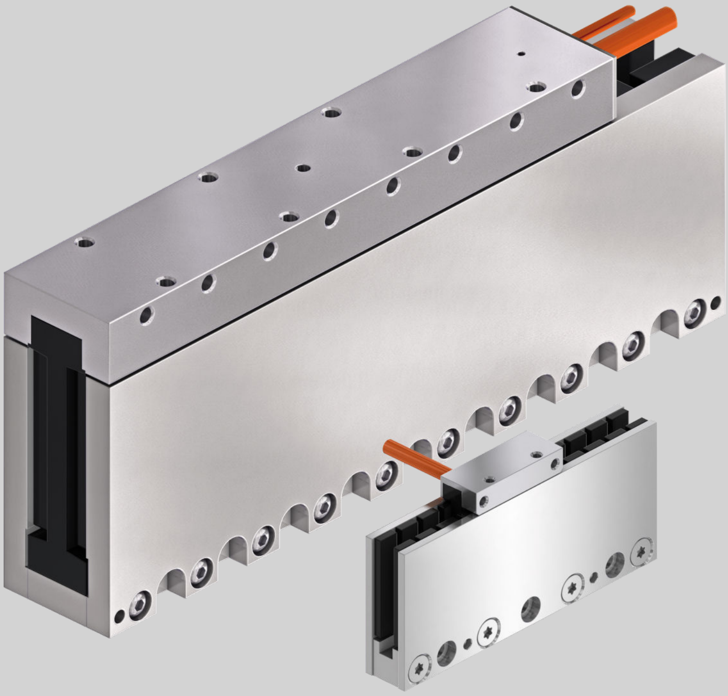
MCL

Ironless Linear Motors

Project Planning Manual
R911330592

Edition 06



Title	MCL Ironless Linear Motors
Type of Documentation	Project Planning Manual
Document Typecode	DOK-MOTOR*-MCL********-PR06-EN-P
Internal File Reference	RS-82551fe8ab5f14650a6846a001697ff3-9-en-US-3

Record of revisions: Edition 06, 2020-06

See tab. 1-1 "Record of revisions" on page 4.

Liability: The specified data is intended for product description purposes only and shall not be deemed to be a guaranteed characteristic unless expressly stipulated in the contract. All rights are reserved with respect to the content of this documentation and the availability of the product.

Note: This document has been printed on chlorine-free bleached paper.

Table of Contents

Page

Page

Page

1 Introduction to the product

1.1 Fields of application

Continuously increasing demands on the economic benefit of electric machines require new problem-solving approaches to fulfill the requirements on dynamic, accuracy and synchronization. Conventional NC-drives, consisting of a rotary electrical motor and mechanical transmission elements like gearboxes, belt transmissions or gear rack pinions, cannot fulfill these demands or, only with high effort.

Due to the wide application range of ironless linear motors, medium to midget mass can be moved and positioned high-dynamically and high-precisely.

Based on the above-mentioned advantages, typical applications result for example in:

- Electronic, placement technology and manufacturing technology
- Semi-conductor technology (z.B. wafer inspection and bonding)
- Medical technology (e.g. transport of pipettes)
- Solar technology (e.g. laser structuring)
- Precision and ultra-precision machining

Even in other areas, for example, in machine tool industry, printing industry and especially in measuring technology, the advantages of this technology becomes important.

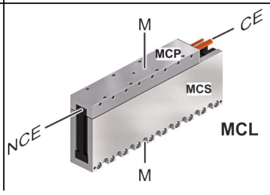
The ironless drive technology offers a lot of significant advantages in opposite to a ferrous motor, without accepting disturbing ancillary effects like cogging. For this reason, it is the optimum option for many applications.

Significant advantages of ironless linear motors are:

- Highest dynamic
- Excellent control quality and synchronization
- No magnetic attractive force, no detent torque
- High-precision positioning behavior
- Direct power transfer – no mechanical transmission elements like ball screw, toothed belt, gear rack, etc.
- High efficiency - low overhead
- Maintenance-free drive (no wearing parts at the motor)
- Simplified machine structure

☞ For a comprehensive overview of all product groups of Bosch Rexroth Electric Drives and Controls, please refer to the online product catalog: http://www.boschrexroth.com/indradyn.

1.2 Basic features

Product	3~ PM motor
Type	MCL consist of MCP and MCS
Ambient temperature during operation	0 … 40 °C
Protection class (EN 60034-5)	IP00 (IP20)
Cooling mode (EN 60034-6)	IC410, Self-cooling
Installation altitude	0 ... 1000 m above MSL (without derating)
Thermal class (EN 60034-1)	130 (B)
Encoder system	**Hall sensor digital** SUP-E01-D15-MCP020 SUP-E01-D30-MCP030/040/070 **Hall sensor analog** SUP-E01-A15-MCP020 SUP-E01-A30-MCP030/040/070
Electrical connection	Connection cable with open cable ends shielded cable (3x power + 1x PE, 2x KTY)
Mechanical protection	Primary part moulded with synthetic resin Magnets of the secondary part coated with synthetic resin
Motor ends	 CE Cable End, *Kabelabgangsseite* NCE Non Cable End, *Nicht-Kabelabgangsseite* M Mounting face, *Montagefläche*

1.3 Setup

Ironless linear motors MCL consist of the components primary and secondary part and have an optional Hall unit .

The ironless primary part bears the electrically active part of the linear motor with a winding, cast in plastics. The primary part carrier made of aluminum serves to assemble the primary part and for heat dissipation out of the primary part. A fastening of an optional Hall unit for position recording is prepared on the primary part. Additionally, a temperature sensor is placed in the winding. Hall unit and temperature sensor are available for all MCL, except for the smalles frame size.

The secondary part consists of an u-shaped iron yoke. The legs of the yoke bear permanent magnets and surround the primary part. The line is built with the secondary parts and can be realized as long as you want.

The motor type designation depends on the ironless primary part. The designation is as follows:

- MCL: Motor Coreless Linear
- MCL: Motor Coreless Primary part
- MCS: Motor Coreless Secondary part

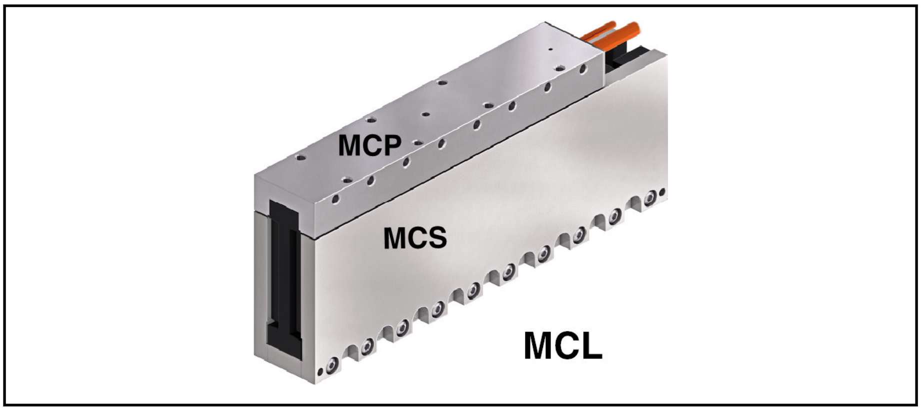


Fig. 1-1: Rexroth MCL example

1.4 Comparison ironless with ferreous linear motors

Ferreous linear motors use the iron, in which the winding is inserted to bundle the magnetic flow. Therewith, a very high force density is reached. Act up to a principle, very high magnetic attractive forces exist among the motor components (primary and secondary part). These lead to detent force and due to saturation effecst to other parasitic effects, such as e.g. winding influences for ripple of the operation force.

No attractive forces exist among primary and secondary part towards ferreous linear motors. Detent forces due to a slotting, existing for ferreous linear motors are also not created. These aspects and the relatively small moved mass of the primary part allow a vergy high dynamic with high precision at the same time.

Additionally wearing mechanical components are not necessary due to direct installation into the machine. Due to not existing mechanical elements, a backlash free, with minimum or without hysteresis afflicted drive train, is available.

1.5 Motor power spectrum

New solutions due to practice-oriented combination of motor technique with digital intelligent drive controllers with ironless linear direct drive technique are available. The spectrum of ironless linear drive technique of Bosch Rexroth realized drives with feed forces of 10 N up to 3,300 N, acceleration up to 250 m/s² and maximum velocity up to 1,400 m/min. The following diagram gives an overview of the performance spectrum :

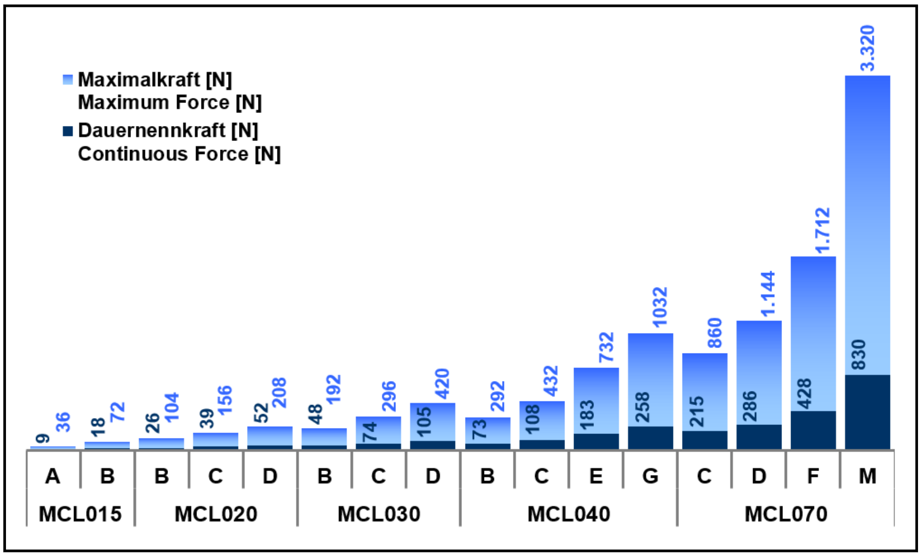


Fig. 1-2: Perfomance spectrum Rexroth MCL

1.6 About this documentation

1.6.1 Editions of this documentation

Edition	Release date	Notes
06	2020-06	Revision / supplement
05	2015-02	Ddetails about parallel arrangement added
04	2014-06	Details about commutation adjustment Chapter 14.6 amended
...	...	...
01	2011-01	First edition

Tab. 1-1: Record of revisions

1.6.2 Document structure

This documentation includes safety-related guidelines, technical data and operating instructions. The following table provides an overview of the contents of this documentation.

<table>
<tr><th>Chapter</th><th>Title</th><th colspan="4">Content</th></tr>
<tr><td>1</td><td>Introduction</td><td colspan="4">Product presentation / Notes regarding reading</td></tr>
<tr><td>2</td><td>Important instructions for use</td><td colspan="4" rowspan="2">Important safety instructions</td></tr>
<tr><td>3</td><td>Safety</td></tr>
<tr><td>4</td><td>Technical data</td><td rowspan="8">Product description</td><td rowspan="8">for planners and designers</td><td></td><td></td></tr>
<tr><td>5</td><td>Specifications</td><td></td><td></td></tr>
<tr><td>6</td><td>Type codes</td><td></td><td></td></tr>
<tr><td>7</td><td>Accessories</td><td rowspan="8">Practice</td><td rowspan="8">for operating and maintenance personnel</td></tr>
<tr><td>8</td><td>Connection technique</td></tr>
<tr><td>9</td><td>Operating condition and application instructions</td></tr>
<tr><td>10</td><td>Motor-control combination</td></tr>
<tr><td>11</td><td>Motor dimensioning</td></tr>
<tr><td>12</td><td>Handling, transport and storage</td><td></td><td></td></tr>
<tr><td>13</td><td>Installation</td><td></td><td></td></tr>
<tr><td>14</td><td>Startup, operation and maintenance</td><td></td><td></td></tr>
<tr><td>15</td><td>Service & Support</td><td colspan="4" rowspan="2">Additional information</td></tr>
<tr><td>16</td><td>Index</td></tr>
</table>

Tab. 1-2: Chapter structure

1.6.3 Information presentation

Safety instructions

The safety instructions in this documentation include signal words (danger, warning, caution, note) and a signal symbol (acc. to ANSI Z535.6-2006).

The signal word is intended to draw your attention to the safety instructions and describes the seriousness of the danger. The warning triangle with exclamation mark indicates the danger for persons.

⚠ DANGER

Non-compliance with this safety instructions **will** result in death or severe personal injury.

⚠ WARNING

Non-compliance with this safety instructions **can** result in death or severe personal injury.

⚠ CAUTION

Non-compliance with this safety instructions **can** result in moderate or minor personal injury.

NOTICE

Non-compliance with this safety instructions **can** result in material damage.

Safety symbols

The following internationally standardized safety symbols and graphic symbols are used in this documentation. The meaning of the symbols is described in the table.

Safety symbols	Meaning
	Warning against dangerous electric voltage
	Warning against hot surfaces
	Warning against overhead load
	Electrostatic sensitive devices
	No access for persons with cardiac pacemakers or implanted defibrillators.
	Do not carry along metal parts or clocks.

Tab. 1-3: Meaning of safety signs

Markup

The following markups are used for a user-friendly text information representation:

Reference to supplementary documentation

This note gives important information, which must be observed.

- Listings on the first level contain a bullet point
  – Listings on the second level contain a dash

1. Handling instructions are specified in numbered lists. Please comply with the order of the handling instructions.

1.6.4 Further documentation

To plan the drive-systems with MCL motors, it is possible that you need additional documentation referring the used devices. Rexroth provides the complete product documentation in PDF format in the following Bosch Rexroth media directory:

http://www.boschrexroth.com/various/utilities/mediadirectory/index.jsp

1.6.5 Standards

This documentation refers to German, European and international technical standards. Documents and sheets on standards are subject to copyright protection and may not be passed on to third parties by Rexroth. If need be, please contact the authorized sales outlets or, in Germany, directly:

BEUTH Verlag GmbH

Burggrafenstraße 6

10787 Berlin, Germany

Tel. +49 (0)30-26 01-22 60

Fax +49 (0)30-26 01-12 60

Internet: http://www.din.de/beuth

E-Mail:postmaster@beuth.de

1.6.6 Additional components

Documentation for external systems which are connected to Bosch Rexroth components are not included in the scope of delivery and must be ordered directly from the corresponding manufacturers.

1.6.7 Your feedback

Your experiences are an essential part of the improvement process of product and documentation.

Please send your feedback to:

Bosch Rexroth AG

Dept. DC-AE/EPI5 (fs, mb)

Buergermeister-Dr.-Nebel-Straße 2

97816 Lohr am Main, Germany

E-Mail: dokusupport@boschrexroth.de

2 Important instructions on use

2.1 Appropriate use

2.1.1 Introduction

Bosch Rexroth products are designed and manufactured using the latest state-of-the-art-technology. Before shipping, all products are checked for safety.

However, the products may only be used in compliance with their appropriate use. If they are not used as intended, property damage and personal injury may occur.

☞ Bosch Rexroth, as the manufacturer, does not provide any warranty, assume any liability, or pay any damages for damage caused by products not being used as intended. Any risks resulting from the products not being used as intended are the sole responsibility of the user.

Before using the products by Bosch Rexroth, the following condition precedent must be fulfilled so as to ensure that they are used as intended:

- Personnel that in any way uses our products must first read and understand the relevant safety instructions and be familiar with their appropriate use.
- Hardware products must be left in their original condition, i.e. no structural changes may be made. Software products must not be decompiled and their source code must not be changed.
- Damaged or defective products must not be installed or put into operation.
- It must be ensured that products are installed in compliance with all regulations specified in the documentation.

2.1.2 Areas of use and application

Ironless linear motors MCL of Bosch Rexroth are intended for use as linear servo drive motors.

For application-specific use of motors, drive controllers with various levels of power, DC bus voltage and different interfaces are available. For regulation and controlling of motors, additional sensors like length measuring systems must be connected.

☞
- The motors may only be used with the accessories and attachments specified in this documentation. Components that are not explicitly specified must not be installed nor connected. The same applies for cables and lines.
- The device may only be operated in the explicitly specified configurations and combination of components and in compliance with the respective functional description of the software and firmware.

Before commissioning, every connected drive controller must be programmed according to the specified motor function for the specified application.

The motors may only be operated under the assembly, mounting and installation conditions, in the normal position, and under the environmental conditions (temperature, degree of protection, humidity, EMC etc.) specified in this documentation.

2.2 Inappropriate use

Any use of motors outside of the fields of application mentioned above or under operating conditions and technical data other than those specified in this documentation is considered as "non-intended use".

MCL motors may not be used if

- they are exposed to operating conditions that do not meet the specified ambient conditions. For example, they may not be operated under water, under extreme temperature fluctuations or extreme maximum temperatures;
- the intended application range is not explicitly approved for Bosch Rexroth motors.

☞ MCL motors are not suited to be operated directly on the power supply.

3 Safety instructions for electric drives and controls

3.1 Definitions of terms

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

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

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

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

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

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

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

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

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

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

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

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

- to be trained, instructed or authorized to switch electric circuits and devices safely on and off, to ground them and to mark them.
- to be trained or instructed to maintain and use adequate safety equipment.
- to attend a course of instruction in first aid.

Qualified personnel for handling functionally safe products

Individuals configuring, commissioning and operating functionally safe products must have the knowledge specified under "Qualified persons". Additionally, these individuals must be familiar with technical safety concepts as well as prevailing standards and regulations in the field of functional safety.

User

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

3.2 General information

3.2.1 Using the Safety instructions and passing them on to others

Do not attempt to install and operate the components of the electric drive and control system without first reading all documentation provided with the product. Read and understand these safety instructions and all user documentation prior to working with these components. If you do not have the user documentation for the components, contact your responsible 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 follow the safety instructions in this document or tampering with the product, including disabling of safety devices, could result in property damage, injury, electric shock or even death.

3.2.2 Requirements for safe use

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

- Bosch Rexroth is not liable for damages resulting from failure to observe the safety instructions.
- Read the operating, maintenance and safety instructions in your language before commissioning. If you find that you cannot completely understand the application documentation in the available language, please ask your supplier to clarify.
- Proper and correct transport, storage, mounting and installation, as well as care in operation and maintenance, are prerequisites for optimal and safe operation of the component.
- Only qualified persons may work with components of the electric drive and control system or within its proximity.
- Only use accessories and spare parts approved by Bosch Rexroth.
- Follow the safety regulations and requirements of the country in which the components of the electric drive and control system are operated.

- Only use the components of the electric drive and control system in the manner that is defined as appropriate. See chapter "Appropriate Use".
- The ambient and operating conditions given in the available application documentation must be observed.
- Applications for functional safety are only allowed if clearly and explicitly specified in the application documentation "Integrated Safety Technology". If this is not the case, they are excluded. Functional safety is a safety concept in which measures of risk reduction for personal safety depend on electrical, electronic or programmable control systems.
- The information given in the application documentation with regard to the use of the delivered components contains only examples of applications and suggestions.

  The machine and installation manufacturers must

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

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

National regulations which the user has to comply with

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

3.2.3 Hazards by improper use

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

- High electrical voltage by incorrect connection! Danger to life or injury by electric shock!
- Dangerous movements! Danger to life, serious injury or property damage by unintended motor movements!
- Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electric drive systems!
- Risk of burns by hot housing surfaces!
- Risk of injury by improper handling! Injury by crushing, shearing, cutting, hitting!
- Risk of injury by improper handling of batteries!
- Risk of injury by improper handling of pressurized lines!

3.3 Instructions with regard to specific dangers

3.3.1 Protection against contact with electrical parts and housings

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

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

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

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

  Always wait **30 minutes** after switching off power to allow live capacitors to discharge before accessing an electric component. Measure the electrical voltage of live parts before beginning to work to make sure that the equipment is safe to touch.
- Install the covers and guards provided for this purpose before switching on.
- Never touch any electrical connection points of the components while power is turned on.

- Do not remove or plug in connectors when the component has been powered.
- Under specific conditions, electric drive systems can be operated at mains protected by residual-current-operated circuit-breakers sensitive to universal current (RCDs/RCMs).
- Secure built-in devices from penetrating foreign objects and water, as well as from direct contact, by providing an external housing, for example a control cabinet.

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

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

Cross section outer conductor	Minimum cross section equipment grounding conductor Leakage current ≥ 3.5 mA	
	1 equipment grounding conductor	2 equipment grounding conductors
1.5 mm² (16 AWG)	10 mm² (8 AWG)	2 × 1.5 mm² (16 AWG)
2.5 mm² (14 AWG)		2 × 2.5 mm² (14 AWG)
4 mm² (12 AWG)		2 × 4 mm² (12 AWG)
6 mm² (10 AWG)		2 × 6 mm² (10 AWG)
10 mm² (8 AWG)		-
16 mm² (6 AWG)	16 mm² (6 AWG)	-
25 mm² (4 AWG)		-
35 mm² (2 AWG)		-
50 mm² (1/0 AWG)	25 mm² (4 AWG)	-
70 mm² (2/0 AWG)	35 mm² (2 AWG)	-
...	...	...

Tab. 3-1: Minimum cross section of the equipment grounding connection

3.3.2 Protective extra-low voltage as protection against electric shock

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

On components of an electric drive and control system provided by Bosch Rexroth, all connections and terminals with voltages up to 50 volts are PELV

("Protective Extra-Low Voltage") systems. It is allowed to connect devices equipped with basic insulation (such as programming devices, PCs, note-books, display units) to these connections.

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

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

3.3.3 Protection against dangerous movements

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

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

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

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

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

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

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

To avoid accidents, injury and/or property damage:

- Keep free and clear of the machine’s range of motion and moving machine parts. Prevent personnel from accidentally entering the machine’s range of motion by using, for example:
  - Safety fences
  - Safety guards
  - Protective coverings
  - Light barriers

- Make sure the safety fences and protective coverings are strong enough to resist maximum possible kinetic energy.
- Mount emergency stopping switches in the immediate reach of the operator. Before commissioning, verify that the emergency stopping equipment works. Do not operate the machine if the emergency stopping switch is not working.
- Prevent unintended start-up. Isolate the drive power connection by means of OFF switches/OFF buttons or use a safe starting lockout.
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- Additionally secure vertical axes against falling or dropping after switching off the motor power by, for example,
  - mechanically securing the vertical axes,
  - adding an external braking/arrester/clamping mechanism or
  - ensuring sufficient counterbalancing of the vertical axes.
- The standard equipment **motor holding brake** or an external holding brake controlled by the drive controller is **not sufficient to guarantee personal safety**!
- Disconnect electrical power to the components of the electric drive and control system using the master switch and secure them from reconnection ("lock out") for:
  - Maintenance and repair work
  - Cleaning of equipment
  - Long periods of discontinued equipment use
- Prevent the operation of high-frequency, remote control and radio equipment near components of the electric drive and control system and their supply leads. If the use of these devices cannot be avoided, check the machine or installation, at initial commissioning of the electric drive and control system, for possible malfunctions when operating such high-frequency, remote control and radio equipment in its possible positions of normal use. It might possibly be necessary to perform a special electromagnetic compatibility (EMC) test.

3.3.4 Protection against electromagnetic and magnetic fields during operation and mounting

Electromagnetic and magnetic fields!

Health hazard for persons with active implantable medical devices (AIMD) such as pacemakers or passive metallic implants.

- Hazards for the above-mentioned groups of persons by electromagnetic and magnetic fields in the immediate vicinity of drive controllers and the associated current-carrying conductors.
- Entering these areas can pose an increased risk to the above-mentioned groups of persons. They should seek advice from their physician.
- If overcome by possible effects on above-mentioned persons during operation of drive controllers and accessories, remove the exposed persons from the vicinity of conductors and devices.

3.3.5 Protection against contact with hot parts

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

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

3.3.6 Protection during handling and mounting

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

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

3.3.7 Battery safety

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

Risk of injury by improper handling!

- Do not attempt to reactivate low batteries by heating or other methods (risk of explosion and cauterization).
- Do not attempt to recharge the batteries as this may cause leakage or explosion.
- Do not throw batteries into open flames.
- Do not dismantle batteries.

- When replacing the battery/batteries, do not damage the electrical parts installed in the devices.
- Only use the battery types specified for the product.

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

3.3.8 Protection against pressurized systems

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

Risk of injury by improper handling of pressurized lines!

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

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

3.4 Explanation of signal words and the Safety alert symbol

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

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

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

⚠ DANGER

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

⚠ WARNING

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

⚠ CAUTION

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

NOTICE

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

4 Technical data

4.1 Explanations about technical data

4.1.1 Introduction

All relevant technical motor data as well as the functional principle of this motors are provided on the following pages in terms of tables and characteristic curves. The following dependencies are taken into consideration:

- Frame size and frame length of the primary part
- Winding design primary part
- Available power connection or DC bus voltage

☞ All specified data and characteristic curves refer to the following conditions, unless otherwise specified:

- Self-cooling
- Installation mode B acc. to Tab. 9-12 on page 131
- Keeping installation tolerances acc. tochapter 5.1 "Specifications" on page 45
- Keeping ambient temperatures acc. to chapter 9.3 "Installation altitude and ambient conditions" on page 100
- Motor winding temperature ≤110 °C

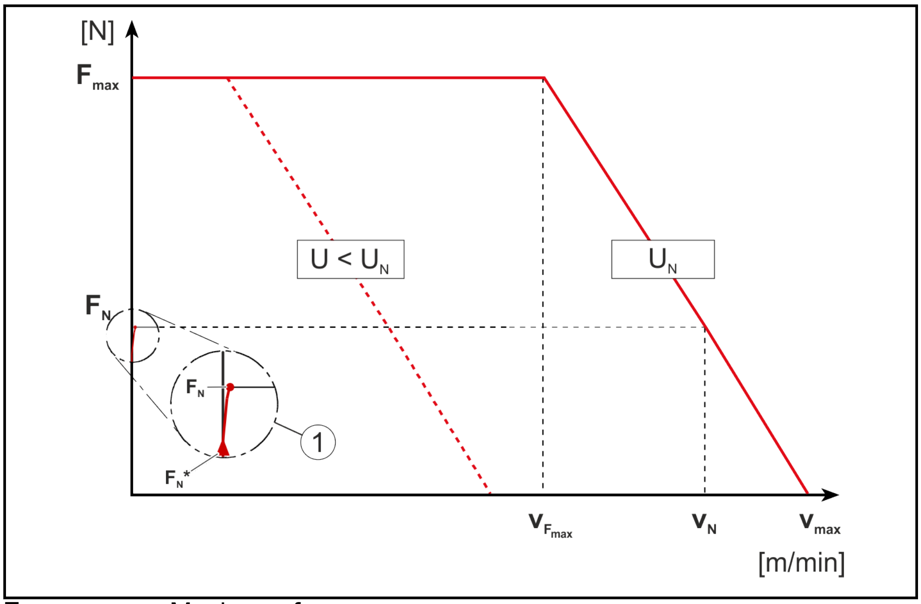
☞ Specified values in the data sheet are effective values according to DIN EN 60034-1. The reference value is a maximum DC bus voltage of 300 V_{DC} at MCP020 ... 070 or 48V_{DC} for MCP015. Resulting data from special motor-controller combinations may differ from this specified data.

☞ All relationships and data described in the following sections may only apply if exclusively primary and secondary parts of the same size are combined (e.g. MCP015 with MCS015).

4.1.2 Operating behavior

The characteristic curve “force over speed” is specified as a characteristic curve The basic parameters and the run of the characteristic curve is defined by the height of the intermediate circuit voltage and by the corresponding motor specific data, like e.g. inductivity, resistance, force constant and so on. By varying the intermediate circuit voltage (different controllers or supply modules and connection voltages) and different motor windings result in different characteristics result.

Furthermore, a continuous force characteristic curve F_N for installation mode B (good thermal connection) is shown. The installation modes are described in Chapter 9.22 .



F_{max}	Maximum force
F_N	Continuous nominal force
F_N*	To avoid damaged winding in standstill operation, limit the current or the operation duration.
v_{Fmax}	Maximum velocity at maximum force
v_N	Nominal velocity
v_{max}	Maximum velocity
U_N	DC bus voltage 300 V_{DC}
①	When using the motor in this operating range, observe information specified in chapter 9.23 .

Fig. 4-1: Example motor characteristic curve

☞ For deviating connection or DC bus voltages, the specified characteristic curves can be converted – in linear form – according to the existing voltages.

The maximal force F_{max} is available up to speed v_{Fmax}. There, the specified voltage limit is reached due to the DC bus voltage. However, during increasing velocity, the induced voltage of the motor increases. This leads to a velocity-dependend reduced maximum force, as the motor control voltage will be reduced due to the constant DC bus voltage.

The continuous nominal force F_N is available up to nominal velocity v_N.

The maximum velocity v_{max} is the maximum reachable motor velocity at appropriate U_{DC} up to approximately F_N = 0 N.

☞ The reachable motor data are significantly dependent from the thermal coupling of the motor onto the machine (power loss dissipation) and from the used drive controller. The reference quantity for details of technical data and the presentation of the motor characteristic curves is an uncontrolled DC bus voltage of 300 V_{DC} from MCP020 up to MCP070 or 48 V_{DC} for MCP015.

You will find additional notes about thermal coupling under Chapter 9.22 .

Notes about standstill operation in Chapter 9.23 .

Parallel operation of two primary parts on a drive controller

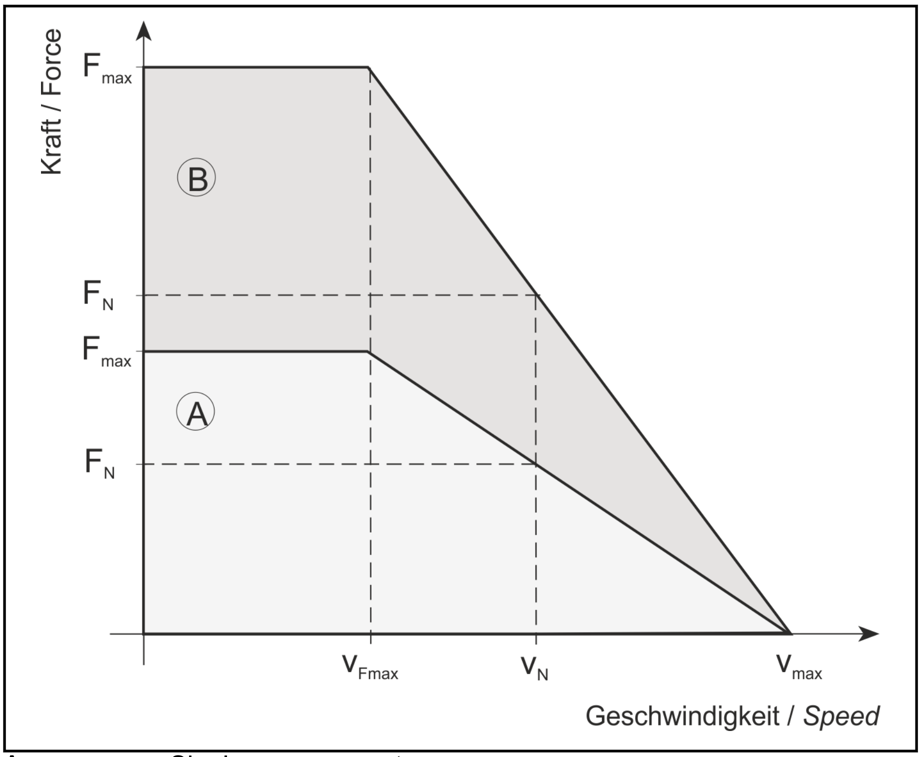
☞ It is only allowed to connect primary parts parallel, which features are identical. Usually this is only the case with identically constructed types.

In the following is spoken of "identical" primary parts.

- Same force constant K_{FN} or voltage constant K_{EMK}
- Same winding resistance R_{12}
- Same winding inductivity L_{12}

The following interrelations exist for the parallel connection of two identical primary parts at one drive controller (see Fig. 4-2):

- Doublication of the feed force of the axis in the case of same current in each primary part (it not limited by the drive controller).
  $F_{total} = 2 \times F_{Motor}$
- Doublication of the voltage within the drive controller (if not limited by it)
  $I_{Inverter} = 2 \times I_{Motor}$
- Velocity v_{Fmax}, v_N and v_{max} as for single arrangement
  $v_{Fmax,total} = v_{Fmax,Motor}$ / $v_{N,total} = v_{N,Motor}$ / $v_{max,total} = v_{max,Motor}$
- Same motor and voltage constant (K_{FN}, K_{EMK})
  $K_{FN,total} = K_{FN,Motor}$ / $K_{EMK,total} = K_{EMK,Motor}$
- Total motor resistance and inductivity halved
  $R_{12,total} = 1/2 \times R_{12,Motor}$ / $L_{12,total} = 1/2 \times L_{12,Motor}$



A Single arrangement
B Parallel arrangement

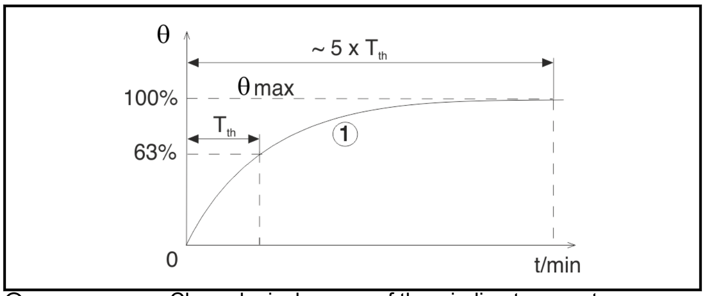
Fig. 4-2: Characteristics force over velocity at single or parallel arrangment of two primary parts on one controller

☞ For parallel connection of two primary parts at one drive controller, relevant motor parameters for start-up are specified in this documentation (see Kapitel 14.4.3 on page 170).

4.1.3 Description of specified sizes

☞ The PWM-Frequency of the drive controller affects the resulting motor data. All data in this documentation refer to a PWM-Frequency of 4 kHz.

Characteristics for primary parts MCL

Designation	Symbol	Unit	Toler-ance	Description
Maximum force	F_{max}	N	± 5 %	Maximum force at maximum current I_{max}. The force that can be reached depends on the drive control device used.
Continuous nominal force	F_N	N	± 5 %	Available continuous nominal force of the motor up to v_N at nominal current I_N.
Maximum current	I_{max}	A		Maximum current of the motor at F_{max}.
Rated current	I_N	A		Rated current of the motor at continuous nominal force F_N.
Reference voltage DC bus voltage	U_{DC}	V		Reference voltage of intermediate circuit for determination of the winding velocity.
Maximum velocity at F_{max}	v_{Fmax}	m/min		Maximum velocity at maximum force F_{max}. The velocity reached depends on the DC bus voltage of the used drive control device.
Nominal velocity	v_N	m/min		Velocity, up to continuous nominal force F_N of the motor is available.
Force constant	K_{FN}	N/A	± 5 %	Relation of force increase to increase of force-creating current. Due to the principle of an ironless primary part, no saturation effects occur. Therewith, the constant is not current-dependent.
Voltage constant at 20 °C	K_{EMK}	Vs/m	± 5 %	Induced motor voltage depending from the travel velocity relating on velocity 1 m/s at 20°C.
Winding resistance at 20 °C	R_{12}	Ω		Measured winding resistance among two strands at 20 °C.
Winding inductivity	L_{12}	mH		Measured winding inductivity between two strands. The defined measuring values are fluctuating due to boundary effects. These details are typical values, which are determined with a measuring current of 1 mA at a measuring frequency of 1 kHz.
Winding inductivity	$L_{23/31}$	mH		Measured winding inductivity among two strands (strand 2/3 or 3/1). Due to fringe effects, the specified measured values are different to L_{12}. These details are typical values, which are determined with a measuring current of 1 mA at a measuring frequency of 1 kHz.
Rated power loss	P_{VN}	W		Power loss in operation mode S1 (continuous operation) at nominal velocity v_N.
Pole width	τ_P	mm		Distance dimension of pole center to pole center of the magnets on the secondary part.
Thermal time constant	T_{th}			Duration of temperature rise to 63% of the final temperature of the winding at natural convection and load with continuous nominal force in S1-operation.  ① Chronological course of the winding temperature **θ_{max}** Max. winding temperature **T_{th}** Thermal time constant *Fig. 4-3: Thermal time constant*
Mass primary part	m_P	kg		Mass of primary part

Characteristics for secondary parts MCS

Designation	Symbol	Unit	Tolerance	Description
Mass secondary part	m_S	kg		Mass secondary part m_S.
	m_{S_rel}	kg/m		Relative mass of the secondary part relating on 1 m length.

4.2 IndraSize

By using the IndraSize software, drive controllers, motors and mechanic gearboxes can be easily sized. The engineering tool covers the entire range of Rexroth drives and motors. Calculate the characteristic curves for your application by using the sizing and calculation tool IndraSize: www.boschrexroth.com/IndraSize

4.3 General technical data

The data specified in Tab. apply for all motor sizes. In this context, however, the comments on the individual items in Chapter “Application notes” must be observed.

Designation	Symbol	Unit	MCPxxx	MCSxxx
Maximum allowed DC bus voltage MCP015	U_{DC}, max	V	72	/
Maximum allowed DC bus voltage MCP020 ... 070			420	
Ambient temperature in operation (see also chapter 9.3 "Installation altitude and ambient conditions" on page 100)	T_{amb}	°C	0 ... +40	
Allowed transport temperature (see also chapter 12.3.1 "Notes about transport" on page 156)	T_T	°C	-20 ... +80	
Allowed storage temperature (see also chapter 12.3.2 "Information on storage" on page 157)	T_L	°C	-25 ... +55	
Thermal class acc. to DIN EN 60034-1	-	-	130 (B)	/
Warning temperature (winding) (See auch chapter 9.10 "Motor temperature monitoring" on page 107)	T_{warn}	°C	110	/
Shutdown temperature (winding) (see also chapter 9.10 "Motor temperature monitoring" on page 107)	T_{abst}	°C	130	/
Degree of protection MCP and MCS according to DIN EN 60034-5	-	-	IP00 (IP20 for front surface of MCP020 ... 070)	
RoHS conformity according to EC guidelines 2011/65/EG	-	-	RoHS conform	
				Latest amendment: 2019-12-16

Tab. 4-1: General technical data

4.4 Frame size 015

4.4.1 Data sheet MCP015

Designation	Symbol	Unit	MCP015	
			A	B
			L040	L040
Maximum force	F_{max}	N	36	72
Continuous nominal force	F_N	N	9	18
Maximum current	I_{max}	A	6.0	12.8
Rated current	I_N	A	1.5	3.2
Reference voltage DC bus voltage	U_{DC}	V	48	
Maximum velocity at F_{max}	v_{Fmax}	m/min	0	
Nominal velocity	v_N	m/min	430	480
Force constant	K_{FN}	N/A	6.0	5.6
Voltage constant at 20 °C	K_{EMK}	Vs/m	3.6	3.2
Winding resistance at 20 °C	R_{12}	Ohm	5.3	2.7
Winding inductance	L_{12}	mH	0.56	0.25
Winding inductivity	$L_{23, 31}$	mH	0.56	0.25
Rated power loss	P_{VN}	W	23.9	55.2
Pole width	τ_p	mm	8.25	
Thermal time constant	T_{th}	min	0.6	
Primary part mass	m_P	kg	0.050	0.075
Latest amendment: 2018-04-04				

Tab. 4-2: MCP015 - Technical data

4.4.2 Data sheet MCS015

Designation	Symbol	Unit	MCS015-__-0066	MCS015-__-0099
Secondary part mass	m_S	kg	0.2	0.3
Mass secondary part, relative	m_{S_rel}	kg/m	3.0	
Latest amendment: 2012-06-21				

Tab. 4-3: MCS015 - Technical data

4.4.3 Motor characteristic curve frame size 015

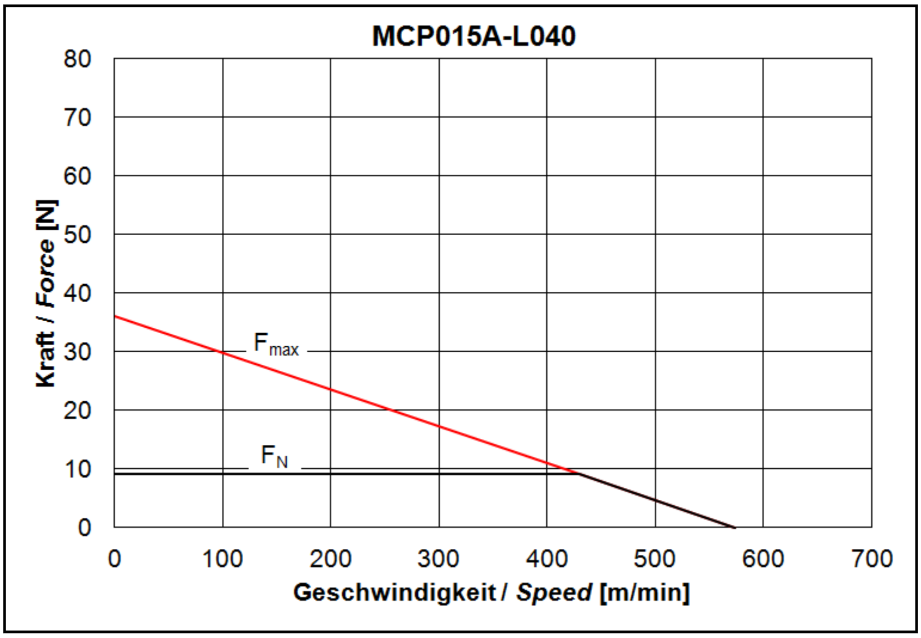


Fig. 4-4: Motor characteristic curve MCP015A-L040 at 48 V_{DC}

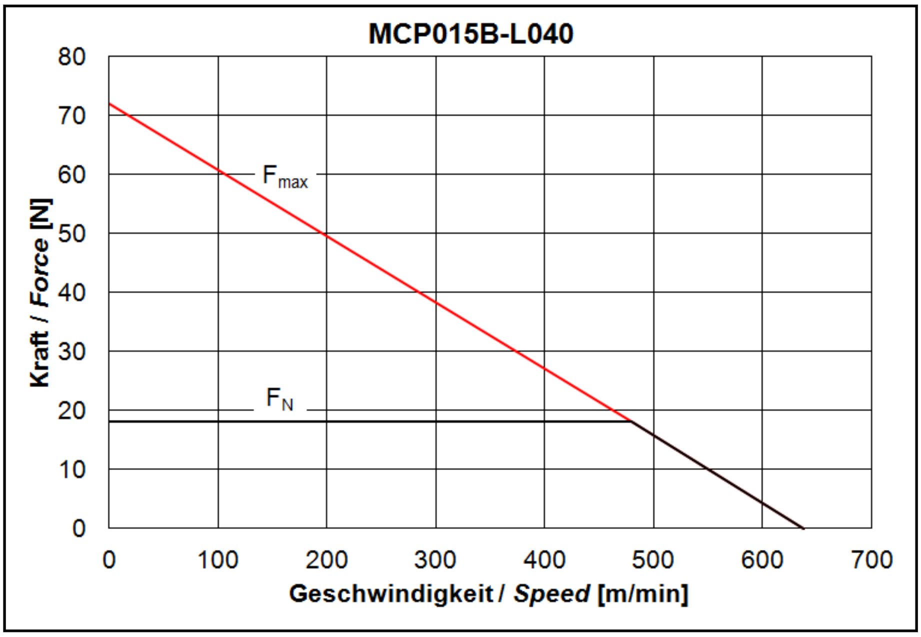


Fig. 4-5: Motor characteristic curve MCP015B-L040 at 48 V_{DC}

4.5 Frame size 020

4.5.1 Data sheet MCP020

Designation	Symbol	Unit	MCP020					
			B		C		D	
			V180	V720	V180	V720	V180	V720
Maximum force	F_{max}	N	104		156		208	
Continuous nominal force	F_N	N	26		39		52	
Maximum current	I_{max}	A	3.2	5.6	4.9	8.8	7.0	13.0
Rated current	I_N	A	0.8	1.4	1.2	2.2	1.7	3.2
Reference voltage DC bus voltage	U_{DC}	V	300					
Maximum velocity at F_{max}	v_{Fmax}	m/min	200	690	160	660	220	820
Nominal velocity	v_N	m/min	560	1100	550	1095	620	1260
Force constant	K_{FN}	N/A	32.5	18.6	32.0	17.8	30.1	16.0
Voltage constant at 20 °C	K_{EMK}	Vs/m	18.8	10.7	18.5	10.3	17.4	9.2
Winding resistance at 20 °C	R_{12}	Ohm	40.5	13.3	28	8.8	18	5.5
Winding inductivity	L_{12}	mH	4.4	1.5	2.9	0.9	1.9	0.6
Winding inductivity	$L_{23, 31}$	mH	6.6	2.2	4.3	1.3	2.7	0.9
Rated power loss	P_{VN}	W	51.8	52.1	94.5	85.1	129.8	134.6
Pole width	τ_p	mm	15					
Thermal time constant	T_{th}	min	1.7		1.9		2.1	
Primary part mass	m_P	kg	0.18		0.28		0.38	
Latest amendment: 2019-04-09								

Tab. 4-4: MCP020 - Technical data

4.5.2 Data sheet MCS020

Designation	Symbol	Unit	MCS020-__-0120	MCS020-__-0180	MCS020-__-0300
Secondary part mass	m_S	kg	0.4	0.7	1.1
Mass secondary part, relative	m_{S_rel}	kg/m	3.7		
Latest amendment: 2012-03-29					

Tab. 4-5: MCS020 - Technical data

4.5.3 Motor characteristic curves frame size 020

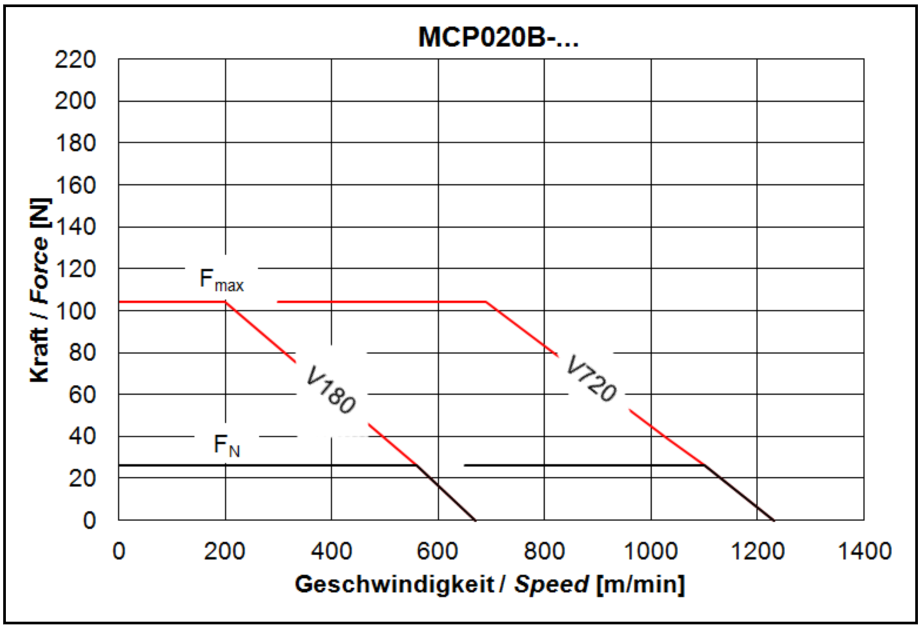


Fig. 4-6: Motor characteristic curves MCP020B at 300 V_{DC}

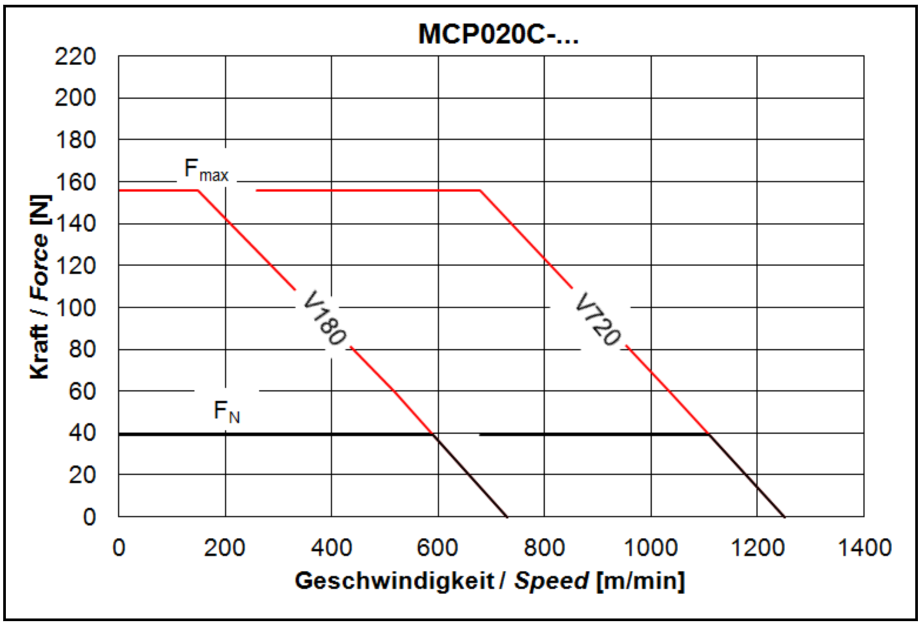


Fig. 4-7: Motor characteristic curves MCP020C at 300 V_{DC}

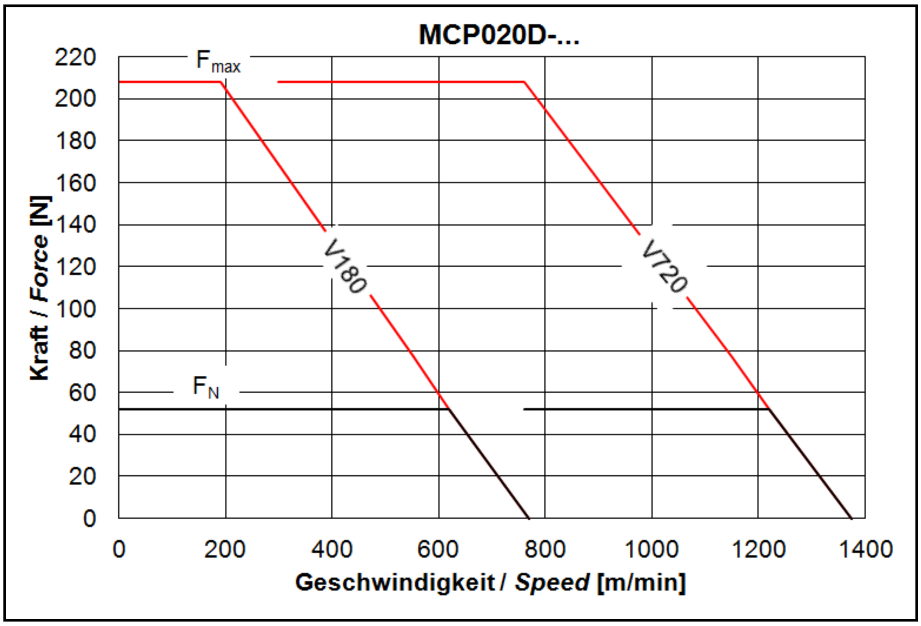


Fig. 4-8: Motor characteristic curves MCP020D at 300 V_{DC}

4.6 Frame size 030

4.6.1 Data Sheet MCP030

Designation	Symbol	Unit	MCP030					
			B		C		D	
			V180	V390	V180	V390	V180	V390
Maximum force	F_{max}	N	192		296		420	
Continuous nominal force	F_N	N	48		74		105	
Maximum current	I_{max}	A	5.2	6.4	7.2	9.6	10.0	14.0
Rated current	I_N	A	1.3	1.6	1.8	2.4	2.5	3.5
Reference voltage DC bus voltage	U_{DC}	V	300					
Maximum velocity at F_{max}	v_{Fmax}	m/min	180	400	170	370	180	380
Nominal velocity	v_N	m/min	510	680	460	630	440	660
Force constant	K_{FN}	N/A	36.9	30.0	41.1	30.8	42.0	30.0
Voltage constant at 20 °C	K_{EMK}	Vs/m	21.3	17.3	23.7	17.8	24.2	17.3
Winding resistance at 20 °C	R_{12}	Ohm	27	14.6	20	10.6	14	7.9
Winding inductivity	L_{12}	mH	10.1	5.6	7.5	4.19	5.56	2.9
Winding inductivity	$L_{23, 31}$	mH	16.2	9.1	11.6	6.16	8.17	4.7
Rated power loss	P_{VN}	W	91.1	74.6	129.4	121.9	174.8	193.3
Pole width	τ_p	mm	30					
Thermal time constant	T_{th}	min	2.2		2.4		2.6	
Primary part mass	m_P	kg	0.34		0.52		0.70	
Latest amendment: 2018-04-04								

Tab. 4-6: MCP030 - Technical data

4.6.2 Data sheet MCS030

Designation	Symbol	Unit	MCS030-__-0120	MCS030-__-0180	MCS030-__-0300
Secondary part mass	m_S	kg	0.7	1.0	1.6
Mass secondary part, relative	m_{S_rel}	kg/m	5.5		
Latest amendment: 2012-03-29					

Tab. 4-7: MCS030 - Technical data

4.6.3 Motor characteristic curve frame size 030

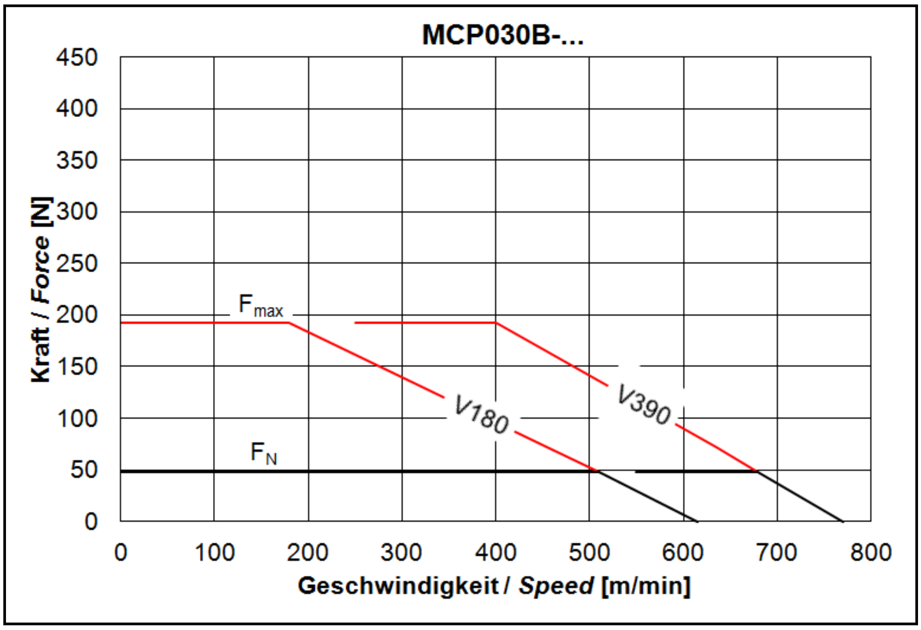


Fig. 4-9: Motor characteristic curve MCP030B at 300 V_{DC}

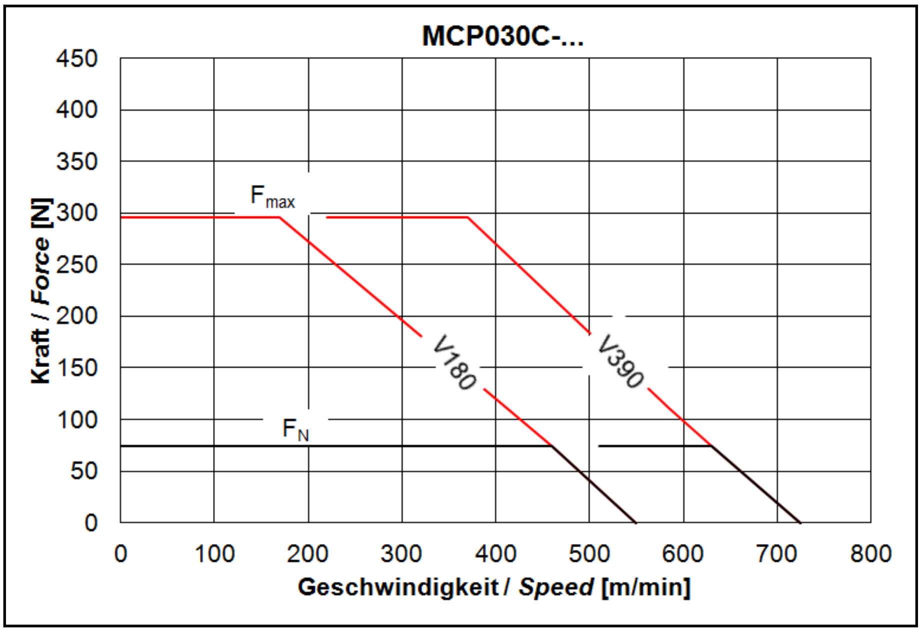


Fig. 4-10: Motor characteristic curve MCP030C at 300 V_{DC}

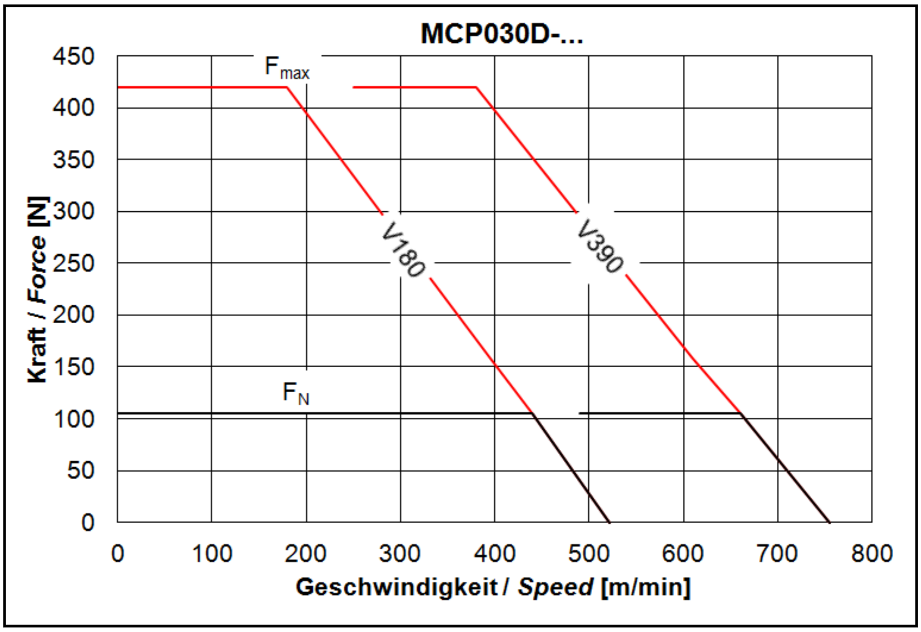


Fig. 4-11: Motor characteristic curve MCP030D at 300 V_{DC}

4.7 Frame size 040

4.7.1 Data sheet MCP040

Designation	Symbol	Unit	MCP040			
			B		C	
			V070	V300	V070	V300
Maximum force	F_{max}	N	292		432	
Continuous nominal force	F_N	N	73		108	
Maximum current	I_{max}	A	4.8	7.6	6.8	11.6
Rated current	I_N	A	1.2	1.9	1.7	2.9
Reference voltage DC bus voltage	U_{DC}	V	300			
Maximum velocity at F_{max}	v_{Fmax}	m/min	80	290	60	310
Nominal velocity	v_N	m/min	290	530	290	530
Force constant	K_{FN}	N/A	60.8	38.4	63.5	37.2
Voltage constant at 20 °C	K_{EMK}	Vs/m	35.1	22.2	36.7	21.5
Winding resistance at 20 °C	R_{12}	Ohm	30	11.4	22	7.4
Winding inductivity	L_{12}	mH	14.6	5.6	10.8	3.7
Winding inductivity	$L_{23, 31}$	mH	22.6	8.9	15.9	5.6
Rated power loss	P_{VN}	W	86.3	82.2	127.0	124.3
Pole width	τ_p	mm	30			
Thermal time constant	T_{th}	min	2.3		2.4	
Primary part mass	m_P	kg	0.56		0.81	
Latest amendment: 2018-04-04						

Tab. 4-8: MCP040B/C - Technical data

Designation	Symbol	Unit	MCP040			
			E		G	
			V070	V300	V070	V300
Maximum force	F_{max}	N	732		1032	
Continuous nominal force	F_N	N	183		258	
Maximum current	I_{max}	A	11.6	18.8	15.6	26.4
Rated current	I_N	A	2.9	4.7	3.9	6.6
Reference voltage DC bus voltage	U_{DC}	V	300			
Maximum velocity at F_{max}	v_{Fmax}	m/min	60	260	50	290
Nominal velocity	v_N	m/min	280	510	260	500
Latest amendment: 2018-04-04						

Designation	Symbol	Unit	MCP040			
			E		G	
			V070	V300	V070	V300
Force constant	K_{FN}	N/A	63.1	38.9	66.2	39.1
Voltage constant at 20 °C	K_{EMK}	Vs/m	36.4	22.5	38.2	22.6
Winding resistance at 20 °C	R_{12}	Ohm	12.7	5	9.7	3.3
Winding inductance	L_{12}	mH	6.4	2.4	4.8	1.6
Winding inductivity	$L_{23, 31}$	mH	9.5	3.5	7	2.4
Rated power loss	P_{VN}	W	213.3	220.6	294.7	287.1
Pole width	τ_p	mm	30			
Thermal time constant	T_{th}	min	2.6		2.8	
Primary part mass	m_P	kg	1.26		1.71	
Latest amendment: 2018-04-04						

Tab. 4-9: MCP040E/G - Technical data

4.7.2 Data sheet MCS040

Designation	Symbol	Unit	MCS040-__-0120	MCS040-__-0180	MCS040-__-0300
Secondary part mass	m_S	kg	1.3	1.9	3.2
Mass secondary part, relative	m_{S_rel}	kg/m	10.7		
Latest amendment: 2012-03-29					

Tab. 4-10: MCS040 - Technical data

4.7.3 Motor characteristic curves frame size 040

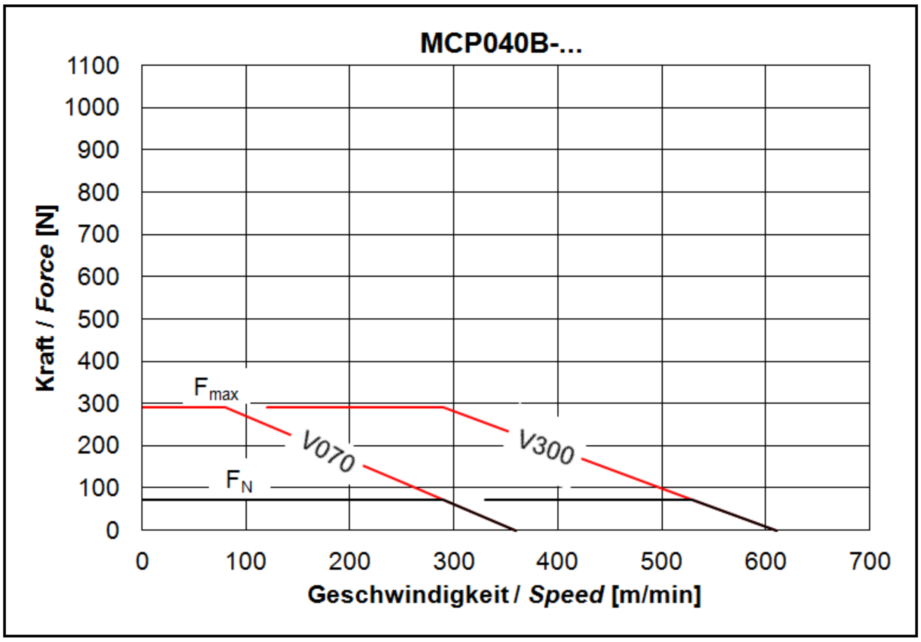


Fig. 4-12: Motor characteristic curve MCP040B at 300 V_{DC}

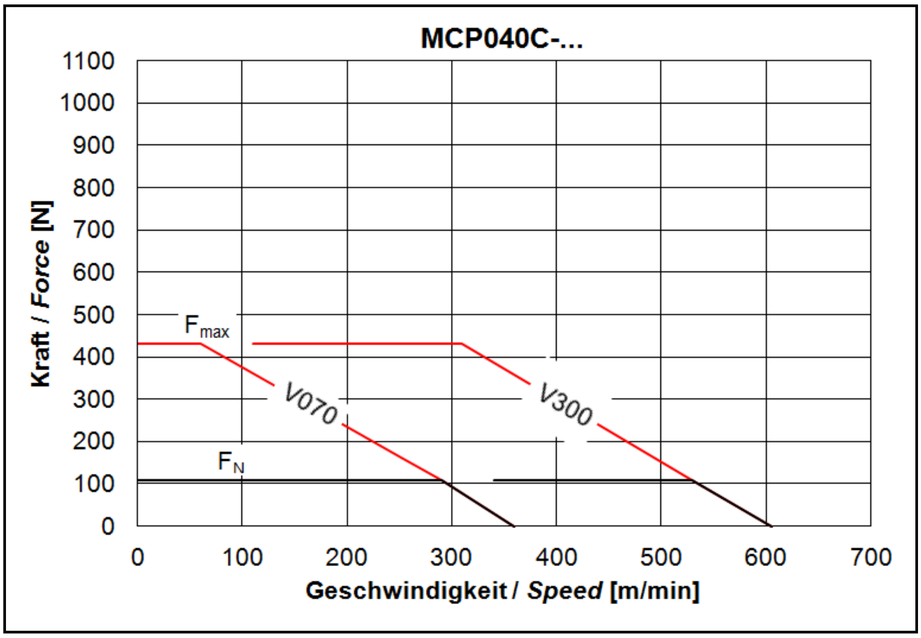


Fig. 4-13: Motor characteristic curve MCP040C at 300 V_{DC}

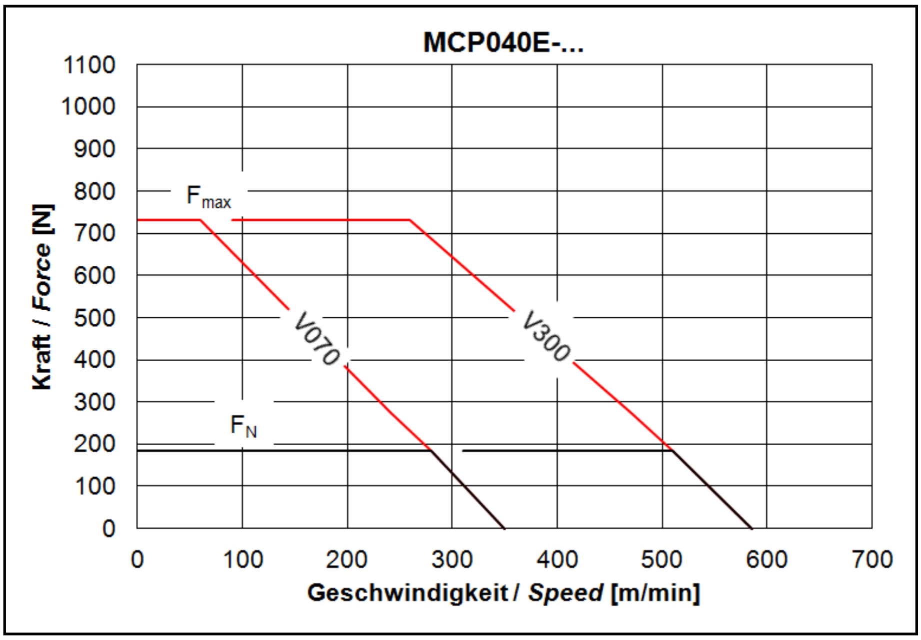


Fig. 4-14: Motor characteristic curve MCP040E at 300 V_{DC}

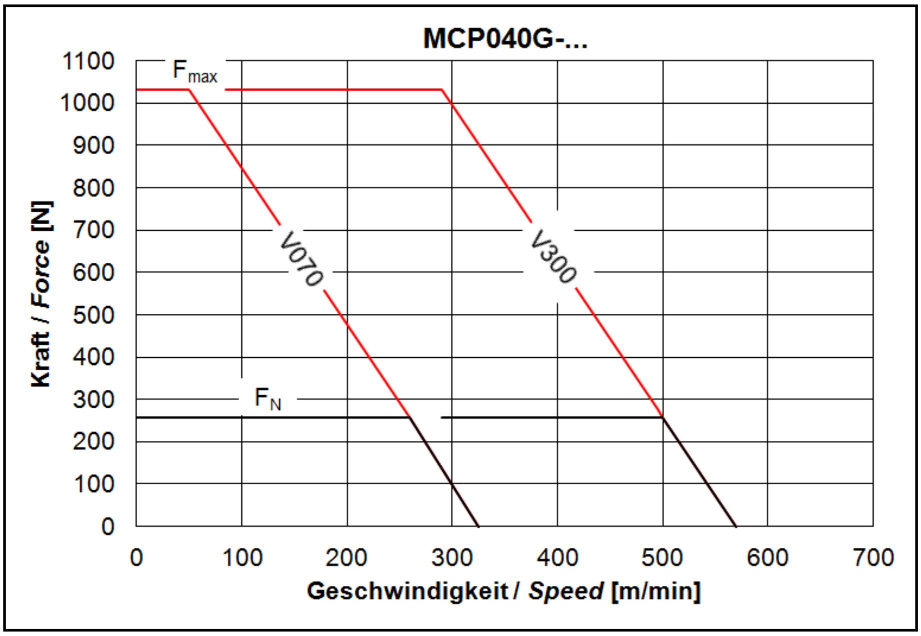


Fig. 4-15: *Motor characteristic curve MCP040G at 300 V_{DC}*

4.8 Frame size 070

4.8.1 Data sheet MCP070

Designation	Symbol	Unit	MCP070			
			C		D	
			V050	V300	V050	V300
Maximum force	F_{max}	N	860		1144	
Continuous nominal force	F_N	N	215		286	
Maximum current	I_{max}	A	8.8	20.4	11.2	25.6
Rated current	I_N	A	2.2	5.1	2.8	6.4
Reference voltage DC bus voltage	U_{DC}	V	300			
Maximum velocity at F_{max}	v_{Fmax}	m/min	50	340	50	280
Nominal velocity	v_N	m/min	180	470	180	460
Force constant	K_{FN}	N/A	97.7	42.2	102.1	44.7
Voltage constant at 20 °C	K_{EMK}	Vs/m	56.4	24.3	59.0	25.8
Winding resistance at 20 °C	R_{12}	Ohm	15.7	3.03	13.2	2.94
Winding inductivity	L_{12}	mH	12	2.3	10	2
Winding inductivity	$L_{23, 31}$	mH	17.1	3.3	14.1	2.9
Rated power loss	P_{VN}	W	151.8	157.4	206.7	240.5
Pole width	τ_p	mm	30			
Thermal time constant	T_{th}	min	3.0		4.0	
Primary part mass	m_P	kg	1.50		1.95	
Latest amendment: 2018-04-04						

Tab. 4-11: MCP070C/D - Technical data

Designation	Symbol	Unit	MCP070			
			F		M	
			V050	V300	V050	V230
Maximum force	F_{max}	N	1712		3320	
Continuous nominal force	F_N	N	428		830	
Maximum current	I_{max}	A	18.4	36.0		62.8
Rated current	I_N	A	4.6	9.0		15.7
Reference voltage DC bus voltage	U_{DC}	V	300			
Maximum velocity at F_{max}	v_{Fmax}	m/min	70	290	60	230
Nominal velocity	v_N	m/min	210	460	200	370
Latest amendment: 2018-04-04						

Designation	Symbol	Unit	MCP070			
			F		M	
			V050	V300	V050	V230
Force constant	K_{FN}	N/A	93.0	47.5	92.2	52.9
Voltage constant at 20 °C	K_{EMK}	Vs/m	53.7	27.4	53.2	30.5
Winding resistance at 20 °C	R_{12}	Ohm	7.5	2.2	3.8	1.25
Winding inductivity	L_{12}	mH	5.7	1.39	2.66	0.92
Winding inductivity	$L_{23, 31}$	mH	7.8	1.94	3.92	1.23
Rated power loss	P_{VN}	W	317.0	355.9	614.8	615.4
Pole width	τ_p	mm	30			
Thermal time constant	T_{th}	min	5.0	3.1	3.3	
Primary part mass	m_P	kg	2.85		5.9	
Latest amendment: 2018-04-04						

Tab. 4-12: MCP070F/M - Technical data

4.8.2 Data sheet MCS070

Designation	Symbol	Unit	MCS070-__-0120	MCS070-__-0180	MCS070-__-0300
Secondary part mass	m_S	kg	3.0	4.5	7.4
Mass secondary part, relative	m_{S_rel}	kg/m	24.8		
Latest amendment: 2012-03-29					

Tab. 4-13: MCS070 - Technical data

4.8.3 Motor characteristic curve frame size 070

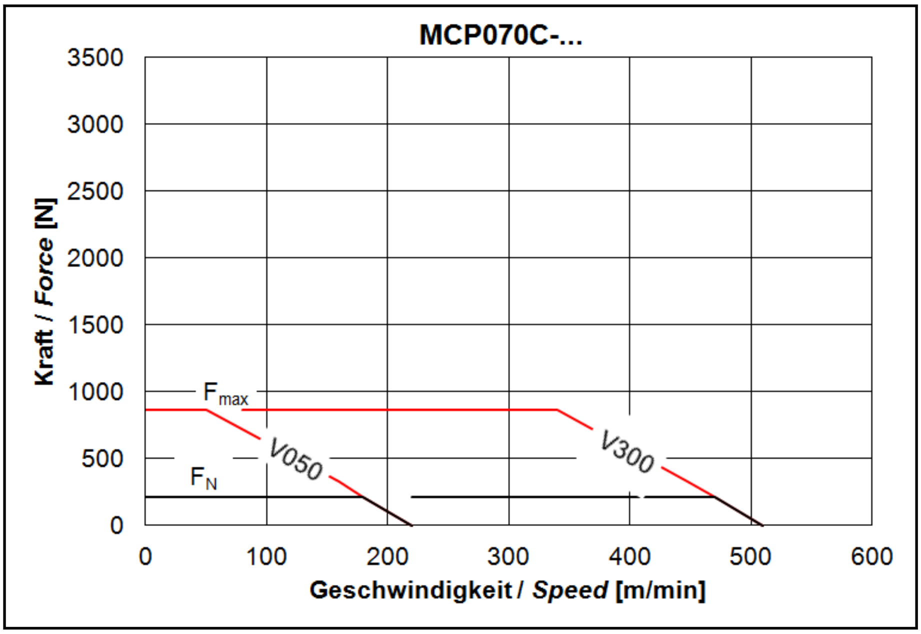


Fig. 4-16: Motor characteristic curve MCP070C at 300 V_{DC}

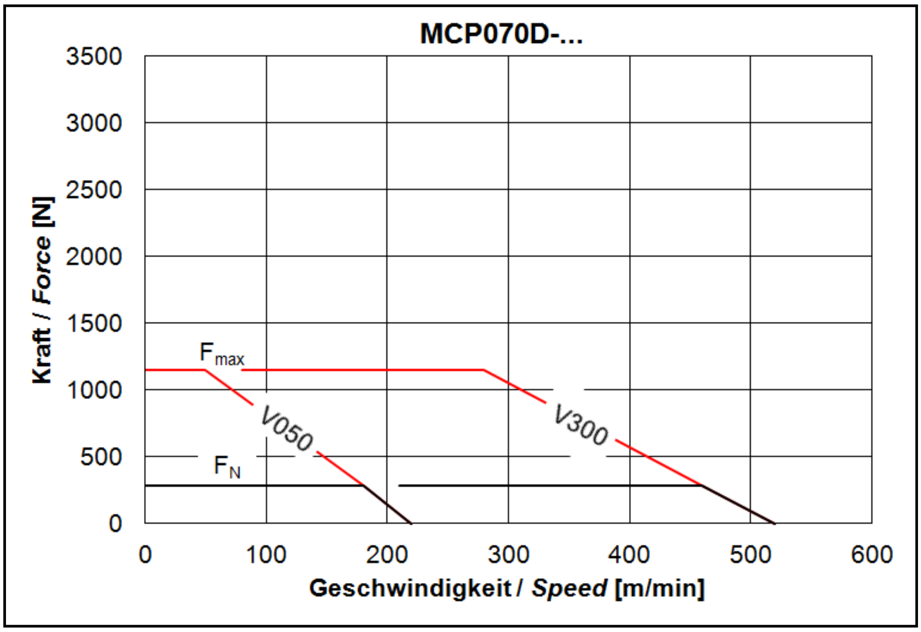


Fig. 4-17: Motor characteristic curve MCP070D at 300 V_{DC}

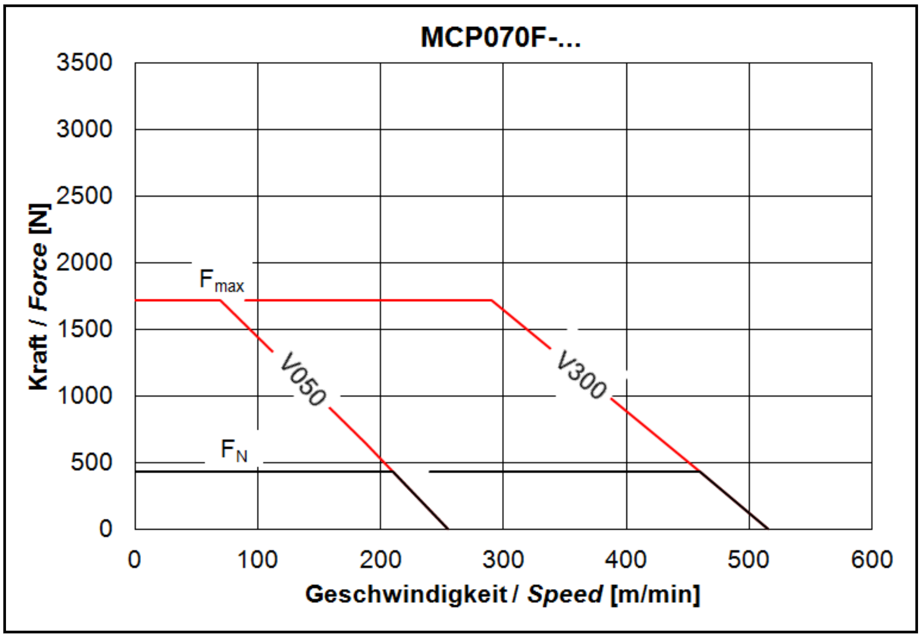


Fig. 4-18: Motor characteristic curve MCP070F at 300 V_{DC}

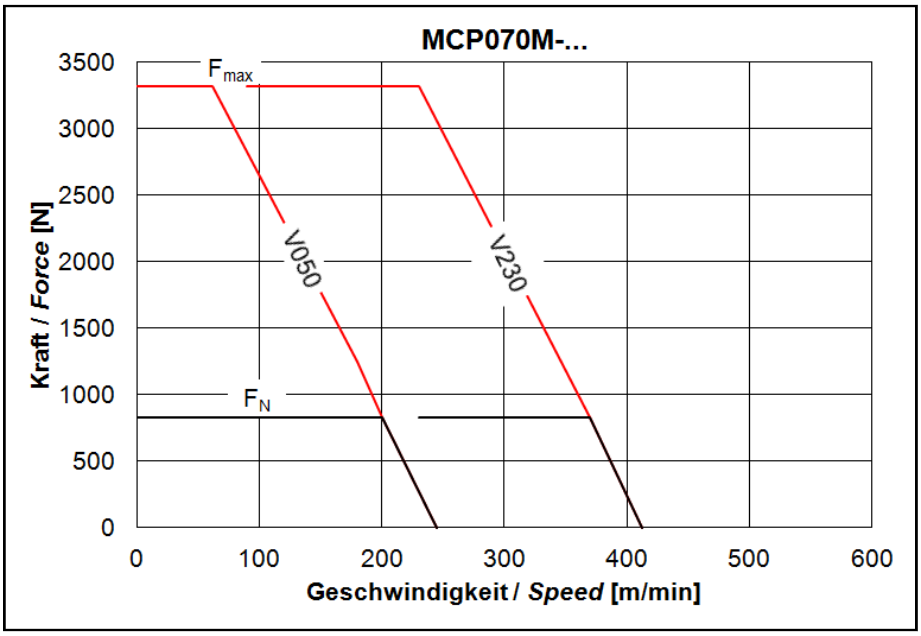


Fig. 4-19: Motor characteristic curve MCP070M at 300 V_{DC}

5 Dimension sheets

5.1 Specifications

☞ Comply with the trademark rights of third parties during assembly and use of single components delivered by Bosch Rexroth. For any infringement of the right, the customer is liable for the accruing damage.

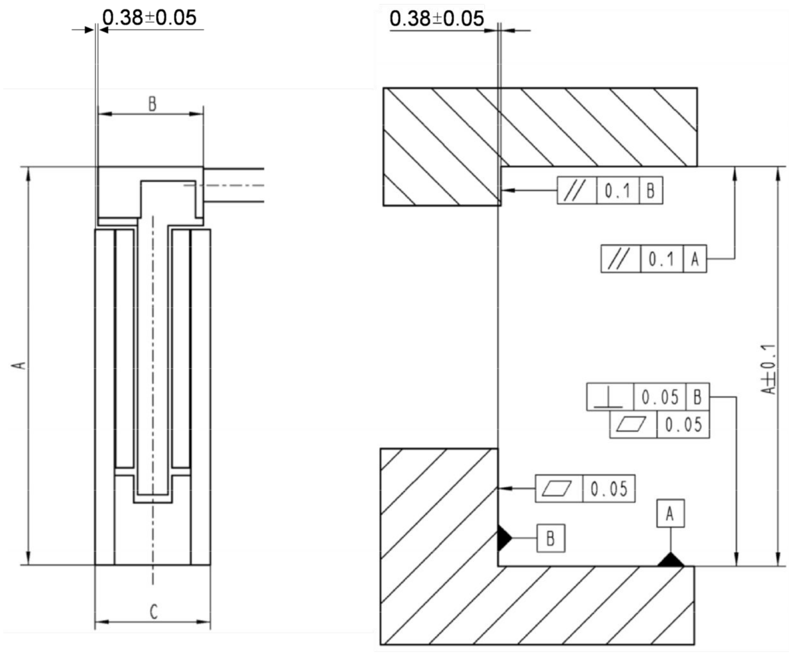
5.1.1 Air gap and installation height

To ensure safe operation and constant force over the entire travel range, an air gap is required between primary and secondary part. For this purpose, the individual parts of the motor are tolerated accordingly. The distance of the mounting surface, the parallelism and the symmetry of the primary and secondary part of the linear motor in the machine must be within a certain tolerance above the entire travel length. Any deformations that result from weight, attractive forces and process forces must be taken into account.

☞
- The specified installation dimensions with respective tolerances must always be complied with over the entire travel length. An insufficient air gap may lead to contact between the primary part and the secondary part and thus to damaged and destroyed motor components.
- Long distances can make is necessary that the contact surfaces of the motor components must be directly processed from the mounted slide.

For the installation of the motors into the machine structure, Bosch Rexroth specifies a defined installation position with tolerances. Thus, the specified size and tolerances of the air gap are maintained automatically – even if individual motor components are replaced.

5.1.2 Installation dimensions MCL015



Motor dimensions

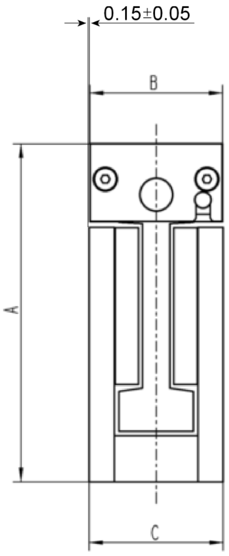
Motor installation space
(by the customer)

Frame size	Motor height	Motor width	
	MCL	MCP	MCS
	A	B	C
015	51 mm	13.5 mm	14.8 mm

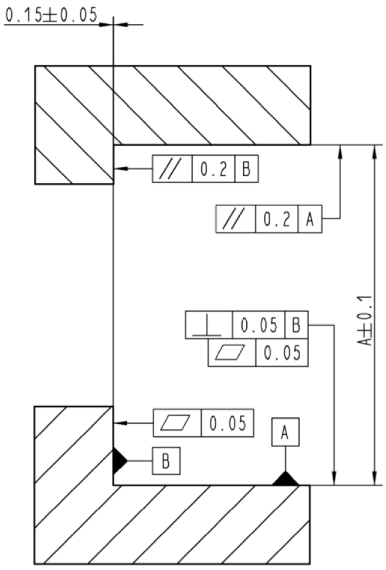
For tolerance details refer to the dimension sheet

Tab. 5-1: MCL015 Installation dimensions and tolerances

5.1.3 Installation dimensions MCL020 ... 070



Motor dimensions



Motor installation room
(by the customer)

Size	Motor height	Motor width	
	MCL	MCP	MCS
	A	B	C
020	52.0 mm	20.5 mm	20.8 mm
030	67.0 mm	24.7 mm	25.0 mm
040	86.4 mm	34.0 mm	34.3 mm
070	124.0 mm	49.2 mm	49.5 mm

For tolerance details refer to the dimension sheet

Tab. 5-2: Installation dimensions and tolerances MCL020 ... 070

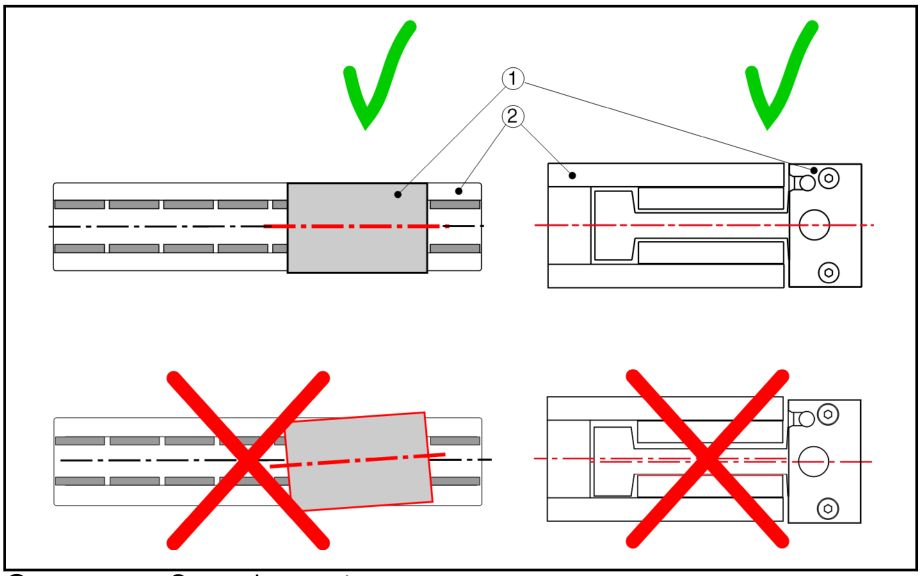
☞ The specified installation dimensions with respective tolerances must always be complied with over the entire travel length.

5.1.4 Parallelism and symmetry of machine parts

Before primary and secondary part can be mounted, align the parts of the machine. Especially the machine slide is to be brought into a defined position to the machine bed. When aligning, the installation dimensions and tolerances regarding parallelism and symmetry must be kept.

To keep the tolerances, it is necessary that the fastening holes for the primary part and the threaded holes for the primary and secondary part in the machine are strictly realized according to the dimensions of the particular dimension sheets. The alignment of the motor components must be done according to Fig. 5-1.

You will find further notes regarding assembly of primary and secondary parts in chapter 13 on page 159.



① Secondary part
② Primary part

Fig. 5-1: Parallelism and symmetry between primary part and secondary part

5.2 Dimensional sheets for MCL015

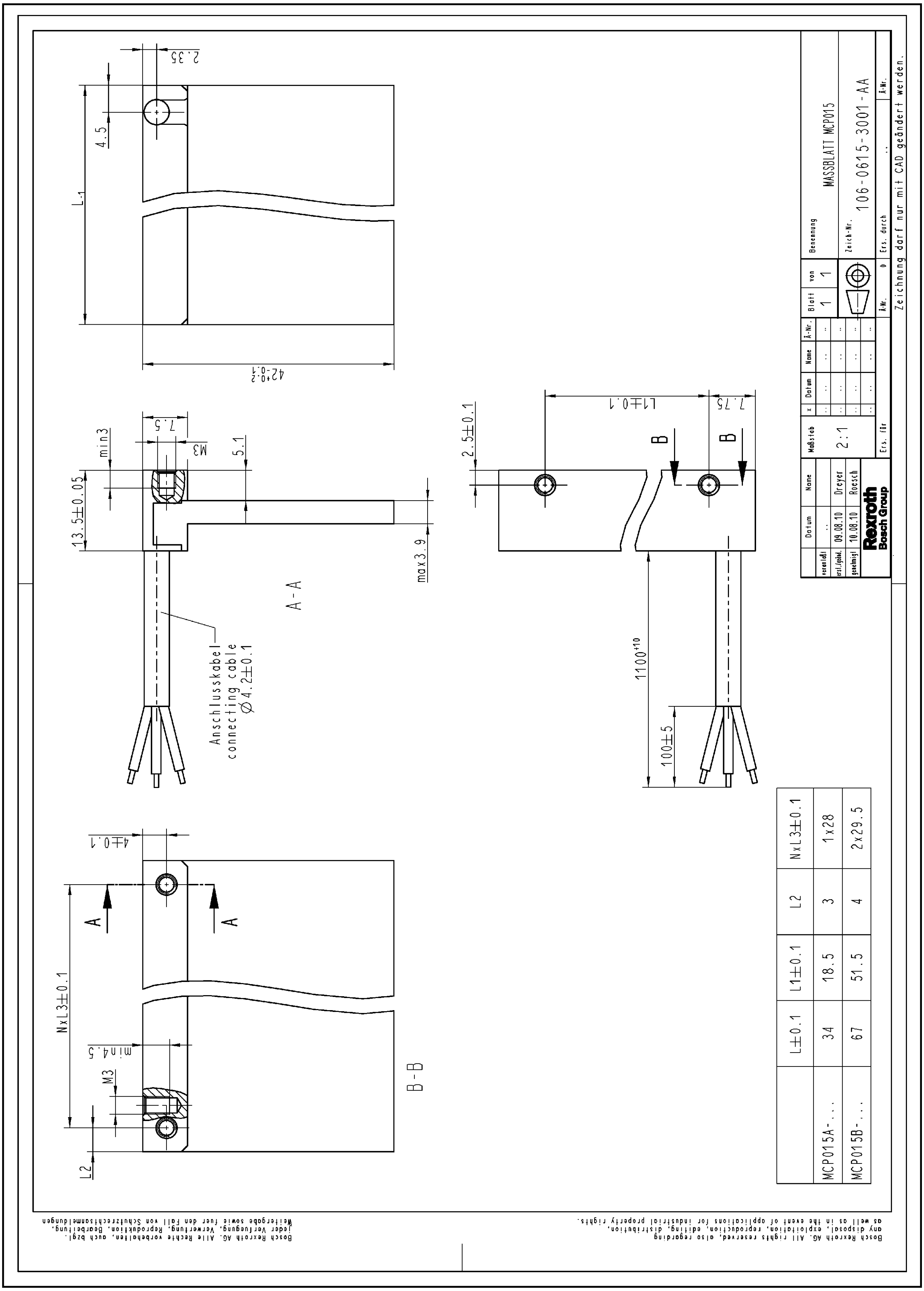


Fig. 5-2: Dimensional sheets primary part MCP015

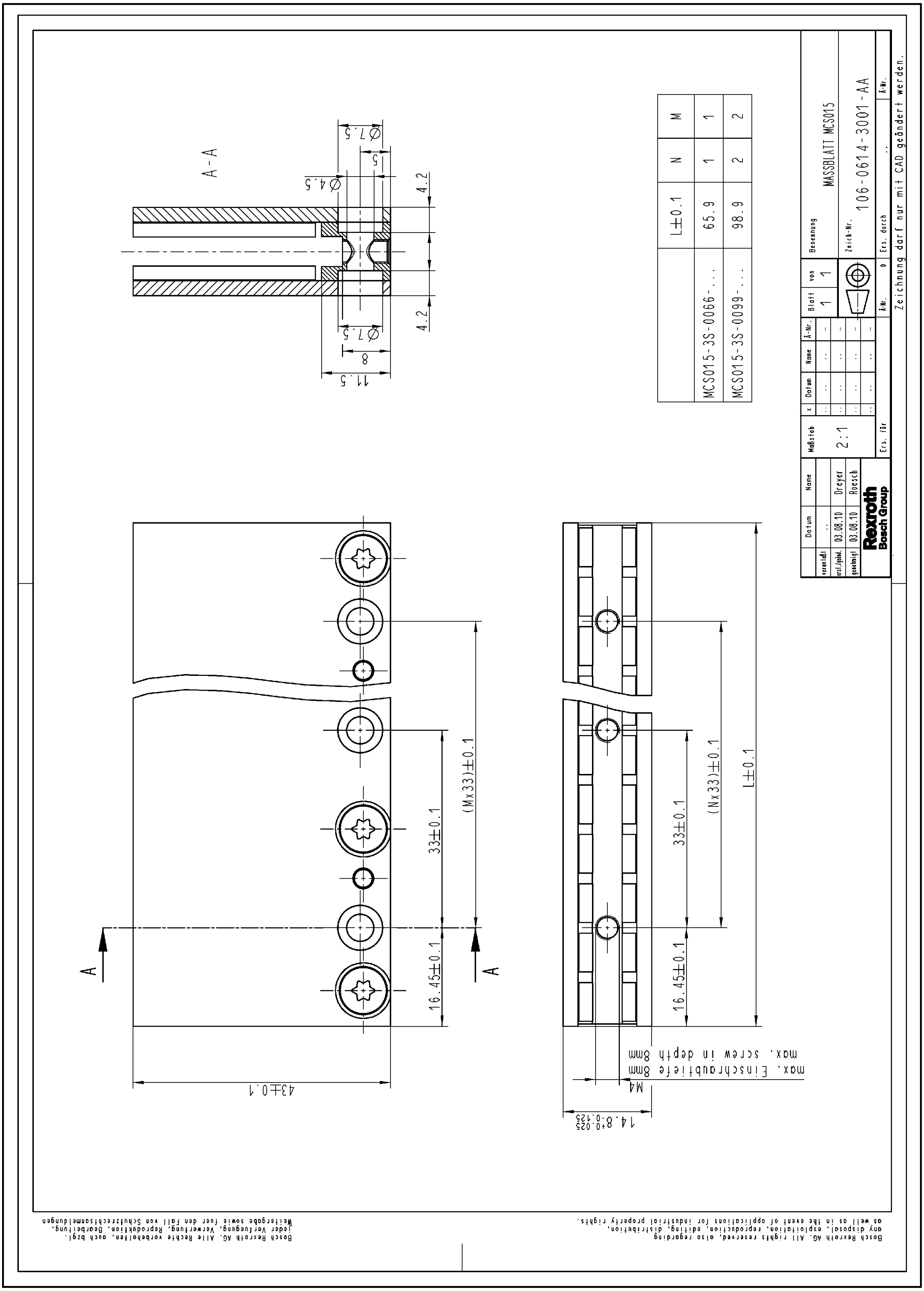


Fig. 5-3: Dimensional sheets secondary part MCS015

5.3 Dimensional sheets MCL020

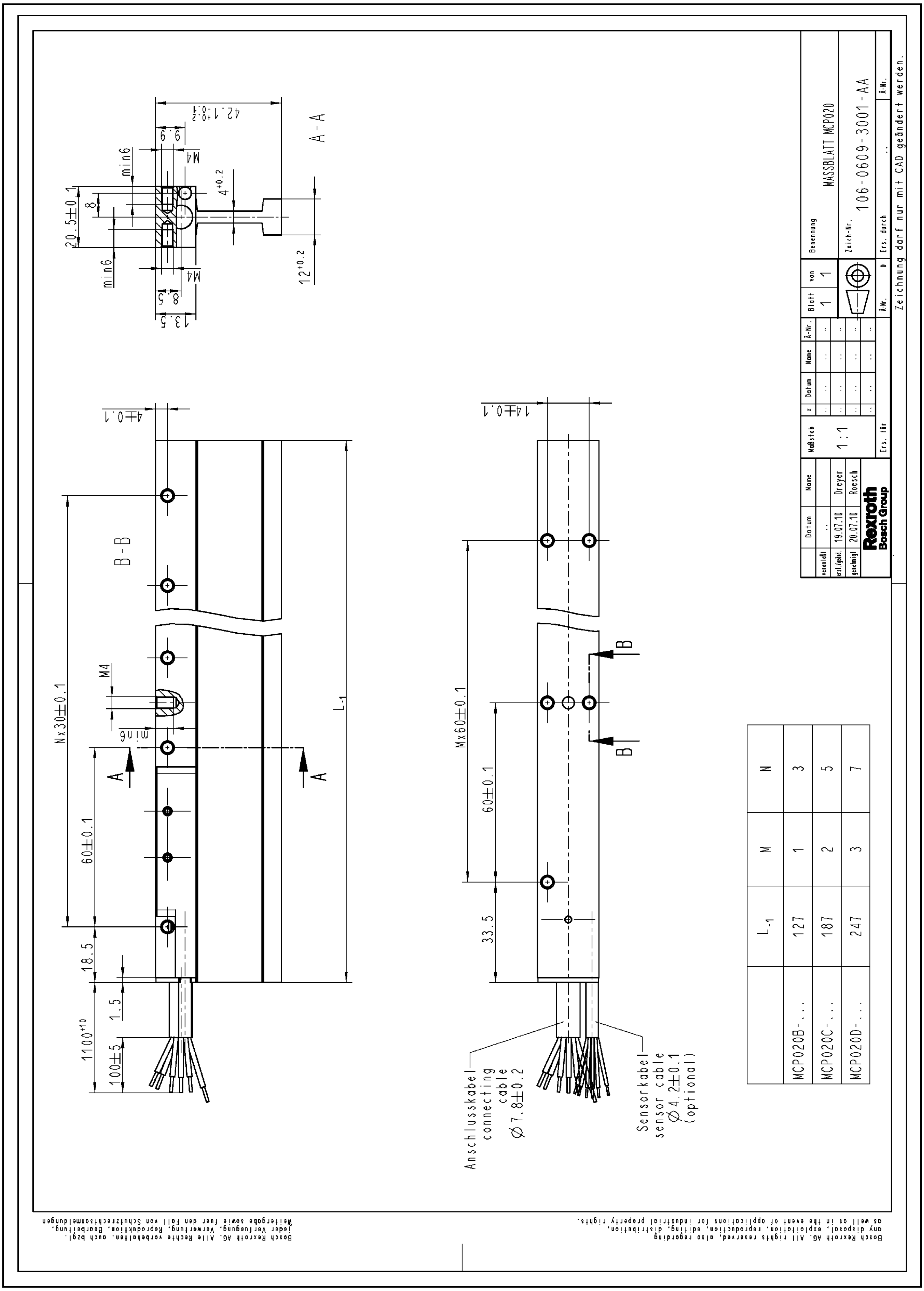


Fig. 5-4: Dimensional sheets primary part MCP020

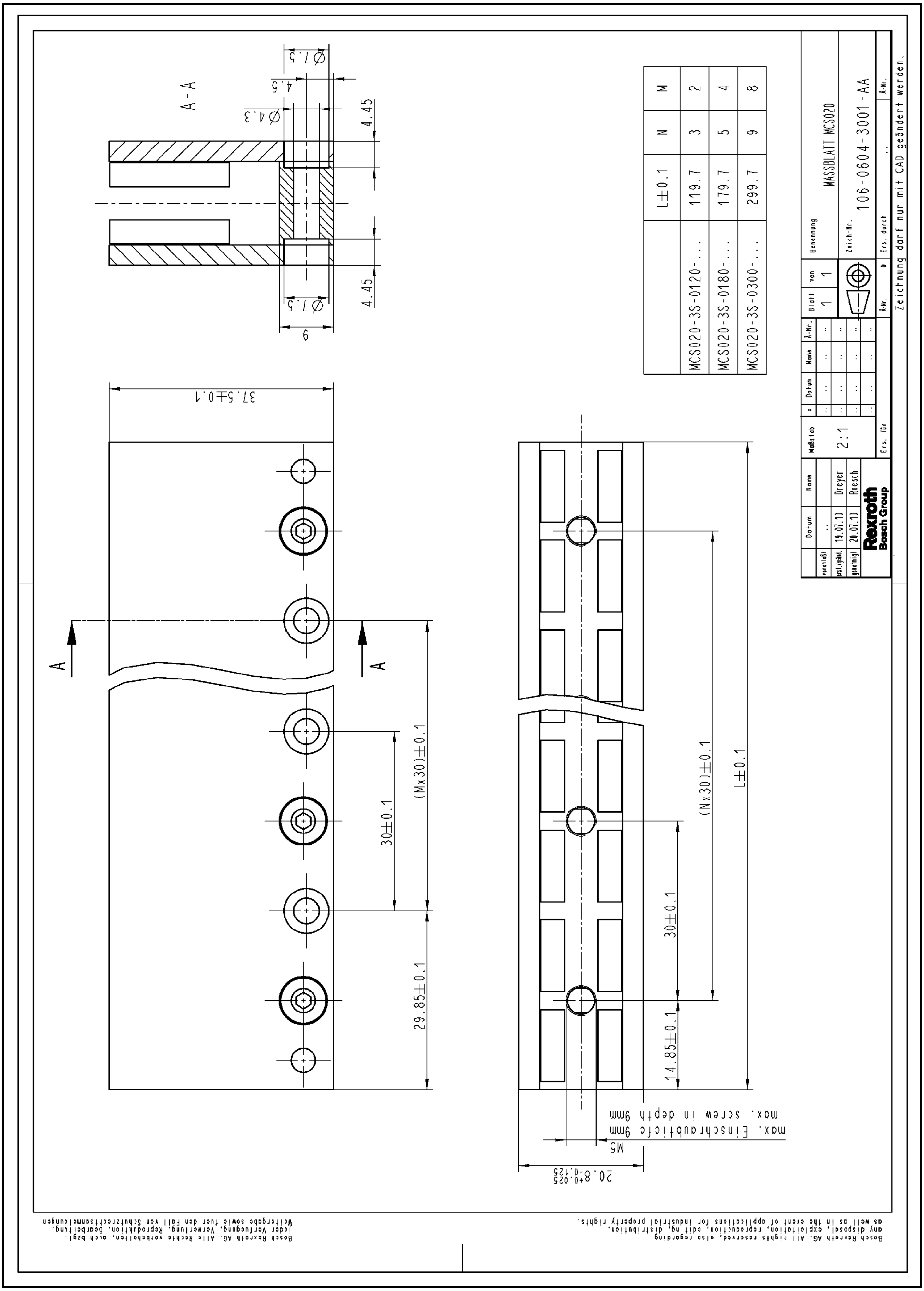


Fig. 5-5: Dimensional sheets secondary part MCS020

5.4 Dimensional sheets for MCL030

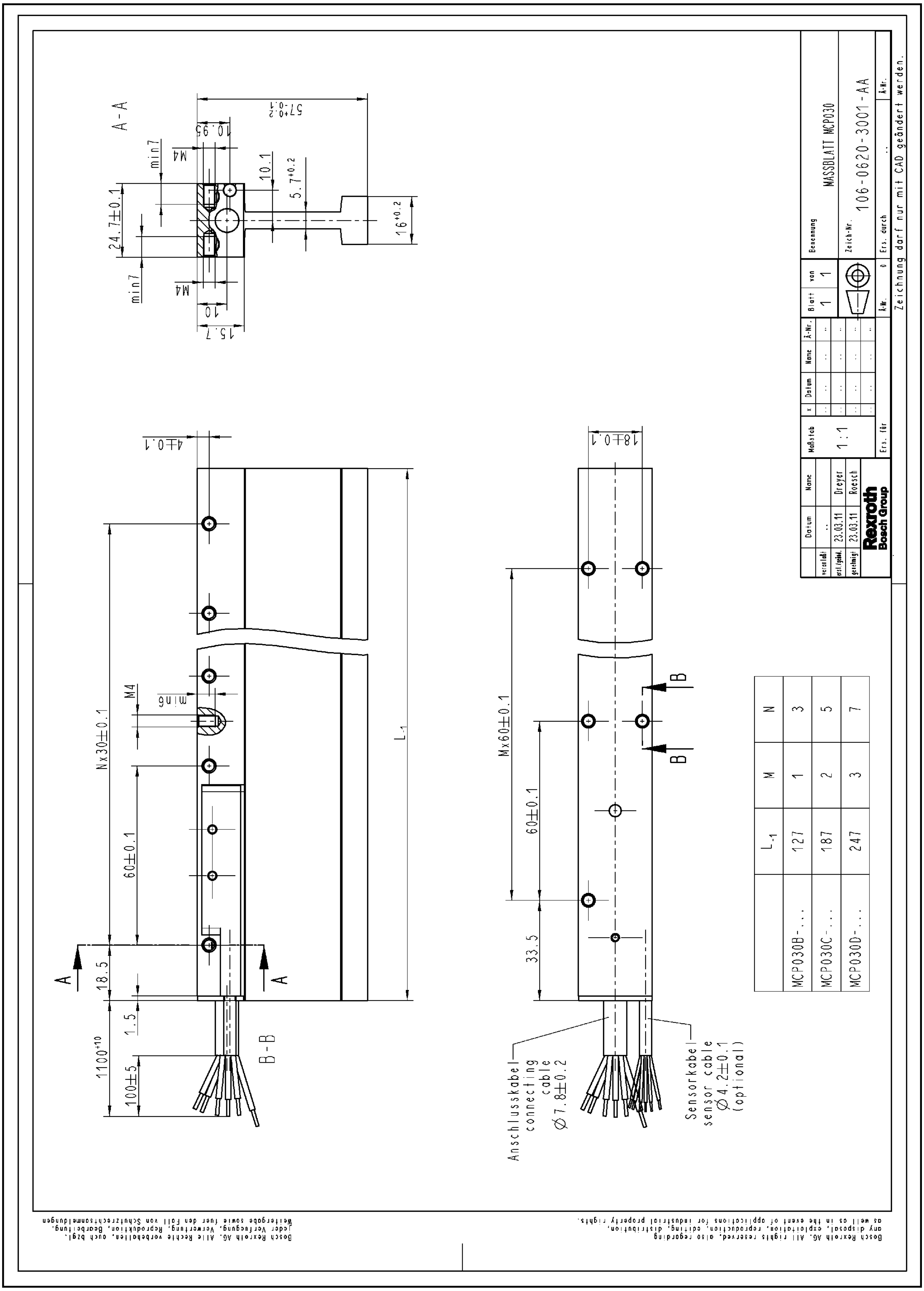


Fig. 5-6: Dimensional sheets primary part MCP030

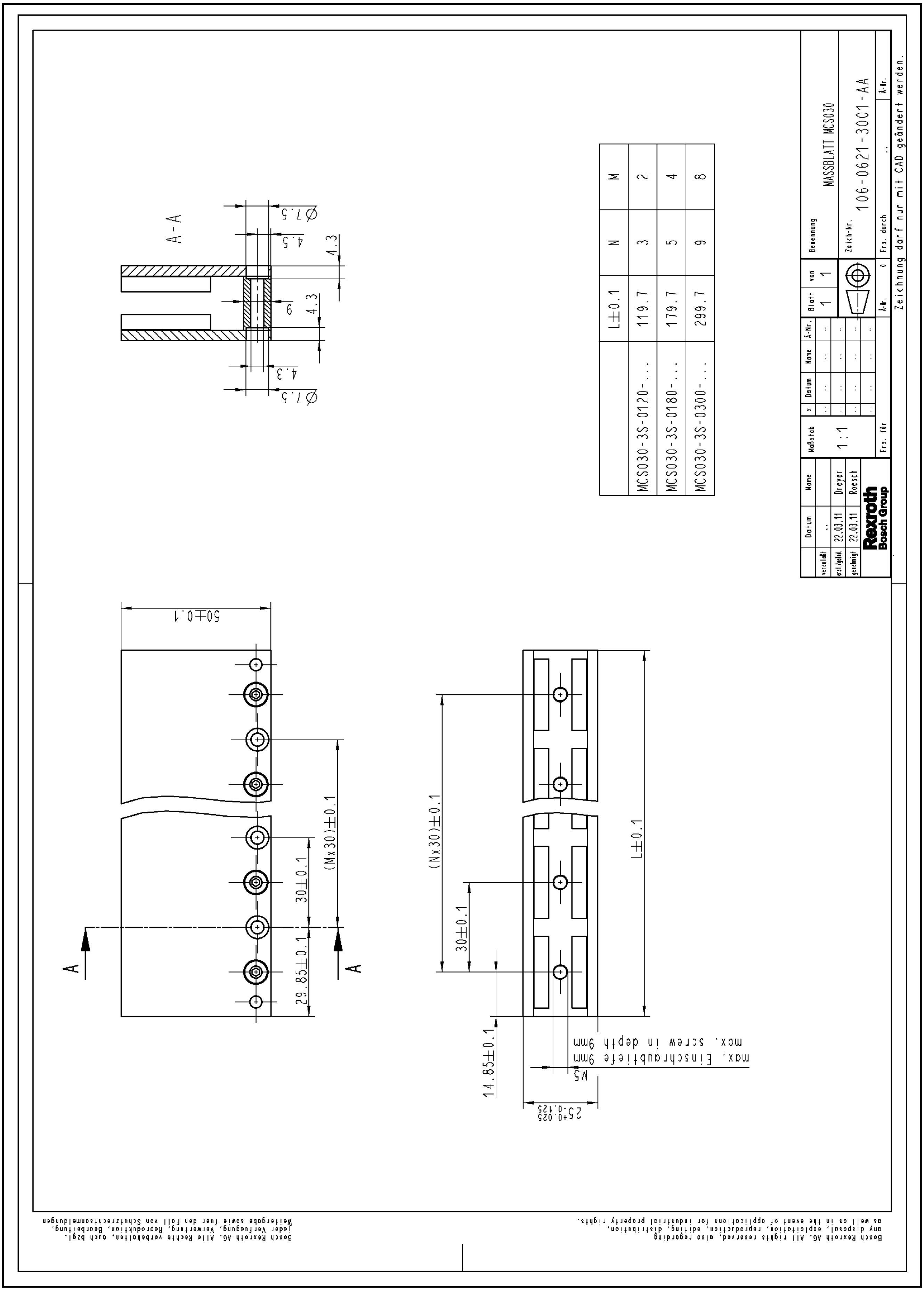


Fig. 5-7: *Dimensional sheets secondary part MCS030*

5.5 Dimensional sheets MCL040

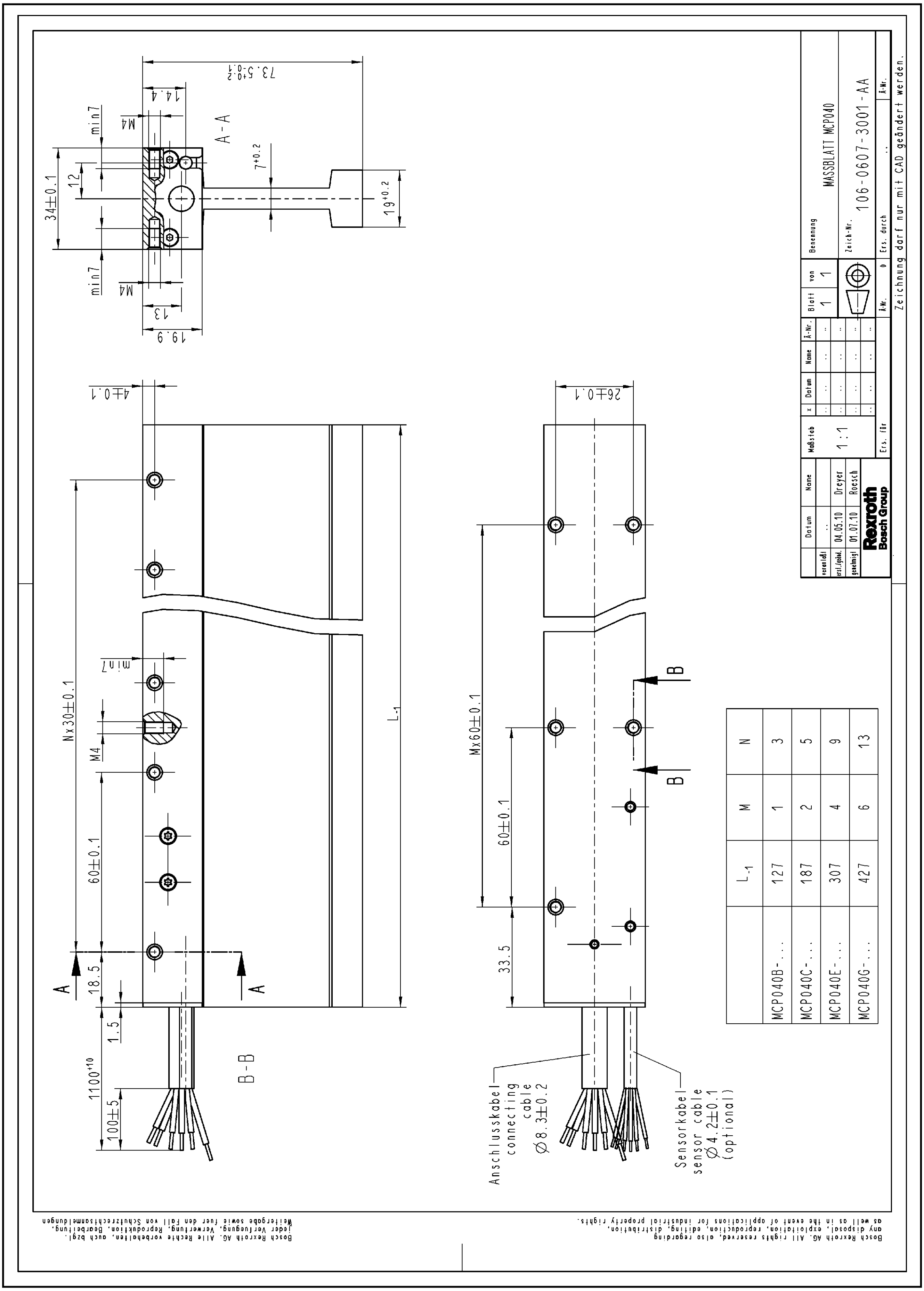


Fig. 5-8: Dimensional sheets primary part MCP040

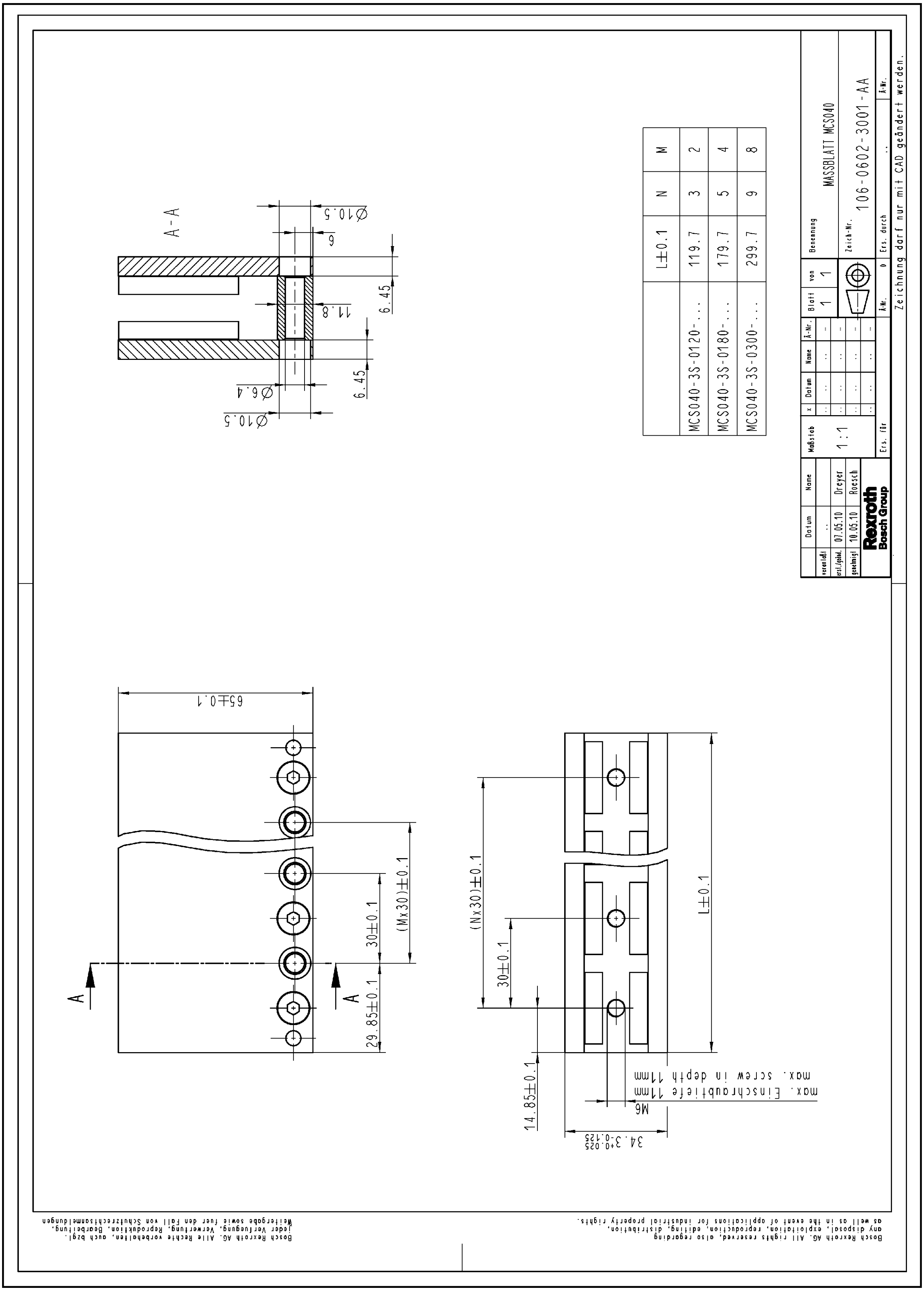


Fig. 5-9: Dimensional sheets secondary part MCS040

5.6 Dimensional sheets MCL070

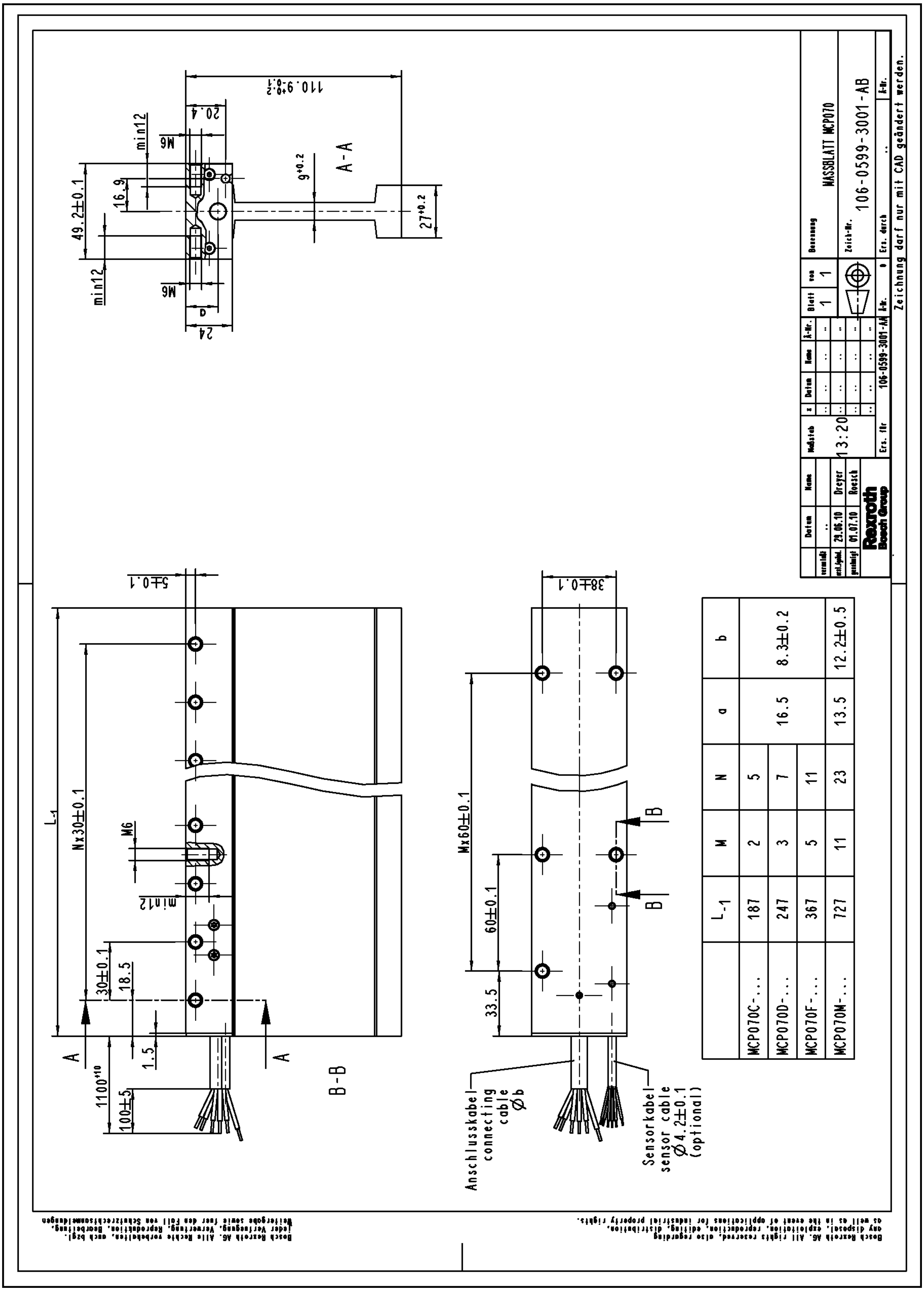


Fig. 5-10: Dimensional sheets primary part MCP070

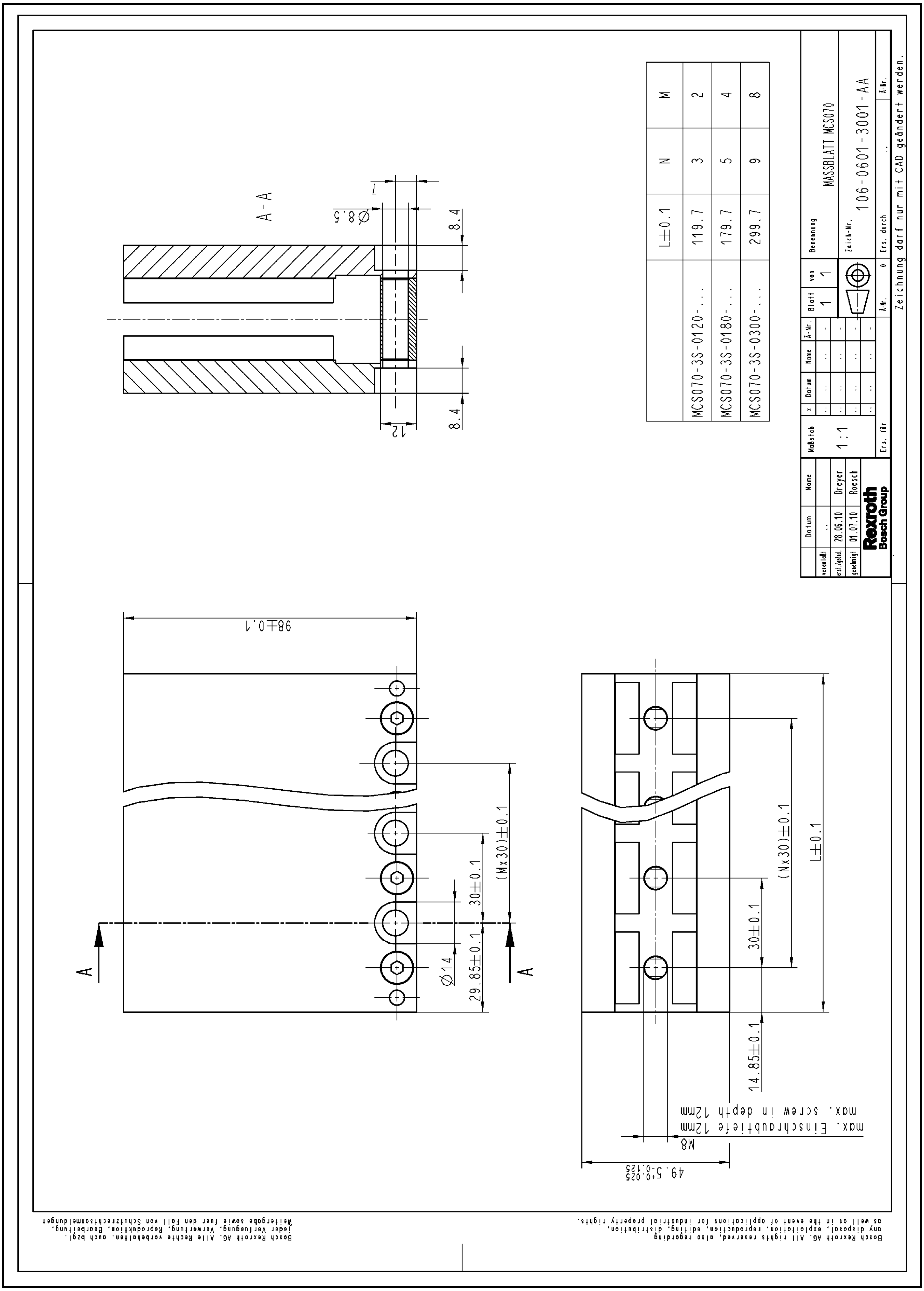


Fig. 5-11: Dimensional sheets secondary part MCS070

6 Identification

6.1 Type codes

6.1.1 General

The type code describes the deliverable motor variants. It is the basis for selecting and ordering products from Bosch Rexroth. This applies to new products as well as to spare parts and repairs..

Based on an exemplary motor, type codes are listed by which an exact determination of the single components (e.g. for orders) is possible.

The following description gives an overview over the separate columns of the type code (”abbrev. column”) and its meaning.

☞ When selecting a product, always consider the detailed specifications in chapter 4 "Technical data" on page 21 and chapter 9 "Application and construction instructions" on page 97.

6.1.2 Type codes primary part MCP

General

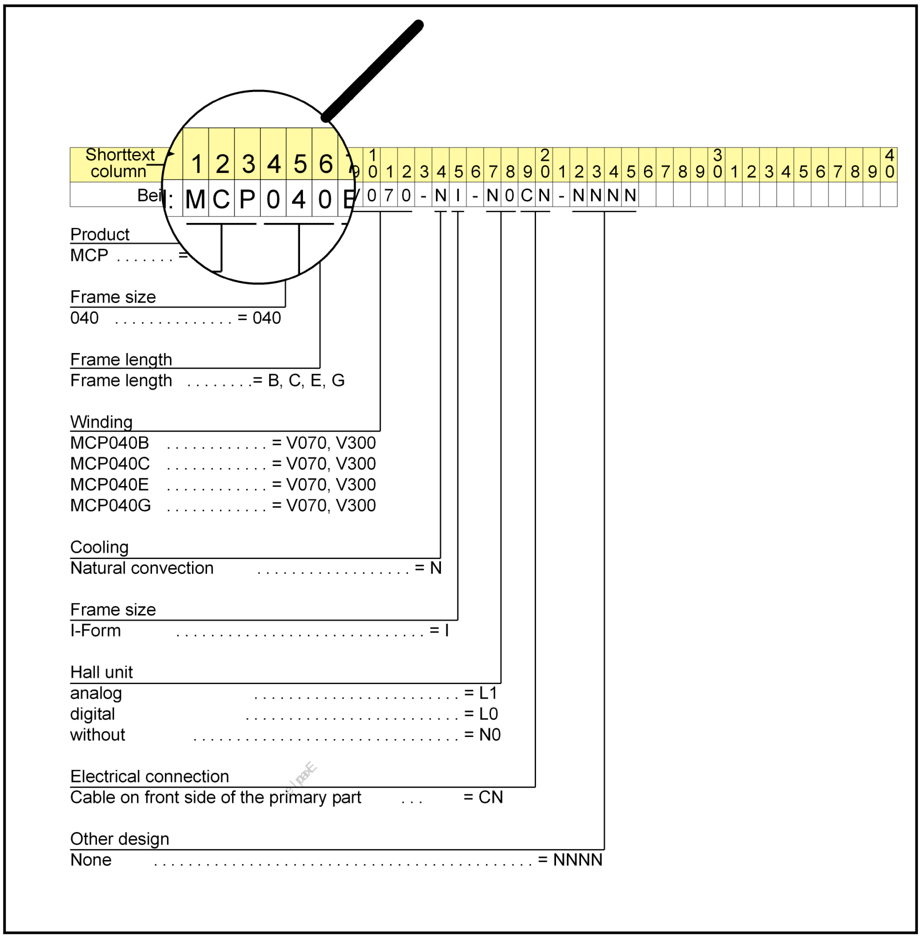


Fig. 6-1: Example - type code primary part MCP040

Product

Abbrev. column 1 2 3

MCP is the designation of the primary part of an ironless linear motors.

Frame size

Abbrev. column 4 5 6

The motor frame size is derived from the active motor length and represents different power ranges.

Frame lengths

Abbrev. column 7

Within a series, increasing motor frame length is graded by means of code letters.

Winding

Abbrev. column 9 10 11 12

The specified winding designation is done via a preceeded “V” for a DC bus voltage of 300 V_{DC}, with a preceeded “L” for a DC bus voltage of 48 V_{DC}.

Cooling

Abbrev. column 14

MCP primary parts are only available with self cooling.

Frame shape

Abbrev. column 15

Two different frame sizes are available, depending from the frame size. The frame size is derived from the cross section of the respective primary part and is described by the letters “T” and “I”.

Hall unit

Abbrev. column 17 18

Primary parts in frame sizes 020 up to 070 can be optionally fitted with a Hall unit for position acquisition. Depended from the frame size, the following Hall units with different output signals are available:

- L1 = analog
- L0 = digital
- N0 = none

The cable output direction of the Hall unit is done to the same front side as for the power connection.

The necessary length measuring system is not in the scope of delivery of Bosch Rexroth and must be provided and mounted by the machine manufacturer.

Electrical connection

Short-text column 19 20

All primary parts are fitted with a flexible and shielded connection cable. The connection cable is fixed with the primary part and is done at the front side at MCP020 up to MCP070, laterally for the MCP015.

Other designs

Abbrev. column 22 23 24 25

NNNN = no other design.

6.1.3 Type code MCS secondary part

General

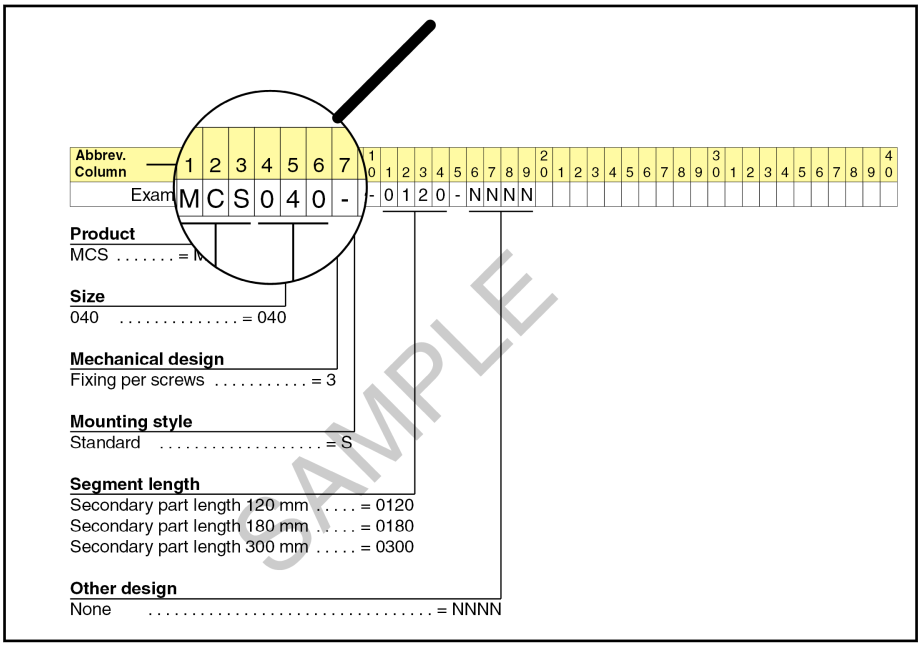


Fig. 6-2: Example - type code secondary part MCS040

Product

Abbrev. column 1 2 3

MCS is the designation of the secondary part of an ironless linear motor.

Frame size

Abbrev. column 4 5 6

The frame size of the secondary part is derived from the active motor length and represents different power ranges.

Mechanical design

Abbrev. column 8

The number **3** stands for fastening of the secondary part with screws.

Mechanical protection

Abbrev. column 9

To ensure the optimal operation reliability, the permanent magnets of the secondary part are protected against outside influences like corrosion by coating. Hence, no additional cover is necessary for this specified environmental conditions.

Segment lengths

Abbrev. column 11 12 13 14

Depending from the motor frame size, different secondary part lengths are available.

Other designs

Abbrev. column 16 17 18 19

NNNN = no other design.

6.1.4 Type code frame size 015

Abbrev. Column	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	20	1	2	3	4	5	6	7	8	9	30	1	2	3	4	5	6	7	8	9	40
Example:	M	C	P	0	1	5	A	-	L	0	4	0	-	N	T	-	N	0	F	N	-	N	N	N	N															

Product
MCP .... = MCP

Size
015 .... = 015

Length
Lengths .... = A, B

Winding
MCP015A .... = L040
MCP015B .... = L040

Cooling
Natural convection .... = N

Mounting style
T-shape .... = T

Hall unit
None .... = N0

Electrical connection
Cable conducted through the side .... = FN

Other design
None .... = NNNN

ZN-40037-015_EN_2011-07-22.fh11

Fig. 6-3: Type code primary part MCP015

Abbrev. Column	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	20	1	2	3	4	5	6	7	8	9	30	1	2	3	4	5	6	7	8	9	40
Example:	M	C	S	0	1	5	-	3	S	-	0	0	6	6	-	N	N	N	N																					

Product
MCS . . . . = MCS

Size
015 . . . . = 015

Mechanical design
Fixing per screws . . . . = 3

Mounting style
Standard . . . . = S

Segment length
Secondary part length 66 mm . . . . . . = 0066
Secondary part length 99 mm . . . . . . = 0099

Other design
None . . . . = NNNN

Fig. 6-4: Type code secondary part MCS015

6.1.5 Type code frame size 020

Abbrev. Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Example:	M	C	P	0	2	0	C	-	V	1	8	0	-	N	I	-	N	0	C	N	-	N	N	N	N															

Product
MCP . . . . = MCP

Size
020 . . . . = 020

Length
Length. . . . .= B, C, D

Winding
MCP020B . . . . = V180, V720
MCP020C . . . . = V180, V720
MCP020D . . . . = V180, V720

Cooling
Natural convection . . . . = N

Mounting style
I-shape . . . . = I

Hall unit
Digital . . . . = L0
Analogue . . . . = L1
None . . . . = N0

Electrical connection
Cable conducted through front of the primary part . . . . = CN

Other design
None . . . . = NNNN

ZN-40037-020_EN_2011-07-22.fh11

Fig. 6-5: Type code primary part MCP020

Abbrev. Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Example:	M	C	S	0	2	0	-	3	S	-	0	1	2	0	-	N	N	N	N	

Product
MCS . . . . = MCS

Size
020 . . . . = 020

Mechanical design
Fixing per screws . . . . = 3

Mounting style
Standard . . . . = S

Segment length
Secondary part length 120 mm . . . . . = 0120
Secondary part length 180 mm . . . . . = 0180
Secondary part length 300 mm . . . . . = 0300

Other design
None . . . . = NNNN

Fig. 6-6: Type code secondary part MCS020

6.1.6 Type code frame size 030

Abbrev. Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Example:	M	C	P	0	3	0	D	-	V	1	8	0	-	N	I	-	N	0	C	N	-	N	N	N	N															

Product
MCP . . . . = MCP

Size
030 . . . . = 030

Length
Lengths. . . . .= B, C, D

Winding
MCP030B . . . . = V180, V390
MCP030C . . . . = V180, V390
MCP030D . . . . = V180, V390

Cooling
Natural convection . . . . = N

Mounting style
I-shape . . . . = I

Hall unit
Digital . . . . = L0
Analogue . . . . = L1
None . . . . = N0

Electrical connection
Cable conducted through front of the primary part . . . . = CN

Other design
None . . . . = NNNN

ZN-40037-030_EN_2011-07-22.fh11

Fig. 6-7: Type code primary part MCP030

Abbrev. Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Example:	M	C	S	0	3	0	-	3	S	-	0	1	2	0	-	N	N	N	N																					

Product
MCS . . . . = MCS

Size
030 . . . . = 030

Mechanical design
Fixing per screws . . . . = 3

Mounting style
Standard . . . . = S

Segment length
Secondary part length 120 mm . . . . . = 0120
Secondary part length 180 mm . . . . . = 0180
Secondary part length 300 mm . . . . . = 0300

Other design
None . . . . = NNNN

ZN-40038-030_NOR_N_EN_2010-10-29.fh11

Fig. 6-8: Type code secondary part MCS030

6.1.7 Type code frame size 040

Abbrev. Column	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	20	1	2	3	4	5	6	7	8	9	30	1	2	3	4	5	6	7	8	9	40
Example:	M	C	P	0	4	0	E	-	V	0	7	0	-	N	I	-	N	0	C	N	-	N	N	N	N															

Product
MCP . . . . = MCP

Size
040 . . . . = 040

Length
Lengths .. . .= B, C, E, G

Winding
MCP040B . . . . = V070, V300
MCP040C . . . . = V070, V300
MCP040E . . . . = V070, V300
MCP040G . . . . = V070, V300

Cooling
Natural convection . . . . = N

Mounting style
I-shape . . . . = I

Hall unit
Digital . . . . = L0
Analogue . . . . = L1
None . . . . = N0

Electrical connection
Cable conducted through front of the primary part . . . . = CN

Other design
None . . . . = NNNN

ZN-40037-040_EN_2011-07-22.fh11

Fig. 6-9: Type code primary part MCP040

Abbrev. Column	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	20	1	2	3	4	5	6	7	8	9	30	1	2	3	4	5	6	7	8	9	40
Example:	M	C	S	0	4	0	-	3	S	-	0	1	2	0	-	N	N	N	N																					

Product
MCS . . . . = MCS

Size
040 . . . . = 040

Mechanical design
Fixing per screws . . . . = 3

Mounting style
Standard . . . . = S

Segment length
Secondary part length 120 mm . . . . . = 0120
Secondary part length 180 mm . . . . . = 0180
Secondary part length 300 mm . . . . . = 0300

Other design
None . . . . = NNNN

ZN-40038-040_NOR_N_EN_2010-02-17.fh11

Fig. 6-10: Type code secondary part MCS040

6.1.8 Type code frame size 070

Abbrev. Column	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	20	1	2	3	4	5	6	7	8	9	30	1	2	3	4	5	6	7	8	9	40
Example:	M	C	P	0	7	0	D	-	V	0	7	0	-	N	I	-	N	0	C	N	-	N	N	N	N															

Product
MCP . . . . = MCP

Size
070 . . . . = 070

Length
Lengths . . . .= C, D, F, M

Winding
MCP070C . . . . = V050, V300
MCP070D . . . . = V050, V300
MCP070F . . . . = V050, V300
MCP070M . . . . = V050, V230

Cooling
Natural convection . . . . = N

Mounting style
I-shape . . . . = I

Hall unit
Digital . . . . = L0
Analogue . . . . = L1
None . . . . = N0

Electrical connection
Cable conducted through front of the primary part . . . . = CN

Other design
None . . . . = NNNN

ZN-40037-070_EN_2012-01-13.fh11

Fig. 6-11: Type code primary part MCP070

Abbrev. Column	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	20	1	2	3	4	5	6	7	8	9	30	1	2	3	4	5	6	7	8	9	40
Example:	M	C	S	0	7	0	-	3	S	-	0	1	2	0	-	N	N	N	N																					

Product
MCS . . . . = MCS

Size
070 . . . . = 070

Mechanical design
Fixing per screws . . . . = 3

Mounting style
Standard . . . . = S

Segment length
Secondary part length 120 mm . . . . . = 0120
Secondary part length 180 mm . . . . . = 0180
Secondary part length 300 mm . . . . . = 0300

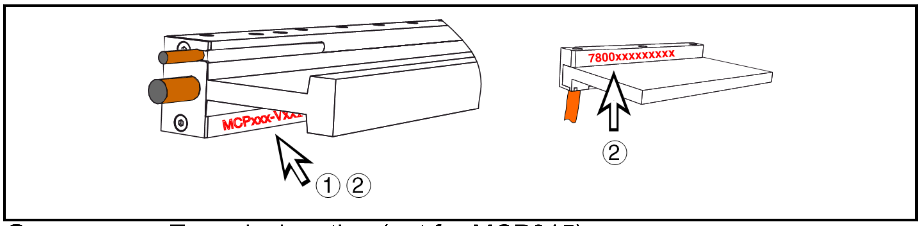
Other design
None . . . . = NNNN

Fig. 6-12: Type code secondary part MCS070

6.2 Identification

6.2.1 Identification MCP primary part

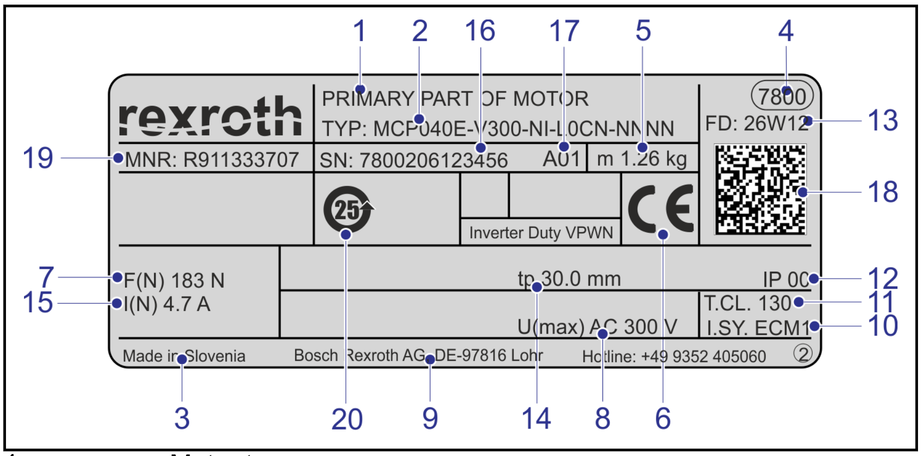
An engraved type designation is on the primary part.



①	Type designation (not for MCP015)
②	Serial number

Fig. 6-13: Position of type designation and serial number of primary part

Additionally, the primary part has two identical type plates at delivery. The type plates allow an univocal identification of the primary part and can be fixed on the machine or used be used elsewhere by the user.

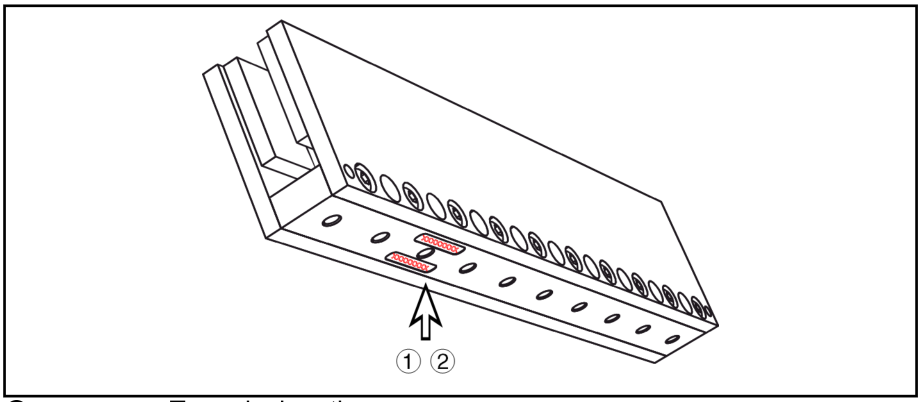


1	Motor type
2	Type designation
3	Designation of origin
4	Factory number
5	Mass of primary part
6	EC declaration of conformity
7	Rated power
8	Maximum input voltage
9	Company address
10	Insulation system
11	Thermal class
12	Degree of protection by housing
13	Manufacturing date
14	Pole pitch
15	Rated current
16	Serial number
17	Change status
18	Rexroth barcode
19	Material number
20	China RoHS conformity mark

Fig. 6-14: Type plate example primary part

6.2.2 Identification MCS secondary part

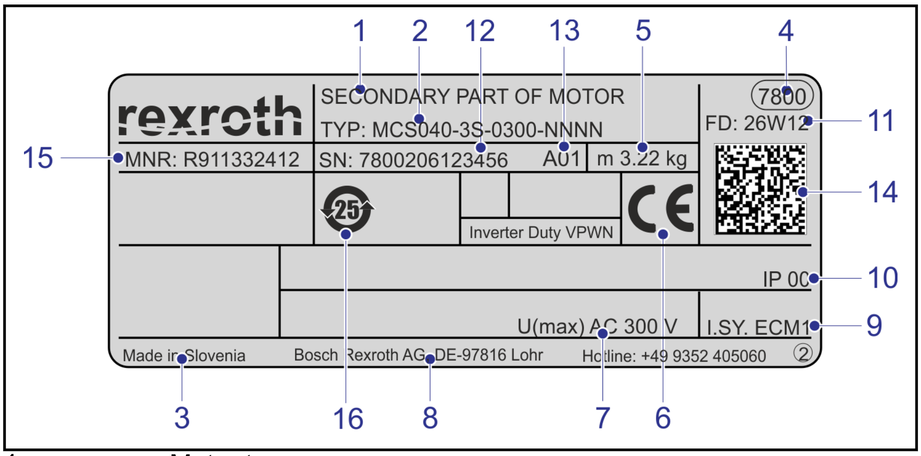
The type designation with serial number is at the bottom of the secondary part.



①	Type designation
②	Serial number

Fig. 6-15: Position of type designation and serial number of secondary part

Additionally, the secondary part has two identical type plates at delivery. The type plates allow an univocal identification of the secondary part and can be fixed on the machine or used be used elsewhere by the user.



1	Motor type
2	Type designation
3	Designation of origin
4	Factory number
5	Mass secondary part
6	EC declaration of conformity
7	Maximum input voltage
8	Company address
9	Thermal class
10	Degree of protection by housing
11	Manufacturing date
12	Serial number
13	Change status
14	Rexroth barcode
15	Material number
16	China RoHS conformity mark

Fig. 6-16: Type plate example secondary part

6.2.3 Certification mark

Certification mark	Significance
CE	Conformity with applicable EC Directives
EAC	EAC stands for Eurasian Conformity.
25	Conformity according to RoHS and China RoHS2.

Tab. 6-1: Certification mark at type plate

7 Accessories and options

7.1 Hall unit

7.1.1 General

For control of synchronous motors, the absolute position information regarding a pole pair is required to recognize the position of the permanent magnets to the motor windings. Only in connection with an electrical commutation offset angle to be determined on initial commissioning, the current with correct phase position to the magnetic field can be set via the controller to enable generation of a defined force in the dedicated travel direction by the motor.

If an incremental length measuring system is used, commutation of the axis has to be performed every time the phase of the drive is step up. This is realized by a drive-internal procedure. Subsequently, the motor power can develop.

☞ The commutation is determined automatically during the phase step up by the Hall unit. Therefore, no power switch-on is necessary (no motor movement).

The Hall unit offers special advantages, for commutation of linear motors, for example ...

- in gantry arrangement
- at vertical axes
- in mechanically secured state,
- that must not be moved for safety reasons during commutation.

7.1.2 Hall unit function

The Hall unit (analog or digital) serves for motionless commutation of the linear motor in connection with an incremental measuring system. For IndraDrive Cs, the motor commutation is performed automatically on phase switching to operating mode. For this, motion is not required. The motor may also be in a fixed stop or positioned at the end of the travel length (end stop), for example.

Rexroth linear motors of MCL020 ... 070 series can be ordered according to the motor type code with or without Hall unit (seechapter 6.1.2 "Type codes primary part MCP" on page 61).

☞ Independent from the origin order, primary parts of frame size 020 ... 070 can be converted or upgraded with a separately orderable Hall unit.

Hall unit analog

Analog Hall units for MCL of Rexroth create two sinusoidal signals, with a phase offset of 120°. The output voltage is 1 V_{SS} dependend from the position of the Hall unit over the magnets of the secondary part and is provided at the lines according to 7-1 The voltage supply is 7 ... 20V. A minimum current consumption of 40 mA to the Hall unit must be ensured.

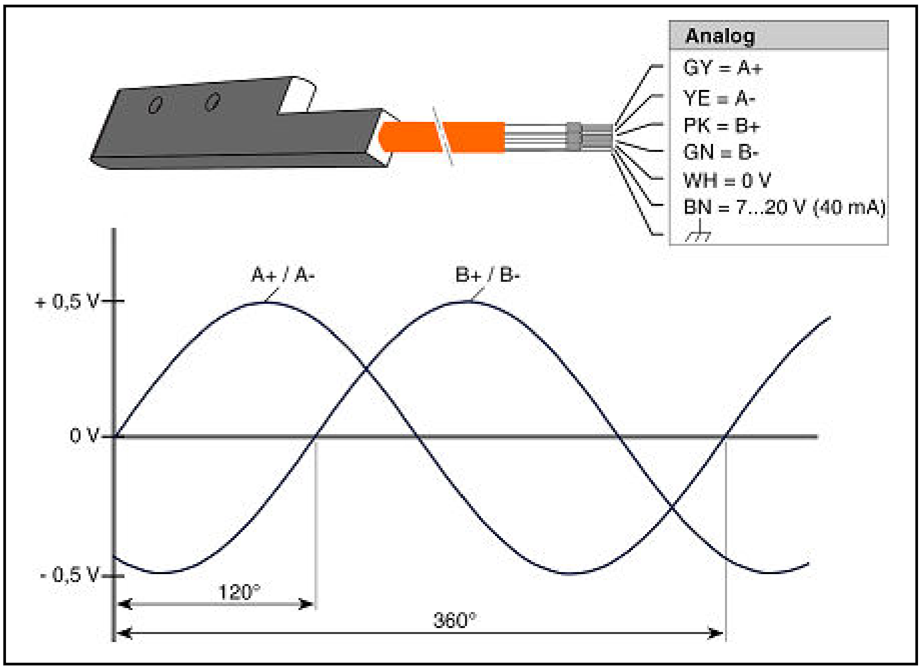


Fig. 7-1: Signal process of an analog Hall unit

☞ Bosch Rexroth controllers use a supply voltage of 12 V for the analog Hall unit.

Hall unit digital

Digital Hall units for MCL of Rexroth create three rectangular signals, with a phase offset of 120°. The signals from the open-collector circuit are provided at the lines according to 7-2 The voltage supply is 3 ... 24V. A minimum current consumption of 40 mA to the Hall unit must be ensured.

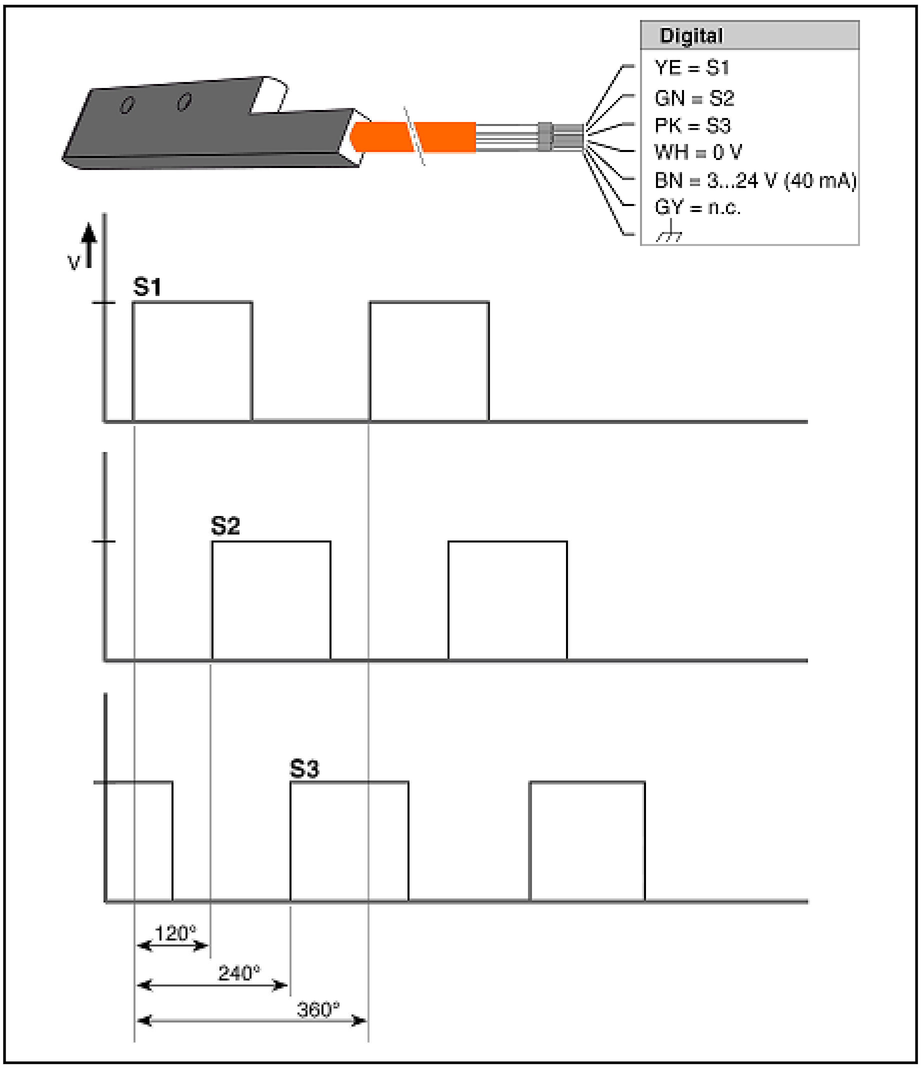


Fig. 7-2: Signal course of digital Hall unit

☞ The signal amplitude of the digital Hall unit depends on the supply voltage of the open-collector circuit. Bosch Rexroth controllers use a supply voltage of 5 V.

7.1.3 Hall unit assembly/Disassembly

☞ The Hall unit is a component that may by damaged by ESD. Before connecting the Hall unit, take appropriate measures for ESD protection (ESD = electrostatic discharge).

If a Hall unit on the primary part must be add on or exchanged, remove a dummy or the Hall unit to be exchanged in the installation space of the sensor first. To press out the dummy or the Hall unit slightly, we provide a small auxilliary device in the accessory delivery. The existing fastening screws can be used to assemble the new Hall unit. Do not exceed the permitted tightening torque (see Fig7-1. A too high tightening torque can damage the fastening thread of the Hall unit and can therewith make them useless.

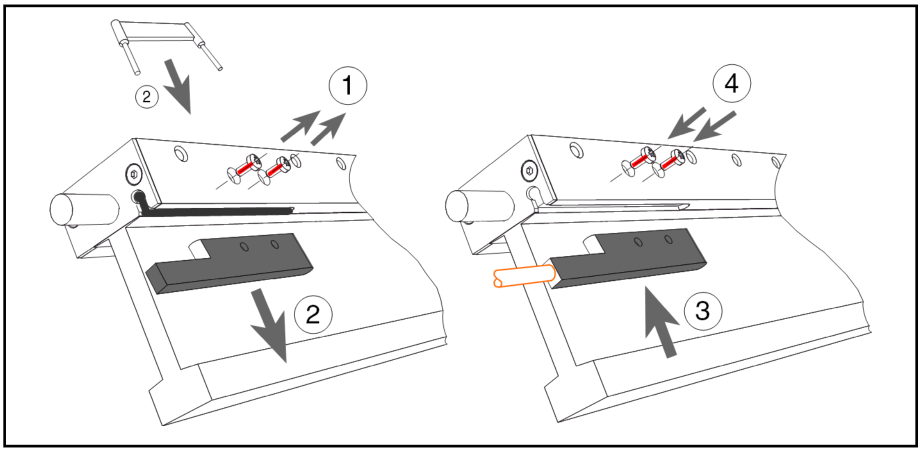


Fig. 7-3: Hall unit assembly / disassembly

1. Untighten both fastening screws. Store them to fasten a new Hall unit. When the fastening screws are lost, only use screws of the same design (see Fig. 7-1)!
2. Press the dummy or the Hall unit by means of an auxiliary device out of the installation space and remove it.
3. Assemble the new Hall unit

Hall unit assembly - screw tightening torque

Hall unit on	Screw size	Strength class	Tightening torque
MCP020	M2.5x16 (DIN EN ISO 7045 - Torx)	8.8	0.8 Nm
MCP030	M2.5x5 (DIN EN ISO 7045 - Torx)		
MCP040	M2.5x5 (DIN EN ISO 7045 - Torx)		
MCP070	M2.5x8 (DIN EN ISO 7045 - Torx)		

Tab. 7-1: Tightening torque Hall unit

7.1.4 Ordering code separate Hall unit

Primary part MCP ...	Hall unit order designation	
	Analog	Digital
015	No Hall unit available	
020	SUP-E01-A15-MCP020 (R911335794)	SUP-E01-D15-MCP020 (R911335797)
030 ... 070	SUP-E01-A30-MCP030/040/070 (R911335796)	SUP-E01-D30-MCP030/040/070 (R911335798)

Tab. 7-2: Hall unit order designation

7.2 Hall unit adapter box SHL03.1 for digital Hall unit

7.2.1 General mode of functioning

If Rexroth linear motors of MCL020 ... 070 series are operated at IndraDrive Cs, the Hall unit SHL03.1 adapter box enables simultaneous use of a digital Hall unit with an incremental length measuring system. By means of the SHL03.1 adapter box, the signals of these two components are connected and forwarded to the dedicated interface at the IndraDrive Cs.

☞ A possible circuitry with Rexroth cables is described underchapter 8.3.4 "Connect digital Hall unit" on page 93

7.2.2 Ordering code

SHL03.1 adapter box	
Short name	SHL03.1-NNN-S-NNN
Material number	R911335257

Tab. 7-3: SHL03.1 adapter box order designation

8 Connection technique

8.1 Notes

NOTICE **Motor destruction by direct connection to the 50/60 Hz mains power supply (three phase or single phase net)!**

MCL motors can only be operated with suitable drive controllers with variable output voltage and frequency (converter mode) as specified by Rexroth.

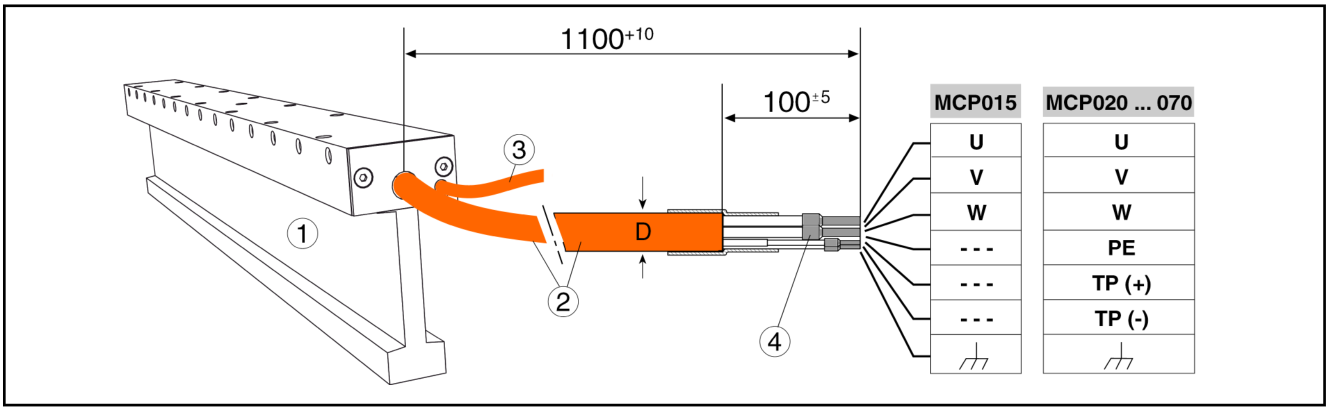
Rexroth offers a wide range of ready-made cables for connecting MCL motors. These cables are optimally adapted to the products and a great variety of requirements.

☞ Note that self assembled cables or cable systems of other manufactures possibly do not meet these requirements. Rexroth shall not be held responsible for resulting malfunction states or damage.

8.2 Power connection

8.2.1 Connection cable on primary part

Primary parts of MCL motors are fitted with a flexible and totally shielded connection cable. This 1100 mm long connection cable is connected with the primary part.



① Primary part MCP
② Connection cable power
③ Connection cable Hall unit (optional for MCP020 ... 070; seeFig.8-8)
④ Wires with wire end ferrules (wire designation acc. to DIN EN 60445)

Fig. 8-1: Design of connection cable (power) on the primary part MCP

Wire designation on power connection cable

Designation	MCP015 1)	MCP020 ... 070 1)	
U	BN (YE)	1	BN (YE)
V	BK (GN)	2	BK (GN)
W	GY (BU)	3	GY (BU)
PE	not applicable	GNYE	
TP(+)	not applicable	7	PK
TP(-)	not applicable	8	WH (GY)
Shield	Shield	Shield	

1) Colors in brackets can be transitionally available.

Tab. 8-1: Wire designation (power) on MCP primary parts

⚠ DANGER **Exceeding of voltage limits!**

Prepare a suitable connection with a protective switch via the primary part carrier when using AC voltage > 50 V or DC > 120 V (DIN IEC 60364-4-41) for MCP015.

Technical data connection cable Power

Frame size	Connection cables 1) (Bulk cable)	Diameter [D in mm]	Cross section Power wires [mm²]	Cross section Control wire [mm²]	Coupling	Flange socket
MCP015	REL0010	4.2 ±0.1	3 x 0.14	- / -	Not available	Not available
MCP020	REL0011	7.8 ±0.2	4 x 0.5	2 x 0.14	RLS1722/CM50 (R911340201)	RLS1703/C01 (R911388339)
MCP030						
MCP040	REL0012	8.3 ±0.2	4 x 0.75		RLS1722/CM07 (R911373943)	RLS1703/C01 (R911388339)
MCP070C/D/F						
MCP070M	INK0650	12.2 ±0.5	4 x 1.5	4 x 0.75 (only 2 wires are necessary and lead out from the temperature sensor)	RLS1712/CM01 (R911381140)	RLS2303/C02 (R911381141)

1) Max. permitted bending radius [R]: for fix installation 5 x D; for flexible installation 7.5 x D

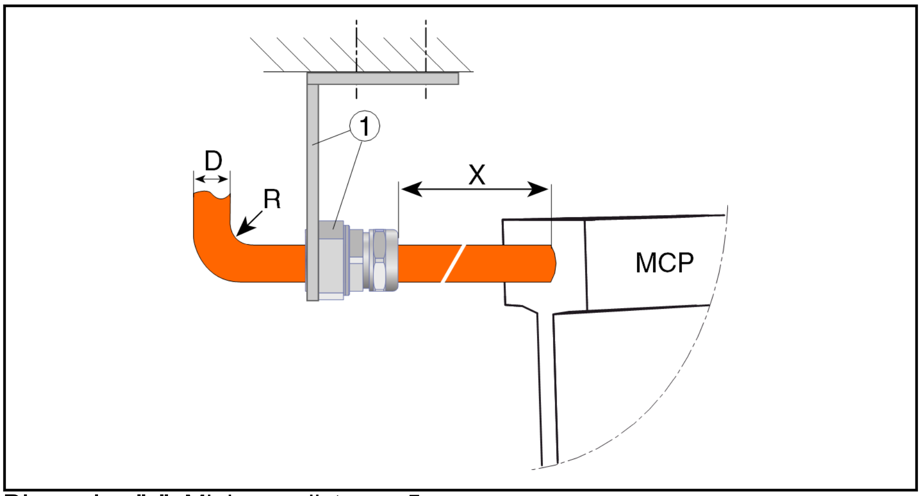
Tab. 8-2: Connection cable power on MCP primary parts

Routing of the connection cable

The connection cable is mulded fix with the primary part and ends with open cable ends with wire end ferrules . Basically, we recommend to lead the connection cable in fix installation to a junction, provided by the customer, like e.g. flange sockets or terminal boxes. Flange socket or terminal boxes must also be fixed with the machine construction. From this junction, a suitable additional power cable can be laid to supply power through the energy chains or the machine construction.

NOTICE	**Avoid bending, pulling and pushing loads as well as continuous movements of the connection cable at the point where the cable exits from the primary part. Any load of this kind can lead to irreparable damage (e.g. cable break) on the primary part!**

If a fixed installation is not possible, provide the connection cable with a strain relief (see Fig. 8-2) to protect the cable and the primary part from any damage (e.g. cable break).



Dimension "x"	Minimum distance 5 mm
①	Strain relief of the connection cable on MCP primary part
D	Diameter connection cable (see Fig.8-2 and Fig.8-3
R	Observe the permitted bending radius of the connection cable (see Tab. 8-2)

Fig. 8-2: Example for strain relief of connection cable

Ground connection

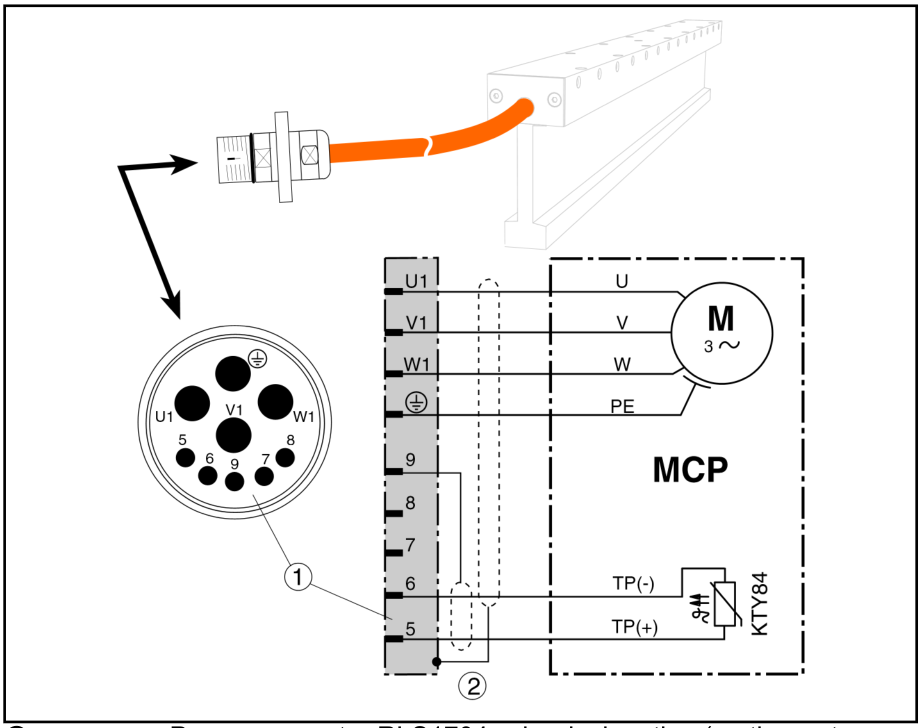
☞ If the grounding of the secondary parts cannot be ensured with mounting into the customer`s machine construction, connect it according to DIN VDE 0100-410 with the potential of the protective conductor .

8.2.2 Assembly Connection cable on primary part

Bosch Rexroth offers ready-made power cables to connect MCP primary part on Rexroth controllers. Also refer to chapter 8.2.3 .

Mount the connection cable on the flange socket (RLS1704) to connect the primary part with the power cable. Available ready-made power cables of Rexroth can be connected on these flange sockets.

☞ The assignment of the power cables results from the motor-controller-combination and can be seen in tabletab. 10-2 "Motor-control combination with IndraDrive Cs" on page 134.



①	Power connector RLS1704; wire designation (on the motor side) see fig.8-1
②	Connect total shield over the cable gland with the connector housing.

Fig. 8-3: RLS1704 connection assignment on connection cable MCP

☞ Observe the assembly instruction, which is delivered with the male connector.

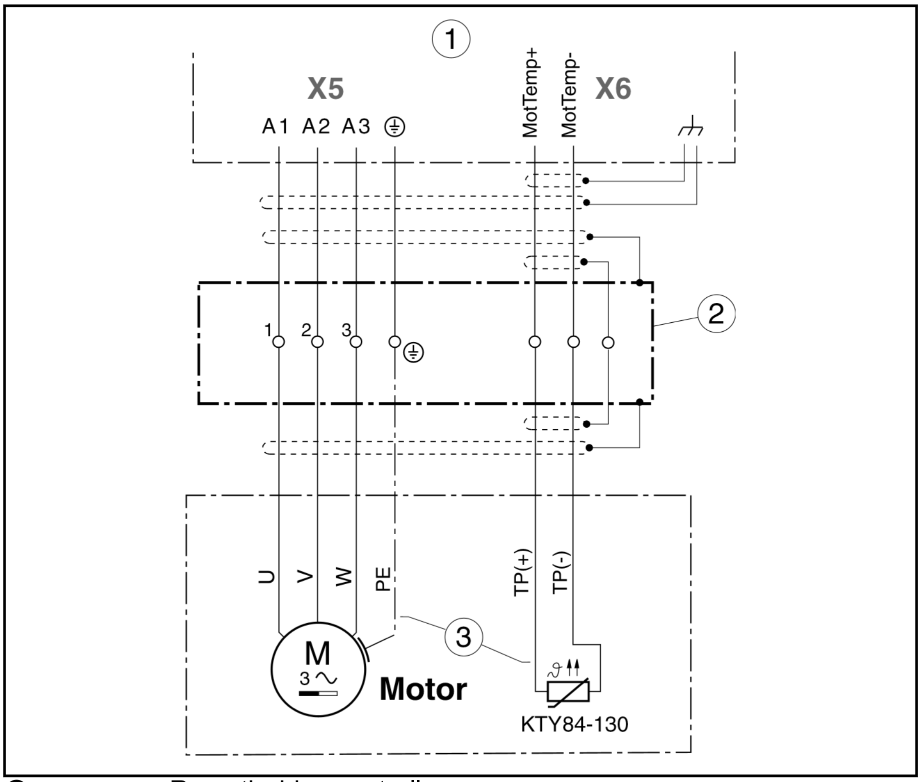
8.2.3 Connection power

Bosch Rexroth provides ready-made power cables available for motor connection. The cables RKL4800, RKL4801, RKL4802, RKL4803 and INK0650 are optimally adjusted to our products and their most different demands.

☞ Please observe that ready-made cables or cable systems of other manufacturers may not fulfill these demands completely. Rexroth shall not be held responsible for resulting malfunction states or damage.

You can find additional information ...

- on the **selection** of power and encoder cables for Rexroth motors in documentation "Rexroth Connection Cables IndraDrive and IndraDyn" (DOK-CONNEC-CABLE*INDRV-AU□□-□□-P),
- on "**Electromagnetic Compatibility** in Drive and Control Systems" (DOK-GENERL-EMV********-PR□□-□□-P).



①	Rexroth drive controller
②	Junction (terminal box)
③	Temperature sensor and ground wire available only for frame size MCP020 ... 070. For MCP015 connect a separate protective switch with the primary part carrier acc. to DIN EN 61140 for operation on voltages above protective extra-low voltage.

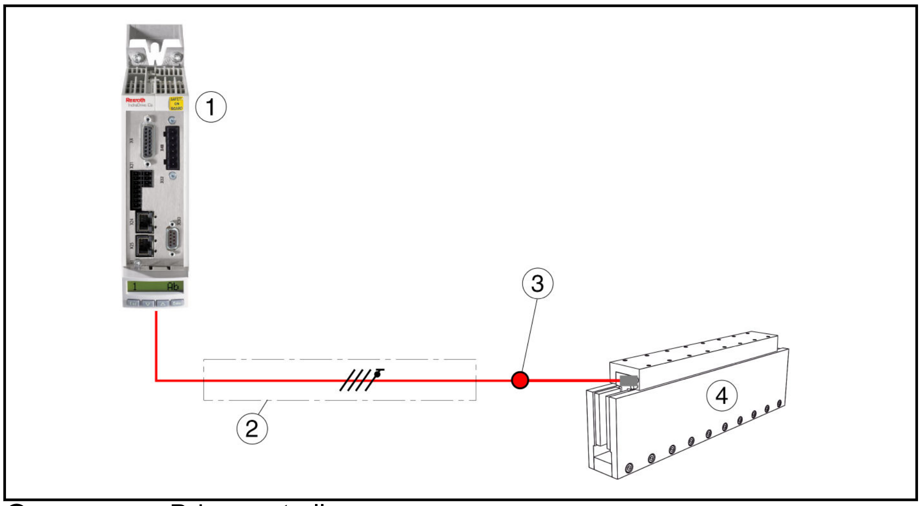
Fig. 8-4: Power connection on drive controller

Connection power cable in dependence from primary part at parallel arrangement

At parallel arrangement of two primary parts, the connection (phase sequence) of the power wires of the connection cable on the drive controller depends from the direction of the cable output. Observe the notes about connecting power wires inchapter on page 115.

8.2.4 Installation of power connection

Installation method for motor single arrangement



① Drive controller
② Energy chain
③ Junction (connector or terminal boxes)
④ Motor

Fig. 8-5: Motor single arrangement

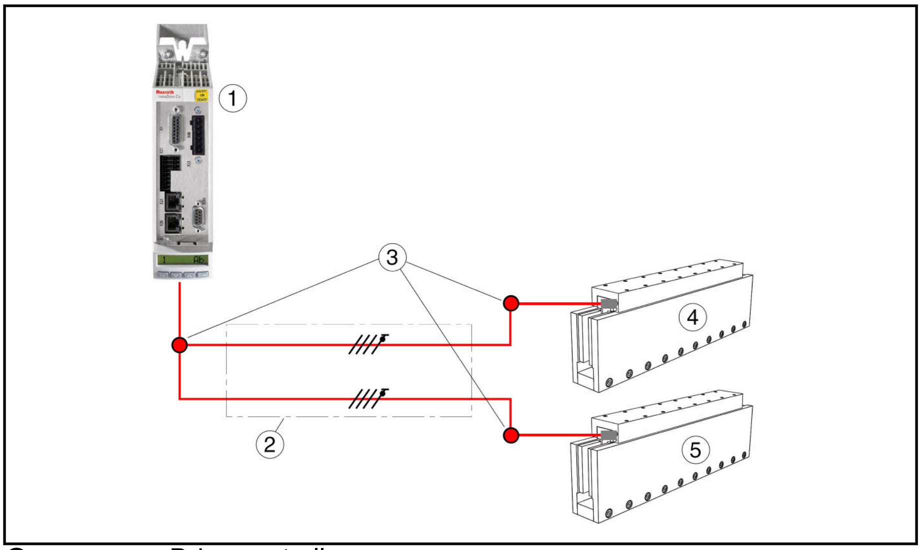
Parallel motor connection

When connecting a motor parallel on a drive controller, the following possibilities exist to assembly the motor cable.

- Installation with two separate power cables
- Installation with a collective power cable with bigger cross section

The description of the power cables is done in the documentation "Rexroth Connection Cables", MNR R911322948 (DE) or R911322949 (EN).

Parallel connection, installation method separate power cables

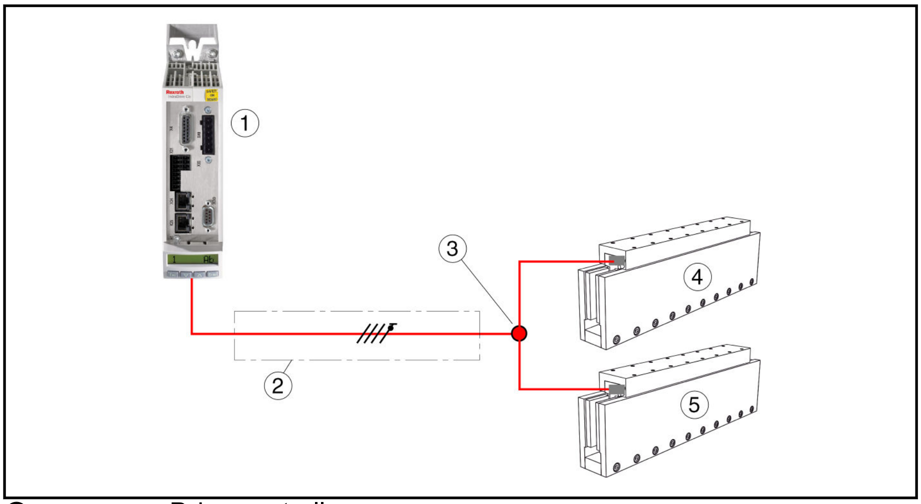


①	Drive controller
②	Energy chain
③	Junctions (connector or terminal boxes)
④	Motor 1
⑤	Motor 2

Fig. 8-6: Parallel connection, separate power cables

Parallel connection, installation method collective power cable

☞ If this installation method (collective power cable) is used, bigger power wire cross section can be necessary. Observe the current rating dependent from the rated current of the motor when selecting the power cable



①	Drive controller
②	Energy chain
③	Junction (terminal boxes)
④	Motor 1
⑤	Motor 2

Fig. 8-7: Parallel connection, collective power cable

8.3 Sensors

8.3.1 Connection temperature sensor

All primary parts - except frame size MCP015 - are equipped with a PTC temperature sensor **KTY84-130**. The temperature sensor is fixed within the motor winding and serves for winding temperature measuring. The temperature sensor itself offers no safe protection of the winding from thermal overload. The thermal monitoring of the motor must additionally be done via a working temperature modell in the controller.

Heed the right polarity of the connection wires when connecting the KTY84-130 . The wire designation can be found under Fig. 8-1.

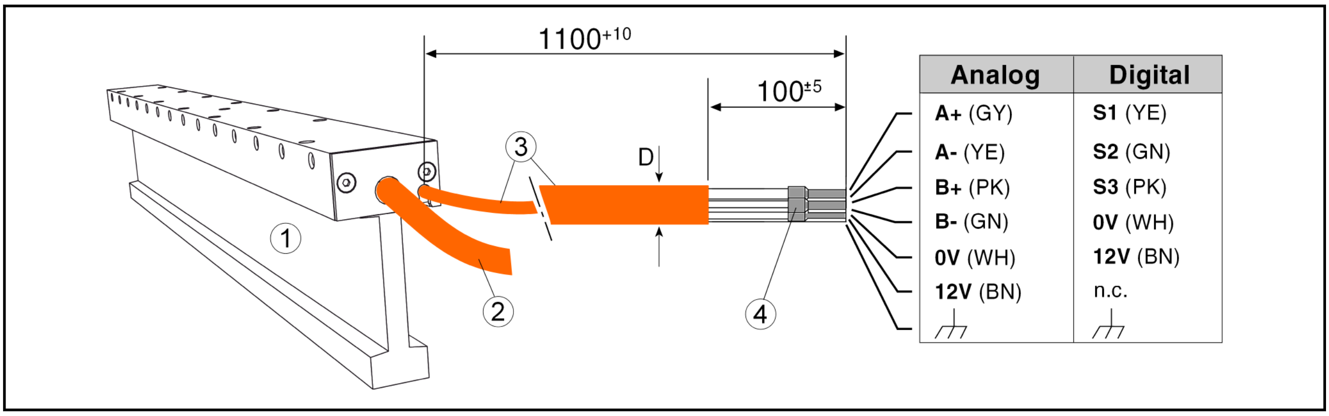
For additional information on the temperature sensor, please refer to chapter 9.10 "Motor temperature monitoring" on page 107.

☞

- Temperature sensor KTY84-130 is a component that might by damaged by ESD! For this reason, the wires of the sensor are protected by a protective foil at the connection cable. Before connecting the sensor, take measures regarding ESD protection.(ESD = electrostatic discharge).
- The used temperature sensors are double or reinforced insulated according to DIN EN 50178, so separation exists according to DIN EN 61800-5-1.

8.3.2 Connection Hall unit

Motors with Hall unit have an additional cable to connect the sensor. This cable is beside the connection cable for the power. After motor installation, the cable of the Hall unit can be shortened to the required length and be assembled with a D-sub connector, 9-pole (pin), for example. Also refer to Chap. 8.3.3 .



① Primary part MCP
② Connection cable power (see chapter 8.2.1 "Connection cable on primary part" on page 83)
③ Connection cable Hall unit (optional for MCP020 ... 070)
④ Wires with wire end ferrules

Fig. 8-8: Wire designation connection cable Hall unit

Connection cable Hall unit

Motor frame size	Diameter [D]	Cross section Control wire [mm²]	Allowed bending radius [R]*
MCP020 ... 070	4.2 ±0.1	6 x 0.14	- for fix installation 5 x D - for flexible installation 7.5 x D
*) See notes regarding bending radius under Fig.8-2			

Tab. 8-3: Connection cable Hall unit on primary parts MCP020 ... 070

NOTICE

Avoid bending, pulling and pushing loads as well as continuous movements of the connection cable at the point where the cable exits from the primary part. Any load of this kind, can lead to irreparable damage (e.g. cable break) on the primary part!

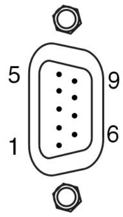
The connection cable of the Hall unit can be connected with the power cable via cable ties, if the power cable is provided with a strain relief. If a fixed installation is not possible, equip the connection cable of the Hall unit with strain relief (for example, see Fig. 8-2) to protect the cable and the primary part from any damage (e.g. cable break).

☞ The Hall unit is a component that may by damaged by ESD. For this reason, the wire ends on the connection cable are protected with a protective foil. Before connecting the Hall unit, take appropriate measures for ESD protection (ESD = electrostatic discharge).

For more information about the Hall unit, please refer to chapter 7.1 "Hall unit" on page 77.

8.3.3 Assembly Hall unit connection cable

Before the Hall unit can be connected to the SHL03.1 adapter box, the connection cable of the Hall unit must be assembled with a 9-pole D-sub connector (RGS0005). The assignment

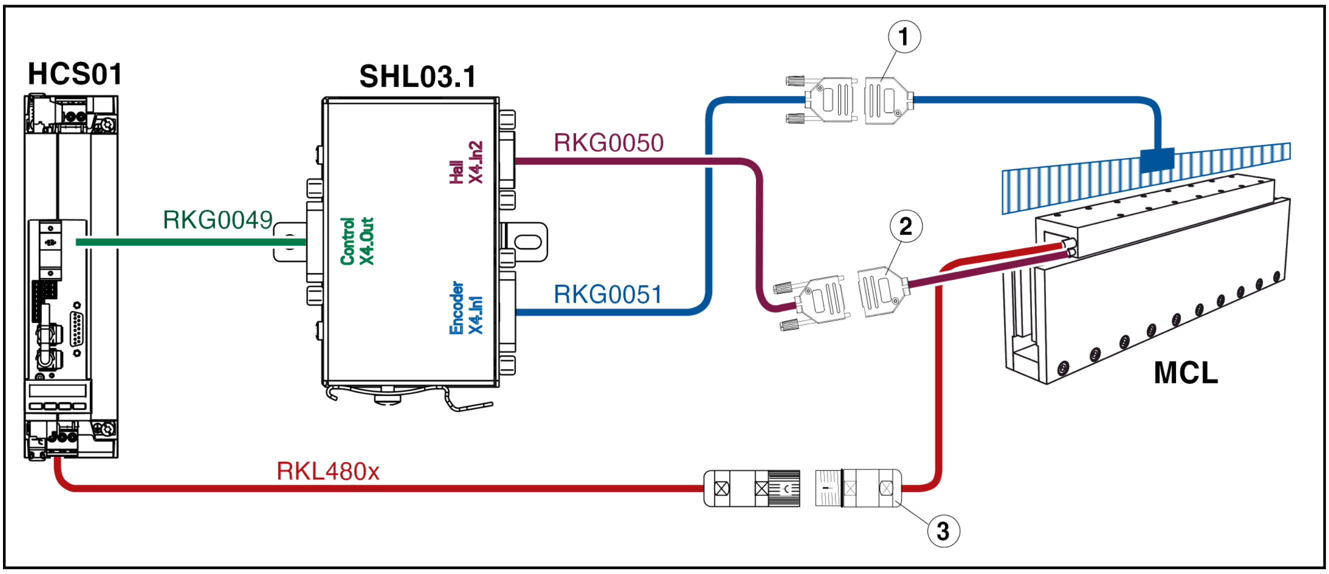
	Connection cable Hall unit	
	analog	digital
1	12 V (BN)	12 V (BN)
2	A+ (GY)	S1 (YE)
3	A- (YE)	/
4	0V (WH)	S2 (GN)
5	B+ (PK)	0V (WH)
6	B- (GN)	/
7	/	/
8	/	S3 (PK)
9	/	/
Connector housing	Outer shield	Outer shield

Tab. 8-4: Connection assignment RGS0005 for Hall unit connection

8.3.4 Connect digital Hall unit

To connect a digital Hall unit in connection with an incremental length measuring system on a conroller of the IndraDrive Cs family, use the **SHL03.1 adapter box**.

The SHL03.1 brings both incoming signal cables of Hall unit and length measuring system together and redirects their signals via a single connection cable to the drive controller for encoder evaluation.



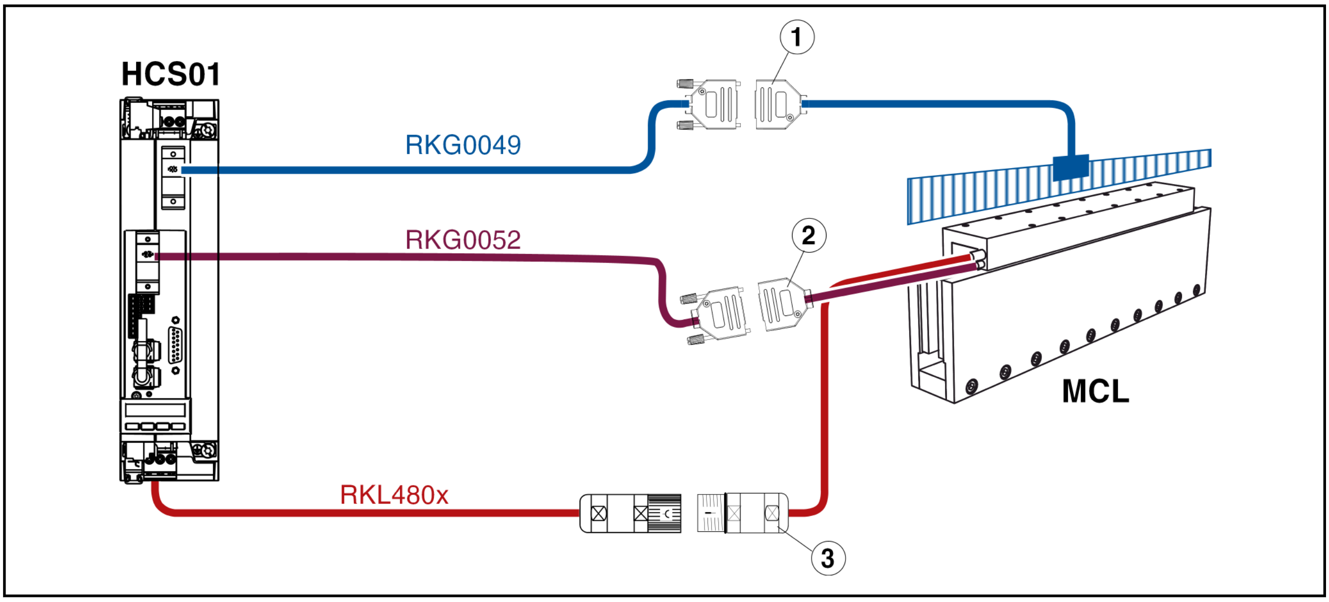
①	Flange socket RGS0006 (D-sub connector 15-pole (pins))
②	Flange socket RGS0005 (D-sub connector 9-pole (pins))
①	Flange socket RLS1704
RKL480x	Motor power cables (max. cable length 75 m)
RKG0049	Adapter box ↔ encoder evaluation on drive controller (max. cable length 75 m)
RKG0050	Digital Hall unit ↔ adapter box (max. cable length 30 m)
RKG0051	Length measuring system ↔ adapter box (max. cable lengths 75 m)

Fig. 8-9: Connection overview MCP with digital Hall unit

- The total distance between drive controller and the head of the length measuring system and/or the Hall unit must not exceed a length of 75 m!
- Observe further notes about the SHL03.1 adapter box in the documentaion DOK-INDRV*-HCS01******-PRxx-xx-P, MNR R911322210 and under chapter 7.2 "Hall unit adapter box SHL03.1 for digital Hall unit" on page 81.

8.3.5 Connect analog Hall unit

To connect an absolute measuring system and an analog Hall unit, a shelf with 2 encoder interfaces in the IndraDrive Cs controller is necessary.



①	Flange socket RGS0006 (D-sub connector 15-pole (pins))
②	Flange socket RGS0005 (D-sub connector 9-pole (pins))
③	Flange socket RLS1704
RKL480x	Motor power cables (max. cable length 75 m)
RKG0049	Length measuring system ↔ Encoder evaluation at drive controller (max. cable length 75 m)
RKG0052	Analog Hall unit ↔ encoder evaluation on drive controller (max. cable length 75 m)

Fig. 8-10: Connection overview MCP with analog Hall unit

8.4 Length measuring system

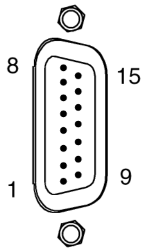
☞ The length measuring system is not in the scope of delivery of the motor and must be prepared and assembled by the maschine manufacturer (see chapter 9.14 "Length measuring system" on page 120).

Setting the encoder polarity depends on the direction of rotation of the primary part and must be parameterized at start-up of the controller. Also observe the manufacturer's instruction of the length measuring system.

To connect an incremental length measuring system on a Rexroth controller or on the adapter box SHL03.1, Bosch Rexroth provides two connection cables.

- **RKG0049** for connection of the length measuring system directly on the controller
- **RKG0051** to connect the length measuring system on the SHL03.1

To use this connection cable, fit the connection cable on the incremental length measuring system with a compatible flange socket (RGS0006).

 DA000056v01_nn.FH9	Signal	Function
1	GND_shld	Connection signal shields (inner shields)
2	A+	Track A positive
3	A -	Track A negative
4	GND_Encoder	Reference potential voltage supplies
5	B+	Track B positive
6	B -	Track B negative
7	n.c.	/
8	n.c.	/
9	R+	Reference track positive
10	R-	Reference track negative
11	VCC_Encoder (12 V)	Encoder supply 12 V
12	VCC_Encoder (5 V)	Envoder supply 5 V
13	n.c.	/
14	n.c.	/
15	Sense-	Feedback of reference potential (Sense line)
Connector housing	/	Outer shield

Tab. 8-5: Connection assignment to be done on RGS0006 to connect the length measuring system on the customer-side

9 Application and construction instructions

9.1 Mode of functioning

The force generation for an ironless synchronous-linear motor, is the same as the torque generation at rotary synchronous motors. The ironless primary part (active part) has a winding; the secondary part (passive part) has permanent magnets.

Both, the primary part and the secondary part can be moved.

Realization of any traverse path lengthcan be done by stringing together several secondary parts.

Axis construction

The MCL motor is a kit motor. The components primary and secondary part(s) are delivered separately and completed by the user via linear guide and the linear measuring system. They are mounted into the machine or system.

The construction of an axis fitted with a linear motor normally consists of

- Primary part with Hall unit
- one or more secondary parts with permanent magnets
- Length measuring system
- Linear guide
- Energy flow
- Slide or machine construction

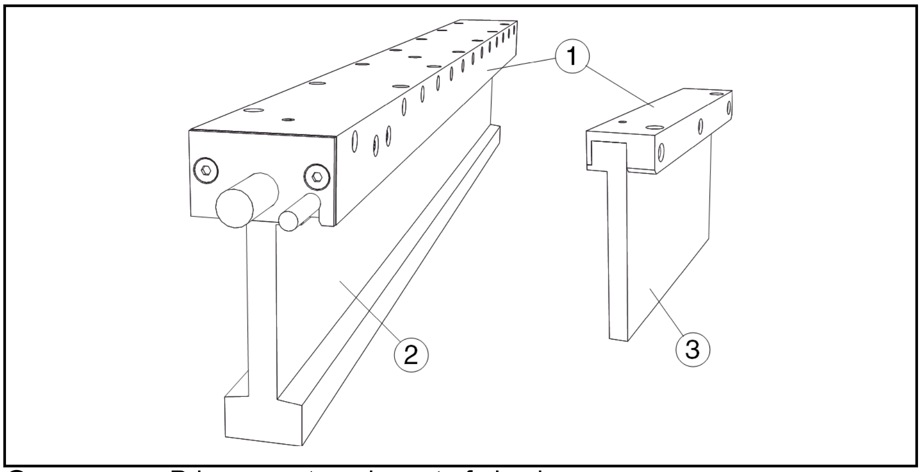
For force multiplication can be two or more primary parts mechanically coupled, arranged in-line. For further information see chapter 9.13.2 "Several motors per axis" on page 113.

☞ Only the primary and the secondary part(s) belong to the scope of delivery of the motor. Linear guide and length scale as well as further additional components have to be made available by the user.

9.2 Motor design

9.2.1 Design primary part

The primary part consists of an u-shaped aluminum primary part carrier which bears the coil body and is molded with plastic resin. This mold serves for mechanical property of the MCP. It is no protection against humidity, foreign bodies or touch of electrically active parts. Due to the mold process, sometimes small blowholes can occur on the surface of the mold. They are not relevant for the function and mechanical property of the motor. The motor cooling happens due to the thermal couplingof the primary part on the machine and via the natural convection.



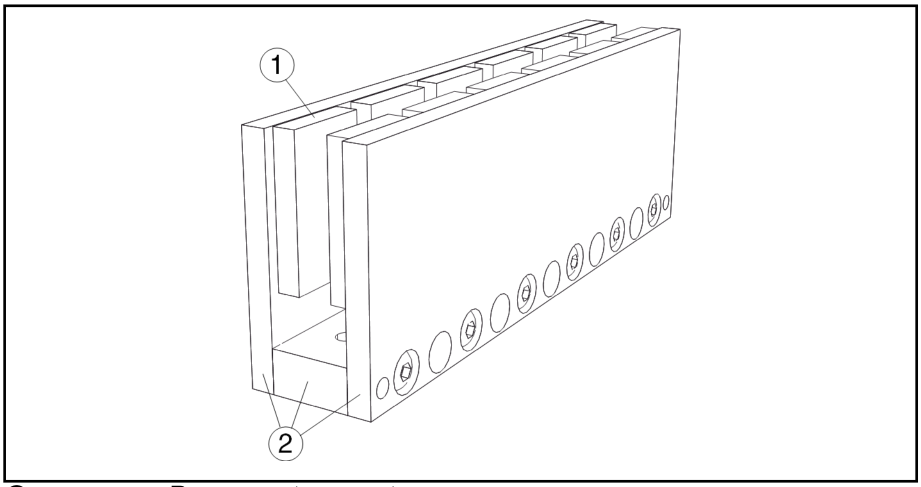
① Primary part carrier out of aluminum
② Form of molded motor winding in design **I-form** (MCP020 ... 070)
③ Form of molded motor winding in design **T-form** (MCP015)

Fig. 9-1: Design MCP primary part

9.2.2 Design secondary part

The MCS consists of an u-shaped screwed steel base plate with adhered permanent magnets. All fastening holes are in the fastening rail along the secondary part.

To ensure a high corrosion protection , the iron parts of the secondary part are nickel-plated and the permanent magnets are coated with epoxy.



① Permanent magnets
② Screwed secondary part body

Fig. 9-2: Secondary part MCS040

Available lengths secondary parts

Secondary parts are available in different lengths. Please also refer to the data underType code.

Required length of the secondary parts

The required length L of the secondary part can be defined as follows:

$$L_{Secondary\ part} \geq L_{Traversepath} + L_{Primary\ part}$$

Fig. 9-3: Defining the required length of the secondary part

9.2.3 Frame size and frame length

For adjusting on different feed force requirements, Bosch Rexroth offers MCL motors in a modular system in different sizes and lengths.

Frame sizes

The designation of frame size is derived from the active height l_{Fe} and power of MCL.

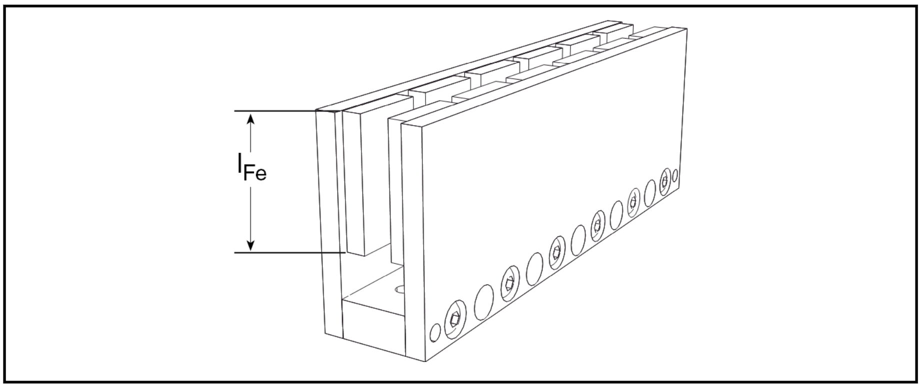


Fig. 9-4: l_{Fe} = Active magnet heigth

According to this system, the MCL modular construction system contains the following motor frame sizes:

- MCP015 / MCS015
- MCP020 / MCS020
- MCP030 / MCS030
- MCP040 / MCS040
- MCP070 / MCS070

Frame lengths

Primary and secondary parts of one size are graduated additionally to different frame sizes. The length designation of the primary part in the type code is done via code letters, like A, B, C. The length designation of the secondary part in the type code is given directly by the length in mm.

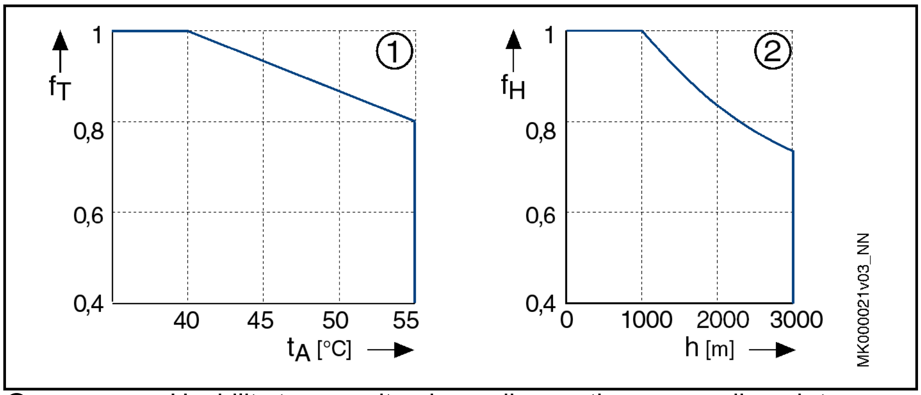
☞ For detailled information about the available frame sizes and lengths please refer to the Type code of the motor.

9.3 Installation altitude and ambient conditions

The motor performance data specified are applicable for

- Ambient temperature 0 ... +40 °C
- Setup elevation of up to 1,000 m above sea level.

Different conditions lead to a departing of the data according to the following diagrams. Do occur deviating ambient temperatures and higher installation altitude at the same time, both utilization factors must be multiplied.



①	Usability to capacity, depending on the surrounding air temperature
②	Usability to capacity, depending on the installation altitude
f_T	Temperature utilization factor
t_A	Ambient temperature in degrees Celsius
f_H	Height utilization factor
h	Installation altitude in meters

Fig. 9-5: Derating of ambient temperature, installation altitude (in operation)

Calculation of performance data in case the limits specified are exceeded:

Ambient temperature > 40 °C

$F_{N\_red} = F_N \times f_T$

Installation altitude > 1,000 m

$F_{N\_red} = F_N \times f_H$

Ambient temperature > 40 °C and **setup elevation > 1,000 m**

$F_{N\_red} = F_N \times f_T \times f_H$

☞ The details for the utilization depending from the installation altitude and environmental temperature do not only apply to the motor , but on the whole drive system, consisting of motor, drive controller and mains supply. Ensure that the reduced data are not exceeded by your application.

9.4 Environmental conditions during operation

Environmental conditions are defined according to DIN EN 60721-3-3 in different classes. They are based on long-term experiences and take all influencing variables into account, e.g., air temperature and air humidity.

Overview of allowed classes of ambient conditions according to DIN EN 60721-3-3 during operation

Classification type	Allowed class
Classification of climatic environmental conditions	3K22
Classification of biological environmental conditions	3B1
Classification of mechanically active materials	3S6
Classification of mechanical environmental conditions	3M12

Tab. 9-1: Allowed classes of environmental conditions during operation

Based on DIN EN 60721-3-3, some limit values are partially defined in the following, which our products are allowed to be exposed to during operation. Observe the detailed description of the classifications to take all of the factors which are specified in the particular class into account.

Allowed operation conditions

Environmental factor	Unit	Value
Air temperature	°C	0 ... +40
Air humidity (relative)	%	5 … 95
Air humidity (absolute)	g/m³	1 ... 29

Tab. 9-2: Operating conditions

Unless otherwise specified, the values given are the values of the particular class. However, Bosch Rexroth reserves the right to adjust these values at any time based on future experiences or changed environmental factors.

9.5 Type of protection

The design of MCL motors is according to protection mode according to DIN EN 60034-5.

Motor component	Type of protection
Primary part (Front face MCP020 ... 070)	IP00 (IP20)
Secondary part	IP00
Hall unit	IP00

Tab. 9-3: Protection modes on MCL motors

- The mold of primary parts serves for mechanical property. This is no protection against humidity. Due to the coating thickness of the mold for MCP020 ... 070, only a small protection against foreign bodies or touch of dangerous electric voltage is ensured on the front sides (cable output and opposite side). Therefrom, the protection mode IP20 is derived on the front.
- Observe the notes under chapter 9.12.4 "Protection of the motor installation space" on page 112 regarding protection modes.

⚠ CAUTION

Any failure to observe the degree of protection of the motor may damage or destroy the motor components or result in personal injury!

The motors or components may only be used in environments where the degree of protection specified is adequate.

9.6 Acceptances and approvals

9.6.1 CE

CE

Certificate of conformity certifying the structure of and the compliance with the valid EN standards and EC guidelines are available for all motors. If required, the declarations of conformity can be requested from the responsible sales office. The CE mark is attached to the motor type label of the motors.

9.6.2 EAC

EAC

EAC stands for Eurasian Conformity.

Motors of MCL series fulfill the specified technical requirements of the EAC member states in the tariff union. The member states are Russia, Belarus and Kazakhstan.

9.6.3 RoHS

We confirm in our manufacturer´s declaration TC 30806-1 that our products confirm with the RoHS directive 2011/65/EG "Restriction of the use of certain hazardous substances in electrical and electronic equipment".

9.6.4 China RoHS 2

Motors of the MCL series are according to the specifications of standard SJ/T11364 and they have an EFUP (Environmentally friendly use period) of 25 years. A corresponding labeling is in preparation). For more information, refer to https://www.boschrexroth.com.cn/zh/cn/home_2/china_rohs2 www.boschrexroth.com.cn/zh/cn/home_2/china_rohs2 in section "Kit motors".

9.7 Magnetic fields

During operation of electric motors, electromagnetic fields are generated at live components and connection lines of these motors. The secondary parts equipped with permanent magnets of synchronous linear motors and rotors of synchronous kit motors are magnetically not shielded and permanently generate a static magnetic field (DC field) even if not activated. This is indicated by a warning label attached to each package with open permanent magnet components.

if all regulations and safety measures are complied with, synchronous kit motors with open permanent magnet components do not cause any inadmissible hazards. As of a distance of approx. 100 mm to the surface of open permanent magnet parts, there is practically no effective magnetic attraction of ferromagnetic parts. However, for people with implants, a minimum safety distance of 1 meter (1000 mm) is recommended.

Depending on the operating location, transport ways and storage of the machine and its components, local regulations and laws apply and have to be complied with during construction, transport and operation of the machine.

⚠ WARNING **Electromagnetic / magnetic fields! Health hazard for persons with heart pacemakers, metal implants or hearing aids! Material damage.**

Hazards due to magnetic and electromagnetic fields at live components or permanent magnets of electric motors.

Persons with active implantable medical devices (AIMD) or passive metallic implants must keep clear from these motor components.

The above-specified persons are prohibited from accessing areas where such drive components are installed and operated or access is subject to prior medical consultation.

Keep magnetic data carriers, credit cards, check cards and identity cards and all ferromagnetic metal parts away from magnetic fields. Do not wear jewelry, particularly made of ferromagnetic material, during work at magnetic components.

Safety measures for operating personnel

In the European Community (EU), directive 2004/40/EC specifies minimum requirements for protection of the safety and health of employees from hazards due to electromagnetic and magnetic fields. Regulations and guides for machine manufacturers and machine operators are included in the following documents:

- Standard EN 50499 (Germany: DIN EN 50 499, DIN VDE 0808-499)
- Standard EN 50527 (Germany: DIN VDE 0848-3)
- In Germany: Accident prevention regulations BGV/GUV-V B11

This list does not claim to be exhaustive. Machine manufacturers and machine operators are required to define the regulations applicable on site and the occupational health and safety measures to be applied for working in the area of exposition. The decisive factors are not the electromagnetic properties of individual machine components but the effective overall exposition in electrical, magnetic and electromagnetic fields in the actual working area.

Construction information

During construction of the machine, suitable covers and safety equipment for safe operation must be applied.

- During construction of the machine, observe applicable standards and regulations on marking of and access to exposition areas.
- Prevent any access of operating personnel in the motion range of motors during operation.
- Prevent any contamination, chips and dirt in the motion range of motors.

Notes on transport

For shipping by air freight of magnetic components, the limit values for magnetic flux density in all directions in accordance with IATA953 must be complied with. All rotors of Bosch Rexroth synchronous motors comply with category I according to the figure below. Depending on their geometry and construction, the secondary parts of Bosch Rexroth linear motors comply with one of the three listed categories. Before shipping, the category of the package must be determined.

Category	Distance to the edge of the package	Flux density	Measure
I	2.1 m	≤ 0.525 µT ≤ 5.25 mG	Package does not require declaration and marking for shipping.
II	4.6 m	≤ 0.525 µT ≤ 5.25 mG	Declaration and marking as magnetic material is required.
III	4.6 m	> 0.525 µT > 5.25 mG	Shipping requires prior approval of responsible national authorities in the country of dispatch and the state of the air freight carrier.

Tab. 9-4: Limit values of magnetic flux density for air freight

9.8 Noise emission

The noise emission of synchronous linear drives can be compared with conventional inverter-operated feed drives. Empirically, it is dependent from the following factors:

- the employed linear guides (velocity-related travel noise),
- used length measuring system,

- mechanical construction (rotating covers, a.s.o.)
- The settings of drive and controller (e.g. switching frequency)

9.9 Thermal behavior

Power loss

The rated feed force of a synchronous linear motor can be achieved is mainly determined by the power loss P_V produced during the energy conversion process. The power loss fully dissipates in form of heat. Due to the limited permissible winding temperature it must not exceed a specific value.

☞ The allowed winding temperature of the motors is 130 °C.

The total loss of synchronous linear motors are significantly defined by the short-circuit loss of the primary part.

$$P_V \approx P_{VI} = \frac{3}{2} \times I^2 \times R_{12} \times f_T$$

$$fT = 1 + \Delta T \times \alpha_{20}$$

P_V	Total loss in W
P_{VI}	Short-circuit loss in W
I	Current in motor cable in A
R_{12}	Electrical resistance of the motor at 20 °C in Ohm (see Chapter 4 ”Technical data”)
f_T	Factor temperature-related resistance raise
ΔT	Temperature increase in K
α_{20}	Temperature coefficient of cupper in 1/K

Fig. 9-6: Power loss of synchronous linear motors

☞ When you determine the power loss according to Fig. 9-6 you must take the temperature-related rise of the electrical resistance into account. At a temperature rise of 100 K (from 20 °C up to 120 °C), for example, the electrical resistance goes up by the factor f_T = 1.39.

Thermal time constant

The temperature variation vs. the time is determined by the produced power loss and the heat-dissipation and –storage capability of the motor. The heat-dissipation and –storage capability of an electrical machine is (combined in one variable) specified as the thermal time constant.

The following figure (Fig. 9-7) shows a typical heating and cooling process of an electrical machine. The thermal time constant is the period within which 63% of the final over temperature is reached.

Together with the duty cycle, the correlation to Fig. 9-8 and Fig. 9-10 are used to define the operating modes, e.g. acc. to DIN EN 60034-1.

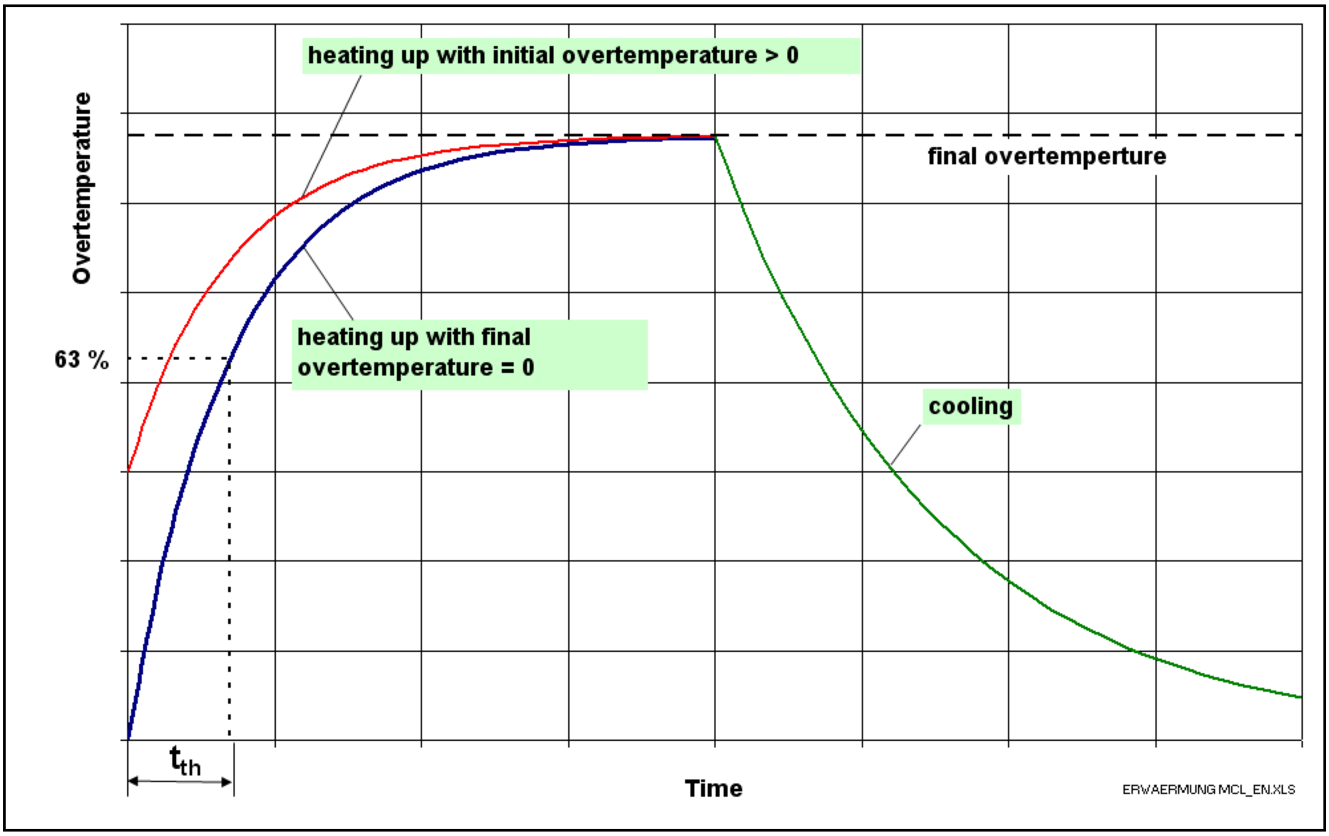


Fig. 9-7: Heating up and cooling down of an electrical machine

Heating up

$$\vartheta(t) = \vartheta_e \cdot \left(1 - e^{-\frac{t}{t_{th}}}\right) + \vartheta_a \cdot e^{-\frac{t}{t_{th}}}$$

ϑ_e	Final excess temperature in K
ϑ_a	Initial excess temperature in K
t	Time in min
t_{th}	Thermal time constant in min (see motor data sheet)

Fig. 9-8: Heating (excessive temperature) of an electric machine

Final over temperature

Since the final over temperature is proportional to the power loss, the expected final over temperature ϑ_e can be estimated according to:

$$\vartheta_e = \frac{P_{ce}}{P_{vN}} \cdot \vartheta_{e\max} = \frac{F_{eff}^2}{F_{dN}^2} \cdot \vartheta_{e\max}$$

P_{ce}	Continuous power loss or average power loss over cycle duration in W (see chapter 11.4 "Determining the drive power" on page 150)
P_{vN}	Nominal power loss of the motor in W
ϑ_{emax}	Maximum final over temperature of the motor in K
F_{eff}	Effective force in N (from application)
F_{dn}	Continuous nominal force of motor in N (see motor data sheet)

Fig. 9-9: Expected final over temperature of the motor

Cooling down

$$\vartheta(t) = \vartheta_e \cdot e^{-\frac{t}{t_{th}}}$$

ϑ_e	Final excess temperature or shutdown temperature in K
t	Time in min
t_{th}	Thermal time constant in min (see motor data sheet)

Fig. 9-10: Cooling down of an electrical machine

9.10 Motor temperature monitoring

The motor temperature is monitored by two systems that are operated independently of each other

- Temperature sensor (motor)
- Temperature model (controller)

and ensures thus the best protection of motors against irreversible damage by thermal overload.

Primary parts of frame sizes MCP020 ... 070 are standardly fitted with an integrated temperature sensor (KTY84-130) for measuring the winding temperature. An all-phase monitoring is impossible with only one KTY. Thus, it is possible that a phase in standstill operation with continuous currents are near the rated current, which is monitored by a KTY, is thermally overloaded, despite the KTY only displays measuring values < 110°C. The exclusive use of the KTY for temperature monitoring means no sufficient motor protection for the primary parts.

☞ A possible form of an additional motor protection is, to limit the motor current to 87% of the rated current at low velocity (< 1 m/min) or at movement via a short traverse path (< 2 · t_P).

The Rexroth IndraDrive control devices monitor the functionality of the temperature sensors. For more information, please refer to the functional description for IndraDrive controllers.

Standstill operation

For safe operation of MCL in standstill observe the information in chapter 9.23 .

Temperature sensor KTY84-130

KTY84-130	Value
Resistance at 25 °C	min. 577 ... max. 629 Ohm
Resistance at 100 °C	min. 970 ... max. 1000 Ohm
Continuous current at 100 °C	2 mA

Tab. 9-5: Standard values on temperature sensors KTY84-130

The response temperatures of the sensor are

⇒110 °C pre-warning temperature

⇒130 °C shut-off temperature

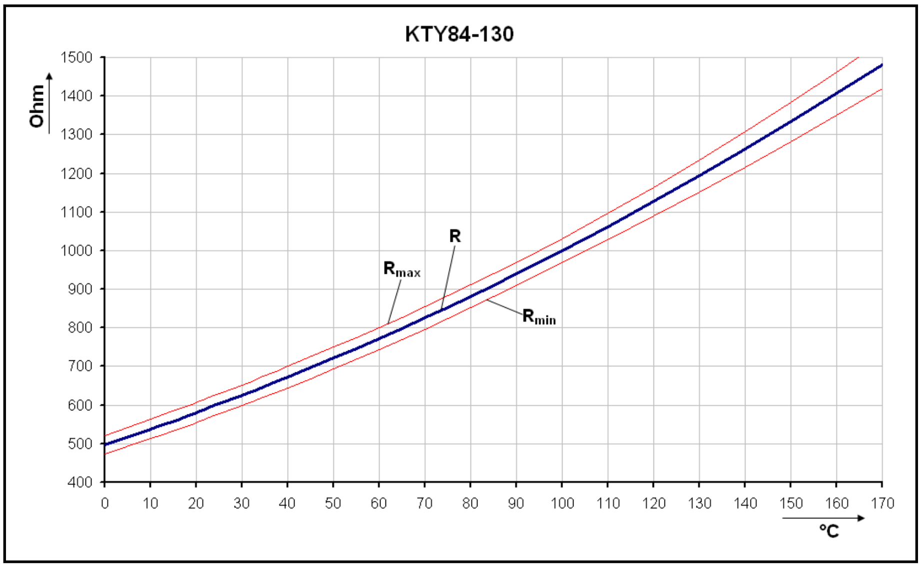


Fig. 9-11: Characteristic temperature sensor KTY84-130

☞ KTY84-130 is an ESD sensitive device! For this reason, the wires of the sensor are protected by a protective foil at the connection cable. Before connecting the sensor, take appropriate measures for ESD protection (ESD = electrostatic discharge).

To connect temperature sensors heed the details under chapter 8.3.1 "Connection temperature sensor" on page 90.

9.11 Feed force at reduced covering between primary and secondary part

When moving in the end position range of an axis, it can be necessary that the primary part moves beyond the end of the secondary part. This results in a partial coverage between primary and secondary part.

If primary and secondary part are only partially covered, a reduced feed force and attractive force results.

Inserted force reduction

Outside the beginning and end areas (s_{R1} or s_{R2}), the reduction of the force is linear with the reduced overlap area.

The following diagram illustrates the correlation between the coverage between primary and secondary part and the resulting force reduction.

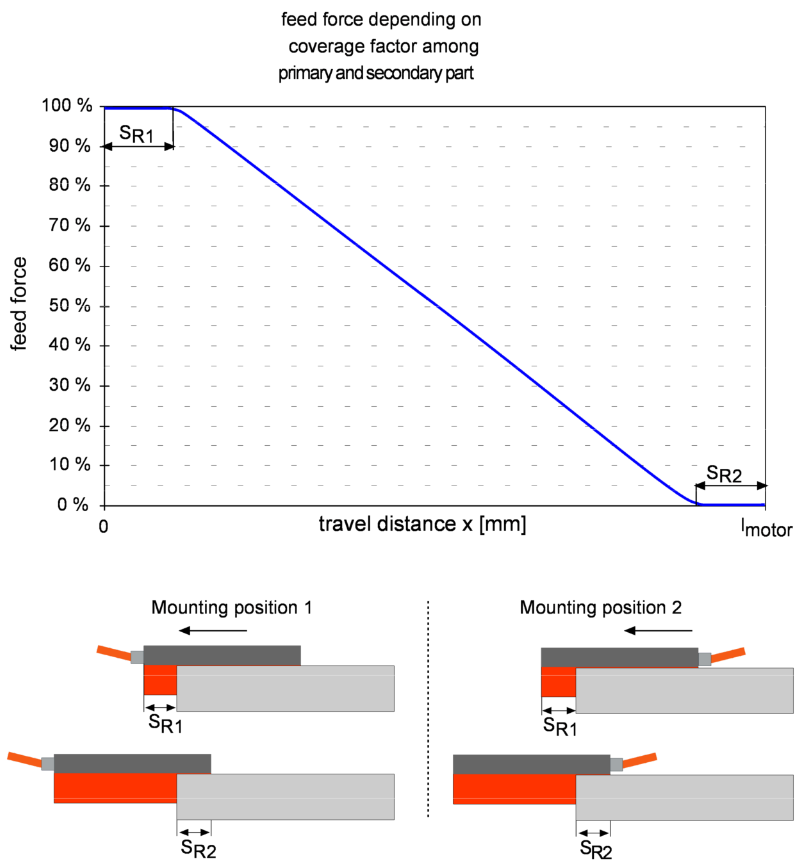


Fig. 9-12: Force reduction with partial coverage of primary and secondary part

Motor version	S_{R1} [mm]	S_{R2} [mm]
without Hall unit	Installation position 1	
MCL015	0.5	0.5
MCL020 ... 70	6.5	0.5
	Installation position 2	
MCL015	0.5	0.5
MCL020 ... 70	0.5	6.5
with Hall unit		
If a Hall unit is used for commutation, the primary part on the cable output side must be completely within the secondary part. During operation, which is normally without analysis of the Hall unit, the primary part can be operated as described under "without Hall unit".		

Tab. 9-6: Partial coverage vs. installation position

The partial coverage of primary and secondary parts must not be used in continuous operation since there is an increased current consumption of the motor due to control strategies. Instabilities in the control loop can be expected from a certain reduction of the degree of coverage onwards.

9.12 Requirements on the machine design

9.12.1 General

Derived from design and properties of linear direct drives, the machine construction must meet various requirements. For example, minimizing of moving masses with simultaneous high rigidity should be realized.

9.12.2 Mass reduction

To ensure a high acceleration capability, the mass of the moved machine elements must be reduced to a minimum. This can be done by using materials of a low specific weight (e.g. aluminum or compound materials) and by design measures (e.g. half-timbered construction).

If there are no requirements for the highest acceleration, even relative big mass can be moved. A very rigid coupling of the motor to the weight is a precondiiton.

9.12.3 Mechanical rigidity

In conjunction with the mass and the resulting resonant frequencies, the rigidity of the individual mechanical components within a machine chiefly determines the quality a machine can reach. The rigidity of a motion axis is determined by the overall mechanical structure. The goal of the construction must be to obtain an axis structure that is as compact as possible.

Natural frequency

The increased loop bandwidth of linear drives required higher mechanical natural frequencies of the machine structure in order to avoid the excitation of vibrations.

To ensure a sufficient control quality, the lowest natural frequency that occurs inside the axis should not be less than approximately 200 Hz. The natural frequencies of axes with masses, that are not constantly moving (e.g. due to work pieces that must be machined differently), change, so that the natural frequency is reduced as the mass increases. $f \approx \sqrt{1/m}$

Mechanically coupled axes

With the stiffness of kinematically coupled axes, it should be taken into account that the flexibility of the axes - both the mechanical and the control components - add up.

If several axes must be coupled cinematically in order to produce path motions (e.g. cross-table or gantry structure), the mutual effects of the individual axes on each other should be minimized. Thus, cinematic chains should be avoided in machines with several axes. Axis configurations with long projections that change during operation are particularly critical.

Reactive forces

Initiated by acceleration, deceleration or process forces of the moved axis, reactive forces can deform the stationary machine base or cause the fixed machine base body to vibrate.

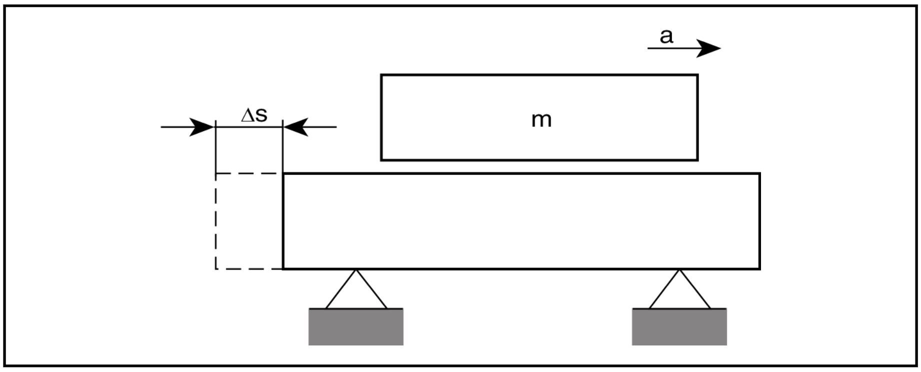


Fig. 9-13: Deformation of the machine base body caused by the reactive force during the acceleration process

$$\Delta s = \frac{m \cdot a}{c} = \frac{1\,kg \cdot 1000\,m/s^2}{1000\,N/\mu m} = 1\,\mu m$$

Δs	Deformation or displacement of the machine base body in µm
m	Mass in kg
a	Acceleration in m/s²
c	Rigidity of the machine base body in N/µm

Fig. 9-14: Calculation example of the machine base body deformation

Integrating the linear scale

The rigidity of the length measuring system integration is particularly important. For explanations refer to chapter 9.14 "Length measuring system" on page 120.

9.12.4 Protection of the motor installation space

Due to protection mode IP00 of the motor components, the protection of the motor installation space need especial observance. To avoid that dirt comes into the air gap between primary and secondary part (e.g. due to any kind of residues, dust, etc.) during motor operation, the motor installation space must be designed according to the environmental conditions. The motor installation space must be designed in such a way, that the protection class IP65 according to DIN EN 60034-5 equivalent environmental conditions are ensured (see chapter 9.5 "Type of protection" on page 102).

Heed appropriate protection measures when designing the machine construction. If dirt gets between the motor components due to insufficient protection measures, during operation this can lead to...

- an increased heat introduction due to friction between the motor components. Thereby, temperatures can arise, which can cause a motor damage.
- Due to the high mechanical force effectgrinding traces and /or scratchformation on the motor components can result in the destroying of casting compounds on the primary part, to motor breakdown,, among others.

Please note that dirt can also enter indirectly into via compressed air or due to other machine parts (e.g. grease of the guides). This must be prevented.

Make sure by regularly maintenance of the safety measures that their function is still kept and the motor components could not be damaged.

9.13 Arrangement of motor components

9.13.1 Single arrangement

The single arrangement of the primary part is the most common arrangement. One or more primary parts can be controlled independently of each other. In such an arrangement, the length measuring system can also be equipped with two or more scanning heads.

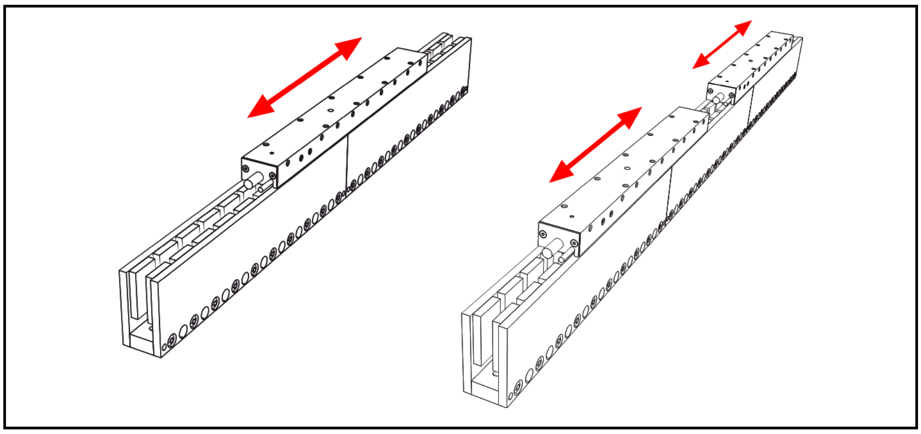
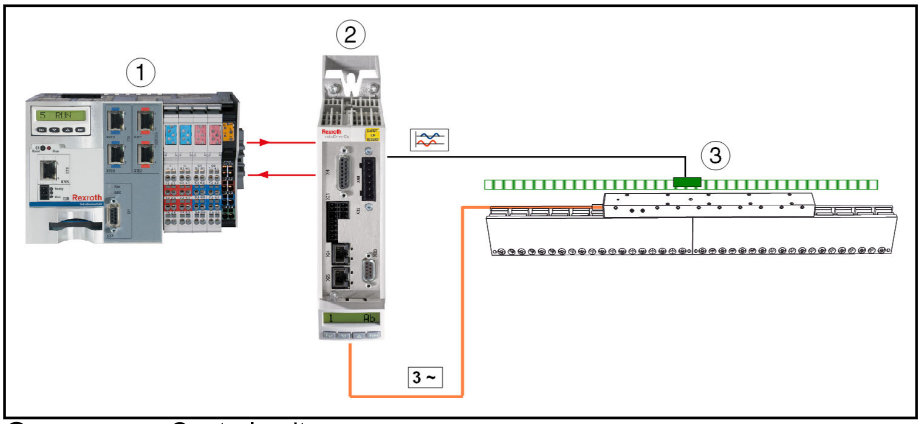


Fig. 9-15: Single axis arrangement of primary parts



① Control unit
② Controller
③ Length measuring system

Fig. 9-16: Controlling a linear motor with single arrangement of the motor components

9.13.2 Several motors per axis

The arrangement of several motors per axis provides the following benefits:

- Multiplied feed forces
- Optimized utilization of available installation space

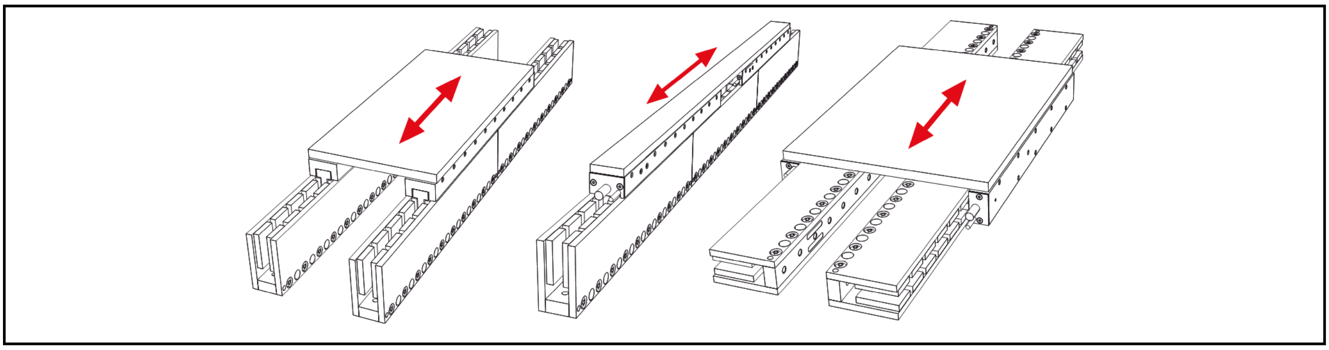


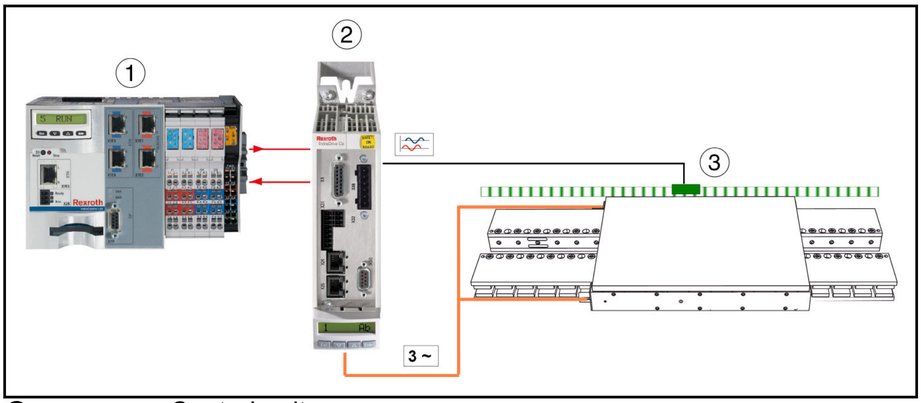
Fig. 9-17: Examples for arrangement

Depending on the application, the motors can be controlled in two different ways:

- Two or more motors at one drive controller and one linear scale (parallel connection)
- Two motors at two drive controllers and two linear scales (Gantry arrangement)

Parallel connection: Several primary parts in parallel

The arrangement of two or more primary parts on one drive controller in conjunction with a linear scale is known as parallel arrangement.



① Control unit
② Controller
③ Length measuring system

Fig. 9-18: Parallel connection of two primary parts on one drive controller in conjunction with a length measuring system

To ensure successful operation, the following conditions must be fulfilled:

- Use identical primary parts MCP and same line length MCS
- Stiff motor coupling within the axis
- Position offset between the primary parts <1 mm in feed direction
- Position offset between the secondary parts <1 mm in feed direction
- If possible, load stationary and arranged symmetrically with respect to the motors

The determination of the distance that must be adhered depends on the direction of the cable outlet and the permissible bending radius of the power cable.

Parallel connection: Gantry arrangement (primary parts in a row)

For parallel connection, primary parts in feed direction can also be arranged in a row, mechanically coupled.

To ensure successful operation, the primary parts must be arranged in a specific distance to each other and must fulfill the following conditions. The determination of the grid dimension that must be adhered, depends on the direction of the cable outlet and the permissible bending radius of the power cable.

Cable outlet in the same direction

If the primary parts are arranged behind each other and with cable outlets into the same directions to Fig. 9-19 a distance x_P must be kept.

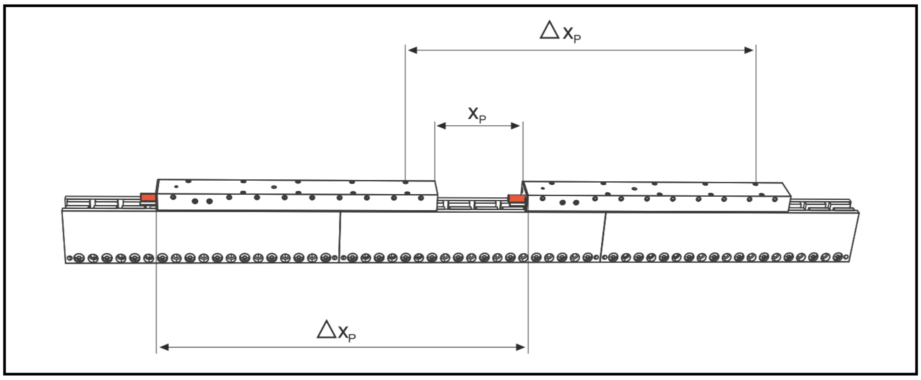


Fig. 9-19: Arrangement of the primary parts behind each other and cable outlet in the same direction

$$x_p = n \cdot 2 \cdot \tau_p + x_{p\,\mathrm{min}}$$
$$x_p > R$$

x_P	Distance between the front faces of the primary parts in mm
n	Freely selectable integer factor ≥ 0
τ_p	Pole width see Chapter Technical data)
x_{Pmin}	smallest allowed distance between the primary parts (see Tab. 9-7)
R	Allowed bending radius of the connection cable (see Tab. 8-2)

Fig. 9-20: Determining the distance x_P between the primary parts with cable outlet in the same direction

The grid dimension Δx_P acc. to Fig. 9-19 must be a integer multiple of the double pole width. Always use the same reference point for both primary parts (e.g. the same fastening hole or the same primary part front side).

$$\Delta x_p = m \cdot 2 \cdot \tau_p$$

Δx_p	Required grid spacing between the primary parts in mm
m	Freely selectable integer factor ≥ 0
τ_p	Pole width see Chapter Technical data)

Fig. 9-21: Determining the grid dimension between the primary parts with cable outlet in the same direction

The distance x_P between the primary parts according to Fig. 9-19 my not deceed the minimum distance x_{Pmin}:

Primary part	Distance x_{Pmin}	Phase sequence	
		Primary part 1*)	Primary part 2
MCP015	4.5 mm	U-V-W	V-W-U
MCP020	53 mm 63 mm 73 mm		U-V-W V-W-U W-U-V
MCP030 ... 070C/D/F	53 mm 73 mm 93 mm		U-V-W V-W-U W-U-V
MCP070M	73 mm 93 mm 113 mm		V-W-U W-U-V U-V-W

*) Reference motor to determine the encoder polarity and commutation adjustment is always primary part 1

Tab. 9-7: Distance and phase sequence at arranged primary parts behind each other and cable outlet in the same direction

Cable outlet in opposite direction (variant 1: back to back)

If the primary parts are arranged behind each other and with cable outlets in opposite directions to Fig. 9-22, a defined distance x_P must be kept between the primary parts.

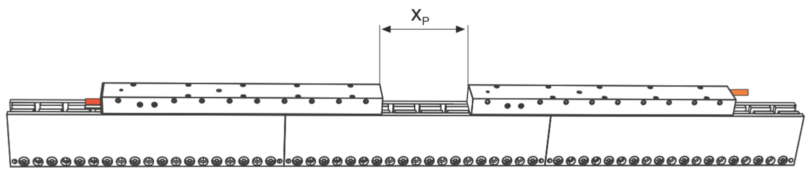


Fig. 9-22: Variant 1: Arrangement of primary parts behind each other with cable outlets in opposite directions

$$x_P = n \cdot 2 \cdot \tau_p + x_{P\,min}$$

x_P Distance between the front faces of the primary parts in mm
n Freely selectable integer factor ≥ 0
τ_p Pole width see Chapter Technical data)
x_{Pmin} smallest allowed distance between the primary parts (see Tab. 9-8)

Fig. 9-23: Determining the distance between primary parts with cable outlets in opposite directions

☞ When determining the correct primary part distance according to Fig.9-22, only the distance between the primary part end faces (xpmin) as reference point can be used.

Primary part	Distance x_{Pmin}	Phase sequence	
		Primary part 1*)	Primary part 2
MCP015	1.75 mm	U-V-W	U-W-V
MCP020	3 mm	U-V-W	U-W-V
	13 mm		W-V-U
	23 mm		V-U-W
MCP030 ... 070	8 mm	U-V-W	U-W-V
	28 mm		W-V-U
	48 mm		V-U-W

*) Reference motor to determine the encoder polarity and commutation adjustment is always primary part 1

Tab. 9-8: Distance and phase sequence at arranged primary parts behind each other with cable outlets in opposite directions (option 1)

Cable outlet in opposite direction (variant 2: cables to each other)

If the primary parts are arranged behind each other and with cable outlets in opposite directions to Fig. 9-24, a defined distance x_P must be kept between the primary parts.

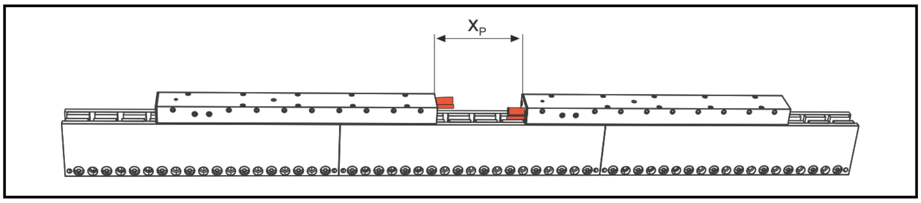


Fig. 9-24: Variant 2: Arrangement of primary parts behind each other with cable outlets in opposite directions

$$x_P = n \cdot 2 \cdot \tau_p + x_{P\,\min}$$

$$x_P > R$$

x_P Distance between the front faces of the primary parts in mm
n Freely selectable integer factor ≥ 0
τ_p Pole width see Chapter Technical data)
x_{Pmin} smallest allowed distance between the primary parts (see Tab. 9-9)
R Allowed bending radius of the connection cable (see Tab. 8-2)

Fig. 9-25: Determining the distance x_P between the primary parts with cable outlet in the same direction

☞ When determining the correct primary part distance according to Fig.9-24, only the distance between the primary part end faces (xpmin) as reference point can be used.

Primary part	Distance x_{Pmin}	Phase sequence	
		Primary part 1*)	Primary part 2
MCP015	1.75 mm	U-V-W	W-V-U
MCP020	53 mm	U-V-W	W-V-U
	63 mm		V-U-W
	73 mm		U-W-V
MCP030 ... MCP070C/D/F	58 mm	U-V-W	W-V-U
	78 mm		V-U-W
	98 mm		U-W-V
MCP070M	78 mm	U-V-W	V-U-W
	98 mm		U-W-V
	118 mm		W-V-U

*) Reference motor to determine the encoder polarity and commutation adjustment is always primary part 1

Tab. 9-9: Minimum distance and phase sequence at arranged primary parts behind each other with cable outlets in opposite directions (option 2)

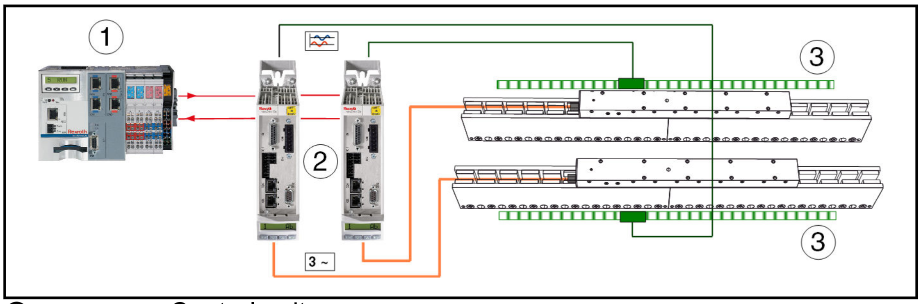
Gantry arrangement

If different load conditions occur during operation, both locally and temporally, and a sufficient rigidity between the motors cannot be ensured, the operation should be planned with two linear scales and drive controllers (Gantry arrangement). This is frequently the case with axis in a Gantry structure, for example.

☞ Within a Gantry arrangement, even parallel connected motors can be used.

Double comb arrangement (Gantry)

Within a Gantry arrangement, the primary parts in feed direction can be mechanically coupled and arranged in the form of a double comb arrangement.



① Control unit
② Controller (2 pcs.)
③ Length measuring system (2 pcs.)

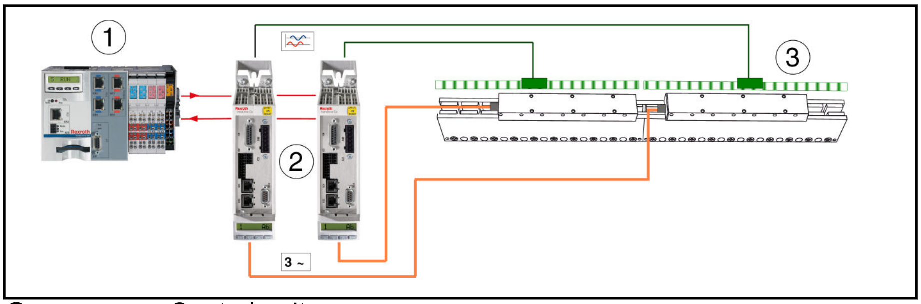
Fig. 9-26: Gantry arrangement (double comb)

With Gantry arrangements it must be remembered that the motors may be stressed asymmetrically, although the position offset is minimized. As a consequence, this permanently existing base load may lead to a generally higher stress than a single arrangement. This must be taken into account when the drive is selected.

☞ The asymmetric capacity can be reduced to a minimum by exactly aligning the length measuring system and the primary and secondary parts to each other, and by an internal axis error correction.

Arrangement of primary parts in a row (Gantry)

Primary parts in feed direction can also be arranged in a row, mechanically coupled.



① Control unit
② Controller (2 pcs.)
③ Length measuring system (1 scale, 2 scanning heads)

Fig. 9-27: Gantry arrangement (primary parts in a row)

9.13.3 Arrangement of secondary parts

During assembly, you must not heed the arrangement of the secondary parts. Due to construction of MCS, a "polarity reversal" - arrangement of several secondary parts within a path is prevented. The order of magnetization is unchanged by a 180° - rotation of secondary parts.

Please observe the notes in chapter 13.4 "Air-gap, parallelism and symmetry of the motor components" on page 160 and chapter 13.5 "Fastening secondary part" on page 161 about alignment and fastening of secondary parts.

9.13.4 Vertical axis

⚠ CAUTION **Uncontrolled movements! Risk of injuries!**

Motors in vertical axes are not self-locking when de-energize. Prevent a sinking of the axis with appropriate holding devices.

☞
- On vertical axis, the use of an absolute measuring system is recommended.
- Incremental measuring systems can only be used, if a Hall unit is additionally used beside the holding device.

Weight compensation

An additionally used weight compensation ensures that the motor is not exposed to an unnecessary thermal stress that is caused by the holding forces and the acceleration capability of the axis is independent of the motion direction. The weight compensation can be pneumatic or hydraulic. Weight compensation with a counterweight is not suitable since the counterweight must also be accelerated.

9.14 Length measuring system

9.14.1 General

A linear measuring system is required for measuring the position and the velocity. Particularly high requirements are placed upon the linear scale and its mechanical connection. The length measuring system is used for high-resolution position recognition and the determination of the actual velocity.

☞ The necessary length measuring system is not in the scope of delivery of Bosch Rexroth and has to be provided and mounted from the machine manufacturer themselves(tab. 9-10 "Manufacturers of length measuring systems" on page 121).

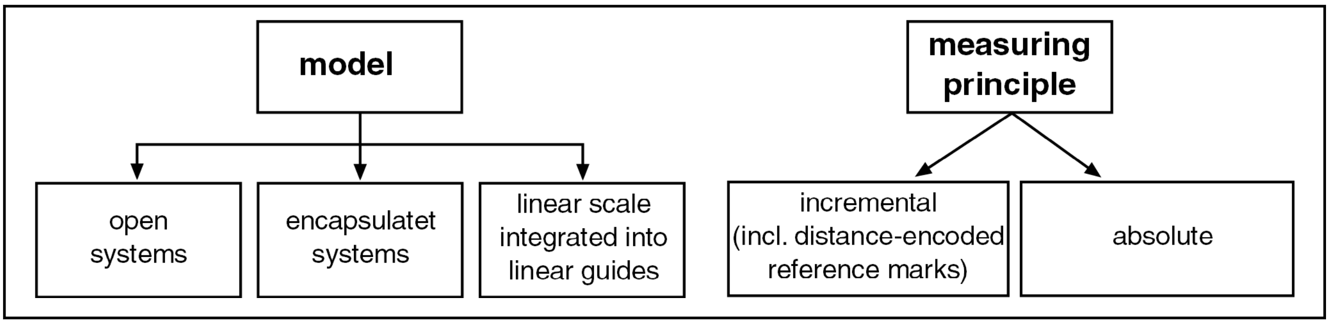


Fig. 9-28: Classification of linear scales

Particularities of synchronous linear motors

It is necessary at synchronous linear motors to receive the position of the primary part relating on the secondary part by return after start or after a malfunction (pole position recognition). Using an absolute linear scale is the optimum solution here.

9.14.2 Selection criteria for length measuring system

General

Depending on the operating conditions, open or encapsulated linear scales with different measuring principles and signal periods can be used. The selection of a suitable linear scale mainly depends on:

- The maximum feed rate (model, signal period)
- The maximum travel range (measuring length, model)
- If applicable, utilization of coolant lubricants (model)
- Incidental dirt, chips, etc. (frame size)
- the accuracy requirements (signal period)

Manufacturers of length measuring systems

The following selection is exemplary and does not claim to be complete. You can also use products from other manufacturers, according to the encoder interface of the used controller.

Bosch Rexroth AG Linear and assembly technique	Maria-Theresien-Straße 23 97816 Lohr am Main, Germany info@boschrexroth.de http://www.boschrexroth.com/business_units/brl/de/ (Integrated measuring system for profiled rail guide)
AMO Automatisierung Messtechnik Optik GmbH	NÖFING 4 A-4963 ST. PETER AM HART office@amo.at http://www.amo-gmbh.com
DR. JOHANNES HEIDENHAIN GmbH	Postfach 1260 83292 Traunreut, Germany info@heidenhain.de http://www.heidenhain.de/
NUMERIK JENA GmbH	Ilmstraße 4 07743 Jena, Deutschland applikation@numerikjena.de http://www.numerikjena.de/
Renishaw GmbH	Karl-Benz Straße 12 72124 Pliezhausen, Germany http://www.renishaw.de/
SICK AG	Erwin-Sick-Straße 1 79183 Waldkirch, Germany http://www.sick.com/
SIKO GmbH	Weihermattenweg 2 79256 Buchenbach, Germany info@siko.de http://www.siko.de/

Tab. 9-10: Manufacturers of length measuring systems

- To ensure maximum interference immunity, Rexroth recommends the voltage interface with 1 V_{SS}.
- Please refer to the documents from the corresponding manufacturer for detailed and updated information.

Measuring system cables

Ready-made cables of Rexroth are in preparation for the electrical connection between the output of the linear scale and the input of the scale interface. To ensure maximum transmission and scale interference safety, you should preferably use these ready-made cables.

9.15 Linear guiding systems

Linear guiding systems for linear motors are, depending on the motor arrangement, necessary due to feed and process forces as well as the speeds achievable today. The used linear guiding system must be able to adjust process and acceleration force.

Depending on the application, the following linear guides are employed:

- Ball or roll rail guides

- Slide ways
- Hydrostatic guides
- Aerostatic guides

The following requirements should be taken into account when a suitable linear guide system is selected:

- High accuracy and no backlash
- Low friction and no stick-slip effect
- High rigidity
- Steady run, even at high velocities
- Easy mounting and adjustment

Manufacturer

Linear guiding systems are not in the scope of delivery of the motor and must be ordered separately. The selection of a suitable linear guiding system is in the sole responsibility of the machine manufacturer. When selecting linear measuring systems please observe that this system uses sinusoidal instead of rectangular output signals. With sinusoidal output signals, a significantly higher position resolution and better position accuracy is reached via special evalutation revolution of our controllers. See also chapter 9.21 "Position and velocity resolution" on page 128.

In the following you will find an incomplete list of manufacturers of suitable length measuring systems for linear motors: Furthermore, other manufacturers are available which cannot be listed all.

Bosch Rexroth AG Linear and assembly technique	Maria-Theresien-Straße 23 97816 Lohr am Main, Germany info@boschrexroth.de http://www.boschrexroth.com/business_units/brl/de/ (Integrated measuring system for profiled rail guide)

Tab. 9-11: Manufacturers of length measuring systems

9.16 Braking systems and holding devices

The following systems can be used as braking systems and/or holding devices for linear motors:

- External braking devices
- Clamping elements for linear guides
- Holding brakes integrated in the weight compensation

Further designs about stand-still of linear motors are given in chapter 9.17 "End position shock absorber " on page 123 and chapter 9.20 "Deactivation upon EMERGENCY STOP and in the event of a malfunction " on page 125 as well as in the appropriate functional description of the drive controller.

9.17 End position shock absorber

⚠ WARNING	Damage on machine or motor components when driving against hard stop!

⇒ Use suitable energy-absorbing end position shock absorber

⇒ Adhere to the specified maximum decelerations

Suitable energy-absorbing end position shock absorber must be provided in order to protect the machine during uncontrolled coasting of an axis.

If the maximum deceleration is exceeded, this can cause the primary part to come loose and damage the engine components.

☞
- When moving against a fixed stop, the maximum permissible deceleration must be limited to **250 m/s²** by a suitable energy-absorbing end position damper.
- The necessary spring excursion of the shock absorbers must be taken into account when the end position shock absorbers are integrated into the machine (in particular when the total travel length is determined).

9.18 Axis cover systems

Depending on the application, design, operational principle and features of synchronous linear motors, the following requirements on axis cover systems apply:

- High dynamic properties (no overshoot, little masses)
- Accuracy and smooth run
- Protection of motor components against chips, dust and foreign objects (in particular ferromagnetic parts),
- Resistance to oil and coolant lubricants
- Robustness and wear resistance

Different covering systems can be used, like bellow covers, telescopic covers or roller covers. A suitable axis cover system should be configured, if possible, during the early development process of the machine or system – supported by the corresponding specialized supplier.

9.19 Motor control and regulation

9.19.1 General

The following figures shows a complete linear direct drive, consisting of a synchronous linear motor, length scale system, drive controller and superordinate control.

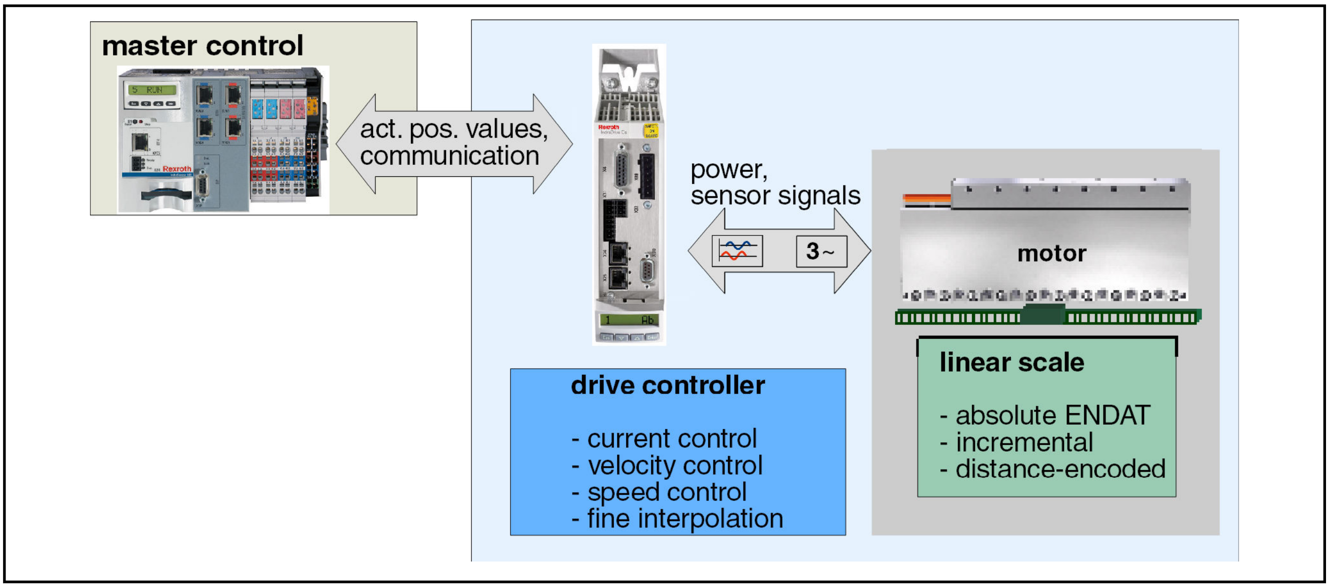


Fig. 9-29: Linear direct drive

9.19.2 Drive controllers

For MCL motor control, different digital drive controllers and power supply modules are available. (see chapter 10 "Motor-control combinations" on page 133).

9.19.3 Control systems

A master control is required for generating defined movements. Depending on the functionality of the whole machine and the used control systems, Bosch Rexroth offers different control systems..

9.20 Deactivation upon EMERGENCY STOP and in the event of a malfunction

9.20.1 General

Deactivation of an axis equipped with MCL motor, can be initiated by

- EMERGENCY STOP,
- Drive fault (e.g. response of the encoder monitoring function) or
- Power outage

In the options for deactivation of MCL motors in case of malfunction, a distinction must be made between

- Deactivation by the drive,
- Deactivation by a master control and
- Deactivation by a mechanical braking device.

9.20.2 Deactivation by the drive

As long as there is no fault or malfunction in the drive system, shutdown by the drive is possible. The shutdown possibilities depend on the occurred drive error and on the selected error response of the drive. Certain faults (interface faults or fatal faults) lead to a force disconnection of the drive.

⚠ WARNING **Death, serious injuries or damage to equipment may result from an uncontrolled coasting of a switched-off linear drive!**

⇒ Construction and design according to the safety standards

⇒ Protection of people by suitable barriers and enclosures

⇒ Using external mechanical braking facilities

⇒ Use suitable energy-absorbing end position shock absorber

The parameter values of the drive response to interface faults and non-fatal faults can be selected. The drive switches off at the end of each fault response.

The following fault responses can be selected:

0 – Setting velocity command value to zero

1 - Setting force command value to zero

2 - Setting velocity command value to zero with command value ramp and filter

3 - Retraction

☞ Please refer to the corresponding firmware function description for additional information about the reaction to faults and the related parameter value assignments.

9.20.3 Deactivation by a master control

Deactivation by control functions

Deactivation by the master control should be performed in the following steps:

1. The machine PLC or the machine I/O level reports the fault to the CNC control
2. The CNC control deactivates the drives via a ramp in the fastest possible way
3. The CNC control causes the power at the power supply module to be shut down.

Drive initiated via the control shutdown

Deactivation via means of drive functions should be performed in the following steps:

1. The machine I/O level reports the fault to the CNC control and SPS
2. The CNC control or the PLC resets the controller enabling signal of the drives. If SERCOS interface is used, it deactivates the ”E-STOP” input at the SERCOS interface module.
3. The drive responds with the selected error response.
4. The power at the power supply module must be switched off 500 ms after the controller enabling signal has been reset or the ”E-Stop” input has been deactivated.

☞ The delayed power shutdown ensures the safe shutdown of the drive by the drive controller. With an undelayed power shutdown, the drive coasts in an uncontrolled way once the DC bus energy has been used up.

9.20.4 Deactivation via mechanical braking device

Shutdown by mechanical braking devices should be activated simultaneously with switching off the power at the power supply module. Integration into the holding brake control of the drive controllers is possible, too. The following must be observed:

- Braking devices with electrical 24V DC control (electrically-released) and currents < 2 A can directly be triggered.
- Braking devices with electrical 24V DC control and currents > 2 A can be triggered via a suitable protection.

Once the controller enabling signal has been removed, the holding brake control has the following effect:

- Fault reaction ”0”, ”1” and ”3”.

  The holding brake control drops to 0 V once the velocity is less than 10 mm/min or a time of 400 ms has elapsed.
- Fault reaction "2":

  The holding brake control drops to 0 V immediately after the drive enabling signal has been removed.

9.20.5 Response to a power outage

In order to be able to shut down the linear drive as fast as possible in the event of a power outage,

- either an interruption-free power supply or
- additional DC bus capacities (capacitors), and /or
- mechanical braking facilities

must be provided.

Determining the required additional DC bus capacity

Additional capacities in the DC bus represent an additional energy store that can supply the brake energy required in the event of a power outage.

☞ The control voltage must be available even at a power failure for the time of braking! If needed, buffer the control voltage supply or feed the control voltage from the DC intermediate circuit if possible!

The additional capacity required for a deactivation upon a mains failure can be determined as follows:

$$C_{add} = \frac{m \cdot v_{\max}}{U_{DC\max}^{2} - U_{DC\min}^{2}} \cdot \left[3{,}5 \cdot \frac{F_{\max}}{k_{FN}^{2}} \cdot R_{12} - v_{\max} \cdot \left(\frac{F_R}{F_{\max}} + 0.3 \right) \right]$$

C_{add}	Required additional DC bus capacitor in mF
m	Moved mass in kg
v_{max}	Maximum velocity in m/s
U_{DCmax}	Maximum DC bus voltage in V
U_{DCmin}	Minimum DC bus voltage in V
F_{max}	Maximum braking force of the motor in N
k_{FN}	Motor constant (force constant) in N/A
R_{12}	Winding resistance at 20 °C
F_R	Friction force in N

Fig. 9-30: Determining the required additional DC bus capacitor

Prerequisites:

- final velocity = 0

- velocity-independent friction

- constant deceleration

- winding temperature 135 °C

☞ The maximum possible DC bus capacity of the employed power supply module must be taken into account when additional capacities are used in the DC bus. Do not initiate a DC voltage short-circuit when additional capacitors are employed.

9.20.6 Short-circuit of DC bus

Most of the power supply modules of Bosch Rexroth permit the DC bus to be shortened when the power is switched off, which also establishes a short-circuit between the motor phases. When the motor moves, this causes a braking effect according to the principle of induction; thereby the motor phases are short-circuited. However, the achievable braking force is not very high and also depends on the velocity. The DC bus short-circuit can therefore only be used to support existing mechanical braking devices.

9.21 Position and velocity resolution

9.21.1 Drive internal position resolution and position accuracy

In linear direct drives, a linear scale is used for measuring the position. The linear scale for linear motors supply sinusoidal output signals. The length of such a sine signal is known as the signal period. It is mainly specified in mm or µm.

With the drive controllers from Bosch Rexroth, the sine signals are amplified again in the drive (see Fig.9-32). The drive-internal amplification also depends on the maximum travel area and the signal period of the length measuring system. It always employs 2^n grid points (e.g. 2048 or 4096).

$$f_{int} = 2^{31} \cdot \frac{s_p}{x_{max}} \qquad \textit{rounding to } 2^n$$

f_{int} Multiplication factor (S-0-0256, Multiplication 1)
s_p Linear scale system signal period in mm (S-0-0116 Resolution of encoder 1)
x_{max} Maximum travel (S-0-0278, Maximum travel)

Fig. 9-31: Multiplication factor

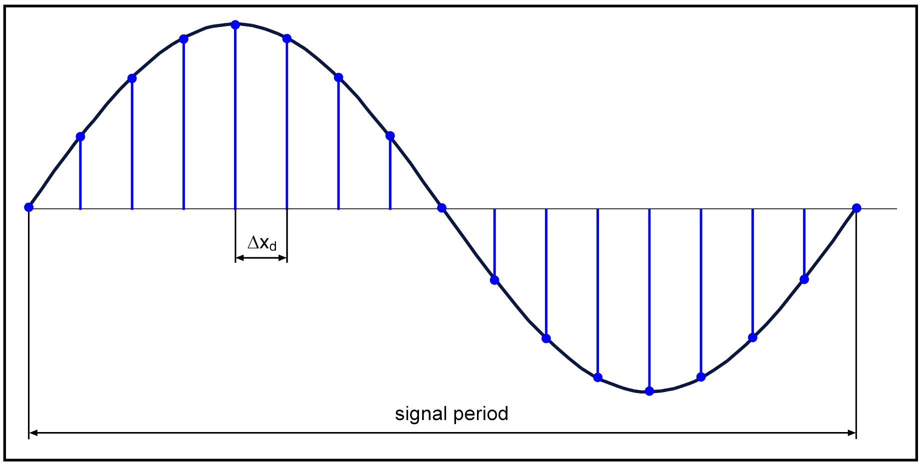


Fig. 9-32: Drive-internal multiplication and/or interpolation of the measuring system signals

With a known signal period and a drive-internal multiplication, the drive-internal position resolution results as:

$$\Delta x_d = \frac{s_p}{f_{int}}$$

Δx_d	Drive-internal position resolution
s_p	Linear scale system signal period (S-0-0116 Resolution of encoder 1)
f_{int}	Multiplication factor (S-0-0256, Multiplication 1)

Fig. 9-33: Drive-internal position resolution

☞ The drive-internal position resolution is not identical to the reachable positioning accuracy.

Reachable positioning accuracy

The reachable position accuracy depends on the mechanical and control-engineering total system and is not identical to the drive-internal position resolution.

The reachable position accuracy can be estimated as follows (using empirical values):

$$\Delta x_{abs} = \Delta x_d \cdot 30...50$$

Δx_d	Drive-internal position resolution
Δx_{abs}	Position accuracy

Fig. 9-34: Estimating the reachable position accuracy

Prerequisites: Optimum controller setting

☞ The expected position accuracy cannot be better than the smallest position command increment of the superordinate control.

9.21.2 Velocity resolution

The resolution of the velocity is proportional to the position resolution (see fig. 9-33 "Drive-internal position resolution" on page 129) and inversely proportional to the cycle rate t_{AD} from:

$$\Delta v_d = \frac{\Delta x_d}{t_{AD}}$$

Δv_d	Velocity resolution in m/s
Δx_d	Drive-internal position resolution
t_{AD}	Cycle rate in s (IndraDrive: Basic performance 250 µs / Advanced 125 µs)

Fig. 9-35: Velocity resolution

9.22 Thermal connection - Installation modes

An effective heat loss dissipation is a prerequisite for achieving the specified motor data. The amount of heat loss in the motor is largely determined by the utilization rate of the motor. How well or how quickly the heat loss can be dissipated determines the performance of the motor.

If the heat of the motor cannot be sufficiently dissipated by means of natural convection, the heat introduction via the contact surfaces into the machine construction is increased. Particularly high heat dissipation is achieved if the contact surfaces of the primary and secondary parts are combined with a highly heat-dissipating machine construction.

In this connection, please observe that an increased heat introduction into the machine construction has a negative impact on the achievable accuracy. During design of a system with maximum accuracy, the operating temperature of the motor winding is decisive.

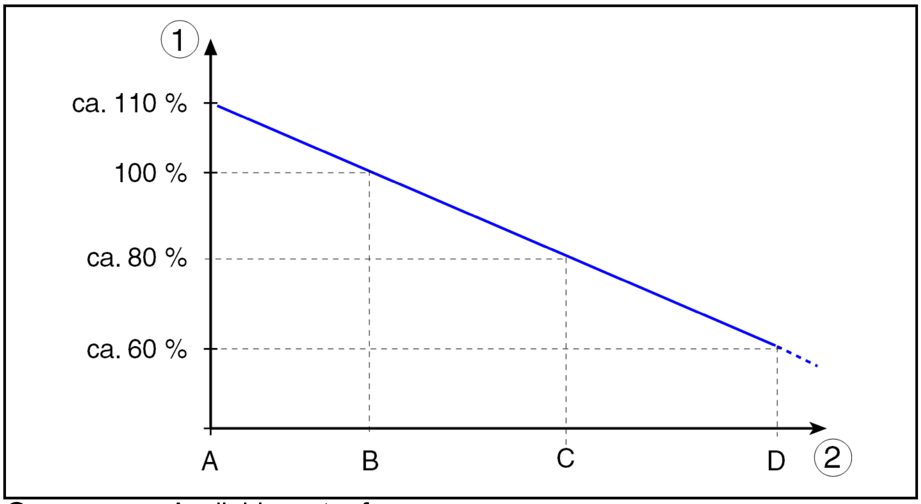
With increasing winding temperature, the emitted heat of the machine is also increased. If the temperature level of the machine has to be kept at a constant level, the motor should be sufficiently dimensioned or equipped with machine-side cooling.

☞ If the contact surfaces of the motor components, particularly of the primary part, are made of a material with low heat conductivity (e.g. plastic), a reduction in motor performance has to be expected.

In general, the heat dissipation must be increased proportionally with the size and frame length and the respectively higher power loss of the motor if the same utilization capacity of the motor is to be achieved.

For this reason, observe maximum heat dissipation of motor components when designing the machine. Only this way optimum dissipation of the emitted heat of the motor via the surrounding machine components can be ensured.

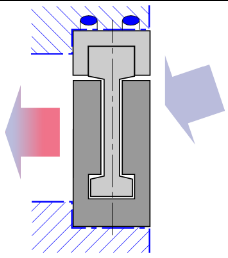
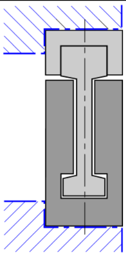
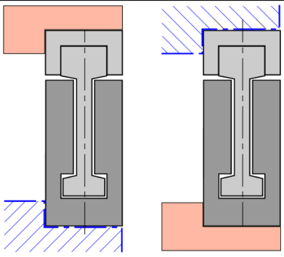
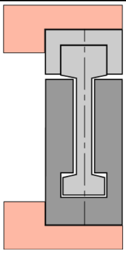
The following specifications serve as reference to estimate the required motor performance data depending on the thermal connection of the motor. The illustrated installation modes can be selected and taken into account for motor controller dimensioning in IndraSize and for commissioning in IndraWorks.



① Available motor force
② Installation mode

Fig. 9-36: Motor force dependent on thermal connection

Explanation of installation modes

Installation mode	Schematic illustration	Description
A		**Installation mode A** requires **good thermal connection** of the motor in combination **with additional cooling**, e.g. by using a fan or by cooling the contact surfaces. Regarding the structure of the contact surfaces at the machine, a metal surface with high conductivity is required.
B		**Installation mode B** requires **good thermal connection** of the motor to the machine. Regarding the structure of the contact surfaces at the machine, a metal surface with high conductivity is required. The technical data for this installation mode is specified in chapter 4 "Technical data" on page 21.
C		**Installation mode C** assumes that a motor component (primary or secondary part) is thermally isolated and the other components must be well-conductively connected to the machine. In this case, reckon with a performance reduction of the motor due to **moderate heat dissipation**
D		**Installation mode D** assumes that both motor components (primary and secondary part) are connected to the machine in a thermally isolated way. This mode of assembly is the **worst case** and it must be reckoned with a significant disability of the motor.

Tab. 9-12: Explanation of installation modes

9.23 Operation at or near motor standstill

In the motor is to be operated at standstill or close to standstill, special conditions apply. For means of simplification, this operation is indicated as standstill operation in the following. The absolute standstill operation is marked by the following aspects:

- The duration of the standstill operation is longer than 10 % of the respective thermal time constant T_{th}
- Motor does not move
- Motor performs only very small strokes ($\leq 2 * T_p$)
- Motor moves only at very low frequency ($f \leq 0.1$ Hz)

Due to the 3-phase system, during standstill operation in one of the three phases there is always an instantaneous value of the current, the amount of which is higher than the permissible continuous current. Does the current flow continuously, the motor will overheat and be thermally damaged. Also refer to chapter 9.10 "Motor temperature monitoring" on page 107). The peak value of the instantaneous current is equal with the amplitude of the sinusoidal assumed phase current. Its value is higher by root 2 than the effective value of the continuous current (I_N). The power loss P_V, created in the coil, is calculated using

$$P_V = 1{,}5 \cdot I^2 \cdot R_{12} \cdot (1 + \Delta\vartheta \cdot \alpha_{Cu})$$

Δθ	Temperature difference between operation temperature and 20 °C
α_{Cu}	Temperature coefficient of the specific resistance of copper = 0.0039 Ohm * m / mm²

Fig. 9-37: Power loss coil

For the nominal current, a double power loss occurs in the affected coil.

To avoid damaged winding in standstill operation, limit the current or the operation duration. A possible form of an additional motor protection is the limitation of the motor current to 87% of the nominal current.

10 Motor-control combinations

10.1 General

The technical data and the figure of the motor characteristics of several motors is displayed inchapter 4 "Technical data" on page 21.

☞ A dimensioning and selection of individual motors must be done in Gantry arrangement.

Maximum allowed intermediate circuit.

Frame size dependend maximum DC bus voltages for MCL motors are defined. Please also observe the information provided under tab. 4-1 "General technical data" on page 27.

⚠ DANGER **Exceeding of voltage limits!**

Prepare a suitable connection with a protective switch via the primary part carrier when using AC voltage > 50 V or DC > 120 V (DIN IEC 60364-4-41) for MCP015.

10.2 Motor-control combinations with NYCe 4000

	NYCe 4120		NYCe 4140
	48 V	72 V	150 V
MCP015A-L040 MCP015B-L040	■	■	-
MCP020x-Vxxx		x	x
MCP030x-Vxxx		x	x
MCP040x-Vxxx		x	x
MCP070x-Vxxx		x	x

■ optimum combination
x permitted combination - reduced velocity, as DC bus voltage is reduced in relation to nominal voltage.
\- Combination not permitted

Tab. 10-1: Motor-control combinations with NYCe 4000

10.3 Motor-control combinations with IndraDrive Cs

		HCS01.1E-Wxxxx-A-02-...					HCS01.1E-Wxxxx-A-03-...				
		3x AC 110 ... 230 V / 1x AC 110 ... 230 V					3x AC 200 ... 230 V				
		W003	W006	W009	W013	W018	W005	W008	W018	W028	W054
Power cables		RKL4800				RKL4801	RKL4800		RKL4801		RKL4803
MCP020	020B-V180	■					□				
	020B-V720		■				x	□			
	020C-V180		■				x	□			
	020C-V720			■				x	□		
	020D-V180			■				□			
	020D-V720				x	■			□		
MCP030	030B-V180		■				x	□			
	030B-V390		x	■				□			
	030C-V180			■				□			
	030C-V390			x	■				□		
	030D-V180				■				□		
	030D-V390				x	■			□		
MCP040	040B-V070		■				□				
	040B-V300			■				□			
	040C-V070		x	■				□			
	040C-V300				■				□		
	040E-V070				■				□		
	040E-V300					x			x	■	
	040G-V070					■			□		
	040G-V300									■	
MCP070	070C-V050			■				x	□		
	070C-V300					x			x	■	
	070D-V050				■				□		
	070D-V300									■	
	070F-V050					x			x	■	
	070F-V300									x	■
	070M-V050									x	■
	070M-V230										x

■ optimum combination
□ permitted combination
x permitted combination - maximum force, however, reduced, as the controller is under-dimensioned.

Tab. 10-2: Motor-control combination with IndraDrive Cs

11 Motor dimensioning

11.1 General procedure

Linear drive dimensioning is determined by the application-dependent characteristics of velocity and feed force and from the thermal connection. The sequence of dimensioning of linear drives is illustrated by the following figure.

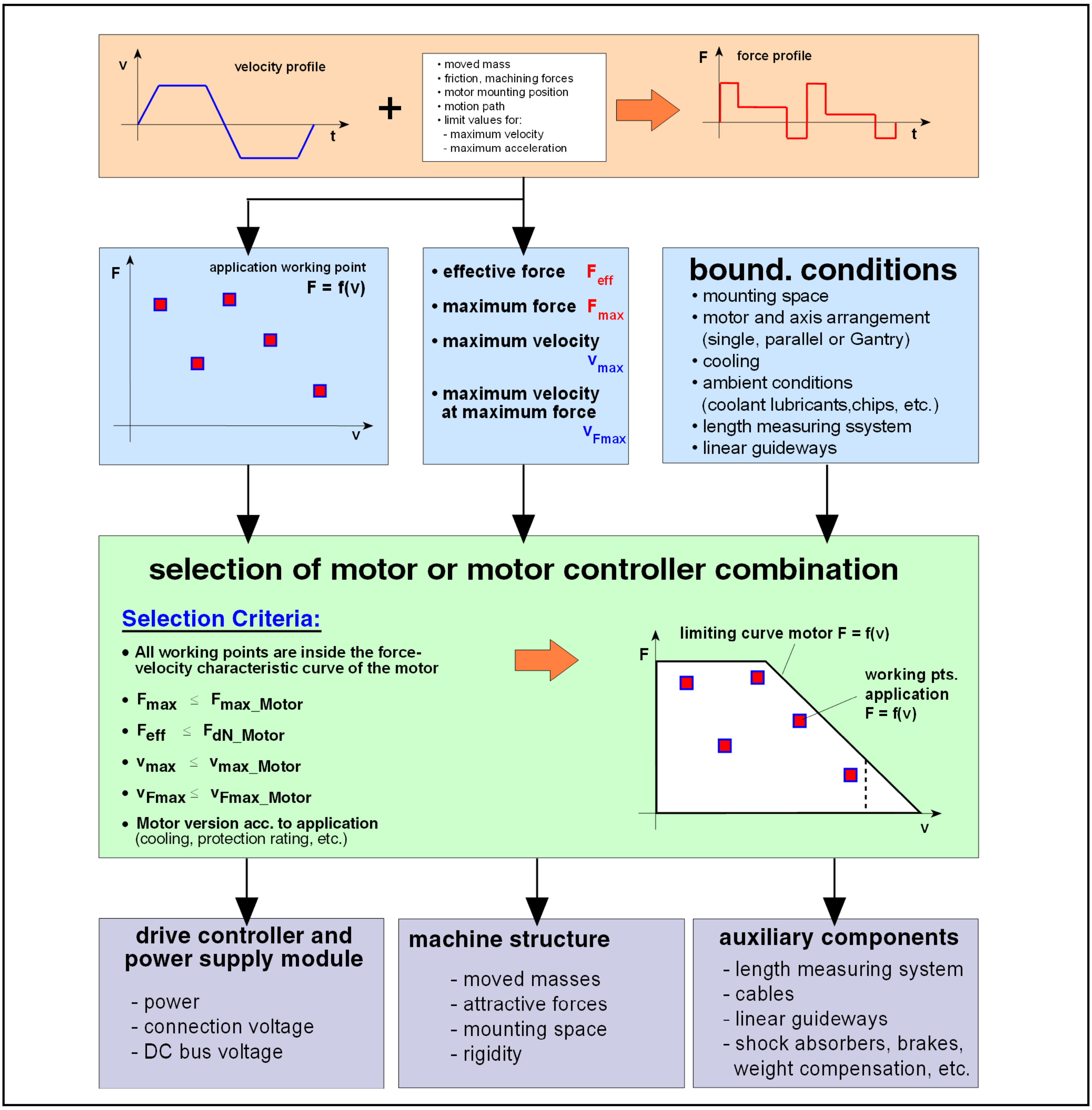


Fig. 11-1: General procedure of linear drives dimension

11.2 Basic formulae

11.2.1 General movement equations

The variables required for sizing and selecting the motor are calculated using the equations shown in the following.

☞ The process-related feed forces and speeds are used directly for drive selection during project planning of linear direct drives without conversions.

Velocity	$v(t) = \frac{s(t)}{dt}$
Acceleration:	$a(t) = \frac{v(t)}{dt}$
Force:	$F(t) = a(t) \cdot m + F_0(t) + F_P(t)$
Effective force:	$F_{eff} = \sqrt{\frac{1}{T} \cdot \int_0^T F(t)^2 dt}$
Average velocity:	$v_{avg} = \frac{1}{T} \cdot \int_0^T v(t)\ dt$

v(t) Velocity profile over time in m/s
s(t) Distance course over time in m
a(t) Acceleration profile vs. time in m/s²
F(t) Force course over time in N
m Moved mass in kg
F_0(t) Base force and friction in N
F_P(t) Processing force or operation force in N
F_{eff} Effective force in N
v_{avg} Average velocity in m/s
t Time in s
T Total time in s

Fig. 11-2: General equations of motion

In most cases the mathematical description of the required positions vs. the time is known (NC-program, electronic cam disk). By means of path function, the calculation of velocity, acceleration and force can be done. Standard software (such as MS Excel or MathCad) can be used for calculating the required variables, even with complex motion profiles.

☞ The following chapter provides a more detailed correlation for trapezoidal, triangular or sinusoidal speed curves.

11.2.2 Feed forces

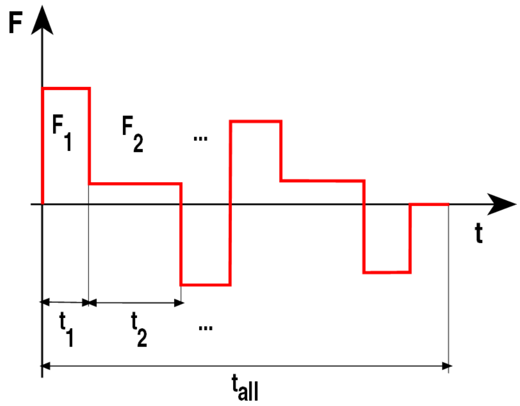


Fig. 11-3: Determining feed forces

Acceleration force : $F_{ACC} = m \cdot a$

Force due to weight : $F_W = m \cdot g \cdot \sin\alpha \cdot (1 - \frac{f_{cb}}{100})$

Frictional force: $F_F = \mu \cdot (m \cdot g \cdot \sin\alpha + F_{ATT}) + F_0$

Maximum force : $F_{MAX} = F_{ACC} + F_F + F_W + F_P$

Effective force: $F_{EFF} = \sqrt{\frac{F_1^2 \cdot t_1 + F_2^2 \cdot t_2 + \ldots}{t_{all}}}$

F_{ACC}	Acceleration force in N
F_W	Weight force in N
F_F	Friction force in N
F_0	Additional friction or base force in N (e.g. due to sealings of linear guides)
F_{MAX}	Maximum force in N
F_{EFF}	Effective force in N
F_P	Processing force in N
a	Acceleration in m/s²
m	Moved mass in kg
g	Final velocity (9,81 m/s²)
α	Axis angel in degrees (0°: horizontal axis; 90°C: vertical axis)
f_{CB}	Weight compensation in %
t_{all}	Total duty cycle time in s
F_{ATT}	Attractive force between primary and secondary part in N
μ	Friction coefficient

Fig. 11-4: Determining feed forces

☞ For dimensioning of linear motor drives, take the moving mass of the motor components into consideration (in particular in case of low load inertia). However, the moving mass is only known after the motor has been selected. For this reason, an assumption must first be made and checked again after the motor has been selected.

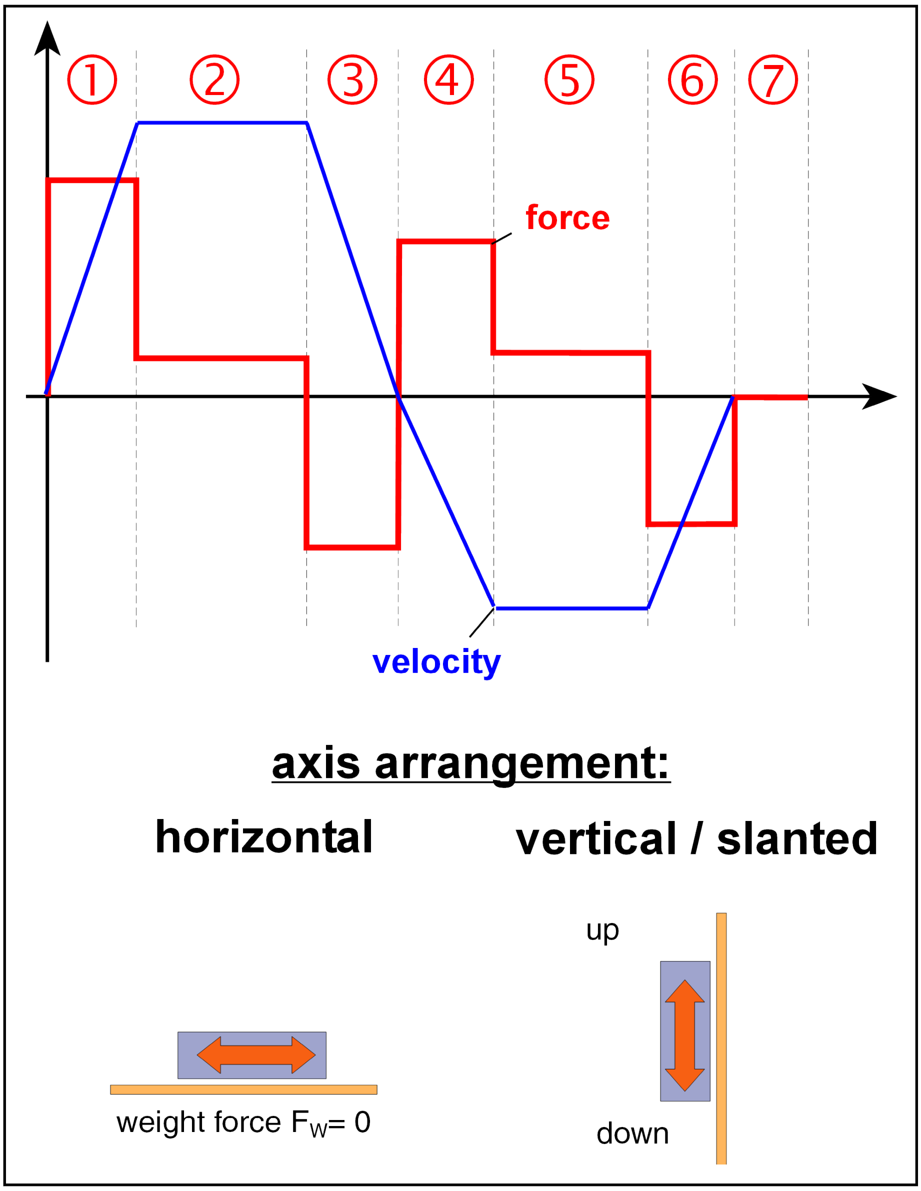


Fig. 11-5: Determining resulting feed forces, dependend from the mode of motion and direction.

(1)	Acceleration (up) :	$F = F_{ACC} + F_F + F_W$
(2)	Const. velocity (up) :	$F = F_F + F_W$
(3)	Deceleration (up) :	$F = -F_{ACC} + F_F + F_W$
(4)	Acceleration (down) :	$F = F_{ACC} + F_F - F_W$
(5)	Const. velocity (down) :	$F = F_F - F_W$
(6)	Deceleration (down) :	$F = -F_{ACC} + F_F - F_W$
(7)	Idle time:	$F = F_W$

F Resulting force in N
F_{ACC} Acceleration force in N
F_W Weight force in N
F_F Friction force in N

Fig. 11-6: Determining resulting feed forces, dependend from the mode of motion and direction.

☞ With horizontal axis arrangement, the weight is $F_W = 0$. Further direction-dependend base and process forces must be additionally observed.

11.2.3 Average velocity

The mean velocity is required to determine the mechanic continuous power of the drive. The generally valid determination of the average velocity is specified in fig. 11-2 "General equations of motion" on page 136. The following calculation can be used for a user-friendly determination of trapezoidal or triangular speed profiles:

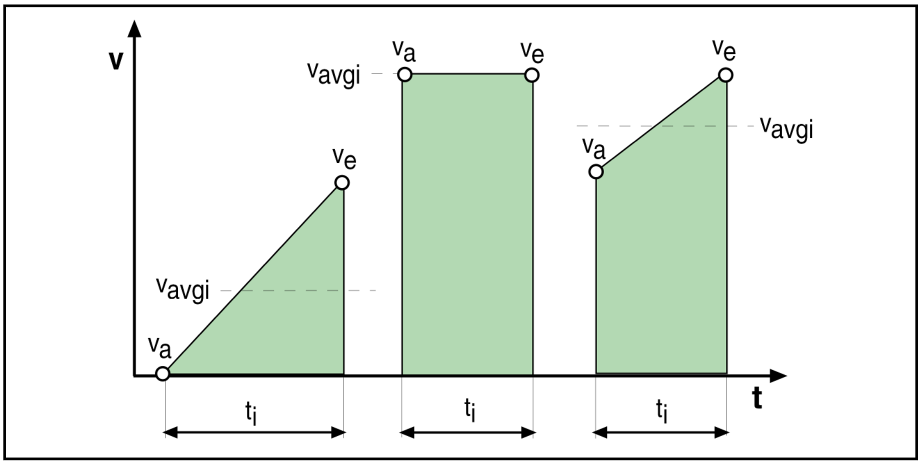


Fig. 11-7: Triangular or trapezoidal velocity profile

$$v_{avgi} = \frac{|v_a| - |v_e|}{2}$$

$$v_{avg} = \frac{\sum v_{avg\,i} \cdot t_i}{t_{all}}$$

v_{avgi}	Average velocity for a velocity segment with a duration ti in m/s
v_a	Initial velocity of the velocity segment in m/s
v_e	Final velocity of the velocity segment in m/s
v_{avg}	Average velocity over total cycle duration in m/s
t_i	Duration velocity segment in s
t_{all}	Total duty cycle time, including breaks and/or standstill time, in s

Fig. 11-8: Determining the mean velocity of triangular or trapezoidal speed profiles

11.2.4 Trapezoidal velocity profile

General

This mode of operation is characteristic for the most applications. After a constant acceleration phase, a motion with constant velocity up to braking phase with constant delay follows.

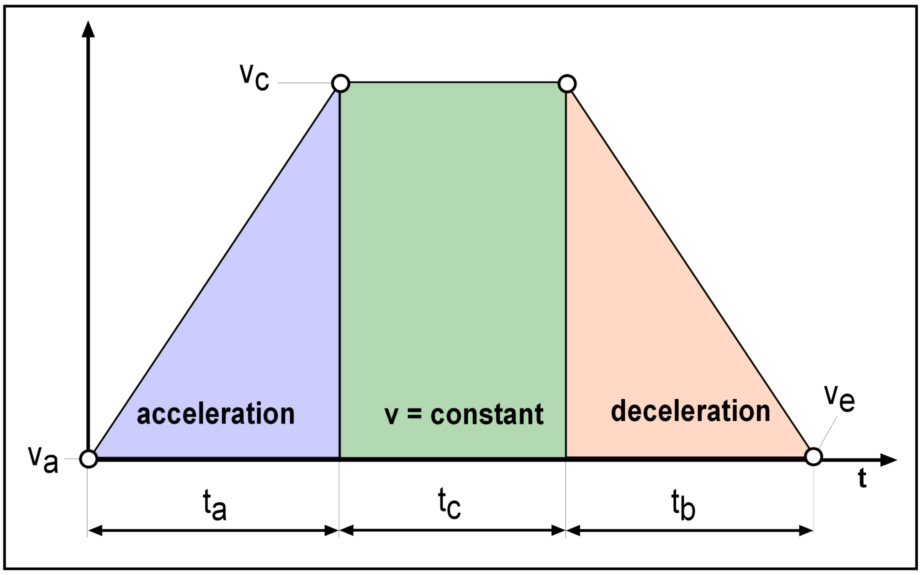


Fig. 11-9: Trapezoidal velocity profile

When determining the respective parameters acceleration a, velocity v, displacement s and time t for trapezoidal travel, a case distinction must be made with regard to velocity:

- Initial velocity $v_a = 0$ or $v_a <> 0$
- Final velocity $v_e = 0$ or $v_e <> 0$

Acceleration, initial velocity v_a= 0

☞
- Velocity v ≠ constant
- Initial velocity $v_a = 0$
- Acceleration a = constant and positive

Acceleration: $$a = \frac{v_c}{t_a} = \frac{2 \cdot s}{t_a^2} = \frac{v_c^2}{2 \cdot s}$$

Final velocity: $$v_c = a \cdot t_a = \sqrt{2 \cdot a \cdot s} = \frac{2 \cdot s}{t_a}$$

Travel: $$s = \frac{v_c}{2} \cdot t_a = \frac{v_c^2}{2 \cdot a} = \frac{a \cdot t_a^2}{2}$$

Time: $$t_a = \frac{v_c}{a} = \frac{2 \cdot s}{v_c} = \sqrt{\frac{2 \cdot s}{a}}$$

a	Acceleration in m/s²
v_c	Final velocity in m/s
t_a	Acceleration time in s
s	Distance during acceleration in m

Fig. 11-10: Constantly accelerated movement, initial velocity v_a= 0 (for trapezoidal velocity profile)

Acceleration, initial velocity v_a= 0

☞
- Velocity v ≠ constant
- Initial velocity $v_a \neq 0$
- Acceleration a = constant and positive

$$\text{Acceleration:}\quad a = \frac{v_c - v_a}{t_a} = \frac{2 \cdot s}{t_a^2} - \frac{2 \cdot v_a}{t_a} = \frac{v_c^2 - v_a^2}{2 \cdot s}$$

$$\text{Velocity:}\quad v_c = v_a + a \cdot t_a = \sqrt{2 \cdot a \cdot s + v_a^2} = \frac{2 \cdot s}{t_a} - v_a$$

$$\text{Travel:}\quad s = \frac{v_c + v_a}{2} \cdot t_a = \frac{v_c^2 - v_a^2}{2 \cdot a} = v_a \cdot t_a + \frac{a \cdot t_a^2}{2}$$

$$\text{Time:}\quad t_a = \frac{v_c - v_a}{a} = \frac{2 \cdot s}{v_c + v_a} = \frac{\sqrt{2 \cdot a \cdot s + v_a^2} - v_a}{a}$$

a	Acceleration in m/s²
v_c	Final velocity in m/s
v_a	Initial velocity in m/s
t_a	Acceleration time in s
s	Distance during acceleration in m

Fig. 11-11: Constantly accelerated movement, initial velocity v_a= 0 (for trapezoidal velocity profile)

Constant velocity

- Velocity v =constant
- Acceleration a = 0

$$\text{Acceleration:}\quad v_c = \frac{s_c}{t_c}$$

$$\text{Travel:}\quad s_c = v_c \cdot t_c$$

$$\text{Time:}\quad t_c = \frac{s_c}{v_c}$$

v_c	Constant velocity in m/s
t_c	Time during constant velocity in s
s_c	Distance during constant velocity in m

Fig. 11-12: Constant velocity (for trapezoidal velocity profile)

Brakes, final velocity v_e= 0

- Velocity v ≠ constant
- Final velocity v_e = 0
- Acceleration a = constant and negative

Acceleration:	$a = \frac{v_c}{t_b} = \frac{2 \cdot s}{t_b^2} = \frac{v_c^2}{2 \cdot s}$
Velocity:	$v_c = a \cdot t_b = \sqrt{2 \cdot a \cdot s} = \frac{2 \cdot s}{t_b}$
Travel:	$s = \frac{v_c}{2} \cdot t_b = \frac{v_c^2}{2 \cdot a} = \frac{a \cdot t_b^2}{2}$
Time:	$t_b = \frac{v_c}{a} = \frac{2 \cdot s}{v_c} = \sqrt{\frac{2 \cdot s}{a}}$

a Acceleration in m/s²
v_c Final velocity in m/s
t_b Braking time in s
s Distance during deceleration in m

Fig. 11-13: Constantly decelerated movement, final velocity v_e= 0 (for trapezoidal velocity profile)

Brakes, final velocity v_e= 0

☞
- Velocity v ≠ constant
- Final velocity v_e ≠ 0
- Acceleration a = constant and negative

Acceleration:	$a = \frac{v_c - v_e}{t_b} = \frac{2 \cdot v_c}{t_b} = \frac{2 \cdot s}{t_b^2} = \frac{v_c^2 - v_e^2}{2 \cdot s}$
Velocity:	$v_e = v_c - a \cdot t_b = \sqrt{v_c^2 - 2 \cdot a \cdot s} = \frac{2 \cdot s}{t_b} - v_c$
Travel:	$s = \frac{v_c + v_e}{2} \cdot t_b = \frac{v_c^2 - v_e^2}{2 \cdot a} = v_c \cdot t_b + \frac{a \cdot t_b^2}{2}$
Time:	$t_a = \frac{v_c - v_e}{a} = \frac{2 \cdot s}{v_c + v_e} = \frac{v_c - \sqrt{v_c^2 - 2 \cdot a \cdot s}}{a}$

a	Acceleration in m/s²
v_c	Initial velocity in m/s
v_e	Final velocity in m/s
t_b	Braking time in s
s	Distance during deceleration in m

Fig. 11-14: Constantly decelerated movement, final velocity v_e= 0 (for trapezoidal velocity profile)

11.2.5 Trapezoidal velocity profile

This velocity profile has no phase of constant velocity in contrast to trapezoidal profiles. The acceleration phase is immediately followed by the deceleration phase. This process is frequently encountered with short-stroke movements.

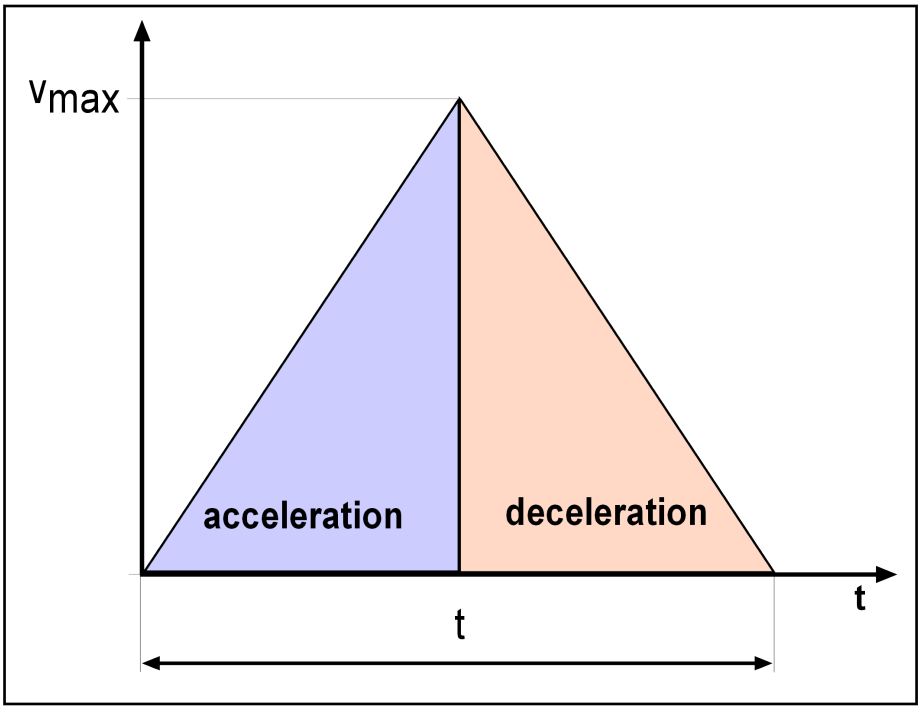


Fig. 11-15: Trapezoidal velocity profile.

Acceleration: $$a = \frac{2 \cdot v_{max}}{t} = \frac{4 \cdot s_{all}}{t^2} = \frac{v_{max}^2}{s}$$

Velocity: $$v_{max} = \frac{a \cdot t}{2} = \sqrt{a \cdot s_{all}} = \frac{2 \cdot s_{all}}{t}$$

Travel: $$s_{all} = \frac{v_{max} \cdot t}{2} = \frac{v_{max}^2}{4 \cdot a} = \frac{a \cdot t^2}{4}$$

Time: $$t = \frac{2 \cdot v_{max}}{a} = \frac{4 \cdot s_{all}}{v_{max}} = \sqrt{\frac{4 \cdot s_{all}}{a}}$$

v_{max}	Maximum reachable velocity in m/s
a	Acceleration in m/s²
s_{all}	Total travel path in m
t	Positioning time in s

Fig. 11-16: Calculation of triangular velocity profile

11.2.6 Sinusoidal velocity profile

This velocity characteristic results, for example, from circular interpolation of two axes (circular movement) or from the oscillating movement of one axis, e.g. during grinding.

The specified variables are chiefly the motion travel s or the circle diameter 2r and the period duration T.

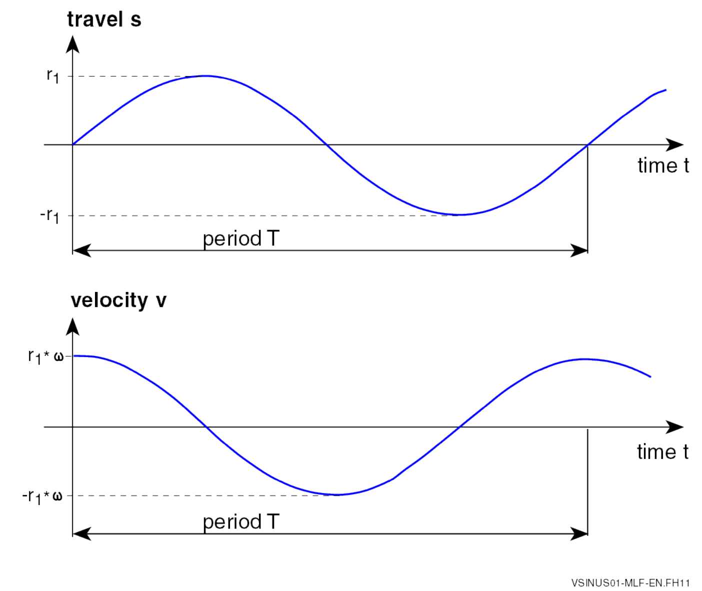


Fig. 11-17: Insert distance and velocity of an axis at sinusoidal velocity

Travel profile: $$s(t) = r_1 \cdot \sin\ (\omega \cdot t)$$

Velocity profile: $$v(t) = r_1 \cdot \cos\ (\omega \cdot t) \cdot \omega$$

Acceleration profile: $$a(t) = -r_1 \cdot \sin(\omega t) \cdot \omega^2$$

Jerk profile: $$r(t) = -r_1 \cdot \cos(\omega t) \cdot \omega^3$$

$$\omega = \frac{2 \cdot \pi}{T} = 2 \cdot \pi \cdot f$$

s(t)	Chronological course of distance
r_1	Radius
r(t)	Chronological course of velocity
t	Time
a(t)	Acceleration
ω	Circular frequency
T	Period duration
f	Frequency

Fig. 11-18: Calculation formular for distance and velocity of an axis for sinusoidal velocity

By means of fig. 11-17 "Insert distance and velocity of an axis at sinusoidal velocity" on page 146 and fig. 11-18 "Calculation formular for distance and velocity of an axis for sinusoidal velocity" on page 147 results in the following calculation base:

Maximum accerlation:	$a_{max} = r \cdot \left(\frac{2 \cdot \pi}{T}\right)^2$
Maximum velocity:	$v_{max} = r \cdot \frac{2 \cdot \pi}{T}$
Average velocity:	$v_{avg} = \frac{2 \cdot v_{max}}{\pi} = \frac{4 \cdot r}{T}$
Acceleration force:	$F_{ACC} = a_{max} \cdot m$
Effective force:	$F_{EFF} = \sqrt{\frac{F_{acc}{}^2}{2} + F_0^2}$
Vertical axis arrangement:	
	$F_{EFFv} = \sqrt{\frac{F_{acc}^2 + F_{0\ up}^2 + F_{0\ down}^2}{2}}$
Base force up movement:	$F_{0\ up} = F_0 + F_w$
Base force down movement:	$F_{0\ down} = F_0 - F_w$

a_{max}	Maximum acceleration in m/s²
v_{max}	Maximum velocity in m/s
r	Travel length in one direction or radius in m
T	Period duration in s
m	Moved mass in kg
F_{ACC}	Acceleration force in N
F_{EFF}	Effective force in N
F_{EFFv}	Effective force at vertical or inclined axis arrangement in N
F_0	Base force, e.g. friction, in N
F_W	Weight force in N

Fig. 11-19: Calculation formula for sinusoidal velocity profile

☞ Further direction-dependend base and process forces must be additionally observed.

11.3 Duty cycle and feed force

11.3.1 General

The relative duty cycle ED specifies the duty cycle percentage of the load with respect to a total duty cycle time, including idle time. The thermal load capacity of the motor limits the duty cycle. Loading the motor with a continuous nominal force is possible during the entire duty cycle time. To avoid thermal overload at motors with higher feed forces reduce the duty cycle at F > F_{dN} (see fig. 11-20 "Correlation between duty cycle and feed force." on page 149).

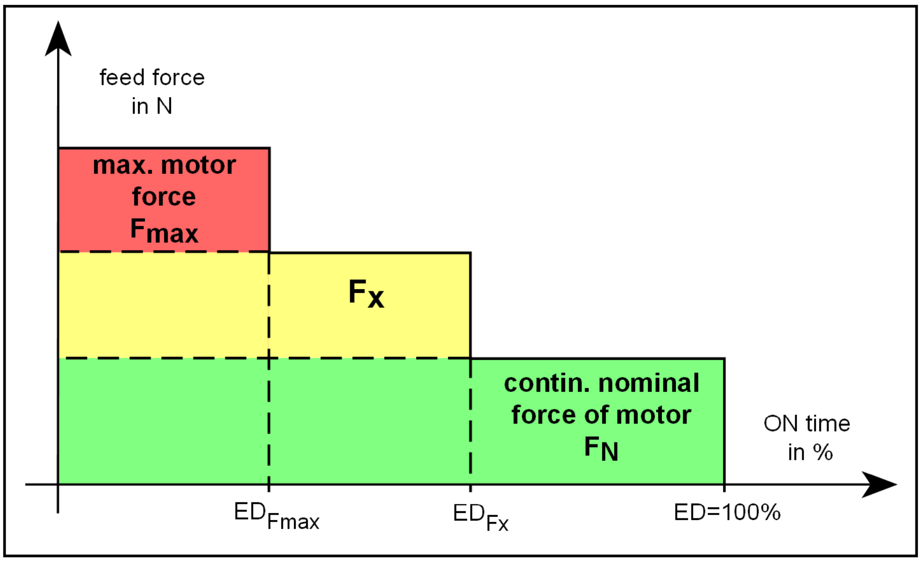


Fig. 11-20: Correlation between duty cycle and feed force.

11.3.2 Determining the duty cycle

Due to the linear correlation of force and current, the approximate determination of the relative duty cycle ED_{ideal} is performed via the correlation:

$$ED_{ideal} = \left(\frac{F_{EFF}^2}{F_{MAX}^2} \right) \cdot 100$$

ED_{ideal}	Cyclic duration factor in %
F_{EFF}	Effective force or continuous force in N
F_{MAX}	Maximum feed force

Fig. 11-21: Approximate determination of duty cycle ED

Determination of possible relative duty cycle can done with the help of fig. 11-22 "Determining the duty cycle ED" on page 150.

$$ED_{real} = \frac{P_{vN}}{P_{AVG\ a}} \cdot 100$$

ED_{real}	Possible relative duty cycle in %
P_{vN}	Maximum heat dissipation of the motor in W (for continuous power loss see chapter 4 “Technical data”).
$P_{AVG\ a}$	Average motor power loss in application over a duty cycle time including idle time in W

Fig. 11-22: Determining the duty cycle ED

11.4 Determining the drive power

11.4.1 General

To size the power supply module or the mains rating, you must determine the rated (continuous) and maximum power of the linear drive.

☞ Take the corresponding simultaneity factor into account when determine the total power of several drives that are connected to a single power supply module.

11.4.2 Continuous power

The continuous power corresponds to the sum of the mechanical and electrical motor power.

Total rated output: $P_c = P_{cm} + P_V$

Mechanical rated output: $P_{cm} = F_{eff} \cdot v_{avg}$

Rated electrical output: $P_V = \left(\frac{F_{eff}}{F_N}\right)^2 \cdot P_{VN} \quad with \quad F_{eff} \leq F_N$

P_c	Continuous power in W
P_{cm}	Mechanical continuous power in W
P_V	Electrical continuous power loss of motor in W
F_{eff}	Effective force in N (from application)
v_{avg}	Average velocity in m/s
F_N	Rated force of the motor in N (see chapter 4 ”Technical data”)
P_{VN}	Rated power loss of the motor in W (see chapter 4 ”Technical data”)

Fig. 11-23: Continuous power of the linear motor

☞ When reducing the continuous nominal force, the electric continuous power is also reduced (seefig. 11-23 "Continuous power of the linear motor" on page 150).

11.4.3 Maximum output

The maximum output is also the sum of the mechanical and electrical maximum output. It must be made available to the drive during acceleration and deceleration phase or for very high machining forces, for example.

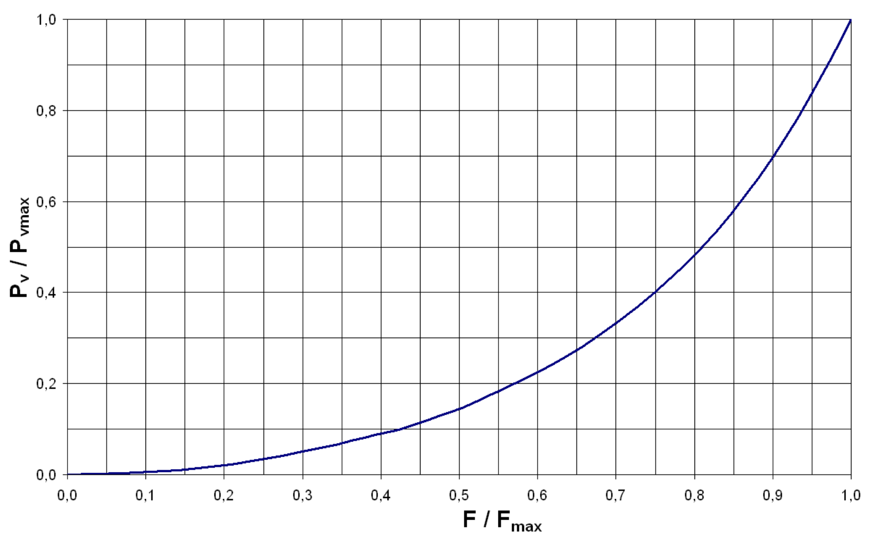
Total maximum power: $P_{max} = P_{max\,m} + P_{max\,e}$

Mechanical maximum power: $P_{max\,m} = F_{max} \cdot v_{F\,max}$

P_{max}	Total maximum power in W
P_{maxm}	Mechanical maximum power in W
P_{maxe}	Electrical maximum power in W (see the following diagram)
F_{max}	Maximum feed force in N
v_{Fmax}	Maximum velocity with Fmax in N

Fig. 11-24: Maximum power of the linear motor

☞ If the maximum feed force is reduced in relation to the achievable maximum force of the motor, the maximum electrical power is also reduced P_{maxe}. To determine the reduced electrical maximum output P_{maxe}, use fig. 11-25 "Diagram used for determining the reduced electrical power loss" on page 151.



F_{max}	Maximum force motor in N
F	Maximum force application in N
P_{Vmax}	Maximum power loss of the motor in W
P_V	Power loss of motor application in W

Fig. 11-25: Diagram used for determining the reduced electrical power loss

11.4.4 Power loss

The power loss corresponds to the continuous electrical power loss of the motor.

$$\text{Required cooling capacity:} \quad P_{ce} = \left(\frac{F_{eff}}{F_N}\right)^2 \cdot P_{VN} \quad with\ F_{eff} \le F_N$$

P_V	Electrical power loss of motor in W
F_{eff}	Effective force in N
F_N	Rated force of the motor in N (see chapter 4 ”Technical data”)
P_{vN}	Rated power loss of the motor in W (see chapter 4 ”Technical data”)

Fig. 11-26: Required cooling capacity of the linear motor

11.5 Energy regeneration

Compared with rotary servomotors, the energy of a linear motor during deceleration is lower. The translational velocity of a linear motor is usually much lower than the circumferential speed of a rotary servomotor.

The regenerative power of a synchronous linear drive results from the energy balance during braking and can be estimated as follows for dimensioning additional braking resistors or regenerative supply units:

$$P_R = \frac{m \cdot v^2}{2 \cdot t_b} - \frac{v \cdot F_R}{2} - \frac{3}{2} \cdot m^2 \cdot R_{12warm} \cdot \left(\frac{a_{max}}{k_{iFN}}\right)^2$$

$$R_{12warm} = R_{12} \cdot (1 + \Delta\vartheta \cdot \alpha_{Cu})$$

$$P_{Ravg} = \frac{1}{T} \cdot \int_0^T P_R(t)\ dt = \frac{\sum P_{R\,i} \cdot t_{bi}}{t_{all}}$$

P_R	Energy regeneration during a braking phase in W
P_{Ravg}	Average energy regeneration over total cycle duration in W
m	Moved mass in kg
v	Maximum velocity in m/s
t_b	Braking time in s
F_R	Friction force in N
R_{12}	Winding resistance of the motor at 20°C in Ohm (see Chapter 4 “Technical data”)
a_{max}	Brake retardation (negative acceleration) in m/s²
k_{iFN}	Motor constant in N/A
t_{all}	Total cycle duration in s

Fig. 11-27: Energy regeneration of linear motor

Prerequisites: Velocity-independent friction

Constant deceleration

Final velocity = 0

☞ If the determined regenerative power according to Fig. 11-27 is negative, no energy is fed back, i.e. energy must be supplied to the motor during braking.

11.6 Efficiency

The efficiency of electrical machines is the ratio between output and input power and, in the case of linear motors, is determined by the application-dependent travel speeds and forces and the corresponding motor losses.

The motor efficiency can be determined or estimated with the help of fig. 11-28 "Efficiency determination for linear motors" on page 153.

$$\eta = \frac{P_{mech}}{P_{mech} + P_V} = \frac{F \cdot v}{(F \cdot v) + P_V} = \frac{1}{1 + \frac{P_V}{F \cdot v}}$$

η	Efficiency
P_{mech}	Mechanical power in W
P_V	Power loss in W
F	Feed force in N
v	Velocity in m/s

Fig. 11-28: Efficiency determination for linear motors

12 Handling, transport and storage

12.1 Delivery status and packaging

12.1.1 Primary parts

The primary parts are packaged in a box. For identification, the package is marked with a label with the type designation of the primary part.

12.1.2 Secondary parts

The secondary parts are individually packaged in a box. For identification, the package is marked with a label with the type designation of the secondary part.

Warning notes on the package of the secondary parts

A self-adhesive warning note is on the packaging of the secondary parts with a warning about danger after opening the package and resulting handling of the secondary parts.

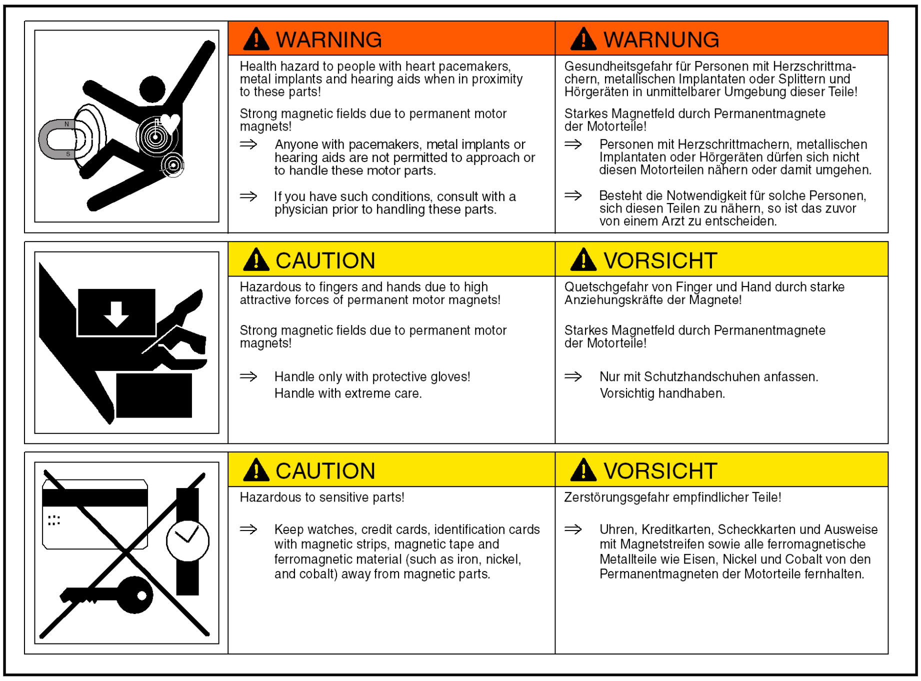


Fig. 12-1: Warning label on the package of secondary parts

☞ The self-adhesive warning label (dimensions approx. 110 mm x 150 mm) can be ordered from Rexroth (MNR R911278745) for the user's own purposes.

12.2 Testing of motor components

12.2.1 Factory checks of the motor components

Electrical testing

During manufacturing, the following electrical tests are performed at linear motors of Bosch Rexroth:

- High voltage test according to DIN EN 60034-1
- Insulation resistance testing according to DIN EN 60204-1
- Testing for compliance with electrical characteristics

Mechanical testing

Linear motor components of Bosch Rexroth are subject to the following mechanical testing:

- Shape and position tolerance according to DIN ISO 1101
- Construction and fitting according to DIN 7157
- Surface structure according to DIN ISO1302
- Thread testing DIN 13 part 20

⚠ CAUTION **Destruction of motor components due to improperly executed high-voltage testing! Loss of warranty!**

⇒ Avoid repeated testing.

⇒ Comply with the guidelines of DIN EN 60034-1

EMC radio interference suppression

Linear motor components of Bosch Rexroth have been subject to EMC type testing and are certified for compliance

EN 55011 Limit Class B, VDE 0875 Part 11

12.3 Transport and storage

12.3.1 Notes about transport

Our products must be transported in their original package only. Also refer to the specific ambient factors to protect the products from transport damage.

⚠ CAUTION **Risk of injuries and / or damage when using secondary parts!**

The inside of the secondary parts is laminated with permanent magnets. Make sure that no small ferromagnetic parts like screws get into contact with the air gap. Also observe the warning notes in fig. 12-1 "Warning label on the package of secondary parts" on page 155.

Based on DIN EN 60721-3-2, the tables below specify classifications and limit values which are allowed for our products while they are transported by land, sea or air. Refer to the detailed description of the classifications to take all of the factors which are specified in the particular class into account.

Allowed classes of environmental conditions during transport acc. to DIN EN 60721-3-2

Classification type	Allowed class
Classification of climatic environmental conditions	2K11
Classification of biological environmental conditions	2B1
Classification of chemically active materials	2C1
Classification of mechanically active materials	2S5
Classification of mechanical environmental conditions	2M4

Tab. 12-1: Allowed classes of environmental conditions during transport

For a better overview, some essential environmental influencing variables of the previously mentioned classifications are listed. Unless otherwise specified, the specified values are the values of the particular class. However, Bosch Rexroth reserves the right to adjust these values at any time based on future experiences or changed environmental factors.

Deviating from DIN EN 60721-3-2 permissible ambient conditions

Environmental factor	Unit	Value
Temperature	°C	-25 ... +70[1)]
Relative air humidity	%	5 ... 75[1)]
Absolute air humidity	g/m³	1 ... 29[1)]

1) Differs from DIN EN 60721-3-2

Tab. 12-2: Deviating permissible storage conditions

Air freight

⚠ CAUTION **Possible influence of plane electronic on board through magnet fields!**

⇒ Heed the packaging and transport instructions (IATA 953)

12.3.2 Information on storage

Storage conditions

Generally, Bosch Rexroth recommends storing all components until they are actually installed in the machine as follows:

- in their original packaging
- at a dry and dust-free location
- at room temperature
- free from vibrations and oscillations
- protected against light or direct sunlight

Upon delivery, protective sleeves and covers can be attached to Bosch Rexroth motors. They have to remain on the motor for transport and storage. Do not remove these parts until shortly before assembly.

Based on DIN EN 60721-3-1, the tables below specify classifications and limit values which are allowed for our products while they are stored. Refer to the detailed description of the classifications to take all of the factors which are specified in the particular classification into account.

Allowed classes of ambient conditions during storage acc. to DIN EN 60721-3-1

Classification type	Class
Classification of climatic environmental conditions	1K21
Classification of biological environmental conditions	1B1
Classification of chemically active materials	1C1
Classification of mechanically active materials	1S10
Classification of mechanical environmental conditions	1M11

Tab. 12-3: Allowed classes of environmental conditions during storage

For a better overview, some essential environmental influencing variables of the previously mentioned classifications are listed. Unless otherwise specified, the specified values are the values of the particular class. However, Bosch Rexroth reserves the right to adjust these values at any time based on future experiences or changed environmental factors.

Deviating from DIN EN 60721-3-1 permissible ambient conditions

Environmental factor	Unit	Value
Air temperature	°C	-25 ... +55[1]
Relative air humidity	%	5 ... 75[1]
Absolute air humidity	g/m³	1 ... 29[1]

1) Differs from DIN EN 60721-3-1

Tab. 12-4: Deviating permissible storage conditions

Storage times

Additional measures have to be taken upon commissioning to ensure smooth functioning – irrespective of the storage time which may be longer than the warranty period of our products. However, this does not entail any additional warranty claims.

Motors

<table>
<tr><th>Storage time</th><th>Measures for commissioning</th></tr>
<tr><td>< 1 year</td><td rowspan="3">Visual inspection of all parts to be damage-free
Check the electric contacts to verify that they are free from corrosion</td></tr>
<tr><td>1 ... 5 years</td></tr>
<tr><td>> 5 years</td></tr>
</table>

Tab. 12-5: Measures before commissioning motors that have been stored over a prolonged period of time

Cable and plug connector

Storage time	Measures prior to commissioning
< 1 year	None
1 ... 5 years	Check the electric contacts to verify that they are free from corrosion
> 5 years	If the cable or the cable jacket has porous parts, replace it; otherwise check the electric contacts to verify that they are free from corrosion

Tab. 12-6: Measures before commissioning of cables and connectors that have been stored over longer periods of time

13 Assembly

13.1 Basic precondition

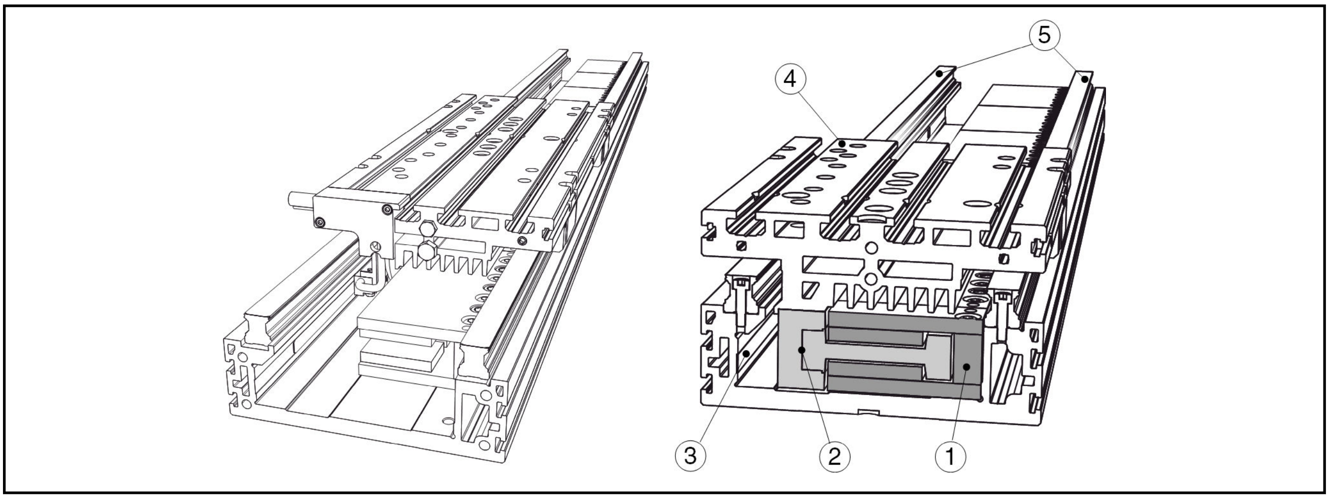
The following points must be considered or checked before starting the assembly work:

- Observe of the necessary installation sizes (see chapter 5.1 "Specifications" on page 45)
- Machine construction fulfills the requests for mounting (stiffness, attractive force, feed and acceleration force, etc.) and is prepared for installation of the motor components.
- Clean screw-on surfaces between machine and motor components
- Installation of motor components by skilled personnel only
- Compliance of danger and safety notes is guaranteed.

13.2 Arrangement of motor components

During machine planning, observe and specify the position of the motor components in the machine. All fixtures and screw-on surfaces must be prepared from the machine manufacturer for installation of the motor components.

Basically, no limitations about arrangement of the motor components exists. It can be an advantage to mount the secondary part sidewards (see fig. 13-1 "Arrangement of motor components within ready-to-mount compact module CKL of Rexroth" on page 159) or downwards toppled that dirt, residues a.s.o. can drop into the air gap between primary and secondary part from above. In this content, please observe the notes under chapter 9.12.4 "Protection of the motor installation space" on page 112 on how the installation space must be created to optimally protect the motor components. The following figure shows a possible motor assembly. Dependend from the application, another arrangement can be preferred.



① Secondary part MCS ...
② Primary part MCP
③ Measurement system
④ Machine slide
⑤ Guidances / profile rails

Fig. 13-1: Arrangement of motor components within ready-to-mount compact module CKL of Rexroth

13.3 Installation of motor components

The order of installation of motor components is depending on the machine construction or the available space in the machine. Also, the arrangement of the motor components plays a significant role.

In the following assembly example, always motor setup in single arrangement is assumed.

- Possibility A

  First, determine the secondary parts. Then, insert the primary part laterally into the secondary parts and fasten it on the machine. MCP015 primary parts can also be mounted from above into the secondary part due to their design (T-shape).
- Possibility B

  Initially assemble only one secondary part. Insert the primary part on the front side (or MCP015 from above) into the secondary part and fasten it on the machine. Then, mount the remaining secondary parts.
- Possibility C

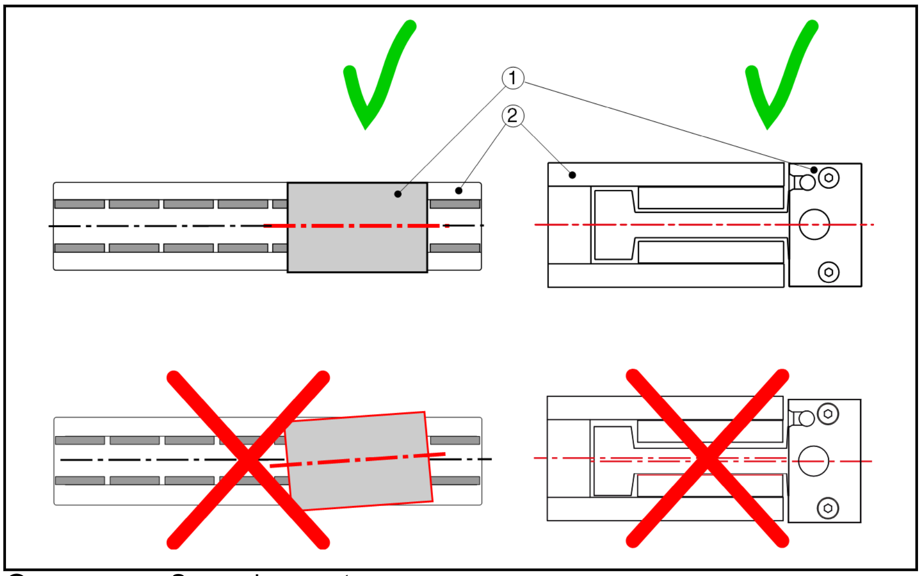
  First, mount the primary part and afterwards the secondary part.

13.4 Air-gap, parallelism and symmetry of the motor components

Parallelism and symmetry

When mounting primary and secondary parts, their position is specified by the holes or threads within the machine slide and within the machine bed.

Due to the clearance, which exists within the holes of the screw connections, the motor components must be adjusted correctly acc. to fig. 13-2 "Aligning the motor components" on page 160 before the screws are tightened. This can be done via pressing the motor components on the screw-on surfaces and stop faces. If all installation dimensions tab. 5-1 "MCL015 Installation dimensions and tolerances" on page 46Installation dimensionstab. 5-2 "Installation dimensions and tolerances MCL020 ... 070" on page 47were adhered to, the correct arrangement of both motor components to each other results.



① Secondary part
② Primary part

Fig. 13-2: Aligning the motor components

Air gap

NOTICE	Motor damage due to insufficient air gap between primary and secondary part!

After assembly, check the free movement of the motor components to each other immediately. Therefore, move the versatile motor components by hand over the complete travel length. The versatile motor components must be freely movable at each position over the total travel length - without any contact to fixed motor components. This check can detect faulty assembly in time (e.g. dirt under the assembly surfaces, faulty installation dimensions, insufficient machine rigidity etc.).

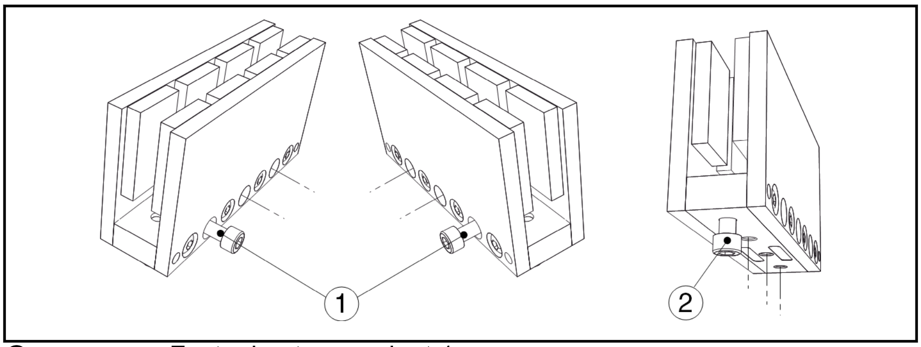
13.5 Fastening secondary part

Observe absolute cleanness during assembly. No dirt should exist on the screw-on surface and stop faces and no dirt or other parts (e.g. screws, washers, etc.) should reach the area of magnetic pull on the secondary part. Any kind of foreign bodies in this area could damage the primary or secondary part at the first traverse of the motor components.

☞

- For safety reasons, the user or machine manufacturer is NOT allowed to dismount the secondary part in its separate parts!
- To fasten the secondary parts, it is only allowed to use new, unused screws.
- After aligning, tighten all screws with the specified tightening torque (see Chapter 13.4). Additionally secure the screw connection with Loctite 243.
- After assembly, check if any foreign bodies exist in the secondary part.

The secondary parts can be connected with the machine via two different ways.



① Fastening type variant 1
② Fastening type variant 2

Fig. 13-3: Secondary part fastening types

The screw-on surfaces and stop faces must be cleaned and be free of grease before the secondary parts can be screwed on the machine construction. For suitable screw selection and its tightening torques refer to the following table.

NOTICE **Motor damage due to insufficient air gap between primary and secondary part!**

Observe during fastening of the secondary parts according to variant 2 that the maximum screw-in depth specified in the table, is kept. In the case of defiance, the primary part can be irreparably damaged due to collision with overhanging screws.

Fastening type - variant 1

Secondary part MCS ...	Drilling diameter within the secondary part	maximum screw-in depth	Screw size (DIN EN ISO 4762)	Fastening class	Tightening torque (+/-10%)
		Variant 1			
015	4.5 mm	depending from the customer´s application	M4	8.8	3.1 Nm
020	4.3 mm		M4		3.1 Nm
030	4.3 mm		M4		3.1 Nm
040	6.4 mm		M6		10.4 Nm
070	8.5 mm		M8		25 Nm

Tab. 13-1: Fastening mode (variant 1) with tightening torques for MCS

Fastening type - variant 2

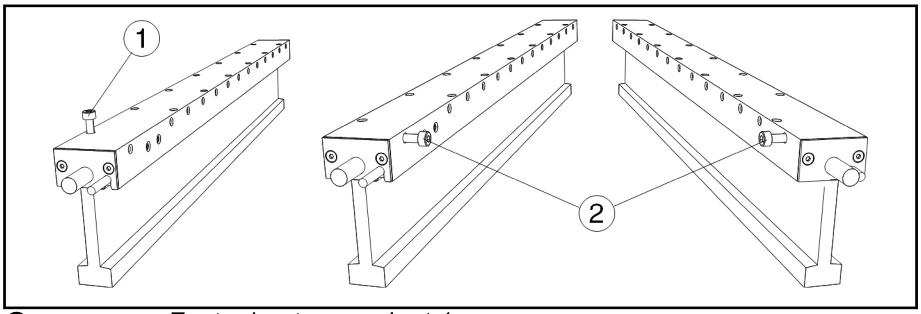
Secondary part MCS ...	Thread diameter within secondary part	maximum screw-in depth	Screw size (DIN EN ISO 4762)	Fastening class	Tightening torque (+/-10%)
		Variant 2			
015	M4	9 mm	M4	8.8	3.1 Nm
020	M5	9 mm	M5		6.1 Nm
030	M5	9 mm	M5		6.1 Nm
040	M6	11 mm	M6		10.4 Nm
070	M8	12 mm	M8		25 Nm

Tab. 13-2: Fastening mode (variant 2) with tightening torques for MCS

The calculation about firmness of screw connection for fastening the secondary part are based on the assumption that the screwing surface of the secondary part and the screwing surface of the machine are clean and the secondary part is screwed in direct contact with the machine and secured with Loctite 243.

- In certain cases it is not possible to screw the secondary part with the machine directly, as additional materials like distance plates, thermal grease and so on, are among secondary part and machine. Then a sufficient fastening of the screw connection must be ensured by the machine manufacturer.
- The effect of liquid screw lock is damaged by loosening or re-tightening of screws (e.g. due to torque tests) and must be renewed.
- Use all fastening points to fasten the secondary part.

13.6 Fastening the primary part



① Fastening type variant 1
② Fastening type variant 2

Fig. 13-4: Primary part fastening type

Primary part MCP ...	Screw size (DIN EN ISO 4762)	Screw-in depth		Fastening class	Tightening torque (+/-10%)
		Variant 1	Variant 2		
015	M3	see chapter 5 "Dimension sheets" on page 45		8.8	1.3 Nm
020	M4				3.1 Nm
030					
040					
070	M6				10.4 Nm

Tab. 13-3: Tightening torque for the fastening screws of the primary parts

The screw-on surfaces and stop faces must be cleaned and be free of grease before the primary parts can be screwed on the machine construction. Secure all screwed connections with screw connection, e.g. Loctite 243.

Mounting instructions:

1. Preparing the threades holes and screws for assembly
2. Fasten the primary part with screws 1, 2, 3...n until the primary part lies on the slide.

   Fasten screws - from inside to outside - 1, 2, 3 ... x with nominal tightening torque:

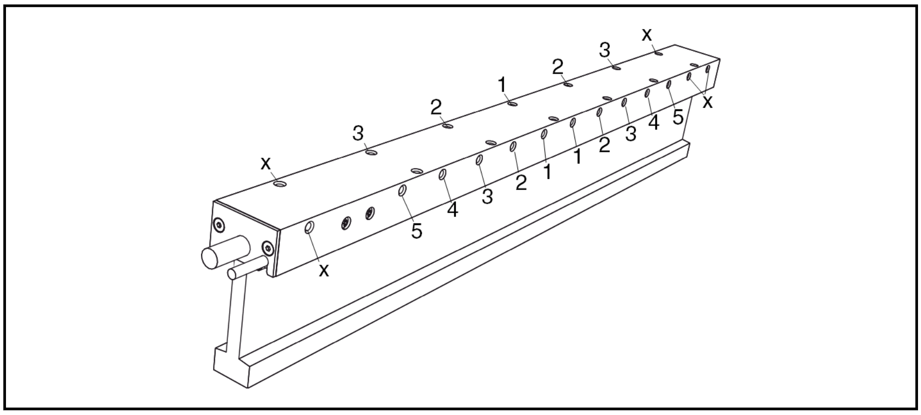


Fig. 13-5: Tightening row of screws

☞

- Use **all fastening points** to fasten the primary part.
- The effect of liquid screw lock Loctite 243 is damaged by loosening or re-tightening of screws (e.g. due to torque tests) and must be renewed.

13.7 Electrical connection

Connect the motor electrically according to the connection diagrams and the instructions in chapter 8 "Connection technique" on page 83. Refer to the references to supplementary documentation.

☞

- When using self-manufactured cables, ensure EMC-compliant design and installation.
- Where applicable, ensure that connectors and lines are fastened for strain relief purposes.
- The connection diagrams of the product documentation serve to create system circuit diagrams. Only the machine manufacturer's system wiring diagrams are relevant for the connection of the drive components in the machine.

---

14 Commissioning, operation and maintenance

14.1 General

In some points, commissioning of linear motors is different in comparison to rotary servo motors. For commissioning of synchronous linear motors, the following points must be observed in particular:

Parameters

Synchronous linear motors are kit motors whose single components are directly installed into the machine by the manufacturer – completed by an encoder system. As a result, kit motors do not feature any data memory to provide motor parameters, standard controller settings, etc. All parameters must be manually entered or loaded to the drive during commissioning. The IndraWorks commissioning program provides all Rexroth motor parameters.

Controller optimization

The procedure for controller optimization (current, velocity and position controller) at linear direct drives corresponds to the procedure for rotary servo drives. Only the setting limits of linear drives are higher. For example, this enables setting up to 10 times higher kv factors at linear direct drives in comparison to rotary servo drives. However, this requires a respective machine construction (see chapter 9.12 "Requirements on the machine design" on page 110).

Moving masses

With controlled rotary servo drives, there are control limitations in the ratio of motor moment of inertia to load moment of inertia. This restriction does not apply for direct drives with linear motors: The moved external load depends on load of the motor itself.

Encoder polarity

The polarity of the actual velocity (length measuring system) must comply with the force polarity of the motor. Before commutation adjustment, this relation must be established.

Commutation adjustment

It is necessary at synchronous linear motors to receive the position of the primary part relating on the secondary part by return after start or after a malfunction. This is referred to as pole position detection or commutation adjustment. This means that the commutation adjustment is the establishment of a position reference to the electrical or magnetic model of the motor. Commutation adjustment can only be made after installation of motor components and the length measuring system. The commutation adjustment method depends on the measuring principle of the length measuring system.

14.2 General requirements

14.2.1 General

The following requirements have to be met to ensure successful commissioning:

- Compliance with safety-related guidelines and instructions
- Check of electrical and mechanical components for reliable functioning
- Availability and provision of required tools
- Adherence to the commissioning procedure described below

14.2.2 Checking all electrical and mechanical components

Check all electrical and mechanical components prior to commissioning and pay particular attention to the following issues:

☞

- Ensure safety for man and machine
- Correctly install the motor
- Correct power connection of the motor
- Connect connection of the length measuring system
- Ensure proper function of existing safety limit switches, door switches, etc.
- Ensure correct function of the emergency stop circuit and emergency stop.
- Ensure proper and complete machine construction (mechanical installation)
- Availability and function of suitable end position dampers
- Ensure correct connection and function of drive controller and control unit

14.2.3 Tools

IndraWorks commissioning software The motors can be commissioned either directly via an NC terminal or via special commissioning software. The IndraWorks commissioning software allows menu-driven, custom-designed and motor-specific parameterization and optimization.

PC For commissioning by means of IndraWorks, a conventional Windows PC is required.

Commissioning via NC Commissioning via the NC control unit requires access to all drive parameters and functionalities.

Multimeter Troubleshooting and component checks can be facilitated by a multimeter allowing the measurement of voltage, current and resistance values.

14.3 General commissioning procedure

The general commissioning sequence for MCL ironless synchronous linear motors is explained in the following diagram. The individual items are explained in more detail in the chapters following thereafter.

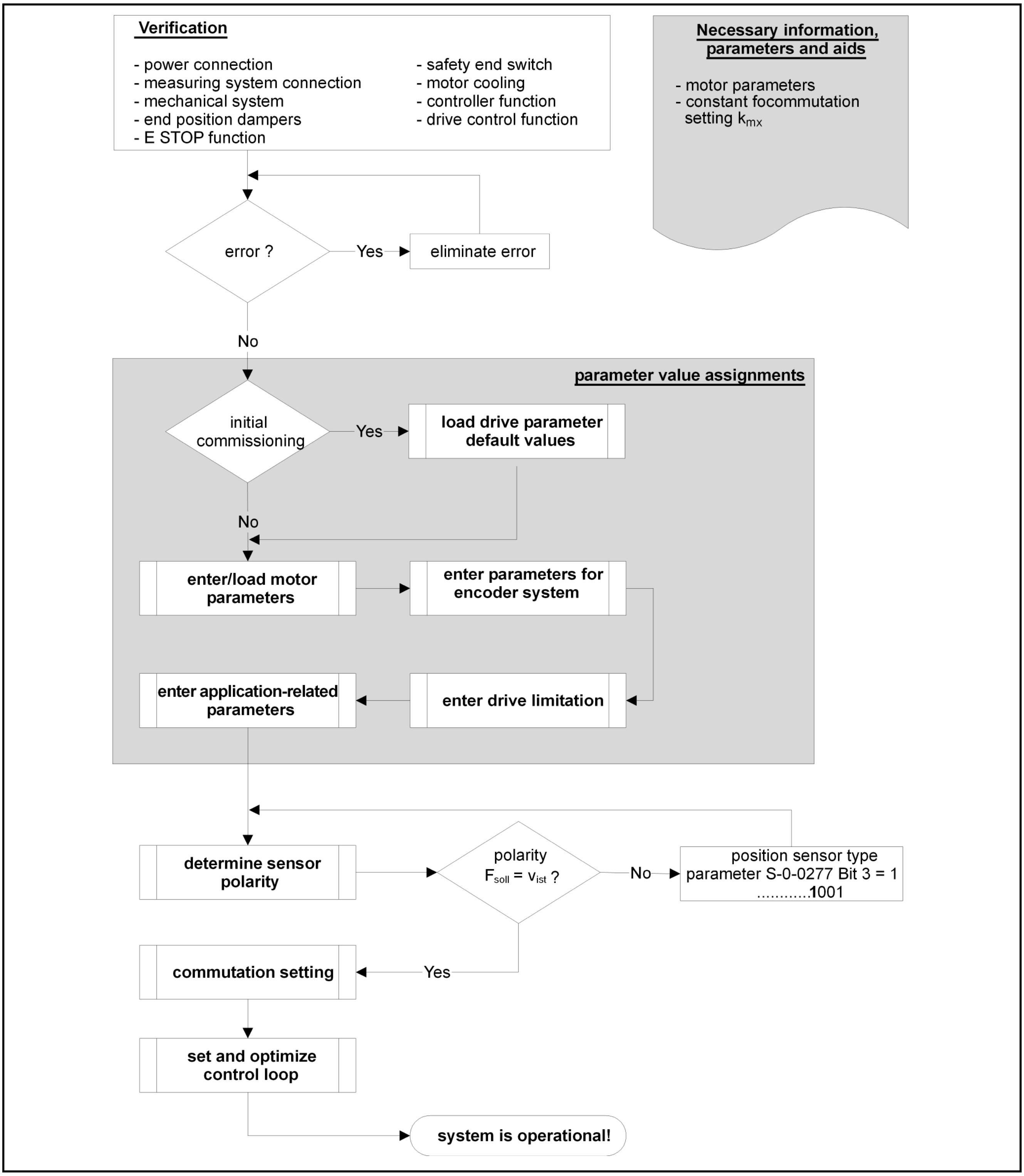


Fig. 14-1: General commissioning procedure for synchronous linear drives

14.4 Parameterization

14.4.1 General

IndraWorks allows entering or editing certain parameters and executing commands during commissioning by means of menu-driven dialogs and list representations or, optionally, via the control terminal.

14.4.2 Entering motor parameters

☞ Motor parameters are specified by Rexroth and cannot be changed by the user. If these parameters are not available, commissioning is not possible! In this case, please contact your Rexroth Sales and Service Facility.

⚠ WARNING

Activation of the motor immediately after motor parameter input may result in injury and mechanical damage! The motor is not yet ready for operation simply by entering the motor parameters!

⇒ Enter parameters for length measuring system

⇒ Check and adjust the measuring system polarity

⇒ Configure the commutation settings

The motor parameters can be entered as follows:

- Use IndraWorks to load all motor parameters.
- Enter the individual parameters manually via the controller
- Load a complete parameter set at serial machines via the controller or IndraWorks

14.4.3 Motor parameter at parallal arrangement

Are two linear motors operated in a control device, the following parameters have to be adjusted when commissioning:

Parameter	Designation	Adjustment factor
P-0-4016	Direct-axis inductance of motor	x 0.5
P-0-4017	Quadrature-axis inductance of motor	x 0.5
P-0-4048	Motor winding resistance	x 0.5
S-0-0106	Current loop proportional gain 1	x 0.5
S-0-0109	Motor peak current	x 2
S-0-0111	Motor current at standstill	x 2

Tab. 14-1: Parameter adjustment at parallel arrangement

☞ A smaller controller can be used, if the maximum possible continuous nominal force or the maximum possible peak force of the motor is not required. In this case, re-adjust the configured currents to the selected controller. Therefor, use Rexroth IndraSize (see Chapter 4.2).

14.4.4 Entering length measuring system parameter

Encoder type

The type of the length measuring system has to be defined. By means of parameter P-0-0074, Encoder type 1.

Encoder type	P-0-0074
Incremental measuring system	2
Absolut encoder with ENDAT interface	8
Incremental encoder with Hall sensor	14 or 15 (depending from Hardware configuration)

Tab. 14-2: Defining the encoder type

☞ Detailed descriptions can be found in the firmware or parameter description of the drive controller used.

- Rexroth IndraDrive MPx-xx Parameter Description, MNR R911328651
- Rexroth IndraDrive MPx-xx Parameter description, MNR R911328651
- Rexroth IndraDrive Firmware MPx-xx Functional Description, MNR R911328670
- Rexroth IndraDrive MPx-xx Application Manual, MNR R911326767

Signal period

Linear scale for linear motors generate and interpret **sinusoid signals.** The sine signal period has to be entered in parameter S-0-0116, Resolution of feedback 1.

Please also observe the information provided by the measuring system manufacturer for resolution of encoder signals.

14.4.5 Entering drive limitations and application-related parameters

Drive limitations

The drive limitations that can be set, include:

- Current limitation
- Force limitation
- Velocity limitations
- Travel range limitations

Application-related parameters

Application-related drive parameters include, for example, parameterization of the drive fault reaction.

☞ Detailed descriptions can be found in the firmware or parameter description of the drive controller used. See also chapter 14.4.4 "Entering length measuring system parameter" on page 171.

14.5 Determining the polarity of the linear scale

In order to avoid direct feedback in the velocity control loop, the effective direction of the motor force and the count direction of the length measuring system must be identical.

⚠ WARNING

Different effective directions of motor force and count direction of the encoder system cause uncontrolled movements of the motor upon switch-on!

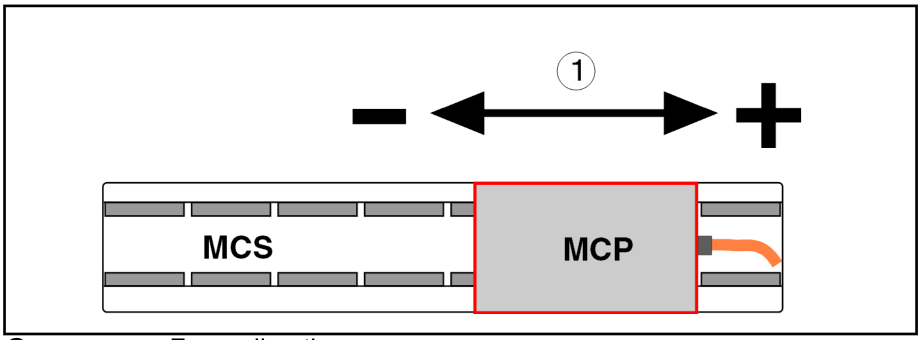
⇒ Secure against uncontrolled movement

⇒Setting of the effective direction of the motor force identically to the counting direction of the length measuring system

Effective direction of motor force

The following applies for setting of the correct encoder polarity:

The effective direction of the motor force is always positive in the direction of the cable connection of the primary part.

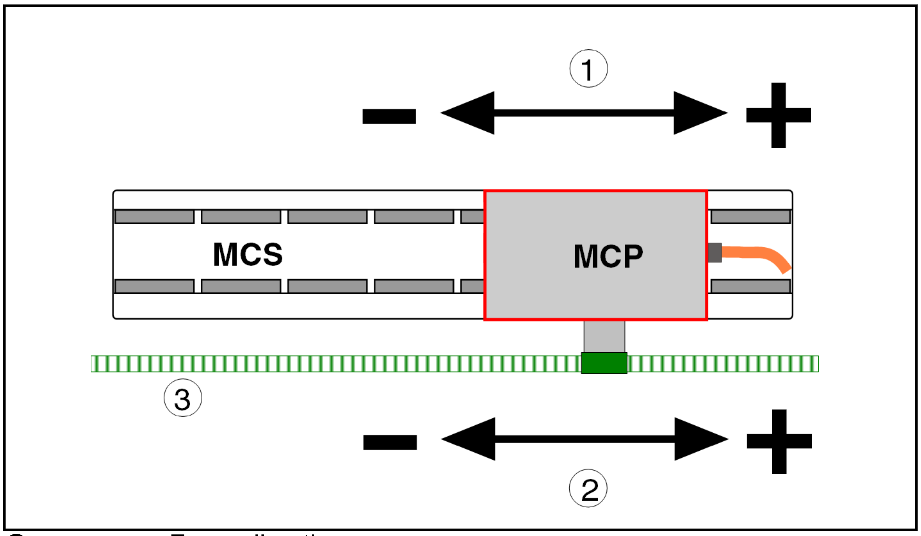


① Force direction

Fig. 14-2: Effective direction of motor force

Effective direction of the motor force = Counting direction of the length measuring system

In case of motion of the primary part in the direction of the cable connection, the counting direction of the length measuring system must also be positive:



① Force direction
② Counting direction
③ Length measuring system

Fig. 14-3: Effective direction of the motor force = Counting direction of the length measuring system

☞ The encoder polarity is always set in regard to the primary part (cable connection). The installation direction or pole sequence of the secondary part does not have any impact on the encoder polarity setting.

The encoder polarity is set via parameters

S-0-0277, Position encoder type 1 (Bit 3)

Position, velocity and force data must not be inverted when the length measuring system count direction is set:

S-0-0085, Torque/force polarity parameter: 0000000000000000

S-0-0043, Velocity polarity parameter 0000000000000000

S-0-0055, Position polarity 0000000000000000

14.6 Commutation adjustment

14.6.1 General

The force of the synchronous linear motor can only develop to a maximum and constant degree, if the commutation angle is set correctly.

☞ Commutation adjustment always has to be performed in the following cases:

⇒ Initial commissioning

⇒ Modification of the mechanical attachment of the linear scale

⇒ Length measuring system replacement

⇒ Modification of the mechanical attachment of the primary and/or secondary part

This procedure ensures that the angle between the current vector of the primary part and the flux vector of the secondary part is always 90°. The motor supplies the maximum force in this state.

Adjustment procedure

Different commutation adjustment procedures have been implemented in the firmware. The following figure shows the connection between the length measuring system used and the procedure to be applied.

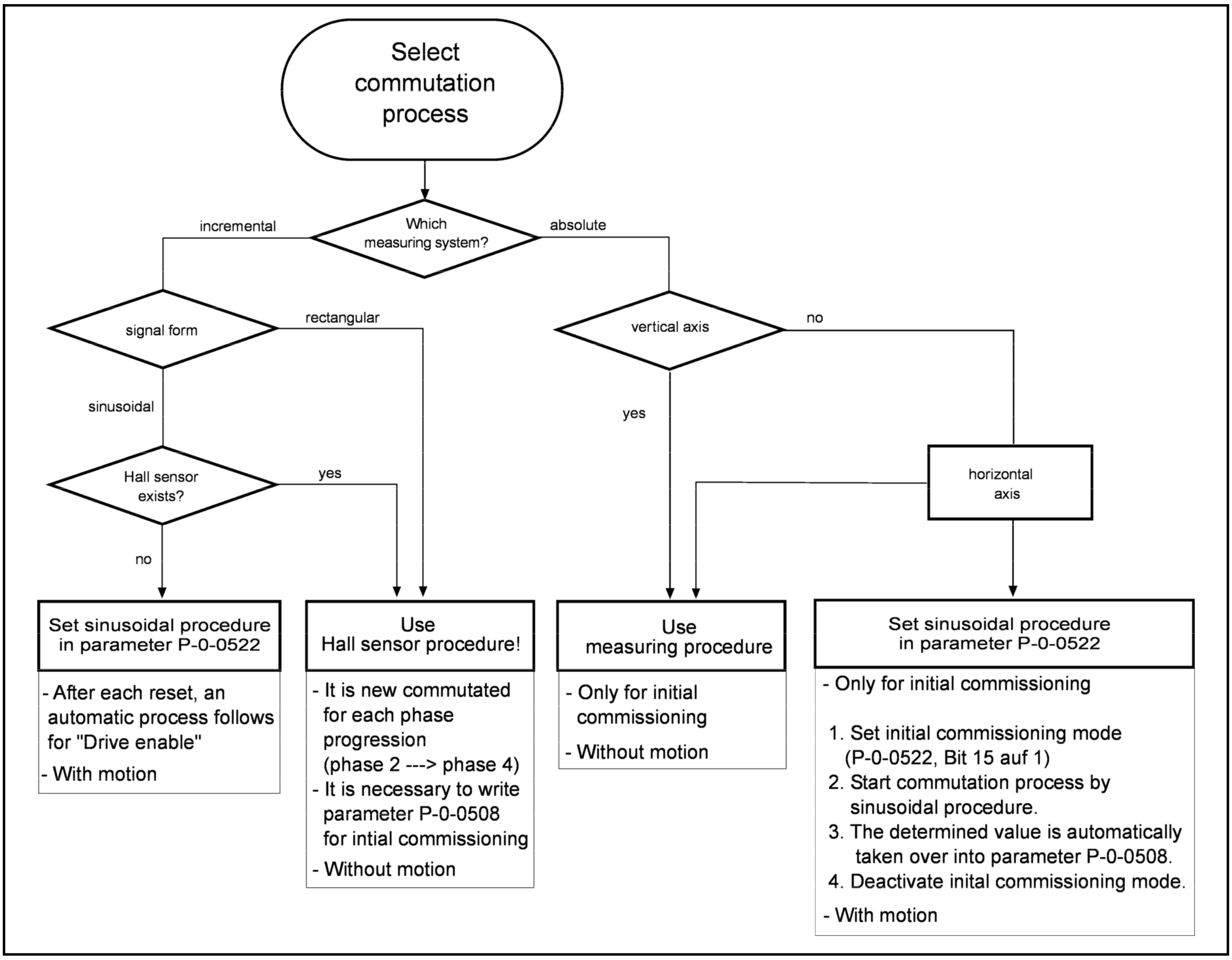


Fig. 14-4: Procedure for commutation adjustment for ironless synchronous linear motors

---

☞ Observe the following requirements for commutation adjustment:

⇒ Effective direction of the motor force = Counting direction of the length measuring system

⇒ Correct motor and encoder parameterization

⇒ Complying with the described setting procedures

⇒ Appropriate parameterization of current and velocity control loops

⇒ Correct connection of motor power cable

⇒ Protection against uncontrolled movements

⚠ DANGER

Errors in commutation adjustment can result in malfunctions and/or uncontrolled movements of the motor!

Take care when carrying out the commutation adjustment. For commutation, observe the detailed information in the documentation under chapter 14.4.4 "Entering length measuring system parameter" on page 171.

Motor connection The individual phases of the motor power connection have to be assigned correctly.

Parameter checking To ensure proper commutation adjustment, the following parameters should be checked again:

Ident number	Description	Designation/function
S-0-0085	Torque/force polarity parameter	Refer to Parameter Description • Rexroth IndraDrive MPx-xx, MNR R911328651 • Rexroth IndraDrive MPx-xx, MNR R911297317
S-0-0043	Velocity polarity parameter	
S-0-0055	Position polarity	
P-0-4014	Type of motor	
P-0-0018	Number of pole pairs/pole pair distance	
S-0-0116	S-0-0116, Encoder 1 resolution	
P-0-0522	Commutation adjustment control word	
P-0-0074	Encoder type 1 (motor encoder)	

Tab. 14-3: Parameters to be checked before commutation adjustment

14.6.2 Sinusoidal procedure

You will find limitations and detailed notes about the sinusoidal procedure in

- Rexroth IndraDrive Firmware MPx-xx Functional Description, MNR R911328670
- Rexroth IndraDrive MPx-xx Application Manual, MNR R911326767

14.6.3 Hall sensor procedure

The Hall sensor procedure is applied if an incremental measuring system is used in combination with a Hall unit in the primary part. Also observe the information on the Hall unit in chapter 7.1 "Hall unit" on page 77.

Commutation by means of analog Hall unit For operation on Rexroth IndraDrive Cs, the following sercos parameters must be edited before commissioning.

Ident number	Description	Value
P-0-0508 (for MCP020)	Commutation offset[1)]	590
P-0-0508 (for MCP030 ... 070)	Commutation offset[1)]	922
P-0-0074	Encoder type 1 (motor encoder)	15

1) The parameter is used to enter the motor depending constants. It is not the actually commutation offset. This is displayed within parameter P-0-0521 “Effective commutation offset” after automatic calculation.

Tab. 14-4: Parameters to be checked before commutation adjustment

With the above-specified settings, the effective commutation offset (P-0-0521) is automatically calculated on switching to operating mode. The drive is ready for power activation.

☞ The procedure “Reference point optimum commutation offset” cannot be used in the case of analog Hall units, as the necessary parameter P-0-0508 already uses the procedure “Commutation via analog Hall units”.

Commutation by means of digital Hall unit

For operation on Rexroth IndraDrive Cs, the following sercos parameters must be edited before commissioning:

Ident number	Description	Value
P-0-0509 (for MCP020)	Rough commutation offset[1)]	**946**
P-0-0509 (for MCP030 ... 070)	Rough commutation offset[1)]	**62**
P-0-0074	Encoder type 1 (motor encoder)	**23**

1) The parameter is used to enter the motor depending constants. It is not the actually commutation offset. This is displayed within parameter P-0-0521 “Effective commutation offset” after automatic calculation.

Tab. 14-5: Parameters to be checked before commutation adjustment

With the above-specified settings, the effective commutation offset (P-0-0521) is automatically calculated on switching to operating mode. Commutation by means of digital Hall unit only enables reaching of an electrical accuracy of +/- 30°. In this respect, a maximum power loss of 14 % is to be expected.

Hence the maximum motor force is available, a “Reference point optimum commutation offset” must be stored on the reference point.

Procedure at IndraDrive Cs:

1. Activate initial commissioning mode (P-0-0522, bit 15)
2. Carry out commutation adjustment using the sinusoidal procedure.
3. Switch axis to "AF".
4. Start fine commutation.
5. Initiate reference point run.

   If the reference point is reached, the "reference point of optimum commutation offset" (P-0-0508) is placed there.

6. Deactivate initial commissioning mode.

On each restart of the machine, the rough commutation offset (+/- 30°) is determined by switching to operating mode. The drive may now run to the reference point with reduced force. If the reference point is reached or passed, the optimum reference point for the commutation offset is applied by the drive and the maximum force is available to the axis.

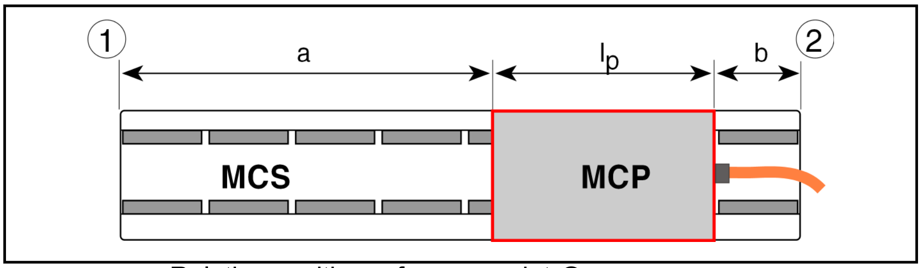
14.6.4 Measuring procedure: Measuring of the relation between primary and secondary part

For commutation setting, this procedure requires determination of the relative position of the primary part in relation to the secondary part. This procedure has the advantage that commutation adjustment does not require any power switching and axis motion. Commutation adjustment only needs to be carried out on initial commissioning.

☞ This procedure requires an absolute length measuring system.

Measuring of the relative position of the primary to the secondary part

Depending on the accessibility of the primary and secondary part in the machine or system, the relative position of the primary to the secondary part may be calculated in different ways:



a	Relative position reference point ①
b	Relative position reference point ②
l_p	Primary part length

Fig. 14-5: Measuring of the relative position of the primary to the secondary part

☞ The position of the primary part must not be changed before the procedure for commutation adjustment is completed!

Calculation of P-0-0523, Commutation adjustment measured value

The input value for P-0-0523 that is required for calculating the commutation offset, is determined from the measured relative position of the primary part with respect to the secondary part (Fig. 14-5, distance a or b, depending on accessibility), and a motor-related constant k_{mx} (Fig. 14-6 and Fig. 14-6).

$$\text{Reference point 1:} \quad P-0-0523 = a - k_{mx}$$

$$\text{Reference point 2:} \quad P-0-0523 = -b - l_p - k_{mx}$$

P-0-0523	Commutation adjustment measured value in mm
a	Relative position reference point ① in mm (Fig. 14-5)
b	Relative position reference point ② in mm (Fig. 14-5)
k_{mx}	Motor constant for commutation adjustment in mm
l_p	Primary part length in mm

Fig. 14-6: Calculation of P-0-0523, Commutation adjustment measured value

☞ Ensure that the sign is correct when you determine P-0-0523, Commutation adjustment measured value. If P-0-0523 is determined with a negative sign, this must also be entered in the beginning of the setting procedure.

Motor constant k_{mx} for commutation adjustment

Primary part	k_{mx} in mm
MCP020	24.1
MCP030 / 040 / 070	49.6

Tab. 14-6: Motor constant k_{mx} for commutation adjustment

Example at MCP040C for reference point ①

a = 100 mm , k_{mx} = 49.6 mm

P-0-0523 = a - k_{mx} = 100 mm - 49.6 mm = 50.4 mm

Example at MCP040C for reference point ②

b = 20 mm, k_{mx} = 49.6 mm, l_p = 187 mm

P-0-0523 = -b - l_p -k_{mx} = -20 mm - 187 mm - 49.6 mm = - 256.6 mm

Activation of commutation adjustment command

Prerequisites:

1. The drive must be in status A0-13 during the following adjustment procedure (= ready for power switching).
2. The position of the primary part or the slide must not have changed after measuring of the relative position of the primary to the secondary part.

After the determined value P-0-0523 (Commutation adjustment measured value) is entered, command P-0-0524 (D300 Commutation adjustment command) has to be started. In this process, the commutation offset is calculated.

☞ If the drive is in command start "AB" (drive ready for operation), the commutation offset with the selected procedure (saturation or sinusoidal procedure) is determined for automatic commutation.

Afterwards, the command is to be cleared.

14.7 Setting and optimizing the control loop

14.7.1 General procedure

The control loop settings in a digital drive controller have an essential importance for the properties of the servo axis. The control loop structure consists of a cascaded position, velocity and current controller. Which controller is active is defined by the operation mode.

☞ Defining the control loop settings requires the corresponding expertise.

The procedure for control loop optimization (current, velocity and position controller) at linear direct drives corresponds to the procedure for rotary servo drives. Only the setting limits of linear drives are higher.

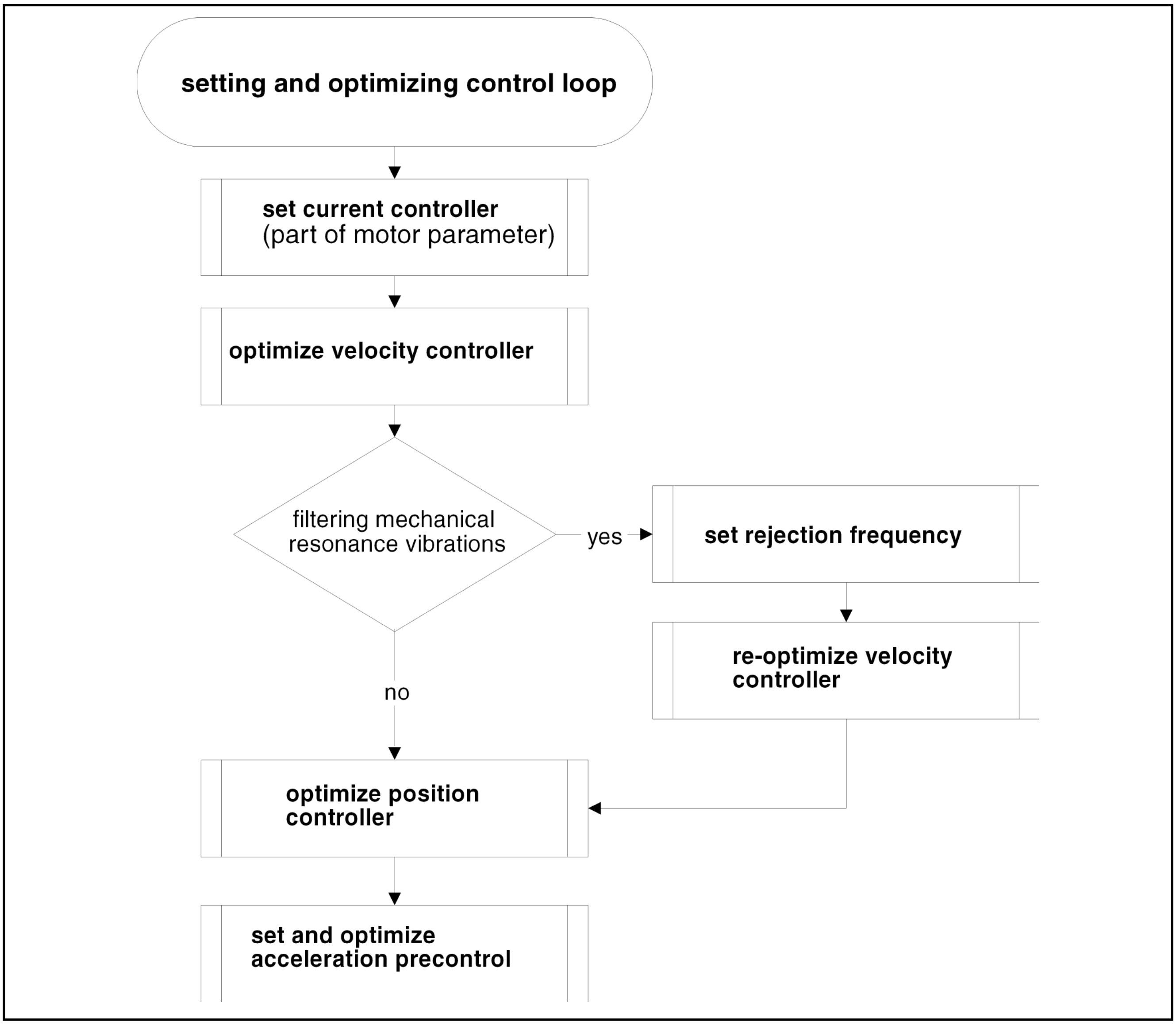


Fig. 14-7: Setting and optimizing the control loop of synchronous linear motors

---

☞ For additional and detailed information, refer to

- Rexroth IndraDrive Firmware MPx-xx Functional Description, MNR R911328670
- Rexroth IndraDrive MPx-xx Application Manual, MNR R911326767

Automatic control loop setting

Rexroth drive controllers enable automatic control loop setting.

Filtering mechanical resonance vibrations

Digital drives from Rexroth are able to provide a narrow-band suppression of vibrations that are produced due to the power train between motor and mechanical axis system. This results in increased drive dynamics with good stability.

The mechanical system of the slide that is moved by the linear drive is stimulated to vibrate mechanically due to the position and/or velocity return within the closed control loop. This behavior, known as "Two-mass vibrational system", is mainly in the frequency range from 400 to 800 Hz. It depends on the rigidity of the mechanical system and the spatial expansion of the system.

In most cases, this "Two-mass vibrational system" has a clear resonant frequency that can be selectively suppressed by a rejection filter installed in the drive.

When the mechanical resonant frequency is suppressed, the dynamic properties of the velocity control loop and of the position control loop may, under certain circumstances, be improved as compared with closed-loop operation without rejection filter.

This leads to an increased profile accuracy and shorter cycle times for positioning processes at a sufficient distance to the stability limit.

Rejection frequency and bandwidth of the filter can be selected. The rejection frequency is the frequency with the highest attenuation. The bandwidth defines the frequency range in which the attenuation is less than –3 dB. A higher bandwidth leads to less attenuation of the rejection frequency!

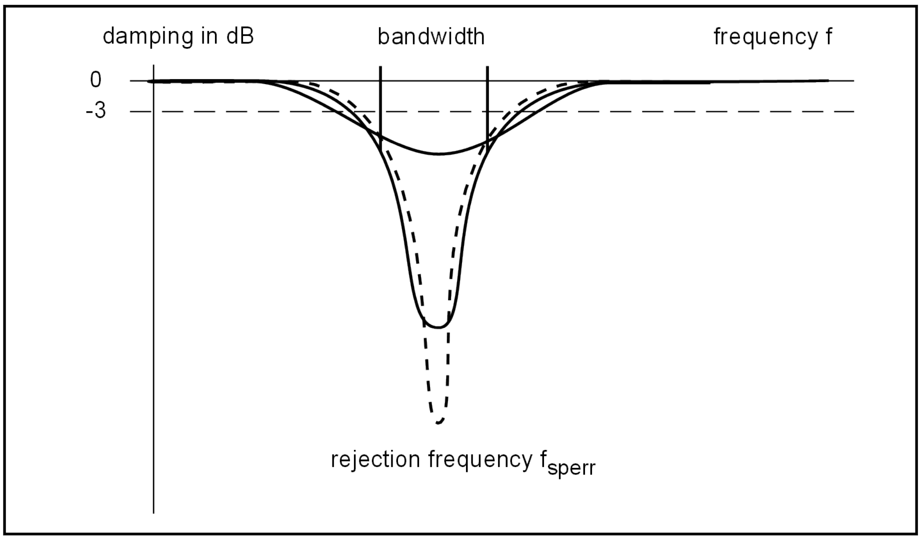


Fig. 14-8: Amplitude response of the rejection filter in relation to the bandwidth, qualitative

14.7.2 Parameter value assignments and optimization of Gantry axes

General

Prerequisites:

- Parametrization or axes is realized identically
- Parallelism of guides of Gantry axes
- Parallelism of length measuring systems
- The axes are registered as individual axes in the control unit

☞ For compensation of alignment errors between two length measuring systems or the mechanical system, drive-internal axis error correction procedures can be applied. Please refer to the corresponding description of functions of the drive controller for a description of the operational principle and the parameter settings.

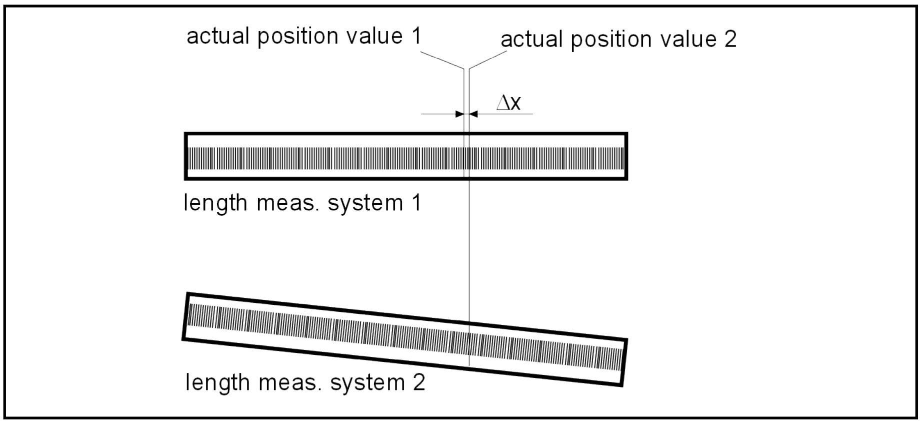


Fig. 14-9: Possible alignment errors at length measuring systems of Gantry axes

Parametrization

For operation of Gantry axes, identical parameterization of the following parameters must be ensured:

- Motor parameter
- Polarity parameter for force, velocity and position
- Control loop parameter

We have:

$$k_{v1} = k_{v2}$$

$$k_{p1} = k_{p2}$$

k_v Position controller kv factor S-0-0104

k_p Velocity loop proportional gain S-0-0100

Fig. 14-10: Proportional gain in position and velocity control loop of both axes

Velocity loop integral action time (integral part)

For velocity loop integral action time (integral part), the following possibilities must be taken into consideration:

	Possibility 1	Possibility 2	Possibility 3	Possibility 4
Alignment of length measuring systems and guides	ideal	not ideal	not ideal	not ideal
Integral part	in both axes	in both axes	in one axis only	in no axis
Behavior of the axes	Tensioning of the mechanical system is not realized as both motors ideally follow the position command value	Both axes work against each other until compensation via the mechanical coupling or until the maximum current is reached at one or both drive controllers and no more control effect can be achieved	The axis without integral part allow continuous position offset. The position offset depends on the stiffness of the mechanical coupling of both axes as well as the proportional gains in the position and velocity control loop	Both axes allow continuous position offset. The position offset depends on the proportional gains in the position and velocity control loop

Tab. 14-7: Parametrization of the velocity loop integral action time S-0-0101 at Gantry axes.

Optimization

For optimization of velocity and position control loop, the above-described procedure must be observed.

☞ Parameter changes during optimization of Gantry axes must always be carried out at both axes. If this is not possible, the parameter changes during optimization should be carried out subsequently in small steps at both axes.

14.7.3 Estimating the moved mass using a velocity ramp

The moving weight of a machine slide is often not precisely known. This may be obstructed by subsequently installed attachments, moving components, etc.

The procedure described below enables estimation of the moved axis mass according to recording of a velocity ramp. For example, this enables estimation of the acceleration capacity of the axis.

Preparation

Precondition for positioning is oscillographical representation of the following parameters:

- S-0-0040, Velocity actual value
- S-0-0080, Torque/force command value

For this purpose, an oscilloscope or the oscilloscope function of the drive can be used in combination with IndraWorks or NC.

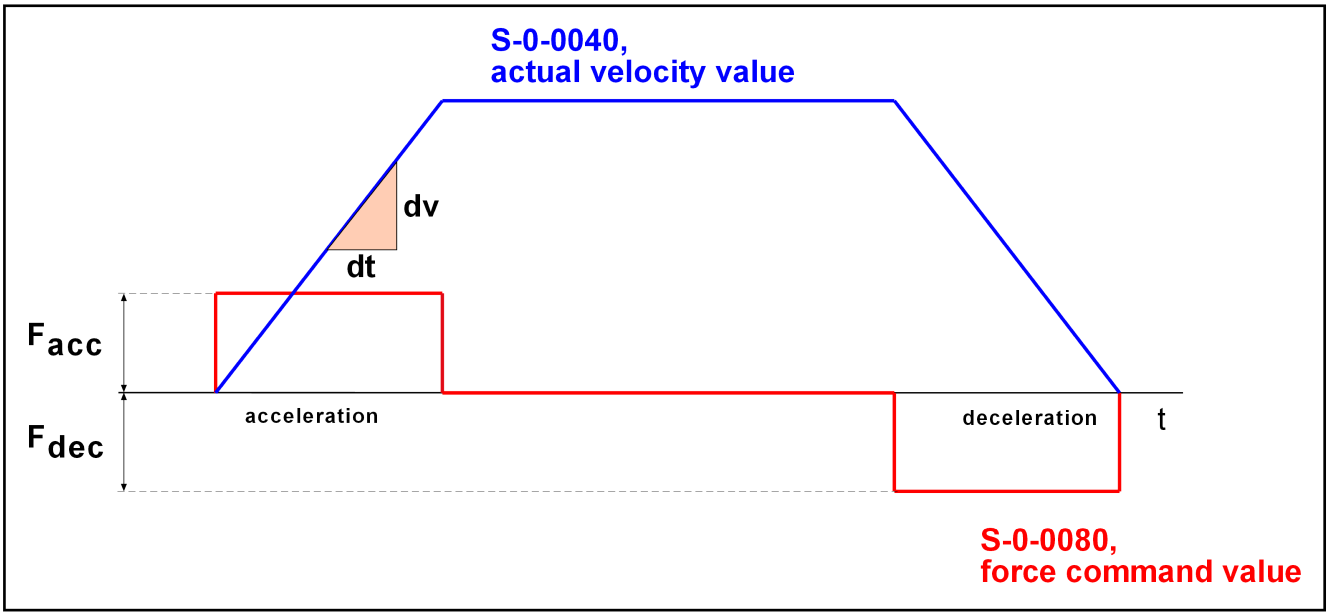


Fig. 14-11: Oscillogram of velocity and force

$$m = 30 \cdot F_N \cdot \left(\frac{F_{ACC} + F_{DEC}}{100\%} \right) \cdot \frac{\Delta t}{\Delta v}$$

m	Moved axis mass in kg
F_N	Continuous nominal force of the motor in N
F_{ACC}	Force command value during acceleration in %
F_{DEC}	Force command value during deceleration in %
Δv	Velocity change during const. acceleration in m/min
Δt	Time change during const. Acceleration in s

Fig. 14-12: Determination of the moved axis mass according to recording of a velocity ramp

Prerequisites:

1. Correct parameter settings of the rated motor current (basis of representation S-0-0080)

2. Frictional force not directional

3. Recording of Δv and Δt at constant acceleration

4. Measuring with a motor force between F_N and F_{max}

☞ The procedure is not suitable or suitable only to a limited extend for vertical axes due to potential direction-depending force changes.

14.8 Maintenance and checking of motor components

14.8.1 General

MCL motor components do not require any maintenance. During operation, however, external influences may cause damage at motor components. Within the service intervals of the machine or system, preventive checking of linear motor components should be carried out.

14.8.2 Checking of motor and additional components

The following points should be observed and if necessary restored during the preventive check of motor and auxiliary components:

- Noticeable sound during operation
- Scratches on primary and secondary part
- Dirt (e.g. shavings, dust, grease by guides etc.) within the air gap between primary and secondary part
- State of power and encoder cables in a drag chain.
- State of length measuring system (e.g. contamination)
- State of guides (e.g. deterioration of linear guides)

14.8.3 Electrical check of motor components

Electrical defects at a primary part are can be indicated in advance by measuring the electrical characteristics. The following variables are relevant:

- Resistance between motor connecting wires 1-2, 2-3 and 1-3
- Inductance between motor connecting wires 1-2, 2-3 and 1-3
- Insulation resistance between motor connecting wired and guides

Resistance and inductivity

The measured values of resistance and inductance can be compared to the values specified in chapter "Technical data". The individual values of resistance and inductance measured between the connections 1-2, 2-3 and 1-3 should be identical within a tolerance of ± 5 %. There can be a phase short circuit, a fault between windings, or a short circuit to ground if one or more values differ significantly. If so, the primary part must be exchanged.

Insulation resistance

The insulation resistance measured between the motor connection wires and ground should be at least 1 MΩ (MegaOhm). If this value is fallen below, replacement of the primary part is recommended.

☞ If necessary, please contact the Bosch Rexroth customer service for inspection of the electrical system.

14.9 Operation with third-party controllers

Rate of rise of voltage

The electrical insulation of the motor is subject to a higher dielectric load in converter mode than when it is operated with a merely sinusoidal source voltage. The voltage load of the winding insulation in converter mode is mainly defined by the following factors:

- Crest value of voltage
- Rise time of pulses at the motor terminals
- Switching frequency of final converter stage
- Length of power cable to the motor

Main components are the switching times of the final converter stage and the length of the power cable to the motor. The rates of rise of the voltage occurring at the motor may not exceed the pulse voltage limits specified in DIN VDE 0530-25 (VDE 0530-25):2009-08 (picture 14, limit curve A), measured at the motor terminals of two strands in relation to the rise time.

☞ These limits are complied with by the final stages of IndraDrive converters.

14.10 Environmental protection and disposal

14.10.1 Environmental protection

Production processes

The products are manufactured in energy- and resource-optimized production processes which allow re-using and recycling the resulting waste. We regularly try to replace pollutant-loaded raw materials and supplies by more environment-friendly alternatives.

No release of hazardous substances

Our products do not contain any hazardous substances which may be released in case of appropriate use. Normally, our products will not have any negative influences on the environment.

Significant components

Significant components of our products are:

Electronic devices	Motors
• Steel	• Steel / Stainless steel
• Aluminum	• Aluminum
• Copper	• Copper
• Plastics	• Brass
• Electronic components	• Magnetic materials
	• Elektronic components

14.10.2 Disposal

Return of products

Our products can be returned to us for disposal free of charge. However, this requires that the products be free from oil, grease or other dirt.

Furthermore, the products returned for disposal may not contain any undue foreign material or foreign components.

Deliver the products "free domicile" to the following address:

Bosch Rexroth AG
Electric Drives and Controls
Buergermeister-Dr.-Nebel-Straße 2
97816 Lohr am Main, Germany

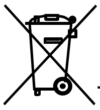
Packaging

Packaging materials consist of cardboard, wood and polystyrene They can be recycled anywhere without any problem.

For ecological reasons, please refrain from returning the empty packages to us.

Batteries and accumulators

Batteries and accumulators can be labeled with this symbol.



The symbol indicating "separate collection" for all batteries and accumulators is the crossed-out wheeled bin.

End users in the EU are legally bound to return used batteries and accumulators. Outside the validity of the EU Directive 2006/66/EC, the particularly applicable regulations must be followed.

Batteries and accumulators can contain hazardous substances which can harm the environment or people's health when improperly stored or disposed of.

After use, the batteries or accumulators contained in Rexroth products must be properly disposed of according to the country-specific collection systems.

Recycling

Most of the products can be recycled due to their high content of metal. In order to recycle the metal in the best possible way, the products must be disassembled into individual assemblies.

Metals contained in electric and electronic assemblies can also be recycled by means of special separation processes.

Plastic parts of the products may contain flame retardants. These plastic parts are labeled according to EN ISO 1043. They have to be recycled separately or disposed of according to the applicable legal provisions.

15 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 Hotline** and **Service Helpdesk** 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
- Type plate specifications of the affected products, in particular type codes and serial numbers
- Your contact data (phone and fax number as well as your e-mail address)

Index

Notes

Notes

Bosch Rexroth AG
P.O. Box 13 57
97803 Lohr a.Main, Germany
Bgm.-Dr.-Nebel-Str. 2
97816 Lohr a.Main, Germany
Phone +49 9352 18 0
Fax +49 9352 18 8400
www.boschrexroth.com/electrics

R911330592

DOK-MOTOR*-MCL********-PR06-EN-P