

Rexroth HydraulicDrive 13VRS

Central Controller

Functional Description

R911336586
Edition 02

Application Description



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Central Controller
Functional Description

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Purpose of Documentation This documentation describes all functional properties of the HydrDrive in the HDS/central controller variant.

Record of Revision

Edition	Release Date	Notes
Edition 01	03.2012	First edition
Edition 02	03.2013	Controller underclocking changes as well as incremental encoder changes have been implemented.

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1 About this Documentation

1.1 Validity of the Documentation

Target group This documentation is intended for users wanting to use the central hydraulic controller together with IndraLogic XLC/IndraMotion MLC.

In the following illustration, the framed activities, product phases and target groups refer to the present documentation.

Example: In the product phase "Engineering", the target group "programmer" can execute the activities "parameterizing" and "programming" using this documentation.

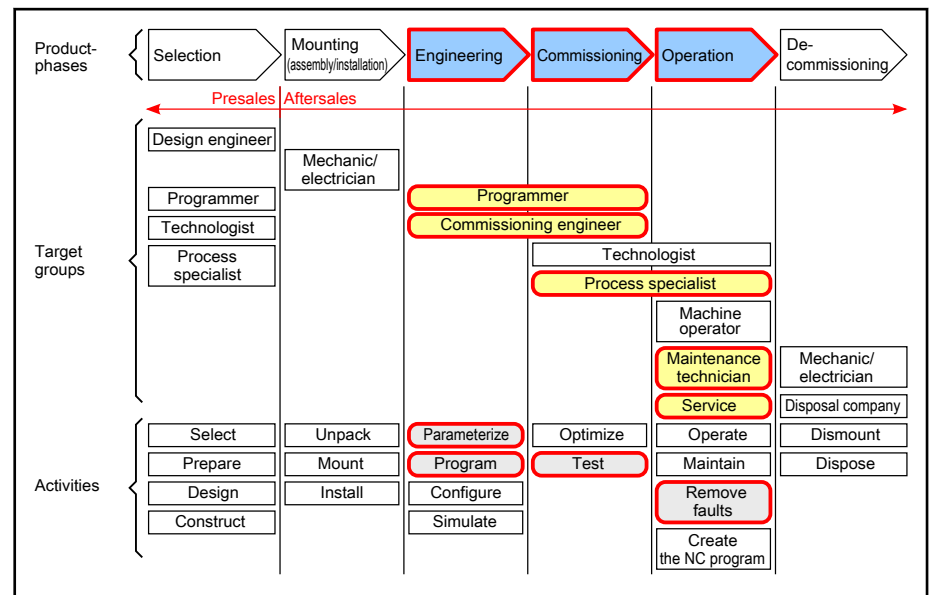


Fig. 1-1: Assigning this documentation to the target groups, product phases and target group activities

1.2 Required and Supplementing Documentations

Documentation titles with type codes and parts numbers

IndraWorks		MLC	XLC
/36/	Rexroth IndraWorks 13VRS Software Installation DOK-IWORKS-SOFTINS*V13-CORS-EN-P, R911336880 This documentation describes the IndraWorks installation.	X	X
/5/	Rexroth IndraWorks 13VRS Engineering DOK-IWORKS-ENGINEE*V13-APRS-EN-P, R911336870 This documentation describes the application of IndraWorks in which the Rexroth Engineering tools are integrated. It includes instructions on how to work with IndraWorks and how to operate the oscilloscope function.	X	X
/20/	Rexroth IndraMotion MLC 13VRS Functional Description DOK-MLC***-FUNC****V13-APRS-EN-P, R911336295 This documentation describes wizards, context menus, dialogs, control commissioning, device configuration and functionalities of the IndraMotion MLC.	X	

About this Documentation

IndraWorks		MLC	XLC
/20/	Rexroth IndraLogic XLC 13VRS Functional Description DOK-XLC***-FUNC***V13-APRS-EN-P, R911336352 This documentation describes wizards, context menus, dialogs, control commissioning, device configuration and functionalities of the IndraLogic XLC.		X
/7/	Rexroth IndraWorks 13VRS CamBuilder DOK-IWORKS-CAMBUIL*V13-APRS-EN-P, R911336291 This documentation describes the basic principles and operation of the CamBuilder, the cam editing tool.	X	X
/37/	Rexroth IndraLogic XLC IndraMotion MLC 13VRS Automation Interface DOK-XLCMLC-AUT*INT*V13-APRS-EN-P, R911336356 This documentation describes the script-based access to IndraWorks project data via the interface of the Automation Interface.	X	X
/38/	Rexroth IndraWorks 12VRS FDT Container DOK-IWORKS-FDT*CON*V12-APRS-EN-P, R911334398 This documentation describes the IndraWorks FDT Container functionality. It includes the activation of the functionality in the project and working with DTMs.	X	X
/29/	Rexroth IndraLogic XLC IndraMotion MLC 13VRS Project Conversion DOK-XLCMLC-PROCONV*V13-APRS-EN-P, R911336366 This documentation describes the project conversion of IndraLogic 04VRS and IndraMotion MLC04VRS on IndraWorks version 12 with IndraLogic 2G. Changes with regard to Motion and PLC are described in detail.	X	X
/28/	Rexroth IndraMotion MLC 13VRS Commissioning DOK-MLC***-STARTUP*V13-CORS-EN-P, R911336308 This documentation describes the steps to commission and service the IndraMotion MLC system. It includes checklists for frequent tasks and a detailed description of the steps.	X	

Fig. 1-2: XCL/MLC documentation overview

Motion		MLC	XLC
/23/	Rexroth IndraLogic XLC IndraMotion MLC 13VRS PLCopen Libraries DOK-XLCMLC-FUNLIB**V13-LIRS-EN-P, R911336360 This documentation describes the function blocks, functions and data types of the RIL_Common-Types, ML_Base and ML_PLCOpen libraries for the IndraLogic XLC/IndraMotion MLC. It also includes the error reactions of function blocks.	X	X
/27/	Rexroth IndraLogic XLC IndraMotion MLC 13VRS Generic Application Template DOK-XLCMLC-TF*GAT**V13-APRS-EN-P, R911336370 This documentation provides a structured template to the IndraLogic PLC programmer. This template can be used to add and edit the PLC programming code. It includes the template, the template wizard and example applications.	X	X
/31/	Rexroth IndraMotion MLC 13VRS RCL Programming Instruction DOK-MLC***-RCL*PRO*V13-APRS-EN-P, R911336297 This documentation provides information on the RobotControl. The programming language RCL (RobotControl Language) is focused. The program structure, variables, functions, motion statements and the required system parameters are described.	X	

About this Documentation

Motion		MLC	XLC
/21/	Rexroth IndraLogic XLC IndraMotion MLC 13VRS Parameters DOK-XLCMLC-PARAM***V13-RERS-EN-P, R911336364 This documentation describes the parameters of the XLC/MLC systems as well as the interaction between parameterization and programming. It includes the axis parameters, control parameters, kinematic parameters, touch probe parameters and programmable limit switch parameters.	X	X
/10/	Rexroth IndraDrive Firmware for Drive Controllers MPH-, MPB-, MPD-, MPC-07 DOK-INDRV*-MP*-07VRS**-FKRS-EN-P, R911328670 This documentation describes all functional properties of the IndraDrive firmware in the variants MPH-07, MPB-07, MPD-07 and MPC-07.		
/11/	Rexroth IndraDrive MPx-17 Functions DOK-INDRV*-MP*-17VRS**-APRS-EN-P, R911331236 This documentation describes all functional properties of the IndraDrive firmware in the variants MPB-17, MPM-17, MPC-17 and MPE-17.		

Fig. 1-3: XCL/MLC documentation overview

Field Buses		MLC	XLC
/4/	Rexroth IndraWorks 13VRS Field Buses DOK-IWORKS-FB*****V13-APRS-EN-P, R911336872 This documentation describes the supported field buses and their diagnostic function blocks.	X	X
/4a/	Rexroth IndraWorks 13VRS Field Buses Libraries DOK-IWORKS-FB*LIB**V13-LIRS-EN-P, R911337857 This manual describes the field bus libraries: RIL_ProfibusDP_02, RIL_ProfibusDP Slave, RIL_ProfinetIO, RIL_ProfinetIODevice, RIL_EtherNetIPAdapter, RIL_MappingList, RIL_SERCOSIII, RIL_Inline including their diagnostics and error reactions of the function blocks.	X	X
/63/	SERCOS System Manual for I/O Devices DOK-CONTRL-ILS3*****-APRS-EN-P, R911333512 This documentation describes the configuration, parameterization, commissioning and diagnostics of I/O devices with a SERCOS interface.	X	X

Fig. 1-4: XCL/MLC documentation overview

HMI		MLC	XLC
/8/	Rexroth IndraWorks 13VRS HMI DOK-IWORKS-HMI*****V13-APRS-EN-P, R911336874 This documentation describes the functions, configuration and operation of the user interfaces IndraWorks HMI Engineering and IndraWorks HMI Operation.	X	X
/6/	Rexroth IndraWorks 13VRS WinStudio DOK-IWORKS-WINSTUD*V13-APRS-EN-P, R911336882 This documentation describes the installation of the software, working with WinStudio and the creation and operation of applications.	X	X
/50/	Rexroth IndraLogic XLC IndraMotion MLC 13VRS HMI Connection DOK-XLCMLC-HMI*****V13-APRS-EN-P, R911336362 This documentation describes the visualization systems supported by the IndraLogic XLC and IndraMotion MLC and their connection.	X	X

Fig. 1-5: XCL/MLC documentation overview

About this Documentation

PLC		MLC	XLC
/3/	Rexroth IndraWorks 13VRS IndraLogic 2G Programming Instruction DOK-IWORKS-IL2GPRO*V13-APRS-EN-P, R911336876 This documentation describes the PLC programming tool IndraLogic 2G and its use. It includes the basic use, first steps, visualization, menu items and editors.	X	X
/33/	Rexroth IndraWorks 13VRS Basic Libraries IndraLogic 2G DOK-IL*2G*-BASLIB**V13-LIRS-EN-P, R911336285 This documentation describes the system-comprehensive PLC libraries.	X	X

Fig. 1-6: XCL/MLC documentation overview

Technology		MLC	XLC
/30/	Rexroth IndraMotion MLC 13VRS Technology Libraries DOK-MLC***-TF*LIB**V13-LIRS-EN-P, R911336324 This documentation describes the function blocks, functions and data types of the "ML_TechInterface.library", "ML_TechMotion.library", "RMB_TechCam.library" and "ML_TechBase.library". It also includes libraries for the winder functionality, register controller functionality and CrossCutter functionality.	X	
/60/	Rexroth IndraMotion MLC 13VRS RegisterControl (Library) DOK-MLC***-REGI*CO*V13-LIRS-EN-P, R911336306 This documentation describes the inputs and outputs of the individual function blocks and provides notes on their use.	X	
/62/	Rexroth IndraMotion MLC 13VRS RegisterControl (Application Manual) DOK-MLC***-REGI*CO*V13-APRS-EN-P, R911336304 This documentation describes the application of the integrated register control for a rotogravure printing machine. The components of the mark stream sensor, the HMI application and the error recovery options are described. This instruction provides information on how to operate the register control, react to errors and query diagnostics. This documentation is written for machine setters and machine operators.	X	
/49/	Rexroth IndraMotion MLC 13VRS Winder Function Application DOK-MLC***-TF*WIND*V13-APRS-EN-P, R911336326 This application-related system documentation describes the application of the winder technology functions.	X	

Fig. 1-7: XCL/MLC documentation overview

Hardware		MLC	XLC
/1/	Rexroth IndraControl L45/L65/L85 Control DOK-CONTRL-ICL45L65L85-PRRS-EN-P, R911332116 This documentation describes the IndraControl L45/L65/L85 controls.	X	X
/2/	Rexroth IndraControl L25 DOK-CONTRL-IC*L25*****-PRRS-EN-P, R911328474 This documentation describes the IndraControl L25 controls.	X	X
/24/	Rexroth IndraControl Lxx 13VRS Function Modules DOK-CONTRL-FM*LXX**V13-APRS-EN-P, R911336283 This documentation describes all function modules of the Lxx controls including engineering and diagnostics.	X	X

About this Documentation

Hardware		MLC	XLC
/12/	Rexroth IndraDrive Drive Controllers MPx-02 to MPx-07 DOK-INDRV*-GEN-**VRS**-PARS-EN-P, R911297317 This documentation describes all parameters implemented in the firmware for drive controllers of the IndraDrive family. It supports the parameterization of the drive controllers.		
/13/	Rexroth IndraDrive MPx-02 to MPx-07 and HMV DOK-INDRV*-GEN-**VRS**-WARS-EN-P, R911297319 This documentation describes all diagnostics implemented in the following firmwares: • Drive controller firmwares from MPx-02 to MPx-08 and • firmwares of the supply devices of the type "HMV". It supports the operating crew as well as the programmer at troubleshooting.		
/35/	Rexroth IndraDrive Drive Controller Control Sections CSB01, CSH01, CDB01 DOK-INDRV*-CSH*****-PRRS-EN-P, R911295012 This documentation is a project planning manual to select and use the control sections CSB01, CDB01 and CSH01 for drive controllers of the product families Rexroth IndraDrive M and Rexroth IndraDrive C.		

Fig. 1-8: XCL/MLC documentation overview

Diagnostics and service		MLC	XLC
/26/	Rexroth IndraWorks 13VRS IndraMotion Service Tool DOK-IWORKS-IMST****V13-RERS-EN-P, R911337707 This documentation describes the IndraMotion Service Tool (IMST). It is a web-based diagnostic tool to access the control systems IndraMotion MLC L25, L45 or 65 as well as the MLP via an Ethernet high-speed connection. The IMST allows OEMs, end users and service engineers to access and remotely diagnose a system. A PC with Internet Explorer version 6 or 7 is required.	X	X
/22/	Rexroth IndraLogic XLC IndraMotion MLC 13VRS Diagnostics DOK-XLCMLC-DIAG****V13-RERS-EN-P, R911336358 This documentation includes all control parameters implemented in the control systems IndraLogic XLC and IndraMotion MLC.	X	X

Fig. 1-9: XCL/MLC documentation overview

System Overview		MLC	XLC
/48/	Rexroth IndraMotion for Printing 13VRS System Overview DOK-IM*PR*-SYSTEM**V13-PRRS-EN-P, R911336289 This documentation describes the product IndraMotion for Printing. It introduces the control systems, drive systems and I/O systems as well as the commissioning and programming.	X	
/48/	Rexroth IndraMotion for Packaging 13VRS System Overview DOK-IM*PA*-SYSTEM**V13-PRRS-EN-P, R911336287 This documentation describes the product IndraMotion for Packaging. It introduces the control systems, drive systems and I/O systems as well as the commissioning and programming.	X	

About this Documentation

System Overview		MLC	XLC
/9/	Rexroth IndraMotion MLC 13VRS System Overview DOK-MLC***-SYSTEM**V13-PRRS-EN-P, R911336310 This documentation provides an overview on the hardware/software components of the automation system IndraMotion MLC in the mentioned version. It helps assembling a system.	X	
/9/	Rexroth IndraLogic XLC 13VRS System Overview DOK-XLC***-SYSTEM**V13-PRRS-EN-P, R911336354 This documentation provides an overview on hardware/software components of the automation system IndraLogic XLC in the respective version. It helps assembling a system.		X

Fig.1-10: XCL/MLC documentation overview

First Steps		MLC	XLC
/25/	Rexroth IndraMotion MLC 13VRS, First Steps DOK-MLC***-F*STEP**V13-CORS-EN-P, R911336293 This documentation describes the first steps of the IndraMotion MLC and the RobotControl. It includes the hardware and software prerequisites as well as the creation of a project.	X	
/25/	Rexroth IndraLogic XLC 13VRS, First Steps DOK-XLC***-F*STEP**V13-CORS-EN-P, R911336350 This documentation describes the first steps of the IndraLogic XLC. It includes the hardware and software prerequisites as well as the creation of a project.		X

Fig.1-11: XCL/MLC documentation overview

1.3 Information Representation

1.3.1 Safety Instructions

If there are safety instructions, they contain certain signal words (Danger, Warning, Caution, Notice) and if applicable, signal alert symbols (acc. to ANSI Z535.6-2006).

The signal word draws attention to the safety instruction and indicates the risk potential.

The signal alert symbol (warning triangle with exclamation mark) positioned in front of the signal words Danger, Warning and Caution indicates hazards for individuals.

 DANGER In case of non-compliance with this safety instruction, death or serious injury will occur.
 WARNING In case of non-compliance with this safety instruction, death or serious injury can occur.
 CAUTION In case of non-compliance with this safety instruction, minor or moderate injury can occur.

NOTICE

In case of non-compliance with this safety instruction, material or property damage can occur.

1.3.2 Symbols Used

Note Notes are represented as follows:



This is a note for the user.

Tip Tips are represented as follows:



This is a tip for the user.

1.3.3 Names and Abbreviations

Term	Explanation
IL	Instruction list
FB	Function block
FBD	Function block diagram
IWO	IndraWorks Operation
CA	Criteria analysis
LD	Ladder diagram
POU	Program organization unit
SFC	Sequential function charts
ST	Structured text
LCR	Link result

Fig. 1-12: Names and abbreviations used

2 System Overview

2.1 General Information

2.1.1 Overview

The MLC (Motion Logic Control) combines a Motion Controller and a PLC in one device.

Classic PLC tasks as well as movements of the Motion are programmed in the PLC application.

In contrast to classic drives, central hydraulic axes are controlled in the PLC. Apart from being cost-effective, all controller parameters and variables can be accessed without restrictions. The central hydraulic controller is provided in the MLC by means of the **MH_HydrControl** library and is marked with **HDS** as drive or drive firmware in this document.

The drive firmware HDS is handled and commanded as a real drive in the MLC. All PLCOpen commands as well as the extensions developed by Bosch Rexroth can be used on a hydraulic axis. Please note that not all technology blocks of electric drives can be used on central hydraulic controllers as not all parameters are supported.

A wizard is available to create the HDS drive. The wizard supports the user during the assignment of the required signals, generates the required PLC code and references all required libraries. The parameterization is executed via dialogs and parameters as is the case for a real axis. For example, parameter S-0-0030 contains the firmware string.

The coupling modules listed by the wizard can be used to convert signals and to assign I/O modules. The currently available module R-ILB AO4 AI12 SSI-IN4 ("4-axis module") fulfills the signal technology requirements (cycle time, synchronicity, resolution, ...) for four hydraulic axes (position recording, pressure recording, valve actuation).

This documentation describes the hydraulic central controller functions (drive firmware HDS).

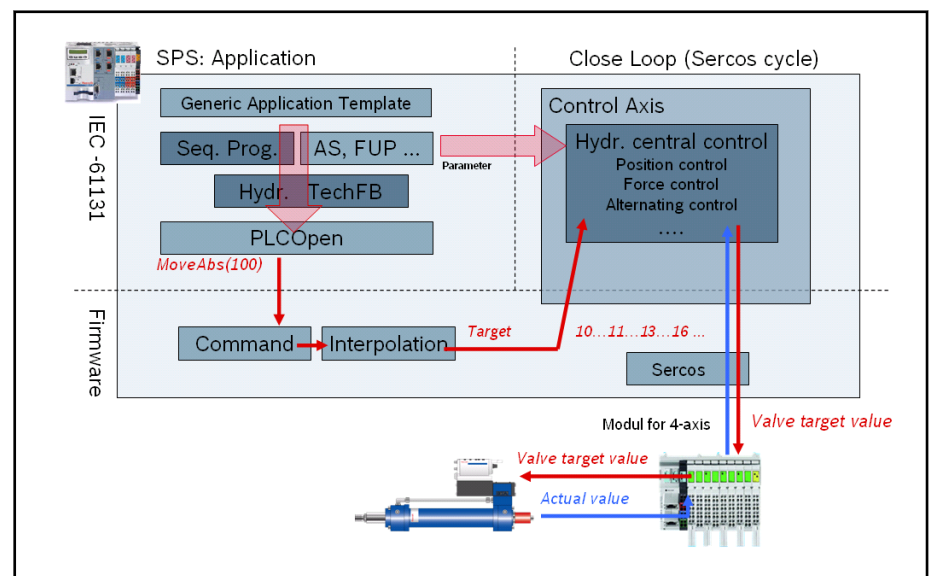


Fig.2-1: Hydraulic central controller

System Overview



The hydraulic controllers of Bosch Rexroth use the same algorithms and parameters for drive control. Accordingly, notes/descriptions are available in these documents that are not relevant for the HDS drive firmware. It is described for which firmware (e.g. HDB for IAC devices or HDS for MLC devices) the functions/descriptions are valid.

2.1.2 Special Features of the Hydraulic Control

Known special features of hydraulic axes: Generation of very large torques and forces, simple generation of linear drive motions, high ruggedness and reliability. However, the physical properties of the drive have to be taken into consideration for an optimized control. Physical properties, such as compensation of the valve characteristics or an increased dampening of low-frequency drives. That is why a special control is available for hydraulic axes.

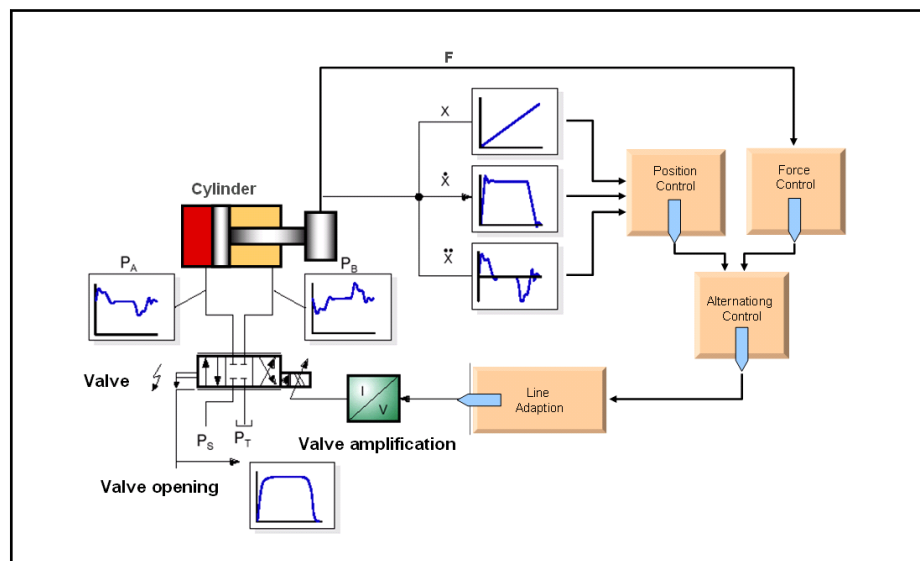


Fig.2-2: Special features of hydraulic axes: Controlled system and control structures

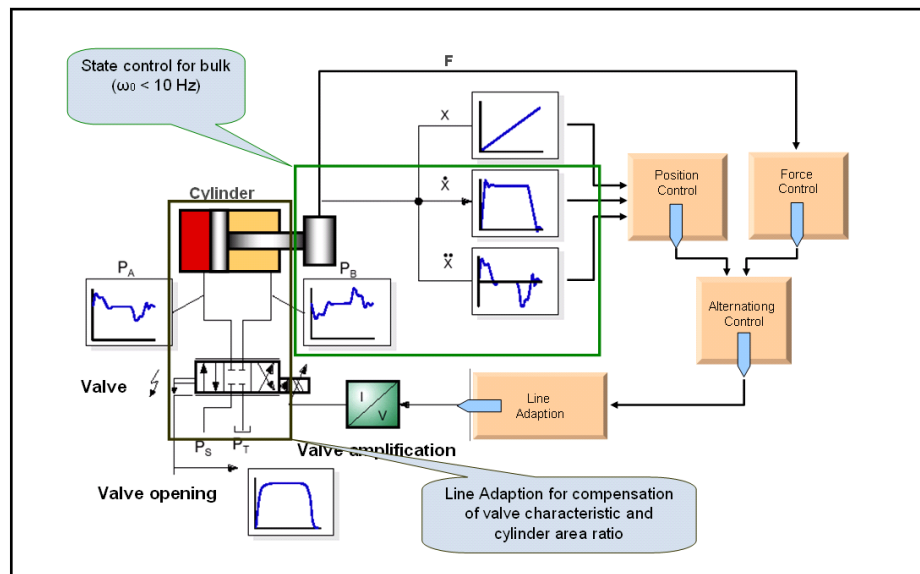


Fig.2-3: Special features of hydraulic axes: State controller and path adjustment

2.2 Exemplary Application Structure

The MLC and the Bosch Rexroth drives are compatible. Thus, electric as well as hydraulic (central or decentral) drives can be commanded in a control. Both drive types are configured and programmed using the same Engineering tool.

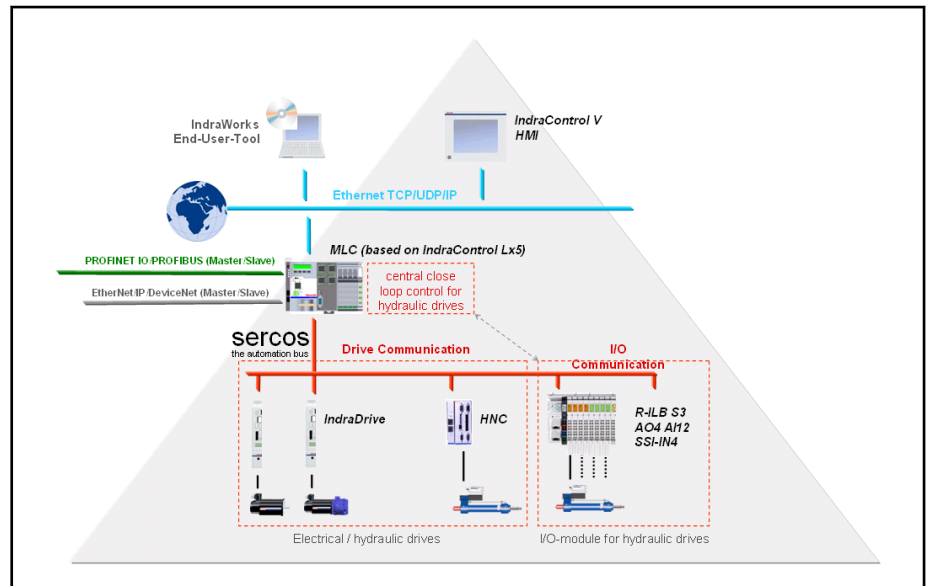


Fig.2-4: Exemplary architecture

3 Important Directions for Use

3.1 Appropriate Use

3.1.1 Introduction

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

WARNING

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

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



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

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

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

3.1.2 Areas of Use and Application

Hydraulic axes made by Bosch Rexroth are designed to control electrical motors and monitor their operation.

Control and monitoring of the Hydraulic axes 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.

Hydraulic axes have to be programmed before commissioning to ensure that the motor executes the specific functions of an application.

Hydraulic axes of the Rexroth HydrDrive line have been developed for use in single- and multi-axis drive and control tasks.

Important Directions for Use

To ensure application-specific use of Hydraulic axes, 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.

Hydraulic axes 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.).

3.2 Inappropriate Use

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

Hydraulic axes may 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, Hydraulic axes may not be used in applications which have not been expressly authorized by Bosch Rexroth. Please carefully follow the specifications outlined in the general Safety Instructions!



Components of the Rexroth HydrDrive system are **products of category C3** (with limited availability) according to IEC 61800-3. To ensure that this category (limit values) is maintained, suitable line filters must be used in the drive system.

These components are not provided for use in a public low-voltage network supplying residential areas with power. If these components are used in such a public network, high-frequency interference is to be expected. This can require additional measures of radio interference suppression.

4 Safety Instructions for Electric and Hydraulic Drives and Controls

4.1 Definitions of Terms

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

Safety Instructions for Electric and Hydraulic Drives and Controls

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

4.2 General Information

4.2.1 Using the Safety Instructions and Passing Them on to Others

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

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

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

4.2.2 Requirements for Safe Use

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

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

Safety Instructions for Electric and Hydraulic Drives and Controls

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

The machine and installation manufacturers must

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

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

- The technical data, connection and installation conditions of the components are specified in the respective application documentations and must be strictly observed at all times.
- Observe safety-relevant information and information on risks in the operating instructions of the manufacturer of the connected hydraulic system before you commission a control in conjunction with a hydraulic system.

National regulations which the user must take into account

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

Safety Instructions for Electric and Hydraulic Drives and Controls

4.2.3 Hazards by Improper Use

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

4.3 Instructions with Regard to Specific Hazards

4.3.1 Protection Against Contact With Electrical Parts and Housings



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

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

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

- Only qualified personnel are allowed to operate, maintain and/or repair the components of the electric drive and control system.
- Observe the general installation and safety regulations when working on high-voltage units.
- Before switching the machine on, the equipment grounding conductor must have been permanently connected to all electric components in accordance with the connection diagram.
- Even for brief measurements or tests, operation is only allowed if the equipment grounding conductor has been permanently connected to the points of the components provided for this purpose.
- Before accessing electrical parts with voltage potentials higher than 50 V, you must disconnect electric components from the mains or from the power supply unit. Secure the electric component against reconnection.
- For electric components, observe the following:
Always wait **30 minutes** after switching off power to allow live capacitors to discharge before accessing an electric component. Measure the electrical voltage of live parts before beginning to work to make sure that the equipment is safe to touch.
- Install covers and guards provided for this purpose before switching on.
- Never touch electrical connection points of the components while power is turned on.
- Do not remove or plug in connectors when the component is connected to the power supply.
- Under certain conditions, electric drive systems can be operated at mains protected by residual-current-operated circuit-breakers sensitive to universal current (RCDs/RCMs).
- For built-in devices, ensure protection against the ingress of foreign bodies and water as well as against direct contact by providing an external housing, for example a control cabinet.

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

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

Safety Instructions for Electric and Hydraulic Drives and Controls

- Connect the equipment grounding conductor of the components of the electric drive and control system permanently to the main power supply. The leakage current is greater than 3.5 mA.
- Establish an equipment grounding connection with a minimum cross-section according to the table below. With an outer conductor cross section smaller than 10 mm² (8 AWG), the alternative connection of two equipment grounding conductors is allowed, each having the same cross-section as the external conductors.

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

Fig.4-1: Minimum Cross-Section of the Grounding Conductor Connection

4.3.2 Protective Extra-Low Voltage as Protection Against Electric Shock

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

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

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

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

Safety Instructions for Electric and Hydraulic Drives and Controls

4.3.3 Protection Against Dangerous Movements

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

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

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

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

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

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

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

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

To avoid accidents, injury and/or property damage:

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

Safety Instructions for Electric and Hydraulic Drives and Controls

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

4.3.4 Protection Against Magnetic and Electromagnetic Fields During Operation and Mounting

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

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

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

Safety Instructions for Electric and Hydraulic Drives and Controls

4.3.5 Protection Against Contact With Hot Parts

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

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

4.3.6 Protection During Handling and Mounting

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

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

4.3.7 Battery Safety

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

Risk of injury by improper handling!

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

Safety Instructions for Electric and Hydraulic Drives and Controls



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

4.3.8 Protection Against Pressurized Lines

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

Risk of injury by improper handling of pressurized lines!

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



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

4.4 Explanation of Signal Words and the Safety Alert Symbol

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

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

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



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

Safety Instructions for Electric and Hydraulic Drives and Controls

⚠ WARNING

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

⚠ CAUTION

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

NOTICE

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

5 Measuring Systems

5.1 Measuring Systems

5.1.1 General Information

Control loops and measuring systems	Measuring systems are required to operate drives in the closed control loop. They record the current status (actual value) of the physical variable to be controlled. <i>The following drive control loops exist:</i> • Position control loop Actual position value $\Rightarrow$ Analysis of the position measuring system • Velocity control loop Actual velocity value $\Rightarrow$ Derivation of the actual position value after time • Torque/force control loop Actual torque/force control value $\Rightarrow$ Analysis of pressure or load cell(s) and conversion
Position measurement options	Absolute position measuring systems (SSI interface or analog variables), relative position measuring systems and a simulation are supported. This can be set via parameter "P-0-0074, Encoder type 1".
Absolute encoder accuracy	The absolute accuracy is an encoder property (position measuring system). The accuracy is determined by the encoder structure as well as by the component quality. The data for absolute accuracy is specified by the encoder manufacturer on the relevant data sheet.
Resolution	The measuring system resolution is entered in the following parameters: S-0-0116, Encoder 1 resolution S-0-0117, Resolution of feedback 2 <i>The following generally applies:</i> • Encoder 1 refers to "Encoder" and has to be used as main encoder by default • Encoder 2 refers to the "optional encoder" In case of digital linear encoders, the value of "S-0-0116, Encoder 1 Resolution" or "S-0-0117, Encoder 2 Resolution", refers to the number of increments per position unit (e.g. [mm]).
Encoder mode	<i>The following encoder or mode can be used to determine the actual position value using the parameters "S-0-0520, Axis controller control word" and "P2936.0.1, Encoder control word, extended":</i> • Only Encoder 1 ("S-0-0520, Axis controller control word" bit 1, 2 are set to 00) • Only Encoder 2 ("S-0-0520, Axis controller control word" bit 1, 2 are set to 01) • Redundancy: Encoder 1 and Encoder 2 are read in. By default, Encoder 1 is used. If one encoder fails, the other encoder is used. ("S-0-0520, Axis controller control word" bit 1,2 are set to 1x and "P2936.0.1, Encoder control word, extended" bit 0 is 0) • Sum: The sum of Encoder 1 and Encoder 2 is used as actual position value ("S-0-0520, Axis controller control word" bit 1,2 are set to 1x and "P2936.0.1, Encoder control word, extended" bit 0 is 1)

Measuring Systems

If **Redundancy** is selected, the "correctly functioning" encoder is automatically used.

All cases are listed:

1. Encoder 1 and Encoder 2 are operational. The delta between both actual values is smaller than "S-0-0391 Monitoring window Encoder 2". Encoder 1 is active.
2. Encoder 1 and Encoder 2 are operational. The delta between both actual values is greater than S-0-0391. An encoder that is closer to the calculated model is used for closed loop-control and a warning (E2080) is displayed.
3. Encoder 1 is faulty. Now, Encoder 2 is used for closed loop-controlling and the warning (E2031) is displayed.
4. Encoder 2 is faulty. Now, Encoder 1 is used for closed loop control and the warning (E2042) is displayed.
5. Encoder 1 is faulty. Subsequently, Encoder 2 is also faulty. The error F8042 is reported and the axis is stopped (not closed loop-controlled).
6. Encoder 2 is faulty. Subsequently, Encoder 1 is also faulty. The error F8022 is reported and the axis is stopped (not closed loop-controlled).



The redundancy is used to maintain the control as long as possible.

Encoder jump suppression

Some encoder types temporarily report incorrect actual position values (encoder jumps) under certain ambient conditions (one to two sampling actions). Consequently, the system is switched off due to monitoring. By means of the encoder jump suppression, the monitoring can be bridged for an optional number of cycles "P2936.0.6, Maximum cycle number of encoder jump suppression". The actual position values continue to be calculated in a linear way. The setting is active after the position generation, e.g. when generating the sum and is thus set only once for both encoders. The suppression is disabled with value 0.

Inverting the sense of motion

The sense of motion (direction of counting) can be set by means of "S-0-0277, Position encoder type 1" bit 3 (or "S-0-0115 Position encoder type 2", bit 3).

Structure image

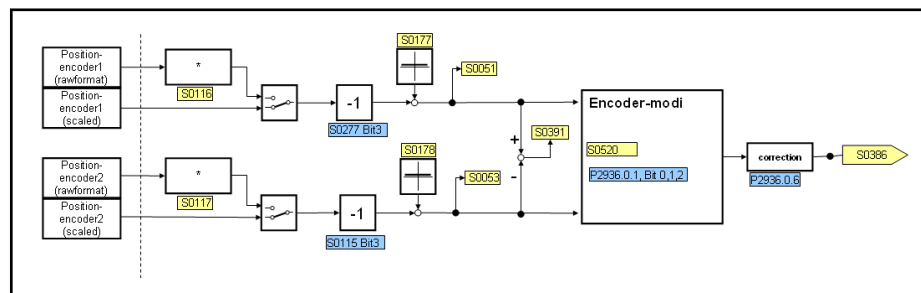


Fig.5-1: Structure image for absolute measuring systems

Derived velocity and acceleration signals

The values of the velocity "S-0-0535, Actual velocity" and acceleration "S-0-0536, Actual acceleration" are derived from the actual position value. These values are filtered by default. The filters can be adjusted using the parameters "P-0-2936.0.7, Actual velocity filter time" (or "P-0-2936.0.9, Actual acceleration filter time").

5.1.2 Simulation

For tests without a hardware, Encoder 1 (via "P-0-0074, Encoder type 1") can be set to simulation. The actual values (position, force) are calculated using a

simplified model. The valve output is set to the standstill value during the simulation.

The following parameters are used for internal calculation:

- P-0-2917.0.1 Simulation control word
- P-0-2917.0.2, Mass
- P-0-2917.0.3, Filter time of simulation
- P-0-2917.0.5, Negative stop
- P-0-2917.0.4, Positive stop
- P-0-2917.0.6, Spring length



Only Encoder 1 can be simulated.

5.1.3 Pressure/Force Recording

Structure image

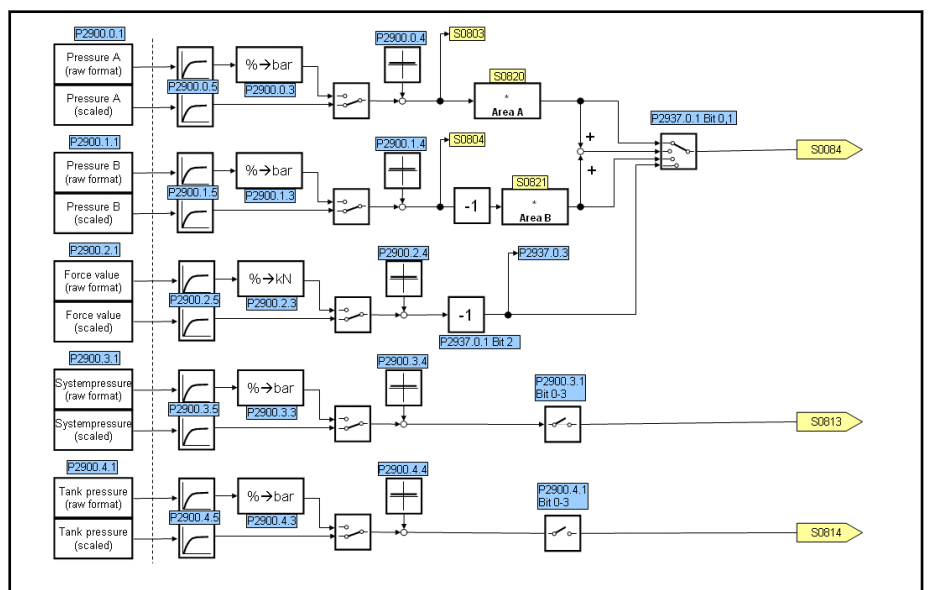


Fig.5-2: Structure image for pressure recording

Description

The force recording is done either directly via a load cell or indirectly via pressure recording and multiplication with the active cylinder plane. In case of standard cylinders, the pressures in chamber A and B are read in and calculated. In case of plungers (cylinders with only one chamber), only side A is read in and calculated. This is specified by means of "P2937.0.1, Force recording control word".

An inversion for load cells can be executed by means of "P2937.0.1, Force recording control word". When using pressure cells, the areas/surfaces (piston area or ring surface) have to be entered.

System and tank pressure values can either be entered or read in via pressure cells:

- Input: Setting to zero (default) via "S-0-0813, System pressure" (or "S-0-0814, Tank pressure") and "P-0-2900.x.1, Analog input, assignment, control word x"
- Reading in: Integrate pressure cells when creating the axis using the wizard. Subsequently set "P-0-2900.x.1, Analog input, assignment, control word x".

Measuring Systems

A resolution of "P-0-2900.x.3, Analog input, assignment, evaluation x" and an offset value "P-0-2900.x.4, Analog input, assignment, offset x" has to be entered for each read in pressure value.

Using the control word "P-0-2900.x.1, Analog input, assignment, control word x", it can be defined for each pressure value, whether a faulty signal resulted in a warning or an error in the drive. A detected faulty signal is displayed in the status word "P-0-2900.x.2, Analog input, assignment, status word x".

5.1.4 Physical Effective Direction of the Drive

To commission a hydraulic axis, it is important to know the effective cylinder direction expected by the controller.

The subsequent figure shows the correlations:

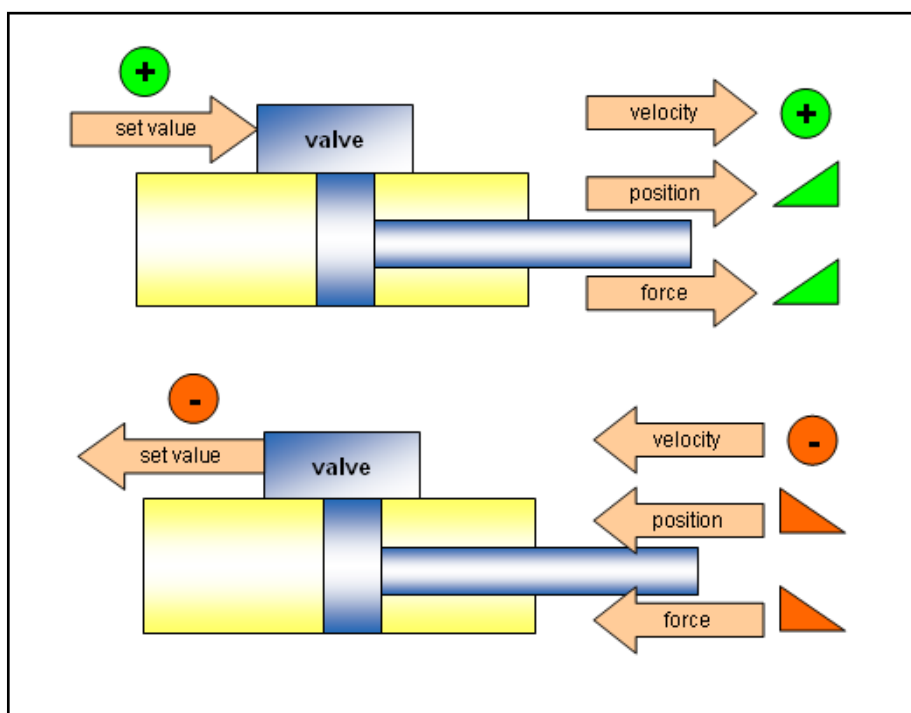


Fig.5-3: Functional principle of the valve control

The following is expected when specifying a positive valve command value:

- the cylinder extends
- the actual position values increase
- Thus, the actual velocity values are positive
- Actual force values in the direction of movement change to positive values in case of pushing counteracting forces

The following is expected when specifying a negative valve command value:

- the cylinder retracts
- the actual position values decrease
- Thus, the actual velocity values are negative
- Actual force values in the direction of movement change to negative values in case of pulling counteracting forces

If this effective direction is not given during the commissioning, a coupling occurs in the control loop that results in an error switch-off. The effective direction can be set correctly using the parameters for inversion of the actual position value, the actual force value and the controlled variable (in the controlled

variable adjustment). A subsequent inversion when determining the force using pressure cells is not possible or required, as the pressure cells have to be unambiguously assigned to cylinder sides.

If another effective direction is required to display the actual values and thus also the command value specification (position, velocity, force), it can be achieved by setting the scaling of the respective variable. This does not influence the controller.

5.2 Establishing Position Data Reference

5.2.1 Establishing Position Data Reference in Absolute Measuring Systems

Actual position values with a fixed encoder-independent reference point are reported to the controller by the encoder during the absolute position measurement. After enabling the drive, the correct actual position value is available immediately in each axis position. Due to the mostly undefined installation position of the encoder at the motor or the axis mechanic, a one-time determination of the position offset might be required upon the initial commissioning ("Set absolute value").

Establish position data reference by drive command

In case of absolute evaluable measuring system, the position data reference can be established independently by the drive by starting the command "C0300, Command Set absolute dimension".

It is recommended to start the command "Set absolute dimension" in case of axis standstill without drive enable. In case the axis is positioned for referencing and is to be held by the drive, "Set absolute dimension" can also be executed if the drive is active.

If two absolute measuring systems are connected to the controller, a position data reference can be established individually for the two systems. Selection of the absolute encoder to be referenced:

If several absolute evaluable encoders are connected to the controller, it can be selected using "S-0-0448, Control word, set absolute dimension" on which encoder the command "Set absolute dimension" should become active.

Establish manual position data reference

By directly entering the parameter "S-0-0177, Offset Encoder 1" or "S-0-0178, Offset Encoder 2", the position data reference can also be established manually. The calculated actual position value is displayed in "S-0-0051 Actual position value, Encoder 1" or "S-0-0053 Actual position value, Encoder 2".

5.2.2 Establishing Position Data Reference in Relative Measuring Systems

The actual position values of incremental encoders do not have any position reference. In each axis position, the actual position value of the respective incremental encoder is initialized when switching the MLC on or after all operations that result in a loss of the reference. The initial value is determined by the respective incremental encoder module. The following mode is supported to establish the axis-related absolute measurement:

Drive-controlled referencing (fixed stop):

After enabling "S-0-0148, C0600 Drive-controlled homing procedure command" the drive traverses the axis according to the "S-0-0147, Homing parameter" set direction of approach of the reference.

The generated command value profile depends on the controller:

- S-0-0041, Homing velocity
- S-0-0042, Homing acceleration
- S-0-0108, Feedrate override

Measuring Systems

Command values of the MLC interpolators are ignored by the controller when executing the command C0600!



If the encoder has already been referenced upon start of the command C0600, the reference is deleted!

Also see parameter description "S-0-0403, Position feedback value status"



The PLC Open function block "MB_Home" operates the command "C0600 Command drive-controlled referencing". Before starting the command, Drive Enable has to be reported (MC_Power).

6 Drive Control

6.1 Overview

6.1.1 Basics and Terms

The following principles of the drive control are supported, depending on the device type:

- **p/Q-function**

Generally, a position encoder is not available. Depending on the pressure sensors (hardware conditions), it can be selected between open loop Q-controlled (valve opening) and flow control (closed loop Q-controlled).

- **Axis control or open-loop mode**

A position encoder is not available. The valve opening is open loop-controlled. Optionally, the force can be closed loop-controlled depending on the connected sensor technology.

- **Axis control or closed-loop mode**

A position encoder is available that is used for position feedback (position control). Optionally, the velocity can be closed loop-controlled and depending on the connected sensor technology, the force can also be closed loop-controlled.

The following table provides an overview on the different control methods supported in the different operation modes by the different device variants:

Operation mode	Control type	Device variant	Position encoder available	Sensor technology	Required basic package
Valve direct control	Open loop traversing	HDB, HDS	Yes		Closed-loop
			No		Open-loop
Flow control	Flow control	HDB	No	Internal pressure sensors	Open-loop
Pressure control/valve control (p/Q)	Open loop-controlled operation incl. changeover logic in pressure control	HDB	No	Pressure sensor	Open-loop
Pressure/flow control	Flow control incl. changeover logic in pressure control	HDB	No	Internal pressure sensors	Open-loop
Position control	Position control incl. alternating control (force control)	HDB, HDS	Yes	Pressure sensors or force sensor	Closed-loop
Drive-controlled positioning, positioning block mode	Position control incl. alternating control (force control)	HDB	Yes	Pressure sensors or force sensor	Closed-loop
Torque/force control	Torque/force control	HDB, HDS	No	Pressure sensors or force sensor	Open-loop
		HDB, HDS	Yes	Pressure sensors or force sensor	Closed-loop

Drive Control

Operation mode	Control type	Device variant	Position encoder available	Sensor technology	Required basic package
Force control/valve control	Open loop-controlled operation incl. alternating control (force/torque control)	HDB	No	Pressure sensors or force sensor	Open-loop
Velocity control	Velocity control incl. alternating control (force control)	HDB, HDS	Yes	Pressure sensors or force sensor	Closed-loop

Fig.6-1: Overview of operation modes and possible types of controls



The selection between p/Q function and axis control partly depends on the correct device type. A special device with in-built pressure sensor technology an measured valve characteristic curve is required for the flow control. This has to be taken into consideration when ordering the device. For certain operation modes, pressure sensors or a position encoder are/is required. By selecting the function package, it can be switched between the open-loop and the closed-loop basic package (only HDB).

6.1.2 Drive Control Principles

Overview of the p/Q-functionality

By means of the p/Q-function, the valve opening to the open loop-controlled axis operation can be specified. By using the flow control, the drive can be traversed, comparable to a velocity control without a position encoder and closing of the position control loop. Requirement: Pressure sensors integrated in the hydraulic valve, recording the pressure in the chambers. Furthermore, the pressure control can be enabled or disabled via a changeover logic.

The following operation modes are supported:

- Valve direct control
- Flow control
- Pressure control/valve control (p/Q)
- Pressure/flow control

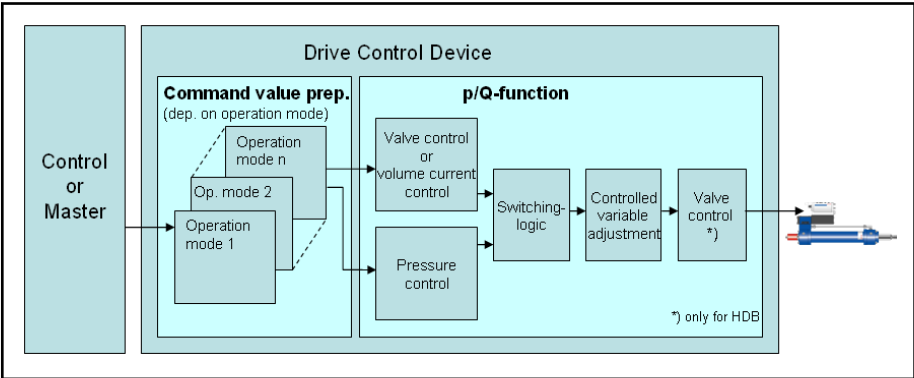


Fig.6-2: p/Q-function principle

Overview of axis control (open-loop mode)

The axis control (or open-loop mode) facilitates an open loop-controlled operation of the drive without the position encoder.

HDB: The main operation mode "Valve direct control" is configured.

Drive Control

HDS: "No encoder" is configured in the selection of Encoder 1 and Encoder 2.

A control (position and velocity) and depending functions and operation modes are not possible. A force/torque control can alternately take place ("Alternating control").

The following operation modes are supported:

- Valve direct control
- Force/torque control (additional sensor technology to record the force using pressure or force sensors required)
- Force control/valve control
- Pressure control/valve control

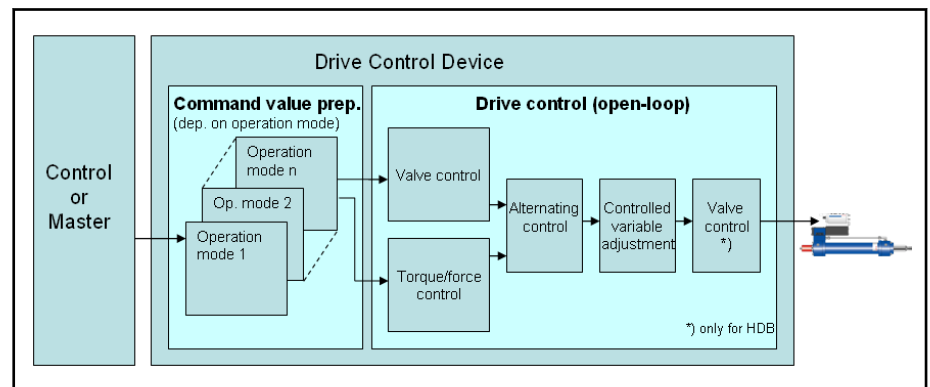


Fig.6-3: Drive control principle (open-loop mode)

Overview of axis control (open-loop mode)

The axis control (or closed-loop mode) facilitates a closed loop-controlled operation of the drive.

The position control loop and if required, subordinate velocity controller are closed via the encoder feedback.

The following operation modes are supported:

- Valve direct control
- Closed-loop position control with cyclic command value specification
- Velocity control (can also be used for velocity control)
- Positioning operation modes (e.g. drive-controlled positioning) (only HDB)
- Force/torque control (additional sensor technology to record the force using pressure or force sensors required)
- Force control/valve control
- Pressure control/valve control

Drive Control

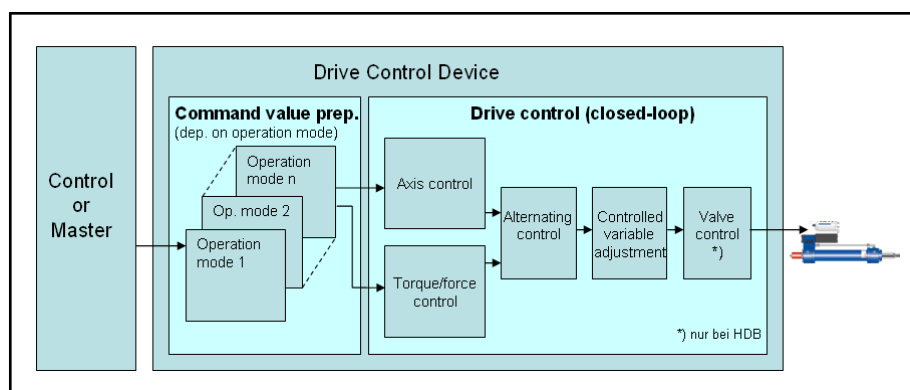


Fig. 6-4: Drive control principle (closed-loop mode)

6.1.3 Control Loop Features

Performance (controller cycle times)

The specified controllers as well as the internal controller cycle times depend on the following conditions and parameters:

- Hardware feature
- Activating function packages (only HDB)
- HDB: "P-0-0556, Axis controller configuration" (bit 2 and 5) HDS: Performance depends on Motion and sercos cycle times (C-0-0400 and C-0-0503) as well as the controller underclocking.

The following cycle times can be reached, depending on these factors:

	HDB	HDS
Valve controller cycle	100 µs	n. r.
Flow rate controller cycle	1 ms	n. r.
Pressure controller cycle	0.5 ms	n. r.
Position controller cycle	1 ms	0.5 ms
Velocity controller cycle	0.5 ms	0.5 ms
Force/torque controller cycle	0.5 ms	0.5 ms

Valve controller

The valve controller is only contained in IAC devices. These devices are directly mounted on the hydraulic valve and replace the standard OBE (on-board electronics). Otherwise, the valve command value is usually transmitted to the standard OBE via an analog interface.

If the valve controller is integrated, it is by default set to the corresponding hydraulic valve and does not require any application-specific adjustments.

Flow rate controller

The flow rate controller has the following features:

- Calculating the valve control signal using the flow equation and the flow characteristic of the valve

Pressure controller

The pressure controller has the following features:

- PI-controller with controllable I-ratio and corresponding logic

Position controller with subordinate velocity controller

The position controller has the following features:

- Kv with D-ratio and fine positioning incl. corresponding logic for the control of the I-ratio
- Velocity feed forward

	• Subordinate velocity controller as PI-controller incl. corresponding logic to control the I-ratio • Status feedback (velocity, acceleration or force)
Force/torque controller	<i>The force controller has the following features:</i> • Standardization of control difference to velocity. Thus, the controller parameters and the controller gains and outputs relate to velocity • PI-controller with controllable I-ratio and corresponding logic • Option for velocity feed forward • Quadrant limit
Controller underclocking (only HDS)	By means of the central hydraulic controller (HDS), the controller underclocking can be realized. The control variables of the controller do not have to be calculated anymore in each sercos cycle using the underclocking. The sampling interval can be set to a lower value to optimize the performance. <i>Settings of the controller underclocking:</i> • Underclocking 1 = Sampling each clock cycle • Underclocking 2 = Sampling every second clock cycle • Underclocking 4 = Sampling every fourth clock cycle • Clock cycle sequence: 1 = from first clock cycle • Clock cycle sequence: 2 = from second clock cycle • Clock cycle sequence: 3 = from third clock cycle (only in case of number of underclocking = 4) Thus, "slow" and "fast" axes can be operated and a high cycle time load can be distributed more effectively.

6.1.4 General Commissioning and User Information

Additive command values and access options to subordinate control loops	The user has the option to enable additive command values in addition to the command values during the closed loop-controlled operation. These parameters can be taken from the description of the respective operation mode.
Information about the commissioning of control loop settings	The hydraulic axis properties depend on the correct setting of the control loops.
Order of the manual control loop settings	Initially, the controlled variable adjustment parameters have to be adjusted to the hydraulic system to be controlled: Standard valve velocity, motion-dependent gain and characteristic valve line. No other settings have to be selected for direct valve control (open-loop operation). For p/Q-applications, the parameterization of the controlled variable adjustment and the subsequent setting of the pressure controller and the change-over logic are executed for devices with flow rate control. In case of closed loop operation, the position controller is parameterized after the controlled variable adjustment has been set. For applications in path controls, the subordinate velocity controller has to be used; otherwise, the controller is not enabled. To stabilize and increase the control loop gain, status feedbacks can be activated. Subsequently, the force controller as well as the alternating control can be enabled, if required.

Drive Control

6.2 Control Variable Adjustment

Layout Diagram

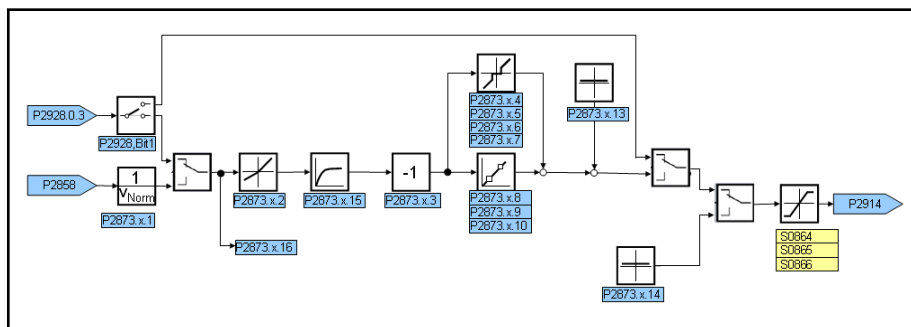


Fig. 6-5: Control Variable Adjustment Detail Diagram

Description

Control variable adjustment can be used to adjust the variable to the valve or section. The adjustment is independent of the selected operation mode. When the operation mode is switched, all settings remain as they are. In addition to inversion, offset and limitation of the variable, it is also possible to compensate the non-linearity of the valve.

Standard Valve Velocity

The "P-0-2873.0.1, Valve standard velocity" is the velocity at which the hydraulic drive can move with maximum valve opening (100%). Since valve activation is based on percentage values, the output value of the particular controller is scaled to percent by means of the standard valve velocity. The scaled value is displayed in parameter "P-0-2873.0.16, Control variable adjustment of command value". The corresponding adjustments are made subsequently.



Movements with feeding via a pre-fill valve or rapid traverse mode should not be used as reference.

Forward/Backward Adjustment

By setting parameter "P-0-2873.0.2, Direction-dependent gain", the velocity ratio is taken into account for moving the cylinder in and out in a controlled manner. The effects involved here are, e.g., the cylinder area ratio or the load impact effect of vertical axes. As a result, the loop gain is kept constant while the cylinder is extended and retracted.

The factor can be determined in two ways:

- By measuring the control variable when the cylinder is extended and retracted at the same velocity.

$$P-0-2873.0.2 = \text{Move-in control variable} / \text{move-out control variable}$$

- By measuring the actual velocity when the cylinder is moved in and out with the same control variable.

$$P-0-2873.0.2, = \text{Move-out velocity} / \text{move-in velocity}$$

The negative control variable adjustment command value is multiplied by this factor. If the value entered here is 1, the behavior of the axis is dependent on the direction.

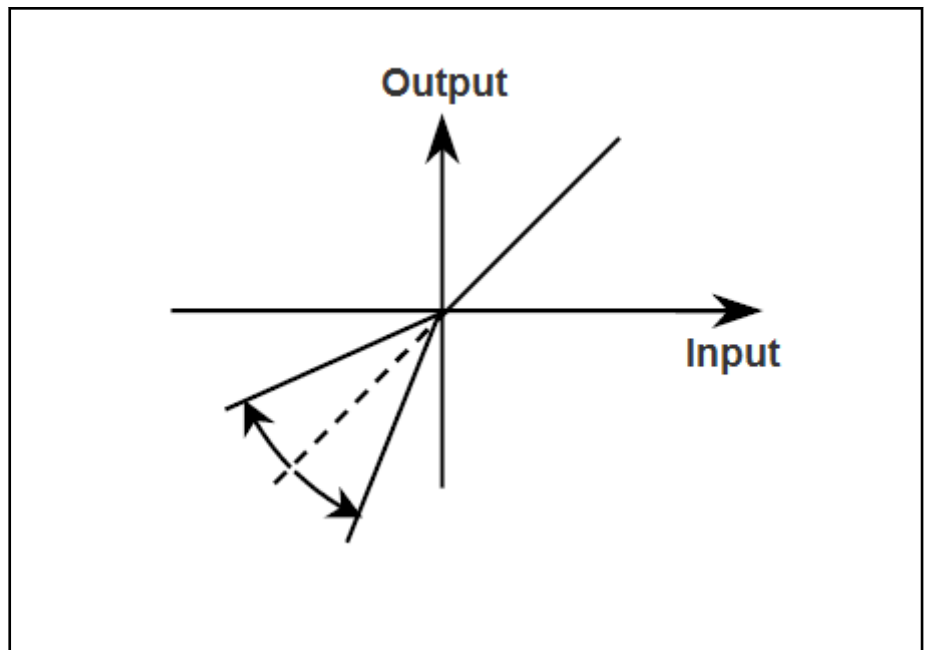


Fig.6-6: Direction-Dependent Gain

Filter The control variable adjustment command value can be filtered with parameter "P-0-2873.0.15, Filter time of valve control variable". If the value entered here is 0, the filter is inactive. For example, this filter is used with drives where the natural frequency of the valve is considerably greater than that of the hydraulic drive (e.g. cylinder).

Inversion The control variable adjustment command value is multiplied with parameter "P-0-2873.0.3, Control variable inversion". If the value entered here is -1 , the control variable adjustment command value is inverted.

Overlap This principle compensates for the dead band behavior of valves with positive overlap. This means that the control variable does not have to pass through the dead band of the valve first before a reaction becomes effective at the cylinder. Parameter "P-0-2873.0.4, Valve overlap type" can be used to select "jump compensation" or "linear compensation" or to disable the overlap compensation function.

The following parameters are available for either variant:

- P-0-2873.0.5, Valve overlap A-side
- P-0-2873.0.6, Valve overlap B-side
- P-0-2873.0.7, Valve overlap threshold

The valve overlap threshold defines the input value starting at which the value "P-0-2873.0.5, Valve overlap A-side" is output for positive values and the value "P-0-2873.0.6, Valve overlap B-side" is output for negative values. Above the valve overlap threshold, the values are linearly extrapolated up to $\pm 100\%$.

If valve overlap type 1 (value = 1) is selected, 0% is output inside the "valve overlap threshold". As a result, the valve is always in its central position in this range, therefore shutting off the hydraulic drive.

Drive Control

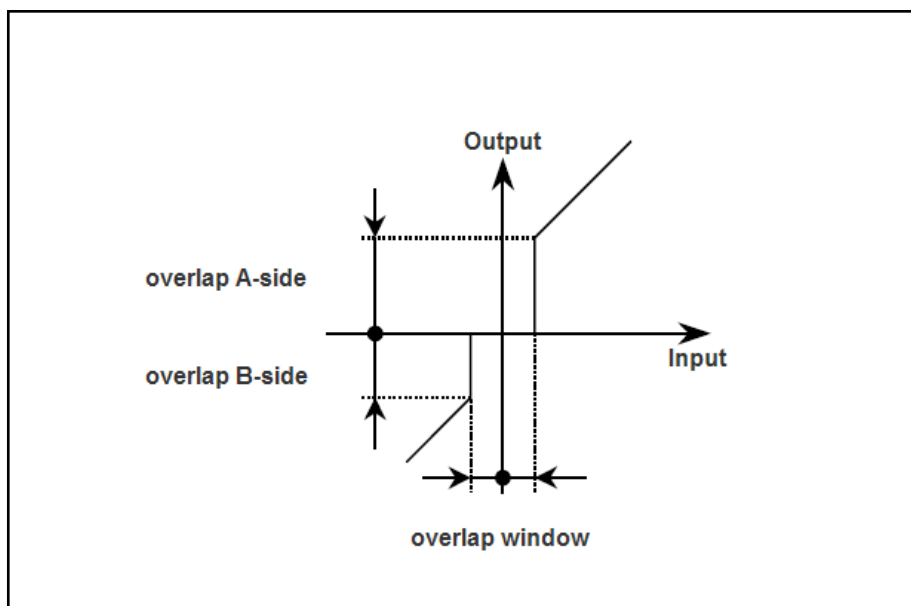


Fig. 6-7: Valve Overlap Type 1 "Jump"

If valve overlap type 2 (value = 2) is selected, the system linearly interpolates inside the "valve overlap threshold" between the "valve overlap B-side" and "valve overlap A-side". This variant is selected when the central position of the valve is to form the basis for controlling.

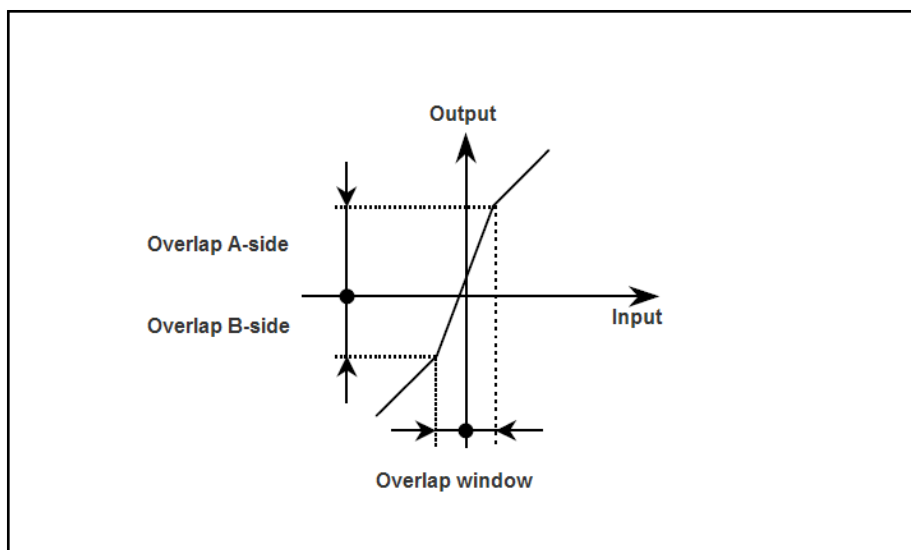


Fig. 6-8: Valve Overlap Type 2 "Straight"

Valve overlap type 0 (value = 0) deactivates the valve overlap compensation function.

Valve Characteristic Curve

The valve characteristic curve describes the ratio between the command value (control variable) and the flow of a valve at a defined pressure via a control edge. In most cases, valves with linear characteristic curves are selected so that the valve characteristic curve does not have to be corrected. There are application cases, however, where valves with progressive or inflected characteristic curves are selected in order to achieve a higher resolution with low velocities. In order to achieve a linear behavior for the upstream controller, the valve characteristic curve is compensated by entering the inverted characteristic curve.

The valve characteristic curve from the data sheet must be mirrored for compensating the non-linearity. The two tabular parameters "P-0-2873.0.9, Valve characteristic curve input value" and "P-0-2873.0.10, Valve characteristic curve input value" are used to enter the plot points.

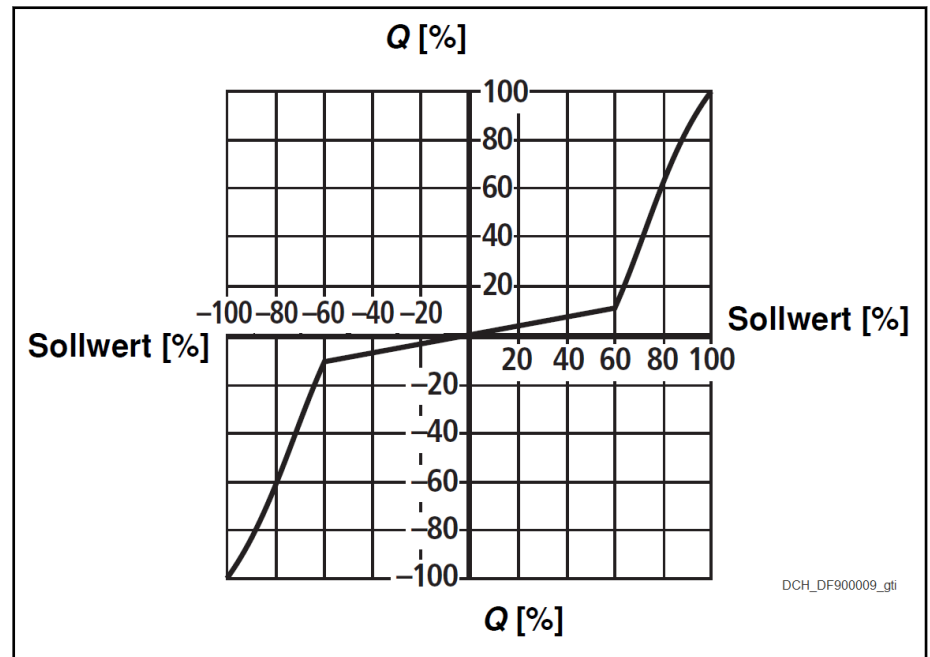


Fig.6-9: Representation Of a Valve Characteristic Curve To Be Entered

When regarding the setting for a symmetrical characteristic curve (see fig. 6-9 "Representation Of a Valve Characteristic Curve To Be Entered" on page 45), then it is evident that the plot points for input value = 0% and output value = 0% as well as input value = 100% and output value = 100% must be set. The central plot point results automatically because the flow is 10% with a valve opening of 60%. This results in an input value of 10% and an output value of 60%. This corresponds to an inversion of the existing valve characteristic curve. This inversion results in a linear valve activation.

The following "P-0-2873.0.8, Valve characteristic curve types" can be selected:

- 0: Valve characteristic curve deactivated.
- -1: Symmetrical; use is only made of the positive branch of the input characteristic curve. For negative values, the curve is mirrored to the negative range.
- -2: Asymmetrical; use is made of both the positive and the negative branches of the input characteristic curve. The plot points start in the maximum negative range and end in the positive maximum range.



- The number of values must be the same in either table.
- The values of "P-0-2873.0.9" must be entered in monotonically increasing order.
- Intermediate values of the valve characteristic curve are determined by linear interpolation.

Valve Control Variable Offset

Parameter "P-0-2873.0.13, Valve control variable offset" can be used to add a constant percentage value to the "valve controller command value".

This allows correcting a valve zero point error or signal-bound offsets.

Drive Control

Valve Control Variable Standstill Value

The "valve control variable offset" is not inverted because it takes effect only after the inversion.

Parameter "P-0-2873.0.14, Valve control variable standstill value" defines the value with which the valve is activated as long as the axis is not in closed-loop control mode. Particularly when high-response valves without overlap or vertical axes are used, this value must be unequal to 0% in order to reach standstill of an axis without controller enable.



This parameter does not ensure that the drive is brought to standstill. To implement machine safety, this can only be ensured by taking additional switching measures (usually shut-off valves).



Some hydraulic circuits or applications may also require values that are clearly unequal to zero, e.g. shut-off valves of the cylinder on one side only or desired retracting movement of the cylinder.

Valve Variable Limit Value

This parameter allows setting a limit for the valve variable. The limit can be set separately for the positive and negative ranges using parameters "S-0-0866, Negative spool limit value" and "S-0-0865, Positive spool limit value". If a symmetrical limitation is desired, parameter "S-0-0864, Bipolar spool limit value" can be used. It is always ensured that the minimum value of the positive and negative limit value, respectively, is calculated with the correct sign and the bipolar limit value.



This limitation function is preferably used during commissioning in order to avoid undesired rapid movements.

Parameters Involved

- S-0-0864, Bipolar spool limit value
- S-0-0865, Positive spool limit value
- S-0-0866, Negative spool limit value
- P-0-2873.0.1, Valve standard velocity
- P-0-2873.0.2, Direction-dependent gain
- P-0-2873.0.3, Control variable inversion
- P-0-2873.0.4, Valve overlap type
- P-0-2873.0.5, Valve overlap A-side
- P-0-2873.0.6, Valve overlap B-side
- P-0-2873.0.7, Valve overlap threshold
- P-0-2873.0.8, Valve characteristic curve type
- P-0-2873.0.9, Valve characteristic curve input value
- P-0-2873.0.10, Valve characteristic curve output value
- P-0-2873.0.13, Valve control variable offset
- P-0-2873.0.14, Valve control variable standstill value
- P-0-2873.0.15, Filter time of valve control variable
- P-0-2873.0.16, Filter time of valve control variable
- P-0-2914, Effective valve command value

6.3 Drive Control

6.3.1 Overview / Controller Structures

Control Loop Structure

The drive controller is combined cascade and parallel structure. Position, velocity and valve controller are interconnected in a cascaded manner. In contrast, the force controller is arranged in parallel to the position-velocity controller cascade and can take over control by alternating control. Subject to the active operation mode, a combination of controllers is closed in the drive.

The diagram outlines the layout and the cooperation of the control loops (information on adjustment and display parameters can be found in the chapters describing the particular controllers).

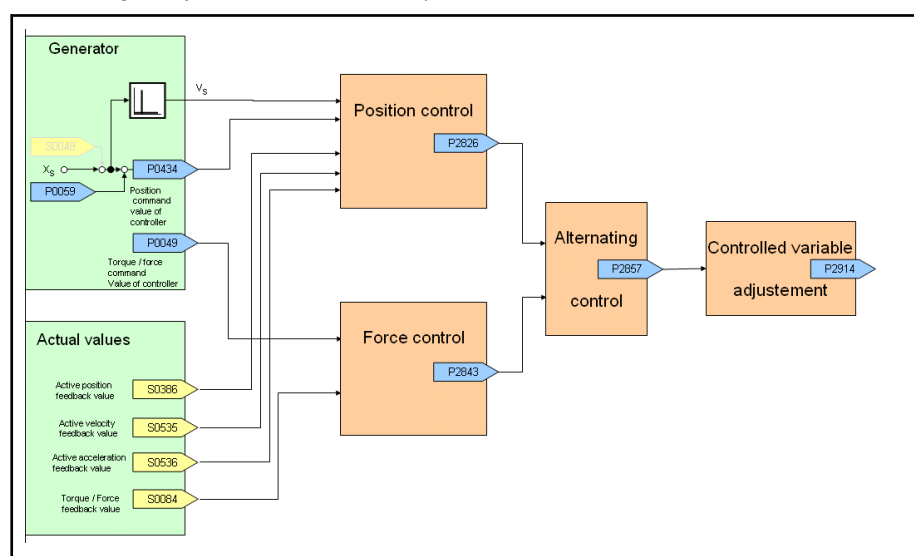


Fig.6-10: Overview of Position Controller Structure

Command values can be specified by an external master or the analog peripherals. These command values are interpolated and transferred to the controllers, subject to the operation mode selected. The control signal outputting the control variable adjustment is transferred to the valve controller. In case of an IAC, this is done inside the axis controller and, in case of an external motion controller, e.g., via an analog interface to a valve.



In case of an IAC, additional information on the command value, actual value and control deviation of the valve is always available to the user.

Drive Control

6.3.2 Closed-Loop Position Control

Layout Diagram

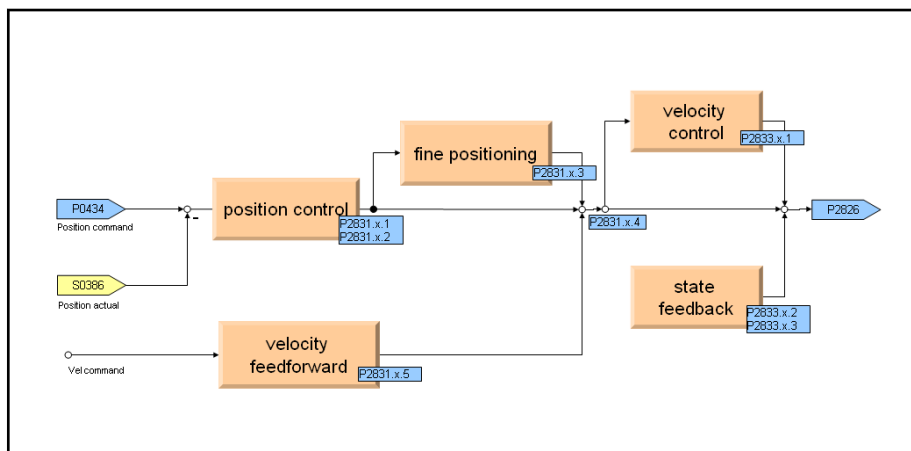


Fig. 6-11: Position Controller Structure

In addition to the position controller itself, other components can be connected to implement position control: fine positioning (integrator), velocity feedforward, subordinate velocity controller and status feedback.

Position Controller With Velocity Feedforward

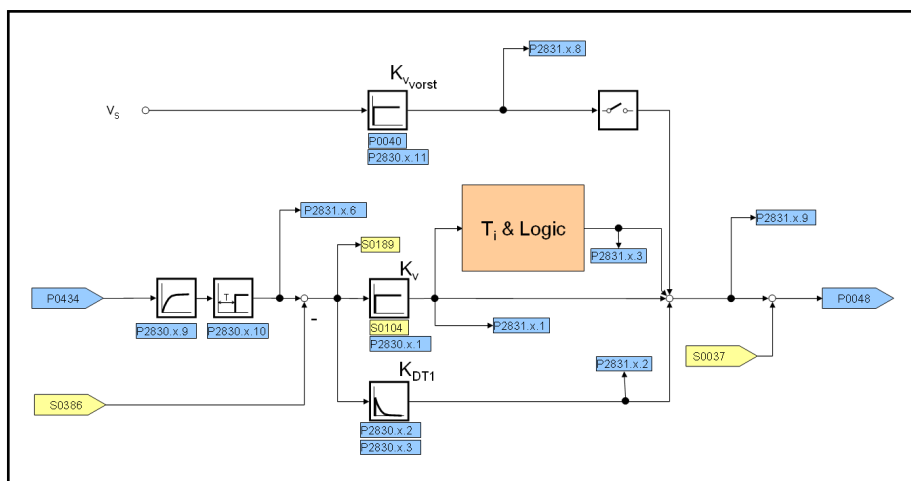


Fig. 6-12: Position Controller Detail Diagram

If necessary, the position command value can be filtered via a T1 filter (P-0-2830.0.9) and a dead time filter (P-0-2830.0.10). The filtered value is then shown in parameter P-0-2831.6 (Position command value of controller, delayed).

PDT1 Position Controller

A DT1-component which is calculated with parameters P-0-2830.0.2 (Position loop time constant D-component) and P-0-2830.0.3 (Position controller filter time D-component) can be connected to the proportional controller (position loop Kv factor, S-0-0104). This may become necessary if the natural frequency of the cylinder/mass system exceeds the natural frequency of the valve.

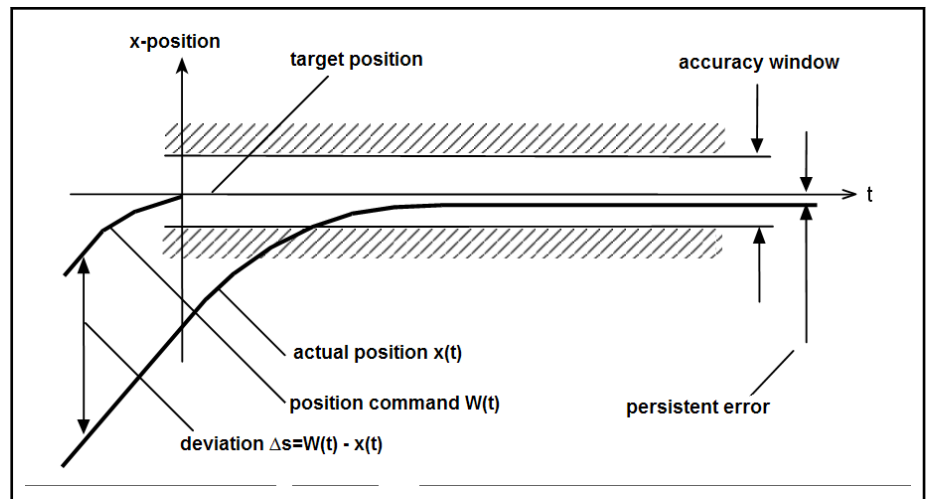


Fig. 6-13: Position Controller Positioning Procedure

If the Kv parameter is changed while position operation mode is active, the Kv value is adjusted via a ramp with parameter P-0-2830.0.1 (Position controller Kv ramp). If the Kv change is set to 0, the adjustment is saltation-like.

Feedforward Control

The feedforward control (command value input) allows processing the command velocity in parallel to the position controller with percentage scaling (P-0-0040). As a result, a following error can be minimized. If the scaling is changed, a ramp (P-0-2830.0.11) is used here as well. Activation is achieved by selecting the corresponding operation mode or with a feedforward value unequal to 0.

Fine Positioner

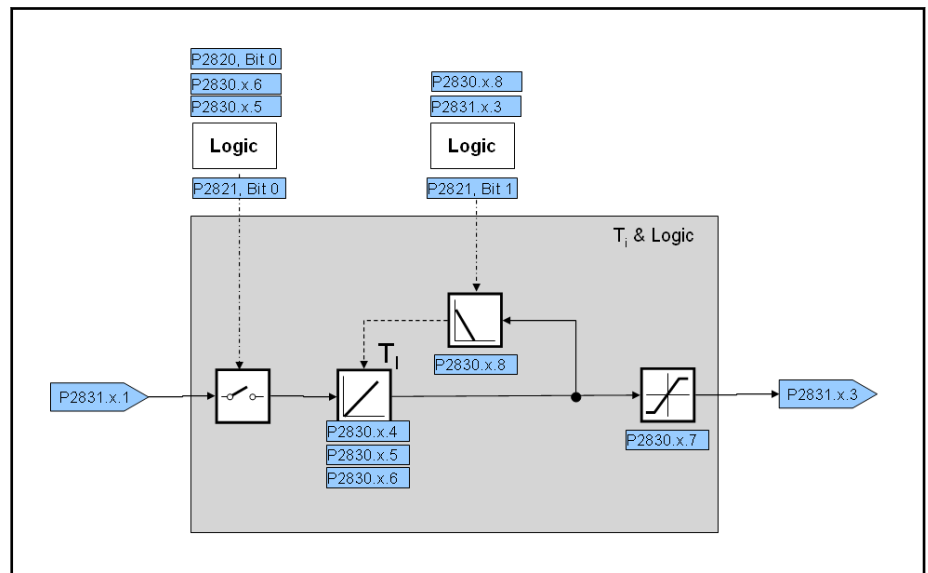


Fig. 6-14: Fine Positioner Detail Diagram

Integrator for Fine Positioning

Precise positioning of a hydraulic axis may require activation of a special fine positioning algorithm. Since it has a disadvantageous influence on the control behavior if travel velocities are high, the integrator is only activated at low travel velocities and in the vicinity of the target position. The accuracy is specified by means of the accuracy window (P-0-2830.0.6).

Drive Control

The input of the integrator is parameter P-0-2831.0.1 (Correction value: position controller Kv). The increase of the I-component is defined by the integration time constant (P-0-2830.0.4).

In addition to an accuracy window that has not been reached yet, another condition for switching the integrator on is a value falling below the I-component enable velocity window (P-0-2830.0.5).

If fine positioning is switched off (e.g. by the corresponding control bit (P-0-2820, bit 0), the value in the integrator is reduced over a ramp (P-0-2830.0.8).

The output of the fine positioning integrator can be additionally limited (p-0-2830.0.7). This means that the integrator sums up to no more than and does not exceed this limit value.



If the limitation of the I-component is set to 0, the limitation is switched off.

The current value of the integrator can be read, e.g. for optimization.

Status Feedback

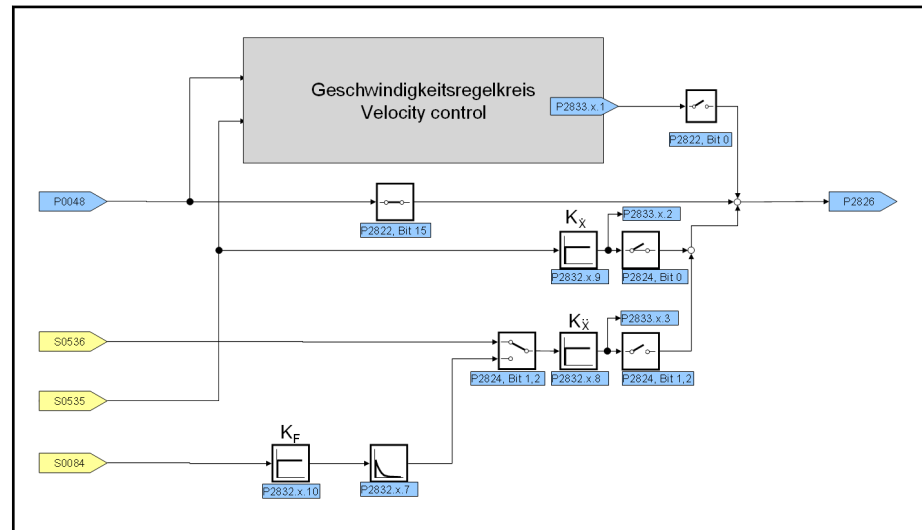


Fig. 6-15: Status Feedback Detail Diagram

The feedback of status variables allows achieving an increased controller gain and therefore an improved control behavior (command value and disturbance reactions, faster signal transitions). The status feedback can be used to improve the dynamic behavior particularly for systems with a relatively low natural frequency ($f_{\text{system}} < 15 \text{ Hz}$). However, this requires that the valve be "sufficiently" fast against the cylinder/mass system ($f_{\text{valve}} > 2 \cdot f_{\text{system}}$)

Feedback Types

If status feedback is used, the following actual process values can be evaluated and then supplied to the control: velocity, acceleration and force (v: P-0-2832.0.9, a: P-0-2832.0.8, F: P-0-2832.10 and P-0-2832.0.8). Actual acceleration and force values are filtered. The feedback can be positive or negative, this being defined by the sign of the corresponding parameter.



The status controller should not be used together with the subordinate velocity controller.

The feedback type is set using the control word P-0-2824.

Use can be made either of acceleration feedback or force feedback. Both feedback types can be combined with velocity feedback.

Subordinate Velocity Control

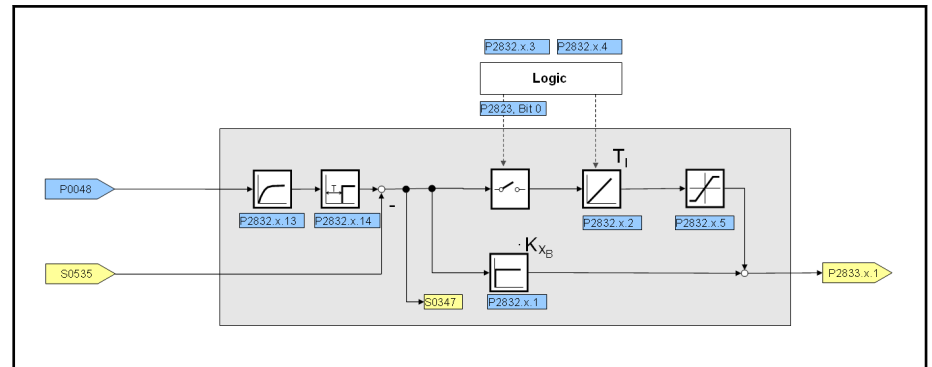


Fig. 6-16: Detail Diagram of Subordinate Velocity Controller

The subordinate velocity controller is a PI controller. It is used to correct the velocity difference between command and actual values. The P-component results from multiplication by the V-controller proportional gain (P-0-2832.0.1).

If the absolute control difference is greater than the V-controller accuracy window (P-0-2832.0.4) and less than the value for enable acceleration window (P-0-2832.0.3), the integrator is connected with the V-controller integration time constant (P-0-2832.0.2). This integrator can also be limited via a parameter (P-0-2832.0.5).

The subordinate velocity control is activated in the velocity controller control word (P-0-2822, bit 0).

Diagnostics

Excessive Control Deviation

The following monitoring functions are carried out in the position controller:

The following error is monitored by means of a model. The model monitors the deviation of the actual position value. This means that the value resulting from model error monitoring may be lower than the actual following error.

If the deviation from the model is greater than the monitoring window (S-0-0159), the drive obviously cannot follow the specified command value so that the error message "F2028 Excessive deviation" is generated.

Drive Control

6.3.3 Closed-Loop Force Control

Layout Diagram

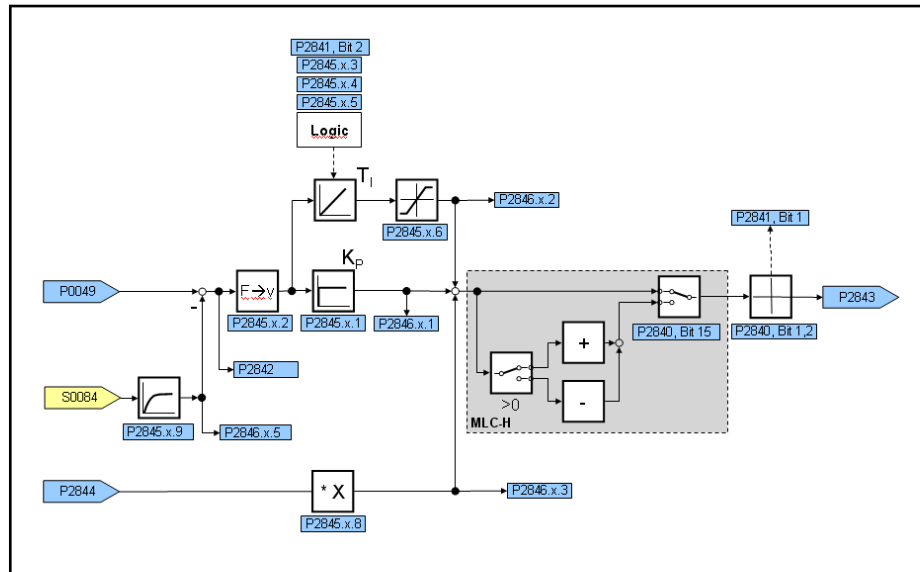


Fig.6-17: Force Controller Detail Diagram

Description

The force controller is called in the "torque/force control" operation mode and controls only the force here. In the "cyclic position" or "closed-loop force control/open-loop valve control" operation modes, however, the force controller is additionally called if the "alternating control" has been activated. If the force controller is in engagement (for conditions, refer to chapter "Alternating Control"), bit 0 of parameter "P-0-2841, Force controller status word" is set to "True". The force controller will then adjust the "S-0-0084, Torque/force feedback value" to the value set in "P-0-0049, Torque/force command value of controller".

Filter A noisy **actual force value** can be filtered with parameter "P-0-2845.0.9, Filter time of force feedback value". If the value entered here is 0, the filter is inactive. The filtered actual force value is shown in parameter "P-0-2846.0.5, Torque/force feedback value, filtered".

Scaling Of Force To Velocity The "P-0-2842, Force control deviation" is the difference between "Torque/force command value of controller" and "Torque/force feedback value, filtered". Parameter "P-0-2845.0.2, Normalization of force by velocity" is used to scale the "force deviation" to velocity units because these are the units used for further calculation in the controllers. This scaling factor is calculated from the entered cylinder geometry data, "S-0-0819, Length of cylinder" and "S-0-0820, Piston area A" and causes the closed-loop control to be free from overshoots if the "P-0-2845.0.1, Force controller P-gain" is 1. This provides a good initial value for further optimization.

In open-loop mode, the scaling factor can be changed because, here, the cylinder stroke is not available.

P-Gain Parameter "P-0-2845.0.1, Force controller P-gain" is used to set the proportional behavior of the controller. Parameter "P-0-2846.0.1, Correction value: force controller P-gain" is used to display the proportional component of the force controller.

Integrator Despite P-gain optimization, there may still be a residual deviation caused by disturbance variables or offsets. This deviation can be corrected by the integrator.

The integrator is set with the following parameters:

- P-0-2845.0.5, Force controller accuracy window integrator
- P-0-2845.0.4, Force controller integrator enable force change window
- P-0-2845.0.3, Force controller accuracy window integrator

The data in **"Force controller integrator enable force change window"** and **"Force controller accuracy window integrator"** can be used to define the integrator switch-on condition. The integrator will not be connected before the specified increase of the **actual force value** is less than the value in enable force change window and the **"force deviation"** is still greater than the value in **"Force controller accuracy window integrator"**. As long as the integrator is in engagement, **bit 2 "Switch-on condition integrator is valid"** becomes true and is set to **"TRUE"** by the **status word**.

If the **control difference** is within the desired accuracy window, the I-component is stopped to avoid any oscillation of the drive around the command value.

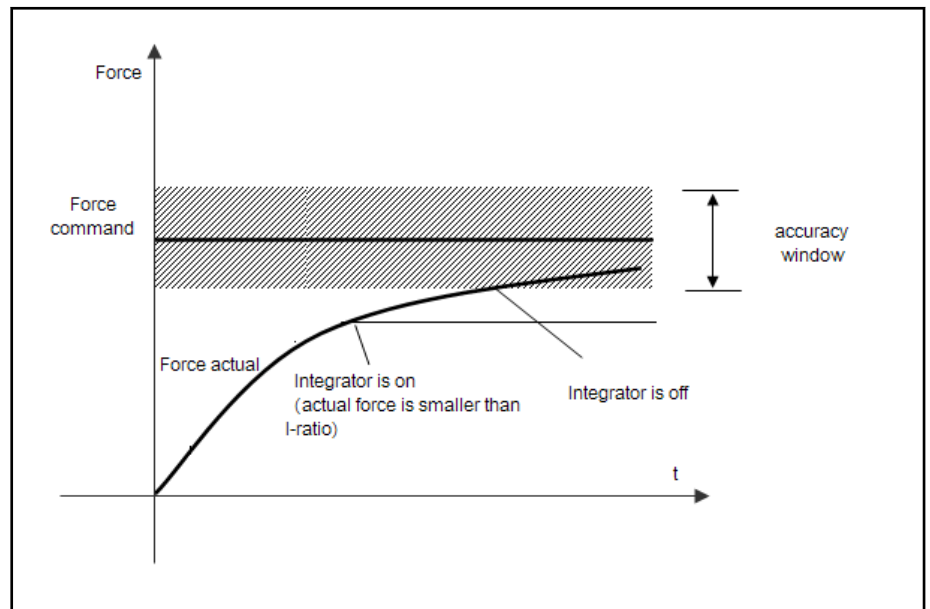


Fig.6-18: Integrator

Parameter **"P-0-2846.0.2, Correction value: force controller integrator"** can be limited by parameter **"P-0-2845.0.6, Force controller limitation integrator"** irrespective of the sign.

Velocity Feedforward Parameter **"P-0-2845.0.3, Correction value: force controller velocity feedforward"** is calculated by multiplying parameter **"P-0-2844, Force controller velocity feedforward control"** by parameter **"P-0-2845.0.8, Force controller scaling of velocity feedforward control"**. This is used for drives which are displaced at a measurable velocity acting on the drive from the outside. In this case, the measured velocity value is cyclically assigned to parameter **"P-0-2844, Force controller velocity feedforward control"**. The resulting velocity feedforward component is added to the controller output.

Valve Root Function This function is only relevant for the central controller of MLC (HDS). It takes the load impact effect of the valve into account. Load impact effect means that the amount of oil flowing across the valve with constant valve command

Drive Control

value varies at different load pressures. If this function is selected, the control result is improved when **velocity feedforward control** is selected in connection with varying force command values. The function is activated by setting **bit 15** in the force controller **control word**.

Quadrant Limitation

The quadrant limitation function is activated in the control word as follows:

Bit 1	Bit 2	Function
0	0	Quadrant limitation is deactivated.
0	1	The axis may only reduce the force.
1	0	The axis may only increase the force.
1	1	May not be selected.

Fig.6-19: Quadrant Limitation Setting

As long as quadrant limitation is in engagement, **bit 1** of the status word is set to "TRUE".

Parameters Involved

- S-0-0084, Torque/force feedback value
- P-0-0049, Effective torque/force command value
- P-0-2840, Force controller control word
- P-0-2841, Force controller status word
- P-0-2842, Force control deviation
- P-0-2843, Output of force controller
- P-0-2844, Force controller velocity feedforward control
- P-0-2845.0.1, Force controller P-gain
- P-0-2845.0.2, Normalization of force by velocity
- P-0-2845.0.3, Force controller integration time
- P-0-2845.0.4, Force controller integrator enable force change window
- P-0-2845.0.5, Force controller accuracy window integrator
- P-0-2845.0.6, Force controller limitation integrator
- P-0-2845.0.8, Force controller scaling of velocity feedforward control
- P-0-2845.0.9, Filter time of force feedback value
- P-0-2846.0.1, Correction value: force controller P-gain
- P-0-2846.0.2, Correction value: force controller integrator
- P-0-2846.0.3, Correction value: force controller velocity feedforward
- P-0-2846.0.5, Torque/force feedback value, filtered

6.3.4 Alternating Control

Layout Diagram

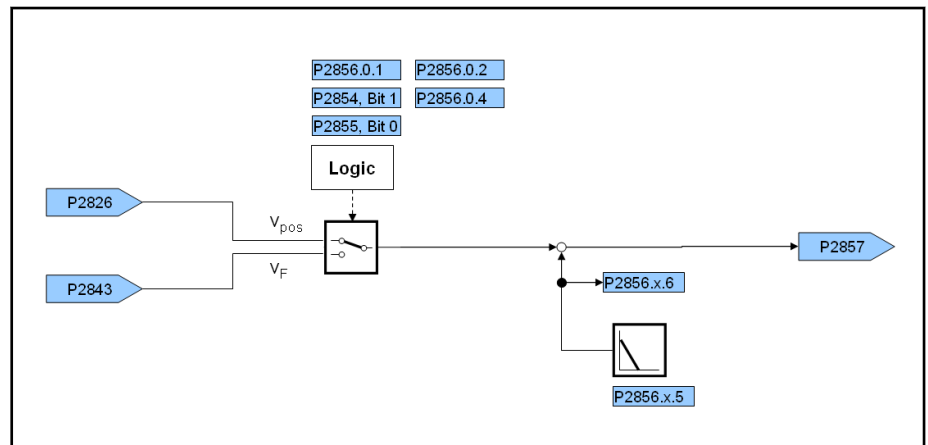


Fig. 6-20: Alternating Control Detail Diagram

Description

The alternating control is used to move an axis in position control mode and simultaneously specify a force limitation. If switchover conditions are fulfilled (see below), the axis automatically switches to force control mode and adjusts to the value specified in "P-0-0049, Torque/force command value of controller". If the switch-back conditions are fulfilled (see below), the axis returns to position control.

Switchover Condition

When switching from position to force control mode, the user can select whether the switchover will be made with a "P-0-2856.0.1, Force controller changeover threshold" or with a "P-0-2856.0.2, Force controller relative changeover window", in relation to the current "P-0-0049, Torque/force command value of controller". The selection of absolute or relative switchover is made via bit 2 in parameter "P-0-2854, Force controller changeover logic control word".

When the "P-0-2856.0.3, Force controller active changeover threshold" is reached, bit 3 or bit 4 respectively of parameter "P-0-2854, Force controller changeover logic control word" is set, and if the adjustable "P-0-2856.0.4, Force controller switch-on logic delay time" is exceeded, the system switches to force control mode. Switchover is made via an adjustable changeover ramp (see below).



Parameter "P-0-2856.0.4, Force controller switch-on logic delay time" is used to suppress pressure peaks in order to prevent an undesired early switchover.

Switch-Back Condition

When the system switches back to position control, the output of the force controller is compared with the output of the position controller. If the "P-0-2826, Output of velocity/status controller" is less than or greater than the "P-0-2843, Output of force controller", the axis moves in positive or negative direction, respectively, and the switch-back disable is deactivated via bit 1 in parameter "P-0-2854, Force controller changeover logic control word", the system switches back to position control mode. If only one direction is allowed by bit 3 and bit 4, the system also switches out of force control mode.

Control / Status Word

Parameter "P-0-2854, Force controller changeover logic control word" can be used to make the following settings.

Drive Control

The respective function is activated with bit = 1:

- **Bit 0:** Activate / deactivate alternating control
- **Bit 1:** Activate / deactivate downshift disable
- **Bit 2:** Absolute switch-on threshold / relative switch-on threshold
- **Bit 3:** Activate / deactivate alternating control in positive direction
- **Bit 4:** Activate / deactivate alternating control in negative direction



When the MLC is used, the alternating control cannot be activated via the control word. This can be achieved by means of application blocks in the TechHydrMotion PLC library.

Parameter "P-0-2855, Force controller changeover logic status word" provides the following information:

- **Bit 0:** Is 1 when the force controller is in engagement
- **Bit 1:** Is 1 as long as the delay time elapses

Changeover Ramp

When there is a switchover between position and force control modes, there may be a control variable jump at the controller output. On switchover between position and force control mode, this is avoided by switching to the respectively active controller output with a defined **"P-0-2856.0.5, Force controller changeover logic ramp time"**. The value is entered in "ms" in relation to the value of **"P-0-2873.0.1, Valve standard velocity"** (corresponding to the maximum control variable value). If the ramp time is set to zero, the ramp is deactivated and switchover takes place immediately.

Parameters Involved

- P-0-2826, Output of velocity/status controller
- P-0-2843, Output of force controller
- P-0-2856.0.1, Force controller changeover threshold
- P-0-2856.0.2, Force controller relative changeover window
- P-0-2854, Force controller changeover logic control word
- P-0-2855, Force controller changeover logic status word
- P-0-2856.0.4, Force controller switch-on logic delay time
- P-0-2856.0.5, Force controller changeover logic ramp time
- P-0-2856.0.6, Correction value: force controller changeover logic ramp

7 Operation Modes

7.1 General Information about Operation Modes

7.1.1 Safety Instructions

WARNING

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

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

7.1.2 Supported Operation Modes



The operation modes supported by the firmware are hardware- and firmware-dependent. They are listed in parameter "S-0-0292, List of supported operation modes" or parameter "A-0-0018".

The following overview shows which basic or function packages support the respective operation mode. It is valid for firmware variant HDB:

Operation mode	Function package
Standard operation modes:	
- Force control	Closed-loop characteristic
- Velocity control	Closed-loop characteristic
- Position control	Closed-loop characteristic
- Valve control	Open-loop characteristic

Fig. 7-1: Supporting operation modes

7.2 Force Control

7.2.1 Brief Description



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

In the "Force control" operation mode, a cyclic force command value is specified for the hydraulic axis in the motion cycle. This command value is fine interpolated in the axis, in the force generator. Intermediate points are calculated before they are transmitted to the force controller in the sercos cycle. The

Operation Modes

force controller and the controlled variable adjustment are described in detail in the chapter "Drive control".

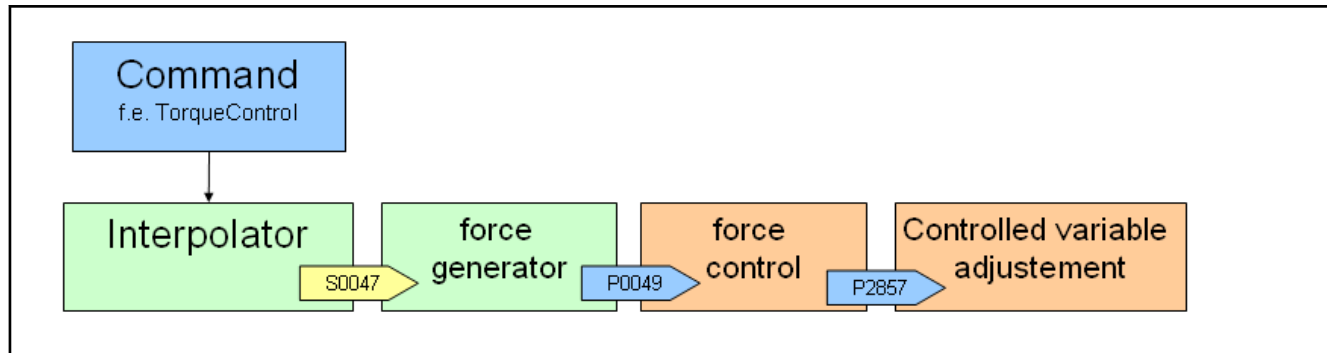


Fig. 7-2: Block diagram "Force control"

- | | |
|----------------------------|---|
| Characteristics | <ul style="list-style-type: none"> Applying the force command values A-0-0156 [interpolated force] of the control interpolator in the motion cycle to parameter "S-0-0080, Force command value" The active force command value (sum of S-0-0080 and S-0-0081 values) is limited to the value specified in "S-0-0092, Force limit value, bipolar" or the parameter "S-0-0082 Force limit value, positive" or "S-0-0083, Force limit value, negative". The smaller limit value - absolute - becomes active. |
| Parameters involved | <ul style="list-style-type: none"> S-0-0080, Force command value S-0-0081, Force command value, additive S-0-0082, Force limit value, positive S-0-0083, Force limit value, negative S-0-0092, Force limit value, bipolar P-0-0049, Active torque/force command value |

7.3 Velocity Control

7.3.1 Brief Description



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

In the "velocity control" operation mode, a cyclic velocity command value is specified for the hydraulic axis in the motion cycle. This command value is fine interpolated in the axis, in the velocity generator. Intermediate points are calculated before they are transmitted to the velocity controller in the sercos cycle.

Operation Modes

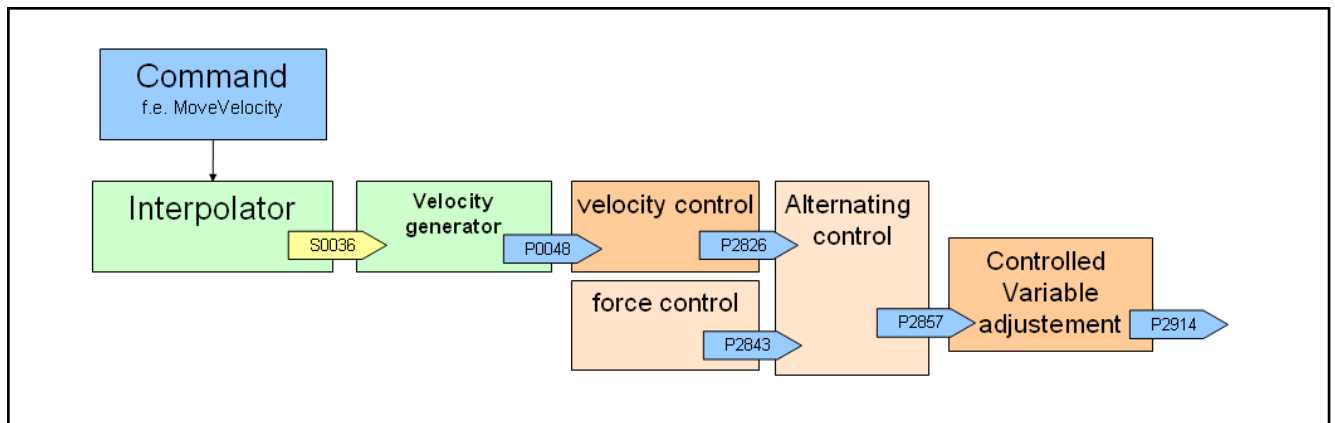


Fig.7-3: Block diagram "Velocity control"



If the alternating control is enabled (e.g. when using a "ForceLimit-On" command), the force controller and the alternating control are also calculated.

Structure image

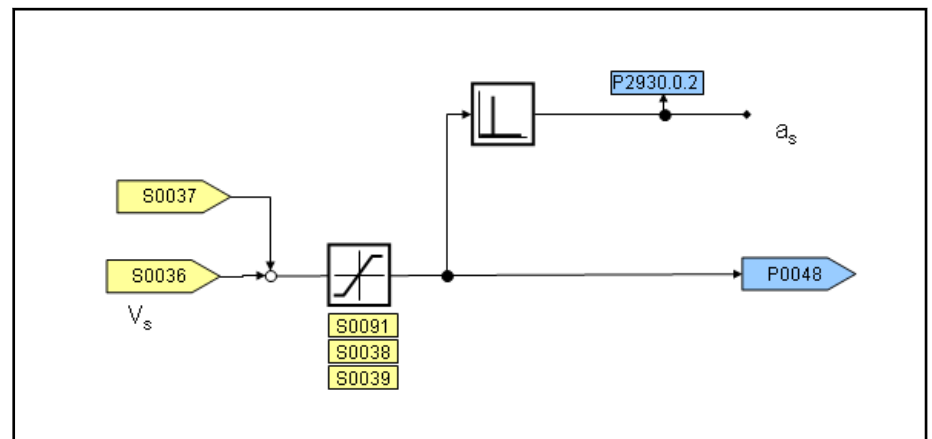


Fig.7-4: Detailed figure of the generator for velocity control

Characteristics

- Applying the velocity command values "A-0-0152 Interpolated velocity value" of the control interpolator in the motion cycle to parameter "S-0-0036 Velocity command value"
- The active force command value (sum of S-0-0080 and S-0-0081 values) is limited to the value specified in "S-0-0091, Velocity limit value, bipolar" or the parameter "S-0-0038 Velocity limit value, positive" or "S-0-0039, Velocity limit value, negative". The absolute smaller limit value becomes active.

Parameters involved

- S-0-0036, Velocity command value
- S-0-0037, Velocity command value, additive
- S-0-0091, Velocity limit value, bipolar
- S-0-0038, Velocity limit value, positive
- S-0-0039, Velocity limit value, negative
- P-0-0048, Effective velocity command value
- P-0-2930.0.2, Feedforward command acceleration

Operation Modes

7.3.2 Alternating Control

It is possible to enable the alternating control in the position control as well as in the velocity control. See chapter "Position Control", "Alternating Control" and Force Controller.

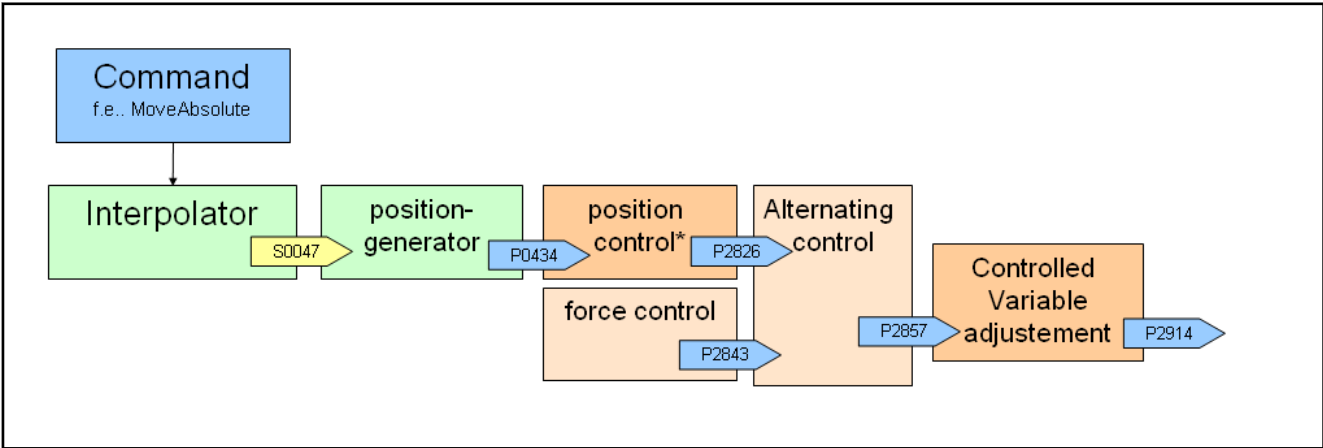
7.4 Position Control

7.4.1 Brief Description



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

In the "position control" operation mode, a cyclic position command value is specified for the hydraulic axis in the motion cycle. This command value is fine interpolated in the axis, in the position generator. Intermediate points are calculated before they are transmitted to the position controller in the sercos cycle.



(*) A subordinate velocity controller can be used in the position controller.
Fig. 7-5: Block diagram of "position control"



If the alternating control is enabled (e.g. when using a "ForceLimit-On" command), the force controller and the alternating control are also calculated.

Structure image

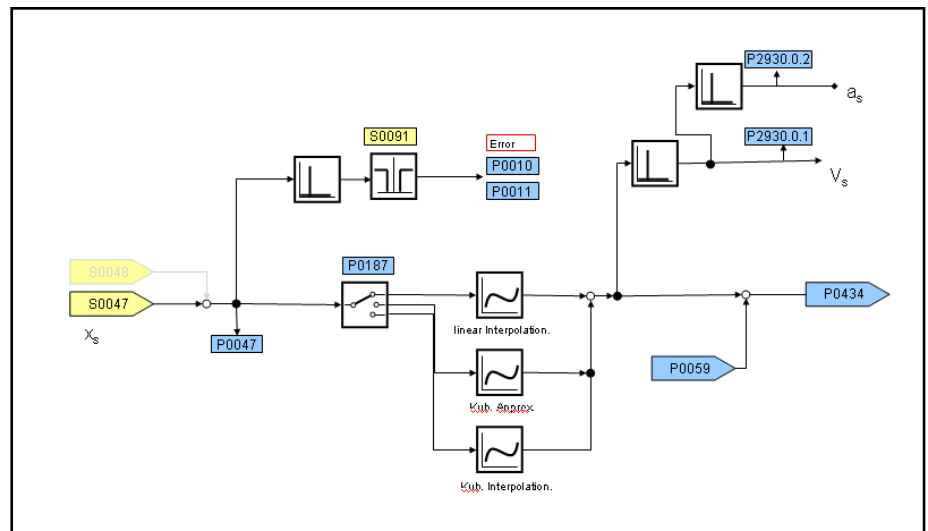


Fig. 7-6: Detailed figure of the generator for position control

Characteristics

- Applying the position command values "A-0-0150 Interpolated position" of the control interpolator in the motion cycle to parameter "S-0-0047 Position command value"
- Monitoring the position command value difference for exceeding parameter "S-0-0091, Velocity limit value, bipolar"
- Fine interpolation of the position command value of the control to the position controller cycle via "P-0-0187, Position command value processing mode" can be switched

Parameters involved

- S-0-0047, Position command value
- P-0-0047, Position command value control
- S-0-0091, Velocity limit value, bipolar
- P-0-0010, Excessive position command value
- P-0-0011, Last valid position command value
- P-0-0059, Position command value, additive, controller
- P-0-0187, Position command value processing mode
- P-0-0434, Position command value controller
- P-0-2930.0.1, Feedforward command velocity
- P-0-2930.0.2, Feedforward command acceleration

Diagnostics involved

- F2037 Excessive position command difference

7.4.2 Alternating Control

A "jerk-free transition" from position control to force control is required for the majority of hydraulic applications. The "jerk-free transition" is achieved by means of the "alternating control".

For this use case, force and position controller are calculated simultaneously. Using the "alternating control", it is switched between both controllers. The position command value continues to be calculated by the interpolator of the control. Parallely, the force command value is calculation via a function block (e.g. ForceLimitOnR) and is transmitted to the force controller.

The blocks "force controller" and "alternating control" are described in detail in the chapter [6 Drive control, page 37](#).

Operation Modes

7.5 Valve Control

7.5.1 Brief Description



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

In the "valve direct control" operation mode, a cyclic valve command value (control value) is specified for the hydraulic axis in the motion cycle. This command value is fine interpolated in the axis, in the "valve generator". Intermediate points are calculated for the sercos cycle.

The axis only traverse open loop-controlled, not closed loop-controlled anymore. This operation mode is only available for hydraulic axes. It is highly recommended for commissioning and service.

The controlled variable adjustment is described in detail in the chapter "Drive Control".

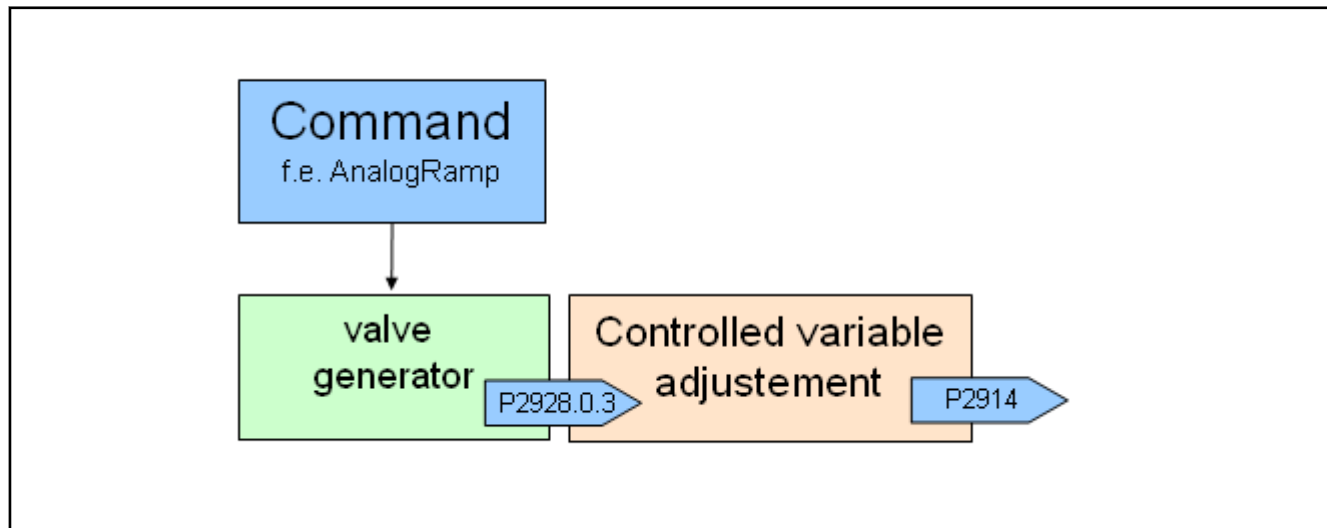


Fig.7-7: Block diagram "Valve control"

Structure image

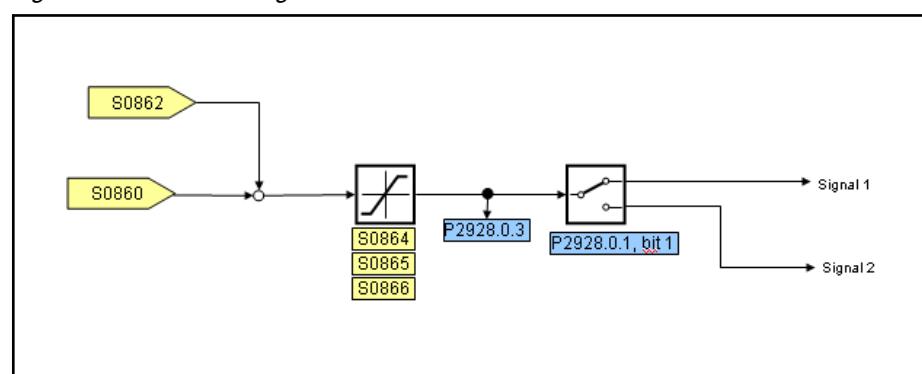


Fig.7-8: Detailed figure of the generator for valve direct control

Characteristics

- The active valve command value (sum of S-0-0860 and S-0-0862 values) is limited to the value specified in "S-0-0864 Valve limit value, bipolar" or the parameter "-0-0865Valve limit value, positive" or "S-0-0866 Valve limit value, negative". The absolute smaller limit value becomes active.

Operation Modes

- The controlled variable adjustment can be skipped in this operation mode. This can be set using parameter "P-0-2913 Valve control word". For decentral axes (e.g.. IAC valve), the controlled variable adjustment is active by default. In case of central axis, the adjustment is not active, as the value is provided at the output and can be verified.
- Parameters involved**
- S-0-0860, Valve command value control
 - S-0-0862, Valve command value control, additive
 - S-0-0864, Valve limit value, bipolar
 - S-0-0865, Valve limit value, positive
 - S-0-0866, Valve limit value, negative
 - P-0-2928.0.3, Active valve command value
 - P-0-2928.0.1, Valve generator control word

8 Extended Axis Functions

8.1 Safety Instructions

WARNING

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

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

8.2 Error Reactions

Regular errors - Closed loop-controlled standstill of the axis

(MLC or PlcOpen error)

If a regular error occurs during the control, the axis is set to standstill in a position controlled way, according to the setting "Rapid stop deceleration". Subsequently, the power enable is automatically removed

- Example PlcOpen error: The axis is set to standstill during an active "MoveAbsolute"
- Generally, all MLC errors with an error code greater than or equal to F2xxxxxx

Fatal errors - Open loop-controlled standstill of the axis

(Errors detected in the controller)

In case of fatal errors, the active operation mode (cyclic position, cyclic velocity, etc.) is exited immediately and it is switched to state "DriveStop". In this state, the drive is set to standstill via an emergency ramp or set to standstill immediately if this option is selected (see "P-0-2928.0.8, Valve command value emergency ramp"). The operation mode is set to standstill by an open loop specification of the valve command value, until the valve standstill value is reached. An axis error is reported to the MLC. The MLC stops the axis.

The following errors results in the mentioned error reaction:

- F2028 Excessive control deviation
- F2037 Excessive position command value difference
- F2270 Analog input 1 or 2, wire break
- F8022 Encoder 1: Incorrect encoder signals
- F8042 Error Encoder 2: Incorrect signal amplitude
- F8079 Velocity limit value exceeded

Extended Axis Functions

8.3 Valve Monitoring

Structure image

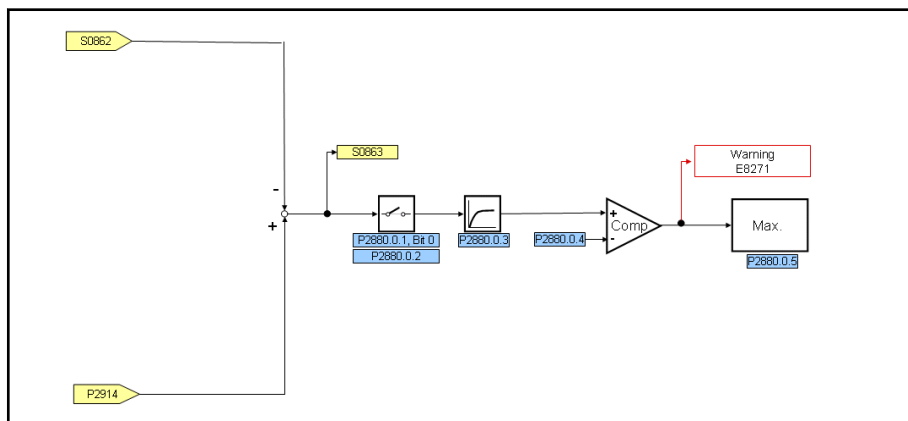


Fig. 8-1: Structure image for valve monitoring

Functional Description

The valve monitoring is used as a "Condition Monitoring". It displays the deterioration of the valve behavior via the HMI. In case of a total valve failure, the excessive actual value difference causes a shutdown. In case of critical systems, the state can be analyzed in the application and can be used for a closed loop-controlled shutdown or to lock the start-up.

Monitoring precondition: The valve requires an electric feedback of the piston position. The position has to be transmitted to the MLC. The wizard facilitates creating a central axis for signal assignment. The actual valve value can be read out in parameter "S-0-0862, Actual valve value". The actual valve value monitoring is enabled using parameter "P-0-2880.0.1, Control word valve monitoring".

The filtered difference between "P-0-2914, Valve command value" and "S-0-0862, Actual valve value" is monitored. The filter time, "P-0-2880.0.3, Valve monitoring filter time" has to be set according to the valve delay time. Warning E8271 is output in case of a deviation greater than "P-0-2880.0.4, Valve monitoring threshold".

In "P-0-2880.0.5, Valve monitoring, maximum valve error", the maximum valve error can be read out. This value can be reset. Once the value has been determined again, it can be used as benchmark to set the threshold. In "S-0-0863 Valve control deviation", the current valve control deviation can be monitored without filter.

9 Service and Support

Our worldwide service network provides an optimized and efficient support. Our experts offer you advice and assistance should you have any queries. You can contact us **24/7**.

Service Germany

Our technology-oriented Competence Center in Lohr, Germany, is responsible for all your service-related queries for electric drive and controls.

Contact the **Service Helpdesk & Hotline** under:

Phone:	+49 9352 40 5060
Fax:	+49 9352 18 4941
E-mail:	service.svc@boschrexroth.de
Internet:	http://www.boschrexroth.com

Additional information on service, repair (e.g. delivery addresses) and training can be found on our internet sites.

Service worldwide

Outside Germany, please contact your local service office first. For hotline numbers, refer to the sales office addresses on the internet.

Preparing information

To be able to help you more quickly and efficiently, please have the following information ready:

- Detailed description of malfunction and circumstances resulting in the malfunction
- Type plate name of the affected products, in particular type codes and serial numbers
- Your contact data (phone and fax number as well as your email address)

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