and controlled via bits 8, 9 and 11 in parameter "P-0-0116, Device control: Control word".

The following applies to parameter P-0-0116:

- Bits 8 and 9 → Selecting primary mode of operation and secondary oper. modes 1 to 3
- Bit 11 → Selecting secondary operation modes 4 to 7 (only SERCOS)

☞ The secondary operation modes 4 to 7 can only be used via SERCOS interface. Bit 11 therefore only takes effect in the control word of the device control (P-0-0116) in conjunction with parameter S-0-0134 (master control word for SERCOS)!

The figure below illustrates the interrelation of the control word of the respective master communication and the device control word/device status word with regard to the operating mode selection.

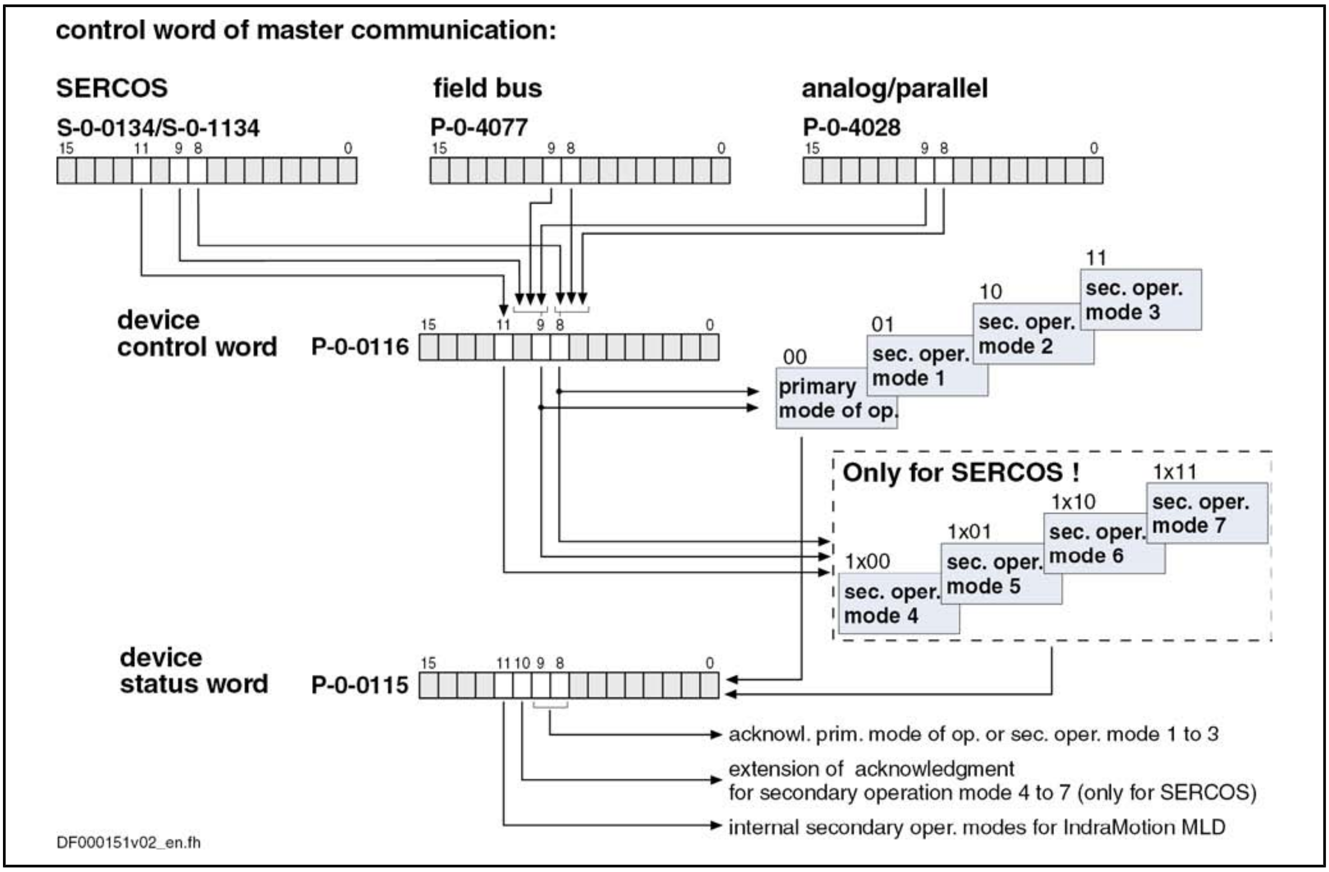


Fig.7-2: Operating Mode Selection via Control Word

☞ The control bits (8 and 9) contained in parameter P-0-0116 are also contained in the control words depending on the master communication (cf. S-0-0134, P-0-4077, P-0-4068 and P-0-4028) and can therefore be written via the control words.

An operating mode defined via the operating mode selection is active when:

- The drive (control section and power section) is ready for operation

- and -

- The drive enable signal sees a positive edge.

Acknowledging the Active Operating Mode

As regards the activation of an operating mode, there are the following kinds of feedback:

- With active operating mode, the display of the control panel reads "AF".
- In parameter "S-0-0390, Diagnostic message number", the respective diagnostic message number of the active operating mode is displayed (e.g. "A0101" in "velocity control" mode).
- In parameter "S-0-0095, Diagnostic message", the active operating mode is displayed in text form (e.g. "A0101 Velocity control").
- In parameter "P-0-0115, Device control: Status word", bit 3 ("drive follows external command values") is used to acknowledge whether the drive is running in the preset operating mode or not.
- In parameter "P-0-0115, Device control: Status word", bits 8, 9 and 10 ("acknowledgment of operating mode") are used to signal the operating mode presently active.

☞ The status bits contained in parameter P-0-0115 (3, 8, 9 and 10) are also contained in the status words depending on the master communication (S-0-0135, P-0-4078) and can therefore be read in the status words. Bit 10, however, is only activated with SERCOS interface!

See also "Device Control and State Machines"

Changing the Operating Mode

When drive enable is activated, the drive, after having gone through the initialization routines, changes to the operating mode that was selected via bits 8 and 9 of the specific control word of the respective master communication (S-0-0134, P-0-4077, P-0-4068 4028 or P-0-0116).

☞ The change of operating modes is carried out within one position loop clock (Advanced: 250 µs; Basic: 500 µs). Another position loop clock passes until the command values of the activated operating mode become effective, because the initialization of the operating mode is carried out first.

Special Cases

With the following **exceptional circumstances**, the desired operating mode is not carried out in spite of the operating mode having been correctly selected:

- **Drive error** is present

  → The corresponding error reaction is carried out.

- **Fatal warning** was triggered

  → The corresponding reaction is carried out.

- A "**drive command**" (e.g. homing procedure, set absolute measuring, ...) is executed

  → The command started is carried out.

- **Drive Halt**

  → This drive function is carried out.

See also "Device Control and State Machines"

Drive-Controlled Change of Operating Mode

In order to achieve a quick and smooth change of operating mode in running operation, it is possible to make a "drive-controlled change of operating mode". Drive-internally this procedure ensures that, when the operating mode is changed, the transition is carried out in a synchronized way, even if the command value changes abruptly.

See also "Command Value Adjustment with Position Control"

Command Value Acceptance and Acknowledgment

Immediate Command Value Acceptance

Each preset command value is accepted immediately, when the respective command value parameter (e.g. S-0-0036, S-0-0080, S-0-0258, …) is written in the case of the operating modes:

- Torque/force control
- Velocity control
- Position control with cyclic command value input
- Drive-internal Interpolation
- Synchronization modes:
  - Velocity synchronization with real/virtual master axis

– Phase synchronization with real/virtual master axis
– Electronic cam with real/virtual master axis
– Electronic motion profile with real/virtual master axis

Command Value Acceptance After Master Request

In the **positioning modes** (drive-controlled positioning, positioning block mode), however, the command value (target position, velocity, positioning block, ...) is only accepted, when the master explicitly requests this by a "command value acceptance".

The command value acceptance is carried out in a different way, according to the positioning mode or profile type:

- "Drive-controlled positioning" operating mode

  Acceptance of preset command value (position, velocity) by toggling bit 0 of parameter "S-0-0346, Positioning control word"

  → **Toggle mechanism**
- "Positioning block mode" operating mode

  Acceptance of the positioning block selected via "P-0-4026, Positioning block selection" by a 0-1 edge of bit 0 of parameter "P-0-4060, Positioning block control word", when the parallel interface or, in the case of field buses, the I/O mode is used as master communication

  → **Edge control**

☞ When the positioning block mode is used for field buses in the freely configurable operating mode (P-0-4084 = 0xFFFE) or with SERCOS interface, the toggle mechanism is used **in spite of the above rule**.

Command Value Acknowledgment

The explicit acknowledgment of the command value acceptance only takes place for the positioning modes (drive-controlled positioning, positioning block mode).

It is possible to check in the master whether and when the preset command value was accepted in the drive (command value acceptance handshake).

The command value acknowledgment is carried out in a different way, according to the positioning mode:

- "Drive-controlled positioning" operating mode

  The drive acknowledges the command value acceptance by toggling bit 0 of parameter "S-0-0419, Positioning command acknowledge".
- "Positioning block mode" operating mode

  The drive acknowledges the command value acceptance by displaying the effective positioning block in parameter "P-0-4051, Positioning block acknowledgment".

☞ In the positioning block mode, too, the acceptance of a new positioning block causes bit 0 of parameter S-0-0419 to be toggled, because in this case the internal processing of the positioning command values is identical to the "drive-controlled positioning" mode.

7.2 Torque/Force Control

7.2.1 Brief Description

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

In the "torque/force control" mode, a torque/force command value is preset for the drive. If required, this command value can be filtered. When the operating mode has been activated, the diagnostic message is "A0100 Torque control".

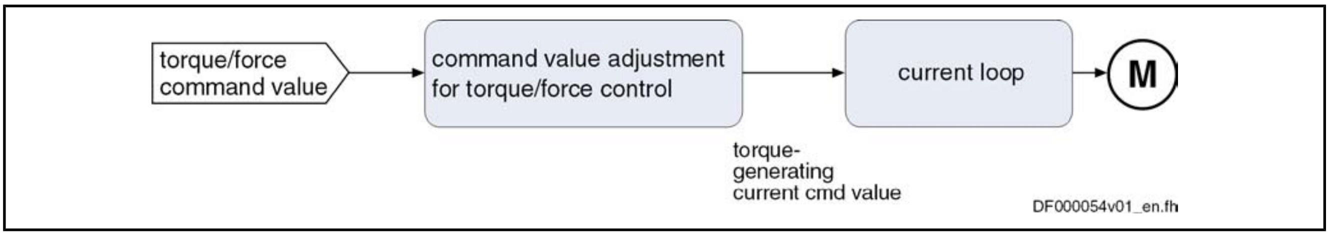


Fig.7-3: "Torque/Force Control" Block Diagram

Features

- Torque/force control with regard to the sum of the command values preset in parameters "S-0-0080, Torque/force command value" and "S-0-0081, Additive torque/force command value"
- Torque/force command value is generated internally by the velocity loop; value of S-0-0081 can be added as additive component
- Limitation of the preset command value to limit value that can be parameterized
- Command value filtered via "S-0-0822, Torque/force ramp" and "S-0-0823, Torque/force ramp time"

Pertinent Parameters

- S-0-0080, Torque/force command value
- S-0-0081, Additive torque/force command value
- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0109, Motor peak current
- S-0-0110, Amplifier peak current
- S-0-0111, Motor current at standstill
- S-0-0822, Torque/force ramp
- S-0-0823, Torque/force ramp time
- S-0-0824, Status "Torque/force command value attained"
- P-0-0001, Switching frequency of the power output stage
- P-0-0038, Torque-generating current, command value
- P-0-0049, Effective torque/force command value
- P-0-0051, Torque/force constant
- P-0-0109, Torque/force peak limit
- P-0-4046, Effective peak current

Pertinent Diagnostic Messages

- A0100 Torque control
- E8057 Device overload, current limit active
- E8260 Torque/force command value limit active
- F8079 Velocity limit value exceeded

7.2.2 Command Value Adjustment in Torque/Force Control

Principle of Command Value Adjustment

Filtering the Command Value

The command value preset by "S-0-0080, Torque/force command value" is filtered. The filter effect can be changed by setting "S-0-0822, Torque/force ramp" and "S-0-0823, Torque/force ramp time".

The message "torque/force command value reached" (S-0-0824) signals that the output value of the filter has reached the input value (S-0-0080).

Additive Current Command Value

In addition, it is possible to add an unfiltered additive command value via "S-0-0081, Additive torque/force command value". If required, this value can be cyclically configured.

Command Value Limitation

We distinguish the following command value limitations:

- Torque/force limitation
- Current limitation

On the user side, it is only possible to directly set the torque/force limits. By setting the switching frequency (P-0-0001), the value of the current limit is indirectly influenced.

Output Variable

The output variable of the command value adjustment for torque/force control is the torque-generating component of the current command value Iq_{cmd} (P-0-0038).

Block Diagram

The figure below illustrates command value processing in the "torque/force control" mode as a block diagram.

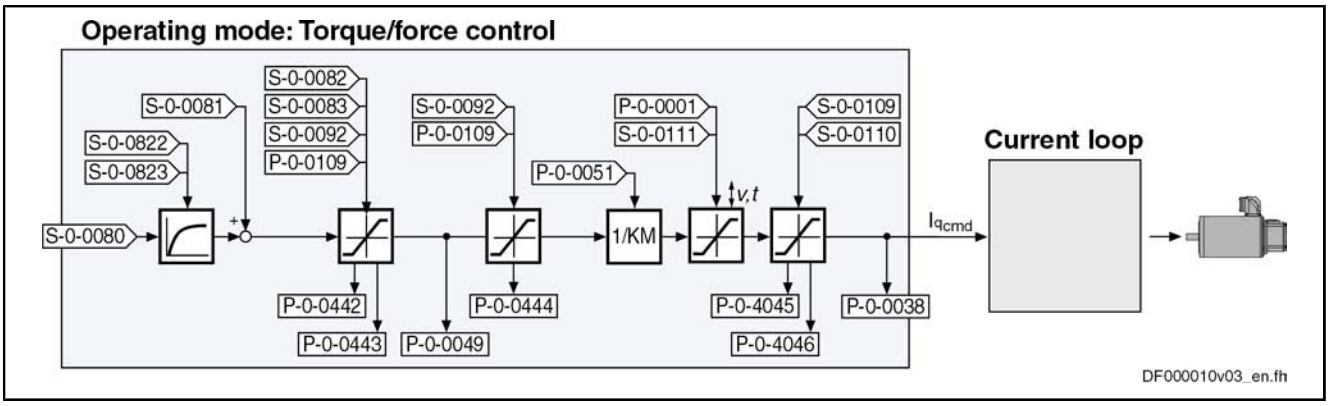


Fig.7-4: Command Value Adjustment in Torque/Force Control

The currently effective actual limit values are displayed (P-0-0442, P-0-0443, P-0-0444; P-0-4045, P-0-4046); so is the output variable of the command value adjustment in torque/force control, the torque-generating component of the current command value (P-0-0038).

Velocity Monitor

In torque/force control, the velocity of the drive is reached depending on the component of the drive torque or the drive force acting on the acceleration. As the velocity of a motor or an axis has to stay within the allowed range in order to avoid damage, the actual velocity value is monitored.

If the value of "S-0-0040, Velocity feedback value" exceeds the 1.125-fold value of "S-0-0091, Bipolar velocity limit value", the drive generates the error message "F8079 Velocity limit value exceeded" and switches off with the error reaction that was set.

7.2.3 Current Loop

Operating Principle of the Current Loop

The current loop is a typical PI loop and can be set via the following parameters:

- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1

See also "Control Loop Structure"

See also "Motor Control"

In fact, the torque is not closed-loop controlled but open-loop controlled. Given the linear relation between torque and current (see P-0-0051), it is possible, however, to assume closed-loop torque/force control. Just the absolute torque precision is limited due to manufacturing tolerances of the motor (max. ±10%).

Control Loop Performance and Cycle Times

According to the available hardware (Basic or Advanced design), the current control loop is closed every 62.5 µs (Advanced) or 125 µs (Basic). (See also "P-0-0556, Config word of axis controller", bit 2.)

7.3 Velocity Control

7.3.1 Brief Description

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

In the "velocity control" mode, a velocity command value is preset for the drive. The velocity command value is limited by ramps and filters.

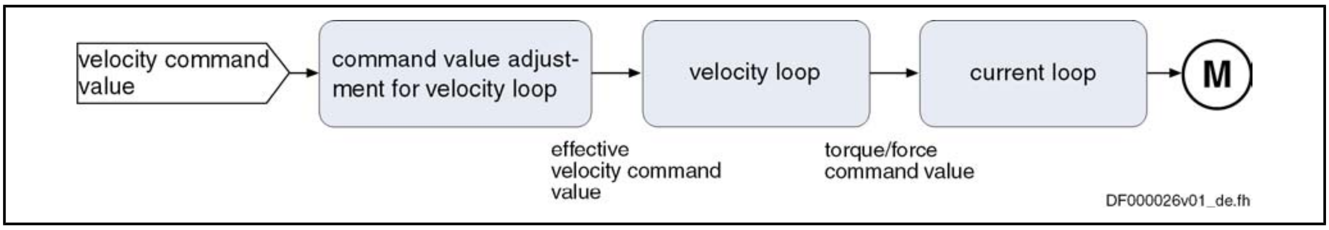


Fig.7-5: "Velocity Control" Block Diagram

Features

- Input of an external velocity command value (total of

  "S-0-0036, Velocity command value" and "S-0-0037, Additive velocity command value") via analog inputs or master communication interface (SERCOS, field bus, ...)
- Selection of predefined and internally stored velocity command values (31 fixed values) is possible via binarily coded digital inputs (e.g. for jogging forward/backward, feeding, setting up, ...) with separately definable acceleration and deceleration ramps (31 different ramps), as well as jerk filter to be set (31 different time constants)
- Use of a drive-internal command value generator for generating command value ramps ("motor potentiometer")
- Inversion of the provided velocity command value before it is processed in the ramp-function generator

- Window comparator for masking critical velocity ranges in the command value channel (e.g. machine resonances) with corresponding acceleration adjustment (see P-0-1209)
- Ramp-function generator with separately adjustable, two-stage acceleration and deceleration limits of the preset velocity command value; switching from ramp 1 to ramp 2 is done with selectable velocity and run-up stop that can be parameterized
- Velocity control via a digital PI loop with extensive filter measures
- Monitoring the command velocity and actual velocity for exceeding parameter "S-0-0091, Bipolar velocity limit value"
- Smoothing of velocity control loop difference via filter that can be parameterized
- Smoothing of preset command value by means of average filter (jerk limitation by means of moving average filter)
- Fine interpolation of the velocity command values; transmission of these command values in the position loop clock; fine interpolator can be switched on or off (P-0-0556, bit 0)
- Velocity control loop monitoring (cannot be parameterized) to prevent the drive from running away; monitor can be switched on or off (P-0-0556, bit 1)
- Velocity loop internally generates the torque/force command value to which the value of parameter "S-0-0081, Additive torque/force command value" can be added as an additive component
- Control word and status word especially for "velocity control" mode (P-0-1200 and P-0-1210)

Pertinent Parameters

- S-0-0036, Velocity command value
- S-0-0037, Additive velocity command value
- S-0-0091, Bipolar velocity limit value
- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time
- P-0-0004, Velocity loop smoothing time constant
- P-0-0048, Effective velocity command value
- P-0-0556, Config word of axis controller
- P-0-1119, Velocity mix factor feedback 1 & 2(valid only for single-axis firmware MPB16 and multi-axis firmware MPM16)
- P-0-1120, Velocity control loop filter: Filter type
- P-0-1126, Velocity control loop: Acceleration feedforward
- P-0-1200, Control word 1 velocity control
- P-0-1201, Ramp 1 pitch
- P-0-1202, Final speed ramp 1
- P-0-1203, Ramp 2 pitch
- P-0-1206, Memory of velocity command values
- P-0-1207, Lower limit of velocity masking window
- P-0-1208, Upper limit of velocity masking window
- P-0-1209, Acceleration factors for velocity masking window
- P-0-1210, Status word of velocity control mode

- P-0-1211, Deceleration ramp 1
- P-0-1213, Deceleration ramp 2
- P-0-1214, Control word 2 velocity control
- P-0-1215, Motor potentiometer, acceleration
- P-0-1216, Motor potentiometer, deceleration
- P-0-1217, Motor potentiometer, step size
- P-0-1218, Motor potentiometer, command value
- P-0-1222, Velocity command filter
- P-0-1223, List of acceleration ramps
- P-0-1224, List of deceleration ramps
- P-0-1225, List of smoothing time constants

Pertinent Diagnostic Messages

- A0101 Velocity control
- E2059 Velocity command value limit active
- E2063 Velocity command value > limit value
- F8078 Speed loop error
- F8079 Velocity limit value exceeded

7.3.2 Command Value Adjustment in Velocity Control

Overview

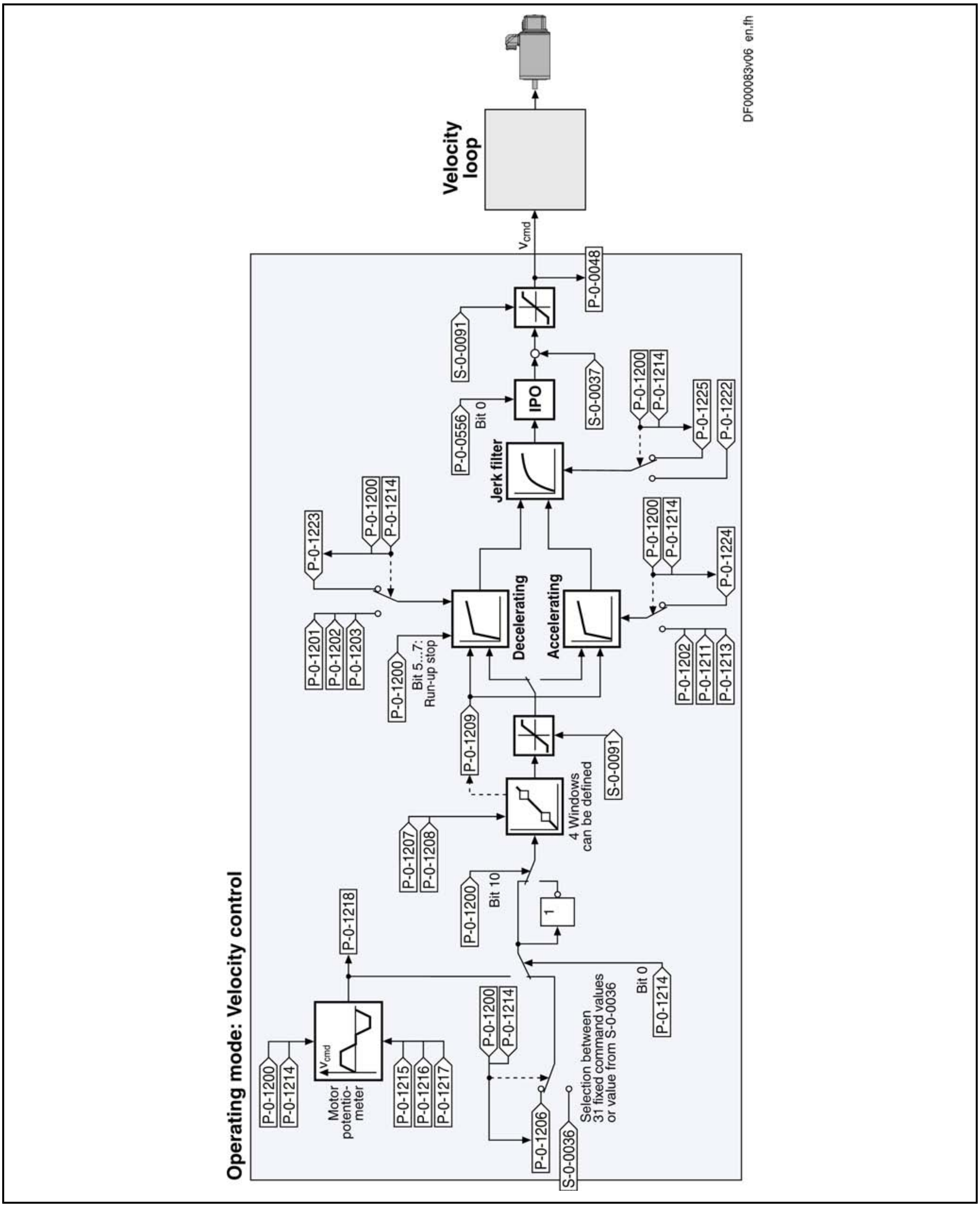


Fig.7-6: Command Value Adjustment in Velocity Control

☞ The value of "S-0-0037, Additive velocity command value" can be added to "S-0-0036, Velocity command value" directly at the input of the velocity loop.

In the "velocity control" mode, velocity command values can be input in the following ways:

- Cyclic command value input by means of "S-0-0036, Velocity command value" via the master communication (analog interface, SERCOS, field bus)
- Using velocity command values internally stored in the drive in "P-0-1206, Memory of velocity command values" (list parameter); selection via digital inputs, master communication interface (SERCOS, field bus)
- Internal generation of command value ramps by a so-called motor potentiometer

The velocity command value is processed by the so-called ramp-function generator.

☞ Information on the status of the ramp-function generator is contained in P-0-1210.

See Parameter Description "P-0-1210, Status word of velocity control mode"

Command Value Generation via Memory of Fixed Command Values

Via the selection bits of parameter "P-0-1200, Control word 1 velocity control" (bit 0...4), you can choose from up to 31 velocity command values (P-0-1206) stored in the drive.

☞ By default, you can only select 5 fixed command values via P-0-1200; one fixed command value is assigned to each individual bit (0...4).

Activating the Fixed Command Values

As soon as at least one of the bits 0...4 has been set in P-0-1200, the corresponding element from the list parameter "P-0-1206, Memory of velocity command values" takes effect.

The following assignment applies to the selection via bits 4…0 of P-0-1200:

- For **direct selection** (P-0-1214, bit 8 = 0)
  - 00000 → Value from S-0-0036 active
  - 0000**1** → Fixed value 1 from P-0-1206 selected and active
  - 000**1**0 → Fixed value 2 from P-0-1206 selected and active
  - 00**1**00 → Fixed value 3 from P-0-1206 selected and active
  - 0**1**000 → Fixed value 4 from P-0-1206 selected and active
  - **1**0000 → Fixed value 5 from P-0-1206 selected and active
- For **binary selection** (P-0-1214, bit 8 = 1)
  - 00000 → Value from S-0-0036 active
  - 0000**1** → Fixed value 1 from P-0-1206 selected and active
  - 000**10** → Fixed value 2 from P-0-1206 selected and active
  - 000**11** → Fixed value 3 from P-0-1206 selected and active
  - etc.
  - **11111** → Fixed value 31 from P-0-1206 selected and active

Via the same control bits of parameter P-0-1200, it is in addition possible to select ramp pitches, as well as time constants for the command value smoothing filter (see sections "Ramp-Function Generator" and "Jerk Limitation").

See also Parameter Description "P-0-1200, Control word 1 velocity control" and "P-0-1214, Control word 2 velocity control"

Command Value Generation via Motor Potentiometer

In the operating mode "velocity control", the command value generator (so-called motor potentiometer) provides the possibility of generating a velocity command value characteristic (P-0-1218, Motor potentiometer, command value) via digital input signals ("ramp+" and "ramp–").

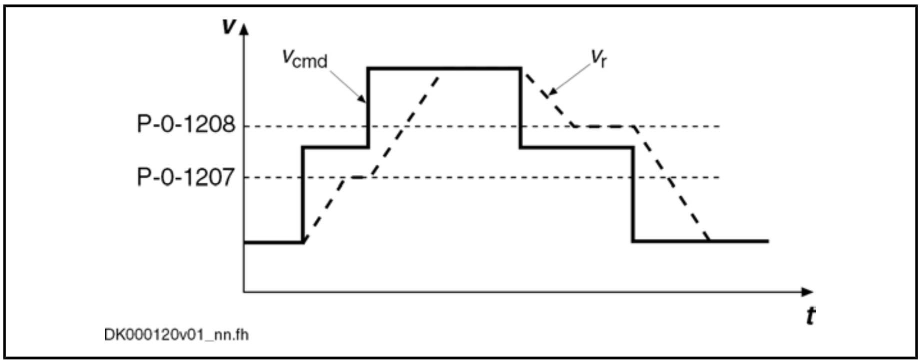
The motor potentiometer is activated by setting bit 0 = 1 in "P-0-1214, Control word 2 velocity control".

Inverting the Velocity Command Value

Before it is processed in the ramp-function generator, the provided velocity command value can be inverted. The value is inverted by setting bit 10 = 1 in "P-0-1200, Control word 1 velocity control".

Masking the Command Value

The masking windows (max. 4) that can be defined via "P-0-1207, Lower limit of velocity masking window" and "P-0-1208, Upper limit of velocity masking window" are used to suppress resonance phenomena of a machine or in an installation. The drive should not be permanently moved at velocities within these windows. A velocity command value within the value range of one of the 4 definable windows is either reduced to the lower limit (P-0-1207) or increased to the upper limit (P-0-1208).

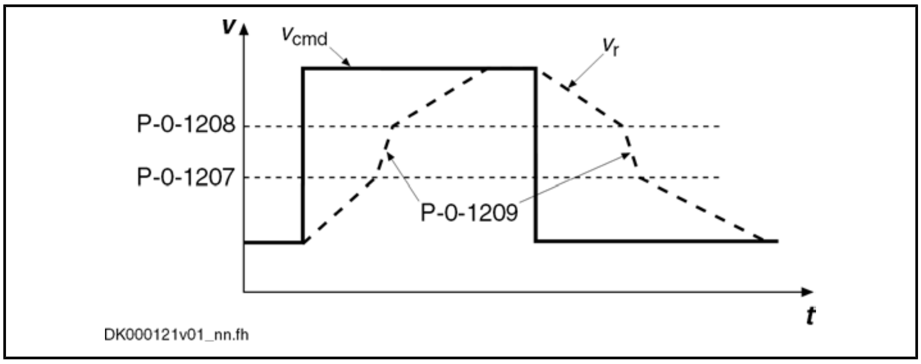


P-0-1207	Lower limit of velocity masking window
P-0-1208	Upper limit of velocity masking window
v_{cmd}	Velocity command value
v_r	Velocity ramp

Fig.7-7: Function "Velocity Masking Window With Hysteresis"

See also Parameter Description "P-0-1207, Lower limit of velocity masking window" and "P-0-1208, Upper limit of velocity masking window"

The subsequent ramp-function generator passes the range of the velocity window; the values indicated in "P-0-1209, Acceleration factors for velocity masking window" have a multiplying effect on the acceleration values of the ramp-function generator (P-0-1201, P-0-1203, P-0-1211 and P-0-1213).



P-0-1207	Lower limit of velocity masking window
P-0-1208	Upper limit of velocity masking window
P-0-1209	Acceleration factors for velocity masking window
v_{cmd}	Velocity command value
v_r	Velocity ramp

Fig.7-8: Operating Principle of the Acceleration Factors From P-0-1209

See also Parameter Description "P-0-1209, Acceleration factors for velocity masking window"

Ramp-Function Generator

For the ramp-function generator, we make the following distinction:

- cyclic command value input via S-0-0036 or motor potentiometer

  → 2 ramps (acceleration and deceleration) and a jerk filter take effect

  Note: For command value input via S-0-0036, also the ramp pitches and the filter time constants can be selected from the list parameters P-0-1223, P-0-1224, P-0-1225 by the control bits in P-0-1200. This option is activated via Bit 9 in "P-0-1214, Control word 2 velocity control".
- Command value input via memory of fixed command values (P-0-1206)

  → 31 sets with individually definable command velocities, jerk limits and acceleration and deceleration ramps can be defined

Command Value Input via S-0-0036 or Motor Potentiometer

The increase (acceleration) and deceleration of the velocity command value input via "S-0-0036, Velocity command value" or a motor potentiometer can be limited in steps via 2 ramps.

- Acceleration process

  → In the first step, the increase of the command value is limited via "P-0-1201, Ramp 1 pitch" (acceleration ramp 1). If the command velocity exceeds the threshold entered in "P-0-1202, Final speed ramp 1", the increase of the command value is limited with the value of "P-0-1203, Ramp 2 pitch" (acceleration ramp 2).
- Deceleration or braking process

  → For the deceleration, "P-0-1211, Deceleration ramp 1" and/or "P-0-1213, Deceleration ramp 2" are used accordingly.

This allows parameterizing different ramps for the acceleration and braking process.

Command Value Input via Memory of Fixed Command Values

With command value input via the memory of fixed command values (P-0-1206), separate ramp values can be defined for each of the 31 fixed command values via the following list parameters:

- P-0-1223, List of acceleration ramps
- P-0-1224, List of deceleration ramps

These are single-step ramps, i.e. one ramp pitch applies to the entire speed range. Via control bits (bits 0…4) in "P-0-1200, Control word 1 velocity control", the single-step ramps can be selected.

☞ The fixed command values (P-0-1206) and the corresponding time constants of the jerk filter (P-0-1225) are selected via the control bits in P-0-1200!

The assignment of bits 0...4 of parameter P-0-1200 depends on bit 8 of parameter "P-0-1214, Control word 2 velocity control" (see "Activating the Fixed Command Values" in section "Command Value Generation via Memory of Fixed Command Values").

Run-Up Stop

When there is acceleration-dependent torque limitation occurring or due to installation-dependent failures/irregularities, it is necessary to interrupt the acceleration ramp. For this purpose, the function "run-up stop" was introduced that is controlled via "P-0-1200, Control word 1 velocity control".

Possible settings for activating the function "run-up stop" via the respective bits of P-0-1200:

- Activation of the function without additional condition
- Triggering of torque limitation (E2060)
- Triggering of command value limitation (cf. S-0-0091)
- Triggering of command value or torque limitation

☞ While a speed masking window is passed, the function "run-up stop" is deactivated.

Jerk Limitation

The velocity command value, the increase and maximum of which are limited, is jerk-limited by means of a 1st order filter.

For jerk limitation, we make the following distinction:

- Cyclic command value input via S-0-0036 or motor potentiometer

  → Jerk limitation takes effect as set in parameter P-0-1222
- Command value input via memory of fixed command values (P-0-1206)

  → Jerk limitation can be separately defined for each of the 31 fixed command values by an individual smoothing time constant (P-0-1225)

Command Value Input via S-0-0036 or Motor Potentiometer

The command value input via "S-0-0036, Velocity command value" or a motor potentiometer is jerk-limited according to the settings in "P-0-1222, Velocity command filter".

Command Value Input via Memory of Fixed Command Values

With command value input via the memory of fixed command values (P-0-1206), an individual filter time constant (P-0-1225, List of smoothing time constants) can be configured for each of the 31 fixed command values; the filter time constant is selected via the control bits (bits 0…4) of parameter "P-0-1200, Control word 1 velocity control".

☞ The control bits in P-0-1200 are also used to select the fixed command values (P-0-1206) and the corresponding ramp pitches (P-0-1223 and P-0-1224)!

The assignment of bits 0...4 of parameter P-0-1200 depends on bit 8 of parameter "P-0-1214, Control word 2 velocity control" (see "Activating the Fixed Command Values" in section "Command Value Generation via Memory of Fixed Command Values").

Command Value Limitation

The effective velocity command value (sum of values from S-0-0036 and S-0-0037) is limited to the value indicated in "S-0-0091, Bipolar velocity limit value" or in the parameters "S-0-0038, Positive velocity limit value" or "S-0-0039, Negative velocity limit value".

See also "Velocity Limitation"

☞ When the limitation takes effect, the drive generates the message "E2059 Velocity command value limit active".

Fine Interpolation

The limited command value available at the output of command value processing can be adjusted, by means of linear fine interpolation, for further processing in the velocity loop. To do this, a command value input in the position loop clock is fine interpolated in the velocity loop clock.

This function has to be activated via bit 0 of parameter "P-0-0556, Config word of axis controller".

7.3.3 Velocity Control Loop

Velocity Loop

The velocity loop is a typical PI loop and can be set via the following parameters:

- S-0-0100, Velocity loop proportional gain
- S-0-0101, Velocity loop integral action time

See also "Control Loop Structure"

Control Loop Performance and Cycle Times

The minimum possible control loop cycle time of the velocity loop depends

- on the existing device (economy, basic, multi-axis)
- on the respective firmware variant (MPE, MPB or MPM)

- and -

- in the case of variant MPB, on the parameterized performance (basic or advanced; see "P-0-0556, "P-0-0556, Config word of axis controller", bit 2).

See "Performance Data"

Current Loop in Velocity Control Loop

In velocity control, the outer current control loop (cascade structure), that can be set via the following parameters, always takes effect, too:

- S-0-0106, Current loop proportional gain 1
- S-0-0107, Current loop integral action time 1
- P-0-0001, Switching frequency of the power output stage

See also "Torque/Force Control: Current Loop"

Possibilities of Filtering

To filter noise components possibly present in the actual velocity value or to attenuate resonance frequencies, the following filter settings can be made:

- Via "P-0-0004, Velocity loop smoothing time constant", the low-pass filter that filters the control difference for the velocity loop can be set.
- To filter the control deviation, it is possible to configure four filters connected in series as low-pass filters or band-stop filters with "P-0-1120, Velocity control loop filter: Filter type".

"S-0-0081, Additive torque/force command value" is added to the output signal of the velocity loop and the resulting value is transmitted to the current and torque/force limit (see also "Current and Torque/Force Limitation").

7.4 Position Control With Cyclic Command Value Input

7.4.1 Brief Description

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

In the "position control" mode, a cyclic position command value is preset for the drive in NC cycle time. This command value is fine interpolated in the drive and jerk-limited via filters, if necessary, before being transmitted to the position loop.

To minimize the lag error, variable acceleration feedforward is available in addition to variable velocity feedforward.

There are different forms of the "position control" mode which result in the corresponding diagnostic messages when the operating mode was activated (see below "Pertinent Diagnostic Messages").

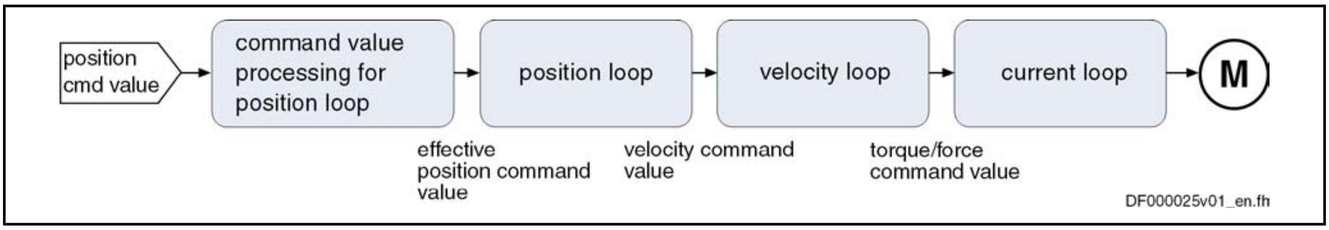


Fig.7-9: "Position Control With Cyclic Command Value Input" Block Diagram

Features

- Position control with regard to the command value preset in parameter "S-0-0047, Position command value"
- NC-controlled or drive-controlled position control with internal, dynamic synchronization when changing operating modes
- Timebase for cyclic command value input defined by "S-0-0001, "
- Monitoring of the position command value difference for exceeding parameter "S-0-0091, Bipolar velocity limit value"
- Position command values of the control unit smoothed by means of adjustable average value filter; calculation from acceleration and jerk limit values; display in parameter "P-0-0042, Current position command average value filter order"
- Fine interpolation of position command value of the control unit to position loop clock; can be switched via "P-0-0187, Position command processing mode"
- Adjustable position command value delay in position cycle times (P-0-0456, Position command value delay), maximally 32 cycles.

- Position control with regard to actual position value encoder 1 (motor encoder) or actual position value encoder 2 [external (load-side) encoder], can be dynamically switched
- Velocity feedforward through adjustable factor of 0…150 % (default = 100 %)
- Acceleration monitor for position command value can be switched on (P-0-0556, bit 15)

☞ The condition for this operating mode is synchronous communication between the control unit and the drive, as it is the case with SERCOS interface, for example.

Pertinent Parameters

- S-0-0047, Position command value
- S-0-0091, Bipolar velocity limit value
- S-0-0138,
- P-0-0010, Excessive position command value
- P-0-0011, Last valid position command value
- P-0-0041, Position command average value filter time constant
- P-0-0042, Current position command average value filter order
- P-0-0047, Position command value control
- P-0-0059, Additive position command value, controller
- P-0-0099, Position command smoothing time constant
- P-0-0142, Synchronization acceleration
- P-0-0143, Synchronization velocity
- P-0-0187, Position command processing mode
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457,
- P-0-0556, Config word of axis controller

Pertinent Diagnostic Messages

- A0102 Position mode, encoder 1
- A0103 Position mode, encoder 2
- A0104 Position mode lagless, encoder 1
- A0105 Position mode lagless, encoder 2
- A0154 Position mode drive controlled, encoder 1
- A0155 Position mode drive controlled, encoder 2
- A0156 Position mode lagless, encoder 1 drive controlled
- A0157 Position mode lagless, encoder 2 drive controlled
- F2037 Excessive position command difference

7.4.2 Command Value Adjustment in Position Control

NC- or Drive-Controlled Position Control

We distinguish the following characteristics of the operating mode "position control with cyclic command value input":

- **NC-controlled position control** (cf. A0102 to A0105)

  The drive generally follows the position command values cyclically input by the master in the NC cycle.
- **Drive-controlled position control** (cf. A0154 to A0157)

In the case of a change of operating mode to cyclic position control, the drive realizes the corresponding synchronization process, i.e. it generates, internally by means of the internal synchronization parameters (P-0-0142, P-0-0143, P-0-0154, P-0-0151), a smooth transition of the internal position command value from the current actual position to the new command value characteristic input by the NC. After the synchronization process has been completed, the drive follows the position command values input by the master in the NC cycle.

The command value cyclically transmitted by the control unit is displayed in parameter "P-0-0047, Position command value control".

The internal position command value at the position loop is displayed in parameter "P-0-0434, Position command value of controller". If required, it can also be read via parameter "S-0-0047, Position command value".

Command Value Filtering (Jerk Limitation)

The position command values preset by the control unit can be smoothed via an average value filter that can be set ("P-0-0041, Position command average value filter time constant", moving average filter for a maximum of 64 values). The resulting filter degree is displayed via "P-0-0042, Current position command average value filter order". This filter can be used for jerk limitation.

In the case of drive-controlled position control, a jump of the position command value is traveled by a change of the position command average value filter with synchronization motion in control.

The PT1 filter for jerk limitation that can be parameterized via "P-0-0099, Position command smoothing time constant" only takes effect for linear fine interpolation.

Fine Interpolation of the Position Command Value

The position command value cyclically transmitted in the NC cycle time by the control unit can be fine interpolated in the drive, if necessary.

Via "P-0-0187, Position command processing mode", it is possible to switch between:

- Cubic fine interpolator (according to contour),
- Linear fine interpolator or
- Cubic approximator.

See also Parameter Description "P-0-0187, Position command processing mode"

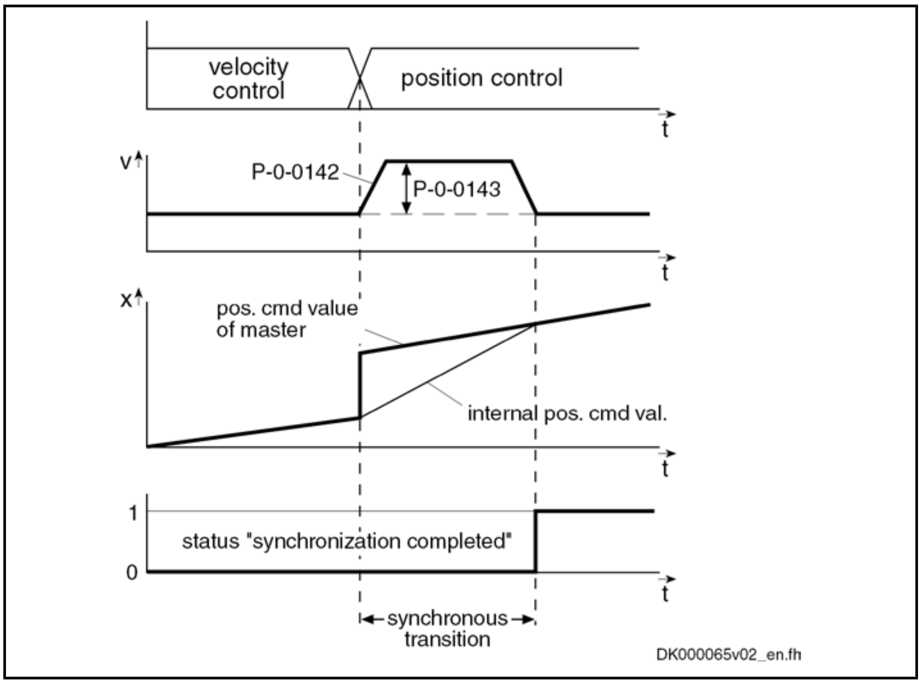
It is recommended to use the cubic fine interpolator according to contour (default setting), because it provides clearly higher quality of velocity and acceleration feedforward, particularly with lagless position control.

Position Command Value Delay

After the fine interpolator, the position command value can be delayed by maximally 32 position cycle times before it is fed into the position loop. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position cycle times is set by means of the position command value delay (P-0-0456). The undelayed position command value generator (P-0-0457) is entered into a ring buffer, the delayed position command value is then taken over into the position command value controller (P-0-0434).

Drive-Controlled Change of Operating Mode

During drive-controlled change of operating mode, the drive makes sure internally that when the operating mode is changed, the transition is carried out in a synchronized way, even if the command value changes abruptly.



P-0-0142 Synchronization acceleration
P-0-0143 Synchronization velocity
Fig.7-10: Time Diagram "Drive-Controlled Change of Operating Mode"

See also "Changing the Operating Mode"

Block Diagram

The figure below illustrates command value processing in the "position control" mode as a block diagram.

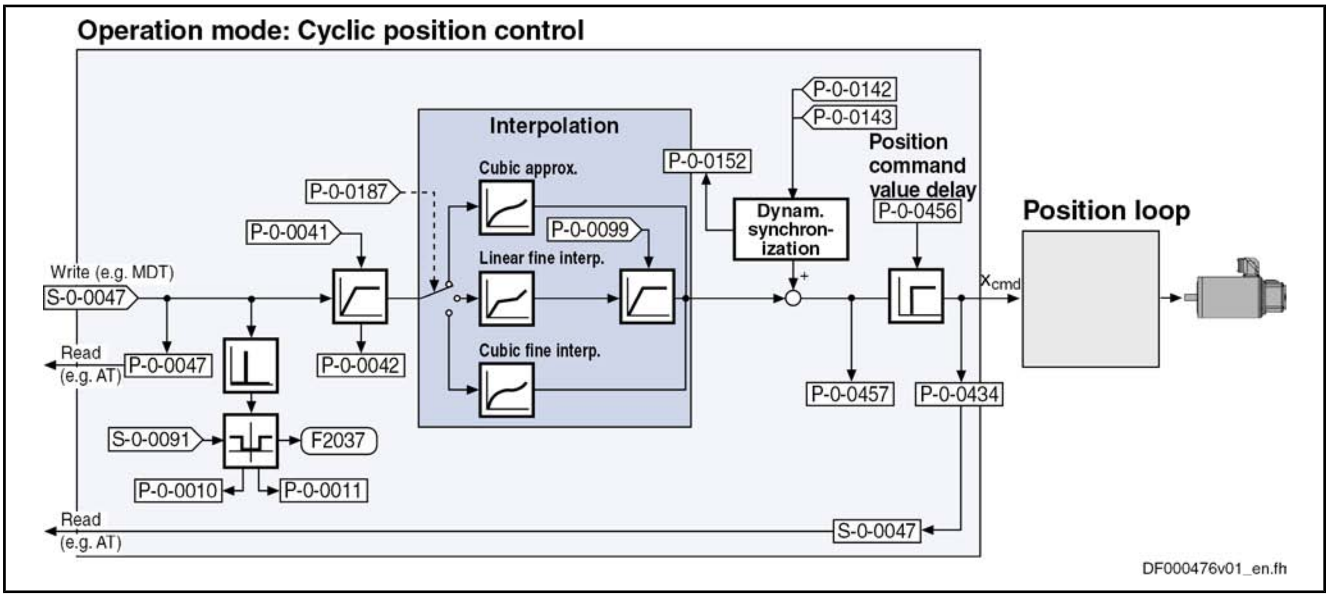


Fig.7-11: Command Value Adjustment in Position Control

See also "Position Loop" in the same section

See also "Velocity Loop" in section "Velocity Control"

See also "Current Loop" in section "Torque/Force Control"

7.4.3 Position Loop

The position loop is a simple P-loop, its proportional gain can be set with the value of "S-0-0104, Position loop Kv-factor".

See also "Control Loop Structure"

Control Loop Performance and Cycle Times

The position control loop is closed according to the available performance design (see "Performance Data").

According to the application, it is possible to set via bit 3 of the operating mode parameters (S-0-0032 to S-0-0035):

- Lagless operation (**with** velocity feedforward)
- Operation with lag error (**without** velocity feedforward)

The lag error is the difference between position command value and actual position value. The current value is stored in parameter "S-0-0189, Following distance".

> If the mechanical system and the application permit it, lagless operation should always be selected.

Possibilities of Feedforward

In lagless operation, variable acceleration feedforward can be activated in addition to variable velocity feedforward (parameter "P-0-0040, Velocity feedforward evaluation").

To do this, the acceleration-proportional feedforward component (additive current command value) is set via parameter "S-0-0348, Acceleration feedforward gain" and the velocity-proportional feedforward component (additive velocity command value) is set via "P-0-0040, Velocity feedforward evaluation".

This allows setting the lag error to a desired percentage value at constant velocity.

> In lagless operation and with P-0-0040 = 100%, there is a minimum lag error of "0" at constant velocity.

> In addition, it is possible to realize feedforward via parameter "P-0-1126, Velocity control loop: Acceleration feedforward", but this feedforward is derived from the velocity command value. Therefore, you have to make sure that you didn't activate both feedforward values by mistake!

See also "Axis Control: Position Loop (With Respective Feedforward Functions and Actual Value Adjustment)"

7.5 Drive-Internal Interpolation

7.5.1 Brief Description

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

The operating modes "drive-internal interpolation" and "drive-controlled positioning" allow time-optimized positioning of a single axis. The "drive-internal interpolation" mode is the basis for the more comprehensive functionality of the "drive-controlled positioning" mode.

In the "drive-internal interpolation" mode, a target position is directly preset for the drive. In the internal positioning generator, a position command value characteristic is generated (interpolated), from the preset value for the target position considering preset positioning data (velocity, acceleration and jerk), as the input value for the position loop.

There are different forms of the "drive-internal interpolation" mode which result in the corresponding diagnostic messages when the operating mode was activated (see below "Pertinent Diagnostic Messages").

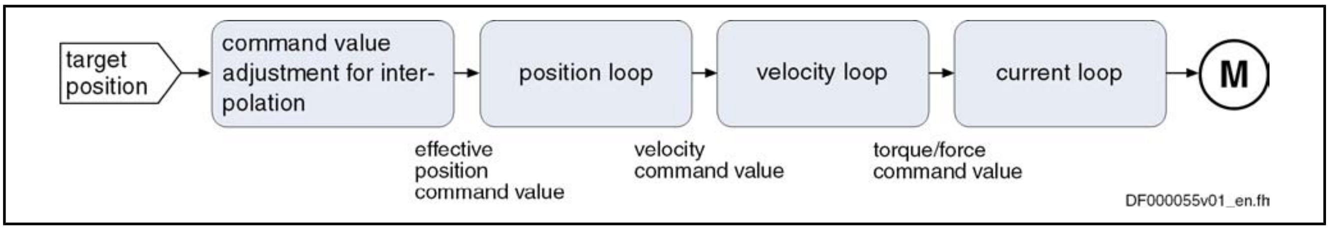


Fig.7-12: "Drive-Internal Interpolation" Block Diagram

Features

- Drive-internal generation of a position command value profile to travel to a preset target position (S-0-0258) while maintaining the positioning velocity (S-0-0259) and positioning acceleration (S-0-0260) or positioning deceleration (S-0-0359) that can be set; can be set separately
- The command value generation takes place in the NC cycle "S-0-0001, ". Transition into the position loop cycle by means of cubic fine interpolation.
- Jerk limitation of the generated position command value via "S-0-0193, Positioning jerk"
- Setting of the average value filter (jerk limitation) to fixed filter time by means of interpolation cmd value average value filter time constant (P-0-0641)
- Adjustable position command value delay in position cycle times (P-0-0456), maximally 32 cycles.
- Evaluation of the positioning velocity with "S-0-0108, Feedrate override"
- Monitoring of the positioning velocity for exceeding "S-0-0091, Bipolar velocity limit value"
- Monitoring of the target position for compliance with the position limit values
- Command value mode can be set (S-0-0393) in modulo format (shortest distance, only positive or only negative direction)
- Position control with regard to "S-0-0051, Position feedback value 1" (motor encoder) or "S-0-0053, Position feedback value 2" [external (load-side) encoder]
- Acceleration and deceleration ramps, can be set separately
- No change in direction of motion when

  "command value mode in modulo format" equal "shortest distance", if v_{act} > S-0-0417
- "Shortest distance" mode when "command value mode in modulo format" equal "only positive/negative direction of motion" and target position within "S-0-0418, Target position window in modulo mode"

☞ In this operating mode, it is possible to separately parameterize the acceleration and deceleration processes. This allows optimum adjustment to the respective application-specific requirements.

Pertinent Parameters

- S-0-0108, Feedrate override

- S-0-0138,
- S-0-0193, Positioning jerk
- S-0-0258, Target position
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0359, Positioning deceleration
- S-0-0393, Command value mode
- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode
- S-0-0430, Effective target position
- S-0-0437, Positioning status
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457,
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant

Pertinent Diagnostic Messages

- A0106 Drive-internal interpolation, encoder 1
- A0107 Drive-internal interpolation, encoder 2
- A0108 Drive controlled interpolation, lagless, encoder 1
- A0109 Drive controlled interpolation, lagless, encoder 2
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2055 Feedrate override S-0-0108 = 0
- F2057 Target position out of travel range

7.5.2 Command Value Adjustment With Drive-Internal Interpolation

The target position can be cyclically preset via parameter "S-0-0258, Target position".

The drive generates the position command value profile necessary to move to the target position, considering the requirements defined in the following parameters:

- S-0-0108, Feedrate override
- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0359, Positioning deceleration

☞ The target position preset by the control master is displayed in parameter S-0-0430.

The figure below illustrates command value processing in the "drive-internal interpolation" mode as a block diagram.

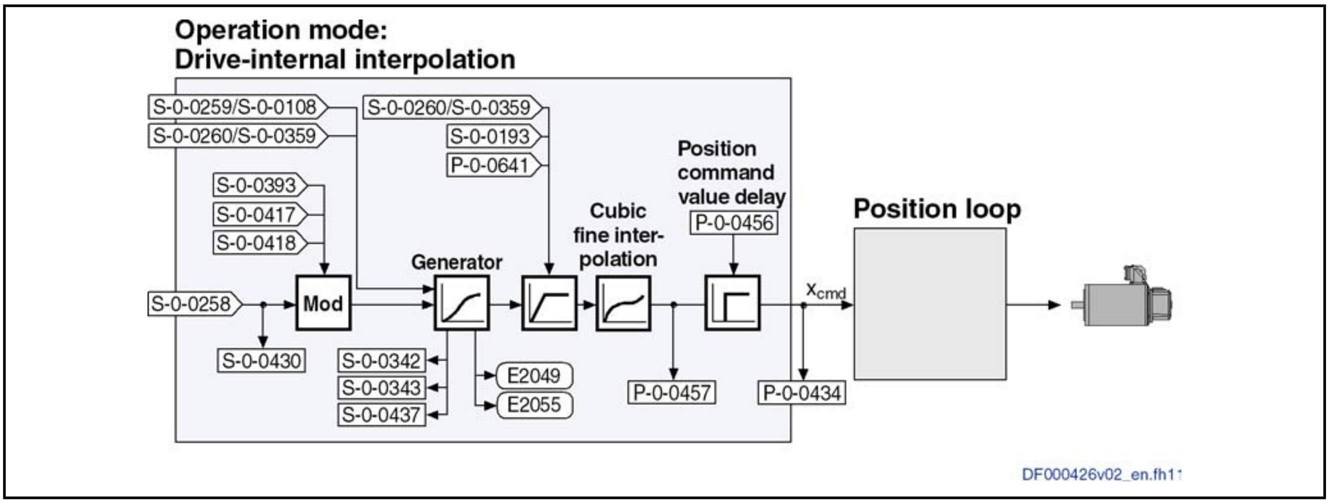


Fig.7-13: Command Value Adjustment With "Drive-Internal Interpolation"

7.5.3 Position Loop With Drive-Internal Interpolation

The position command value generated at the output of the command value generator is displayed in parameter "P-0-0434, Position command value of controller" and can be output at the analog output.

In this operating mode, the same information as relevant in the "position control with cyclic command value input" mode applies to the position control loop.

See also "Control Loop Structure"

See also "Position Loop" in section "Position Control With Cyclic Command Value Input"

7.6 Drive-Controlled Positioning

7.6.1 Brief Description

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

The operating modes "drive-internal interpolation" and "drive-controlled positioning" allow time-optimized positioning of a single axis. The "drive-internal interpolation" mode is the basis for the more comprehensive functionality of the "drive-controlled positioning" mode.

In the "drive-controlled positioning" mode, a positioning command value is preset for the drive. The drive can continue processing this value internally in absolute (position target) or relative (travel distance) form. In the internal interpolator, a position command value characteristic is generated as the input value for the position loop from the preset positioning data (effective target position, velocity, acceleration and jerk).

There are different forms of the "drive-controlled positioning" mode which result in the corresponding diagnostic messages when the operating mode was activated (see below "Pertinent Diagnostic Messages").

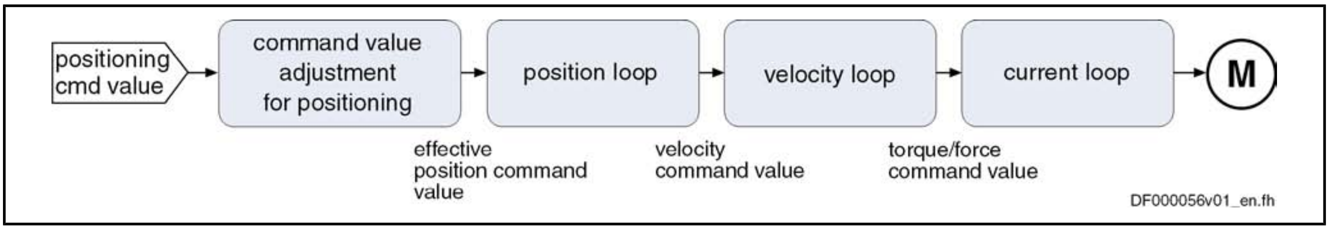


Fig.7-14: Drive-Controlled Positioning Block Diagram

Features

- Processing of an absolute target position or a relative travel distance
- Drive-internal generation of a position command value profile to travel to the positioning command value (S-0-0282) while maintaining the positioning velocity (S-0-0259) and positioning acceleration (S-0-0260) or positioning deceleration (S-0-0359) that can be set; can be set separately
- The command value generation takes place in the NC cycle "S-0-0001, ". Transition into the position loop cycle 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 cycle times (P-0-0456), maximally 32 cycles.
- Evaluation of the positioning velocity with parameter "S-0-0108, Feedrate override"
- Monitoring of the positioning velocity for exceeding the value in parameter "S-0-0091, Bipolar velocity limit value"
- Monitoring of the target position for compliance with the position limit values (see "S-0-0049, Positive position limit value", "S-0-0050, Negative position limit value")
- Command value mode can be set in modulo format in parameter "S-0-0393, Command value mode" (shortest distance, positive only or negative only direction, no reversal of direction of rotation)
- Position control with regard to "S-0-0051, Position feedback value 1" (motor encoder) or "S-0-0053, Position feedback value 2" [external (load-side) encoder]
- Acceleration and deceleration ramps can be set separately ("S-0-0260, Positioning acceleration" or "S-0-0359, Positioning deceleration")
- Position limit values taken into account when accepting target position, positioning velocity and positioning acceleration
- Jog mode ("infinite travel" positive/negative; S-0-0346, bits 1 and 2)
- Residual path processing can be activated
- "On-the-fly acceptance" of the new target position or intermediate stop

---

☞ In this operating mode, it is possible to separately parameterize the acceleration and deceleration processes in order to achieve optimum adjustment to the respective application-specific requirements.

Pertinent Parameters

- S-0-0108, Feedrate override
- S-0-0138,
- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0282, Positioning command value
- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0346, Positioning control word
- S-0-0359, Positioning deceleration
- S-0-0393, Command value mode
- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode
- S-0-0419, Positioning command acknowledge
- S-0-0430, Effective target position
- S-0-0437, Positioning status
- P-0-0059, Additive position command value, controller
- P-0-0434, Position command value of controller
- P-0-0456, Position command value delay
- P-0-0457,
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant

Pertinent Diagnostic Messages

- A0150 Drive-controlled positioning, encoder 1
- A0151 Drive-controlled positioning, encoder 1, lagless
- A0152 Drive-controlled positioning, encoder 2
- A0153 Drive-controlled positioning, encoder 2, lagless
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2055 Feedrate override S-0-0108 = 0
- F2050 Overflow of target position preset memory
- F2057 Target position out of travel range

7.6.2 Command Value Adjustment With Drive-Controlled Positioning

Overview

The figure below illustrates command value processing in the "drive-controlled positioning" mode as a block diagram.

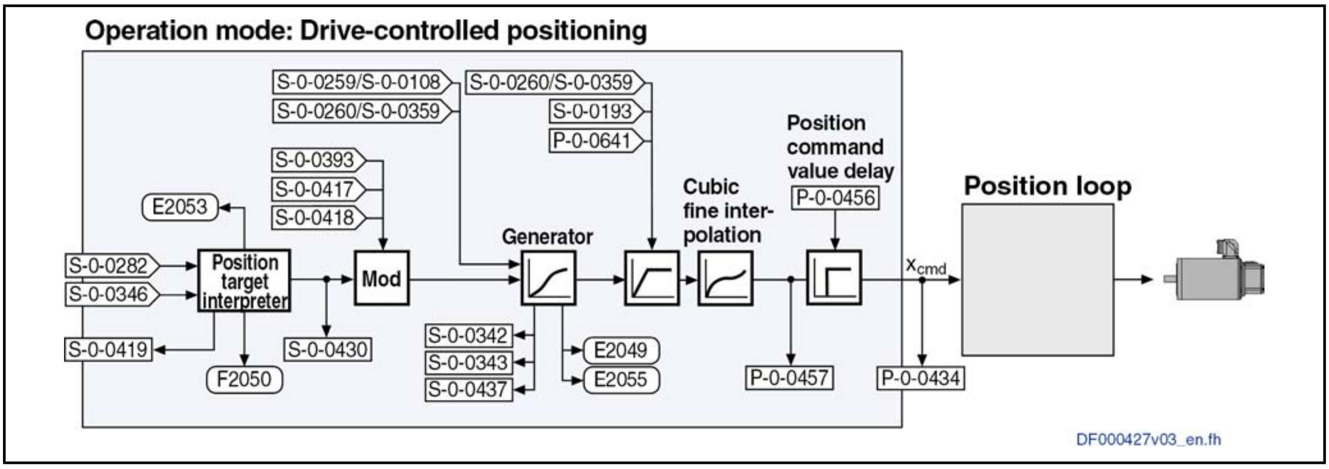


Fig.7-15: Command Value Adjustment With Drive-Controlled Positioning

Position Target Interpreter

Accepting and Acknowledging the Command Value

The acceptance and internal processing of "S-0-0282, Positioning command value" to a value entered in parameter "S-0-0430, Effective target position" is controlled via "S-0-0346, Positioning control word".

At every edge of bit 0 (toggle bit) of S-0-0346, the content of "S-0-0282, Positioning command value", depending on bit 3 of S-0-0346, is

- **copied** to parameter S-0-0430

  (when bit 3 = 0 → absolute **target position**)

- or -

- **added** to the value of parameter S-0-0430

  (when bit 3 = 1 → **travel distance**).

☞ If a positioning process is aborted by switching bits 1 and 2 of S-0-0346 from status "00" to "01", "10" or "11", repeated edge reversal has to take place in bit 0 in order to start a new positioning process! A residual path possibly present is cleared, i.e. the status of bit 4 of S-0-0346 is automatically interpreted as "1" during the next positioning process.

Via "S-0-0419, Positioning command acknowledge" (bit 0), the drive acknowledges that it has applied the positioning command value. This allows realizing a data handshake for monitoring the command value acceptance between master and drive.

☞ The active target position is displayed in parameter "S-0-0430, Effective target position".

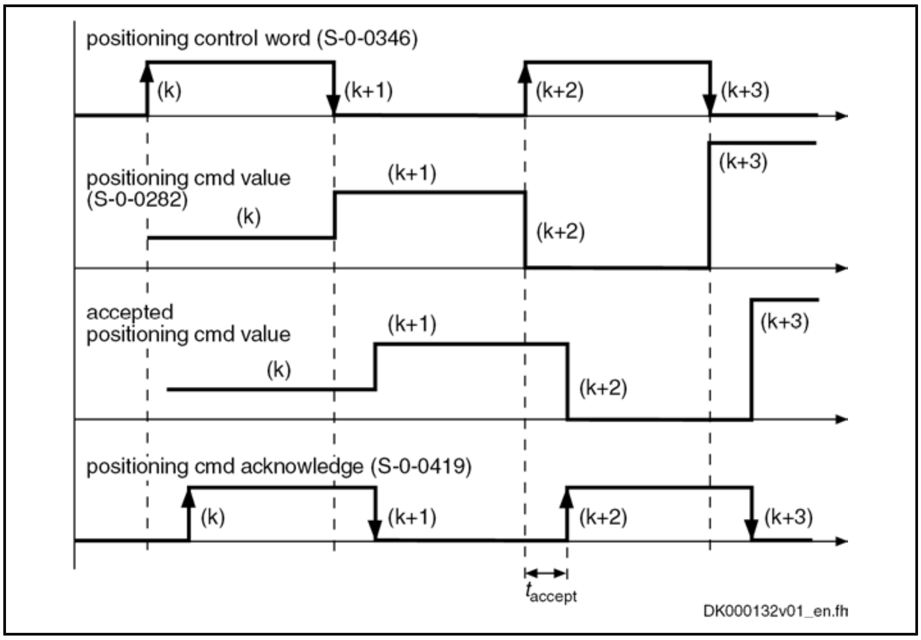


Fig.7-16: Positioning Command Value Acceptance and Acknowledgment

Time t_{accept} (see illustration above) defines the time that passes between status change of the acceptance bit by the control unit and the reception of acknowledgment in the master. The time is made up of the effective transmission time of the command values and actual values and thus depends on the configuration of the interface to the master (e.g. SERCOS/field bus timing parameter).

☞ If the "drive-controlled positioning" mode is not yet active, the acceptance of the new positioning command value is not acknowledged.

If bit 0 of S-0-0346 is unequal bit 0 of S-0-0419 while the operating mode is active, the positioning command value from S-0-0282 is immediately accepted and the drive immediately moves to this command value.

The acknowledgment of acceptance takes place when the new positioning command value is accepted from the intermediate memory to parameter "S-0-0430, Effective target position" and thus to the position command value generator.

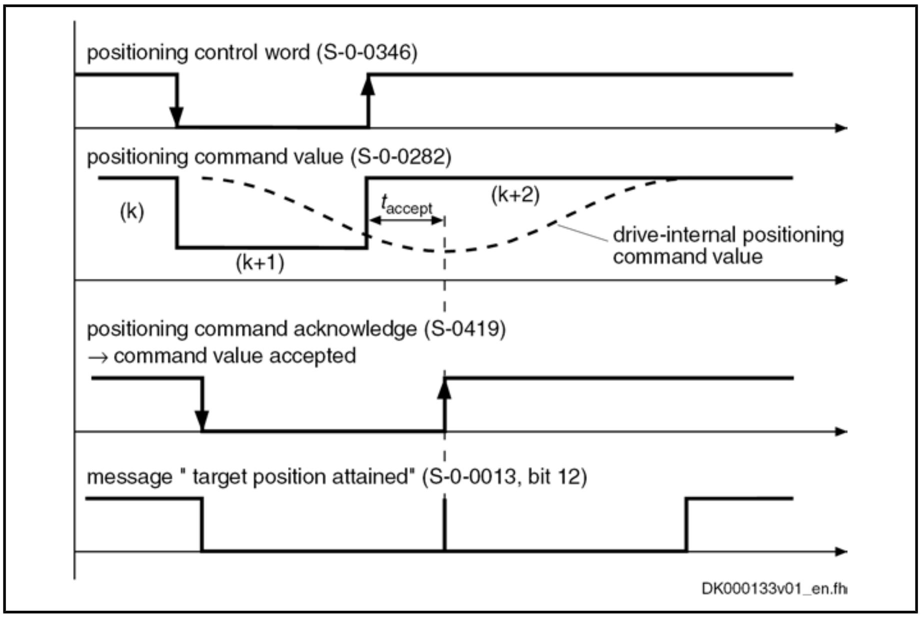


Fig.7-17: Acknowledgment of Positioning Command Value Acceptance in Mode "Complete Move to Positioning Command Value (k+2)"

Acknowledgment With Error "Overflow of Target Position Preset Memory"

When trying, in the "complete move to positioning command value" mode, to preset a new positioning command value by toggling parameter "S-0-0346, Positioning control word", although the previous positioning command value (k+1) was not accepted [because the drive had not yet moved to the previous positioning command value (k)], the error message "F2050 Overflow of target position preset memory" is generated.

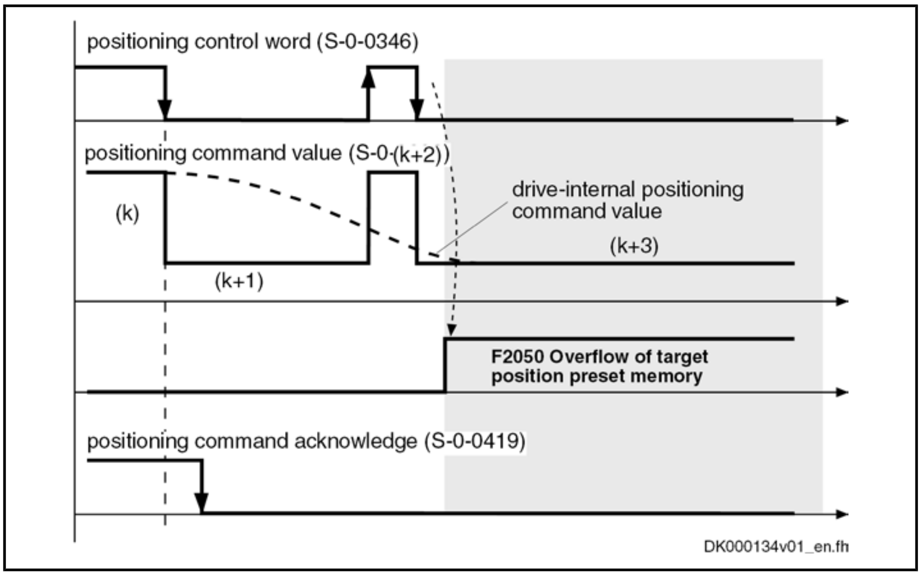


Fig.7-18: Acknowledgment With Error "Overflow of Target Position Preset Memory"

In addition to bit 0 for mere block acceptance, the parameter "S-0-0346, Positioning control word" contains further control bits which are explained below.

Positioning Modes to be Selected

Via bit 1 and bit 2 of S-0-0346, you can determine different positioning modes:

- **"Infinite travel"** (jog positive or negative → **Jog mode**) when:
  – Bit 2/1 = 01 → "Infinite travel" positive
  – Bit 2/1 = 10 → "Infinite travel" negative

- **"Stopping"** (with "S-0-0359, Positioning Deceleration") when:
  – Bit 2/1 = 11

Reference of Active Target Position

Via bit 4 of S-0-0346, it is possible to determine the reference of the active target position.

- **Bit 4 = 0** → Reference for positioning is the "old target position", i.e. a residual path that possibly hasn't been traveled yet is traveled before the drive moves to the new target

  → Incremental dimension is maintained in the case of successive positioning procedures
- **Bit 4 = 1** → Reference for positioning is the current actual position value, a possibly existing residual path is not traveled

  → Incremental dimension reference is maintained

☞ Bit 4 takes effect with every new travel job (edge on bit 0). Residual path processing is only carried out, during the first positioning process after the operating mode was activated, when the position status has been set and bit 2 = 1 in parameter S-0-0393. In this case the residual path, after the operating mode was activated, is traveled without start edge.

Reaction to New Target Position Input

Via bit 5 of S-0-0346, it is possible to determine the time of the reaction to a new target position input:

- **Bit 5= 0** → The drive travels to the last preset target before positioning at the new target. The target is considered to have been reached when the following applies:

  Target position – actual position value < positioning window
- **Bit 5 =1** → The previous target is rejected and the drive immediately travels to the new target.

  → Immediate block change

ℹ See also Parameter Description "S-0-0346, Positioning control word"

Processing in Modulo Format

The parameter "S-0-0393, Command value mode" controls the drive behavior in the case of **position processing in modulo format**. The following definition applies to S-0-0393:

- Bit 1/0 = 00 → Positive direction of rotation
- Bit 1/0 = 01 → Negative direction of rotation
- Bit 1/0 = 10 → Shortest distance

ℹ See also Parameter Description "S-0-0393, Command value mode"

Special Cases

The following special cases apply to the evaluation of the settings for "S-0-0393, Command value mode":

- If the absolute value of the current actual velocity is greater than the velocity threshold for positioning ("S-0-0417, Positioning velocity threshold in modulo mode"), the drive always moves in the last active direction of rotation.
- If the target position is within the target position window (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

☞ If the velocity threshold for positioning behavior was parameterized with very low values that are within the noise level of the actual velocity value, this can cause unpredictable behavior.

See also Parameter Description "S-0-0417, Positioning velocity threshold in modulo mode" and "S-0-0418, Target position window in modulo mode" and "S-0-0430, Effective target position"

Positioning Generator

The drive generates the position command value profile necessary to move to the target position, considering the conditions defined in the following parameters:

- S-0-0108, Feedrate override
- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0359, Positioning deceleration

7.6.3 Position Loop With Drive-Controlled Positioning

The position command value generated at the output of the command value generator is displayed in parameter "P-0-0434, Position command value of controller" and can be output at the analog output.

In this operating mode, the same information as relevant in the "position control with cyclic command value input" mode applies to the position control loop.

See also "Control Loop Structure"

See also "Position Loop" in section "Position Control With Cyclic Command Value Input"

7.6.4 Jog Mode With Drive-Controlled Positioning ("Jogging")

☞ The jog mode is part of the positioning mode and not an individual operating mode! This means that there aren't any separate parameters for the jog mode, but you have to use the parameters of the operating mode "drive-controlled positioning".

Activating the Jog Mode

To use the jog mode, make the following settings:

- Activate the operating mode "drive-controlled positioning"

  - and -
- Select the positioning mode "infinite travel" (jog positive or negative → jog mode) via bits 1 and 2 of parameter "S-0-0346, Positioning control word"

Parameterizing the Jog Mode

When jogging, the following parameters are relevant for operation:

- S-0-0108, Feedrate override

  → To achieve online, if necessary, the reduction of the jog velocity by means of a "potentiometer"
- S-0-0193, Positioning jerk
- S-0-0259, Positioning velocity
- S-0-0260, Positioning acceleration
- S-0-0282, Positioning command value

- S-0-0346, Positioning control word

  → To select the jog direction ("Jog+", "Jog-" and "stopping")
- S-0-0359, Positioning deceleration

Bits 1 and 2 of parameter S-0-0346 are parts of the field bus control word and, if required, can be assigned to the digital inputs.

See "Profile Types (With Field Bus Interfaces)"

See "Digital Inputs/Outputs"

7.7 Positioning Block Mode

7.7.1 Brief Description

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

In the "positioning block mode", it is possible to run up to 64 programmed positioning blocks. The drive moves to the target position in position control, while maintaining velocity, acceleration, deceleration and jerk limits as defined in the respective positioning block.

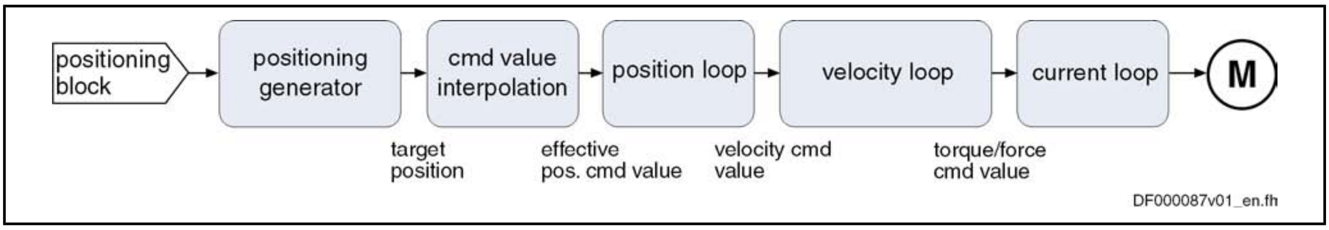


Fig.7-19: "Positioning Block Mode" Block Diagram

Features

- Parameterization of up to 64 positioning blocks; each with target position/travel distance, velocity, acceleration, deceleration and jerk
- The command value generation takes place in the NC cycle "S-0-0001, ". Transition into the position loop cycle by means of cubic fine interpolation.
- Jerk limitation of the generated position command value via "P-0-4009, Positioning block jerk"
- Setting of the average value filter (jerk limitation) to fixed filter time by means of interpolation cmd value average value filter time constant (P-0-0641)
- Adjustable position command value delay in position cycle times (P-0-0456), maximally 32 cycles.
- Defined block acceptance by toggling bit 0 in S-0-0346 with reaction time $t_{R\_strobe} = t_{position}$

  Note: With field bus drives, the I/O mode and control via the parallel interface are exceptions. In these cases, acceptance takes place by a 0-1 edge of bit 0 in P-0-4060.

  → Block selection and acknowledgment via separate parameters (handshake principle)
- Positioning modes to be freely parameterized:
  - Relative positioning

  - Absolute positioning
  - Infinite travel (positive or negative)
- Single-block or sequential block mode with different conditions for advance:
  - Block advance with switch cams
  - Block advance at defined position value
  - Block transition with "old" or "new" positioning velocity
- Positioning block transition with freely definable delay time (P-0-4018)
- Positioning while taking command value mode into account (shortest distance, positive direction, ...)
- Residual path processing can be activated (→ no loss of incremental dimension)
- "Slow travel" mode can be activated
- Velocity override to be set

Fields of Application

Sequential block processing allows executing several positioning blocks in direct sequence without having to give a new start signal each time. Typical fields of application are:

- There is none or only a very simple higher-level control unit available and control is realized via digital I/Os only or a field bus control word (I/O mode with field bus interface).
- There are quick reaction times or block advances required. The required motion profiles can be represented in the drive by the maximum possible 64 positioning blocks.
- There are positioning processes required which cover long distances at high speeds (rapid traverse) and then position at the end position at low speed without any intermediate stops; for example:
  - Taking up or putting down transport goods in handling robots
  - Execution of joining processes in assembly facilities

Pertinent Parameters

- S-0-0138,
- 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,
- P-0-0556, Config word of axis controller
- P-0-0641, Interpolation cmd value average value filter time constant
- P-0-4006, Positioning block target position
- P-0-4007, Positioning block velocity
- P-0-4008, Positioning block acceleration
- P-0-4009, Positioning block jerk

- P-0-4018, Positioning block delay time
- P-0-4019, Positioning block mode
- P-0-4026, Positioning block selection
- P-0-4051, Positioning block acknowledgment
- P-0-4052, Positioning block, last accepted
- P-0-4053, Positioning block, last active
- P-0-4057, Positioning block, input linked blocks
- P-0-4060, Positioning block control word
- P-0-4061, Positioning block status word
- P-0-4063, Positioning block deceleration

☞ Parameter S-0-0259 is used in positioning block mode to reduce positioning velocity (see also "P-0-4060, Positioning block control word").

Pertinent Diagnostic Messages

- A0162 Positioning block mode
- A0206 Positioning block mode, encoder 1
- A0207 Positioning block mode lagless, encoder 1
- A0210 Positioning block mode, encoder 2
- A0211 Positioning block mode lagless, encoder 2
- E2049 Positioning velocity >= limit value
- E2053 Target position out of travel range
- E2054 Not homed
- E2055 Feedrate override S-0-0108 = 0
- E2058 Selected positioning block has not been programmed
- F2028 Excessive deviation

7.7.2 Command Value Adjustment With Positioning Block Mode

The figure below illustrates command value processing in the "positioning block mode" as a block diagram.

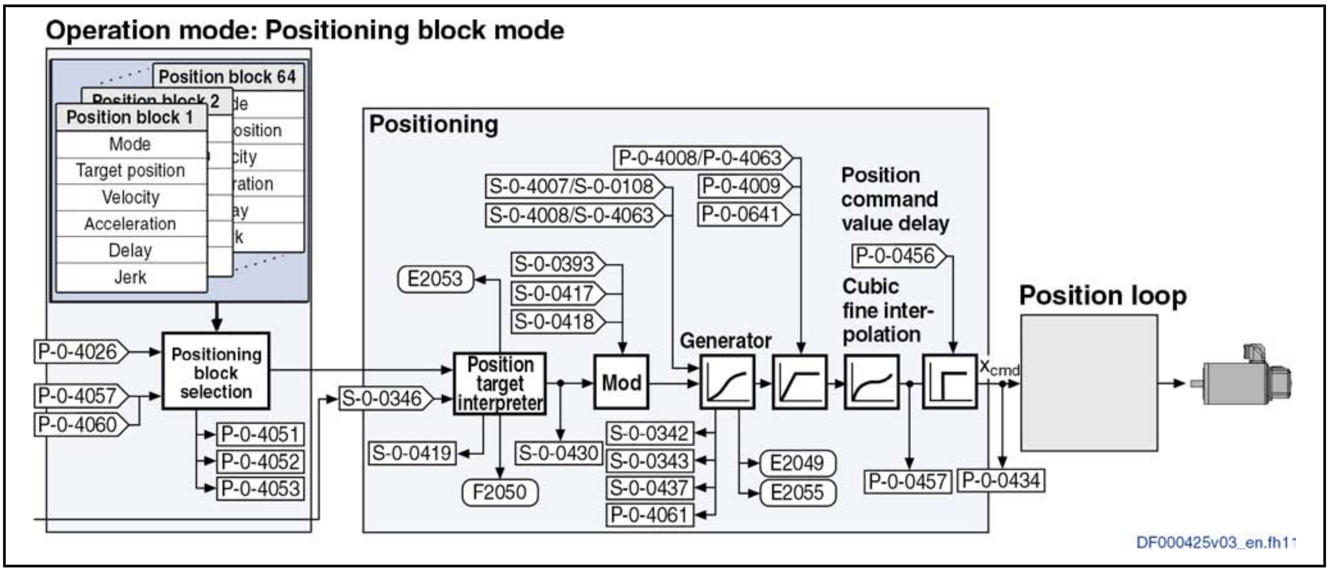


Fig.7-20: Command Value Adjustment With Positioning Block Mode

7.7.3 Single-Block Processing

Description of Basic Function

General Information

Positioning Block Elements

A positioning block is defined by the values of the following list parameters:

- P-0-4006, Positioning block target position
- P-0-4007, Positioning block velocity
- P-0-4008, Positioning block acceleration
- P-0-4009, Positioning block jerk
- P-0-4018, Positioning block delay time
- P-0-4019, Positioning block mode
- P-0-4063, Positioning block deceleration

Each parameter contains 64 elements, elements of the same number generate the travel profile of the respective positioning block.

The drive reaches the relevant positioning block velocity after an acceleration phase with the corresponding positioning block acceleration (P-0-4008).

Effective Positioning Velocity

The effective velocity during a positioning process is calculated as follows:

$$v_{max} = \text{P-0-4007} \times \frac{\text{S-0-0108}}{100\ \%}$$

v_{max}	Velocity
P-0-4007	Positioning block velocity
S-0-0108	Feedrate override

Fig.7-21: Effective Velocity During a Positioning Process

Effective Acceleration and Deceleration

The maximum deceleration is specified by parameter "P-0-4063, Positioning block deceleration".

CAUTION

Property damage!

If the acceleration or deceleration values are equal to zero, the drive can no longer brake. The specified target is never reached or overrun.

⇒ Set acceleration value > 0!

Further limitation takes place by the value of parameter "S-0-0138, " because this limit value takes effect in all operating modes with position control.

Jerk Limitation by Jerk Filter

In the "positioning block mode", the position command value can be filtered at the output of the positioning generator; in this connection, you distinguish between two cases for setting the filter order.

Case 1: filter order calculated from A / R

The filter order of the (moving) average filter available to do this (cf. P-0-0042) is calculated on the basis of the preset positioning block acceleration or the positioning block jerk.

This means that the parameterized acceleration or deceleration only becomes effective after t = P-0-0042 × T_{NCYC}.

T_{NCYC} is the generator cycle time (S-0-0001).

$$P\text{-}0\text{-}0042 = \frac{P\text{-}0\text{-}4008}{P\text{-}0\text{-}4009}$$

– or –

$$P\text{-}0\text{-}0042 = \frac{P\text{-}0\text{-}4063}{P\text{-}0\text{-}4009}$$

P-0-0042	Current position command average value filter order
P-0-4008	Positioning block acceleration
P-0-4063	Positioning block deceleration
P-0-4009	Positioning block jerk

Fig.7-22: Internally Determining the Value of P-0-0042 for Positioning Block Mode

☞ With value equal zero in parameter P-0-4009, the smoothing filter is switched off, i.e. the desired acceleration or deceleration is immediately reached.

Case 2: filter order constant

The filter order can also be set to a constant value; this is done by means of the parameter "P-0-0641, Interpolation cmd value average value filter time constant". The filter order is calculated from the time constant related to the generator cycle time T_{NCYC}; with an order > 0, the constant filter order function is active and the calculation A / R is not effective. In this connection, a new filter order may only take effect upon initialization of the operating mode as well as upon block change. The current filter order is still displayed in P-0-0042.

Position Command Value Delay

After the fine interpolator, the position command value can be delayed by maximally 32 position cycle times before it is fed into the position loop. Thus, synchronous control of a master axis and the controlled slave axis is made possible. The number of position cycle times is set by means of the position command value delay (P-0-0456). The undelayed position command value generator (P-0-0457) is entered into a ring buffer, the delayed position command value is then taken over into 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-0-0051/53| < S-0-0057 && no sequential block

Interrupting a Positioning Block

The positioning block mode can be interrupted by:

- Removing drive enable
- Activating "Drive Halt"
- Changing the operating mode
- Jogging
- Positioning stop or operational stop (S-0-0346, bit 1 and bit 2 = 1)
- A drive error occurring

Positioning Block Modes

Parameter "P-0-4019, Positioning block mode" is used to define the way in which the target position is processed in parameter "P-0-4006, Positioning block target position". There are the following options:

- Absolute positioning
- Relative positioning
- Relative positioning with residual path storage
- Infinite travel in positive/negative direction
- Sequential block processing

See Parameter Description "P-0-4019, Positioning block mode"

It is possible to define an individual positioning mode for each positioning block.

Command Value Mode (S-0-0393)

The parameter "S-0-0393, Command value mode" controls the drive behavior in case "modulo format" was set as processing format of the position data.

See also Parameter Description "S-0-0393, Command value mode"

The following modes are distinguished:

- Shortest distance
- Positive direction
- Negative direction

The following limiting conditions have to be taken into account:

- If the absolute value of the current actual velocity is greater than the velocity threshold for positioning in modulo format (S-0-0417), the drive always moves in the last active direction of rotation.
- If the target position is within the target position window in modulo mode (S-0-0418), positioning is always carried out according to the "shortest distance" mode.

If the velocity threshold for positioning in modulo format was parameterized with very low values that are within the noise level of the actual velocity value, this can cause unpredictable behavior.

See also Parameter Description "S-0-0417, Positioning velocity threshold in modulo mode"

See also Parameter Description "S-0-0418, Target position window in modulo mode"

Activating Positioning Blocks

Requirements

"Positioning block mode" must have been entered as the primary operation mode.

This is done by the respective selection of the active operating mode in the status word, by activating drive enable and by setting "Drive Halt" = 1.

Command Value Acceptance

Depending on the master communication, a positioning block is started by:

- Toggling bit 0 in parameter "S-0-0346, Positioning control word"

- or -

- 0-1 edge of bit 0 in parameter "P-0-4060, Positioning block control word", with **parallel interface orfield bus interface in I/O mode**

The positioning command value is thereby copied to the effective target position S-0-0430 (absolute target position) or added (relative position target, travel distance).

> ☞ The block acceptance is confirmed by updating "P-0-4051, Positioning block acknowledgment" and "S-0-0419, Positioning command acknowledge". In addition, bit 0 of parameter S-0-0346 is toggled internally, too, in the case of a 0-1 edge of bit 0 of parameter P-0-4060.

According to master communication and profile type, the block acceptance requires different configurations in the cyclic command value channel:

- **SERCOS interface**
  - "S-0-0346, Positioning control word" has to be configured in the cyclic data channel (MDT)
- **Field bus interface**
  - In the freely configurable mode (profile type P-0-4084 = 0xFFFE), bit 0 of P-0-4077 is mapped to bit 0 of S-0-0346.
  - In the "I/O mode positioning" (profile type P-0-4084 = 0xFF82), bit 3 of P-0-4068 is mapped to bit 0 of "P-0-4060, Positioning block control word".

    As an alternative, the start in the I/O mode can also take place by setting the start signal (P-0-4068, bit 1).
- **Parallel interface**
  - Bit 0 of P-0-4060 has to be configured on a digital input (see also "Digital Inputs/Outputs")

See also "Command Value Acceptance and Acknowledgment" in section "General Information on the Operating Modes"

> ☞ If bit 0 is different in S-0-0346 and in S-0-0419 when the operating mode is activated, the selected positioning block is immediately accepted and executed.

Block Selection

In the positioning block mode, block selection is always carried out via the content of parameter P-0-4026, Positioning block selection.

Depending on the master communication, the parameter P-0-4026 can be written in different ways:

Configuration of P-0-4026	Master communication		
	SERCOS interface	Field bus interface	Parallel interface
Via cyclic data channel	■	■	--
Via digital inputs	■	■	■
Via serial interface	■	■	■
Via field bus control word	--	■	--

Fig.7-23: Possibilities of Writing Parameter P-0-4026 Depending on the Master Communication

☞ The assignment of P-0-4026 to digital inputs requires, among other things, the parameters "S-0-0144, Signal status word" and "S-0-0145, Signal control word".

Absolute Positioning

Parameter Setting "P-0-4019, Positioning block mode" = **0000 0000 0000 000X**

Function In an absolute positioning block, the target position is a fixed (absolute) position within the machine coordinate system.

For absolute positioning the drive must have been homed.

Requirements Requirements for executing absolute positioning blocks are:

- The drive must have been homed.
- The travel range can be limited with position limit values. Absolute positioning blocks are only executed, if the target position is within the allowed travel range.

Example:

Absolute positioning with target position = 700 (current position = 200)

Operation Modes

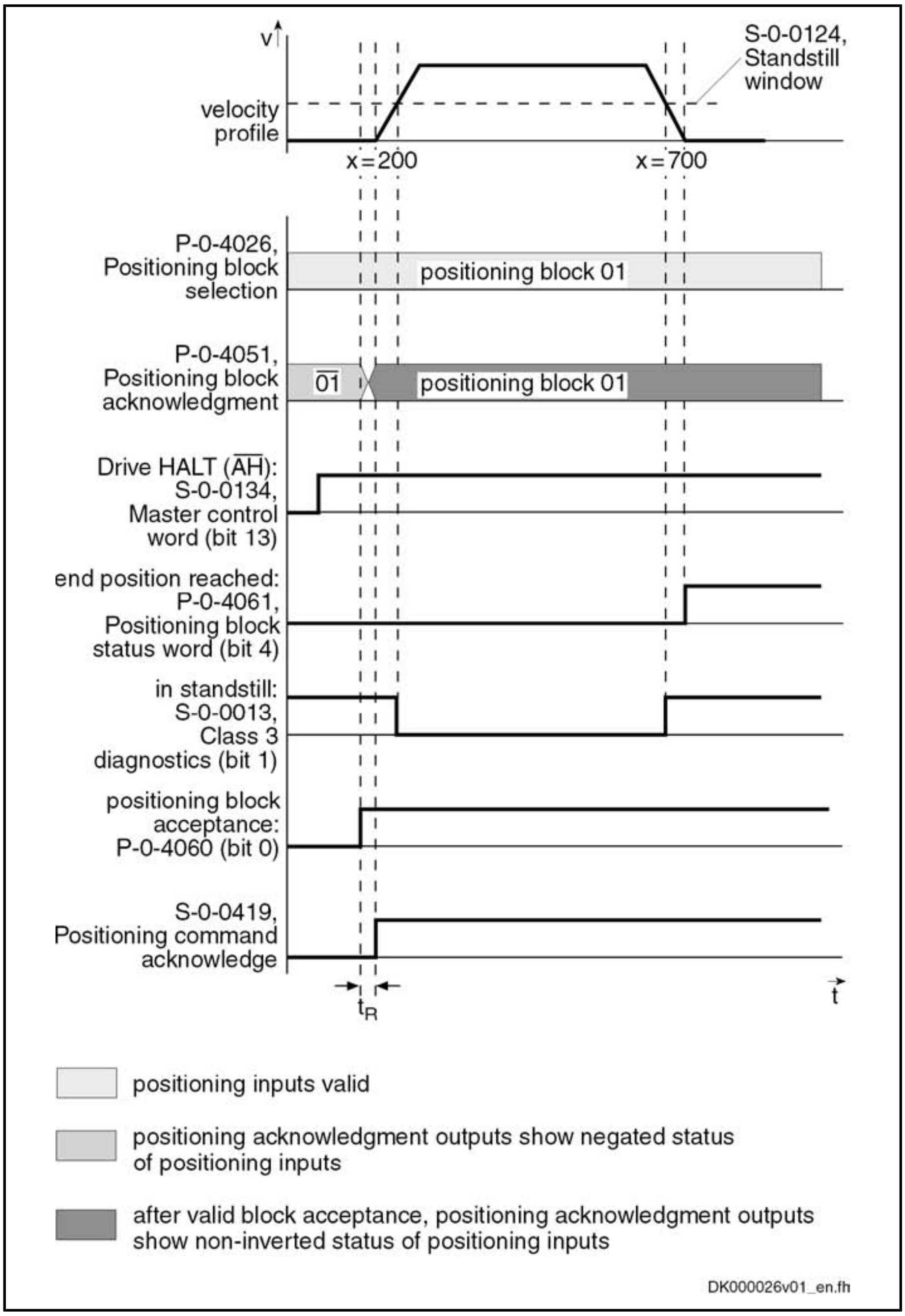


Fig.7-24: Absolute Positioning Block

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Relative Positioning Without Residual Path Storage

Parameter Setting "P-0-4019, Positioning block mode" = **0000 0000 0000 001X**

Dedicated Position In the case of relative positioning blocks without residual path storage, the target position contained in the positioning block is added to the current position.

Relative positioning blocks are also executed, if the drive has not been homed.

Incremental Dimension Reference

By sequencing relative positioning blocks it is possible to position with incremental dimension. If a relative positioning block without residual path storage is interrupted, the incremental dimension reference gets lost.

If the positioning block is completed (i.e. the drive reaches target position and message "end position reached" is active), positioning is possible without losing the incremental dimension reference.

☞ If infinite positioning in either a forward or backward direction is achieved by sequencing relative positioning blocks (transport belt), the position data must be scaled in modulo format (modulo value = length of transport belt or modulo value = 2 × maximum travel distance).

Example:

Relative positioning without residual path storage with travel distance = 700 (current position = 200; target position = 900)

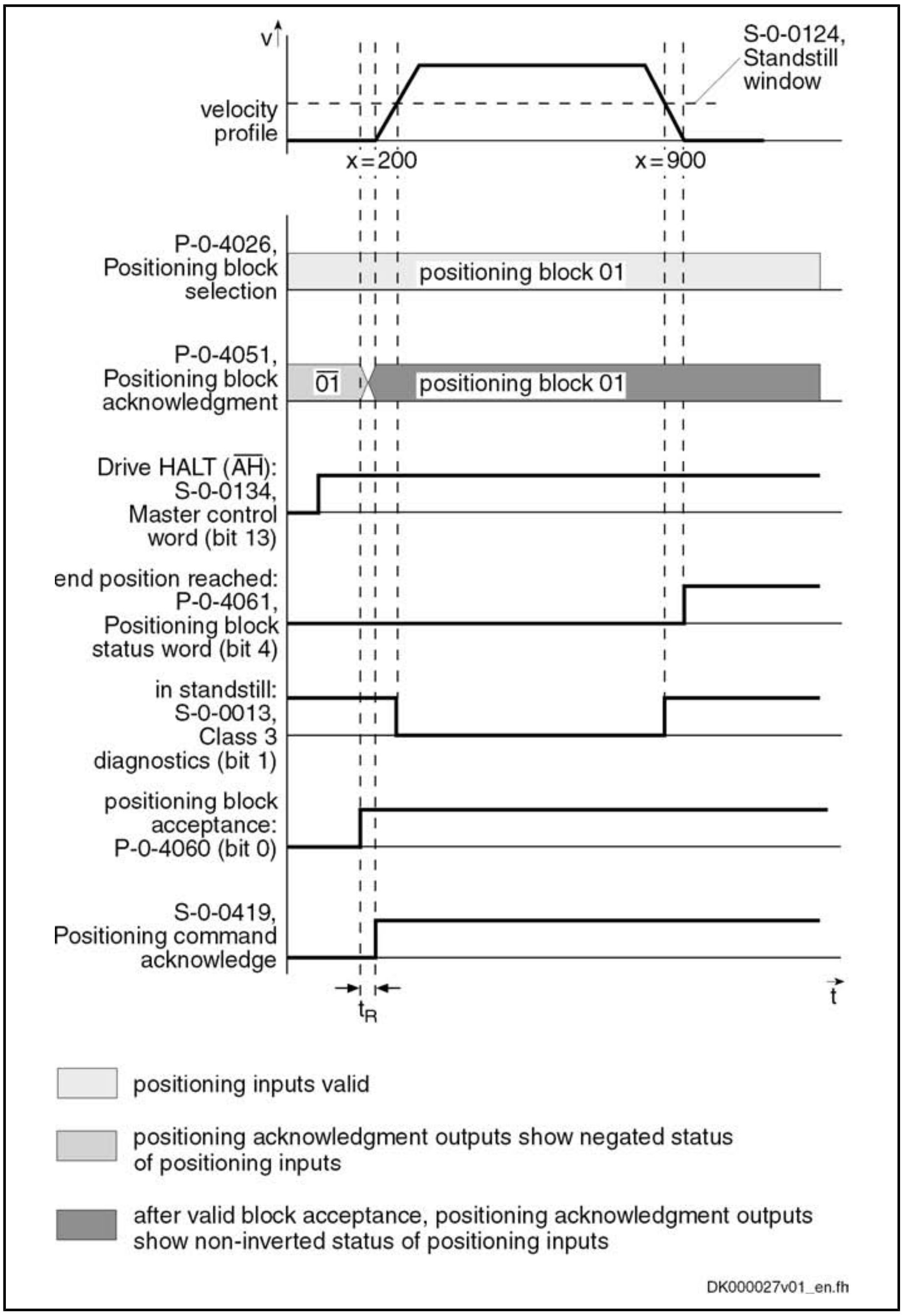


Fig.7-25: Relative Positioning Block Without Residual Path Storage

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Example:

Relative positioning without residual path storage with target position = 700 (current position = 200); interrupting and restarting a relative positioning block without residual path storage

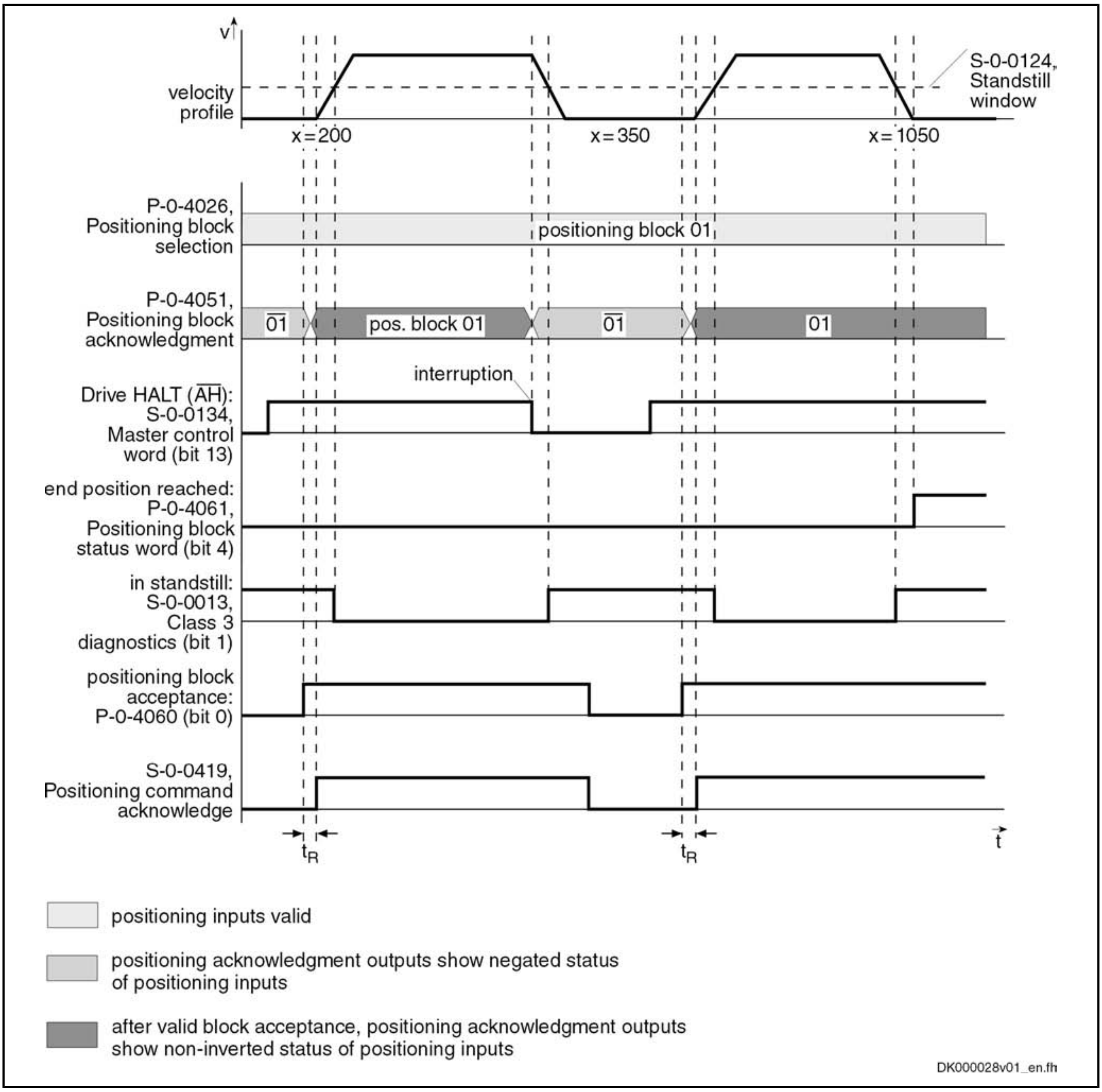


Fig. 7-26: Interrupting a Relative Positioning Bock Without Residual Path Storage

According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Relative Positioning With Residual Path Storage

Basic Function

Parameter Setting "P-0-4019, Positioning block mode" = **0000 0001 0000 001X**

Residual Path If positioning blocks are interrupted, a distance still to be traveled up to the target position remains. This remaining distance is the residual path.

In a relative positioning block with residual path storage, the target position is a relative distance that relates to the target position at which the message "end position reached" was last active.

Relative positioning blocks with residual path storage are also executed, if the drive has not been homed.

Incremental Dimension Reference

By sequencing relative positioning blocks it is possible to position with incremental dimension. If a relative positioning block with residual path storage is interrupted, the incremental dimension reference is retained.

☞ If another positioning block is started while such a positioning block is being executed, the residual path is rejected. If this new block is also a relative positioning block with residual path storage, the target position is related **to the current actual position** as a relative distance.

Example:

- Relative positioning with residual path storage with travel distance = 700 (plus residual path = 20 of positioning block n-1)
- Without interruption
- Current position = 180; new target position = 900

Dedicated Position

The last valid target position is used as dedicated position (in the example, position = 200 of positioning block n-1).

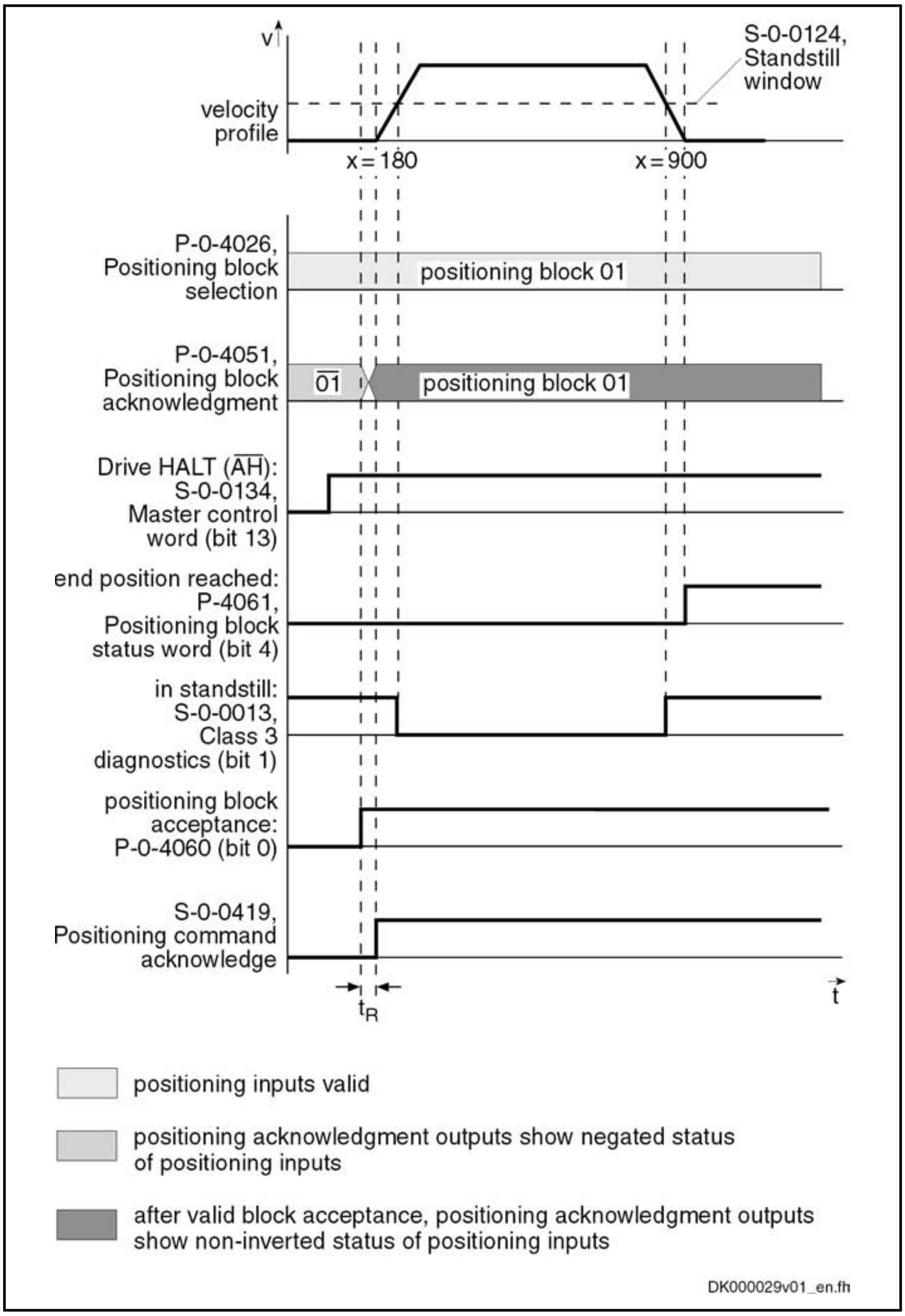


Fig.7-27: Relative Positioning Block With Residual Path Storage

According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Relative Positioning Block With Residual Path Storage After Activating Drive Enable

Example:

Interrupted relative positioning block with residual path storage after activation of drive enable with travel distance = 400 (current position = 200; target position = 800).

Dedicated Position

The position command value at the last "end position reached" (position = 200) message is used as the dedicated position.

☞ The incremental dimension reference is ensured.

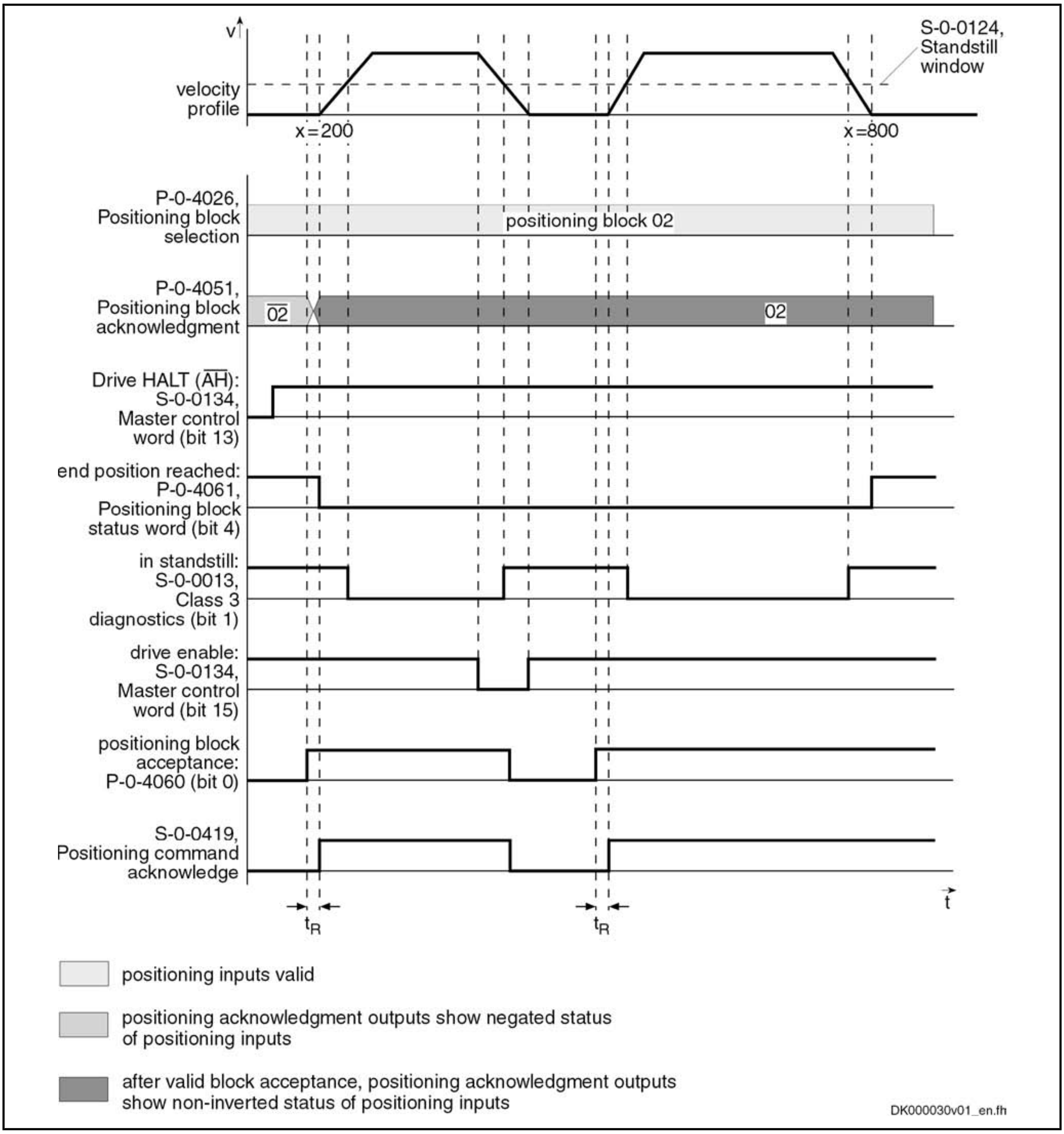


Fig.7-28: Relative Positioning Block With Residual Path Storage After Activating Drive Enable

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Relative Positioning Block With Residual Path Storage After Interrupting With Jog Mode

Example

Interrupted relative positioning block **with residual path storage** after jog mode with target position = 600 **without overrunning the target position** while jogging

Dedicated Position Behavior

Positioning is always continued at the current actual position value.

An interruption by means of jogging or positioning stop clears the residual path memory.

☞ The incremental dimension reference is no longer ensured!

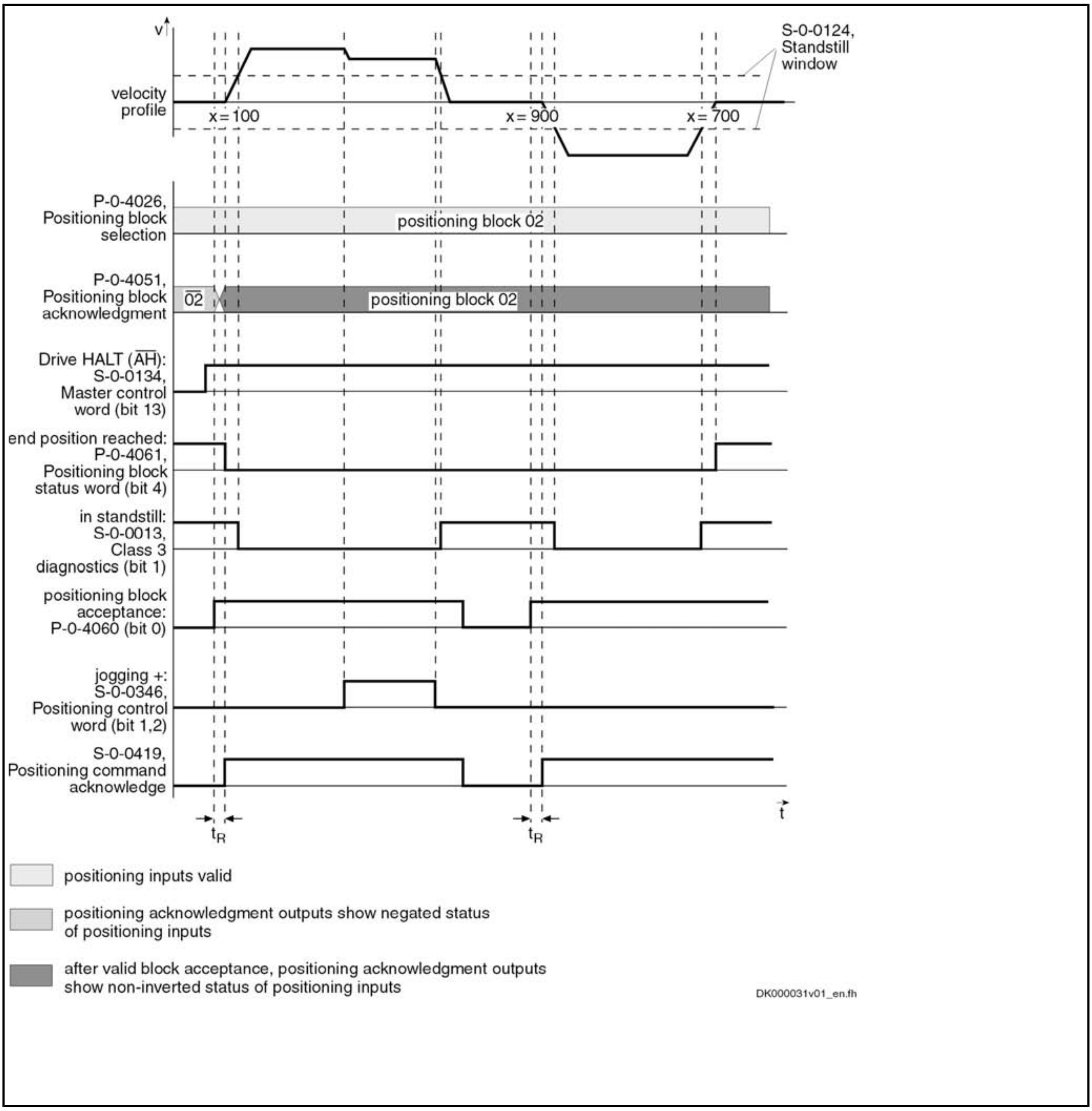


Fig.7-29: Relative Positioning Block With Residual Path Storage After Jog Mode

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Relative Positioning Block With Residual Path Storage After Switching Drive Controller Control Voltage Off and On

If an absolute encoder is used, the incremental dimension reference can be retained after switching control voltage off and on. The previously calculated target position is stored at power shutdown. The rest of the distance is traveled after the interrupted relative positioning block with residual path storage is activated.

If a single-turn encoder is used, the residual path is rejected and positioning continues at the actual position.

Dedicated Position

The position command value at the last "end position reached" (position = 100) message is used as the dedicated position.

☞ If a positioning block is not accepted, the drive behaves as if the positioning block had not been started.

Infinite Travel in Positive/Negative Direction

If an axis is to be moved with defined velocity, acceleration and jerk without a specific target position, the travel block mode "traveling in positive direction" or "traveling in negative direction" must be specified. The drive moves in the indicated direction until the start signal is reset or one of the position limit values or the travel range limit switch is reached.

The target position which was set is irrelevant in this positioning mode.

Parameter Setting

- P-0-4019, Positioning block mode = **0000 0000 0000 010X**
  → Travel in positive direction
- "P-0-4019, Positioning block mode" = **0000 0000 0000 100X**
  → Travel in negative direction

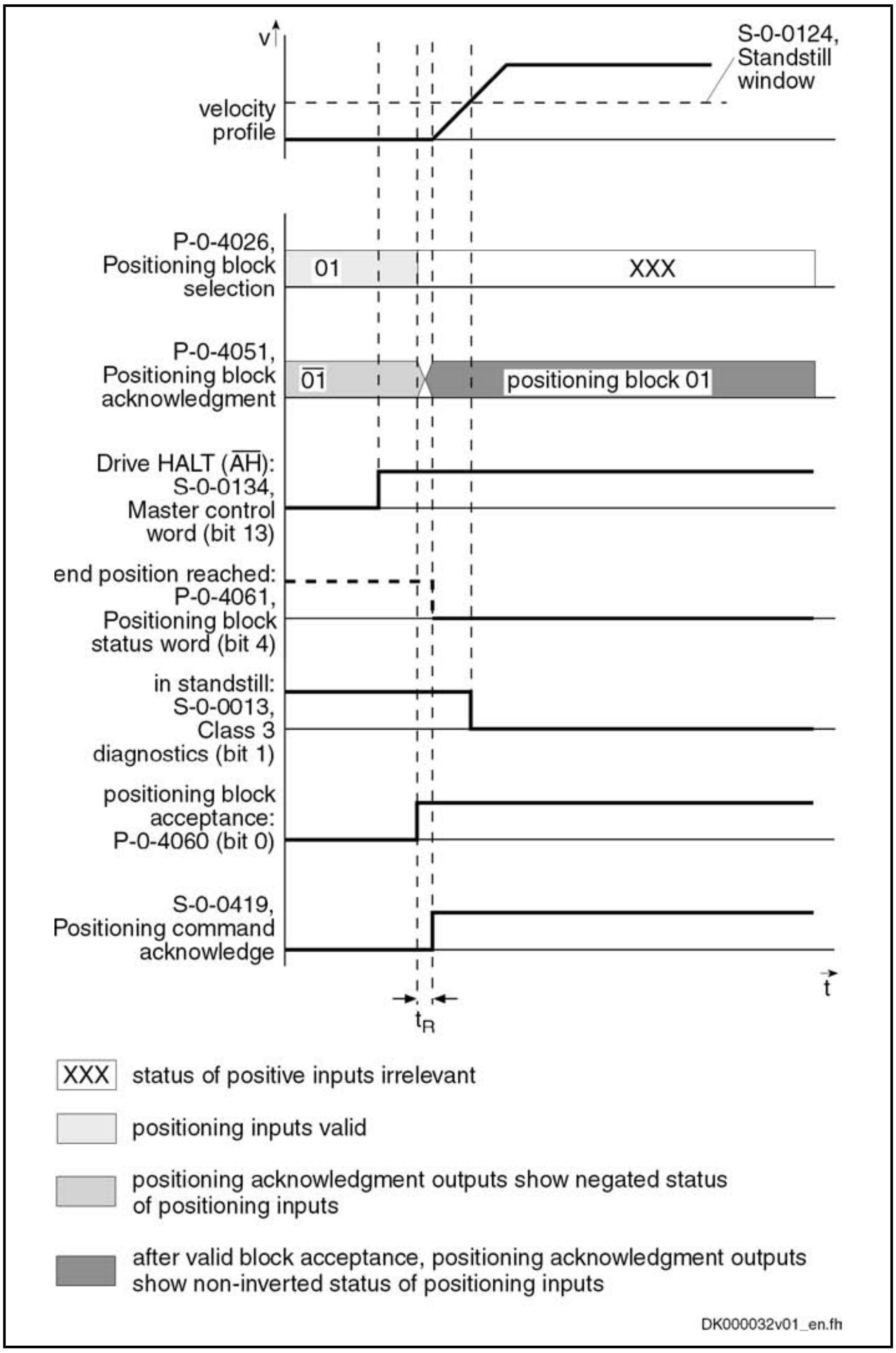


Fig.7-30: Example: Infinite Travel in Positive/Negative Direction

According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

7.7.4 Sequential Block Processing

Basic Function

☞ For sequential block processing, it is first of all the same basic rules as for single-block processing which apply (see that section). In addition to mere positioning block functions with defined positioning blocks and block acceptance, there also is a defined block transition to be parameterized.

Selecting and Activating a Sequential Block

A positioning block with sequential block is selected and activated in the usual way, only the first block of the sequential block chain being selected. The sequential block is the block with the next higher block number. A sequential block can also have a sequential block so that after a start block up to 63 sequential blocks can be set.

☞ The potential sequential block of the last valid block is block 0.

Conditions to Advance in Sequential Block Mode

There are two basically different modes for block advance; these modes can be subdivided:

- **Position-dependent block advance**
  - Block transition with old positioning velocity
  - Block transition with new positioning velocity
  - Block transition with intermediate stop and defined delay time (see P-0-4018)
- **Switch-signal-dependent block advance**

Position-Dependent Block Advance

General Information

With position-dependent block advance, switching to the sequential block is carried out at the target position of the start block.

There are three different types of block transition:

- Block transition with old positioning velocity (Mode 1)
- Block transition with new positioning velocity (Mode 2)
- Block transition with intermediate stop and defined delay time

Block Transition With Old Positioning Velocity (Mode 1)

Parameter Setting

- "P-0-4019, Positioning block mode" = **0000 0000 0001 000X**
  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0001 001X**
  → Relative block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0001 010X**
  → Infinite block in positive direction with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0001 100X**
  → Infinite block in negative direction with sequential block

Function

In this mode, the target position of the start block is run through at the velocity of the start block. Then the positioning velocity is switched to that of the sequential block.

With relative and absolute positioning blocks with block advance, the drive moves in the direction of the target position. As soon as the target position is passed, the drive switches to the next travel block n+1.

With infinite positioning blocks, the drive moves in positive or negative direction. As soon as the target position is passed, the drive switches to next positioning block n+1, the block n representing the positioning block currently in process.

☞ If the target position is not in the selected travel direction, the drive moves in the direction of the target position. Thus the drive always reaches the switching position.

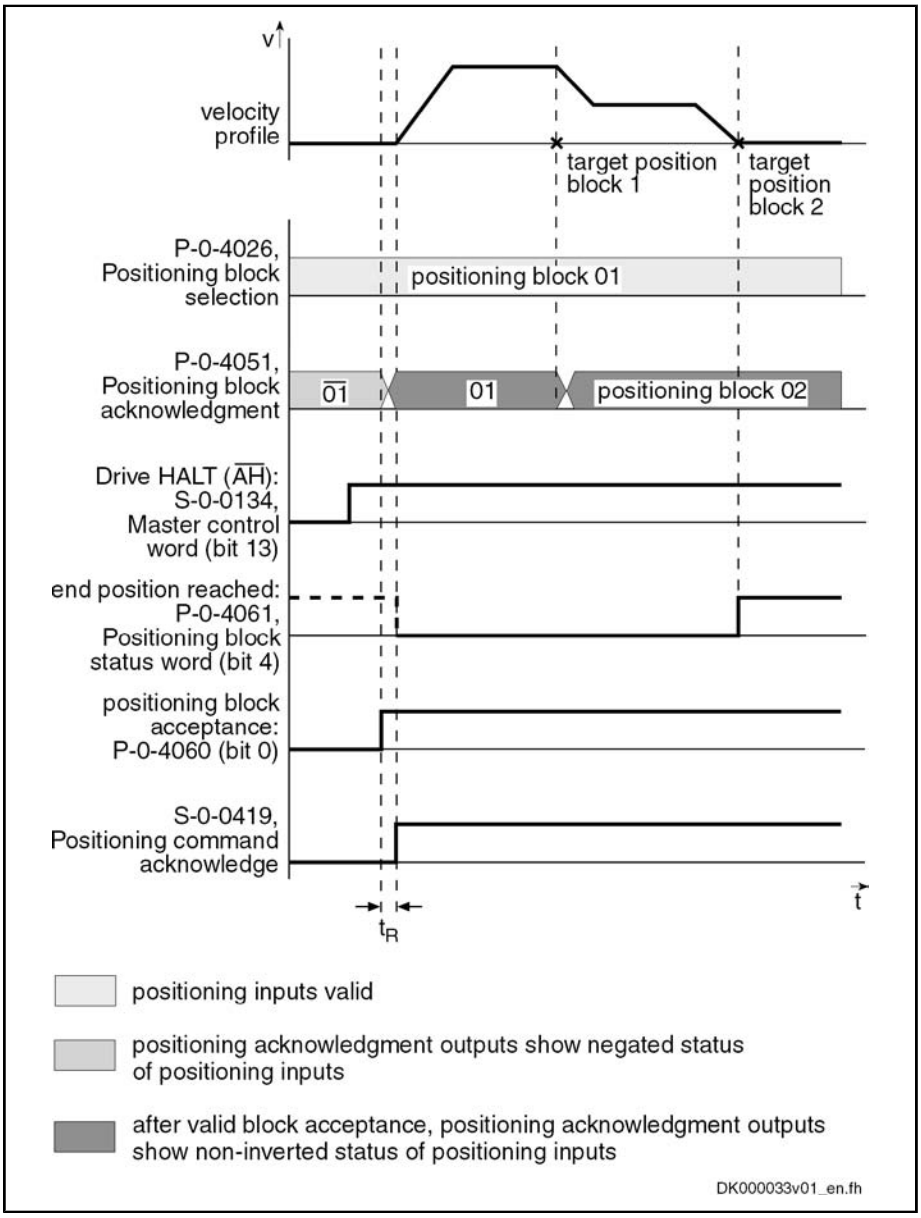


Fig.7-31: Example: Position-Dependent Block Advance (Mode 1)

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Block Transition With New Positioning Velocity (Mode 2)

Parameter Setting

- "P-0-4019, Positioning block mode" = **0000 0000 0010 000X**
  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0010 001X**
  → Relative block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0010 010X**
  → Infinite block in positive direction with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0010 100X**
  → Infinite block in negative direction with sequential block

Function

In this mode, the target position of the start block is run through at the positioning velocity of the sequential block. The deceleration or acceleration processes required to adjust the velocity are already carried out in the start block.

The drive moves in the direction of the target position x_n (with infinite blocks in the preset direction) set in current positioning block n. In due time before that, the acceleration is used to accelerate or decelerate to the next positioning velocity v_{n+1} so that the velocity v_{n+1} is reached at the target position x_n.

But switching to the next positioning block does not occur until the target position is overrun.

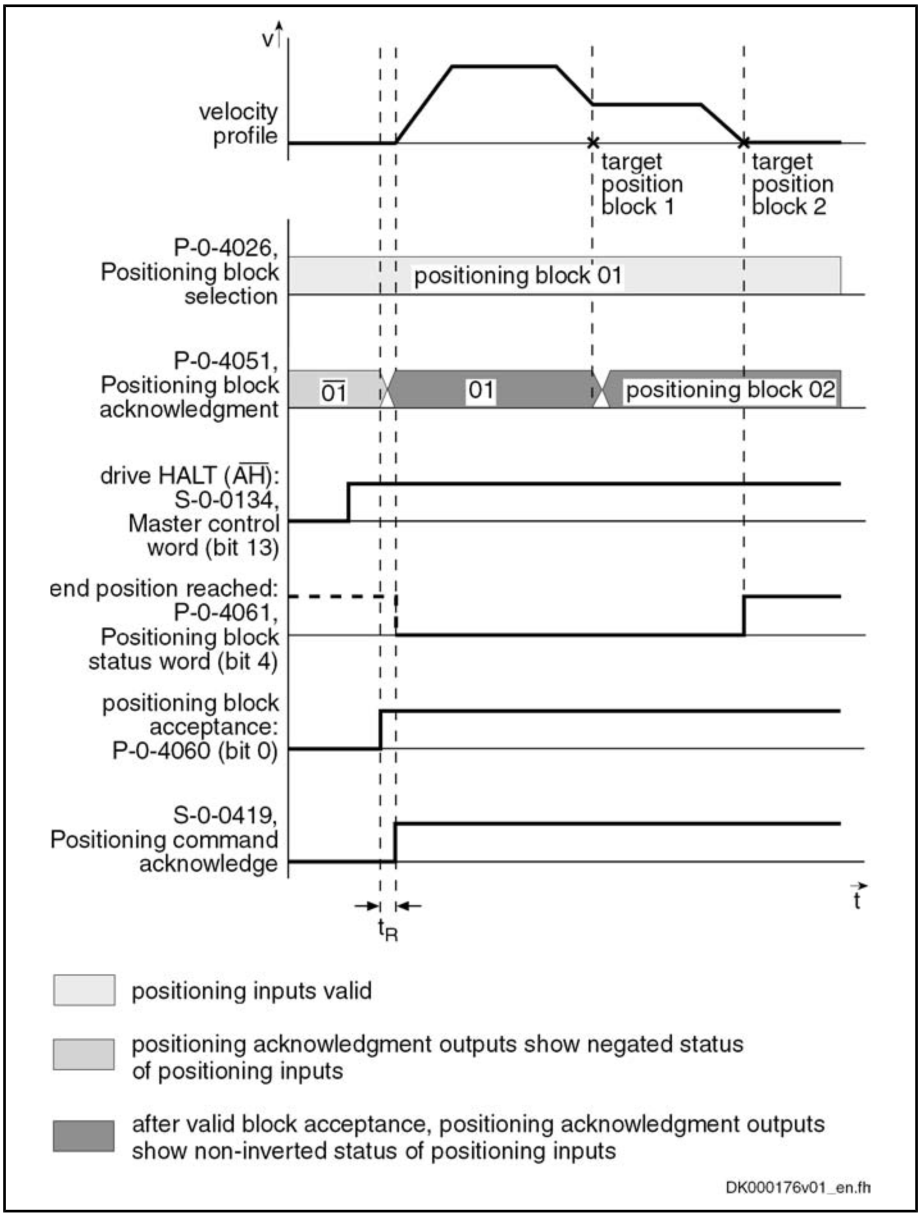


Fig. 7-32: Example: Position-Dependent Block Advance (Mode 2)

According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Block Transition With Intermediate Stop and Defined Delay Time

Parameter Setting

- "P-0-4019, Positioning block mode" = **0000 0000 0100 000X**
  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 0100 001X**
  → Relative block with sequential block

Function

In this mode, the drive positions at the target position of the start block. Once the position command value is at the target position, the sequential block is automatically started without a new start signal having been given externally.

If a delay time (P-0-4018) was parameterized for the positioning block, the sequential block is only started when the delay time is over.

Another operating mode is switching when overrunning the target position with intermediate stop.

In this case, the drive is decelerated to speed "0" at the target position and then accelerated to the new positioning velocity.

☞ Advance takes place when the internal command value generator has reached the target position and a possibly parameterized delay time (P-0-4018) has passed. With very low jerk values, the resulting dwell time is relatively long.

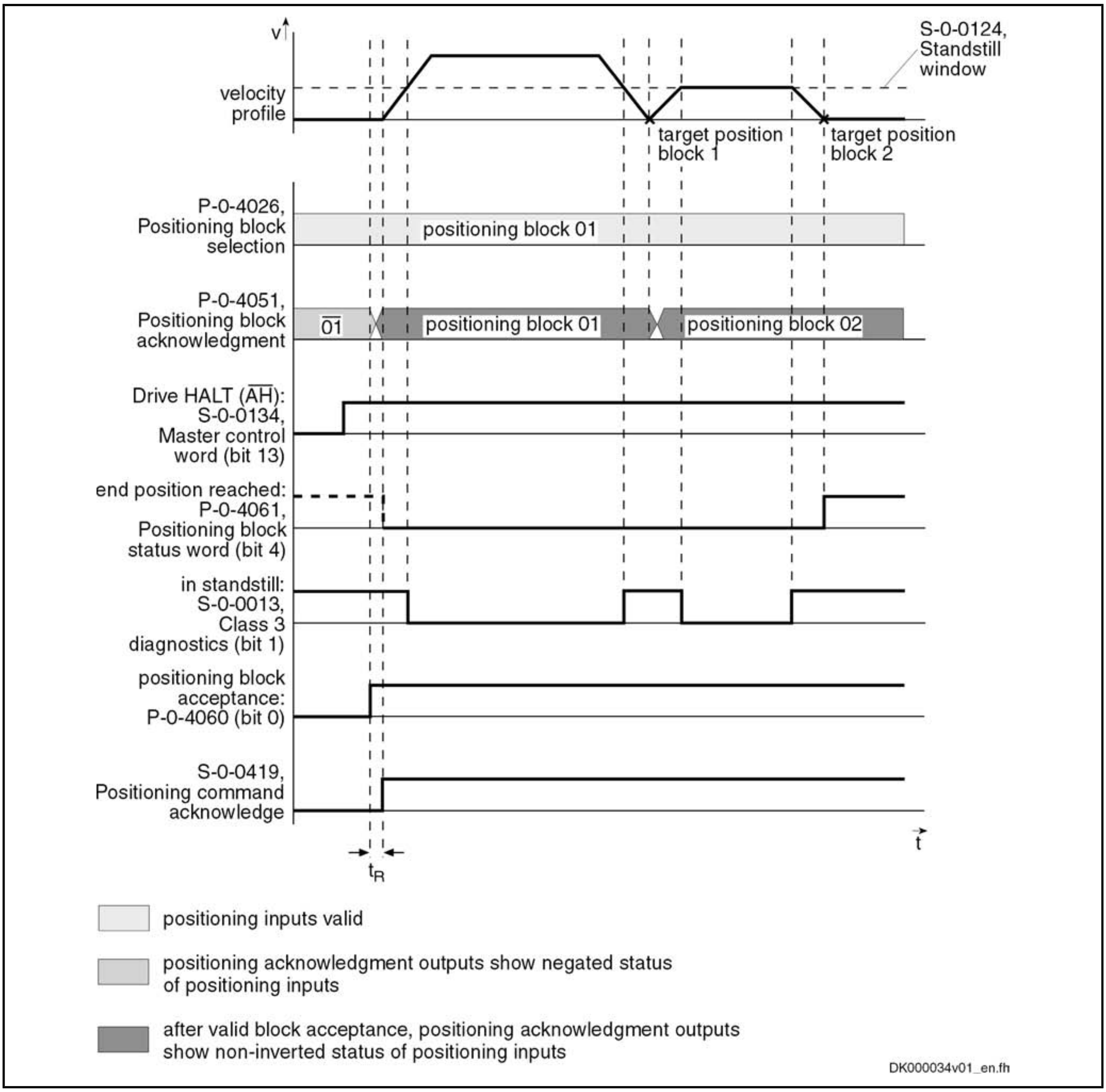


Fig.7-33: Example: Sequential Block Advance for Target Position With Intermediate Stop

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

☞ This mode should be used if there is a change in direction in the case of two consecutive sequential blocks within one sequential block chain. Otherwise, the position at which the direction is changed will be inevitably overrun.

Switch-Signal-Dependent Block Advance

For switch-signal-dependent block advance, there are the following positioning modes:

- "P-0-4019, Positioning block mode" = **0000 0000 1000 000X**
  → Absolute block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 1000 001X**
  → Relative block with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 1000 010X**
  → Infinite block in positive direction with sequential block
- "P-0-4019, Positioning block mode" = **0000 0000 1000 100X**
  → Infinite block in negative direction with sequential block

☞ Advance to the block with the next higher block number is triggered by an externally applied switch signal.

Switching With Cams

The switch-signal-dependent block advance allows transition to a sequential block, triggered by an external switch signal. As input for this switch signal, there are two sequential block inputs/probe inputs available.

The status of the hardware signals is displayed in parameter "P-0-4057, Positioning block, input linked blocks".

Function

The drive switches to the **next travel block n+1**, as soon as the input for the **sequential block cam 1** changes from "0" to "1". If the target position is not reached, switching to the new positioning block is carried out while traveling.

The drive switches to the **travel block after the next n+2**, as soon as the input for the **sequential block cam 2** changes from "0" to "1". If a sequential block cam is activated during this travel, the drive switches to the positioning block after the next.

Dedicated Position

A following relative positioning block refers to the position at which the sequential block cam was switched.

☞ The sequential block cams are sampled in the position loop clock (see "Performance Data"). The precision of position detection therefore strongly depends on the velocity during overrun.

Assignment Table for Cams

Cam 2	Cam 1	Drive reaction
0	0	Drive moves to target position of block n
x	0 → 1	Block n+1 is started
0 → 1	x	Block n+2 is started

n Positioning block preselected via the parallel inputs or parameter "P-0-4026, Positioning block selection"

x Not relevant

Fig.7-34: Drive Reaction With Different Switch Signal Sequences

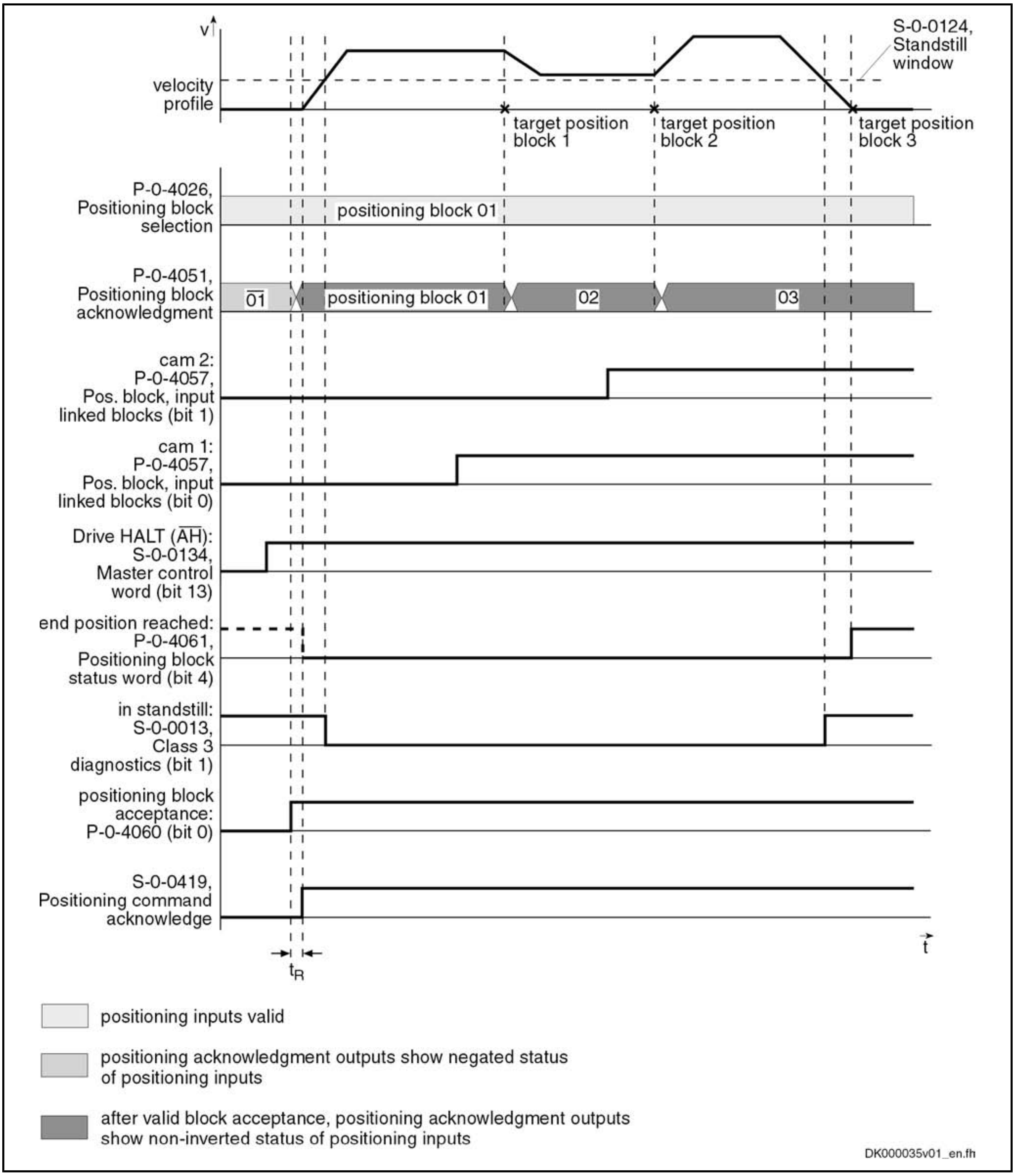


Fig.7-35: Example: Switch-Signal-Dependent Block Advance

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Failure of Switch Signal for Block Advance

If the start block of a switch-signal-dependent sequential block is an absolute or relative positioning block, the drive positions at target position, if the switch signal for block advance is not received. The drive thus only generates the message "end position reached" after the sequential block chain is completed. If a switch signal is then applied, the drive will carry out the sequential block.

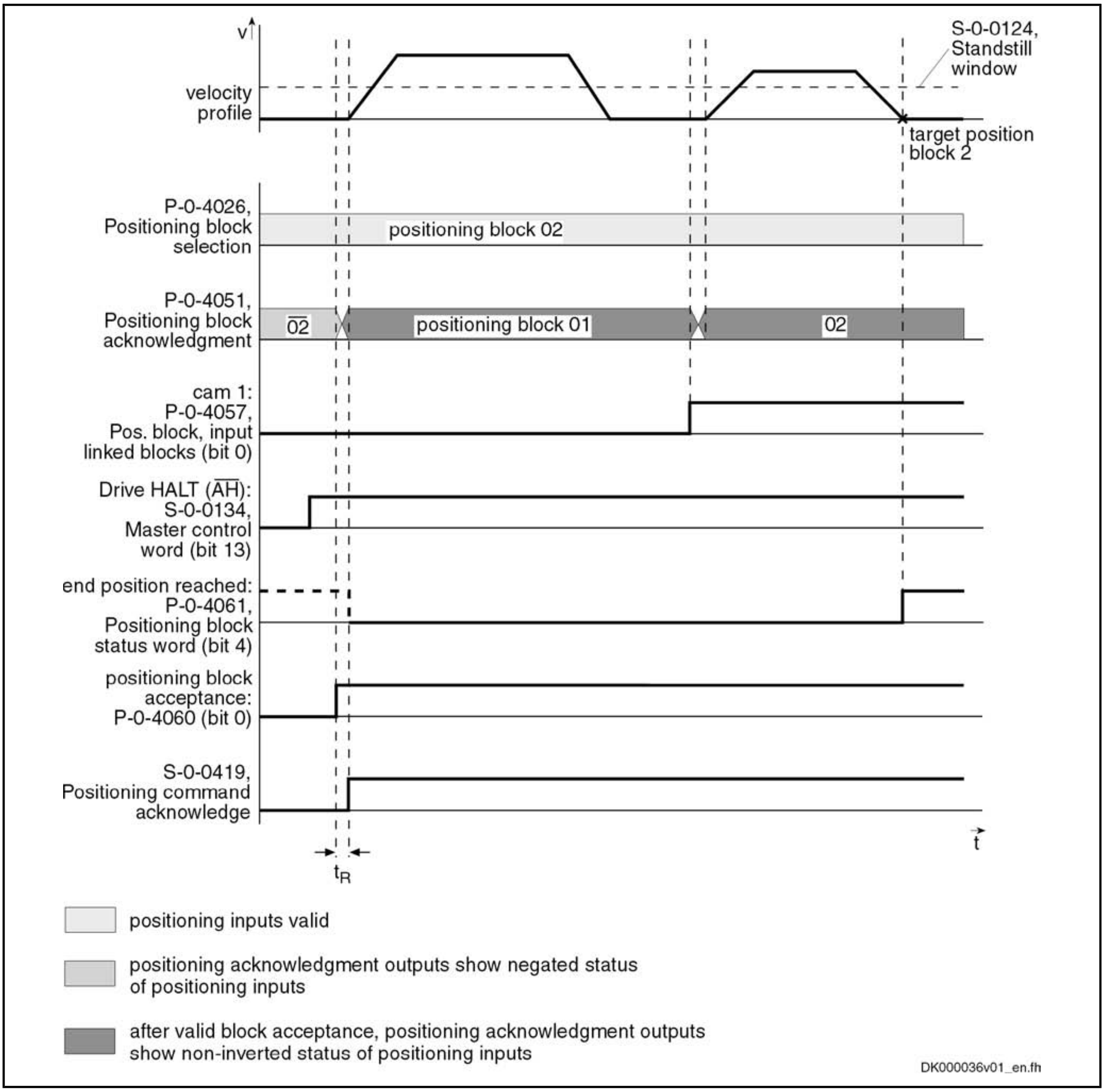


Fig.7-36: Example: Switch-Signal-Dependent Block Advance (Behavior With Failure of Switch Signal)

☞ According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

☞ All conditions for advance are constantly queried and evaluated to be able to switch to the correct sequential block, even after the sequential block chain was interrupted. Only the first condition for advance occurring during an interruption is recognized, however. All other conditions are not taken into account!

Interrupting a Sequential Block Chain

There are two basically different behaviors when a sequential block chain is interrupted:

- **Residual path is rejected** when interruption by:
  - Positioning stop (S-0-0346, bit 1 and bit 2 = 1)
  - Jogging +/-
  - Control voltage "Off"

  After interruption with "positioning stop"" and "jogging +/-", positioning always continues at the current actual position. The sequential block chain interrupted before is not completed, but the currently selected block is executed. Thereby the incremental dimension reference gets lost!
- **Residual path is maintained** when interruption by:
  - Removing drive enable
  - Removing the "drive start" signal
  - Changing the operating mode

Depending on the block type of the sequential block chain that was interrupted and the events occurring during this interruption, the sequential block chain is processed differently after a restart.

☞ In sequential block mode, relative positioning blocks **without residual path storage** are **not allowed**, as otherwise the incremental dimension reference would get lost in the case of interruption.

Given an interruption, a restart will end the sequential block chain.

Dedicated Position

The dedicated position is the original start position of the sequential block chain.

☞ The incremental dimension reference is retained, as only absolute and relative positioning blocks with residual path storage are used in sequential block mode!

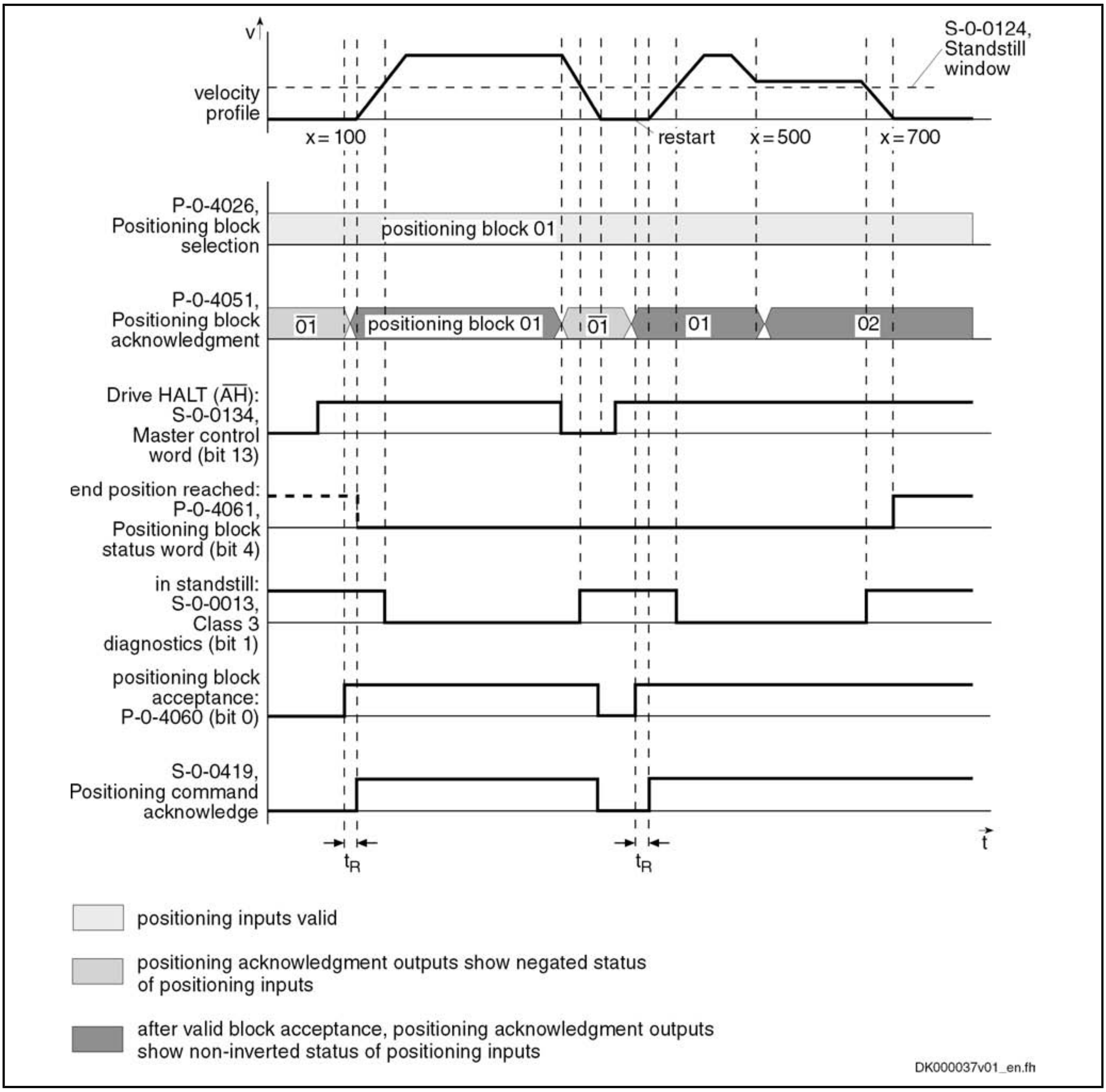


Fig.7-37: Example: Sequential Block Interruption With Same Block Selected

According to master communication, positioning block acceptance takes place by toggling bit 0 in S-0-0346 or by a 0-1 edge of bit 0 in P-0-4060.

Changing to Different Operating Mode

When changing the operating mode during an interruption, the sequential block chain interrupted before is completed at the restart, if there hadn't been any new block selected.

Given a sequential block with advance due to target position, only the overrun of the target position of the current positioning block will be detected. The processing of the sequential block is completed from this position.

The advance condition due to switch signals is always detected.

Interrupting a Sequential Block Chain With Selection of New Positioning Block

If a new positioning block is selected during an interruption (e.g. with "Drive Halt"), the previously interrupted sequential block chain is not completed after a restart, but the currently selected block is executed.

Dedicated Position

The dedicated position is the current actual position value.

☞ The incremental dimension reference gets lost, if the sequential block is interrupted.

The conditions for the interruption of sequential blocks also apply after the control voltage is switched off, if an absolute encoder is used.

Interrupting a Sequential Block Chain With Absolute Sequential Blocks

An interruption with absolute positioning blocks does not represent any problem, as the position data reference is always guaranteed.

When a **new block number** is selected in the case of an interruption, the sequential block interrupted before is not completed when toggling bit 0 in "S-0-0346, Positioning control word" or with a 0-1 edge of bit 0 in "P-0-4060, Positioning block control word", but the currently selected block is executed.

When **no new block number** is selected in the case of an interruption, the sequential block interrupted before is completed when toggling bit 0 in "S-0-0346, Positioning control word" or with a 0-1 edge of bit 0 in "P-0-4060, Positioning block control word".

7.8 Synchronization Modes

7.8.1 Basic Functions of the Synchronization Modes

Overview

General Information on the Synchronization Modes

The synchronization modes allow the drive to run synchronously with regard to a real or virtual master axis. The synchronization modes are basically divided into the following groups:

- **Velocity synchronization**
- **Position synchronization with the operating modes**
  - Phase synchronization
  - Electronic cam
  - MotionProfile

The figure below illustrates how the synchronization modes are integrated in the control loop structure.

Operation Modes

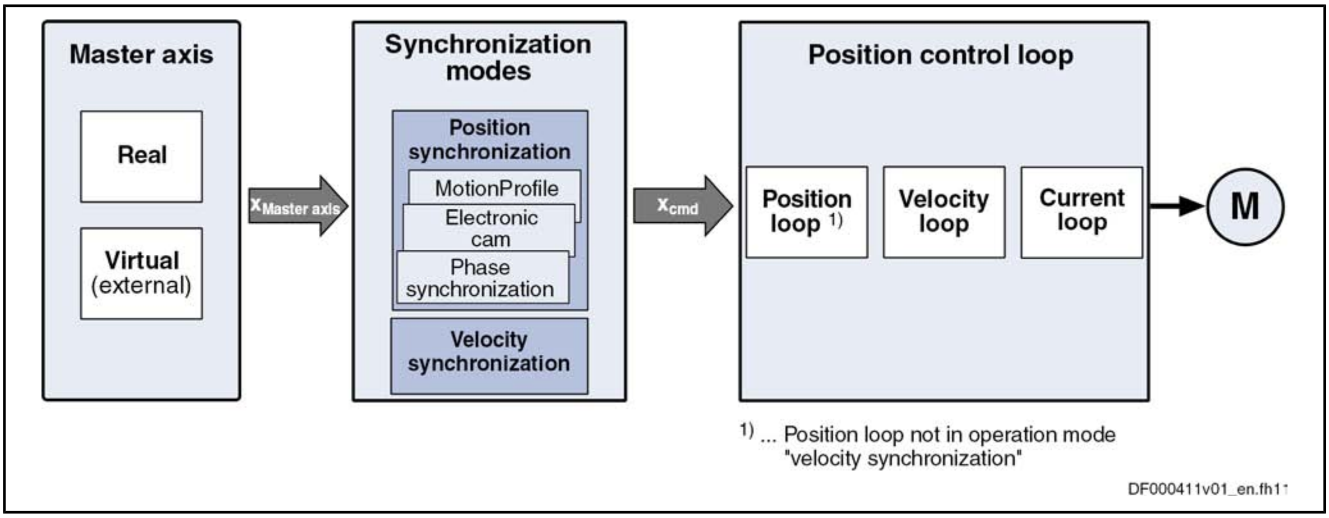


Fig.7-38: General Block Diagram of the Synchronization Modes

All synchronization modes have the following identical or similar basic functions which are comprehensively described in this section:

- Adjustment of master axis, consisting of
  - Generation of master axis
  - Master axis offset and modulo limitation
  - Electronic gear with fine adjustment
- Drive-controlled dynamic synchronization

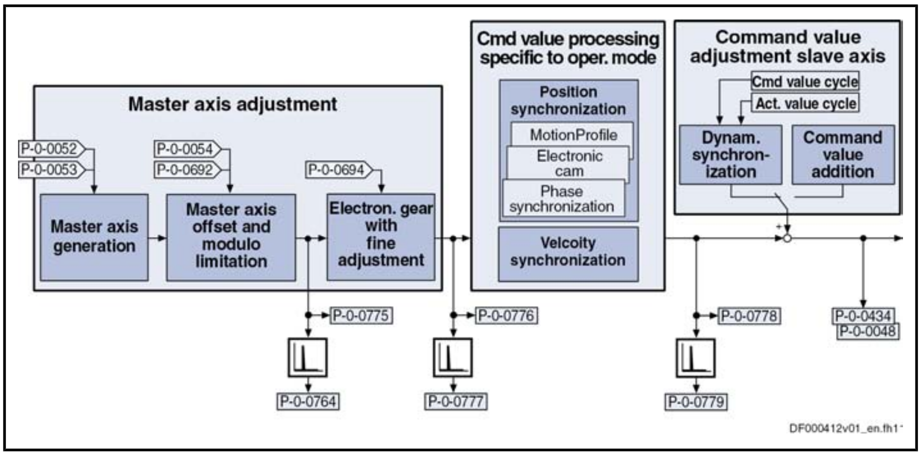
☞ The individual synchronization modes basically differ in the following function blocks:

- Command value processing specific to operating mode

- Command value addition for slave axis

These function blocks are described specific to operating mode in the individual sections on the respective synchronization modes.

The figure below illustrates the interaction of the individual basic functions (function blocks) of the synchronization modes.



P-0-0048	Effective velocity command value
P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0054	Additive master axis position
P-0-0434	Position command value of controller
P-0-0692	Additive position command value, process loop
P-0-0694	Gear ratio fine adjustment, process loop
P-0-0764	Master axis speed
P-0-0775	Resulting master axis position
P-0-0776	Effective master axis position
P-0-0777	Effective master axis velocity
P-0-0778	Synchronous position command value
P-0-0779	Synchronous velocity

Fig.7-39: Function Blocks of the Synchronization Modes

Explanation of Terms

Master axis:

The virtual or real axis which makes available the master axis position for generating the synchronous position command value for the slave axis is called master axis.

Master axis cycle

The master axis cycle specifies the range of the master axis values. It corresponds to a master axis revolution or a multiple thereof. In order to allow for the correct processing of the master axis positions (e.g. in case of modulo overflows), the drive must now the value of the master axis cycle. By configuring parameter **"P-0-0750, Master axis revolutions per master axis cycle"**, the control notifies the drive the value of the master axis cycle.

Slave axis:

The drive following the command values derived from the master axis is referred to as slave axis.

Actual value cycle (position actual value in actual value cycle / modulo value):

The modulo range within which the actual position values (P-0-0753, Position actual value in actual value cycle) of the slave axis are to be found in case of active position synchronization mode is called actual value cycle. The position synchronization modes (phase synchronization, cam and MotionProfile) use the "position actual value in actual value cycle" in order to close their position control loop. When activating one of the position synchronization operating modes, the travel distance for synchronization is determined using the "position actual value in the actual value cycle". In this connection, the travel distance is limited to the synchronization range (command value cycle, division of the command value cycle or modulo range (S-0-0103)) that has been set.

See Parameter Description "P-0-0753, Position actual value in actual value cycle"

See Parameter Description "P-0-0786, Modulo value actual value cycle"

The modulo range of the actual value cycle has to be determined so that is corresponds to an integer multiple of the synchronization range.

Command value cycle:

In processes with different machining cycles, the drives must be able to synchronize over several master axis revolutions or divisions of a master axis revolution. This property is defined via the so-called command value cycle.

The modulo range within which the synchronous position command values of the slave axis are to be found is called command value cycle.

See Parameter Description "P-0-0754, Command value cycle"

Configuring and Controlling the Synchronization Modes

The synchronization modes velocity synchronization and position synchronization are configured and controlled by means of the following synchronization parameters.

Pertinent Parameters (Synchronization Parameters)

- S-0-0520, Control word of axis controller
- S-0-0521, Status word of position loop
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes

By means of parameter P-0-0520, it is possible to make the following determinations for the position-controlled operating modes:

- Position control with lag error or lagless
- Use of encoder 1 or encoder 2

See also "Operating Mode Handling"

Command Value Addition

This section contains an overview of the basic possibilities of adding command values. The characteristics and details specific to operating mode are described in the section of the respective synchronization mode.

Pertinent Parameters

- S-0-0037, Additive velocity command value
- S-0-0048, Additive position command value
- P-0-0048, Effective velocity command value
- P-0-0054, Additive master axis position
- P-0-0060, Filter time constant additive position cmd value
- P-0-0434, Position command value of controller
- P-0-0686, Additive position command value, positioning velocity
- P-0-0687, Additive position command value, positioning acceleration
- P-0-0688, Additive master axis position, positioning velocity
- P-0-0689, Additive master axis position, positioning acceleration
- P-0-0690, Additive velocity command value, process loop
- P-0-0691, Additive position command value, process loop
- P-0-0692, Additive master axis position, process loop
- P-0-0693, Filter time constant, add. master axis pos., process loop

The figure below contains a rough overview of the command values which can act on the master and slave axis and of how they can be influenced.

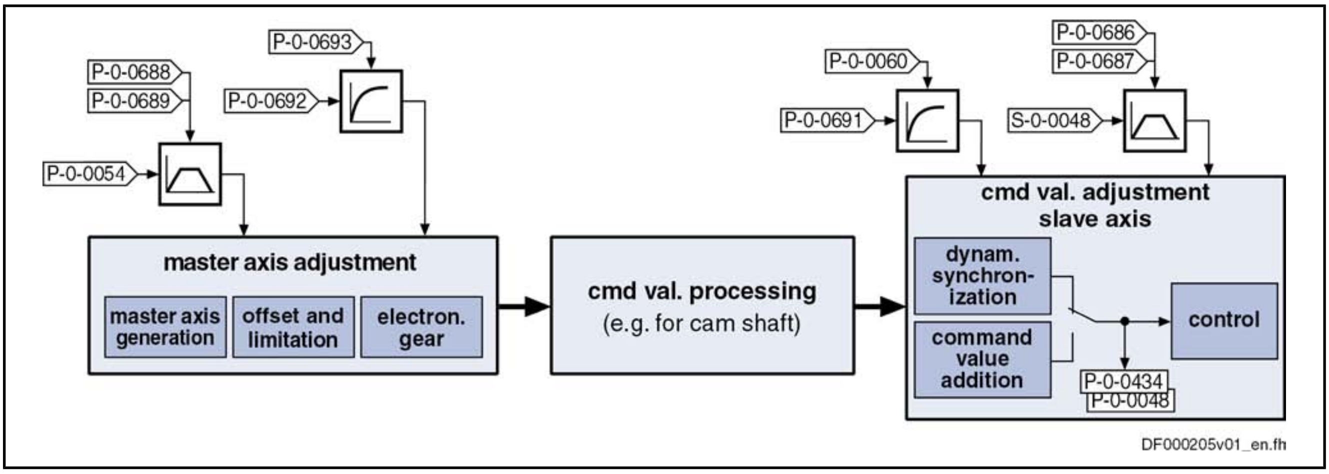


Fig.7-40: Possibilities of Command Value Addition for Master and Slave Axis

Master Axis Adjustment

Brief Description

Master Axis Generation

The following are possible as signal sources for the resulting master axis position **(P-0-0775)**:

- **Real master axis** (P-0-0052, Actual position value of measuring encoder)
- **Virtual master axis, external** (P-0-0053, Master axis position)

Master Axis Offset and Modulo Limitation

For internal adjustment or processing of the master axis information, there are the following options:

- Addition of components (= offset) to the incoming master axis angle:
  - via parameter "P-0-0054, Additive master axis position"
  - via parameter "P-0-0692, Additive master axis position, process loop"
- Limitation to modulo range of master axis

Electronic Gear Function

By means of factors to be set (e.g. input revolutions, output revolutions, polarity), the electronic gear function can influence the master axis position relevant for the operating mode as compared to the master axis position preset by master axis evaluation.

Pertinent Parameters

The following parameters are used in conjunction with master axis adjustment:

- P-0-0052, Actual position value of measuring encoder
- P-0-0053, Master axis position
- P-0-0054, Additive master axis position
- P-0-0084, Number of bits per master axis revolution
- P-0-0688, Additive master axis position, positioning velocity
- P-0-0689, Additive master axis position, positioning acceleration
- P-0-0692, Additive master axis position, process loop
- P-0-0693, Filter time constant, add. master axis pos., process loop
- P-0-0750, Master axis revolutions per master axis cycle
- P-0-0764, Master axis speed
- P-0-0765, Modulo factor measuring encoder

- P-0-0775, Resulting master axis position

The following parameters are used in conjunction with the electronic gear with fine adjustment:

- P-0-0083, Gear ratio fine adjustment
- P-0-0108, Master drive polarity
- P-0-0156, Master drive gear input revolutions
- P-0-0157, Master drive gear output revolutions
- P-0-0694, Gear ratio fine adjustment, process loop
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity

Command Value Processing for Slave Axis Depending on Operating Mode

When the output value of the electronic gear is processed, there are different operations carried out, according to the synchronization mode, for generating the position or velocity command value for the subsequent control loop (slave axis). This "command value processing depending on operating mode" is described in the sections on the respective operating mode:

- See "Velocity Synchronization"
- See "Position Synchronization: Phase synchronization"
- See "Position Synchronization: Electronic cam"
- See "Position Synchronization: MotionProfile"

Master Axis Cycle, Command Value Cycle, Actual Value Cycle and Synchronization Ranges

Applications

The extended functions of synchronization (master axis cycle, command value and actual value cycle) are required in conjunction with the following applications:

- Change of format, i.e. variable master axis gear settings in operation
- Necessity of mechanical relation of slave axis to master axis

---

☞ Command value and actual value cycle are only relevant for the position synchronization modes ("phase synchronization", "cam" and "MotionProfile").

The figure below illustrates the interaction of the pertinent parameters for the command value cycle and the actual value cycle:

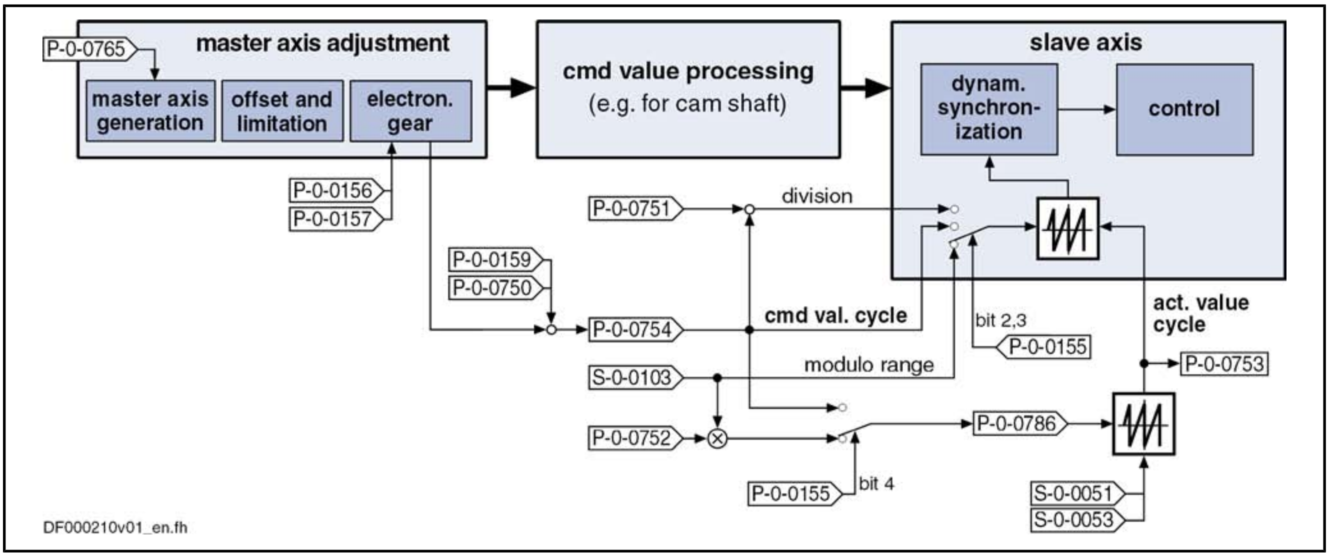


Fig.7-41: Generation and Operating Principle of the Command Value and Actual Value Cycle

Master Axis Cycle

The master axis cycle specifies the range of the master axis values. It corresponds to a master axis revolution or a multiple thereof. The drive must be notified the master axis cycle by the control in order to allow for the correct processing of the master axis positions (e.g. modulo overflows).

The master axis cycle is configured via parameter **"P-0-0750, Master axis revolutions per master axis cycle"**. See Parameter Description "P-0-0750, Master axis revolutions per master axis cycle"

In printing machines, for example, the master axis cycle specifies how many master axis revolutions are required for producing a (partial) product. After each master axis cycle, the mechanical alignment of all slave axes to each other corresponds to the initial position in the machining process.

In more complex systems, the duration of the partial processes required for producing a product is different. The end product consists of several partial products running through different processing cycles.

In the following example, brochures consisting of 2 double pages A, B are produced. Within one revolution of the impression cylinder, the two double pages A, B are printed onto one path. A cross cutter divides the imprinted path into the partial formats A and B. The partial products A, B are taken over by a collective cylinder. One part B is in each case put onto one part A. After 2 revolutions of the collective cylinder, 6 subsequent partial products A, B are processed. In order to allow for a clear alignment of all drives also after one master axis revolution, the multi-turn capability of the master axis is used. In the drives, different synchronization ranges for the individual partial processes are set.

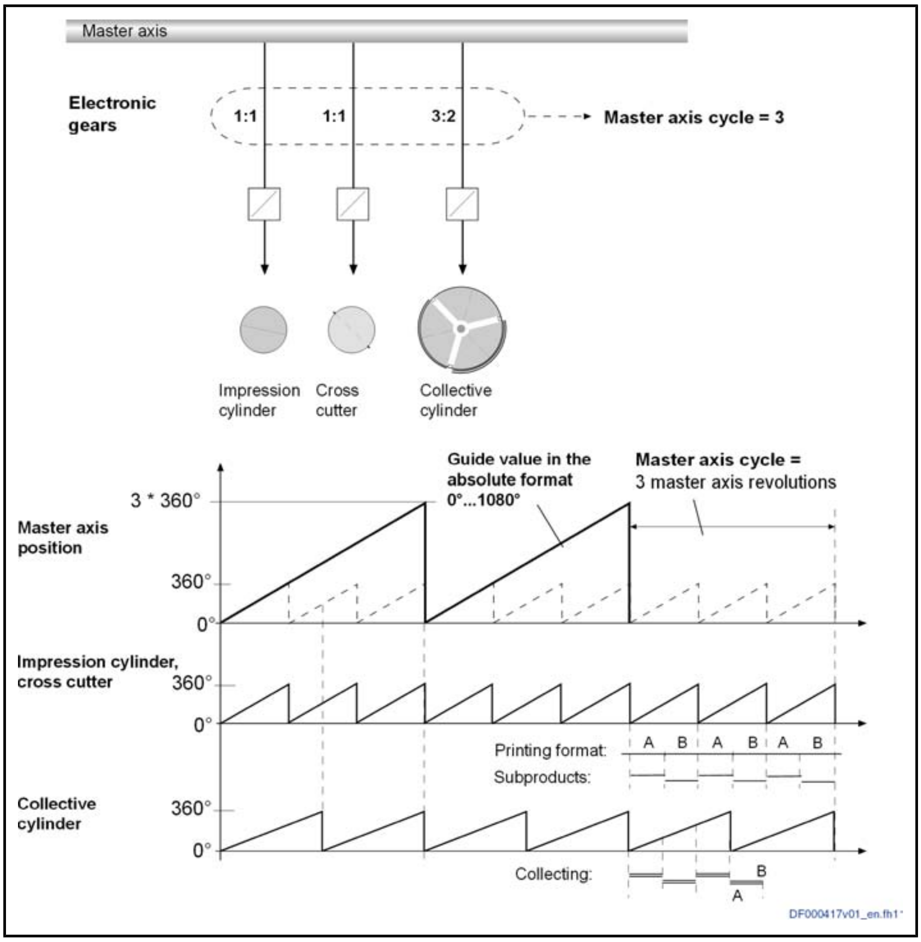


Fig.7-42:

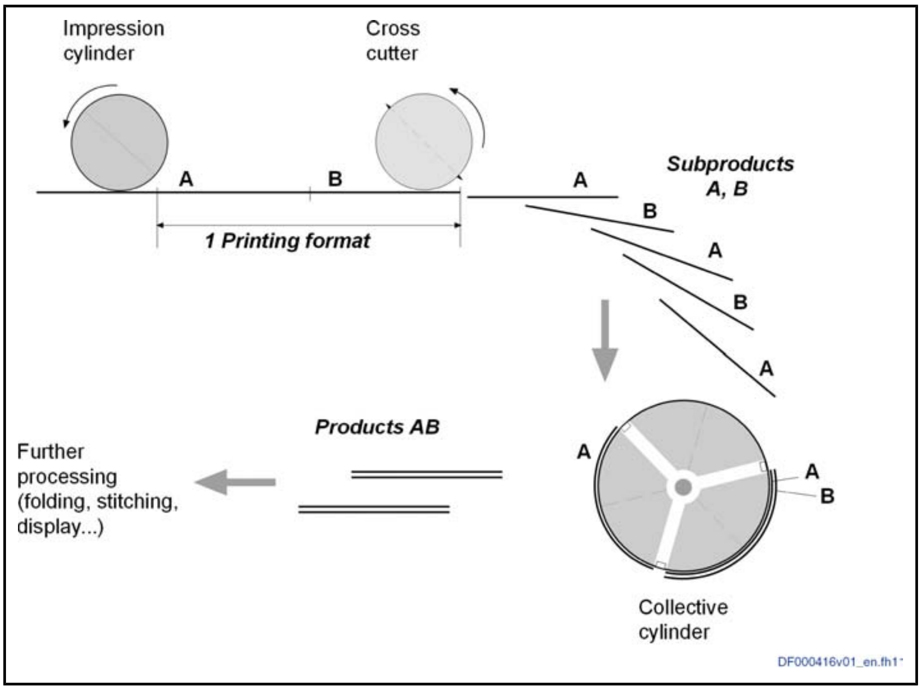


Fig.7-43:

In the commissioning, the master axis cycle is once set according to the following rule:

$$\text{Master axis cycle} = \text{LCM of the P-0-0156}$$

LCM: Least common multiple
P-0-0156: Master drive gear input revolutions
Fig.7-44: Master Axis Cycle

In format-variable processes, the electronic gears of individual slave axes are changed in case of a product change: the partial processes may vary, depending on the product. In these applications, all admissible gear settings must be considered when determining the master axis cycle.

Command Value Cycle

In processes with different machining cycles, the drives must be able to synchronize over several master axis revolutions or divisions of a master axis revolution. This property is defined via the so-called command value cycle.

See Parameter Description "P-0-0754, Command value cycle"

The command value is determined automatically in the drive: From the settings for the master axis cycle and the electronic gear, each drive calculates in which range its synchronous position command values lie. This absolute position range is the command value cycle; i.e. the position range of the slave axis within a master axis cycle.

☞ The command value cycle is calculated internally by the drive and displayed in parameter "P-0-0754, Command value cycle". The command value cycle for the synchronization is only required in case of modulo scaling of the slave axis.

The range for the command value cycle at the slave axis is defined by the master axis cycle and the electronic gear.

With "Phase synchronization",

with "Cam without gear reduction" and (P-0-0755 = 0) and

with "MotionProfile without gear reduction" (P-0-0755 = 0):

$$\text{Command value cycle} = \text{P-0-0750} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times \text{S-0-0103}$$

With "Cam with gear reduction" (P-0-0755 ≠ 0) and

with "MotionProfile with gear reduction" (P-0-0755 ≠ 0):

$$\text{Command value cycle} = \text{P-0-0750} \times \frac{\text{P-0-0157} \times \text{S-0-0103}}{\text{P-0-0156} \times \text{P-0-0755}}$$

Fig.7-45: Command Value Cycle With Modulo Scaling

The active value is displayed in parameter "P-0-0754, Command value cycle". The command value cycle describes the range containing the calculated synchronous position command values.

Actual Value Cycle / Position Actual Value in the Actual Value Cycle

The modulo range within which the actual position values (P-0-0753, Position actual value in actual value cycle) of the slave axis are to be found in case of active position synchronization mode is called actual value cycle. The position synchronization modes (phase synchronization, cam and MotionProfile) use the "position actual value in actual value cycle" in order to close their position control loop. When activating one of the position synchronization operating modes, the travel distance for synchronization is moreover determined using the "position actual value in the actual value cycle". In this connection, the travel distance is limited to the synchronization range (command value cycle, division of the command value cycle or modulo range (S-0-0103)) that has been set.

See Parameter Description "P-0-0753, Position actual value in actual value cycle"

See Parameter Description "P-0-0786, Modulo value actual value cycle".

The modulo range of the actual value cycle has to be determined so that is corresponds to an integer multiple of the synchronization range.

☞ The display shows the value range of the actual value cycle in parameter "P-0-0786, Modulo value actual value cycle".

For the setting of bit 4 in parameter "P-0-0155, Synchronization mode", we distinguish the following cases:

- **Bit 4 = 1**

  → The actual value cycle (P-0-0786) equals the command value cycle (P-0-0754).

- **Bit 4 = 0**

  → The actual value cycle is determined by the parameters "P-0-0752, Load revolutions per actual value cycle slave axis" and "S-0-0103, Modulo value".

$$\text{P-0-0786} = \text{S-0-0103} \times \text{P-0-0752}$$

Fig.7-46: Internal Calculation Formula of the Value for P-0-0786

The actual value cycle (P-0-0786) is calculated

- automatically when progressing from parameter mode to operating mode

- or -

- manually by starting the command "P-0-0071, C3100 Command Recalculate actual value cycle" for recalculating the actual value cycle in the operating mode when a parameter, that is used for calculating the actual value cycle, was changed in the operating mode.

☞ At the start of command C3100, the status bits in "S-0-0403, Position feedback value status" and the status bit in "P-0-0089, Status word synchronization modes" (bit 4) are cleared. After the position data reference has been successfully established, the bits are set again.

Synchronization Range

In the case of modulo scaling, the range for synchronization can be set in parameter "P-0-0155, Synchronization mode", i.e. the distance to be traveled is limited to this range:

- Modulo value (S-0-0103)
- Command value cycle (P-0-0754)
- Division of the command value cycle

☞ The actual position value used for calculating the distance must be unequivocal in the range in which synchronization is to take place. The actual value cycle from which the actual position value is derived must therefore be determined in such a way that is a multiple of the synchronization range.

Synchronization in the Command Value Cycle

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ "S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and the position actual value in actual value cycle (P-0-0753). The synchronization distance is limited to the modulo command value cycle.

$$\text{Distance} = \%\ \text{cmd value cycle}\left[x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - \text{actual position value}\right]$$

Fig.7-47: Synchronization Distance During Synchronization in Command Value Cycle

Within the actual value cycle, there may be several synchronization ranges with the value of a command value cycle.

Example of the calculation of the synchronization distance with standing master axis:

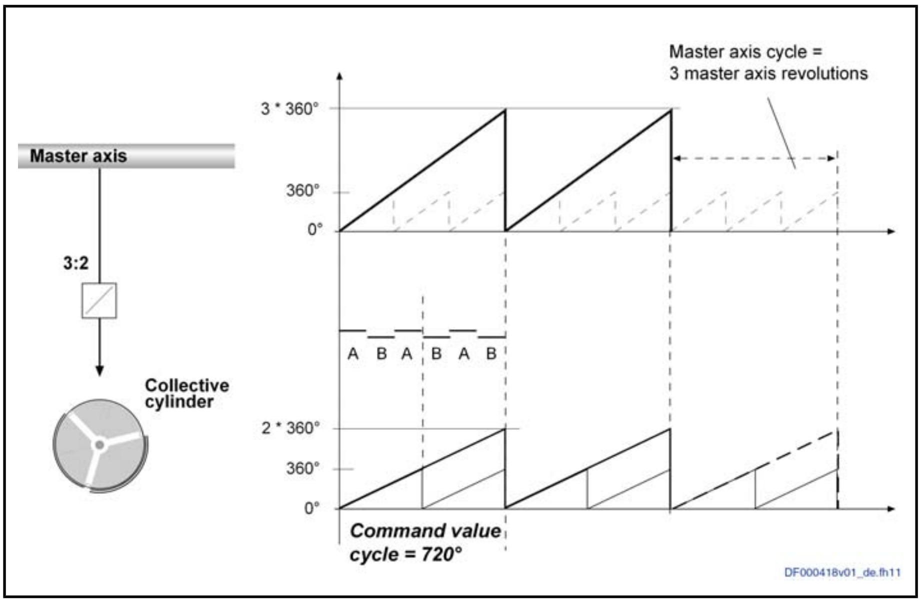


Fig.7-48:

- Phase synchronization operating mode
- Modulo value (S-0-0103) = 360°
- Master axis cycle (P-0-0750) = 3
- Master drive gear input revolutions (P-0-0156) = 3
- Master drive gear output revolutions (P-0-0157) = 2
- Command value cycle (P-0-0754) = 720°
- Actual value cycle (P-0-0786) = 720°
- Additive command values (S-0-0048 / P-0-0691) = 0°
- Number of bits per master axis revolution (P-0-0084) = 20 bits
- Resulting master axis position (P-0-0775) = 2228224 Incr
- Current position actual value in actual value cycle (P-0-0753) = 210°

- Master axis is standing

When the operating mode is activated, the following synchronous position command value results:

X_{SYNC} = %P-0-0786 [P-0-0775 * P-0-0157 * S-0-0103 / ($2^{P\text{-}0\text{-}0084}$* P-0-0156)] = 510°.

According to the preceding formula, the following synchronization distance results:

Distance = %720° [510°- 210°] = 300°

Depending of the configuration of the parameter "P-0-0154, Synchronization direction", the slave axis travels the following distance in order to reach the synchronous position.

- Shortest distance: Synchronization distance = +300° da 300° < (P-0-0754 / 2)
- Positive direction: Synchronization distance = + 300°
- Negative direction: Synchronization position = 300° - P-0-0754 = - 420°

If, however, the shortest distance to the absolute synchronization is smaller than "P-0-0151, Synchronization window for modulo format", the shortest distance will be traveled and the specified synchronization direction will be ignored.

Synchronization in a Division of the Command Value Cycle

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ "S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and the position actual value in actual value cycle. The synchronization distance is limited to a division of the modulo command value cycle.

$$\text{Distance} = \%\ \text{division of cmd value cycle} \left[x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - \text{actual position value} \right]$$

Fig.7-49: Synchronization Distance for Synchronization in a Division of the Command Value Cycle

The number of divisions per command value cycle and thus the division itself are determined via parameter "P-0-0751, Synchronization divisions per command cycle slave axis". This value must be integer.

Example1

- A collective cylinder is to only synchronize within one of several collection areas.

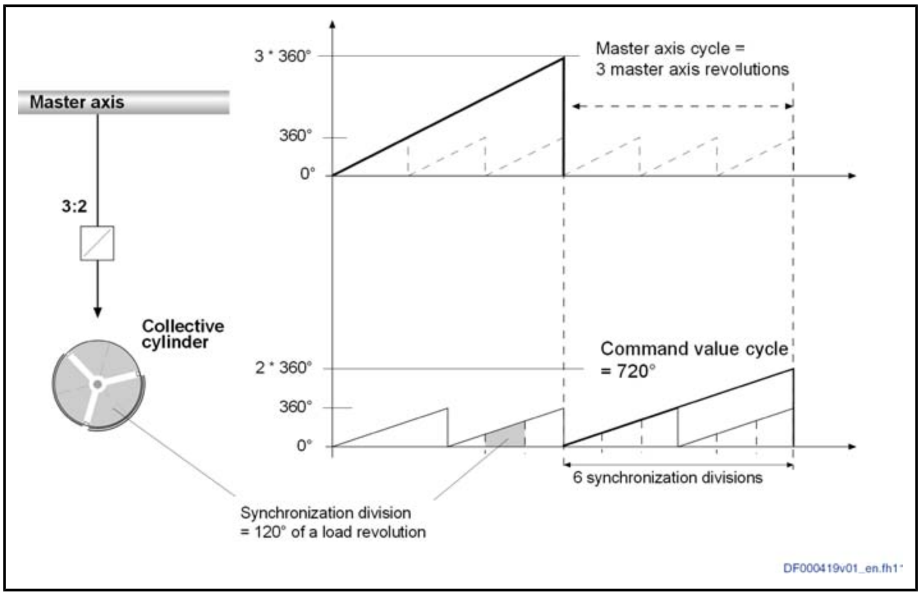


Fig.7-50:

- Phase synchronization operating mode
- Modulo value (S-0-0103) = 360°
- Master axis cycle (P-0-0750) = 3
- Master drive gear input revolutions (P-0-0156) = 3
- Master drive gear output revolutions (P-0-0157) = 2
- Command value cycle (P-0-0754) = 720°
- Synchronization divisions (P-0-0751) = 6
- Actual value cycle (P-0-0786) = 720°
- Additive command values (S-0-0048 / P-0-0691) = 0°
- Number of bits per master axis revolution (P-0-0084) = 20 bits
- Resulting master axis position (P-0-0775) = 2228224 Incr
- Current position actual value in actual value cycle (P-0-0753) = 210°
- Master axis is standing

When the operating mode is activated, the following synchronous position command value results:

X_{SYNC} = %P-0-0786 [P-0-0775 * P-0-0157 * S-0-0103 / ($2^{P-0-0084}$* P-0-0156)] = 510°.

According to the preceding formula, the following synchronization distance results:

Distance = %(P-0-0754 / P-0-0751) [510°- 210°] = 60°

Depending of the configuration of the parameter "P-0-0154, Synchronization direction", the slave axis travels the following distance in order to reach the synchronous position.

- Shortest distance: Synchronization distance = +60° da 60° == (P-0-0754 / (P-0-0751 * 2))

  Synchronization position = P-0-0753° + 60° = 270°
- Positive direction: Synchronization distance = +60°

  Synchronization position = P-0-0753° + 60° = 270°

- Negative direction: Synchronization distance = 60° - (P-0-0754/P-0-0751) = - 60°

  Synchronization position = P-0-0753° - 60° = 150°

If, however, the shortest distance to the absolute synchronization is smaller than "P-0-0151, Synchronization window for modulo format", the shortest distance will be traveled and the specified synchronization direction will be ignored.

Example2

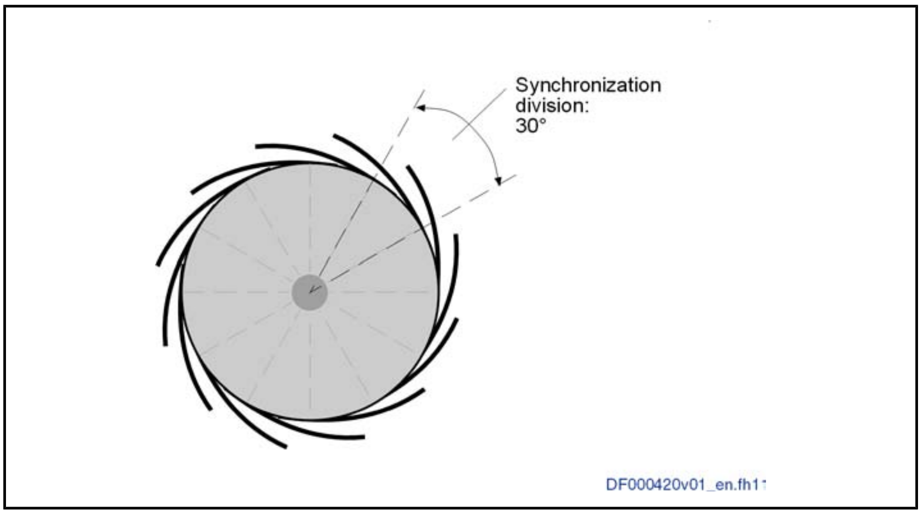


Fig.7-51:

In the ongoing process, each paddle takes up a product; e.g. a printed magazine. Upon switch-on, the paddle wheel only synchronizes in the area of one paddle in order to ensure that collected copies do not fall out.

Synchronization in the Modulo Range

The distance traveled during synchronization is the result of the difference between synchronous position command value (+ "S-0-0048, Additive position command value" + "P-0-0691, Additive position command value, process loop") and the position actual value in actual value cycle. The synchronization distance is limited to the modulo value (S-0-0103).

$$\text{Distance} = \%\ \text{modulo value} \left[x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691}) - \text{actual position value} \right]$$

Fig.7-52: Synchronization Distance for Synchronization in Modulo Range

Dynamic Synchronization of the Slave Axis

Brief Description

The synchronization process is a drive-controlled motion with the objective of achieving absolute or relative synchronization between master axis and slave axis. Depending on the synchronization mode, we distinguish the following characteristics of dynamic synchronization:

Synchronization With Velocity Synchronization

Features of synchronization in the "velocity synchronization" mode:

- Synchronization takes place as velocity adjustment
- Option: Synchronization only in case of activation of the operating mode or always
- Generation of status message "synchronization completed" (P-0-0152, bit 0)

- Generation of status message "synchronous mode in synchronization" (P-0-0089, bit 8)

Synchronization With the Position Synchronization Operating Modes

Features of the synchronization with the position synchronization operating modes:

- Selection sequence of synchronization is **single-step, double-step or double-step optimized**
- Synchronization **absolute** (position and velocity adjustment) or **relative** (only velocity adjustment)
- **Modulo ranges** to be set for synchronization:
  - Modulo value (S-0-0103)
  - Command value cycle slave axis (P-0-0754)
  - Division for command value cycle (setting in P-0-0751)
- Possibility of another synchronization with active operating mode (P-0-0088, bit8)
- Direction for synchronization to be set for position adjustment of modulo axes, shortest distance, positive or negative direction in parameter "P-0-0154, Synchronization direction"; setting the tolerance window with only positive or negative direction via "P-0-0151, Synchronization window for modulo format"
- Display of the difference between position actual value in actual value cycle and the synchronous position command value generated from the master axis position in parameter "P-0-0034, Position command additional actual value"
- Generation of status message "synchronization completed" (P-0-0152, bit 0)
- Command value addition for slave axis possible
- Generation of status message "synchronous mode in synchronization" (bit 8 in "P-0-0089, Status word synchronization modes")

See Parameter Description "P-0-0155, Synchronization mode"

The figure below contains an overview of the different possible settings for carrying out synchronization and for adding command values in the synchronization modes:

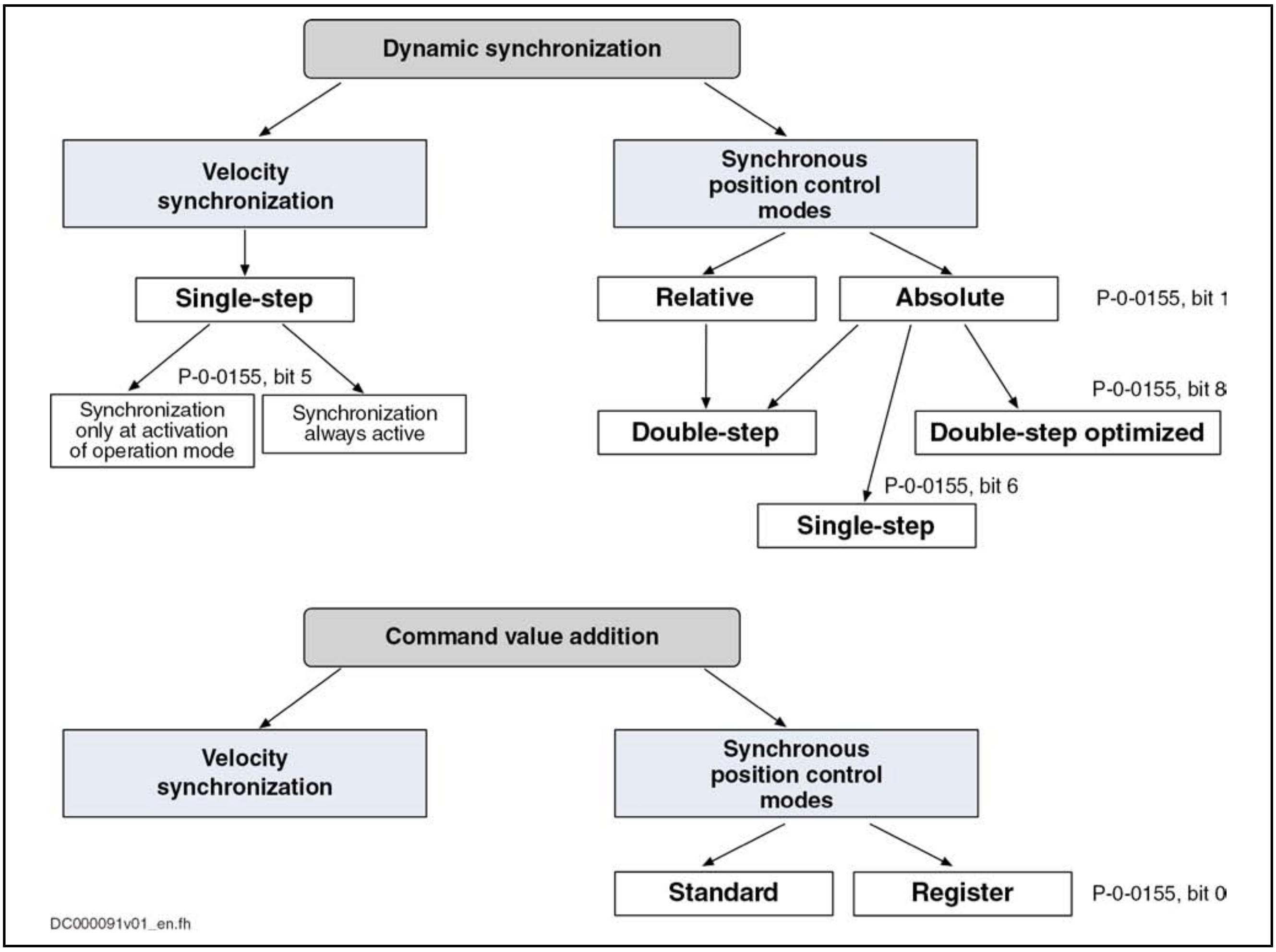


Fig.7-53: Overview of Methods to be Selected for Synchronization and for Command Value Addition

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☞ In the default setting of parameter P-0-0155, all bits are at value "0"!

Pertinent Parameters

The following parameters are used in conjunction with dynamic synchronization:

- S-0-0048, Additive position command value
- S-0-0183, Velocity synchronization window
- S-0-0228, Position synchronization window
- P-0-0034, Position command additional actual value
- P-0-0060, Filter time constant additive position cmd value
- P-0-0071, C3100 Command Recalculate actual value cycle
- P-0-0142, Synchronization acceleration
- P-0-0143, Synchronization velocity
- P-0-0151, Synchronization window for modulo format
- P-0-0152, Synchronization completed
- P-0-0154, Synchronization direction
- P-0-0155, Synchronization mode

- P-0-0686, Additive position command value, positioning velocity
- P-0-0687, Additive position command value, positioning acceleration
- P-0-0691, Additive position command value, process loop
- P-0-0697, Synchronization, master axis synchronous position
- P-0-0698, Synchronization, master axis synchronization range
- P-0-0751, Synchronization divisions per command cycle slave axis
- P-0-0752, Load revolutions per actual value cycle slave axis
- P-0-0753, Position actual value in actual value cycle
- P-0-0754, Command value cycle
- P-0-0786, Modulo value actual value cycle

Command Value Addition for Slave Axis

Brief Description

In the "velocity synchronization" mode, the addition of command values for the slave axis is directly associated with the synchronization process.

In synchronous position control modes, the addition of command values for the slave axis is an independent functional sequence for which you can choose between the following modes as regards command value addition:

- **"Standard" mode**

  → Changes are processed with the values from the parameters P-0-0686 and P-0-0687
- **"Register controller" mode**

  → Changes are smoothed by a 1st order filter (time constant in parameter P-0-0060)

The mode is selected via bit 0 of parameter "P-0-0155, Synchronization mode". As default setting, the "standard" mode is active.

7.8.2 Velocity Synchronization With Real/Virtual Master Axis

Brief Description

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

In the operating mode "velocity synchronization with real/virtual master axis", the drive follows a preset master axis velocity in a velocity-synchronous way.

The real master axis velocity is generated by a measuring encoder, the virtual master axis velocity, however, is preset by the master.

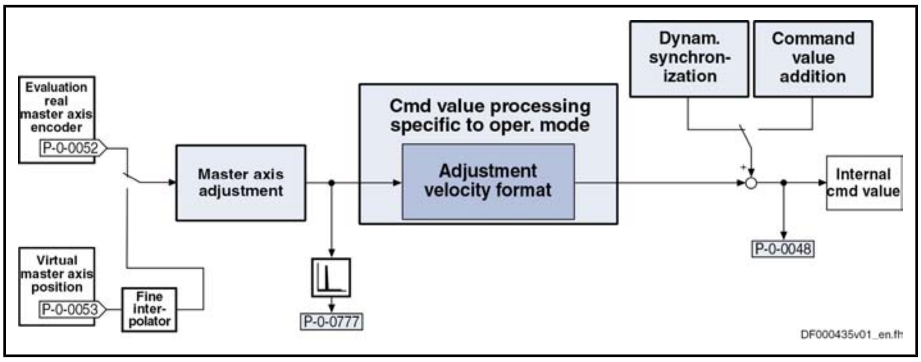
See also "Dynamic Synchronization of the Slave Axis" in section "Basic Functions of the Synchronization Modes"

Features

- Determination of the effective velocity command value (P-0-0048) from the differentiated and fine interpolated sum of master axis position (P-0-0053) or measuring encoder position (P-0-0052) and additive components of "P-0-0054, Additive master axis position" and "P-0-0692, Additive master axis position, process loop", multiplied with master axis gear and fine adjustment
- Adjustable master axis polarity
- Synchronization takes place in single-step form

- Synchronization mode to be selected
  - Velocity adjustment always via synchronization acceleration (P-0-0142)
  - Velocity adjustment via synchronization acceleration (P-0-0142) only in the first synchronization

The figure below illustrates the interaction of the individual subfunctions (function blocks) of the "velocity synchronization" mode:



P-0-0048 Effective velocity command value
P-0-0052 Actual position value of measuring encoder
P-0-0053 Master axis position
P-0-0777 Effective master axis velocity

Fig.7-54: Function Blocks of the Operating Mode "Velocity Synchronization With Real/Virtual Master Axis"

Variants of the Operating Mode

The following variants can be configured:

- Velocity synchronization with real master axis
- Velocity synchronization with virtual master axis

Application of the Operating Mode

Velocity synchronization is used, for example, for simple transport rolls of printing machines. The drive runs with a velocity synchronous to the master axis. The track speed at the circumference of the transport roll or the winder is preset by the electric gear. A defined tension can be set by the fine adjustment of the gear.

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in velocity synchronization:

- S-0-0037, Additive velocity command value
- S-0-0183, Velocity synchronization window
- P-0-0159, Slave drive feed travel
- P-0-0690, Additive velocity command value, process loop
- P-0-0777, Effective master axis velocity

See also "Pertinent Parameters" in the Subsections of "Basic Functions of the Synchronization Modes"

Pertinent Diagnostic Messages

In addition to the general diagnostic messages of all synchronization modes, there are other diagnostic messages involved in velocity synchronization:

- A0110 Velocity synchronization, virtual master axis
- A0111 Velocity synchronization, real master axis
- A0164 Velocity synchronization
- E2063 Velocity command value > limit value

See also "Pertinent Diagnostic Messages" in the Subsections of "Basic Functions of the Synchronization Modes"

Overview of the Operating Mode

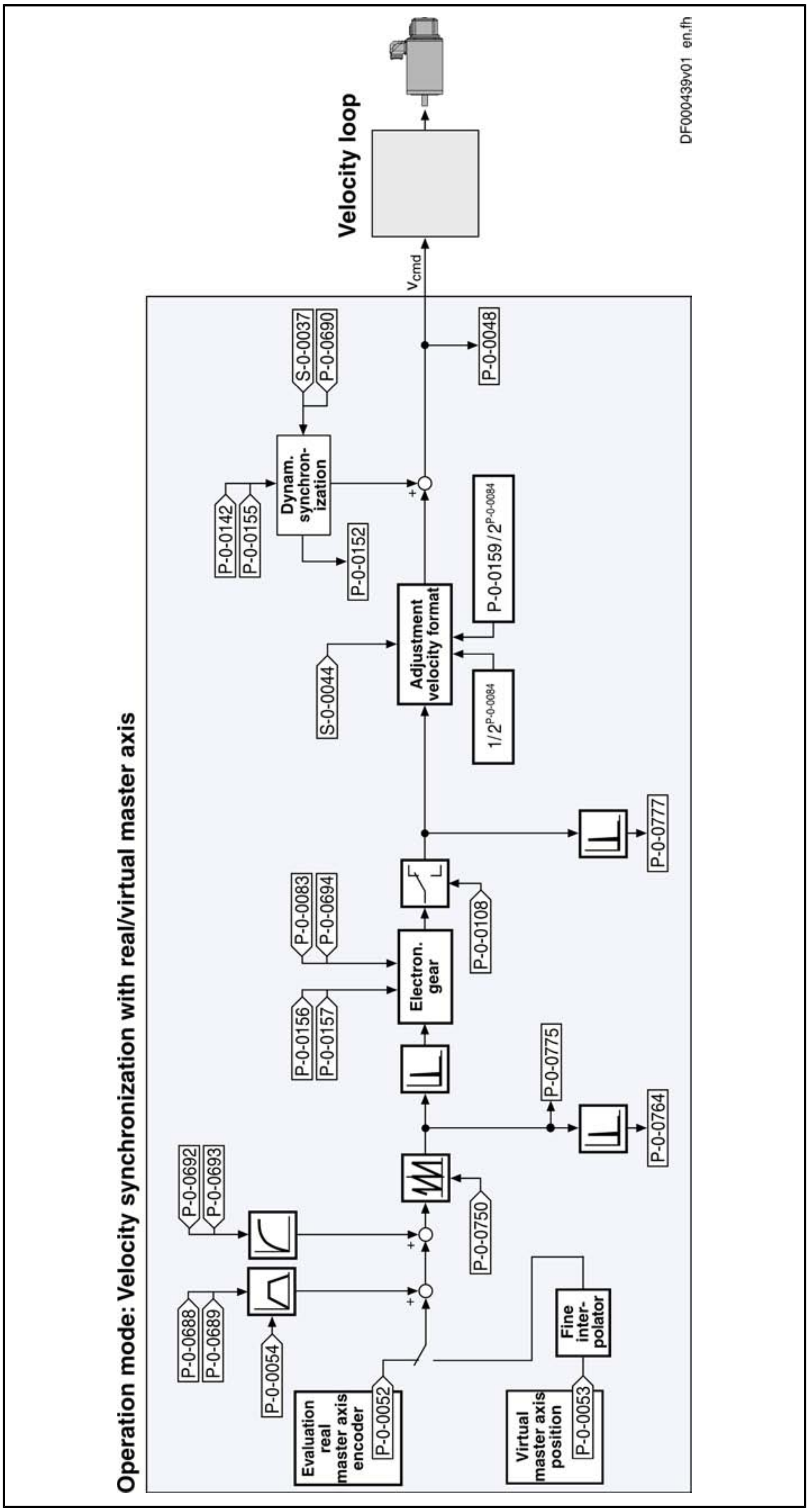


Fig.7-55: Block Diagram: Velocity Synchronization With Real/Virtual Master Axis

Master Axis Adjustment

Master axis adjustment is realized by means of the following subfunctions:

- Generation of master axis
- Master axis offset and modulo limitation
- Electronic gear with fine adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "velocity synchronization" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operating mode
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

Only the function block "command value processing" specific to velocity synchronization is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

See "Basic Functions of the Synchronization Modes"

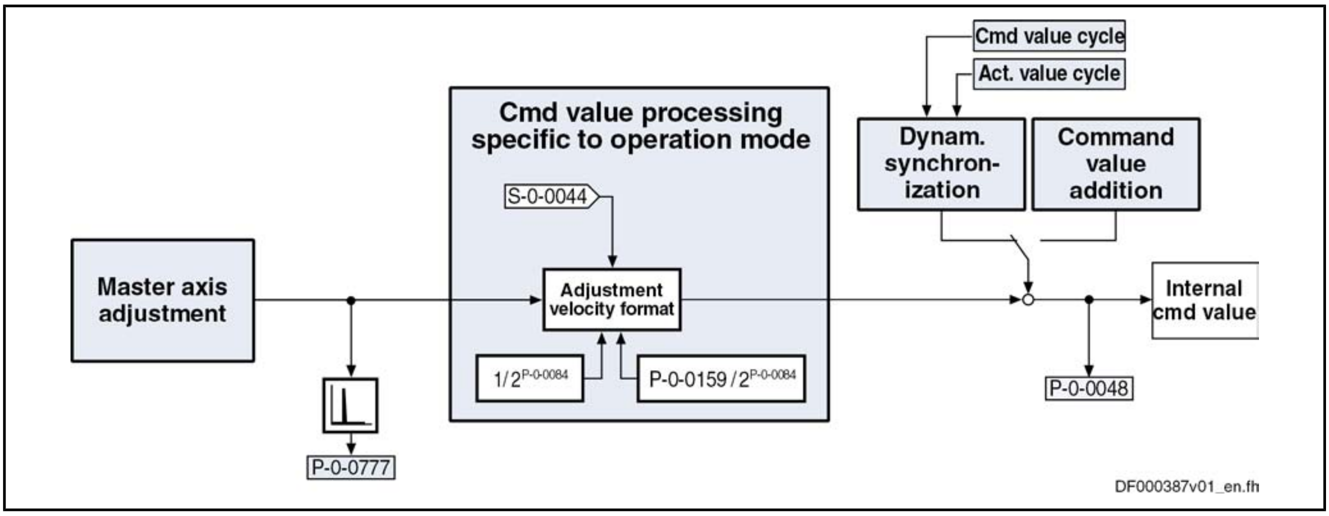


Fig.7-56: Command Value Processing Specific to Operating Mode for Velocity Synchronization

Generating the Synchronous Velocity Command Value

The synchronous velocity command value (dx_{sync}) is generated in terms of the selected master axis polarity (P-0-0108) and the scaling type (S-0-0044) that was set, using one of the following equations:

$$dx_{sync} = \pm\Delta\,[(P\text{-}0\text{-}0053) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)] \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times [1 + (P\text{-}0\text{-}0083)] \times [1 + (P\text{-}0\text{-}0694)] \times \frac{1}{2^{P\text{-}0\text{-}0084}}$$

dx_{sync} Synchronous velocity command value

Fig.7-57: Generating the Synchronous Velocity Command Value With Rotary Scaling

$$dx_{sync} = \pm\Delta\ [(P\text{-}0\text{-}0053) + (P\text{-}0\text{-}0054) + (P\text{-}0\text{-}0692)] \times \frac{P\text{-}0\text{-}0157}{P\text{-}0\text{-}0156} \times [1 + (P\text{-}0\text{-}0083)] \times [1 + (P\text{-}0\text{-}0694)] \times \frac{P\text{-}0\text{-}0159}{2^{P\text{-}0\text{-}0084}}$$

dx_{sync} Synchronous velocity command value

Fig.7-58: Generating the Synchronous Velocity Command Value With Linear Scaling

One master axis revolution is standardized to 2^N increments (with N = value from "P-0-0084, Number of bits per master axis revolution"). This means that the LSB of the master axis position corresponds to 2^{-N} master axis revolutions.

Synchronization With Velocity Synchronization

The synchronization process is a drive-controlled motion with the aim of synchronizing the axis to the master axis velocity. The slave axis is velocity-synchronous when the following condition has been fulfilled:

$$dx_{sync} + (S\text{-}0\text{-}0037) + (P\text{-}0\text{-}0690) = S\text{-}0\text{-}0040$$

dx_{sync} Synchronous velocity command value

S-0-0040 Velocity feedback value

Fig.7-59: Condition for Velocity Synchronism of the Slave Axis

Synchronization Process

Upon activation of the operating mode, a **velocity adjustment** is executed.

This means that the drive either accelerates or decelerates from the current actual velocity at the time of activation to the synchronous velocity.

After the synchronous velocity has been reached, another change of the synchronous velocity is processed depending on "P-0-0155, Synchronization mode".

The following variants are available to do this:

- **P-0-0155, bit 5 = 0**

  → Velocity adjustment only carried out once, all following changes of velocity are carried out with maximum acceleration
- **P-0-0155, bit 5 = 1**

  → Every change of velocity is limited by the value of "P-0-0142, Synchronization acceleration"

See also Parameter Description "P-0-0155, Synchronization mode"

7.8.3 Position Synchronization: Phase Synchronization

Brief Description

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

In the operating mode "phase synchronization with real/virtual master axis", the drive follows a preset master axis position in an absolute or relative phase synchronous way.

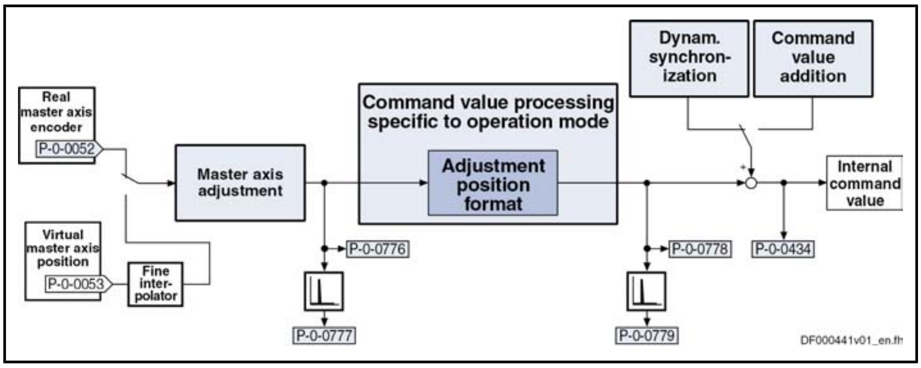
The real master axis velocity is generated by a measuring encoder, the virtual master axis velocity, however, is preset by the master.

See also "Dynamic Synchronization of the Slave Axis" in section "Basic Functions of the Synchronization Modes"

Features

- Determination of the position command value from the master axis position using the electronic gear with fine adjustment, adjustable master axis polarity
- Synchronization mode to be selected
- Single-step, double-step or optimized double-step synchronization
- Absolute or relative phase synchronization
- Synchronization range to be selected

The figure below illustrates the interaction of the individual subfunctions (function blocks) of the "phase synchronization" mode:



P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0434	Position command value of controller
P-0-0776	Effective master axis position
P-0-0777	Effective master axis velocity
P-0-0778	Synchronous position command value
P-0-0779	Synchronous velocity

Fig.7-60: Function Blocks of the Operating Mode "Phase Synchronization With Real/Virtual Master Axis"

Variants of the Operating Mode

The following variants can be configured:

- Position Synchronization: Phase synchronization
  - Phase synchronization with real master axis, encoder 1
  - Phase synchronization with real master axis, encoder 2
  - Phase synchronization with real master axis, encoder 1, lagless
  - Phase synchronization with real master axis, encoder 2, lagless
  - Phase synchronization with virtual master axis, encoder 1
  - Phase synchronization with virtual master axis, encoder 2
  - Phase synchronization with virtual master axis, encoder 1, lagless
  - Phase synchronization with virtual master axis, encoder 2, lagless

☞ The position synchronization mode "phase synchronization", "cam" or "MotionProfile" as well as the active master axis are selected in parameter "P-0-0088, Control word synchronization modes". The encoder selection and the determination position control with lag error or lagless are made in parameter "S-0-0520, Control word of axis controller".

Application "Absolute Phase Synchronization"

In machining processes that require absolute phase synchronization, e.g. printing, punching or perforating in printing machines, the absolute position reference to the master axis is established in the operating mode "phase synchronization". The drive synchronizes with a position command value that is generated from master axis position and additive position command value.

Application "Relative Phase Synchronization"

For machining processes that only require relative phase synchronization, e.g. synchronization of belts or feed rollers without defined starting point, a relative position reference to the master axis is established. During the first synchronization, there is only an adjustment to the synchronous velocity but no position adjustment carried out.

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in phase synchronization:

- S-0-0103, Modulo value
- S-0-0520, Control word of axis controller
- S-0-0521, Status word of position loop
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes
- P-0-0159, Slave drive feed travel
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity
- P-0-0778, Synchronous position command value
- P-0-0779, Synchronous velocity

See also "Pertinent Parameters" in the subsections of "Basic Functions of the Synchronization Modes"

Overview of the Operating Mode

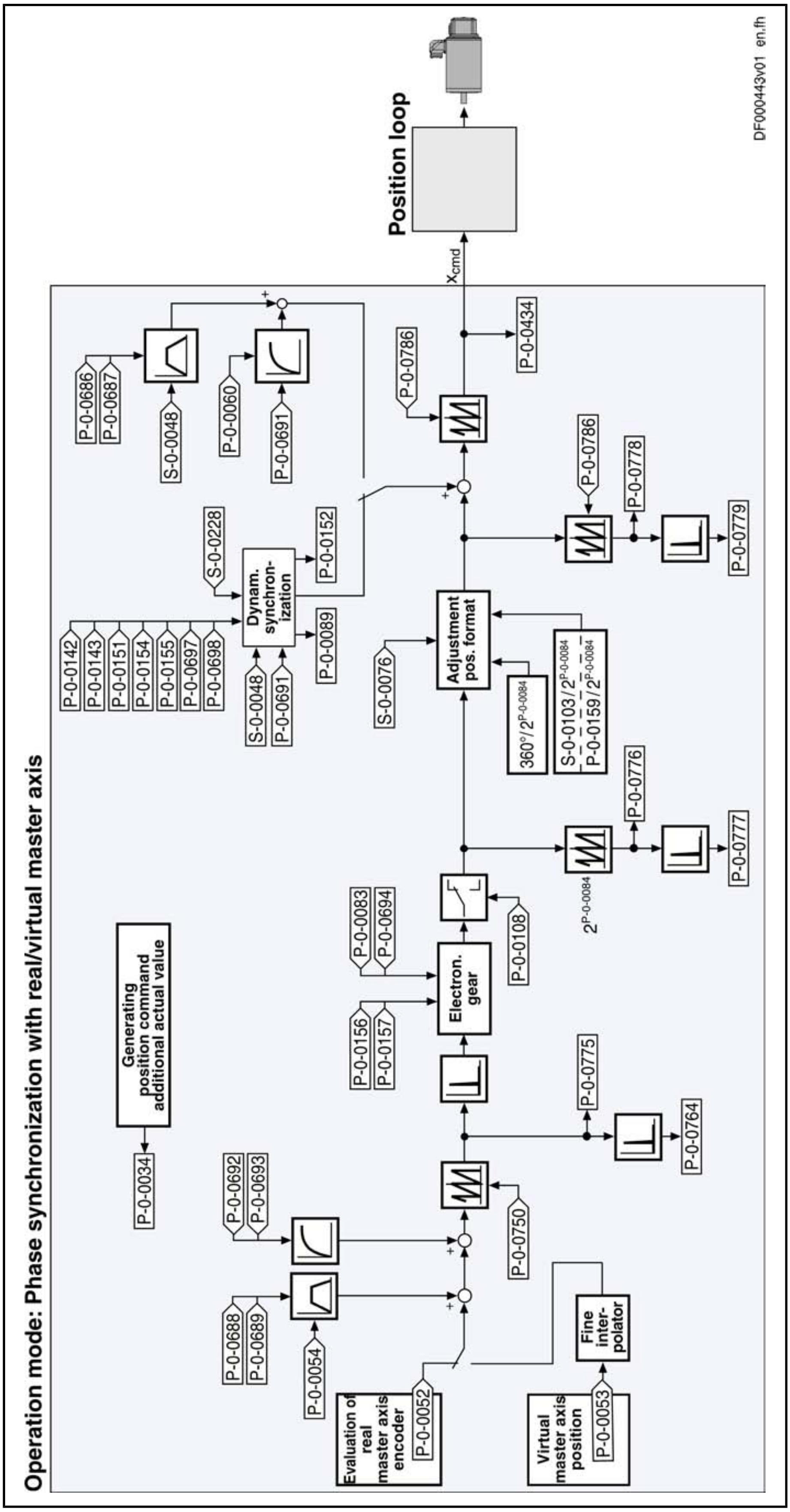


Fig.7-61: Block Diagram: Phase Synchronization With Real/Virtual Master Axis

Master Axis Adjustment

Master axis adjustment is realized by means of the following subfunctions:

- Generation of master axis
- Master axis offset and modulo limitation
- Electronic gear with fine adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "phase synchronization" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operating mode
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

☞ Only the function block "command value processing" specific to phase synchronization is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

See "Basic Functions of the Synchronization Modes"

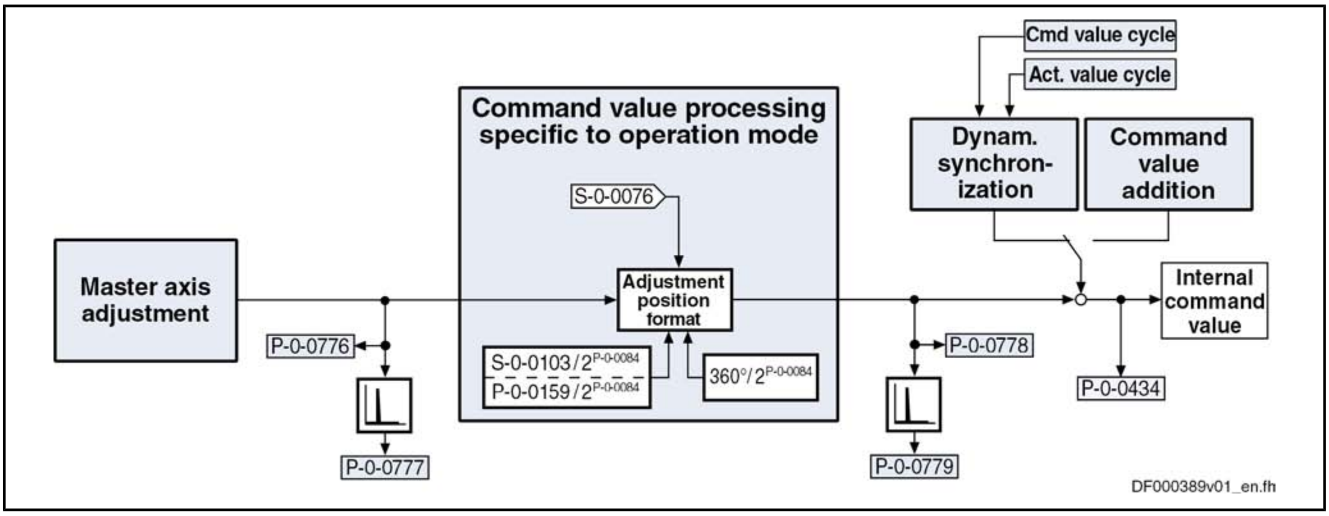


Fig. 7-62: Command Value Processing Specific to Operating Mode for Phase Synchronization

Generating the Internal Position Command Value

In the operating mode "phase synchronization with real/virtual master axis", the internal position command value (P-0-0434) is generated by addition of the synchronous position command value (x_{sync}) with the components of the additive position command value (S-0-0048) and the additive position command value of process loop (P-0-0691).

$$\text{P-0-0434} = x_{sync} + x_{add} + x_{add\_PR}$$

P-0-0434	Position command value of controller
x_{sync}	Synchronous position command value
x_{add}	Filter output of "S-0-0048, Additive position command value"
x_{add_PR}	Filter output of "P-0-0691, Additive position command value, process loop"

Fig.7-63: Generating the Internal Position Command Value

Note: In the synchronized status (P-0-0089; bit 8 = 1), the following applies:

$$\text{P-0-0434} = x_{sync} + (\text{S-0-0048}) + (\text{P-0-0691})$$

Fig.7-64: Generating the Internal Position Command Value in the Synchronized Status

Generating the Synchronous Position Command Value

The synchronous position command value (x_{sync}) is generated in terms of the selected master axis polarity (P-0-0108) and the scaling type (S-0-0076) that was set, using the following equation:

$$x_{sync} = \left\langle \text{P-0-0775} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times [1 + (\text{P-0-0083})] \times [1 + (\text{P-0-0694})] \times \frac{\text{S-0-0103}}{2^{\text{P-0-0084}}} \right\rangle \% \text{ P-0-0786}$$

Fig.7-65: Generating the Synchronous Position Command Value With Modulo Scaling

$$x_{sync} = \left\langle \text{P-0-0775} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times [1 + (\text{P-0-0083})] \times [1 + (\text{P-0-0694})] \times \frac{360\,°}{2^{\text{P-0-0084}}} \right\rangle \% \text{ P-0-0786}$$

Fig.7-66: Generating the Synchronous Position Command Value With Rotary Absolute Scaling

$$x_{sync} = \left\langle \text{P-0-0775} \times \frac{\text{P-0-0157}}{\text{P-0-0156}} \times [1 + (\text{P-0-0083})] \times [1 + (\text{P-0-0694})] \times \frac{\text{P-0-0159}}{2^{\text{P-0-0084}}} \right\rangle \% \text{ P-0-0786}$$

Fig.7-67: Generating the Synchronous Position Command Value With Linear Absolute Scaling

☞ One master axis revolution is standardized to 2^N increments (with N = value from "P-0-0084, Number of bits per master axis revolution"). This means that the LSB of the master axis position corresponds to 2^{-N} master axis revolutions.

Synchronization

See "Basic Functions of the Synchronization Modes"

7.8.4 Position Synchronization: Electronic Cam

Brief Description

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

In the operation mode "electronic cam with real/virtual master axis", there is a fixed relationship between the master axis position and the slave axis.

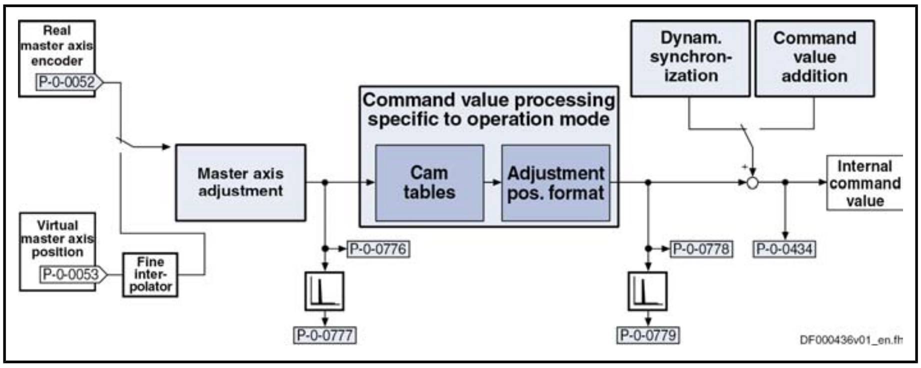
The real master axis velocity is generated by a measuring encoder, the virtual master axis velocity, however, is preset by the master.

See also "Dynamic Synchronization of the Slave Axis" in section "Basic Functions of the Synchronization Modes"

Features

- 4 cam shaft profiles with a max. of 1024 data points (P-0-0072, P-0-0092, P-0-0780, P-0-0781)
- 4 cam shaft profiles with a max. of 128 data points (P-0-0783, P-0-0784, P-0-0785, P-0-0786)
- Cubic spline interpolation of the cam data points
- Dynamic angle offset and angle offset at begin of profile
- Freely definable switch angle for cam and cam distance
- Synchronization mode to be selected
- Single-step, double-step or optimized double-step synchronization
- Absolute or relative phase synchronization
- Synchronization range to be selected
- Change of format "on the fly"
- Cross cutter function
- Clocked Pull Roll

The figure below illustrates the interaction of the individual subfunctions (function blocks) of the "electronic cam" mode:



P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0434	Position command value of controller
P-0-0776	Effective master axis position
P-0-0777	Effective master axis velocity
P-0-0778	Synchronous position command value
P-0-0779	Synchronous velocity

Fig.7-68: Function Blocks of the Operating Mode "Electronic Cam"

Variants of the Operating Mode

The following variants can be configured:

- Position Synchronization: Cam with real master axis, encoder 1
- Position Synchronization: Cam with real master axis, encoder 2
- Position Synchronization: Cam with real master axis, encoder 1, lagless
- Position Synchronization: Cam with real master axis, encoder 2, lagless
- Position Synchronization: Cam with virtual master axis, encoder 1
- Position Synchronization: Cam with virtual master axis, encoder 2

- Position Synchronization: Cam with virtual master axis, encoder 1, lagless
- Position Synchronization: Cam with virtual master axis, encoder 2, lagless

☞ The position synchronization mode "phase synchronization", "cam" or "MotionProfile" as well as the active master axis are selected in parameter "P-0-0088, Control word synchronization modes". The encoder selection and the determination position control with lag error or lagless are made in parameter "S-0-0520, Control word of axis controller".

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in this operating mode:

- S-0-0103, Modulo value
- S-0-0520, Control word of axis controller
- S-0-0521, Status word of position loop
- P-0-0061, Angle offset begin of table
- P-0-0072, Cam table 1
- P-0-0073, Cam distance 2
- P-0-0085, Dynamic angle offset
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes
- P-0-092, Cam table 2
- P-0-093, Cam distance
- P-0-094, Cam switch angle
- P-0-0144, Cam distance switch angle
- P-0-0158, Angle offset change rate
- P-0-0159, Slave drive feed travel
- P-0-0227, Cam table, access angle
- P-0-0695, Angle offset begin of profile, process loop
- P-0-0696, Filter time constant, angle offset profile, process loop
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity
- P-0-0778, Synchronous position command value
- P-0-0779, Synchronous velocity
- P-0-0780, Cam table 3
- P-0-0781, Cam table 4
- P-0-0782, Cam table 5
- P-0-0783, Cam table 6
- P-0-0784, Cam table 7
- P-0-0785, Cam table 8

See also "Pertinent Parameters" in the Subsections of "Basic Functions of the Synchronization Modes"

Pertinent Diagnostic Messages

In addition to the general diagnostic messages of all synchronization modes, there are other diagnostic messages involved in this operating mode:

- A0128 Cam, Cam, encoder 1, virtual master axis
- A0129 Cam, encoder 2, virtual master axis
- A0130 Cam, encoder 1, real master axis
- A0131 Cam, encoder 2, real master axis
- A0132 Cam, lagless, encoder 1, virt. master axis
- A0133 Cam, lagless, encoder 2, virt. master axis
- A0134 Cam, lagless, encoder 1, real master axis
- A0135 Cam, lagless, encoder 2, real master axis
- A0163 Position synchronization
- F2002 Assignment of encoder for synchronization is not allowed
- F2005 Cam table invalid

See also "Pertinent Diagnostic Messages" in the Subsections of "Basic Functions of the Synchronization Modes"

Overview of the Operating Mode

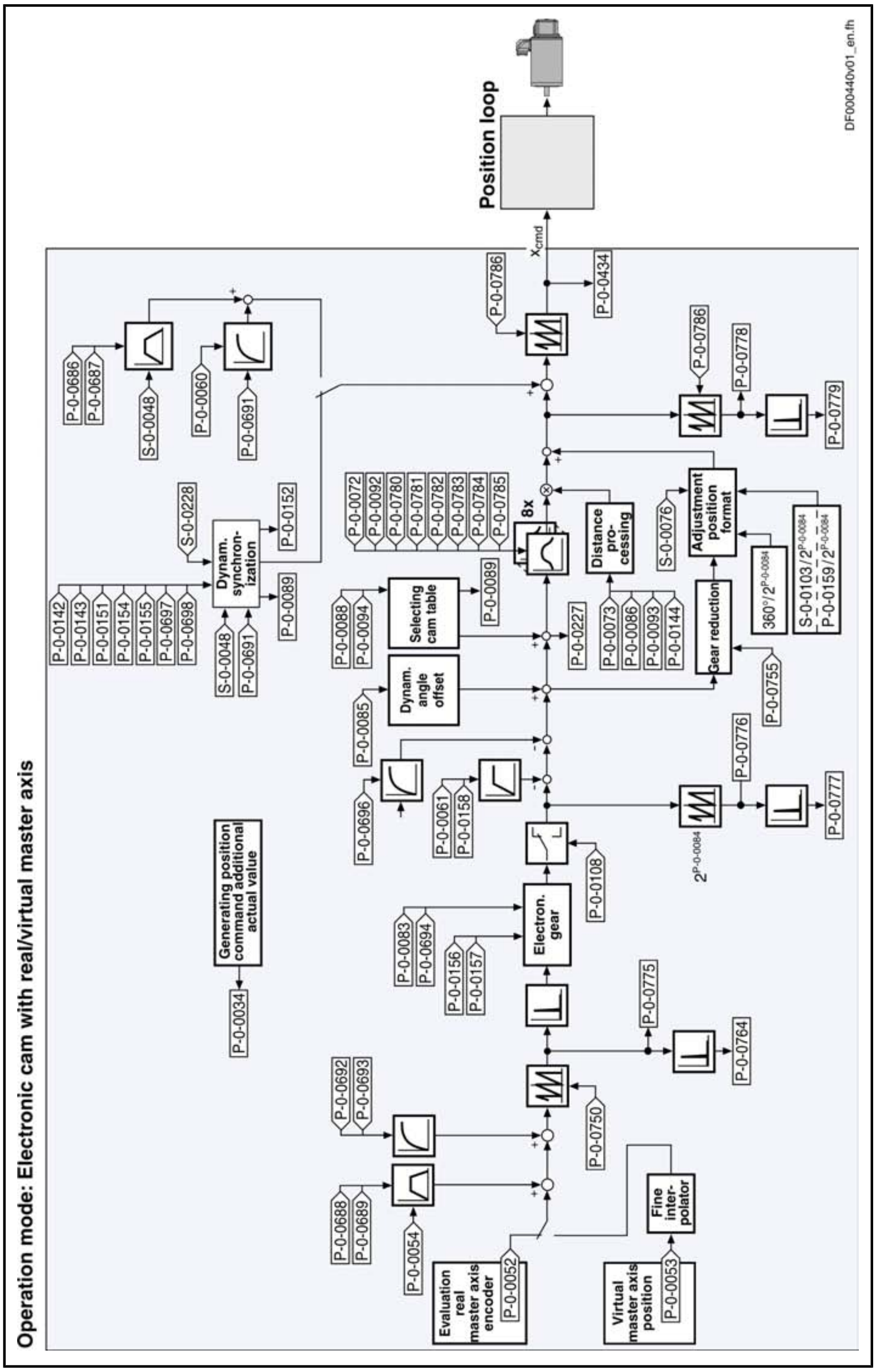


Fig.7-69: Block Diagram: Electronic Cam With Real/Virtual Master Axis

Master Axis Adjustment

Master axis adjustment is realized by means of the following subfunctions:

- Generation of master axis
- Master axis offset and modulo limitation
- Electronic gear with fine adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "electronic cam" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operating mode, consisting of
  - Cam tables (incl. access)
  - Adjustment of position format
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

☞ Only the function block "command value processing" specific to the cam shaft mode is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

See "Basic Functions of the Synchronization Modes"

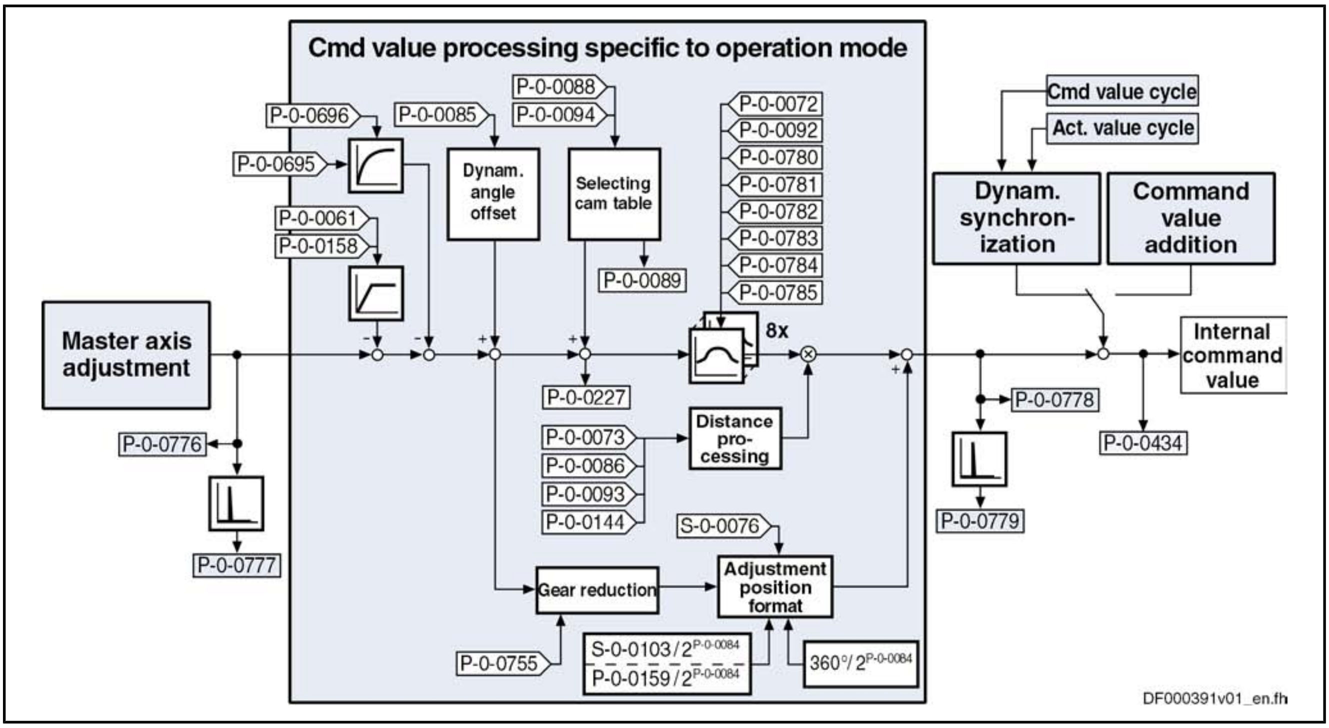


Fig.7-70: Command Value Processing Specific to Operating Mode for Cam Shaft Mode

Generating the Internal Position Command Value

In the operating mode "electronic cam with real/virtual master axis", the internal position command value (P-0-0434) is generated by addition of the synchronous position command value (x_{sync}) with the components of the additive position command value (S-0-0048) and the additive position command value of process loop (P-0-0691).

$$P\text{-}0\text{-}0434 = x_{sync} + x_{add} + x_{add\_PR}$$

P-0-0434	Position command value of controller
x_{sync}	Synchronous position command value
x_{add}	Filter output of "S-0-0048, Additive position command value"
x_{add_PR}	Filter output of "P-0-0691, Additive position command value, process loop"

Fig.7-71: Generating the Internal Position Command Value

Note: In the synchronized status (P-0-0089; bit 8 = 1), the following applies:

$$P\text{-}0\text{-}0434 = x_{sync} + (S\text{-}0\text{-}0048) + (P\text{-}0\text{-}0691)$$

Fig.7-72: Generating the Internal Position Command Value in the Synchronized Status

In the function block "command value processing specific to operating mode" the calculations specific to the cam shaft mode are carried out for generating the synchronous position command value.

Depending on "P-0-0061, Angle offset begin of table" and "P-0-0695, Angle offset begin of profile, process loop", an interpolated table value is taken from the cam tables in every control cycle and the difference to the last interpolated table value is multiplied by the cam distance. The result is added to the position command value.

If the phase-synchronous gear reduction path has been activated by bit 4 of parameter "P-0-0086, Configuration word synchronous operation modes", the master axis position at the output of the electronic gear is additionally divided by the gear reduction (P-0-0755) and multiplied with a scaling-dependent factor. The result is differentiated and added to the position command value.

If the profile limit is exceeded in positive direction, the profile continues with its first value, the same happens if the limit is exceeded in negative direction.

Calculating the Internal Position Command Value (Initialization)

Upon activation of the operating mode "electronic cam with real/virtual master axis", the position command value of the drive is first initialized in terms of the following relation:

$$x_{F(\varphi L)} = \left[h \times tab(\varphi_{ZGW}) + \frac{\varphi_{ZGW}}{U} + x_V + x_{VPR} \right] \% \, IWZ$$

x_F	Position command value of slave drive (P-0-0434)
ϕL	Resulting master axis position (P-0-0775)
h	Cam shaft distance (P-0-0093 or P-0-0073)
tab(ϕ)	Cam tables (P-0072, P-0-0092, P-0-0780, P-0-0781)
ϕ_{ZGW}	Profile access angle
U	Gear reduction (P-0-0755)
x_V	Additive position command value (S-0-0048)
x_{VPR}	Additive position command value, process loop (P-0-0691)
IWZ	Modulo actual value cycle (P-0-0786)

Fig.7-73: Initializing the Position Command Value

$$\varphi_{ZGW} = \pm\varphi_L \times \frac{G_a}{G_e} \times (1+F) \times (1+F_{PR}) - \varphi_V - \varphi_{VPR}$$

ϕ_{ZGW}	Profile access angle
+/-	Master drive polarity (P-0-0108)
ϕ_L	Resulting master axis position (P-0-0775)
G_a	Master drive gear output revolutions (P-0-0157)
G_e	Master drive gear input revolutions (P-0-0156)
F	Gear ratio fine adjustment (P-0-0083)
F_{PR}	Gear ratio fine adjustment, process loop (P-0-0694)
ϕ_V	Angle offset begin of profile (P-0-0061)
ϕ_{VPR}	Angle offset begin of profile, process loop (P-0-0695)

Fig.7-74: Determining the Profile Access Angle

☞ With the operating mode activated, differences, that later on will be added again, are processed in the electronic gear and the cam tables. Therefore, changes in the electronic gear and the cam shaft distance do not cause position command value jumps. Velocity jumps, however, can occur and the absolute position reference, established when activating the operating mode, is lost.

Accessing the Cam Shaft Profile

From the activated cam table, an interpolated table value is taken in each position control cycle, the difference to the last interpolated table value is generated and a multiplication with the cam distance is carried out. The result is added to the position command value.

Cubic spline interpolation takes place between the profile values.

☞ With an infinite cam, the difference between initial value and final value of the cam table is 100%.

Calculating the Internal Position Command Value (in Cyclic Operation)

The position command value is generated as per the following relation:

$$x_{F(n)(\varphi L)} = \left\langle x_{F(n-1)(\varphi L)} + \left[h \times \Delta tab(\pm\varphi_L) \times \frac{G_a}{G_e} - \varphi_V + \varphi_d \right] \pm \Delta\varphi_L \times \left[\frac{G_a}{G_e} \times (1+F) - \frac{\varphi_V}{U} + x_V \right] \right\rangle \% IWZ$$

x_F	Position command value of slave drive (P-0-0434)
ϕ_L	Resulting master axis position (P-0-0775)
h	Cam shaft distance (P-0-0093 or P-0-0073)
tab(ϕ)	Cam tables (P-0072, P-0-0092, P-0-0780, P-0-0781)
+/-	Master drive polarity (P-0-0108)
G_a	Master drive gear output revolutions (P-0-0157)
G_e	Master drive gear input revolutions (P-0-0156)
ϕ_V	Angle offset begin of profile (P-0-0061+ P-0-0695)
ϕ_d	Dynamic angle offset (P-0-0085)
F	Fine adjustment (P-0-0083)
U	Gear reduction (P-0-0755)
x_V	Additive position command value (S-0-0048 + P-0-0691)
IWZ	Modulo actual value cycle (P-0-0786)

Fig.7-75: Cyclically Generating the Position Command Value for the Slave Drive

Synchronization

See "Basic Functions of the Synchronization Modes"

7.8.5 Position Synchronization: MotionProfile

Brief Description

Expansion package **synchronization** (order code **SNC**) for the variants **MPB and MPM** in **closed-loop** characteristic

In the operating mode "MotionProfile with real/virtual master axis", there is a fixed relationship between the master axis position and the slave axis.

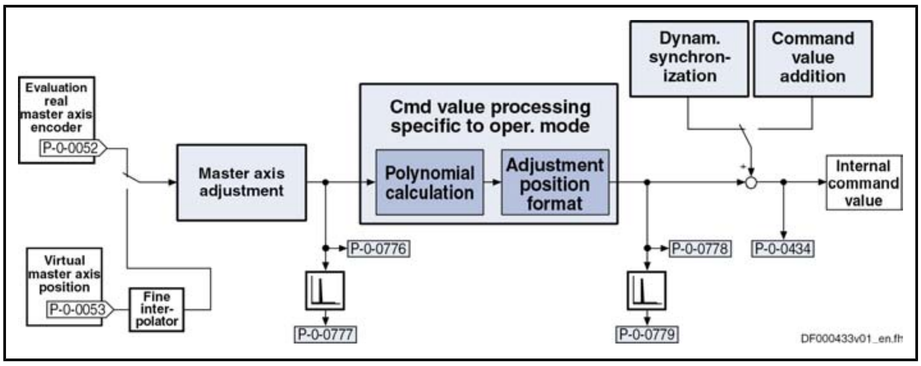
The real master axis velocity is generated by a measuring encoder, the virtual master axis velocity, however, is preset by the master.

See also "Dynamic Synchronization of the Slave Axis" in section "Basic Functions of the Synchronization Modes"

Features

- 2 sequences of motion with up to 8 motion steps per master axis revolution
- Definition of a motion step by standardized profile or cam table
- Motion laws can be selected (rest in rest, rest in velocity, velocity in rest, velocity in velocity, constant velocity)
- Motion laws realized by 5th order polynomial or, in the case of rest in rest, alternatively by inclined sine curve
- Individual distance for each motion step
- Dynamic angle offset and angle offset at begin of profile
- Absolute synchronization can be switched off
- Synchronization mode to be selected
- Absolute or relative processing of the motion steps to be selected
- Synchronization range to be selected
- Cross cutter function

The figure below illustrates the interaction of the individual subfunctions (function blocks) of the "MotionProfile" mode:



P-0-0052	Actual position value of measuring encoder
P-0-0053	Master axis position
P-0-0434	Position command value of controller
P-0-0776	Effective master axis position
P-0-0777	Effective master axis velocity
P-0-0778	Synchronous position command value
P-0-0779	Synchronous velocity

Fig.7-76: Function Blocks of the Operating Mode "MotionProfile"

Variants of the Operating Mode

The following variants can be configured:

- Position Synchronization: MotionProfile
  - MotionProfile with real master axis, encoder 1
  - MotionProfile with real master axis, encoder 2
  - MotionProfile with real master axis, encoder 1, lagless
  - MotionProfile with real master axis, encoder 2, lagless
  - MotionProfile with virtual master axis, encoder 1
  - MotionProfile with virtual master axis, encoder 2
  - MotionProfile with virtual master axis, encoder 1, lagless
  - MotionProfile with virtual master axis, encoder 2, lagless

---

☞ The position synchronization mode "phase synchronization", "cam" or "MotionProfile" as well as the active master axis are selected in parameter "P-0-0088, Control word synchronization modes". The encoder selection and the determination position control with lag error or lagless are made in parameter "S-0-0520, Control word of axis controller".

Pertinent Parameters

In addition to the general parameters of all synchronization modes, there are other parameters involved in this operating mode:

- S-0-0103, Modulo value
- S-0-0520, Control word of axis controller
- S-0-0521, Status word of position loop
- P-0-0061, Angle offset begin of table
- P-0-0085, Dynamic angle offset
- P-0-0086, Configuration word synchronous operation modes
- P-0-0088, Control word synchronization modes
- P-0-0089, Status word synchronization modes
- P-0-0158, Angle offset change rate
- P-0-0159, Slave drive feed travel
- P-0-0227, Cam table, access angle
- P-0-0695, Angle offset begin of profile, process loop
- P-0-0696, Filter time constant, angle offset profile, process loop
- P-0-0700, MotionProfile, master axis switching position
- P-0-0701, Motion step 1, slave axis initial position
- P-0-0702, MotionProfile, diagnosis, set 0
- P-0-0703, Number of motion steps, set 0
- P-0-0704, Master axis velocity, set 0
- P-0-0705, List of master axis initial positions, set 0
- P-0-0706, List of motion laws, set 0
- P-0-0707, List of distances, set 0
- P-0-0708, List of slave axis velocities, set 0
- P-0-0709, MotionProfile, diagnosis, set 1
- P-0-0710, Number of motion steps, set 1

- P-0-0711, Master axis velocity, set 1
- P-0-0712, List of master axis initial positions, set 1
- P-0-0713, List of motion laws, set 1
- P-0-0714, List of distances, set 1
- P-0-0715, List of slave axis velocities, set 1
- P-0-0755, Gear reduction
- P-0-0776, Effective master axis position
- P-0-0777, Effective master axis velocity
- P-0-0778, Synchronous position command value
- P-0-0779, Synchronous velocity

See also "Pertinent Parameters" in the subsections of "Basic Functions of the Synchronization Modes"

Pertinent Diagnostic Messages

In addition to the general diagnostic messages of all synchronization modes, there are other diagnostic messages involved in this operating mode:

- A0136 MotionProfile, encoder 1, virtual master axis
- A0137 MotionProfile, encoder 2, virtual master axis
- A0138 MotionProfile, encoder 2, real master axis
- A0139 MotionProfile, encoder 1, real master axis
- A0140 MotionProfile lagless, encoder 1, virtual master axis
- A0141 MotionProfile lagless, encoder 2, virtual master axis
- A0142 MotionProfile lagless, encoder 1, real master axis
- A0143 MotionProfile lagless, encoder 2, real master axis
- A0163 Position synchronization
- F2002 Assignment of encoder for synchronization is not allowed
- F2003 Motion step skipped
- F2004 Error in MotionProfile

See also "Pertinent Diagnostic Messages" in the subsections of "Basic Functions of the Synchronization Modes"

Overview of the Operating Mode

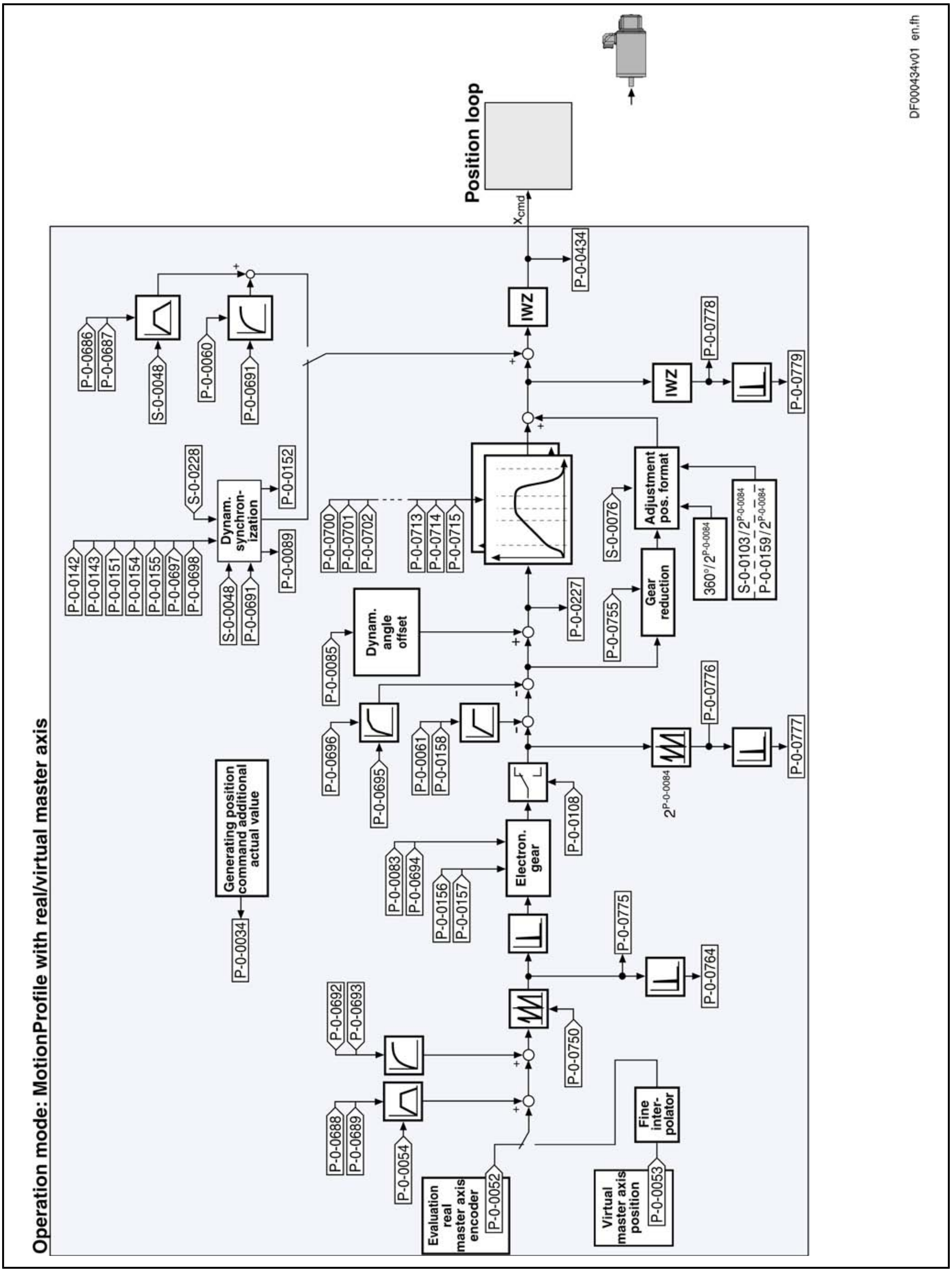


Fig.7-77: Block Diagram: MotionProfile With Real Master Axis

Master Axis Adjustment

Master axis adjustment is realized by means of the following subfunctions:

- Generation of master axis
- Master axis offset and modulo limitation
- Electronic gear with fine adjustment

See "Basic Functions of the Synchronization Modes"

Command Value Adjustment

Overview

Command value adjustment in the "MotionProfile" mode consists of the following basic functions:

- Master axis adjustment
- Command value processing specific to operating mode, consisting of
  - Cam tables (incl. access)
  - Adjustment of position format
- Command value adjustment slave axis, consisting of
  - Dynamic synchronization
  - Command value addition

Only the mode-specific function block "command value processing" for MotionProfile is described in detail below. The detailed descriptions of the other function blocks are contained in section "Basic Functions of the Synchronization Modes".

See "Basic Functions of the Synchronization Modes"

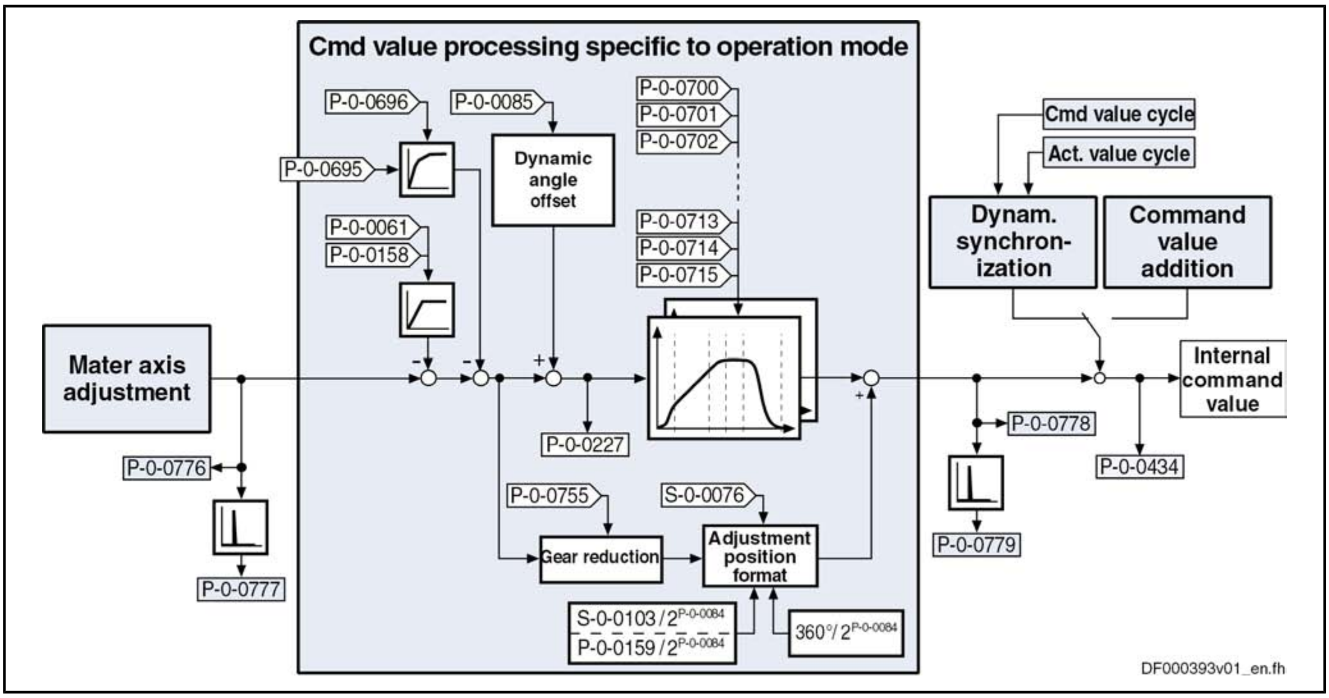


Fig.7-78: Command Value Processing Specific to Operating Mode With MotionProfile

Generating the Internal Position Command Value

In the operating mode "MotionProfile with real/virtual master axis", the internal position command value (P-0-0434) is generated by addition of the synchronous position command value (x_{sync}) with the components of the additive position command value (S-0-0048) and the additive position command value of process loop (P-0-0691).

$$\text{P-0-0434} = x_{\text{sync}} + x_{\text{add}} + x_{\text{add\_PR}}$$

P-0-0434	Position command value of controller
x_{sync}	Synchronous position command value
x_{add}	Filter output of "S-0-0048, Additive position command value"
x_{add_PR}	Filter output of "P-0-0691, Additive position command value, process loop"

Fig.7-79: Generating the Internal Position Command Value

Note: In the synchronized status (P-0-0089; bit 8 = 1), the following applies:

$$\text{P-0-0434} = x_{\text{sync}} + (\text{S-0-0048}) + (\text{P-0-0691})$$

Fig.7-80: Generating the Internal Position Command Value in the Synchronized Status

In the function block "command value processing specific to operating mode" the calculations specific to the MotionProfile are carried out for generating the synchronous position command value.

"P-0-0227, Cam table, access angle" is generated first. The current motion step is determined from this value and the master axis initial positions of the individual motion steps. Depending on the motion law of this motion step, the decision is taken as to whether the current step is determined by a cam table or a standard profile. With the profile access angle, profile access or a polynomial calculation takes place accordingly to calculate the standardization value (factor) for the distance of this step. The standardization value for a cam table is between +799.999999 % and -799.999999 %, for a standard profile it is between 0 and 1. The multiplication of standardization value and distance of the current step results in a position command value which is added to the final position value of the previous motion step. Depending on the setting in the motion law of this step, the sum is processed in absolute or relative form.

If the phase-synchronous path has been activated by bit 4 of parameter "P-0-0086, Configuration word synchronous operation modes", the master axis position at the output of the electronic gear is additionally divided by the gear reduction (P-0-0755) and multiplied with a scaling-dependent factor. The result is differentiated and added to the position command value.

Calculating the Internal Position Command Value (Initialization)

Upon activation of the operating mode "MotionProfile with real/virtual master axis", the position command value of the drive is first initialized in terms of the following relation:

$$x_{F(\varphi L)} = \left[x_{start\_n} + H_n \times f_n(\varphi_{ZGW}) + \left(\frac{\varphi_{ZGW}}{U}\right) \times \left(\frac{MW}{2^{20}}\right) + x_V + x_{VPR} \right] \% IWZ$$

x_F	Position command value of slave drive (P-0-0434)
x_{start_n}	Slave axis initial position of the current motion step
H_n	Distance of the current motion step
$f_{n\ (\phi ZGW)}$	Standardized function value of the current motion step from profile access or polynomial calculation
ϕ_{ZGW}	Profile access angle
U	Gear reduction (P-0-0755)
MW	Modulo value
x_V	Additive position command value (S-0-0048)
x_{VPR}	Additive position command value, process loop (P-0-0691)
IWZ	Modulo actual value cycle

Fig.7-81: Initializing the Position Command Value

$$\varphi_{ZGW} = \pm \varphi_L \times \frac{G_a}{G_e} \times (1 + F) \times (1 + F_{PR}) - \varphi_V - \varphi_{VPR}$$

ϕ_{ZGW}	Profile access angle
+/-	Master drive polarity (P-0-0108)
ϕ_L	Resulting master axis position (P-0-0775)
G_a	Master drive gear output revolutions (P-0-0157)
G_e	Master drive gear input revolutions (P-0-0156)
F	Gear ratio fine adjustment (P-0-0083)
F_{PR}	Gear ratio fine adjustment, process loop (P-0-0694)
ϕ_V	Angle offset begin of profile (P-0-0061)
ϕ_{VPR}	Angle offset begin of profile, process loop (P-0-0695)

Fig.7-82: Determining the Profile Access Angle

The slave axis initial position of the current motion step is supposed to be zero, when relative processing of the position data (bit 10 = 1) has been set in the control word for synchronous operation modes (P-0-0088). Otherwise, the slave axis initial position of the current motion step is the sum of the slave axis initial position (P-0-0701) and the distances up to the current step.

The cyclic calculation of the position command value takes place according to the above formula, too. The slave axis initial position of the respective current step is determined by the end position of the previous step.

☞ With the operating mode activated, differences, that later on will be added again, are processed in the electronic gear. Therefore, changes in the electronic gear do not cause position command value jumps. Velocity jumps, however, can occur and the absolute position reference, established when activating the operating mode, is lost.

Synchronization

See "Basic Functions of the Synchronization Modes"

8 Extended Axis Functions

8.1 Availability of the Extended Axis Functions

The following overview illustrates by which basic or functional packages the respective extended axis function is supported (if not stated otherwise, this applies to all 3 firmware versions, MPB, MPM and MPE).

Extended axis function	In base package (characteristic)	In functional package ... (on the basis of a base package with the following characteristics)		
		Servo function	Synchronization	Main spindle
Drive halt	OL/CL	–	–	–
v_{cmd} reset ("emergency halt")	OL/CL	–	–	–
v_{cmd} reset with ramp ("quick stop")	OL/CL	–	–	–
$_{cmd}$ reset while maintaining a_{max}	CL	–	–	–
Torque disable	OL/CL	–	–	–
Package reaction on error	OL/CL	–	–	–
NC reaction on error	OL/CL	–	–	–
E-Stop function	OL/CL	–	–	–
Friction torque compensation	CL	–	–	–
Backlash on reversal correction	CL 1)	–	–	–
Precision axis error correction	–	CL 1)	–	–
Control-side axis error correction	–	CL 1)	–	–
Temperature error correction	–	CL 1)	–	–
Quadrant error correction	–	CL 1)	–	–
Cogging torque compensation	–	CL 1)	CL 1)	–
Measuring wheel mode	–	–	CL 1)	–
Positive stop drive procedure	OL/CL	–	–	–
Redundant motor encoder	CL 1)	–	–	–
Spindle positioning	–	–	–	CL 1)
Parameter set switching	–	–	–	OL/CL 1)
Drive-controlled oscillation	–	–	–	OL/CL 1)
Parking axis	OL/CL	–	–	–
Programmable position switch	–	CL 1)2)	CL 1)2)	–
Set/shift coordinate system	–	CL 1)	CL 1)	CL 1)

OL Open-loop characteristic
CL Closed-loop characteristic
1) Not for the firmware version MPE
2) Not for the firmware version MPM

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

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

See also "Enabling of Functional Packages"

8.2 Drive Halt

8.2.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The "Drive Halt" function is used to shut down an axis with defined acceleration and defined jerk.

In a default case, drive halt is performed as quick stop in position control or velocity control. The position control mode is activated if one of the operating modes (S-0-0032 ...) is defined with position control (incl. internal PLC operating modes). Otherwise, the velocity control mode is active.

With the configuration drive halt (P-0-0558, bit 1, 2), the control mode can also be selected freely.

- Bit 1,2 = 1,1 position control
- Bit 1,2 = 1,0 velocity control

With the configuration drive halt (P-0-0558, bit 0 = 1), you can switch to the operational stop function. Then, the operating modes velocity control, drive-internal interpolation, drive-controlled positioning and positioning block are internally stopped with V cmd = 0. After cancelation of drive halt, the motion is re-activated.

In addition to the "drive halt" function, there is an operational stop for the operating modes "drive-controlled positioning" and "drive-internal interpolation". This function has, however, an own control signal.

Features

- Activated via "halt bit" of master communication (see "Device Control and State Machines")
- Active operating mode interrupted; drive remains in control (after setting the "halt bit", the interrupted operating mode is continued)
- **Quick Stop in Position Control**

  → Shutdown with acceleration (S-0-0372) and jerk limit values (S-0-0349), in position control.
- **Quick Stop in Velocity Control**

  → Shutdown with acceleration (S-0-0372) and jerk limit values (S-0-0349), in velocity control.
- Acknowledgement "drive halt" in P-0-0115

Pertinent Parameters

- S-0-0124, Standstill window
- S-0-0349, Bipolar jerk limit
- S-0-0372, Drive Halt acceleration bipolar
- P-0-0115, Device control: Status word
- P-0-0558, Drive Halt configuration

8.3 Error Reactions

8.3.1 Overview of Error Reactions

Depending on the operating mode that is used and some parameter settings, the drive controller carries out monitoring functions. An error message is generated by the drive controller, if a status is detected that no longer allows correct operation.

Errors are classified in error classes. The error class is represented by the first two digits of the diagnostic message number.

See also "Terms, Basic Principles"

See also "Diagnostic System"

If the drive controller is in control (drive enable was set) and an error occurs, the drive controller automatically starts a drive error reaction.

This drive error reaction depends on:

- The error class of the error occurred and
- The settings of the following parameters:
  - P-0-0117, Activation of NC reaction on error
  - P-0-0118, Power supply, configuration
  - P-0-0119, Best possible deceleration

At the end of each error reaction, the drive goes torque-free. Power off depends on the setting in P-0-0118!

Error Classes

There are 8 error classes with different priority:

Diagnostic message number	Error class	Error Reaction
F2xxx	Non-fatal error	According to setting in parameters "P-0-0119, Best possible deceleration" and "P-0-0117, Activation of NC reaction on error"
F3xxx	Non-fatal safety technology error	According to setting in "P-0-0119, Best possible deceleration" and "P-0-0117, Activation of NC reaction on error"
F4xxx	Interface error	According to setting in "P-0-0119, Best possible deceleration"
F6xxx	Travel range error	Velocity command value reset ("emergency halt")
F8xxx	Fatal error	Immediate torque disable if this is also the error reaction to non-fatal errors; otherwise, general braking of the motor by shorting the motor windings
F9xxx	Fatal system error	Immediate torque disable
E-xxxx	Fatal system error "processor exception"	Immediate torque disable

Fig.8-2: Error Classes and Drive Reaction

☞ The error class can be recognized by the diagnostic message number and defines the drive behavior in the case of error.

8.3.2 Best Possible Deceleration

Brief Description

The error reaction "best possible deceleration" (to be set in "P-0-0119, Best possible deceleration") is carried out automatically in case of the following states:

- Non-fatal errors (F2xxx)
- Non-fatal safety technology errors (F3xxx)
- Interface errors (F4xxx)
- Communication phase is reset
- Drive enable is removed (see S-0-0134 resp. P-0-4077 or P-0-0115, bit 15)
- Travel range error (F6xxx)
- Fatal warnings which require the reaction "velocity command value reset" (e.g. E8034, E6044)

One of the following reactions for "best possible deceleration" can be set in P-0-0119:

- Velocity command value reset (emergency halt)
- Velocity command value reset with ramp and filter
- Velocity command value reset while maintaining the maximum acceleration
- Torque disable

See also Parameter Description "P-0-0119, Best possible deceleration"

☞ If the "torque disable" error reaction has been set in P-0-0119, the drive reacts with torque disable also in case of F8 errors; otherwise, the motor is - with the majority of F8 errors - decelerated by shorting the motor windings!

Due to the system, braking by shorting the motor windings is not possible with:

- F8000 Fatal hardware error
- F8060 Overcurrent in power section

With fatal system errors (F9xxx), the setting in P-0-0119 is ignored, the drive is decelerated with immediate torque disable.

Time Flow of the Error Reaction

Time Flow With Motor Holding Brake Available

The time flow of the error reaction and of the output stage release in the case of velocity command value reset with motor holding brake available is described in the section "Functional Description: Error Situation 1" under "Operating Behavior of the Motor Holding Brake" .

The activation and function of the motor holding brake depends on the setting in "P-0-0525, Holding brake control word".

See also "Motor Holding Brake"

Deceleration in U/f Operation

In the case of open-loop-controlled U/f operation, deceleration at the torque limit only takes place when the stall protection loop has been activated (see "P-0-0045, Control word of current controller")! The maximum deceleration is preset by the value entered in "P-0-0569, Maximum stator frequency slope".

8.3.3 Package Reaction on Error

Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

"Package reaction" is the simultaneous error reaction of all axis drives supplied by a common power bus (DC bus). Drive errors of a drive can be signaled to all other axis drives via the module bus (signal bus) which allows the simultaneous error reaction (according to setting in parameter "P-0-0119, Best possible deceleration") of all axis drives.

The settings for signaling drive errors and package reaction are made individually for each drive in "P-0-0118, Power supply, configuration". This allows activating the package reaction only for individual axes. The behavior of the axes for which the package reaction has not been activated has to be taken into account for the case of error and must be controlled on the master side, if necessary!

☞ The supply unit switches off power supply only in the case of its own errors and in the case of fatal drive errors (F8xxx), if the drive signaling errors signals F8 errors to the supply.

Fields of Application

Examples of applications with interactive (interpolating, synchronized) use of drives that are supplied by a common power bus ("drive package"):

- Machine tools (e.g. milling, turning, grinding machines)
- Gear cutting machines (gear wheel machining)
- Printing mechanisms of printing machines, etc.

By setting the error reaction of the drive system devices according to the application, the following damages can be minimized:

- Machine damages
- Tool/workpiece/material damages

☞ **The package reaction is not suitable for avoiding personal injury!**

Reaction to drive errors	Priority of appropriate error reactions for typical drive applications	Setting in P-0-0117	Setting in P-0-0118	General conditions
NC master-side reaction	NC master-side priority of shutdown and power off	NC reaction active	No package reaction, no signaling of drive errors	Drive with F8 error does not decelerate!
Drive reaction	Shutdown spindle drive (asynchronous motors) Shutdown servo drives (synchronous motors) Power off	NC reaction not active	Package reaction, signaling of drive errors	Drive with F8 error does not decelerate! , No DC bus short circuit Power off via NC master
	Shutdown servo drives (synchronous motors) Power off Shutdown spindle drive (asynchronous motors) irrelevant	NC reaction not active	Package reaction, signaling of drive errors, signaling of F8 errors to supply	Power off only with F8 error, otherwise via NC master with DC bus short circuit
	Power off Shutdown spindle drive (asynchronous motors) Shutdown servo drives (synchronous motors)	NC reaction not active	Package reaction, signaling of drive errors, signaling of F8 errors to supply	Power off only with F8 error, otherwise via NC master; no DC bus short circuit, drive with F8 error does not decelerate!
	Power off Shutdown servo drives (synchronous motors) Shutdown spindle drive (asynchronous motors)	NC reaction not active	Package reaction, signaling of drive errors, signaling of F8 errors to supply	Power off only with F8 error, otherwise via NC master with DC bus short circuit

Fig.8-3: Examples of Settings in P-0-0117 and P-0-0118, Depending on the Priority of Appropriate Error Reactions (With General Conditions)

The above examples are not binding and provide basic information on the settings that have to be made according to the axis-specific and application-dependent requirements.

Pertinent Parameters

- P-0-0118, Power supply, configuration
- P-0-0119, Best possible deceleration

8.3.4 Control Reaction on Error

NC Reaction on Error

Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

To avoid damages to the machine, some applications require that the master (e.g. NC) retains control of the travel profile of the axes in the case of error, too, and shuts down the machine axes in a coordinated way. For this case, the "NC reaction on error" option was implemented; it can be activated via P-0-0117.

The master is informed of an error in the drive controller via the drive status word (see S-0-0135) so that the master can shut down the machine axes in a coordinated way and therefore avoid possible damage.

NC reaction on error is only possible with non-fatal errors (diagnostic message F2xxx), otherwise the drive always reacts with an immediate drive-side error reaction.

Pertinent Parameters

- S-0-0135, Drive status word
- P-0-0117, Activation of NC reaction on error
- P-0-0119, Best possible deceleration

8.4 E-Stop Function

8.4.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The E-Stop function is used to shut down the drive with selectable drive reaction (see Parameter Description "P-0-0008, Activation E-Stop function") via a digital input of the drive controller.

To use the E-Stop function, you have the following options:

- E-Stop with reaction to interface error (F4034 Emergency-Stop activated)

  → **Reaction:** Best possible deceleration (as set in P-0-0119)
- E-Stop with reaction to travel range error (F6034 Emergency-Stop activated)

  → **Reaction:** Velocity command value reset
- E-Stop as fatal warning "E8034 Emergency-Stop activated"

  → **Reaction:** Best possible deceleration (as set in P-0-0119)

If "E-Stop" was parameterized as a warning, it isn't necessary to clear the diagnostic message!

Pertinent Parameters

- P-0-0008, Activation E-Stop function
- P-0-0119, Best possible deceleration
- P-0-0223, E-Stop input

Pertinent Diagnostic Messages

- E8034 Emergency-Stop activated
- F4034 Emergency-Stop activated
- F6034 Emergency-Stop activated

8.5 Compensation Functions / Corrections

8.5.1 Friction Torque Compensation

Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The behavior of a machine axis is negatively affected by static friction when starting or when reversing the direction. The drive-internal friction torque compensation allows compensating the static friction by adding, depending on the direction of movement, a torque/force command value.

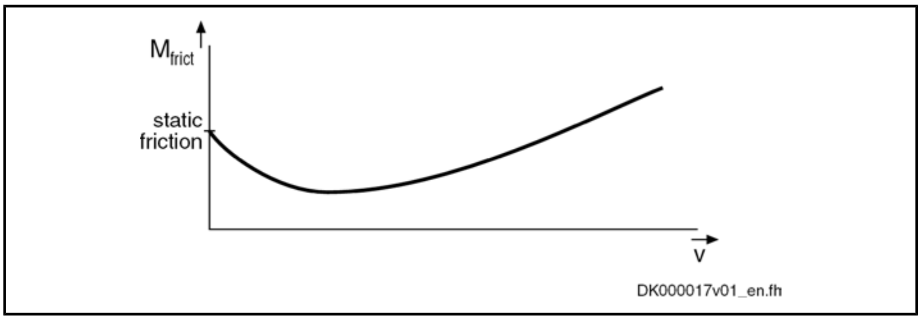


Fig.8-4: Friction Torque Curve With Static Friction

Friction torque compensation is mainly intended to be used in precision machine tools and to reduce the path errors caused by static friction. This applies particularly to circular errors at the quadrant transitions.

Pertinent Parameters

- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0155, Friction compensation

8.5.2 Axis Error Correction

Brief Description

The actual position value provided by the measuring system can differ from the real actual position value at the axis, e.g. at the point of chip removal in the case of metal-cutting machining, due to

- inaccuracy of the measuring system,
- transmission inaccuracy in mechanical transmission elements such as gear, clutch, feed spindle etc.,
- thermal expansion of machine parts of the drive system.

For compensating the mechanically determined position error sources, IndraDrive controllers provide the following correction functions:

- Backlash on reversal correction
- Precision axis error correction
- Control-side axis error correction

The control-side axis error correction is always active. The correction value can be transmitted in the cyclic telegram or in the service channel. In addition, precision axis error correction or reversal clearance can be activated, precision axis error correction having higher priority.

Moreover, it is possible to activate the temperature error correction. IndraDrive controllers provide two possibilities of correcting temperature errors:

- Independent of axis position
- Depending on axis position

Pertinent Parameters

- S-0-0058, Reversal clearance
- S-0-0124, Standstill window

- P-0-0400, Axis correction external correction value
- P-0-0401, Axis correction active correction value
- P-0-0402, Axis correction reference temperature
- P-0-0403, Axis correction reference position for temp. corr.
- P-0-0404, Axis correction actual temperature pos.-dependent
- P-0-0405, Axis correction actual temperature pos.-independent
- P-0-0406, Axis correction temperature factor pos.-dependent
- P-0-0407, Axis correction temperature factor pos.-independent
- P-0-0408, Axis correction start position
- P-0-0409, Axis correction end position
- P-0-0410, Axis correction support point distance
- P-0-0411, Axis correction, correction table positive
- P-0-0412, Axis correction, correction table negative
- P-0-0413, Axis correction control word

8.5.3 Quadrant Error Correction

Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

In the case of axis drives that are controlled, for example, in circular interpolation, static friction at the reversal points of the direction of motion can cause distortion of the circular contour.

In order to compensate this contour error at the so-called "quadrant transitions" (velocity reversal), IndraDrive controllers provide the "quadrant error correction" function.

This correction function is useful for such cases when drives are operated in cyclic position control and in circular interpolation by the control master.

Pertinent Parameters

- P-0-0100, Position command value extension
- P-0-0435, Control word of position controller
- P-0-0436, Reference radius for quadrant error correction
- P-0-0437, Velocity time range for quadrant error correction
- P-0-0438, Velocity time range for quadrant error correction
- P-0-0439, Table of velocity pulse for quadrant error correction

8.5.4 Cogging Torque Compensation

Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Motors for which the magnetic excitation is realized with permanent magnets (e.g. synchronous motors) in many cases show cogging torques or cogging forces. Cogging torques/cogging forces already act on the moving component of the motor in the de-energized state and aim at moving it to a stable position.

When the motor is put into motion by control, the cogging torques/cogging forces act on the motor in a decelerating or accelerating way, according to the position. For applications in which minimum lag error or very constant velocity is important, the position-dependent cogging torques/cogging forces can have a negative effect.

To improve the synchronous operation and lag error behavior of synchronous motors, IndraDrive controllers provide cogging torque and cogging force compensation for drives with high demands on lag error and synchronous operation quality. For this purpose, additive torque command values take effect in drive control in a position-dependent way.

Hardware Requirements

The compensation of cogging torque/cogging force is possible for the use of both measuring systems with absolute evaluation and measuring systems with relative evaluation. The following restriction applies to relative measuring systems:

- The position measuring range may have only **one** reference mark or it is equipped with distance-coded reference marks!

Pertinent Parameters

- P-0-0162, C1800 Command Drive optimization / command value box
- P-0-0165, Drive optimization, control word
- P-0-0170, Drive optimization, acceleration
- P-0-0171, Drive optimization, velocity
- P-0-1130, Table of cogging torque compensation values pos. direction
- P-0-1131, Control word of cogging torque compensation
- P-0-1132, Table of cogging torque compensation values neg. direction
- P-0-1133, Status word of cogging torque compensation
- P-0-1134, Velocity threshold for attenuation of detent cogging compens
- P-0-1135, Velocity threshold for switching off cogging torque compens.
- P-0-1136, Lead time cogging torque compensation
- P-0-1138, C4800 Command Determine cogging torque compensation table

Pertinent Diagnostic Messages

- C1808 Drive not homed
- C4800 Command Determine cogging torque compensation table
- C4801 Cogging torque compensation: Measuring vel. too high
- C4802 Cogging torque compensation: Measuring vel. too low
- C4803 Cogging torque compensation: Inadmissible acceleration
- C4804 Cogging torque comp.: Err. when storing corr. val table
- C4805 Cogging torque comp.: Motor measuring system not homed

8.5.5 Correction of the Torque/Force Constants

Brief Description

Fields of Application

Base package of all firmware variants in **closed-loop** characteristic

Indication of the Motor Load, Load Limit Values

With IndraDrive devices, the current motor load is determined on the drive side and displayed. The load can be limited using the controller.

The unit of the load display or the load limit input can be selected:

- Percentage, related to the continuous or nominal motor current

- Physical, value in "Nm" (rotatory) or "N" (linear)

The load of the motor is determined using the measured motor current; in case of physical scaling, the controller determines the motor torque or force by offsetting the actually flowing current against the motor-specific torque or force constant.

If for axis-mechanical or procedural reasons, torque/force precision up to approx. +/- 5% is required (e.g. for load limitation), the controller provides the "correction of the torque/force constants". In this connection, the motor-specific values are corrected depending on the actual motor current, the motor temperature and the average speed.

☞ Due to firmware downward compatibility and parameter values that might not be available (e.g. in third-party motors), this correction must be activated separately!

Pertinent Parameters

- P-0-0448, Temperature-dependent torque/force coefficient
- P-0-0449, Speed-dependent torque/force coefficient
- P-0-0450, Current torque/force constant
- P-0-0556, Config word of axis controller
- P-0-3055, Maximum motor torque/force, encoder memory
- P-0-3056, Nominal motor torque/force, encoder memory
- P-0-3057, Speed-dependent torque/force coefficient, encoder memory
- P-0-3058, Temperature-dependent torque/force coefficient, enc. memory
- S-0-0533, Nominal torque/force of motor
- S-0-0534, Maximum torque/force of motor

Pertinent Diagnostic Messages

- none -

8.6 Measuring Wheel Mode

8.6.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

The measuring wheel mode is used for material feed axes, e.g. in sheet-metal machining. For direct measurement of the infeed of moved material, a rotary encoder that is detecting the infeed length is driven via a measuring wheel with frictionally engaged contact to the material surface.

The position control loop is closed via motor encoder and measuring wheel encoder, possible slip between motor and material does not cause incorrect measured values of material length.

☞ The measuring wheel mode may only be activated when contact has been established between measuring wheel and material surface.

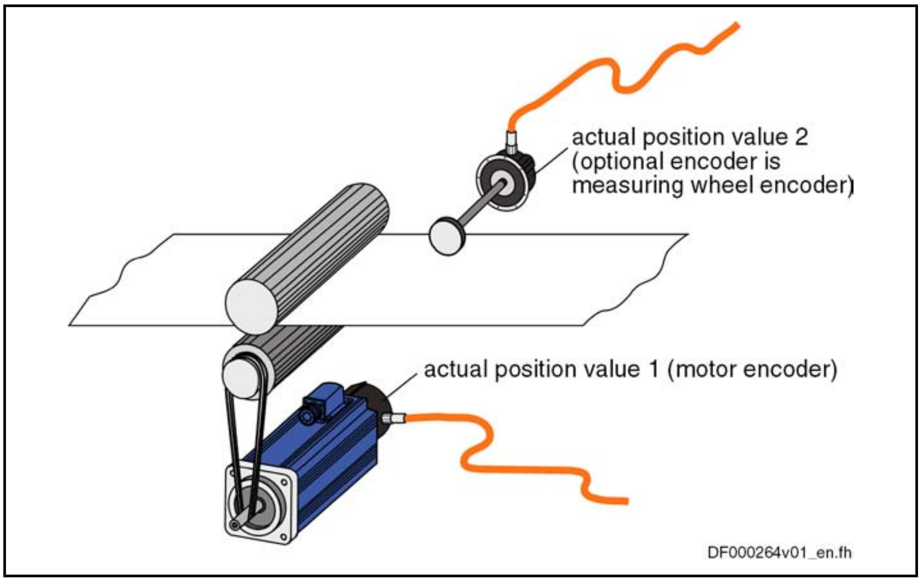


Fig.8-5: Typical Arrangement of Drive for Material Infeed With Measuring Wheel Encoder

Hardware Requirements

The measuring wheel encoder is an optional (external) encoder that is connected according to the connection diagram contained in the "Reference Documentations") documentation.

See also Measuring Systems

Pertinent Parameters

The following parameters are used to parameterize this function:

- S-0-0520, Control word of axis controller
- S-0-0521, Status word of position loop
- P-0-0241,
- P-0-0242,
- P-0-0243,
- P-0-0244,

The following parameters are used to parameterize the measuring wheel encoder:

- S-0-0115, Position feedback 2 type
- S-0-0117, Resolution of feedback 2
- P-0-0123, Feed constant 2 (optional encoder)
- P-0-0124, Gear 2 load-side (optional encoder)
- P-0-0125, Gear 2 encoder-side (optional encoder)
- P-0-0185, Control word of encoder 2 (optional encoder)

Pertinent Diagnostic Messages

- F2036 Excessive position feedback difference

8.7 Positive Stop Drive Procedure

8.7.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

For special applications, it is required to move machine axes operated in position or velocity control up to a limit stop in order to generate forces of pressure.

When an axis in the standard situation has moved up to a limit stop, the drive should signal a drive error by the monitoring facilities of the position or velocity control loop and react with shutdown.

But if the drive can detect the special case of operation "positive stop drive procedure", it can ignore the messages of the position and motions monitors and generate the required force of pressure, if necessary.

The control master signals this special case to the controller of IndraDrive devices via a command. Upon this command, the drive switches off the respective monitors and acknowledges axis standstill to have been detected and a parameterizable force or torque threshold to have been exceeded.

Pertinent Parameters

- S-0-0082, Torque/force limit value positive
- S-0-0083, Torque/force limit value negative
- S-0-0092, Bipolar torque/force limit value
- S-0-0124, Standstill window
- S-0-0149, C1300 Positive stop drive procedure command

Pertinent Diagnostic Messages

- C1300 Positive stop drive procedure command
- C1301 Class 1 diagnostics error at command start

8.8 Redundant Motor Encoder

8.8.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Motor control of synchronous motors requires a position measuring system that measures the position of the moving part of the motor as opposed to the static part. If there is malfunction or defect in the position measuring system (motor encoder), a synchronous motor can no longer be decelerated in a controlled way.

Depending on the requirements, position control can require an external measuring system at the axis which detects the position at the load with the required precision.

For axis control, the entire mechanical drive system between motor encoder and load position of the external encoder is mapped via parameters. This allows calculating the position of the motor encoder from the position of the external encoder or determining the load position from the motor encoder position, if the mechanical drive system is without slip.

If there is a defect in the motor encoder, the motor position, when an external encoder is used, can be determined via the position of the external encoder and the synchronous motor can be decelerated in a controlled way.

For asynchronous motors with motor encoder, it is also possible to use an external measuring system for controlled deceleration, if there is a defect in the motor encoder. But if the asynchronous motor, depending on the drive task, is operated without encoder, controlled deceleration via external encoder in the case of error is not possible!

You can only use measuring systems with U_{pp} = 1V or resolvers as redundant motor encoders!

Pertinent Parameters

- P-0-0185, Control word of encoder 2 (optional encoder)

Pertinent Diagnostic Messages

- F2031 Encoder 1 error: signal amplitude incorrect
- F2042 Encoder 2: Encoder signals incorrect
- F8022 Enc. 1: Enc. signals incorr. (can be cleared in ph. 2)
- F8042 Encoder 2 error: Signal amplitude incorrect

8.9 Spindle Positioning

8.9.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

With the drive function "spindle positioning", the drive, at a command of the master, aligns the spindle independently with regard to the spindle zero position. The command position is transmitted to the drive controller via parameter and can be preset as absolute or relative position.

By means of the "position spindle" command, the spindle can be positioned in a position-controlled way (e.g. within the "velocity control" mode) without having to switch the operating mode from velocity to position control.

How to use the drive function "spindle positioning":

- For **milling and drilling spindles**
  - To prepare tool change → spindle remains at a defined position to allow changing the tool
- For **turning machine main spindles**
  - To change the workpiece (if required)
  - To place balancing drillings for workpieces to be balanced
  - To index the workpiece for further machining
- For **revolving transfer machines**
  - To advance the turntable in order to bring workpieces to a defined machining position at the different stations

Hardware Requirements

The use of a home switch may be required.

See "Establishing Position Data Reference for Relative Measuring Systems"

Pertinent Parameters

- S-0-0152, C0900 Position spindle procedure command
- S-0-0153, Spindle angle position
- S-0-0154, Spindle positioning parameter
- S-0-0180, Spindle relative offset
- S-0-0222, Spindle positioning speed
- S-0-0372, Drive Halt acceleration bipolar
- S-0-0417, Positioning velocity threshold in modulo mode
- S-0-0418, Target position window in modulo mode
- S-0-0437, Positioning status
- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- P-0-1201, Ramp 1 pitch

- P-0-1202, Final speed ramp 1
- P-0-1203, Ramp 2 pitch
- P-0-1211, Deceleration ramp 1
- P-0-1213, Deceleration ramp 2

Pertinent Diagnostic Messages

- C0900 Position spindle command
- C0902 Spindle positioning requires drive enable
- C0903 Error during initialization
- C0906 Error during search for zero pulse

8.10 Parameter Set Switching

8.10.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

IndraDrive devices have been equipped with eight parameter sets; it is possible to switch between these sets in operation. One of the switchable parameter sets is always active. Switching takes place upon command of the control master.

Notes on Applications

With the possibility of adjusting the values of different parameters to different operating phases or machining processes by switching parameter sets, if necessary during operation, the IndraDrive firmware supports the work flow in flexible production facilities.

Examples of application:

- Changing from C-axis to roughing or finishing operation in the case of spindles
- Positioning mode for tool change with different gear ratios
- Changing motor spindles for different machining phases
- Adjusting the control loop gains to different load inertia or load masses (e.g. with very different workpieces)
- Star-delta switching of motors with switchable winding to increase the torque in short-time operation

Classification of Switchable Parameters

Under the application-related point of view, the parameters to be switched are divided into the following groups:

- Application parameters
- Control loop parameters
- Load gear parameters
- Winding parameters
- Motor control and motor encoder parameters

Pertinent Parameters

- S-0-0216, C4100 Switch parameter set command
- S-0-0217, Preselect parameter set command
- S-0-0219, IDN-list of parameter set

  Note: List parameters S-**0**-0219 to S-**7**-0219 contain parameter sets no. 0 to no. 7
- S-0-0254, Current parameter set

- P-0-2216, Parameter set switching, configuration
- P-0-2217, Parameter set switching, preselection range
- P-0-2218, Parameter set switching, delay time

Pertinent Diagnostic Messages

- C0273 Modulo value for motor encoder cannot be displayed
- C0278 Modulo value for optional encoder cannot be displayed
- C0280 Maximum travel range cannot be displayed internally
- C4100 Switch parameter set command
- C4101 Switching only possible without AF
- C4103 Preselect parameter set forbidden value
- C4104 Error during parameter set switching (->S-0-0423)

8.11 Drive-Controlled Oscillation

8.11.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

Upon a command of the control master, the drive ignores the cyclic command value input and independently turns alternately in positive and negative direction (speed oscillation). The cyclic speed characteristic can be set via parameters and can be realized symmetrically or asymmetrically.

Notes on Applications

With speed oscillation the main drive supports the following applications, for example:

- Meshing the toothed wheels when switching a gear train
- Engaging positive clutches (e.g. connecting i.c. engine equipment under test to test stands)

Pertinent Parameters

- S-0-0213, Oscillation speed
- S-0-0214, Oscillation offset speed
- S-0-0215, Oscillation cycle time

Pertinent Diagnostic Messages

- C4200 Drive-controlled oscillation command
- C4201 Oscillation requires drive enable
- C4202 Oscillation command speed cannot be reached

8.12 Parking Axis

8.12.1 Brief Description

Assignment to functional firmware package, see chapter "Availability of the Extended Axis Functions".

If individual axes within a master communication group (e.g. SERCOS ring, PROFIBUS) are to be temporarily deactivated, without taking them out of the axis group on the hardware and communication side, the function "parking axis" can be activated via command.

When a drive has been put into the status "parking axis", it behaves "neutrally" with regard to hardware and master communication. Errors possibly detected by the drive are suppressed and have no effect on the axes in operation.

This allows, for example, uncoupling the motor and the motor encoder in the status "parking axis" without errors being signaled.

The axis that has been "parked" behaves as if it would not exist!

Pertinent Parameters

- S-0-0139, C1600 Parking axis procedure command

Pertinent Diagnostic Messages

- C1600 Parking axis command

9 Optional Device Functions

9.1 Availability of the Optional Device Functions

The following overview illustrates by which basic or functional packages the respective optional device function is supported (if not stated otherwise, this applies to all 3 firmware versions, MPB, MPM and MPE).

Optional device function	In base package (characteristic)	In functional package ... (on the basis of a base package with the following characteristics)		
		Servo function	Synchronization	Main spindle
Digital inputs/outputs 1)	OL/CL	–	–	–
Analog inputs 1)	OL/CL	–	–	–
Command value generator	OL/CL	–	–	–
Command value box	CL	–	–	–
Programmable position switch	–	CL 2)3)	CL 2)3)	–
Probe	CL	–	OL/CL	–
Measuring encoder 1)	–	OL/CL 2)	OL/CL 2)	–

OL Open-loop characteristic
CL Closed-loop characteristic
1) Depending on hardware configuration
2) Not for the firmware version MPE
3) Not for the firmware version MPM

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

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

See also "Enabling of Functional Packages"

9.2 Digital Inputs/Outputs

9.2.1 Brief Description

General Information

The IndraDrive Cs controllers with their ECONOMY and BASIC control section characteristics and the IndraDrive C multi-axis controllers with BASIC control section characteristic already have configurable digital inputs/outputs in their basic configuration.

Hardware Requirements

The number, assignment and function of the digital inputs/outputs depend on the type of the controller (IndraDrive Cs or IndraDrive C multi-axis controller) and are contained in the respective hardware description (Project Planning Manual).

Digital Inputs/Outputs on Control Section

Features

- Sampling of digital inputs and outputs or transmitting data to them in the position loop clock $T_{A\_position}$ (see "Performance Data")

- Configurable digital inputs/outputs with effective direction that can partly be freely set as input or output:
  - **IndraDrive Cs with firmware MPB or MPE**:
    - 1 switchable digital input/output ()
    - 7 digital inputs [thereof 2 rapid inputs as probe inputs (in steps of µs)]
  - **IndraDrive C multi-axis controller with firmware MPM**:
    - 32 digital inputs [thereof 4 rapid inputs as probe inputs (in steps of µs)]
    - 16 digital outputs
- All inputs/outputs designed for level of 0 V (LOW) or 24 V (HIGH)
- Assignment of the inputs/outputs to several sub-devices possible whereas the IndraDrive Cs represents one sub-device and a four-axis controller four sub-devices
- Several sub-devices can be addressed from one digital input
- Any sub-device may access any available hardware input/output
- Multi-assignment of one input to several parameters possible
- An output of one sub-device may also be used as input to the same parameter
- Signal states of digital inputs and digital outputs mapped to individual parameter
- Additionally, the status of the sub-devices is mapped to one parameter
- Signal states of digital inputs can be directly read by the control master
- digital outputs can be directly controlled by the control master, if not used on drive-side
- Galvanic separation of the inputs/outputs from the internal control voltage supply

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☞ Each individual input/output can be assigned to parameters of the drive; IDN of the permitted parameters from IDN lists in S-0-0398 and S-0-0399.

Pertinent Parameters

- S-0-0398, IDN-list of configurable data in signal status word
- S-0-0399, IDN-list of configurable data in signal control word
- P-0-0300, Digital I/Os, assignment list
- P-0-0301, Digital I/Os, bit numbers
- P-0-0303, Digital I/Os, status display
- P-0-0304, Digital I/Os, outputs
- P-0-0306, Digital inputs, assignment connector and pin
- P-0-0307, Digital inputs, input image sub-device
- P-0-0310, Digital outputs, assignment list
- P-0-0311, Digital outputs, bit numbers
- P-0-0312, Digital outputs, assignment sub-device
- P-0-0313, Digital outputs, output image sub-device
- P-0-0316, Digital outputs, assignment connector and pin

Pertinent Diagnostic Messages

- F2010 Error when initializing digital inputs/outputs

Digital Inputs/Outputs on Optional Module OM1 and OM2

For the multi-axis controllers, it is possible to individually configure an extension of these inputs/outputs, apart from the standard digital inputs/outputs.

The optional modules OM1 and OM2 can be used for the following purposes:

- Making available digital inputs/outputs to external control unit
- Enabling input/output of drive parameters

Utilization of digital I/O extension by using the optional module OM1 or OM2 is only possible **for multi-axis controllers with MPM firmware**!

Features

- All inputs/outputs designed for level of 0 V (LOW) or 24 V (HIGH)
- External 24V supply of the digital outputs required
- Galvanic separation of the inputs/outputs from the control voltage supply
- Assignment of inputs/outputs to internal parameters or bits
- 32 digital inputs per optional module OM1 or OM2
- 16 digital outputs per optional module OM1 or OM2

Pertinent Parameters

- S-0-0398, IDN-list of configurable data in signal status word
- S-0-0399, IDN-list of configurable data in signal control word
- P-0-0300, Digital I/Os, assignment list
- P-0-0301, Digital I/Os, bit numbers
- P-0-0303, Digital I/Os, status display
- P-0-0304, Digital I/Os, outputs
- P-0-0306, Digital inputs, assignment connector and pin
- P-0-0307, Digital inputs, input image sub-device
- P-0-0310, Digital outputs, assignment list
- P-0-0311, Digital outputs, bit numbers
- P-0-0312, Digital outputs, assignment sub-device
- P-0-0313, Digital outputs, output image sub-device
- P-0-0316, Digital outputs, assignment connector and pin

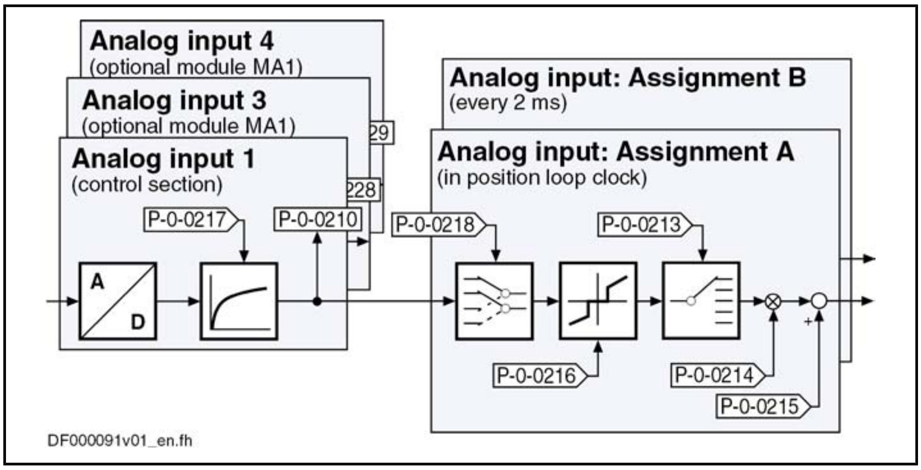
9.3 Analog Inputs

9.3.1 Brief Description

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

Optional Device Functions

Overview



P-0-0210 Analog input 1
P-0-0213 Analog input, assignment A, target parameter
P-0-0214 Analog input, assignment A, scaling per 10V full scale
P-0-0215 Analog input, assignment A, signal value at 0V
P-0-0216 Analog input, assignment A, dead zone
P-0-0217 Analog input 1, time constant input filter
P-0-0218 Analog input, control parameter

Fig.9-2: Overview: Analog Inputs and Their Assignment

Features

General features:

- 2 assignment mechanisms for analog inputs (assignment A or B)
- Different sampling rates of assignments A and B
  - Assignment channel A works in position loop clock (see "Performance Data")
  - Assignment channel B works in 2-ms clock
- Assignment to command value/limit value/control parameters of the drive by means of adjustable scaling
- variable scaling
- Dead zone to be entered for suppressing the zero drift for both analog channels
- Offset and amplification adjust for both analog channels via command

Features of analog inputs at control section:

- Low-pass filtering to be activated for both analog channels
- Analog inputs designed as differential input
- Input voltage range of ± 10 V

Pertinent Parameters

Configuring the analog inputs:

- P-0-0212, Analog input, list of assignable parameters
- P-0-0218, Analog input, control parameter
- P-0-0219, Analog input, maximum value for adjustment
- P-0-0220, C2800 Analog input adjustment command
- P-0-3901, Adjustment values of control section

Analog input values:

- P-0-0210, Analog input 1
- P-0-0217, Analog input 1, time constant input filter

Assignment A:

- P-0-0213, Analog input, assignment A, target parameter
- P-0-0214, Analog input, assignment A, scaling per 10V full scale
- P-0-0215, Analog input, assignment A, signal value at 0V
- P-0-0216, Analog input, assignment A, dead zone

Assignment B:

- P-0-0236, Analog input, assignment B, target parameter
- P-0-0237, Analog input, assignment B, scaling per 10V full scale
- P-0-0238, Analog input, assignment B, signal value at 0V
- P-0-0239, Analog input, assignment B, dead zone

Pertinent Diagnostic Messages

- C2800 Analog input adjustment command
- C2801 Analog input not configured
- C2802 Oscillations of input signal outside tolerance range
- C2803 Measured values at zero point and max. value identical
- C2804 Automatic adjustment failed

9.4 Drive-Integrated Command Value Generator

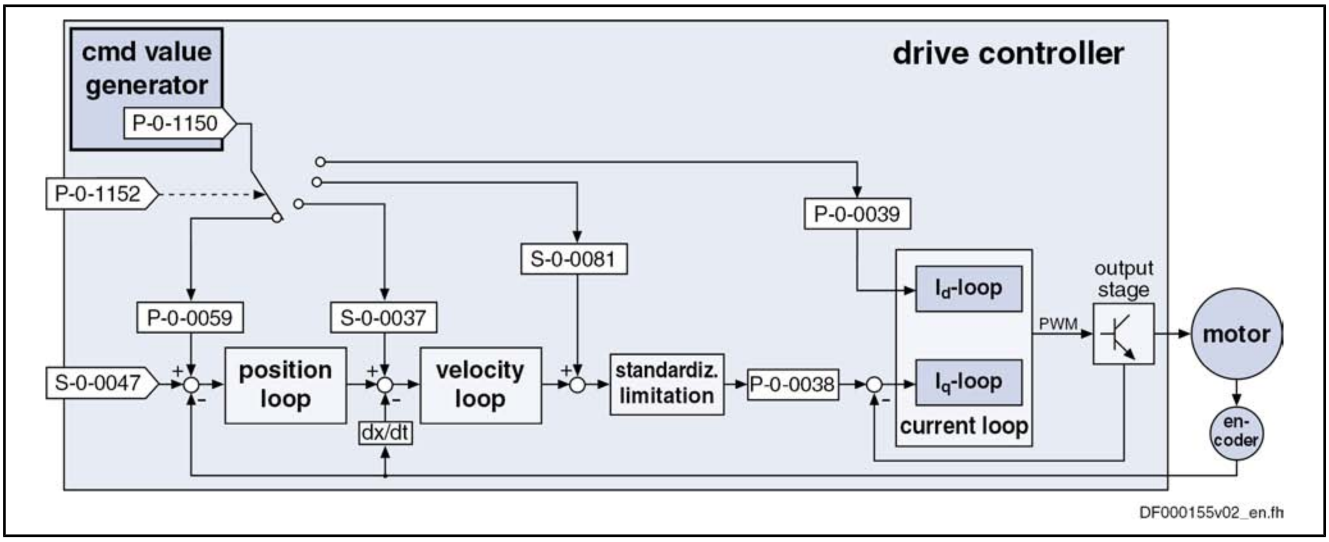
9.4.1 Brief Description

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

The drive-integrated command value generator can be used for commissioning and controller optimization of drives. The command value generator generates the command values required for the active operating mode in different shapes (square-wave, sine, noise); these command values are added to the main command value in the closed control loop.

In conjunction with the integrated oscilloscope function and an additional FFT calculation, the drive-integrated command value generator also provides the possibility of measuring the frequency response.

The figure below illustrates the points at which the drive-integrated command value generator can take effect:



S-0-0037 Additive velocity command value
S-0-0047 Position command value
S-0-0081 Additive torque/force command value
P-0-0038 Torque-generating current, command value
P-0-0039 Flux-generating current, command value
P-0-0059 Additive position command value, controller
P-0-1150 Command value generator output
P-0-1152 Command value generator, target parameter assignment

Fig.9-3: Points at Which Function "Command Value Generator" can Take Effect

Features

- Possibility of generating different signal shapes that are added to the respective control loop command value (position, velocity or current)

  The following signal shapes are possible:

  – **Square-wave signals**
  – **Sine signals**
  – **Noise signals**
  – **Modified sine signals**

- Generating **velocity and position command values** in the position loop clock; **current command values** in the velocity loop clock
- With regard to **amplitude and frequency**, generated command values can be freely defined

Pertinent Parameters

- P-0-1150, Command value generator output
- P-0-1151, Command value generator, list of possible target parameters
- P-0-1152, Command value generator, target parameter assignment
- P-0-1153, Command value generator, control word
- P-0-1154, Command value generator, offset
- P-0-1155, Command value generator, amplitude
- P-0-1156, Command value generator, duration 1
- P-0-1157, Command value generator, duration 2
- P-0-1158, Command value generator, periodic time
- P-0-0028, Oscilloscope: Control word
- P-0-0031, Oscilloscope: Time resolution
- P-0-0032, Oscilloscope: Size of memory

9.5 Drive-Internal "Command Value Box"

9.5.1 Brief Description

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

With IndraDrive controllers, a so-called "command value box" is internally available for manual drive optimization. It offers the possibility to internally (independent of the master) generate a command value characteristic that can be defined by the user. By this, an axis drive can be moved in the same way as with an external command value box, without an external command value being effective (→ internal "command value box"). The drive enable must merely be applied to the drive.

The command value characteristic that can be defined by the user, allows for an axis to be moved within determinable position limits in continuous sequence in the velocity control loop or position control loop. This can be made use of, in order to manually optimize the control loop parameters of the drive, by e.g. moving the drive with a low velocity command value and by evaluating the status variables "actual current value" and "actual velocity value".

☞ More details on the manual control loop setting are described in section "Overview of Drive Control: Notes on Commissioning for Control Loop Setting" .

By the internal command value box, an axis can be continuously moved in an "oscillating movement" (oscillating between two position limit values) or in "stepwise operation" (unidirectional moving over a defined path or a travel range).

The internal command value box is configured via a command word, the command value characteristic is defined via the respective parameters. Activating the internal command value box is carried out via a command.

Pertinent Parameters

- P-0-0162, C1800 Command Drive optimization / command value box
- P-0-0165, Drive optimization, control word
- P-0-0166, Drive optimization, end position negative
- P-0-0167, Drive optimization, end position positive
- P-0-0169, Drive optimization, travel distance
- P-0-0170, Drive optimization, acceleration
- P-0-0171, Drive optimization, velocity
- P-0-0172, Drive optimization, dwell time

Pertinent Diagnostic Messages

- C1800 Command automatic control loop setting
- C1801 Start requires drive enable
- C1806 Travel range exceeded

9.6 Programmable Position Switch

9.6.1 Brief Description

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

The firmware function "programmable position switch" can be used instead of a mechanical position switch that has to be externally mounted.

Features

- Realization of a maximum of **8 dynamic position switch points** (switch cams) in the position loop clock
- Freely **selectable reference signals** (P-0-0130) for generating the switch cams, all 8 cams are referring to the same signal (P-0-0131)
- **Switch-on and switch-off position can be separately parameterized** via list parameters (P-0-0132, P-0-0133); corresponding position switch bit can be inverted by selecting the switch-on and switch-off threshold
- **Lead time that can be separately parameterized** via list parameter (P-0-0134) for compensating internal processing times (dead time compensation)
- **8 position switch bits displayed** in the position switch status word (P-0-0135) which can be assigned to digital outputs or cyclically transmitted via master communication interface
- Permanently defined **switch hysteresis** to avoid position switch bit flicker when the switch-on or switch-off threshold is reached

Pertinent Parameters

- P-0-0130, Position switch signal selection list
- P-0-0131, Position switch signal selection
- P-0-0132, Position switch switch-on threshold
- P-0-0133, Position switch switch-off thresholds
- P-0-0134, Position switch lead times
- P-0-0135, Position switch status word

Pertinent Diagnostic Messages

- C0242 Multiple configuration of a parameter (->S-0-0423)

9.7 Probe Function

9.7.1 Brief Description

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

Features

- 2 probes (S-0-0401 / S-0-0402) per axis can be analyzed.
- Each probe (S-0-0401 / S-0-0402) can be assigned to any probe-compatible digital input. Several probes can use the same digital input. Depending on the control section, the digital inputs E1, E2, E3 and E4 are concerned (see Project Planning Manual Control Sections for Drive Controllers).
- Measuring signals can be actual position values of motor encoder, external encoder or measuring encoder, in addition master axis position values
- Measurement of absolute signal values, of signal value differences, detection of time intervals between measuring signals
- Measurement triggered by positive and/or negative probe signal edges
- Single measurement or continuous measurement to be selected, measurement events are counted in the case of continuous measurement
- Position value range ("expectation window") per probe can be defined within which measurement can take place (activation of a "failure counter" when expectation window is passed through without measuring event)

- Quick stop triggered via probe input
- Adjustable dead time compensation for each probe, separated for each edge (position / negative) up to 50000 µs
- Accuracy of measurement depends on hardware design (see section "Probe" in the documentation "Control Sections for Drive Controllers; Project Planning Manual")

Pertinent Parameters

- S-0-0130, Probe value 1 positive edge
- S-0-0131, Probe value 1 negative edge
- S-0-0132, Probe value 2 positive edge
- S-0-0133, Probe value 2 negative edge
- S-0-0169, Probe control parameter
- S-0-0170, Probing cycle procedure command
- S-0-0179, Probe status
- S-0-0401, Probe 1
- S-0-0402, Probe 2
- S-0-0405, Probe 1 enable
- S-0-0406, Probe 2 enable
- S-0-0409, Probe 1 positive latched
- S-0-0410, Probe 1 negative latched
- S-0-0411, Probe 2 positive latched
- S-0-0412, Probe 2 negative latched
- S-0-0426, Signal selection probe 1
- S-0-0427, Signal selection probe 2
- S-0-0428, Probe, IDN-list signal selection
- S-0-0524, Dead time compensation, positive edge, probe 1
- S-0-0525, Dead time compensation, negative edge, probe 1
- S-0-0526, Dead time compensation, positive edge, probe 2
- S-0-0527, Dead time compensation, negative edge, probe 2
- P-0-0200, Start position probe function 2 active
- P-0-0201, End position probe function 2 active
- P-0-0202, Difference probe values 1
- P-0-0203, Difference probe values 2
- P-0-0204, Start position probe function 1 active
- P-0-0205, End position probe function 1 active
- P-0-0206, Probe 1, max. number of marker failures
- P-0-0207, Probe 2, max. number of marker failures
- P-0-0224, Probe 1, number of marker failures
- P-0-0225, Probe 2, number of marker failures
- P-0-0226, Probe, extended control word
- P-0-0300, Digital I/Os, assignment list
- P-0-0306, Digital inputs, assignment connector and pin

Pertinent Diagnostic Messages

- A0403 Quick stop with probe detection is active
- C0250 Probe inputs incorrectly configured

9.8 Measuring Encoder

9.8.1 Brief Description

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

Position Measurement

Measuring encoders are used for position evaluation of a rotary motion that takes effect as a command variable for drive control. The actual position value of the measuring encoder therefore is of command value nature for drive control, the measuring encoder acts as a master axis encoder, for example.

Evaluating Position Measurement

Depending on its design and the mechanical arrangement at the axis, the measuring encoder can be evaluated as

- Relative encoder (incremental encoder)

- or -

- Absolute encoder (absolute value encoder).

Relative Position Measurement

In the case of relative position measurement, only position differences can be evaluated by means of the measuring system. The actual position values signaled by the measuring system refer to the (mostly undefined) position at the time the drive is switched on. If the actual position value is to refer to an axis or shaft, it is necessary to establish position data reference ("homing").

Absolute Position Measurement

In the case of absolute position measurement, the encoder signals actual position values with a fixed encoder-dependent reference point to the controller. After the drive is switched on, the correct actual position value is immediately available for each axis or shaft position. Due to the mostly undefined mounting situation of the encoder, it is necessary during initial commissioning to once adjust the actual position value to the axis or shaft ("set absolute position").

Precision, Resolution

The precision of the position measurement depends on

- the resolution of the measuring system (division periods = DP),
- the absolute encoder precision,
- the digitalization quality of the analog encoder signals,
- the size of the selected modulo range of the encoder.

Monitoring Functions

The correct position information of the measuring encoder is required for correct recording of a command variable. The encoder signals are therefore monitored for validity and compliance with the allowed tolerances.

In addition, it is possible to monitor drives with an encoder that can be evaluated in absolute form for compliance with the position when switching on compared to the last time the drive was switched off.

See "Monitoring the Measuring Systems"

Hardware Requirements

For connecting the measuring systems to the controller, the control section has to be equipped with the corresponding interfaces. Parameter "P-0-0079, Assignment measuring encoder->optional slot" is used to determine the interface to which the respective encoder is connected.

For controllers with a double-axis control section (CDB01.1-...), it is only possible to assign a measuring encoder to one axis. The assignment is made in parameter "P-0-0076, Encoder type 3 (measuring encoder)". If a measuring encoder was assigned to both axes, an error message will be displayed!

See also separate documentation "Drive Controllers, Control Sections; Project Planning Manual"

Pertinent Parameters

- P-0-0052, Actual position value of measuring encoder
- P-0-0076, Encoder type 3 (measuring encoder)
- P-0-0079, Assignment measuring encoder->optional slot
- P-0-0084, Number of bits per master axis revolution
- P-0-0087, Actual position value offset of measuring encoder
- P-0-0097, Absolute encoder monitoring window for measuring encoder
- P-0-0127, Input revolutions of measuring gear
- P-0-0128, Output revolutions of measuring gear
- P-0-0179, Absolute encoder buffer 3 (measuring encoder)
- P-0-0326, Multiplication of measuring encoder
- P-0-0327, Encoder resolution of measuring encoder
- P-0-0328, Type of position encoder for measuring encoder
- P-0-0329, Smoothing of actual position value 3 of measuring encoder
- P-0-0330, Control word of measuring encoder
- P-0-0331, Status of measuring encoder
- P-0-0332, Actual velocity value of measuring encoder
- P-0-0334, Absolute encoder range of measuring encoder
- P-0-0347, Encoder 3, cosine signal
- P-0-0348, Encoder 3, sine signal
- P-0-0765, Modulo factor measuring encoder
- P-0-1020, Kind of encoder 3, encoder memory
- P-0-1021, Encoder 3 resolution, encoder memory
- P-0-1022, Absolute encoder offset 3, encoder memory

Pertinent Diagnostic Messages

- C0161 Incorr. parameterization of measuring enc. (hardware)
- C0162 Measuring encoder unknown
- C0163 Modulo value for measuring encoder cannot be displayed
- C0227 Error when initializing position of measuring encoder
- C0228 Initialization velocity measuring encoder too high
- E2076 Measuring encoder: Encoder signals disturbed
- F2043 Measuring encoder: Encoder signals incorrect
- F2076 Actual pos. value 3 outside absolute encoder window
- F2176 Loss of measuring encoder reference
- F2179 Modulo limitation error of measuring encoder

10 Handling, Diagnostic and Service Functions

10.1 Parameters, Basics

10.1.1 Properties/Features of Parameters

Brief Description

The controller firmware via data maps the drive to an internal mathematical model. All operating data relevant therefor are mapped to parameters. An identification number (IDN) is assigned to each parameter. The IDN allows accessing operating data via

- the serial interface

- or -

- a master communication interface suited for data transfer.

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

10.1.2 Loading, Storing and Saving Parameters

Brief Description

Parameters All relevant operating data are mapped to parameters and stored in the controller.

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

- In the controller
- In the motor encoder (depending on motor type)

In addition, the controller has a volatile data memory (working memory).

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

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

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

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

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

Application-specific parameter values can be saved via:

- "IndraWorks Ds/D/MLD" commissioning tool → saving the parameter values on external data carrier
- Control master → saving parameter values on master-side data carrier

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

Loading Parameter Values

Loading parameter values is required in the following cases:

- Initial commissioning of the motor (loading basic parameter values and motor-specific parameter values)
- Serial commissioning of machine axes at series machines (loading the values saved after initial commissioning)
- Reestablishing a defined initial status (repeated loading of the values saved after initial commissioning)
- Replacing the controller for servicing (loading the current parameter values saved before servicing)

Possibilities of loading parameter values to the controller:

- Motor encoder data memory → loading the parameter values by command or via the control panel during initial motor commissioning
- "IndraWorks Ds/D/MLD" commissioning tool → loading the parameter values from external data carrier
- Control master → loading the parameter values from master-side data carrier

Checksum of Parameter Values

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

Pertinent Parameters

- S-0-0017, IDN-list of all operation data
- S-0-0192, IDN-list of all backup operation data
- S-0-0262, C07_x Load defaults procedure command
- S-0-0263, C2300 Load working memory procedure command
- S-0-0264, C2200 Backup working memory procedure command
- S-0-0269, Storage mode
- S-0-0270, IDN-list of selected backup operation data
- S-0-0293 , C2400 Selectively backup working memory procedure command
- S-0-0326, Parameter checksum
- S-0-0327, IDN list of checksum parameter
- S-0-0531, Checksum of backup operation data
- P-0-0013, List of all IDNs not corresponding to default value
- P-0-4023, C0400 Communication phase 2 transition
- P-0-4065, Active non-volatile memory
- P-0-4090, Configuration for loading default values

Pertinent Diagnostic Messages

Load defaults procedure (loading controller parameters):

- C07_0 Load defaults procedure com. (load controller param.)
- C0702 Default parameters not available
- C0703 Default parameters invalid
- C0704 Parameters not copyable
- C0706 Error when reading the controller parameters

Load defaults procedure (loading basic parameters):

- C07_1 Load defaults procedure com. (load basic parameters)
- C0751 Parameter default value incorrect (-> S-0-0423)

- C0752 Locked with password

Backup working memory procedure:

- C2202 Error when writing data to non-volatile memory
- C2200 Backup working memory procedure command

Loading working memory:

- C2300 Load working memory procedure command
- C2301 Error when reading non-volatile memory
- C2302 Error when converting parameters

Selectively backup working memory procedure:

- C2400 Selectively backup working memory procedure command
- C2402 Error when saving parameters

Other diagnostic messages:

- F2100 Incorrect access to command value memory
- F2102 It was impossible to address I2C memory
- F2103 It was impossible to address EnDat memory

10.1.3 IDN Lists of Parameters

General Information

Some of the parameters stored in the drive contain, as their operating data (parameter value), a list of IDNs of drive parameters corresponding to a specific, given criterion. These so-called IDN lists enable the master or a commissioning software to handle drive parameters in a specific way.

10.1.4 Using a Password

Brief Description

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

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

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

- **Customer password**

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

  → Parameters protected by a customer password can be written; "administration parameters" remain read-only.
- **Master password**

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

☞ The customer password can be defined by the customer, the control password and the master password are defined by the manufacturer!

Pertinent Parameters

- S-0-0192, IDN-list of all backup operation data
- S-0-0267, Password
- S-0-0279, IDN-list of password-protected operation data
- P-0-4064, Password level

10.2 Device Configuration

10.2.1 Controller Design

The drive controllers of the IndraDrive range consist of several modules. We basically distinguish between control section and power section:

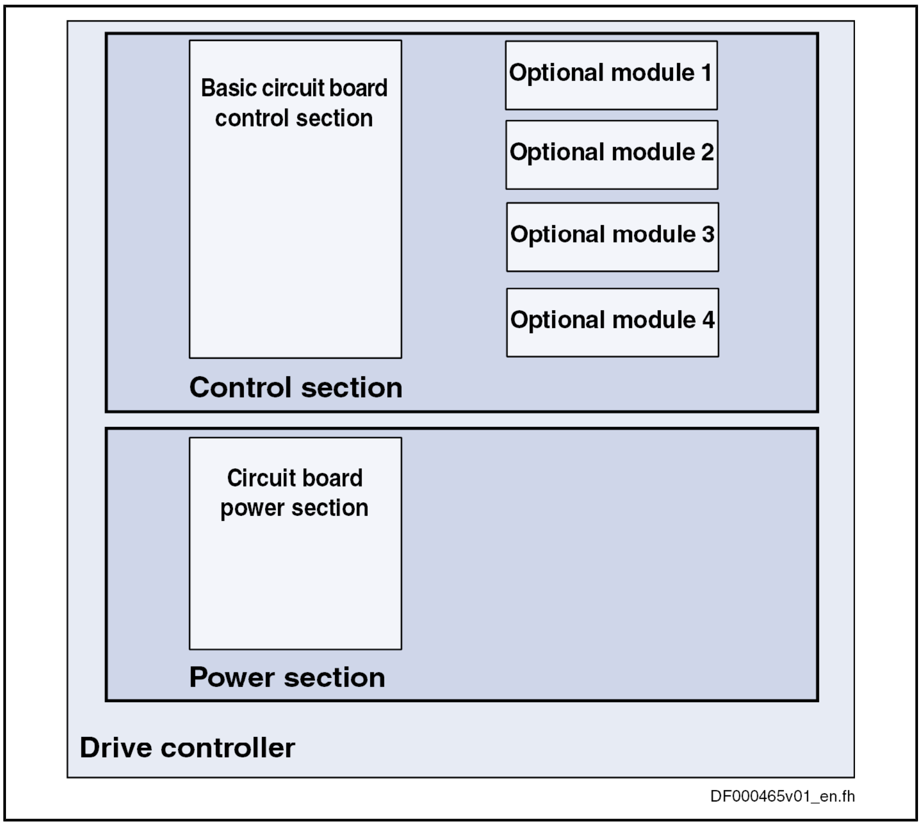


Fig. 10-1: Example of Design Including Device, Modules and Circuit Boards for IndraDrive Controllers

Connection between firmware version and single-axis converter:

Product Line		Per-form-ance class			Design	Required firmware version
HCS01.1E	-	W0006	-	A-02-	B-ET-EC-NN-NN-NN-FW	MPB-16VRS MPE-16VRS
	-	W0008	-	A-03-	B-ET-EC-EC-L2-NN-FW	
	-	W0008	-	A-03-	B-ET-EC-NN-NN-NN-FW	
	-	W0013	-	A-02-	B-ET-EC-EC-L2-NN-FW	
	-	W0013	-	A-02-	B-ET-EC-NN-NN-NN-FW	
	-	W0018	-	A-03-	B-ET-EC-NN-NN-NN-FW	
	-	W0028	-	A-03-	B-ET-EC-EC-L2-NN-FW	
	-	W0028	-	A-03-	B-ET-EC-NN-NN-NN-FW	

Fig. 10-2: Required Firmware Versions for Converters

Connection between firmware version and multi-axis converter:

Product Line		Type per-form-ance			Control section design	Master communication	Supported as of firmware version
HCQ02.1E	-	W0025	-	A-03-	-B-	ET	MPM-16VRS
HCT02.1E	-	W0020	-	A-03-	-B-	ET	MPM-16VRS

Fig. 10-3: Required Firmware Versions for Converters (Multi-Axis)

☞ The devices are configured at the factory and can be read via parameters, if required.

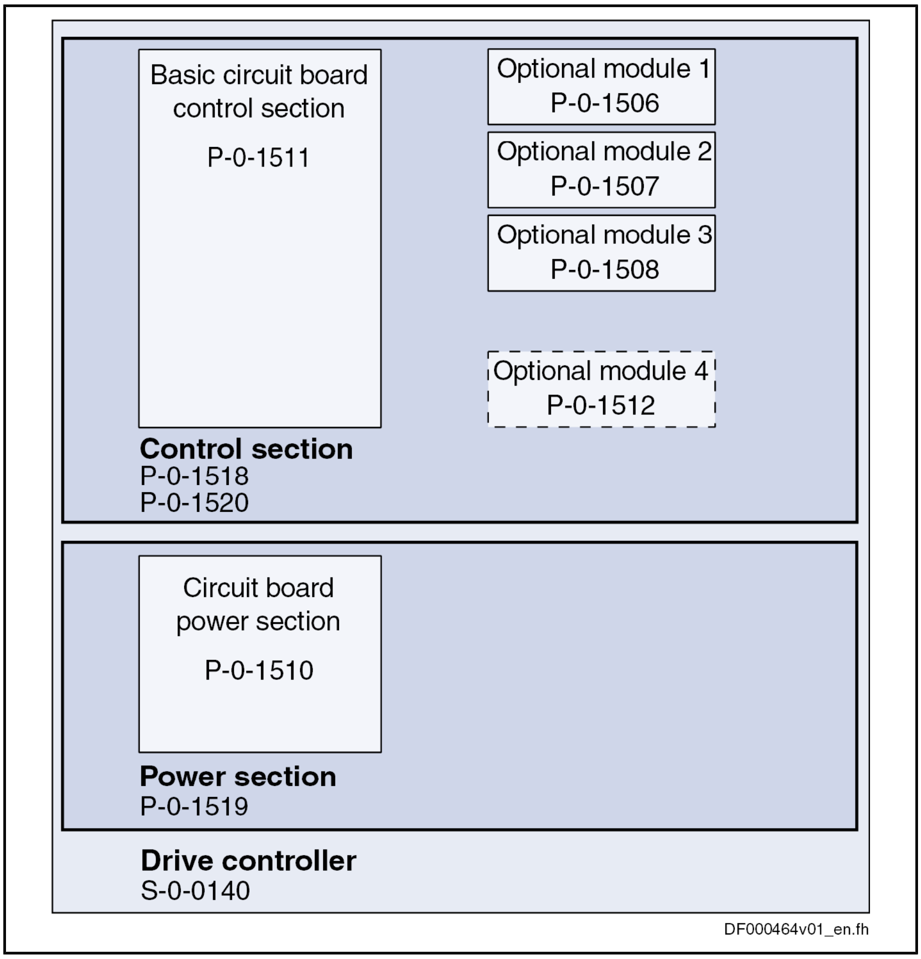
10.2.2 Circuit Board Code

Brief Description

The configurable control section of a drive controller consists of the basic control section circuit board and one or several optional modules (see Type Code in the documentation "Drive Controllers, Control Sections; Project Planning Manual").

An individual parameter is assigned to each slot for circuit board or optional module (cf. P-0-1506 to P-0-1514). The specific data (circuit board code) of the circuit board that has been plugged are stored in these parameters.

☞ The circuit board codes are stored directly on the circuit board or the respective optional module.



S-0-0140	Controller type
P-0-1506	Circuit board code optional module 1
P-0-1507	Circuit board code optional module 2
P-0-1508	Circuit board code optional module 3
P-0-1510	Circuit board code power section
P-0-1511	Circuit board code control section
P-0-1512	Circuit board code optional module 4
P-0-1518	Module code of control section
P-0-1519	Module code of power section
P-0-1520	Control section type

Fig. 10-4: Device Configuration and Circuit Board Code for IndraDrive

In the initialization phase (when booting), the drive firmware automatically checks the arrangement (configuration) of the control section by means of the individual circuit board codes, and on this basis generates the content of parameter "P-0-1520, Control section type". The configuration of the control section used can be read via this parameter.

☞ The control section is configured at the factory and the configuration is displayed in parameter P-0-1520 for diagnostic purposes (type designation in plain text)!

Pertinent Parameters

- S-0-0140, Controller type
- P-0-1506, Circuit board code optional module 1
- P-0-1507, Circuit board code optional module 2

- P-0-1508, Circuit board code optional module 3
- P-0-1510, Circuit board code power section
- P-0-1511, Circuit board code control section
- P-0-1512, Circuit board code of optional module 4
- P-0-1518, Module code of control section
- P-0-1519, Module code of power section
- P-0-1520, Control section type

Pertinent Diagnostic Messages

During the initialization phase the drive, apart from checking the existing configuration, carries out some additional checks. Errors detected during the checks are classified according to their cause.

General malfunction of a circuit board with specific error messages:

- F8091 Power section defective
- F8122 Control section defective

Configuration of control section not allowed, i.e. an optional card was plugged into a slot that does not support this card (observe allowed combinations of the individual optional modules; see documentation "Drive Controllers, Control Sections; Project Planning Manual"):

- F8118 Invalid power section/firmware combination
- F8120 Invalid control section/firmware combination

10.2.3 Operating Hours Counter

Brief Description

There are operating hours counters available in the drive that separately record the operating time for control section and power section. The respective operating time is displayed in the parameters P-0-0190 or P-0-0191. These times are directly stored from the control section or power section so that assignment is maintained also for servicing.

Pertinent Parameters

- P-0-0190, Operating hours control section
- P-0-0191, Operating hours power section

Parameter "P-0-0190, Operating hours control section" displays the operating time of the control section of the drive. The unit is seconds.

The time the drive has been switched on is considered to be the operating time of the control section.

Parameter "P-0-0191, Operating hours power section" displays the operating time of the power section of the drive with drive enable having been set. The unit is seconds.

The time during which the output stage has been enabled is considered to be the operating time of the power section.

☞ Before delivery, the operating hours counters are set to a defined value at the factory. They can therefore indicate the total runtime of a component in field duty.

In addition, there is an operating hours counter for motors with which the dynamic operating data of the motor are collected and stored.

See section "Diagnostic Data of Motor Operation"

10.2.4 Error Memory (Power Section and Control Section)

Brief Description

In the drive, all errors occurred are recorded in an error memory on the control section. If an error occurs in the power section, it is additionally stored in a separate error memory on the power section. It is thereby made sure that the relevant information is still available on the power section after separating the power section and control section.

☞ When an error occurs, the diagnostic message number and the current count of the operating hours counter are automatically stored.

Pertinent Parameters

- S-0-0390, Diagnostic message number
- P-0-0190, Operating hours control section
- P-0-0191, Operating hours power section
- P-0-0192, Error memory of diagnostic numbers
- P-0-0193, Error memory operating hours of control section

☞ The contents of the parameters P-0-0192 and P-0-0193 are stored on the control section. The content of parameter P-0-0194 is stored on the power section.

10.3 Diagnostic System

10.3.1 Coded Diagnostic Messages of the Drive

Brief Description

The drive provides a diagnostic system including different options that are basically divided into two groups:

- Recognizing and displaying the current drive status by means of drive-internal, priority-dependent generation of diagnostic messages
- Collective messages for diverse status messages

Additionally, there are parameters for all important operating data the values of which can be transmitted both via master communication (e.g. SERCOS) and a parameterization interface (RS-232/485 in the ASCII protocol or SIS protocol; see "Serial Communication").

Pertinent Parameters

- S-0-0030, Manufacturer version
- S-0-0095, Diagnostic message
- S-0-0140, Controller type
- S-0-0142, Application type
- S-0-0375, Diagnostic numbers list
- S-0-0390, Diagnostic message number
- P-0-0007, Display text of diagnostic message
- P-0-0009, Error number
- P-0-0478, Logbook event
- P-0-0479, Logbook time stamp

10.3.2 Status Classes, Status Displays, Control Parameters

General Information

In the drive there are many parameters with important status information (bit lists). Some of the bits contained in these lists can be used for configuring real-time status bits and additionally can be assigned to digital outputs or to the configurable signal status word.

See "Digital Inputs/Outputs"

See "Configurable Signal Status Word"

Status Classes

Brief Description

The drive differentiates between 3 states (error, warning and message) for which there is status information. To make the status information available, there are so-called class diagnostics parameters (S-0-0011, S-0-0012, S-0-0013) which contain the respective status bits.

In addition to these class diagnostics parameters, there are change bits contained in the status word of the field bus (e.g. S-0-0135 in the case of SERCOS) which display changes in one of the above-mentioned class diagnostics parameters (collective information).

Features

- Class diagnostics parameter for **errors** (cf. S-0-0011)
- Class diagnostics parameter for **warnings** (cf. S-0-0012)
- Class diagnostics parameter for **messages** (cf. S-0-0013)
- **Change bits in status word** of master communication (e.g. S-0-0135 in the case of SERCOS)
- Change bits of class 2 and 3 diagnostics (S-0-0097 and S-0-0098) **can be masked** in status word of master communication (e.g. S-0-0135 in the case of SERCOS) to suppress individual bits or status messages

Pertinent Parameters

- S-0-0011, Class 1 diagnostics
- S-0-0012, Class 2 diagnostics
- S-0-0013, Class 3 diagnostics
- S-0-0097, Mask class 2 diagnostics
- S-0-0098, Mask class 3 diagnostics
- S-0-0135, Drive status word

Fixed Status Displays

Function-Related Status Parameters

In the drive there are parameters the content of which has a direct relation to the status of the sequence of different drive functions. These parameters are used to display the current status information of the assigned function.

The following parameters are available for function-related status display:

- **S-0-0014, Interface status**

  This parameter displays the status of the communication phase transition and the cyclic communication.
- **S-0-0135, Drive status word**

  This is the status word of the master communication (SERCOS) and contains all essential status information for the master.
- **S-0-0403, Position feedback value status**

This parameter contains status bits for the position data reference of the individual measuring systems.

- **S-0-0419, Positioning command acknowledge**

  This status information is used for acknowledgment in the "drive-controlled positioning" mode.
- **P-0-0046, Status word of current controller**

  This parameter contains status bits of the internal motor control (e.g. overvoltage in DC bus).
- **P-0-0115, Device control: Status word**

  This parameter contains status bits of device control (see also "Device Control and State Machines").
- **P-0-0222, Travel range limit switch inputs**

  This parameter displays the status of the travel range limit switch inputs (see also "Limitations: Travel Range Limit Switches").
- **P-0-0223, E-Stop input**

  This parameter displays the status of the E-Stop input (see also "E-Stop Function").
- **P-0-0445, Status word torque/current limit**

  This parameter contains status bits to display the activation of torque/current limitation (see also "Limitations: Current and Torque/Force Limitation").
- **P-0-0539, Holding brake status word**

  This parameter contains status bits for the status of the motor holding brake (see also "Motor Holding Brake").
- **P-0-0555, Status word of axis controller**

  This parameter displays messages with regard to velocity and limits that have been reached.
- **P-0-4029, Diagnostic report SCSB module**

  Parameter for reading master communication settings and states (with SERCOS interface).
- **P-0-4086, Master communication status**

  This parameter displays control information of the master communication for handling phase switch, drive enable etc., defined during initialization.

Status Parameters for Real-Time Status Bits

The following list contains status parameters that only contain one bit and can therefore be used for configuring real-time status bits (see "SERCOS interface"):

- S-0-0330, Status "n_feedback = n_command"
- S-0-0331, Status "n_feedback = 0"
- S-0-0332, Status "n_feedback < nx"
- S-0-0333, Status "T >= Tx"
- S-0-0334, Status "T >= Tlimit"
- S-0-0335, Status "n_command > n_limit"
- S-0-0336, Status "In position"
- S-0-0337, Status "P >= Px"
- S-0-0341, Status "In coarse position"

- S-0-0342, Status "Target position attained"
- S-0-0343, Status "Interpolator halted"
- S-0-0409, Probe 1 positive latched
- S-0-0410, Probe 1 negative latched
- S-0-0411, Probe 2 positive latched
- S-0-0412, Probe 2 negative latched

Control Parameters

Apart from the parameters for status display, there are parameters available in the drive that are used to control the drive functions (see also Description of Corresponding Parameter):

- P-0-0045, Control word of current controller
- P-0-0522, Control word for commutation setting
- P-0-0556, Config word of axis controller
- P-0-4028, Device control word

10.4 Diagnostic Data of Motor Operation

10.4.1 Brief Description

For preventive maintenance and service purposes, the firmware provides the option to collect dynamic operating data of the motor and store them in the controller.

The operating hours counter for motors allows planning maintenance intervals, minimize machine downtimes and reduce maintenance costs.

Features

- Recording the total time during which:
  - Operating status "AF" available
  - Velocity is unequal zero
  - Motor temperature is greater than 10 K below shutdown threshold (parameter "S-0-0204, Motor shutdown temperature")
- Recording the maximum velocity of the motor in operation
- Determining the average value of the motor velocity in operation
- Recording the maximum temperature of the motor winding in motor operation
- Determining the average value of the motor winding temperature, referring to the duration of the operating status "AF"
- Determining the operational performance of the motor by multiplying average speed and duration with velocity unequal zero

Pertinent Parameters

- P-0-2051, Operating hours counter, motor
- P-0-2052, Thermal operating data, motor
- P-0-2053, Mechanical operating data, motor
- P-0-2054, Operational performance, motor
- P-0-2055, Serial number, motor

10.5 Control Panels of the IndraDrive Controllers

10.5.1 General Information on the Operation Options

Variants of the Control Panels

IndraDrive controllers are equipped with a "control panel" which consists of a display and keys located underneath it. The display shows operating states, command and error diagnoses, as well as present warnings. By means of the keys you can make settings, call information and trigger some commands.

The extent of possible displays and settings depends on the available control panel of the IndraDrive controller.

Standard Control Panel

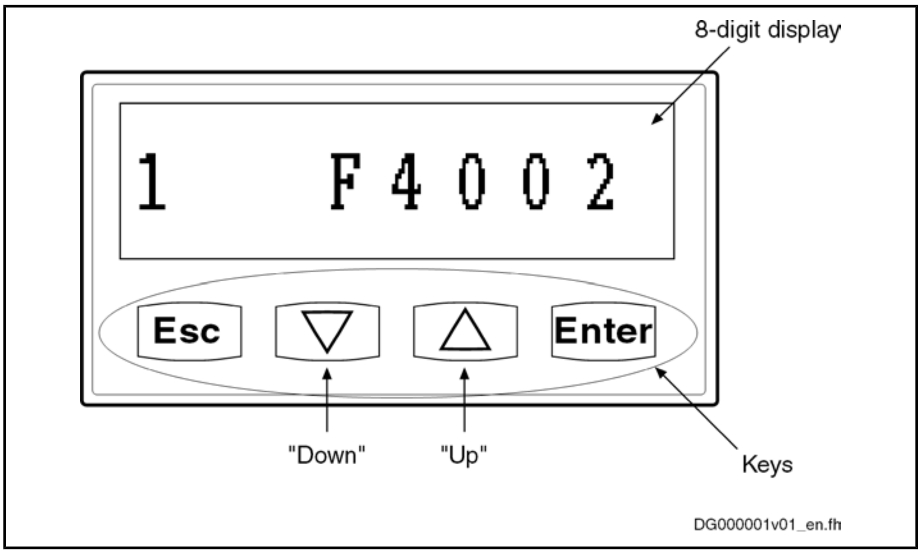


Fig. 10-5: Standard Control Panel With Display and Control Elements (Example of Display)

Possibilities of Display of Standard Control Panel

The standard control panel allows the following displays:

- Status of the master communication
- Operating status
- Activated commands and command diagnoses
- Warnings and diagnostic error messages
- Extended displays such as contents of error memories, diagnostic message memory, operating hours counter of control section, operating hours counter of power section, type designation of firmware active in the device, safety technology code (if safety technology option available)

Possible Settings with Standard Control Panel

The following settings can be made with the standard control panel:

- Set the drive address (drive number in the bus system of the master communication)
- Set the length of the fiber optic cable
- Activate the master communication mode "Easy Startup"

Command Activation with Standard Control Panel

The following commands can be activated with the standard control panel:

- Activate "S-0-0262, C07_x Load defaults procedure command" (load controller parameters or basic parameters)
- Activate other commands, such as:

– C2200 Backup working memory procedure command
– C2300 Load working memory procedure command

10.5.2 Standard Control Panel

Brief Description

The standard control panel of an IndraDrive controller has an 8-digit display and four keys located underneath it.

The display shows operating states, command and error diagnoses, as well as present warnings.

Using the four keys, the commissioning engineer or service technician can opt to display extended diagnostic messages at the drive controller and to activate simple commands (in addition to master communication using the commissioning tool or NC control unit).

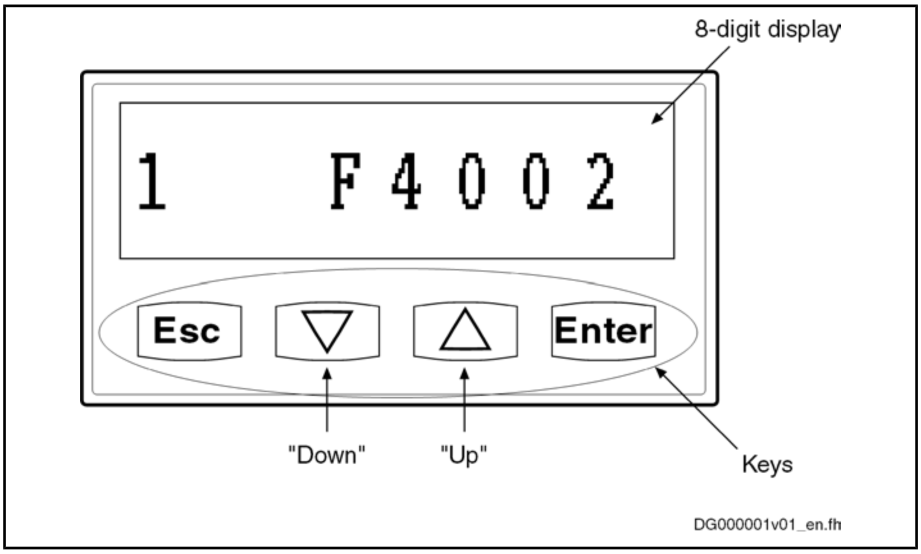


Fig. 10-6: Standard Control Panel With Display and Control Elements (Example of Display)

10.6 Firmware Replacement

10.6.1 Brief Description

Basic Principles

Explanation of Terms

The following cases are distinguished for firmware exchange:

- **Release update**

  An older firmware release located in the device (e.g. MPB16**V02**) is replaced by a new firmware release (e.g. MPB16**V04**).

- **Version upgrade**

  The older firmware version located in the device is replaced by a newer firmware version (example: MPB**16**V06 is replaced by MPB**17**V08).

☞ With firmware MPx-16, there is currently no possibility to make a version upgrade!

Firmware for IndraDrive can be replaced using the following hardware and software:

- Computer with software "IndraWorks" or

- Computer with TFTP client or
- change of the programming module (only IndraDrive Cs)

☞ The "IndraWorks" commissioning software can be ordered from one of our sales and service facilities.

The scope of supply of "IndraWorks" contains a documentation which describes the operation of the program.

Preparations and Conditions for Firmware Replacement

Preparing the Firmware Replacement

You have to make the following preparations for firmware replacement:

1. Drive controller must be on (24 V supply).
2. Drive controller **mustn't** be in operating mode (communication phase 4) (cf. P-0-0115).
3. It is recommended to save the parameter values before exchanging the firmware (see functional description "Loading, Storing and Saving Parameters").

General Notes on How to Carry Out Firmware Replacement

You have to observe the following points when carrying out the firmware replacement:

- Do not switch off the 24 V control voltage while replacing the firmware.
- The firmware replacement must always be performed completely.

10.6.2 Firmware Release Update

IndraDrive Cs

General Information

☞ In case of firmware release update from MP**B**16V**02** to MP**B**16V**04**, the following has to be noted:

- After the firmware release update, drive controllers of type IndraDrive Cs might generate the error F9100; the update has, however, been carried out successfully. By switching the drive controller off and on, the error is reset.
- If after the firmware release update, the master communication protocol is changed to EtherCAT (P-0-4089.000.001), the drive will during phase progression with TwinCAT (BECKHOFF) once generate the switching error C0101. In this case, the parameters listed in S-0-0021 must be set to "valid" using IndraWorks.

☞ Before the firmware release update, it is recommended to save the parameters of the drive to be saved!

Communication Types

For engineering, the two EtherNet ports of the MultiEtherNet interface are available. Here, you must generally distinguish which master communication is used:

- PROFIBUS

  With a PROFIBUS device, the two EtherNet ports (X24/X25) of the MultiEtherNet interface are free and can be used for "Engineering over IP" (see also functional description "TCP/IP Communication").
- EtherCAT, EtherNet/IP, PROFINET

With EtherCAT, EtherNet/IP, and PROFINET, an EtherNet communication ("EtherNet over EtherCat" or "Engineering over IP") is currently not possible. For replacing the firmware, you must firstly change the master communication to "SERCOS III".

☞ After changing the master communication, the device must be restarted for activating the settings.

- SERCOS III

  If SERCOS III has been activated as master communication, "Engineering over IP" is available. The computer can, for example, be directly connected to the last device in the bus and thus, a firmware update may be started.

☞ If there are several devices in the bus, it has to be ensured that each node is assigned an unambiguous IP address.

Via the programming module, the active IP settings can be viewed or adjusted, if necessary (see functional description "Standard Control Panel").

☞ After changing the IP settings, the device must be restarted for activating the settings.

IP Configuration in the "EasyMenu" See Functional Description: "Standard Control Panel"

IP Settings at the Computer See Microsoft help, keyword "LAN connection"

Changing the Master Communication See Functional Description: "MultiEthernet"

Switching to "PM"

1. Via IndraWorks - e.g. Menu **Project ▸ Switch devices online...** or Context menu of the axis, the drive can be switched online.
2. Switch to parameter mode (PM):
   - Via IndraWorks e.g. Menu **Device status ▸ Activate parameterization level** or
   - the pushbutton **PM**.
   - Or via the extended menu of the programming module (see functional description "Standard Control Panel").

Firmware Release Update with Computer

1. Connection the drive to the computer (recommended: Cat-5e EtherNet cable)
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 by Means of IndraWorks*
      1.1. Call "IndraWorks".
      1.2. Load project for corresponding axis or create new project; to do this, address axis via EtherNet.

1.3. Switch project "online".

1.4. Select/highlight controller and call "Firmware Management" in context menu.

A new window opens and firmware currently available in drive is displayed.

1.5. Highlight new firmware (*.ibf file) in the upper part of the dialog and start firmware download via "Download" button.

Firmware download runs automatically and all required firmware components are loaded to drive.

1.6. After firmware download has been completed, close "Firmware Management" window.

2. *Firmware Release Update Using a TFTP Client*

2.1. The firmware update service is made available via a TFTP server. Here, the command for sending the firmware is the "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"):

In order to carry out a firmware release update, only a "put" request is sent. The optional alternative name for the file on the target system is to be left free. 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-INDRV_-MPB-16V04-D5.ibf`

See also Functional Description "Firmware download via TFTP server"

3. Put machine into ready-for-operation status again according to machine manufacturer's instructions.
4. Check functions of drive.

Firmware Release Update Using the Programming Module

On the programming module, the firmware and the user data used in the device are stored.

☞ Before exchanging the programming module, a programming module with desired firmware must be ordered from Bosch Rexroth.

In order to exchange the programming module, proceed as follows:

1. Switch drive off.
2. Remove the old programming module.
3. Plug in the new programming module.
4. Switch drive on.
5. Put machine into ready-for-operation status again according to machine manufacturer's instructions.
6. Check functions of drive.

IndraDrive HCQ / IndraDrive HCT (in Preparation)

In case of firmware release update from MP**M**16V**02** to MP**M**16V**04**, more device parameters are required that can only be entered by a Bosch Rexroth service technician!

10.6.3 Firmware Version Upgrade

With firmware MPx-16, there is currently no possibility to make a firmware version upgrade!

10.6.4 Possible Problems During Firmware Replacement

General Information

After an incomplete firmware update, the drive controller possibly is no longer operable.

Firmware replacement is carried out incompletely, if one of the following situations occurs during the sequence of firmware replacement:

- 24V supply of control section is switched off
- Connection to drive is interrupted (e.g. defective interface cable)
- Crash of update software / of computer

If there isn't any valid firmware available in the control section, the loader is started. The text "LOADER IP Adresse: 192.168.0.1" appears on the display in light writing. With the loader, it is possible to replace the firmware of the control section.

Upon successful firmware replacement in the control section, a restart has to be carried out.

Firmware Replacement in Control Section in the Case of Error

The following steps are required for loading the firmware to the control section in the case of error:

1. Call "IndraWorks".
2. In the menu, call the firmware management under **Tools Drive ▸ Firmware Management**.

   A new window opens and firmware available in current firmware directory is displayed on its left side.

3. Select the "Download via Ethernet" tab.
4. Set the IP address "192.168.0.1".
5. Select the desired firmware (*.ibf file) and start the firmware download using the pushbutton **Download** .
6. Firmware download runs automatically and all required firmware components are loaded to drive.
7. After firmware download has been completed, close "Firmware Management" window.
8. Restart drive.

10.7 Notes on How to Replace the Devices

10.7.1 Replacing the Supply Unit

General Information

The concept of Rexroth supply units includes safe, quick and uncomplicated replacement of devices. This allows reducing production downtimes, caused by failures of these devices, to a minimum.

Failures in the supply unit are displayed by means of diagnostic messages. According to the diagnostic error message, the measure "replacing the supply unit" can be indicated.

See documentation "Notes on Troubleshooting" (description of diagnostic messages)

Immediately after having replaced the device, the drive is operational again, because it is not required to repeat the adjustment of the drive to the machine.

How to Replace the Supply Unit

Procure Replacement Device

Identify device to be replaced by means of type plate; procure supply unit of same type from Bosch Rexroth!

See also documentation of the respective supply unit

Fill Out Fault Report

In the documentation of the respective supply unit, you can find a fault report form to be copied. Please copy this fault report, fill it out carefully and completely and enclose it with the defective device! The fault report filled out completely supports quick handling of repair and helps recognizing application-related failure causes.

Replace Supply Unit

De-energize drive system; wait for DC bus to discharge; then replace defective supply unit!

DANGER

Live conductor bars (higher than 50 V), even if mains voltage switched off!

Electric shock when touching!

⇒ Wait for the DC bus (L+/L-) to discharge; before touching the conductor bar, check whether below 50 V!

For notes on how to dismount and mount the supply unit, see documentation of the respective Supply Unit

Put Drive System Into Operation Again

Put machine into operation again according to machine manufacturer's instructions!

10.8 Replacing the Controller

10.8.1 Overview

A controller of the IndraDrive range consists of the components power section and control section (incl. firmware). The control section can be configured with additional components (encoder interface). Control section and power section are fixedly connected with each other; individual components may only be replaced by Rexroth service technicians or trained users. In the following sections, the replacement of the complete controller with regard to parameter backup is described. The mounting and dismounting of the entire drive controller is described in the Project Planning Manual for the power section.

☞ Any device intended for the replacement that has already been used (i.e. that is not in a brand new condition as supplied) must be put into the condition as supplied again before it may be used ("load basic parameters").

The figure below illustrates the basically required individual steps.

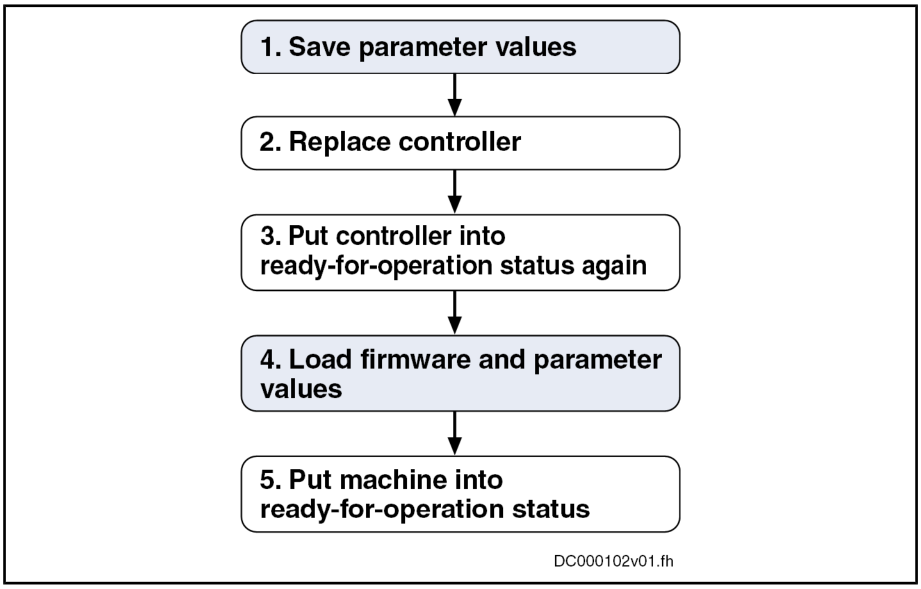


Fig. 10-7: General Sequence of Controller Replacement

10.8.2 Procedure During Controller Replacement

1. **Saving Parameter Values**

   Before dismounting defective device, save drive parameter values, if possible.

☞ If saving the parameter values before replacing the device should be impossible due to a total breakdown of the device, only the parameter values backed up after initial commissioning can be loaded when the parameter values are loaded later on (see "Load Parameter Values in Case of Total Breakdown of Device")!

---

   1. Switch drive off and on again

   2. Switch to parameter mode (PM or P2)

   3. Saving the parameter values of the defective device can take place via the commissioning tool "IndraWorks Ds/D/MLD" or the control master:

   - Commissioning tool "IndraWorks Ds/D/MLD":

     By selecting the respective menu item, the parameter values according to the list parameters S-0-0192 and P-0-0195 are stored on an external data carrier (hard disk, floppy disk or the like). (Depending on the controller, storing can take place via the engineering port or via the MultiEthernet interface.).

   - Control master:

     The parameter values according to the list parameters S-0-0192 and P-0-0195 are stored on a master-side data carrier by the control master.

2. **Replace Controller**

   1. Open main switch

   2. Make sure main switch cannot be switched on again

   3. Make sure drive controller is completely de-energized

WARNING

Lethal electric shock caused by live parts with more than 50 V!

Before working on live parts: De-energize the installation and secure the power switch against unintentional or unauthorized re-energization.

Wait at least **30 minutes** after switching off the supply voltages to allow dis-charging. To shorten the waiting time until voltage has fallen below 50 V, you can use a discharging device (see chapter "Appendix").

Check whether voltages have fallen below 50 V before touching live parts!

4. Remove touch guard and separate connecting lines from drive controller

5. Unscrew screws on top and bottom of housing

6. Take drive controller out of drive system

7. Mount new drive controller

8. Connect new drive controller as specified in machine circuit diagram

9. Mount touch guard

3. **Put Controller Into Ready-For-Operation Status Again**

   Put machine into ready-for-operation status again according to machine manufacturer's instructions.

4. **Load Firmware and Parameter Values**

   When firmware and drive parameters are to be transmitted to the replaced controller, the required firmware and a parameter backup of the respective axis must be available.

   1. Supply controller with control voltage

   2. Loading the parameter values can take place via the commissioning tool "IndraWorks Ds/D/MLD" or the control master:

   - Commissioning tool "IndraWorks Ds/D/MLD"

     By selecting the respective menu item, the parameter values stored on an external data carrier (hard disk, floppy disk or the like), immediately before the device was replaced, according to list parameters S-0-0192 and P-0-0195 are loaded to the controller.

   - Control master

     The axis-specific parameter values saved before having replaced the device can also be loaded via the control master. The parameter values saved immediately before the replacement of the device on a master-side data carrier (according to list parameters S-0-0192 and P-0-0195) are loaded to the controller by the control master.

5. **Put Machine Into Ready-For-Operation Status**

   1. Put machine into ready-for-operation status again according to machine manufacturer's instructions.

   2. Check functions of drive.

10.8.3 Possible Problems During Controller Replacement

The paragraphs below give a brief description of critical problems and their recommended handling.

Load Parameter Values in Case of Total Breakdown of Device

If it should have been impossible to save the parameter values according to the list parameters S-0-0192 and P-0-0195 immediately before replacing the device (total breakdown of device), the parameter values saved after initial commissioning have to be loaded.

☞ In the case of drives with absolute value encoder and modulo format, the position data reference has to be established again after having loaded the parameter values saved after initial commissioning, even if the actual position values are signaled to be valid via parameter "S-0-0403, Position feedback value status"!

WARNING

The parameter values saved after initial commissioning are not generally suited for reestablishing the operatability of the drive after replacement of devices!

⇒ Check actual position values and active target position before drive enable!

10.9 Enabling of Functional Packages

10.9.1 Brief Description

The scope of functionality of the IndraDrive firmware can be scaled by the user. This allows adjusting the scope of firmware functions to the respective requirements and, if necessary, reducing its complexity.

The drive functionality is scaled by licensing (enabling) optional expansion packages that are available in addition to the standard base package of the respective IndraDrive firmware.

See also "Overview of Functions/Functional Packages"

Features

- Activated functional packages displayed in parameter "P-0-2004, Active functional packages"
- Firmware type designation in parameter "S-0-0030, Manufacturer version" dynamically adjusted to the active functional packages displayed in P-0-2004
- Functional packages activated/deactivated via parameter
- Count of operating hours counter at last change of access enable is stored

Pertinent Parameters

- S-0-0030, Manufacturer version
- P-0-2002, Oper. hours of contr. sect. at change of functional packages
- P-0-2003, Selection of functional packages
- P-0-2004, Active functional packages

Pertinent Diagnostic Messages

- C0202 Parameter limit error (->S-0-0423)
- C0299 Configuration changed. Restart

10.10 Extended Diagnostic Possibilities

10.10.1 Monitoring Function

Brief Description

☞ The so-called "monitor function" implemented in the drive is **for internal use** only, or can be used as an extended possibility of diagnosis in the case of error.

The monitoring function provides the following options:

- Displaying memory ranges
- Changing storage locations
- Writing/reading EEPROM memory cells (controller and encoder)

- Adjusting analog measured values
- Displaying internal system states
- Executing several test routines for software and hardware

☞ Using the monitor function requires a VT100 terminal, an ANSI terminal or a corresponding emulation. It is recommended to have a 132-column display.

Pertinent Parameters

- P-0-4021, Baud rate RS-232/485
- P-0-4025, Drive address of master communication
- P-0-4095, RS-232/485 Parity

10.10.2 Logbook Function

Brief Description

A logbook function is realized in the drive firmware in order to obtain a detailed diagnostic error message in the case of error. The information provided by the logbook function allows reproducing the internal firmware sequence, if required.

Pertinent Parameters

- P-0-0478, Logbook event
- P-0-0479, Logbook time stamp

10.10.3 Patch Function

Brief Description

The patch function can be used for reading and writing any storage location (or internal variable) as a data object via the master communication, the analog output or the oscilloscope function.

In conjunction with the analog output or the oscilloscope function, this functionality can be used for locating errors.

The PLC patch function serves for diagnosis of internal signal states and internal data of the PLC by developers and instructed users.

☞ When using the patch display in the oscilloscope you have to take into account that first the patch address and then the oscilloscope signal is assigned. This must be repeated after every change in the patch address.

☞ As it is a **function for exclusive use by the development staff**, the patch display parameters P-0-0485 and P-0-0491 are write-protected with the master password.

The configuration parameters of the patch function are **not stored in the flash**, but are lost when the drive is switched off.

Pertinent Parameters

General patch functions:

- P-0-0480,
- P-0-0481,
- P-0-0482, P
- P-0-0483,
- P-0-0485,
- P-0-0486,

- P-0-0487,
- P-0-0488,
- P-0-0489,
- P-0-0491,

10.11 Oscilloscope Function

10.11.1 Brief Description

The oscilloscope function can be used to record drive-internal and external signals and status variables (parameter contents). This function can be effectively used both for initial commissioning and debugging. Its functionality can be compared to that of a 4-channel oscilloscope.

The total scope of the oscilloscope function is divided into the following function blocks:

- **Recording measured values**

  It is possible to record 4 channels at the same time, the signals being selected by configuration of signal selection lists (IDN lists).
- **Configuration (basic settings)**

  The control/status block determines the basic functions (start/stop, time resolution, size of memory, operating mode). The current status (status diagram) of the oscilloscope is continuously transmitted to the master.
- **Trigger function**

  Besides extensive trigger functions, the drive provides the possibility of triggering at different signals and events in the drive.

Features The oscilloscope function is characterized by the following features:

- **Recording measured values**
  - 4 channels, each with a maximum of 8192 measured values
  - Time resolution to be freely selected in steps of the position loop clock (see "Performance Data")
  - Signal selection by indicating the IDN of the respective parameter
- **Configuration (basic settings)**
  - 4-channel display in "IndraWorks Ds/D/MLD"
  - More than 100 different measuring and trigger signals (cf. P-0-0149)
  - Expanded oscilloscope function using patch function
- **Trigger function**
  - Trigger signal selection by indicating the parameter IDN
  - Internal trigger or external trigger
  - External trigger with trigger offset determination for synchronizing multiple-axis measurements
  - Unit of trigger level adjusting to trigger signal selection
  - Possibility of triggering at internal memory contents with patch signal

Pertinent Parameters Control/status:

- P-0-0028, Oscilloscope: Control word
- P-0-0029, Oscilloscope: Status word
- P-0-0031, Oscilloscope: Time resolution

- P-0-0032, Oscilloscope: Size of memory
- P-0-0149, Oscilloscope: Signal selection list
- P-0-0150, Oscilloscope: Number of valid measured values

Measuring channels:

- P-0-0021, Oscilloscope: List of measured values 1
- P-0-0022, Oscilloscope: List of measured values 2
- P-0-0023, Oscilloscope: Signal selection 1
- P-0-0024, Oscilloscope: Signal selection 2
- P-0-0145, Oscilloscope: List of measured values 3
- P-0-0146, Oscilloscope: List of measured values 4
- P-0-0147,
- P-0-0148,

Trigger function:

- P-0-0025, Oscilloscope: Trigger mask
- P-0-0026, Oscilloscope: Trigger signal selection
- P-0-0027, Oscilloscope: Trigger level
- P-0-0030, Oscilloscope: Trigger edge
- P-0-0033, Oscilloscope: Number of measured values after trigger event
- P-0-0035, Oscilloscope: Control offset
- P-0-0036, Oscilloscope: External trigger signal
- P-0-0037, Oscilloscope: Internal trigger signal

11 Engineering/Diagnostic Interfaces

11.1 TCP/IP Communication

11.1.1 Brief Description

In section "TCP/IP communication", all necessary information for a standard Ethernet communication are described. In this connection, communication via UDP/IP is possible in addition to the TCP/IP communication.

In order to avoid any mixing up with the master communication "EtherNet/IP™ interface", the designation "Ethernet communication" has been waived in this case.

It is possible to communicate with an IndraDrive controller via standard Ethernet telegrams. These Ethernet telegrams contain TCP/IP or UDP/IP telegrams for application-side connection. For communication with the device, the CSMA/CD access method is applied. As connection possibilities, interfaces may be considered via which TCP/IP communication is possible. This may be a free port of the master communication card (e.g. SERCOS III or EtherNet/IP™) or a separate engineering port (if available).

For SERCOS III, in addition to the time-controlled transmission of SERCOS-type Ethernet telegrams (MDT and AT), an NRT channel (NonRealTime or IP channel) exists, for which telegrams are sent in a specially reserved time slot.

Therefore, for SERCOS III, another option for asynchronous data transmission is available in addition to the existing service channel, that is well suitable for large amounts of data due to the maximum lengths of useful data of approx. 1500 bytes.

Possible Applications

With the utilization of the TCP/IP communication in the drive, different application options are available, which are summarized in the following table.

Connection	Server application	Possible client applications
SIS protocol	Parameterization via SIS-based parameter services, integrated in TCP	Addressed client-sidedly via SCP in IndraWorks
TFTP	Firmware update service	Execution of a firmware update

Fig. 11-1: Overview of the Possible Applications

Pertinent Parameters

- S-0-1019, Master comm. engineering over IP: MAC address
- S-0-1020, Master comm. engineering over IP: IP address
- S-0-1021, Master comm. engineering over IP: Network mask
- S-0-1022, Master comm. engineering over IP: Gateway address
- P-0-1044, Master comm. engineering over IP: Status IP communication
- P-0-1530, Engineering: MAC address
- P-0-1531, Engineering: IP address
- P-0-1532, Engineering: Network mask
- P-0-1533, Engineering: Gateway address
- P-0-1534, C6100 Command Activate IP settings

- P-0-1544, Engineering: Status IP communication

Pertinent Diagnostic Messages

- C6101 Incorrect IP settings
- F2190 Incorrect Ethernet configuration

11.2 Firmware Download via TFTP Server

11.2.1 Brief Description

Fields of Application

If a firmware download is to be completed, a TFTP server is available for this purpose. In this connection it is possible, to download new firmware to the device.

Overview of Functions

Firmware Identification

Via a special "ReadRequest", the firmware available in the device can be identified. For this purpose, the "firmware" string is transmitted in the "ReadRequest".

The response telegram contains a data package that contains the control section circuit board code as first four bytes and afterwards the manufacturer version (cf. S-0-0030.0.0).

Firmware Download

Via a WriteRequest, the download process is started. For this purpose, the drive must be in PM. In this connection, the "WriteRequest" additionally initializes the connection to the TFTP server.

Afterwards, the firmware is downloaded to the device via "DataRequests". In this connection, the device performs several checks:

- Can the new firmware file be used for the present device (compatibility check)?
- Has the correct number of data been transmitted (data integrity check)?
- Has the firmware file been transmitted in a correct and valid form (validity check)?

Diagnostic Error Message

Any error during this process is returned via the ErrorFrame in the TFTP. In this connection, the error text is available as plain text.

Features

The TFTP server of an IndraDrive device has the following features:

- A TFTP connection does not know an authentication
- In a TFTP connection, the following 5 package types are available:
  - "ReadRequest" (beginning of the reading of files from server/drive)
  - "WriteRequest" (beginning of the writing of files to the server/drive)
  - "Data" (transmission of data)
  - "Acknowledge" (acknowledgement of data packages)
  - "Error" (any type of error message)
- Any data package must be confirmed by means of "acknowledge" before the next data package is sent.

Pertinent Diagnostic Messages

Occurring errors are transmitted by means of "TFTP ErrorFrame" in plain text (see Troubleshooting Guide: "Firmware Download")

12 Commissioning

12.1 Commissioning Motors

12.1.1 Checking the Installation/Assembly

Checking the Assembly

Check the assembly of the IndraDrive controllers and supply units as well as motors with regard to correct implementation, according to the data contained in respective Project Planning Manual.

Checking the Installation

Check the wiring of control cabinet and machine with regard to correct implementation, according to the data contained in the Project Planning Manual and the recommendations in the documentation "Electromagnetic Compatibility (EMC) in Drive and Control Systems".

12.1.2 Initial Commissioning/Serial Commissioning

Brief Description

The drive can be commissioned after assembly and installation have been correctly implemented.

Initial Commissioning

The initial commissioning of a drive differs from the commissioning of other identical drives (serial commissioning).

The initial commissioning is carried out in the following steps:

- Establishing the operatability of the drive (including the required measuring systems)
- Adjusting the drive behavior to the requirements of the application
- Adjusting the master communication interface between master and drive
- Integrating drive functionalities in the machine processes

In each of the mentioned steps, values of relevant parameters are adjusted to the requirements. The result of the initial commissioning is a drive the behavior of which is exactly adjusted to the axis. By storing the values of the initial commissioning in the form of a parameter set the drive behavior can be reproduced.

Serial Commissioning

For the commissioning of other identical axis drives on machines of the same type, the set of parameter values determined during the initial commissioning is loaded to the respective controller (serial commissioning). This allows

- exactly reproducing the drive behavior

- and -

- reducing the effort for further commissioning to a little adjustment work and, if necessary, search and elimination of assembly/installation errors.

Possibilities of Commissioning

As a matter of principle, commissioning can be carried out by means of

- the "IndraWorks Ds/D/MLD" commissioning tool by Bosch Rexroth connected to the drive via SERCOS interface or via a serial interface, via Ethernet or a field bus,
- the control panel of the controller and digital and analog input signals,
- a control unit connected to the drive via a master communication interface.

Two-Step Commissioning

It is basically recommended to always carry out both the initial commissioning and the serial commissioning in two steps:

- 1st objective: Initial start of the motor
- 2nd objective: Providing drive functions for the machine axis

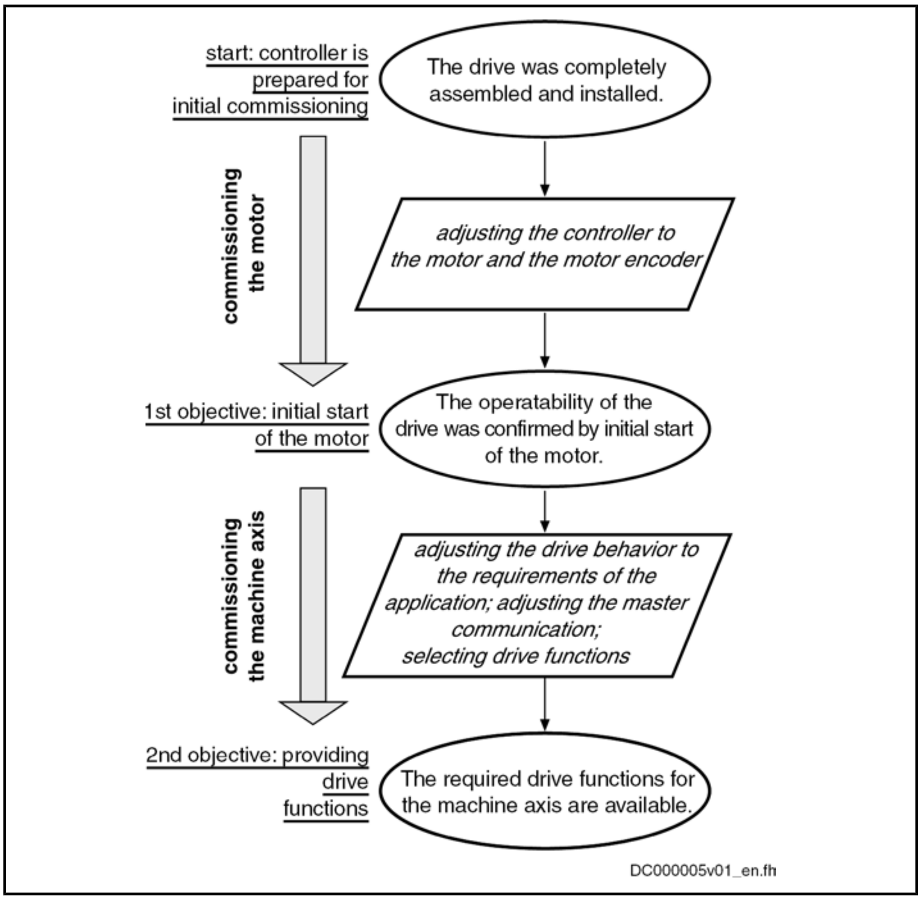


Fig.12-1: Two-Step Drive Commissioning (Schematic)

In the first step, the two-step procedure ensures the operatability of the drive (1st objective during initial commissioning and serial commissioning). In the second step, the drive functions required for the machine axis and the drive's advantageous properties are individually adjusted to the machine axis in a reasonable order (2nd objective during initial commissioning) or the expected functional principle is checked (2nd objective during serial commissioning).

☞ As a matter of principle, it is advantageous to establish the operatability of a drive independent of a higher-level control system. The drive should therefore first be commissioned as a self-contained unit via "IndraWorks Ds/D/MLD" or in the "easy startup" mode!

See following sections:

- "Initial Start in "Easy Startup" Mode"

- "Initial Start With the Commissioning Tool"

12.1.3 Initial Start in "Easy Startup" Mode

Brief Description

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

☞ The easy startup mode is therefore particularly suited for **initial commissioning** of individual axes, as well as for maintaining an **emergency mode** when the control unit has failed.

Features

- **Activation** of the "easy startup" mode is possible in two ways:
  - By activating the command parameter "P-0-4085, C4700 Command Activate easy startup mode" via serial interface or digital input
  - Via control panel of controller (pressing the corresponding keys in a certain order triggers activation of P-0-4085)
- Automatic **deactivation** of master communication interface (see P-0-4077, S-0-0134) and activation of "P-0-0120, Control word easy startup"
- Activation of **drive enable** (P-0-0120, bit 15) via:
  - The digital input assigned to drive enable (different according to hardware design, see default assignment under "Automatic Configuration of the Inputs")
  - Serial interface when configuration of digital inputs for "easy startup" mode made before was removed
- Drive moves in "velocity control" mode with a parameterizable velocity command value (cf. P-0-1206) without external command value box
- Selection of the **travel direction** (positive/negative) via digital input signals (see parameter "P-0-1200, Control word 1 velocity control")

Commissioning

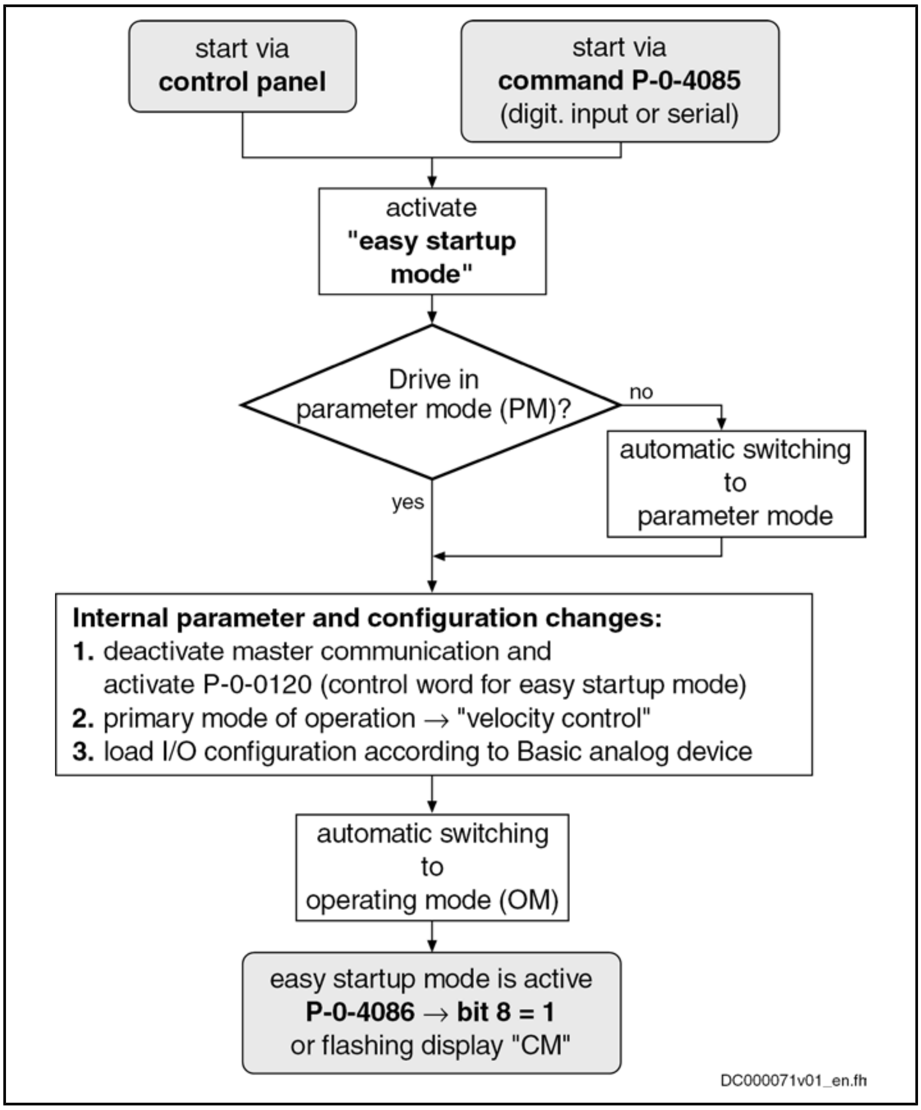


Fig.12-2: Activating the Easy Startup Mode, Overview

Hardware Requirements

Control sections BASIC SERCOS, BASIC PROFIBUS, BASIC UNIVERSAL and ADVANCED

For using the easy startup mode, the digital inputs and outputs (X31, X32) must be connected as follows:

- Connect 24V/0V power supply to respective terminal connectors
- X31/4: +24 V for activating drive enable
- X32/7 and X32/8: 0V/+24V for activating positive or negative rotational direction

  or → X31/3 and X31/7 for control of motor potentiometer

Control sections BASIC UNIVERSAL double-axis

For using the "easy startup" mode, the digital inputs and outputs (X33, X34) must be connected as follows:

- Axis 1:
  - Connect 24V/0V power supply to respective terminal connectors
  - X33/1: +24 V for activating drive enable

- X33/2 and X33/3: 0V/+24V for activating positive or negative rotational direction

  or → X33/4 and X33/5 for control of motor potentiometer

- Axis 2:
  - Connect 24V/0V power supply to respective terminal connectors
  - X34/1: +24 V for activating drive enable
  - X34/2 and X34/3: 0V/+24V for activating positive or negative rotational direction

    or → X34/4 and X34/5 for control of motor potentiometer

Control sections BASIC OPENLOOP and BASIC ANALOG

For drives with these control sections, the "easy startup" mode actually is not required, because these drives can easily be moved with an analog command value (see "Analog interface").

IndraDrive Mi

For using the "easy startup" mode, the digital inputs and outputs (X37, X38) must be connected as follows:

- Connect 24V/0V power supply to respective terminal connectors
- X37/2: +24 V for activating drive enable
- X37/4 and X38/4: 0V/+24V for activating positive or negative rotational direction

Pertinent Parameters

- S-0-0032, Primary operation mode
- S-0-0091, Bipolar velocity limit value
- P-0-0120, Control word easy startup
- P-0-0300, Digital I/Os, assignment list
- P-0-0301, Digital I/Os, bit numbers
- P-0-1200, Control word 1 velocity control
- P-0-1206, Memory of velocity command values
- P-0-4085, C4700 Command Activate easy startup mode
- P-0-4086, Master communication status

Pertinent Diagnostic Messages

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

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

12.1.4 Initial Start With Commissioning Tool

Brief Description

Establishing the Operatability of the Drive

After complete and correct assembly and wiring of the drive or the drives it is advisable to establish the operatability. With drives of the IndraDrive family, the most simple way to do so is by means of initial start in the "easy startup" mode (velocity-controlled operation, master communication master is not required) in connection with the Rexroth commissioning tool "IndraWorks Ds/D/MLD". With older drive families and connection via the SERCOS interfaces, this is possible with the Rexroth commissioning tool "DriveTop" and the Rexroth SERCOS master SYSDA02.2.

According to the available equipment, the initial commissioning of the motor is supported as follows:

- If there is **no** commissioning tool (e.g. PC) available, Rexroth motors with encoder data memory can be easily commissioned in the "easy startup" mode. The motor parameters and motor control parameters of these motors are automatically loaded from the data memory to the controller by switching control voltage on.
- IndraDrive: If a PC with Rexroth commissioning tool is available, the motor parameters and motor control parameters of motors without encoder data memory can be loaded from the internal database of the commissioning tool to the controller via the serial interface. This allows initial commissioning in the "easy startup" mode for these motors, too.
- EcoDrive / Diax: If a PC with the commissioning tool "DriveTop" (version 16VRS) and SYSDA02.2 are available, drives with SERCOS interface can be conveniently commissioned and moved via command values of SYSDA02.2.

Available Commissioning Tools

For drives, Bosch Rexroth offers the following commissioning tools (software):

- EcoDrive / Diax: DriveTop (version 16VRS)
- IndraDrive: IndraWorks Ds/D/MLD

DriveTop

"DriveTop" is a tool for parameterizing and commissioning drives. It supports the Rexroth SERCOS master SYSDA02.2 by means of which it is possible to move drives with SERCOS interface. The communication with the drive or with SYSDA02.2 is established via the serial interface RS232/RS485.

IndraWorks Ds/D/MLD

"IndraWorks Ds/D/MLD" is a component of the software range "IndraWorks" which supports parameterization and commissioning of control units and drives by Bosch Rexroth. "IndraWorks Ds/D/MLD" has been designed for interaction with the SERCOS master SYSDA02.2. The communication with the drive is established via the serial interface RS232/RS485.

The commissioning tools "DriveTop" and "IndraWorks Ds/D/MLD" provide the following possibilities and advantages:

- The functions and features made available by the drive are structurally visualized, the respective parameter values are displayed in their functional context.
- Parameter values can be directly changed and thereby adjusted to the respective requirements.
- The parameter values available in the drive can be saved drive-externally as a group (parameter set), e.g. on the PC hard disk, and can be reloaded from the hard disk.
- Diagnostic messages and operating status messages are displayed in clearly arranged form.
- For the purpose of commissioning, commands can be started.
- Via the so-called "easy startup" mode, IndraDrive devices or in connection with SYSDA02.2, all devices can be commissioned and moved.

12.2 Commissioning Machine Axes

12.2.1 Overview and Practical Tips

Brief Description

Before commissioning machine axis-specific functions it is useful to make sure that the drive, consisting of controller, motor and motor encoder, is operational. The best way to do this is the initial start of the drive with the PC-based commissioning tool "IndraWorks Ds/D/MLD" by Bosch Rexroth (see "Initial Start With the Commissioning Tool").

The commissioning of machine axis-specific functions should also be carried out via "IndraWorks Ds/D/MLD", if possible. The advantage is that the correct sequence of an axis-specific function can be configured and ensured independent of the control unit. Further commissioning of the drive, with widely complete configuration, is then easier for the control unit.

Schematic Sequence

Commissioning procedure as a sequence of steps:

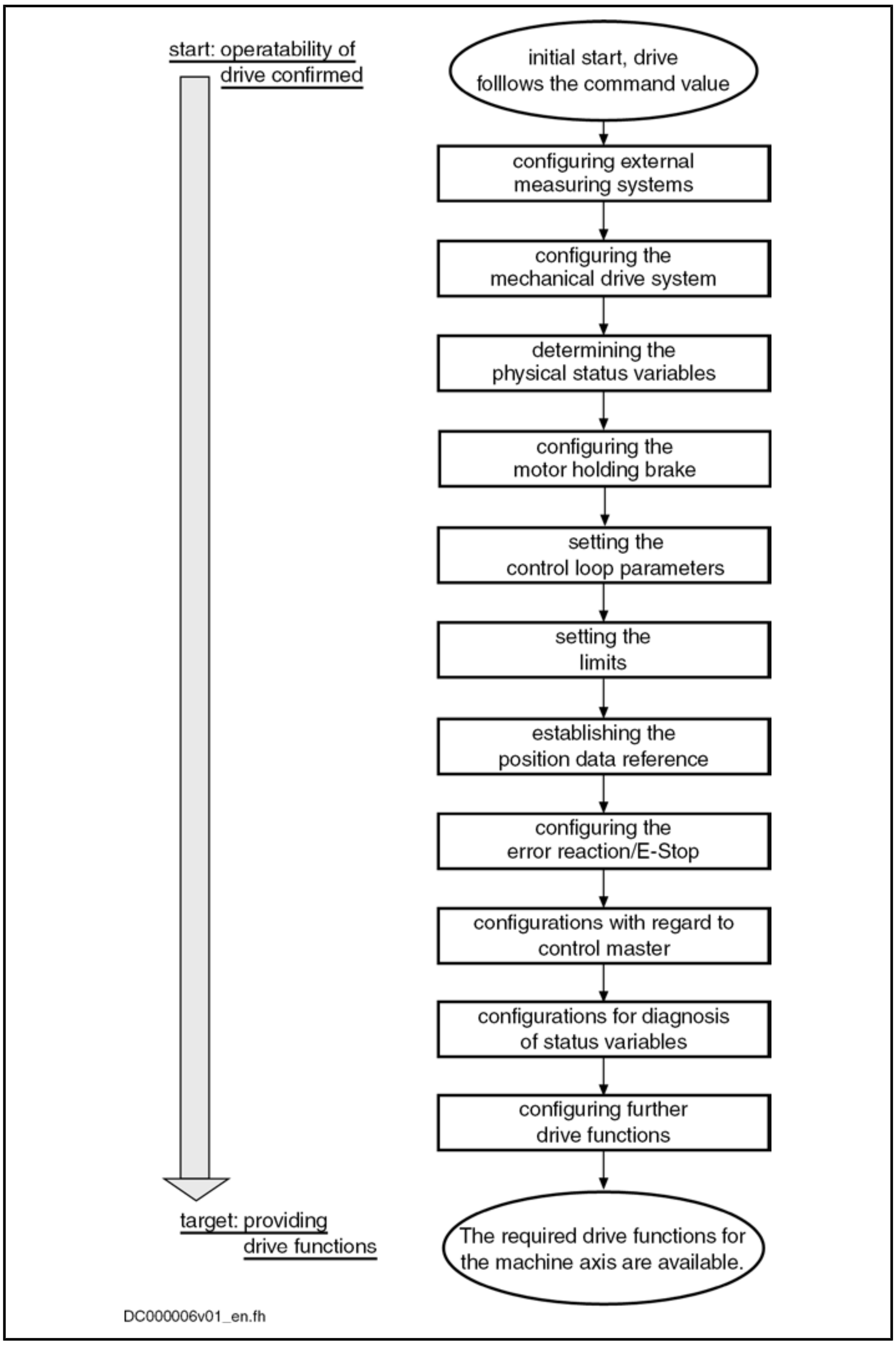


Fig. 12-3: Steps of Machine Axis-Related Commissioning

Notes on the Commissioning Steps

The subjects of the individual commissioning steps are treated in detail in different chapters of this firmware documentation. The information contained in the chapter is basically divided into:

- Brief Description
- Functional Description
- Notes on Commissioning

To explain the individual commissioning steps we refer to the Notes on Commissioning for the respective subject, if possible.

Detailed information about parameters is only contained in the separate documentation "Rexroth IndraDrive, Parameter Description" (reference list of all IndraDrive parameters).

Configuring the Measuring Systems

General Information

Configure controller and encoder (set travel range, if necessary)

See "notes on commissioning" under "Basics on Measuring Systems, Resolution"

Relative Encoders

Set initial position value; configure distance-coded measuring systems

See "notes on commissioning" under "Relative Measuring Systems"

Absolute Encoders

Check whether absolute encoder evaluation is possible (depending on travel range), set initial position value

See "notes on commissioning" under "Absolute Measuring Systems"

Position Monitoring

Set position monitors:

- Axis position monitor (position at time drive is switched on) for absolute encoders
- Position difference monitor of motor encoder and external encoder
- Configure spindle encoder monitor

See "notes on commissioning" under "Monitoring the Measuring Systems"

Configuring the Mechanical Axis System

Depending on the mechanical properties, make the following settings:

- Enter load gear ratio
- Enter feed constant
- Enter motor encoder gear ratio
- Enter gear ratio for external encoder

See "notes on commissioning" under "Mechanical Axis System and Arrangement of Measuring Systems"

Determining the Physical Status Variables

Make scaling settings for position, velocity, acceleration, torque/force and temperature data.

See "notes on commissioning" under "Scaling of Physical Data"

Configuring the Holding Brake

If the motor to be controlled is equipped with a holding brake or the controller has to control an external holding brake (for kit motors, if necessary), make the following settings:

- Enter maximum "drive off" delay time
- Enter holding brake data (external brake), if necessary
- Configure type, functioning principle and monitor of brake in holding brake control word

See "notes on commissioning" under "Motor holding brake"

Setting the Control Loop Parameters

Set controller and filter parameters for the control loops:

- Velocity control loop
- Position control loop

See "notes on commissioning for setting the control loop" under "General Information on Closed-Loop Axis Control"

Setting the Limitations

The controller offers the possibility of limiting physical status variables of the drive. Depending on the application, limit values can be set for:

- Torque/force command value
- Velocity command value
- Position command values and actual position values

Limiting the Torque/Force Command Value

On the user side, limitations are available for:

- Maximum allowed torque/force (S-0-0092, P-0-0109)
- Motive and regenerative load at stationary velocity (S-0-0082, S-0-0083)

The limit values currently effective due to the user-side limit settings are displayed in:

- P-0-0444, Actual value peak torque limit
- P-0-0442, Actual value torque limit positive (stationary)
- P-0-0443, Actual value torque limit negative (stationary)

Current command values are displayed in:

- P-0-0049, Effective torque/force command value
- P-0-0038, Torque-generating current, command value

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

Apart from the user-side limits, further limits take effect in the torque/force or current control loop:

- Absolute current limit values due to controller and motor
- Load-dependent (dynamic), thermal current limit values

See also "Current and Torque/Force Limitation"

Limiting the Actual Velocity Value

On the user-side, in "torque/force control" mode, it is possible to limit the actual velocity value to the lower value of

- 1.125 × Bipolar velocity limit value (S-0-0091)

  \- and -
- Maximum motor speed (S-0-0113)

.

See also "Torque/Force Control"

Limiting the Velocity Command Value

On the user-side, in the "velocity/force control" mode, it is possible to limit the velocity command value via

- Bipolar velocity limit value (S-0-0091)

and in the "position control" mode the limitation of the

- position command value difference (to values of S-0-0091 and S-0-0113)

.

See also "Velocity control" and "Position Control With Cyclic Command Value Input"

Limiting the Position

There are the following possibilities on the user side for limiting the position:

- Limitation of actual position value (firmware "limit switch")
- Limitation of travel range of the axis (hardware limit switch)

See also "Limitations: Position Limitation/Travel Range Limit Switch"

Establishing the Position Data Reference

Measuring Systems to be Evaluated in Absolute Form

For measuring systems that can be evaluated in absolute form, the position data reference has to be established once during initial commissioning.

See "notes on commissioning" under "Establishing Position Data Reference for Absolute Measuring Systems"

Relative Measuring Systems

For relative measuring systems all settings have to be made in such a way that the position data reference can be established internally and automatically (after switching on the machine at a command of the control master to the respective axis drive).

See "notes on commissioning" under "Establishing Position Data Reference for Relative Measuring Systems"

Configuring the Error Reaction/E-Stop

The desired reaction of the drive to errors detected on the drive side has to be set.

See "Error Reactions"

The setting has to be made whether a drive is to carry out an E-Stop reaction at a hardware-side E-Stop signal and how the E-Stop reaction of the drive is to take place.

See "E-Stop Function"

Configurations with Regard to Control Unit (Master)

With regard to master-controlled drive operation the following settings are required:

- Presetting of operating modes (primary mode of operation and secondary operating modes)

  See "General Information on the Operating Modes: Operating Mode Handling"
- Settings for the determined primary or secondary operating modes

  See description of the respective operating mode in chapter "Operation Modes"

With regard to the master communication interface used by the control master, you can make presettings for:

- SERCOS interface

  → When using the "IndraWorks Ds/D/MLD" commissioning tool, this is only appropriate via serial communication!

- PROFIBUS-DP
- Parallel interface
- Analog interface

See description of the respective master communication interface

Configurations for Diagnosis of Status Variables

If status variables of the drive are to be evaluated during operation, these status variables can be transmitted to the control master in different ways.

Diagnostic possibilities with SERCOS interface:

- Content of a parameter cyclically updated that can be cyclically transmitted and that contains the value of the respective status variable

  SERCOS interface
- Message in terms of whether a threshold value of the status variable was exceeded, via "S-0-0144, Signal status word"

  See "Control Options / Additional Functions: Configurable Signal Status Word"
- Drive-internal oscilloscope function

  See "Oscilloscope Function"

Diagnostic possibilities independent of the master communication interface:

- Analog output of the value of the respective status variable as voltage signal

  See "Analog Outputs"
- Digital message in terms of whether a threshold value of the status variable was exceeded, by assigning bits from "S-0-0144, Signal status word" to digital outputs

  See "Digital Inputs/Outputs"

Configuring Further Drive Functions

Further configurable drive functions are:

- Drive Halt
- Friction torque compensation
- Detecting the marker position
- Spindle positioning
- Probe function
- Digital inputs/outputs
- Analog inputs
- Analog outputs

See description of the respective function

13 Service and Support

Our service helpdesk at out headquarters in Lohr, Germany, will assist you with all kinds of enquiries. Out of helpdesk hours please contact our German service department directly.

	Helpdesk	Service Hotline Germany	Service Hotline Worldwide
Time 1)	Mo-Fr 7:00 am - 6:00 pm CET	Mo-Fr 6:00 pm - 7:00 am CET Sa-Su 0:00 am - 12:00 pm CET	Outwith Germany please contact our sales/service office in your area first. For hotline numbers refer to the sales office addresses on the Internet.
Phone	**+49 (0) 9352 40 50 60**	**+49 (0) 171 333 88 26** or **+49 (0) 172 660 04 06**	
Fax	**+49 (0) 9352 40 49 41**	–	
e-mail	service.svc@boschrexroth.de	–	
Internet	http://www.boschrexroth.com You will also find additional notes regarding service, maintenance (e.g. delivery addresses) and training.		

1) Central European Time (CET)

Preparing Information

For quick and efficient help please have the following information ready:

- detailed description of the fault and the circumstances
- information on the type plate of the affected products, especially type codes and serial numbers
- your phone, fax numbers and e-mail address so we can contact you in case of questions.

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Notes

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